Freshwater Fish Stocking in NSW

Environmental Impact Statement

Public Consultation Document

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Details of the public consultation process and contact information are included on page 18 of Chapter A

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Cover images of golden perch fry and impoundment stocking by J Matthews

DECLARATION

For the purpose of section 115K(4) of the *Environmental Planning and Assessment Act 1979*, the Director-General, NSW Fisheries is the person engaged as responsible for the preparation of this Environmental Impact Statement (EIS). The Director-General, NSW Fisheries is Mr Steve Dunn, B.Sc. Hons Fishery Science (Plymouth), Master of Management (Macquarie). A range of NSW Fisheries staff and stakeholders with expertise and qualifications in fisheries management, environmental science, fisheries science and fisheries compliance assisted in the preparation of the EIS. Where expertise was not available within NSW Fisheries, external experts were contracted.

The EIS has been prepared on behalf of NSW Fisheries (the proponent).

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The location of the proposed activity is described in Chapter D. A description of the proposed activity and proposed controls is also provided in Chapter D. An assessment of the environmental impact of the proposed activity as described in the draft Fishery Management Strategy (Chapter D) is presented in the EIS in Chapter E. The EIS contains all available information relevant to the environmental assessment of the activity to which the statement relates. The information provided in the EIS is neither knowingly false nor misleading.

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Advisory Council on Recreational Fishing

Fisheries Resources Conservation and Assessment Council

Indigenous Fisheries Strategy Working Group (sub-committee)

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Abbreviations

4WD	Four wheel drive
AAHCC	Aquatic Animal Health Consultative Committee
AAHL	Australian Animal Health Laboratory
AAS	Aquaculture Administration Section (a section of NSW Fisheries)
ABS	Australian Bureau of Statistics
ACEC	Animal Care and Ethics Committee (convened by NSW Fisheries)
ACFC	NSW Advisory Council on Fisheries Conservation
AFFA	Australian Fisheries Forestry and Agriculture
AIDP	Aquaculture Industry Development Plans
ALC	Aboriginal Land Council
AQUAPLAN	Australia's National Strategic Plan for Aquatic Animal Health 1998-2003
AQUAVETPLAN	Australian Aquatic Animal Disease Emergency Plan
ARC	Australian Research Council
AS/NZS	Australian/New Zealand Standard
ASFB	Australian Society for Fish Biology
ASL	Above sea level
AusRivAS	Australian River Assessment System
BIONET	Biodiversity information resource
BWFCRS	Brackish Water Fish Culture Research Station
CAMBA	China-Australia Migratory Bird Agreement
CANRI	Community Access to Natural Resource Information
CARE	Centre for Agricultural and Regional Economics
CAS	Central Acclimatisation Society
CBA	Cost-benefit analysis
CERRA	Central Eastern Rainforest Reserves of Australia
CMA	Central Map Agency
CSDAC	Council of Southern Districts Angling Clubs
DIPNR	Department of Infrastructure, Planning and Natural Resources
DSE	Department of Sustainability and Environment (Victoria)
DTH	Dutton Trout Hatchery (also known as the LP Dutton Trout Hatchery)
EA	Environment Australia
EHNV	Epizootic haematopoietic necrosis virus
EIS	Environmental Impact Statement
ELISA	Enzyme-linked immunosorbent assays (a test for the presence of EHNV)
EP&A Act	*Environmental Planning and Assessment Act 1979*
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
ESD	Ecologically Sustainable Development
ESU	Evolutionarily Significant Unit
FTE	Full Time Equivalent
FM Act	*Fisheries Management Act 1994*
FMS	Fishery Management Strategy
FRDC	Fisheries Research and Development Corporation
FSC	Fisheries Scientific Committee
GAC	Grafton Aquaculture Centre
GBM	Greater Blue Mountains

GIS	Geographic Information System
GRFL	General Recreational Fishing Licence
GTH	Gaden Trout Hatchery
GUD	Goldfish Ulcer Disease
HAS	Hatchery Accreditation System
HCG	Human Chorionic Gonadotropin hormone
HQAP	Hatchery Quality Assurance Program
IFS	Indigenous Fisheries Strategy
IFWG	Indigenous Fisheries Working Group
IOE	International Office of Epizootics
IUCN	International Union for the Conservation of Nature
JAMBA	Japan-Australia Migratory Bird Agreement
KTP	Key Threatening Process
MAS	Monaro Acclimatisation Society
MDBC	Murray-Darling Basin Commission
mtDNA	Mitochondrial DNA
MU	Management Unit
N_e	Effective population size (see glossary)
NETAS	New England Trout Acclimatisation Society
NFC	Narrandera Fisheries Centre
NHT	Natural Heritage Trust
NP	National Park
NPW Act	*National Parks and Wildlife Act 1974*
NPWS	National Parks and Wildlife Service
NR	Nature Reserve
NSWF	New South Wales Fisheries
OH&S	Occupational health and safety
OH&S Act	*Occupational Health and Safety Act 2000*
OTAS	Orange Trout Acclimatisation Society
OTC	Oxytetracycline, which acts as an antibiotic (as well as a marking agent)
PDF	Adobe Acrobat © portable document format
PFIGA	Professional Fishing Instructors and Guides Association (NSW)
PIT-tag	Passive Integrated Transponder tag
ppm	Parts per million
PSFC	Port Stephens Fisheries Centre
RFFMPC	Recreational Fishing Freshwater Management Planning Committee
RFFTEC	Recreational Fishing Freshwater Trust Expenditure Committee
RFLEC	Recreational Freshwater Licence Expenditure Committee
RIVPACS	River Invertebrate Prediction and Classification System
SEINS	Self Enforcing Infringement Notice System
SIGNAL	Stream Invertebrate Grade Number Average Level
SRMPA	The Scientific Research and Miscellaneous Permit Administration of NSW Fisheries
SWAMP	State Water Assets Management Program
TAP	Threat Abatement Plan
TSBU	Threatened Species and Biodiversity Unit (a section of NSW Fisheries)
TSC Act	*Threatened Species Conservation Act 1995*
UNESCO	United Nations Educational, Scientific and Cultural Organisation

Glossary

1 in 100 year flood level	Elevation having a 1% chance of being flooded in any given year.
Additive genetic diversity	Genetic diversity that contributes to the phenotype and is heritable.
Allele	Multiple forms of a gene are termed alleles when they occur at the same position on the chromosome, but produce different effects on development.
Allelic diversity	The diversity of alleles present in a population or species.
Allozyme electrophoresis	The method of screening protein differences for genetic study by passing them through a starch gel via the flow of electricity.
Anadromous	A life cycle that involves migration from the sea into freshwater for spawning. Opposite of catadromous.
Biodiversity	The variability among living organisms from all sources (including marine and other aquatic ecosystems and the ecological complexes of which they are a part). Includes: diversity within species (genetic diversity), among species (species diversity); and ecosystems (ecosystem diversity).
BIONET	A desktop application for natural resource information (including spatial information) developed by the NSW Fisheries (Aquaculture and Sustainable Fisheries Division), Australian Museum, National Parks and Wildlife and the Australian Botanical Gardens.
Bottleneck (or population bottleneck)	Significant reductions in population size, which can result in loss of genetic diversity.
Brackish	Water of low salinity (typically 5-25 parts per thousand) produced by the mixing of marine and fresh waters.
Broodstock	Fish that are bred (in captivity) to produce stock.
Broodstock collection zones	Geographic zone from within which broodstock is collected and outside which their progeny must not be stocked.
Catadromous	Having a life cycle that involves migration from freshwater to the sea for spawning.
Catchment	The geographical area that is drained by a river or dam.
Clade	A group of species with a common ancestor.
Cline	Continuous gradation of form or genetic differences in a population of a species, correlated with its geographic distribution.
Conservation stocking	Stocking of native species for the purpose of supporting fisheries conservation management objectives at a State, national or international level.
Critical habitat	An area or areas of habitat declared under threatened species legislation to be critical to the survival of a threatened species.
Deleterious recessive alleles	Gene forms (alleles) that are expressed only in the homozygous state and cause a reduction in fitness when expressed.
Deme	Distinct population of a species.
De-snagging	The removal of snags (mostly partially or fully submerged fallen trees) from rivers.
DNA	Deoxyribonucleic acid.
Dollar-for-Dollar Native Fish Stocking Program	Scheme under which community groups may apply to the NSW Recreational Fishing Trust (funded by the recreational fishing licence) for matching funds to purchase native fish from licensed commercial hatcheries to stock into rivers and dams in NSW.
Eastern drainage	Collectively, all catchments east of the Great Dividing Range.
Ecological community	The species that occur together (often delimited by a geographic boundary).
Ecologically Sustainable Development	Using, conserving and enhancing the community's resources so that ecological processes on which life depends, are maintained, and the total quality of life, now and into the future, can be increased (CoA, 1992).

Ecosystem	The biotic (living) community and its abiotic (non-living) environment.
Ectoparasites	Organisms that are external parasites of other organisms.
Endangered species	Species that is likely to become extinct due to threatening process(es), reduction in population size or available habitat (under the FM and TSC Acts).
Epistatic variance	Interaction between genes.
Epizootic	The outbreak of a disease that affects a large proportion of the population.
Evolutionarily Significant Units	Distinct populations on their own evolutionary trajectory – likely to lead to speciation.
Fingerling	Juvenile fish of approximately 7-10 cm in length and several months of age.
FISHPLAN	The NSW component of AQUAVETPLAN (see list of abbreviations).
Fitness	The relative contribution of an individual to the gene pool of the next generation (Darwinian fitness).
Fry	Juvenile fish of 4-12 weeks of age and approximately 2-3cm in length.
Fst	Measure of genetic structuring between populations.
Galaxiid	Fish of the family Galaxiidae.
Genetic diversity	Diversity of alleles or number of heterozygous individuals in a population.
Genetic drift	Divergence of isolated populations through the random assortment of alleles per generation.
Genetic integrity	Natural genetic state.
Genetic structure	The distribution of genetic variability among different populations, sub-populations of a species.
Genetically effective population	The size of an ideal population that is subject to the same degree of genetic drift as an actual population (Hartl and Clark, 1997). Therefore, the effective population is the size of a real population that has been corrected for factors that reduce effective population size such as sex-ratio biases, harem formation, reproductive variance among individuals and inbreeding. In wild populations the genetically effective population is typically much smaller than the census population size (Lande and Barrowclough, 1987).
Genotype	The genetic make-up of an organism (as opposed to its phenotype).
Harvest stocking	The stocking of native and salmonid species into specified public inland waters of NSW in order to provide quality recreational fishing and Aboriginal cultural fishing opportunities.
Heterozygosity	The proportion of individuals that possess different alleles in the two corresponding loci of a pair of chromosomes.
Homozygosity	The proportion of individuals that possess identical alleles in the two corresponding loci of a pair of chromosomes.
Hybridisation	Production of offspring from the crossing of parents that are genetically unlike, such as different species, or marked varieties within a species.
Impoundment	A body of water confined by a dam.
Inbreeding	Reproduction by the mating of closely related individuals.
Inbreeding coefficient	The probability that an individual has a pair of alleles that are identical by descent from a common ancestor; the proportion of loci that carry alleles that are identical by descent from a common ancestor.
Inbreeding depression	A reduction in fitness resulting from inbreeding.
Introduced species	A species that has been introduced into an area outside its natural range.
Introgression	Infiltration of the genes of one species into the genotype of another through the repeated back-crossing of hybrids with the parental species.
Larvae	Pre-adult form that may have distinct morphological, behavioural and habitat associations from the adult form.
Management Units	Genetically distinct populations that are not divergent to the degree of Evolutionarily Significant Units, but should be managed as separate.

Microsatellites	Tandemly repeated DNA sequences used as genetic markers that are expected to be selectively neutral.
Mitochondrial DNA	DNA from the mitochondria of eukaryote cell.
Multiplier effects	Flow on effects of some activity to other areas of the economy. An economic multiplier (generally expressed as a ratio) is used to estimate the value to other parts of the economy (see B3.5.4).
Nei's D	Measure of genetic subdivision between populations.
Neutral molecular markers	Genetic markers that are believed not to be under natural selection – often considered to be junk DNA.
Notified trout waters	Certain NSW streams and impoundments, determined by NSW Fisheries, that have special regulations on gear and season, to protect breeding populations of salmonids and promote sharing of the catch among anglers.
Nucleotide	A molecule comprising either purine or pyrimidine that makes up the bases in DNA.
Øst	A measure of genetic subdivision between populations for mitochondrial DNA.
Otolith	Small hard structure found in the head of bony fish that can be used to determine the age of the fish.
Outbreeding	Reproduction by the mating of distantly related individuals.
Outbreeding depression	Reduction of fitness resulting from outbreeding, for example when individuals from geographically isolated populations that are adapted to different local conditions breed, resulting in the loss of local adaptation.
Ova	Egg cells.
Phenotype	The sum of the characteristics manifested by an organism.
Phenotypic fitness	Fitness related to the phenotype.
Precautionary principle	A principle of ESD, which states that where there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.
Protozoa	A group of single celled, eukaryotic animals. Some protozoans cause disease in higher organisms.
Ramsar Convention	The Convention on Wetlands of International Importance, signed in the Iranian town of Ramsar in 1971. The convention aims to halt the loss of wetlands and to conserve remaining wetlands.
Recovery plan	Plan designed to return a threatened species, population or ecological community to a point where its survival in nature is assured (i.e. it is no longer threatened). Preparation of recovery plans for threatened species is required under the FM Act, TSC Act and EPBC Act.
Recreation stocking	Stocking of fish for the purpose of providing quality recreational fishing opportunities.
Recruitment	Entry of individuals into a particular life-history stage. For example, recruitment of juveniles into the breeding population occurs at sexual maturity.
Register of the National Estate	A list of places that are considered to have natural or cultural significance, administered by the Australian Heritage Commission. Listing does not legally constrain management decisions other than those of the Commonwealth.
Resilience	A measure of the ability of a population, community or ecosystem to return to its former state following an impact.
Risk	The likelihood of an undesired event (or impact) occurring as a result of some behaviour or action.
Risk management	The culture, processes and structures that are directed towards the effective management of potential opportunities and adverse effects.
Rogers' genetic distance	Measure of genetic subdivision between populations.
Salmonid	Fish of the family Salmonidae.

Snowy Lakes Trout Strategy	A localised arrangement designed to promote quality recreational angling, regional economic development, and eco-tourism opportunities specifically in the Snowy Mountains Lakes area (available at the NSW Fisheries website: http://www.fisheries.nsw.gov.au/rec/fw/snowy.htm)
Spawning cues	Environmental signals that induce spawning (e.g. changes in water temperature, salinity, flow).
Stocking zones	Broad grouping of 'like' catchments. These will facilitate the review of stocking events for areas displaying similar environmental requirements and matters of environmental concern that are characteristic of each stocking zone. There are five stocking zones in NSW (East Coast, Montane, Murray, Darling and Far West - see D3.2 for details).
Sub-species	Sub-division of a species into groups whose members resemble each other, but differ from those of other groups.
Sympatric	Having overlapping distribution.
Terapontids	Fishes of the family Terapontidae.
Threatened species	Species listed under NSW or Commonwealth legislation as endangered or vulnerable. For the purpose of this EIS, also includes species that are listed under the Fisheries Management Act as protected species.
Translocation	The stocking of fish from one drainage into another drainage within their natural range; or the transfer, within their natural range, of fish from one population into waters where another population of the same species is known to exist.
Triploid	Having three times the haploid number of chromosomes. Triploid organisms are generally sterile.
Trophic	Relating to feeding by animals, in particular, the relationships (food-webs) between predators, prey and primary producers.
Vulnerable species	A species that is likely to become endangered unless the circumstances and factors threatening its survival or evolutionary development cease to operate.
Western drainage	Collectively, all catchments draining the western side of the Great Dividing Range.
Wilderness Area	An area of land, that together with its plant and animal communities, is in a state that has not been substantially modified by humans and their works or is capable of being restored to such a state; and that it is capable of providing opportunities for solitude and appropriate self-reliant recreation (Wilderness Act 1987).
World Heritage Area	Cultural and natural property considered to be of outstanding universal value, submitted by countries that are signatories to the Convention Concerning the Protection of World Culture and Natural Heritage and listed on UNESCO's World Heritage List.

CHAPTER A EXECUTIVE SUMMARY

Introduction

Stocking fish in freshwaters is an important tool in achieving the objectives sought by the community for recreational and Indigenous fishing and the conservation of aquatic ecosystems. The way that the current activity is managed poses some key environmental, social and economic risks, particularly regarding impacts on threatened species by non-native fish, changes to the genetic integrity of natural fish populations, the potential introduction of pests and diseases into natural waterways, operating standards in fish hatcheries, information management for stocking events, scientific information gaps, and Indigenous expectations.

These risks must be addressed for the activity to proceed in a sustainable way and for the necessary approvals to be granted. A number of actions therefore have been proposed to address the risks, including a new policy for the species and areas to be stocked, lists of waters to be closed temporarily (with a review mechanism) and permanently to stocking, a hatchery quality assurance and accreditation program, annual review of proposed stocking events against specified guidelines, priority research and improved information management, and compliance and education programs. The actions represent a balanced approach to secure the objectives sought for recreational and Indigenous fishing and conservation.

The Environmental Impact Statement for Freshwater Fish Stocking presents a thorough, frank and transparent assessment of the risks associated with the current activity and the measures proposed to address the risks.

Public exhibition of the Environmental Impact Statement for Freshwater Fish Stocking provides an opportunity for the community to review the environmental performance of the activity of freshwater fish stocking and to have input into its future management.

The Development of Fishery Management Strategies and Environmental Impact Statements

In December 2000, the NSW Government initiated changes to ensure that fishing activities in New South Wales are managed in an environmentally sustainable way. The changes require the development of fishery management strategies and associated environmental assessments for each major commercial fishery, the recreational fishery, the recreational charter boat fishery, fish stocking programs and for the beach safety (shark) meshing program.

The management strategy and environmental impact assessment for each activity are joined together in an Environmental Impact Statement (EIS). Its structure is based on guidelines issued by the Department of Infrastructure, Planning and Natural Resources.

This overview presents a summary of the EIS, being the first chapter (Chapter A). Chapter B reviews the existing operation of the activity, including the current management arrangements, where it occurs, the species that are stocked and those that could be affected in the receiving environment, and the socio-economics related to the activity. The risks associated with all aspects of the activity are assessed to identify those aspects that require modification by the Fishery Management Strategy (FMS). Together these chapters (Chapters A and B) comprise Volume 1 of the EIS.

Chapter C provides an outline of feasible alternative management options to those of the existing activity and Chapter D provides details of the proposed management arrangements for the activity (i.e. the draft FMS). Chapter E presents an assessment of the potential impacts of implementing the draft FMS, that is, the extent to which the draft FMS mitigates those risks that were identified in Chapter B. Chapter F provides a justification for the chosen strategy, taking into account its implications in terms of environmental, social and economic factors.

This overview provides an introduction to the environmental assessment process. It briefly outlines the context within which the activity of freshwater fish stocking operates, the management arrangements proposed in the draft FMS, and the findings of the environmental impact assessment for the activity of freshwater fish stocking. It is important to note that this EIS only considers freshwater fish stocking, as there are currently no proposals to establish a marine or estuarine stocking program.

The Existing Activity of Fish Stocking

In NSW, the activity of freshwater fish stocking has been conducted for over 100 years specifically to service recreational fishing interests and to support fish conservation outcomes. Essentially, these objectives provide stocks of freshwater fish to be taken by recreational means and to aid the preservation of certain species whose populations are of conservation concern. Permits have also been provided to religious organisations to allow for the release of fish in accordance with specific cultural or religious beliefs.

Recreational species include both native (golden perch, silver perch, Murray cod, and Australian bass) and non-native salmonid species (Atlantic salmon, brook trout, brown trout, and rainbow trout), which are stocked into rivers, lakes and dams at a rate of around 7 million fish per annum. Primarily representing the main angling species, this number can be roughly broken down to an even split between the native and non-native salmonid species. Salmonids are primarily produced by NSW Fisheries at either the Jindabyne or Ebor (LP Dutton) hatcheries, whereas native species are normally produced by both private and government hatcheries.

Conservation stocking uses other native species in species recovery programs including eastern cod and trout cod, while a number of additional native species have been trialed in previous programs. Eastern cod for the recovery program are produced at a private hatchery west of Grafton according to genetic protocols set by NSW Fisheries, and trout cod are produced at the Narrandera Fisheries Centre (NSW Fisheries). Fish are stocked throughout the former range of the species, with the aim of re-establishing self-sustaining populations.

To date, fish stocking has been an extensive program, with almost all inland catchments stocked to some extent, and most eastern drainages with a significant freshwater component also stocked. Those inland catchments that have not been stocked are located in the far northwest of the State, where flow is generally too variable to maintain stock. Numerous eastern catchments remain unstocked as they broadly represent coastal rivers and intermittently opening lagoons with limited catchment areas.

Whilst often used as a tool to try and combat other anthropogenic impacts and pressures on the environment, stocking has the potential to exacerbate some of those impacts or exert new pressures upon the receiving environment. Several management measures already have been implemented to mitigate the potential impacts of stocking.

For example, stocking is restricted to progeny produced from broodfish taken from an original population or location in order to manage for the possible existence of distinct sub-populations of some native species, in particular golden perch, Macquarie perch, Australian bass and eel-tailed catfish. Other examples include the suspension of stocking as a precautionary measure in a number of waterways due to the presence of threatened species – Australian bass are not stocked in certain waters within the Clarence River catchment to aid the recovery of eastern cod, salmonids are not stocked in Bogong Creek as it is thought to contain the only remaining natural population of spotted tree frogs in NSW, brown trout are not stocked in waters known to contain Macquarie perch, and salmonids are not stocked in a number of waters containing Booroolong frogs. In some cases, stocking has only recommenced on a temporary permit basis from National Parks and Wildlife Service after they conducted an 'eight part test'.

Risk, Response and Predicted Outcome

The following section briefly describes the risks of the current activity as they pertain to environmental, economic and social components, the management responses proposed in the draft FMS to mitigate those risks, and a predictive assessment of the degree to which those measures may mitigate the risks (predicted outcome). This section is also summarised in Table A1.

In order to address any perceived problems with the existing activity of fish stocking, it is first necessary to describe and evaluate the potential impacts arising from the manner in which stocking is conducted. It is also necessary to attempt to isolate those elements of the activity that are thought to contribute the most to those impacts and to adjust those elements through the draft FMS.

Broadly, the activity of fish stocking comprises seven elements that have the potential for a variety of environmental, economic and social impacts. Those elements include:

- broodstock collection, incorporating the methods used to collect parent stock of which the offspring are released into waterways, as well as the number of species collected and the locations from which they are collected
- the species that are stocked
- hatchery protocols, including all aspects of aquaculture facilities from animal husbandry through to disease control
- information management, including record keeping of broodstock collection and offspring distribution
- stocking locations, including the sites where fish are released, the manner of their transport and method of release
- compliance, being the degree to which hatcheries and the releases of fish are monitored by NSW Fisheries, and
- research and monitoring, including aspects such as the development of marking techniques, evaluating the relative success of stocking events and determining the impacts of stocking.

The review of the way hatcheries are involved in the activity and the manner in which they produce fish for stocking highlighted a regime of limited management requirements. Fish hatcheries have predominantly been developed for the aquaculture market, that is, they used to produce fish for sale for either consumption, aquaria or farm dams. The types of animal husbandry and genetic requirements of those historical markets are distinctly different from those that aim to produce fish for stocking into public waterways. That is, species produced for stocking need to maximise genetic diversity, not minimise it through selective breeding as often occurs in aquaculture. Such hatcheries also have very little need for comprehensive information management, as their point of sale is also the endpoint for the product. This is different from hatcheries that produce fish for stocking, in which case the point of sale is only the mid-point before release into a waterway. It is apparent that an accreditation system is needed for hatcheries involved in stocking, including minimum standards applicable to the range of steps in the production process, from broodstock collection and progeny management through to the dissemination of information material.

Information management should also be improved, as should the way that stocking proposals are assessed. The database maintained by NSW Fisheries contains data from the 1960s onwards and whilst providing a good historical record, contains errors and lacks protocols for data validation or dissemination. There is also limited scope for information feedback to stockists both at the proposal and post-stocking phases. The assessments of individual stocking proposals are informal and rely upon the experience of the authorising officers to ensure that good communication is maintained with other staff that should also review the proposal (primarily staff of the Threatened Species and Biodiversity Unit). Whilst this would be satisfactory in most cases, the subjective nature of the assessments cannot ensure consistency among officers or between proposals. Such a system places an unnecessary burden on authorising officers, is less transparent and provides limited feedback to the proponent.

Discussions with stockists and environmental groups alike also found that the perceived compliance level associated with the current activity was a concern. Both groups wanted to see an increase in compliance for stocking events, broodstock collection and the sale of fish, including the aquarium trade (although the latter is beyond the scope of the management strategy for fish stocking).

The review of monitoring and research conducted on the current activity found that the monitoring for assessing the effectiveness of stocking impoundments was generally adequate. There was a clear need, however, to increase the level of research associated with conservation stocking and the stocking of other native species into rivers. The shortcomings associated with these aspects primarily related to the lack of pre-stocking assessments, without which there is no baseline against which to compare the results of post-stocking monitoring. These assessments need to be done at both the species (genetic) level and community level. To date, there have been no direct studies of the impacts of stocking on the receiving environment, without which the effectiveness of stocking beyond survival rates of the stocked species cannot be accurately determined.

To address the risks, the draft strategy offers six major long-term goals for the management of the fishery, which are supported by approximately 20 objectives and 70 management responses. It is important to note that a single management response can mitigate a variety of risks and therefore is not necessary to formulate direct responses for each risk. The responses with a direct relationship to an environmental, economic or social component are briefly described below and summarised in Table A1.

Biophysical impacts

The risk assessment conducted on the existing activity of fish stocking found that almost all aspects are likely to be posing a risk to most components of the environment, in particular, threatened species, unlisted species of conservation concern, areas of conservation significance, genetics and fish health and disease. Although not all aspects of the activity were found to affect all components of the environment, it was apparent that the current management of the activity relating to hatcheries, the approvals process for stocking events, information management, compliance, and information gaps all pose a risk to the environment. Further, all facets were intrinsically linked, so that by addressing one aspect, it is likely that a management response would also address other aspects.

It is important to note when reading the following sections that despite a detailed risk assessment on numerous components of the environment, the lack of reliable information about the impacts of stocking leaves a high level of uncertainty surrounding the activity. There are still many aspects that remain uncertain, and in the absence of scientifically rigorous data, this assessment has been necessarily cautious.

Further, the appraisal of the management responses in the draft FMS in the following sections has been made on the basis that the proposed research will be undertaken. Research will remove a high proportion of the uncertainty surrounding the activity and this assessment and allow a retrospective analysis of the accuracy of the assessment and the implementation of new management measures if necessary.

Overview of potential impacts

The purpose of the overview is to critically evaluate the available information on the ecological impacts of fish stocking and the underlying mechanisms by which impacts occur. An understanding of these mechanisms is important for the evaluation of future impacts of fish stocking, and for evaluating the extent and magnitude of existing impacts. The actual impacts of fish stocking and their underlying mechanisms are poorly understood, despite a strong circumstantial case for the occurrence of impacts attributable to stocking.

It may be concluded that fish stocking has probably had a significant impact on the distribution and abundance of some native fish and frogs. Predation is a likely ecological mechanism of impact of salmonid stocking, and while competition is possible, its relative importance is not known. There is little information for stocked native species and the likely ecological impacts of stocking these species are uncertain, although likely to be less than salmonids. From the broad overview, it is apparent that the draft FMS will need to propose and implement measures to reduce the uncertainty.

Listed threatened species, populations or ecological communities

Initial risk

Of the 18 fish and invertebrate species, population, communities or groups listed under State and Commonwealth legislation that were assessed, several species of freshwater crayfish, four species of fish and two populations of fish are at medium or greater risk due to fish stocking. The risk to these species is that fish stocking would impede the recovery and conservation of a threatened species. The level of risk was determined by examining the spatial and temporal overlap and ecological interactions between stocked species and threatened species.

Of the eight frog species that were assessed, six are considered to be at medium or greater risk due to fish stocking. The elements of the activity thought to be most responsible for those risks are the species stocked, the stocking locations, hatchery protocols and information gaps.

Response

The draft FMS contains a number of policies and measures that contribute to the protection of threatened species and populations, the most direct and influential of which include:

- the conservation stocking policy provides for the restocking, where appropriate, of native fish into areas where their populations are depleted
- the salmonid stocking policy allows the stocking of salmonids into waters in which they have been previously stocked since 1990, but does not allow stocking into previously unstocked waters
- a schedule of waters permanently and temporarily closed to stocking, which provide explicit protection for threatened species, including the use of a buffer zone around verified threatened species locations
- a review of each proposed stocking event in accordance with environmental assessment guidelines (called 'stocking review guidelines'), and
- a research plan designed to address key knowledge gaps.

Predicted outcome

These measures are likely to adequately address the risks identified to threatened species. Considering the presence of threatened species during each stocking proposal should ensure that appropriate and thorough consideration is given to threatened species at the local (site) scale. In particular, the buffer zone should alleviate some of the immediate impacts, but also allow a species to expand its current range with minimal pressure due to stocking. The effectiveness of the buffer zone will also be assessed under various components of the research plan. If the proposed research was not undertaken more stringent measures would be required to mitigate potential impacts, such as not allowing any stocking in waterways known to contain aquatic threatened species.

Unlisted species of conservation concern

Initial risk

Species of fish that are not currently listed under any threatened species legislation are also considered in the EIS. These species were included because concerns have been raised in the scientific literature about their decline and fish stocking has been suggested as a possible cause of decline. It is important to consider the risk to 'unlisted' species as it enables management actions to be implemented that can prevent them from becoming threatened.

Of the eight species of fish that were assessed, two species are considered to be at medium or high risk from salmonid stocking and another three species are at medium risk from the stocking of native fish.

Response

The measures in the draft FMS to reduce the risks to these species are the same as those for threatened species.

Predicted outcome

The risks to four of the unlisted fish of conservation concern at medium or greater risk have been adequately addressed by the draft FMS. For the remaining species, Murray jollytail, there is insufficient information about the species to more accurately determine its status or whether there is a serious or irreversible threat from stocking, and so no direct management measures are warranted. However, it is likely to indirectly benefit from some of the other measures. In particular, the protection afforded these species by the inclusion of certain waterways in the closed water schedules will promote conservation of remaining populations of these species, thus preventing fish stocking activities from contributing to any further decline.

Locations of conservation significance

Initial risk

The risk assessment concluded that the aquatic components of the currently listed Wilderness and World Heritage areas are at medium risk levels under the current management arrangements for fish stocking. The assessment also highlighted previously unstocked waterways and/or waterways that have been largely unaffected by stocking or other anthropogenic impacts as likely to contain unique or unaltered faunal assemblages, and thus represented areas of conservation significance even though they were not recognised in the legislation as such. Ramsar wetlands are considered to be a low risk due to the current activity and this was primarily due to the lack of stocking in those areas. The impact of the current stocking activity on ecosystem processes (which generally create the conservation significance) was largely undetermined in the risk assessment, but some impact is considered likely. The four conservation areas and ecosystem processes are thus all identified as requiring direct or indirect management measures within the draft FMS to ensure that any potential impacts due to stocking are mitigated.

Response

The draft FMS has included existing Wilderness and World Heritage areas in the schedule of waters permanently closed to stocking, and existing Ramsar wetlands in the schedule of temporarily closed waters. Previously unstocked waters cannot be stocked with salmonids, but can be stocked with native species provided they are within the natural range of the species and the new Conservation Stocking protocols are observed. Research is also proposed into the fate and movement of stocked fish and the broader ecological impacts of stocking.

Predicted outcome

Overall, the assessment of the draft FMS concludes that the proposed measures are likely to effectively mitigate any immediate impacts to currently listed Wilderness, World Heritage and Ramsar areas. Prohibiting stocking alleviates pressure on the aquatic components of those areas, and the reduced number of people attracted to such areas also affords some protection to the terrestrial components of those areas by minimising anthropogenic influences. These measures are consistent with the legislation and management principles for those protected areas.

This will mitigate most potential impacts in those areas, but perhaps more importantly, will not be implemented as a stand-alone measure. The draft FMS proposes a series of research programs into the environmental impacts of fish stocking, which should remove most of the uncertainty highlighted as a problem during the risk assessment. In particular, investigating the fate and movement of stocked fish, and their impact on threatened species and other fauna of the receiving environment, will assist in determining the adequacy of the proposed measures. Wilderness and World Heritage areas often represent the upper, more pristine reaches of catchments. Stocked fish are likely to migrate into those headwaters and if conditions permit, may colonise those headwaters. That would effectively nullify the ban on stocking in those areas. Such research may indicate that a buffer zone is also required for those areas, but is considered unnecessary at this stage in light of the other measures.

The draft FMS proposes that salmonids not be stocked into previously unstocked waters. This serves to both minimise any potential extent of impacts due to stocking salmonids and provides all stakeholders with greater certainty. This measure does not apply to native species. Any proposal to stock native fish in such areas will require strong justification, be assessed in accordance with Conservation Stocking protocols (including stringent genetic requirements) and take account of the need to maintain suitable reference waters that are not stocked for comparative research purposes.

Genetics

Initial risk

The review of existing information about genetic protocols of hatcheries and structuring of wild populations of native fish suggests that the current activity of fish stocking is posing a significant risk to the genetic integrity of wild populations of native fish. This risk is compounded by the lack of information about the genetic diversity of the populations from which broodstock are collected and into which progeny are released. The lack of information also means that there is a high degree of uncertainty associated with the designation of high risk.

There is little genetic information for the majority of the species that are currently used for stock enhancement and the genetic profiles of many populations may already be compromised. The monitoring that has been done for some species indicates that not only is there genetic structuring for most native species throughout the State, but also that there are likely to be separate species determined following further work.

The limited available information indicates that inbreeding has been detected in wild populations of golden perch and silver perch that were supplemented from hatchery stock. Inbreeding can cause reduced fecundity and survival, and increases the number of deformities and the probability of extinction in wild populations. The use of insufficient numbers and/or management of broodstock generally cause inbreeding. Further, and of greater concern, is that the genetic guidelines adopted to aid the endangered eastern cod have either been insufficient to maintain genetic diversity or have not been observed or both. The remaining population has a naturally low genetic diversity, and some geneticists believe that the past breeding program has compromised this.

Response

The draft FMS contains a number of policies and measures to reduce the risks to wild populations of native fish, the most direct and influential of which include:

- Hatchery Quality Assurance Program and accreditation scheme for hatcheries that produce fish for stocking
- broodstock collection and genetic resource management guidelines
- compliance inspections and mandatory supply of genetic samples
- improved reporting and information management systems
- improved education of individuals and groups carrying out the stocking activity
- research plan
- setting new standards for Harvest Stocking in terms of the numbers of broodstock and their management, and
- the requirement for stockings of native species into previously unstocked waters to meet the higher standard for Conservation Stocking.

Predicted outcome

Through the Hatchery Quality Assurance Program and accreditation system, the draft FMS significantly reduces the risks to the genetic integrity of wild populations of native fish. Decoupling aquaculture breeding from the production of fish for stocking will mitigate most of the concerns highlighted in the review of the current activity. In conjunction with broodstock and genetic management guidelines, including the submission of samples to allow ongoing compliance, these measures represent a significant step forward for fish stocking relative to the existing activity.

Underpinning the Hatchery Quality Assurance Program is the proposed genetics research. Importantly, the draft FMS proposes to establish a library of micro-satellites (DNA markers that effectively allow the identification of fish from different areas), and to progressively map the distribution of native species (including sub-populations), which will guide future broodstock collection and release locations. This research will ensure ongoing improvement of the management and reduce the impacts of the activity.

Fish health and disease

Initial risk

Translocation of organisms, through the deliberate introduction of fish or the accidental introduction of fish and other organisms during stocking has the potential to affect the health of biota in the receiving environment. Relatively few ecological studies have been conducted on the impact of translocated species within freshwater environments, and none of those studies have been done on the species of stocked fish in NSW.

The studies that have been done report a variety of impacts due to the translocation of organisms, including alterations to the biophysical habitat, trophic effects, disease and genetic effects. A variety of parasites and disease-causing organisms have almost certainly been introduced into and disseminated throughout NSW waters as a result of stocking, and although they have not been reported to cause extensive fish kills in the receiving environment, they do cause significant mortalities within hatcheries. The fact that a variety of exotic viruses and parasites are known from both wild populations and hatcheries suggests that the current protocols of broodstock collection and hatchery management for fish stocking are ineffective at restricting the spread of such organisms. Overall, it is concluded that the current practices associated with fish stocking are posing a medium risk to the health of biota in the receiving environment.

Response

The draft FMS proposes to manage the translocation of organisms throughout State waters by:

- using both State and national translocation policies
- Hatchery Quality Assurance Program and hatchery accreditation scheme, including the use of water filters and transport protocols
- improved education and compliance
- alignment of the activity with national disease response management and the Aquatic Disease Watch Hotline

Predicted outcome

The risks associated with the translocation of organisms outside their natural range will remain high for two species as the draft FMS proposes to maintain the stocking of silver perch and golden perch, both western drainage fish, into the Hunter catchment on the eastern drainage. No other translocations are proposed.

The draft FMS should reduce the risk of translocating unwanted organisms contained within transport media through the use of screens to filter intake water and provisions built into the Stocking Review Guidelines and the Stocking Code of Conduct to be issued with every authority to stock (noting that safeguards will need to be specified). Screening and treatment of transport media are imperative for the draft FMS to meet its translocation objectives. The risk assessment identified a plethora of native and non-native species that are likely to enter hatchery ponds and systems through external water intakes and transferred around the farm by the subsequent movement of water around the site. The use of screens and water treatment, in conjunction with nationally approved disease management plans, a response fund for disease emergencies, establishing a disease mapping program, and registering with the Aquatic Disease Watch Hotline, would enhance the control of aquatic disease in NSW by the activity.

Socio-economic aspects

Initial risk

A socio-economic study commissioned to inform the preparation of the draft FMS was the first formal economic and social assessment of fish stocking in NSW. It was compiled from a limited amount of existing information from NSW Fisheries administrative records, and has been augmented by several targeted surveys of hatcheries, angling clubs, acclimatisation societies and fishing guides involved in fish stocking. A specially commissioned survey of 600 people in the community was also undertaken to obtain current information on community attitudes and the perceived risks associated with fish stocking.

Overall, the community survey results indicate that fish stocking is seen as an acceptable activity by the majority of those surveyed. In particular, survey respondents believe that fish stocking creates increased recreational fishing opportunities, supports tourism and local economies and that stocking edible fish is a desirable use of public impoundments. The results also suggest that there is considerable uncertainty about some possible environmental effects of fish stocking. Over a third of those surveyed considered that there could be some impacts on threatened species of fish due to stocking other species, and less than 25 percent considered that stocking contributed to water pollution. It was acknowledged that stocking of threatened species was seen as an important conservation strategy by a large majority of those surveyed.

The major economic contribution from fish stocking comes from activities involving recreational fishing expenditure and tourism. Expenditure on freshwater fishing is estimated to be $133M each year, based on the results of the recently completed national recreational fishing survey. Previous surveys suggest that in the Snowy Mountains region, which is reliant upon stocking of salmonids, that expenditure is approximately $47M. Although the value of expenditure across the State attributable to stocking is not known, it is apparent from these different surveys that it is likely to be significant and in the range of $47M to $133M.

Direct employment in businesses benefiting from recreational fishing are estimated at 1,729 persons, of which 432 persons are related to tourism expenditure. Indirect employment from the total recreational fishing expenditure is estimated at 864 persons, of which 360 are related to tourism.

Public hatcheries produce approximately 7 million fish each year for stocking or 87.5 percent of the total number of fish produced for stocking. Private hatcheries produce approximately 1 million fish each year or 12.5 percent of the total. The total investment in private and public hatcheries associated with stocking is estimated to be $40M. This comprises $20M in government hatcheries, $15M in private hatcheries (current market value) and $5M in land.

There are 15 private hatcheries that are involved with stocking public waterways, out of a total of approximately 150 private aquaculture hatcheries in NSW. About 50 percent of the production from these 15 hatcheries is attributable to stocking public waterways, although this varies by region from 3 percent in the Darling region to 86 percent in the Murray region. Private hatcheries can only produce native species for recreational stocking purposes, except for one hatchery that produces eastern cod for conservation stocking purposes according to NSW Fisheries guidelines.

Private hatcheries involved in stocking currently employ approximately 32 persons directly, with 50 percent of these people being employed full-time. The size of private hatcheries involved in stocking is generally small, with one or two people per farm and businesses operating on either a part or full time basis.

In the five public hatcheries run by NSW Fisheries, 100 percent of staff time is attributable to stocking activities. A total of 15 people are employed in the public hatcheries whose primary aim is producing fish for stock, with one person part time. There are also seven people employed in research and management and monitoring activities, though not full time. Employment in private hatcheries is seasonal for casual staff, while in public hatcheries the employment is year round for all staff involved in stocking.

At present, many of the risks attributable to the impacts of stocking and stocking related activities and management are borne by the environment, for example, through impacts on threatened species, changes to the genetic integrity of natural fish populations and the potential introduction of pests and diseases into natural waterways. On the other hand, many of the immediate benefits of stocking are received by fishers, fishing dependent businesses and hatcheries, such as through widespread fishing opportunities and lower operating standards and costs. However, these benefits are exposed to considerable uncertainty unless action is taken to reduce the risks attributable to stocking, such as by addressing threatened species, pest and disease issues in a pro-active and orderly way.

Addressing the identified biophysical risks will have implications for some private hatcheries. While a formal survey of the economic returns of private hatcheries was not undertaken, survey interviews suggested there was little, if any, economic profit in some of these operations and that some may be reliant on other non-stocking activities for part of their income. In general, these factors combined with the structure of the industry suggest that there is limited capacity for hatchery operators to adapt to changes in their business environment. In particular, they appear vulnerable to changes in stocking policy (eg demand for stock, alterations to production techniques and administrative charges) and other non-policy factors (eg water access and quality, interest rates and wages). However, there is a limited number of hatchery operators involved in stocking, some expect the implementation of higher standards and some have the option to focus on aquaculture operations. Such elements can be readily considered in any necessary policy changes.

Response

The draft FMS proposes a number of measures to maximise economic benefits, provide social equity from the activity and minimise the risks to hatchery operators:

- Hatchery Quality Assurance Program and hatchery accreditation scheme
- broodstock collection and management guidelines
- to appropriately manage stocking in areas where fish stocking adversely affects threatened species
- to provide for the stocking of sufficient quantities of fish to provide or enhance quality recreational fishing and Aboriginal cultural fishing opportunities
- to develop a classification scheme for NSW waters to evaluate the potential viability of stocking proposals
- to continue to develop the Dollar-for-Dollar Native Fish Stocking Program to enhance recreational fishing opportunities, including hatchery development, and provide an avenue for private enterprises to benefit from the activity
- to continue conducting angler-catch surveys at major inland fishing competitions and gather other information relevant to the management of the activity
- to monitor the level of socio-economic benefit from fish stocking using surveys undertaken on an episodic basis

Predicted outcome

The draft FMS provides for an ongoing stocking program with safeguards to address potential risks (e.g. pests and diseases), thereby providing the basis for the maintenance and development of economic and social activities dependent on stocking at a local and regional level. In particular, hatchery operators should be potential beneficiaries as a result of greater certainty in their business environment. The implementation of higher standards in hatcheries will involve some increase in costs, however, these also may lead to improvements in the efficiency of hatchery operations, if successfully implemented. Notably, a number of private hatchery operators expect higher standards to be implemented in order to underpin the ongoing operation of the industry. Phasing in the standards will enable hatcheries to plan and adjust their operations. However, it is possible that some private operators may choose to focus their operations on aquaculture rather than implement the standards proposed for stocking or for marginal operators to pursue alternative business activities.

Indigenous issues

Initial risk

The review of existing information and responses to surveys from Aboriginal communities made it apparent that despite a long history of fish stocking, Aboriginal communities were largely unaware of and thus had little involvement in the activity. Aboriginal people have a long tradition of integrated cultural and economic associations with the fishery resources (places and species) of NSW rivers, and see stocking as one means to maintain that association. Evidence of their long association with fishery resources is found in the archaeological record and in early nineteenth century ethnographic references to Aboriginal fishing practices and the importance of fish and shellfish in their diets at that time. This cultural and economic tradition has contemporary continuity.

The views expressed by local Aboriginal community representatives during this assessment process indicated a strong community perception that Aboriginal fishers consider themselves as custodians of valuable natural resources, who participate in fishing activities both for subsistence reasons and to continue and transfer cultural values. Aboriginal fishing for cultural purposes has also been affected by the steady decline in traditional native fish species as a result of habitat degradation.

In addition to addressing some concerns about culturally important native fish stocks, the draft FMS is viewed as an opportunity to raise awareness about Aboriginal fishing practices, to improve communication and to support in implementing many of the actions within the Indigenous Fisheries Strategy. These include stocking for cultural purposes and possible involvement in hatchery operations. The stakeholder role of Aboriginal communities was identified as needing enhancement and clarification through the draft FMS. In particular, the role of Aboriginal communities in planning for fish stocking activities, and opportunities for participating more broadly in the stocking process and in the economic aspects of fishery management (such as hatcheries) need to be emphasised.

Response

Within the context of actions being implemented under the Indigenous Fisheries Strategy, the draft FMS proposes a number of measures relating to Aboriginal cultural interests and fishing practices, including:

- minimise negative impacts of the activity on cultural heritage values and provide opportunities for Aboriginal communities to participate in stocking activities and to support cultural fishing practices
- provide for the stocking of native fish for Aboriginal cultural fishing and moiety purposes, taking account of research to identify practices and key species, means to rebuild local species populations and the development of partnership arrangements,
- ensure that new information about areas or objects of cultural significance is taken into account in the stocking review framework
- consult with relevant Aboriginal groups in the assessment of any new sites proposed to be stocked
- conduct client satisfaction surveys
- monitor the level of socio-economic benefit from fish stocking using surveys undertaken on an episodic basis, and
- develop and implement a culturally appropriate educational (communication) plan.

In addition, there are performance indicators to monitor applications for stocking for cultural purposes by Aboriginal persons or groups, and to respond to cultural heritage issues.

Predicted outcome

The draft FMS represents a significant commitment to improving the involvement of Aboriginal communities in the activity of fish stocking, and is consistent with the Indigenous Fisheries Strategy. The draft FMS recognises Aboriginal communities as stakeholders in the activity and provides mechanisms to engage communities in the activity of fish stocking. Importantly, it goes beyond the general consideration of sites, and recognises the importance of fishing as a cultural practice and that many native species have significant value placed on them beyond a food source. The development of the education plan will also be a vital tool for disseminating this type of information to fishers, stockists and the broader community.

Sites of historic, heritage or cultural significance

The assessment of the existing activity found that there was a very low potential for fish stocking activities to interact with, or impact on, heritage items of known historical significance. Continuation of fish stocking activities as proposed under the draft FMS will not increase the risk of impacts on these items.

Importantly, the Stocking Review Guidelines within the draft FMS address heritage features, which should cater for the potential for an extension of fish stocking activities as proposed under the draft FMS or by another proponent involving new stocking locations. Through the proposed education and compliance plan, proponents need to be made aware of the responsibilities implied by the heritage legislation and ensure that the specific constraints associated with proposed stocking locations are identified. This will involve confirmation of the presence of any item listed in a relevant register or inventory and modification of the proposal, as necessary, to ensure that such items are not affected by the activity.

Justification for the Draft Strategy

The risk assessment of the current activity found numerous components of the environment that are at risk due to fish stocking, and that they are invariably affected by multiple elements of the activity. The draft FMS proposes a suite of management responses that the risk assessment concludes would effectively mitigate most of the environmental impacts. The assessment of the draft FMS found that many of the measures are necessarily precautionary, and that they need to be validated by further research and/or monitoring. A review of all research into the activity of fish stocking is proposed to address that concern of the environmental assessment.

The assessment also highlighted the socio-economic and cultural importance of the activity of fish stocking, particularly in rural regions such as the Snowy Mountains. It is evident that the activity provides employment and tourism opportunities that are important for regional economies, even though only a limited number of people are directly employed at fish hatcheries. The assessment suggests that some hatchery owner-operators could incur higher costs in the short term (to fulfil accreditation requirements), however, the changes required, if successful, are expected to increase the efficiency of hatchery operations and provide greater certainty. As providing fish for stocking is the not the sole source of income for most existing hatchery operators it is likely to be a minor imposition. Establishment of sound genetic protocols and information management are seen as vital measures to ensure the sustainability of the resources and the activity of fish stocking.

For these reasons, especially the proposals under the draft FMS to establish waters that will be permanently closed to stocking, some that are temporarily closed to stocking and hatchery accreditation, the draft strategy is considered the most appropriate way to conduct the activity of fish stocking in an ecologically sustainable manner.

Table A1. The environmental impact statement summary table showing the risks associated with the current activity, the programs proposed in the draft FMS to mitigate those risks, and an assessment of the predicted effectiveness of the draft FMS.

It is important to note that many components are related and as such the listed programs address more components than is possible to list in table format.

Issue	Component	Elements of activity contributing to risk	Risk level due to current activity	Programs in draft FMS to mitigate risk	Draft FMS likely to reduce risk
Biophysical	Listed threatened and protected species, populations, communities or groups	Species that are stocked Stocking locations Information gaps	**Medium-high for 13 species** Low for 12 species Indeterminate for one community	Stocking assessment system; schedule of permanently closed waters and another of temporarily closed waters; GIS mapping, classification of waters; research plan	Yes
Key area within EIS			***B2.2***	*D3.3 - D3.5*	
	Unlisted species of conservation concern	Species that are stocked Stocking locations Information gaps	**High for 1 species** **Medium for 4 species** Low for 3 species	Schedules of permanently closed waters and another of temporarily closed waters; GIS mapping, classification of waters; research plan	Yes
Key area within EIS			***B2.3***	*D3.4*	
	Areas of conservation significance	Stocking locations Information gaps	**Medium for aquatic components of Wilderness and World Heritage areas** Low for National Parks and similar reserves	No stocking in existing Wilderness, World Heritage or Ramsar areas	Yes
Key area within EIS			***B2.4***	*D3.3 - D3.5*	
	Genetics	Broodstock collection Hatchery protocols Information management Stocking locations Compliance levels Information gaps	**High**	Genetic resource management guidelines; Hatchery Quality Assurance Program (HQAP); Hatchery Accreditation System (HAS); translocation policy; restriction on certain genetically modified organisms; research plan	Yes
Key area within EIS			***B2.5***	*D4*	

Table A1 cont.

Issue	Component	Elements of activity contributing to risk	Risk level due to current activity	Programs in draft FMS to mitigate risk	Draft FMS likely to reduce risk
Biophysical cont.	Fish health and disease and translocation of organisms	Broodstock collection Hatchery protocols Information management Stocking locations Compliance levels Information gaps	**High**	Alignment of the activity with state and national translocation policies, stocking assessment system; HQAP; HAS; advisory material; alignment of the activity with national disease response management; initial response fund for disease emergencies; Aquatic Disease Watch Hotline	Yes for fish health and disease No for translocation (golden and silver perch stocked into Hunter catchment) Yes for translocation of other species
Key area within EIS			***B2.6***	*D4*	
Socio-economic	Hatchery viability	External factors, e.g. genetic issues and threatened species that create uncertainty	**Medium**	Genetic resource management guidelines; HQAP, HAS; schedules of closed waters; translocation policy; restriction on certain genetically modified organisms; research plan	Yes
Key area within EIS			***B3.7 and B4***	*D4*	
	Regional economies and employment	Stocking locations (extent) and practices	Low	Proposed continuation of stocking; HQAP; stocking guidelines; education and compliance plan	Yes
Key area within EIS			***B4***	*D4*	
Aboriginal culture	Traditional fishing practices	Species that are stocked Stocking locations Communication Information gaps	**Medium-high**	Within the context of the Indigenous Fisheries Strategy, provide for the stocking of native fish for Aboriginal cultural fishing and moiety purposes; provide opportunities for Aboriginal communities to participate in stocking activities; client satisfaction surveys	Yes
Key area within EIS			***B5.1***	*D4 - Goal 2*	
	Sites of cultural significance	Stocking locations	Low	Consult with relevant Aboriginal groups in the assessment of any new sites proposed to be stocked	
Key area within EIS			***B5.3***	*D4 - Goal 2*	
Heritage	Sites or items	Stocking locations	Low	Stocking review guidelines	
Key area within EIS			***B5.3***	*D4*	

How the Environmental Impact Statement was Developed

This EIS was developed using a modified framework of the generic risk management process (AS/NZS 4360) acknowledged by Standards Australia and Standards New Zealand. AS/NZS 4360 uses a seven-step process for risk management, but this EIS has added an eighth step in that following the treatment of risk (i.e. the draft FMS), it has re-evaluated the level of risk that would eventuate if the management strategy was to be implemented. This is the first time that such a process has been applied to a management strategy for fish stocking, and represents the fourth activity in NSW to be assessed in terms of Ecologically Sustainable Development (ESD). The EIS meets the environmental assessment requirements of the NSW *Environmental Planning and Assessment Act 1979*.

Development of the draft strategy

The draft strategy for Fish Stocking was compiled with significant input from the Recreational Fishing Freshwater Management Planning Committee (RFFMPC). The RFFMPC includes elected representatives from the four trout acclimatisation societies and other fish stocking organisations as well as representatives of the private hatchery industry, Aboriginal people and the Nature Conservation Council. Input into the draft strategy was also sought from all angling clubs and hatcheries involved in the activity, the Minister for Fisheries' advisory councils on conservation and recreational fishing, and the Fisheries Resource Conservation and Assessment Council. Government agencies, such as DIPNR, have been consulted during the drafting of the EIS, as have professionals in the fields of socio-economics, Indigenous and European heritage, genetics and freshwater ecology.

The draft strategy for Fish Stocking contains all the proposed rules for management of the fishery, but it is much more than a collection of rules. The draft strategy contains the objectives for the fishery, a detailed description of the way the fishery operates, and describes the management framework for at least the next five years. It also outlines a program for monitoring the environmental, social and economic performance of the fishery, establishes trigger points for the review of the strategy, and requires regular reporting on performance in order to ensure that the strategy meets its objectives.

Development of the environmental impact assessment

It is important to understand that the environmental impact assessment and the strategy have been developed concurrently, in a series of steps. The draft strategy assessed here is in fact the third draft of the strategy. The process has been designed to give early feedback and allow the proponent (NSW Fisheries) to respond to the predicted environmental impacts of the management proposals. Each draft of the strategy is then modified to ensure that the proposed management framework appropriately addresses the environmental impacts identified during the assessment process.

One difference between assessing the impacts of an existing activity and assessing, for example, a new building development is that the activity being assessed already exists. Consequently, any changes to stocking practices and levels of production will have direct social and economic impacts on already-established private hatcheries, recreational fishing and related industries such as regional tourism. It is important that when the impacts of proposed changes are assessed time is allowed, where appropriate, for industry to adjust to any required changes.

The assessment of fishery impacts is also much more difficult than is the case with many other natural resources because, in comparison to our knowledge of terrestrial resources, much less is known about aquatic ecosystems. In reality, and with few exceptions, the population sizes or biomass of fish species are poorly understood in the relatively manageable environments of artificial impoundments and unknown in the more dynamic riverine environments where the activity is conducted. Further, a lack of rigorous scientific studies into the effects of stocking upon the receiving environment means that there is a great deal of uncertainty accompanying determinations of risk. The environmental assessment acknowledges such uncertainty and, where there is little information upon which to draw definitive conclusions, the precautionary principle is applied. The precautionary principle, a key component of the principles of ESD, states that if there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent that environmental degradation.

Consulting the Community

You are invited to comment on the Environmental Impact Statement on Freshwater Fish Stocking in NSW, which is on public exhibition until 19 December 2003. The full EIS can be viewed at NSW Fisheries offices, the head office and regional offices of the Department of Infrastructure, Planning and Natural Resources, NSW Government Information Service, local councils and the Sydney office of Environment Centre (NSW) during normal business hours. A paper or CD copy can be purchased for $25 (includes GST). It is also available on the NSW Fisheries website at www.fisheries.nsw.gov.au.

Need more information?

For enquiries relating to Fish Stocking, please phone (02) 6042 4211.

For enquiries relating to the environmental impact statement, please phone (02) 4916 3832.

Or visit: www.fisheries.nsw.gov.au

Want to comment?

Write to: Environmental Impact Statement Submission
Fish Stocking
PO Box 21
CRONULLA NSW 2230

Fax: (02) 9527 8576 (marked attention "Fish Stocking EIS Submission")

Email: Fishstocking.eis@fisheries.nsw.gov.au

If you wish your submission to remain confidential, it should be so marked.

Comments must be received by 19 December 2003.

CHAPTER B REVIEW OF THE EXISTING ACTIVITY OF FISH STOCKING

Overview

The activity of fish stocking has been practiced across Australia for well over a century. Early stocking began with the importation of trout ova from Europe and New Zealand in an attempt by trout enthusiasts to replicate successful salmonid fisheries established in other countries. In NSW today, the activity has evolved and expanded into a sophisticated operation that now also includes the use of many native species to help meet the increasing demands on the State's freshwater fisheries resources.

Management of the activity was assumed by the NSW Government around 1960 and since then over 80 million fish have been stocked into dams, creeks and rivers across the State at a current rate of approximately 7 million fish per annum.

Management of the activity has been continually challenged in response to ever changing environmental factors and the need to develop stocking practices in an ecologically sustainable manner. Technological advances have seen the activity develop to the point where it now supports a number of vital objectives of today's fisheries management programs. NSW Fisheries' stocking programs support world-class recreational fisheries that generate substantial economic benefit to regional NSW while conservation stocking plays a vital role in the protection and rehabilitation of threatened species.

As the principal authority for the activity, NSW Fisheries is assisted by major native fish stocking groups, trout acclimatisation societies and their affiliates, recreational fishing clubs, the aquaculture industry, local governments, community groups and individuals.

This chapter describes the existing operation in all its elements and examines the current objectives of stocking management and issues affecting the activity.

Chapter D then specifies changes that are proposed by the draft FMS to deal with each of the issues and provide strategic management of the activity into the future.

B1 The Stocking Activity and its Current Management

The current fish stocking activity administered by the New South Wales Government through NSW Fisheries is designed to provide specific services for two main client groups, namely the recreational fishing sector and the conservation sector. Throughout this chapter these services will be referred to as *Recreation Stocking* and *Conservation Stocking* as defined below.

Recreation Stocking: "The stocking of native or salmonid species for the purpose of establishing or maintaining quality recreational fisheries in areas where the naturally available stocks could not support such fisheries". *Examples*: Native fish stocking, salmonid stocking, stocking of newly created waterways.

Conservation Stocking: "The stocking of a native species as part of a recovery plan or other program relative to the conservation of that species or biodiversity generally". *Examples:* Eastern Freshwater Cod Recovery Plan (hereafter referred to as eastern cod), trout cod conservation stocking.

B1.1 Catchments where fish are stocked

B1.1.1 Locations where fish are stocked

The following descriptions of the activity refer solely to stocking by NSW Fisheries and/or stocking events by individuals under permit from NSW Fisheries. It does not account for the possible cross-border movement of stocked individuals from Queensland, South Australia or Victoria.

Non-tidal waters: Under the current operation of the activity fish are stocked into most non-tidal waters of NSW (see stocking records in Appendix B1) to support *Recreation Stocking* and *Conservation Stocking* programs.

Figure B1. NSW catchments that will be used to describe where fish have been stocked.

Marine waters: There have been no marine stockings carried out in NSW for Recreation Stocking or Conservation Stocking or to supplement commercial fisheries. However, there have been several research and development programs for stocking marine species, namely the mulloway-stocking program in Smiths Lake (near Forster) and at Saltwater Lagoon (near Taree) as well as abalone seeding trials along the NSW coast. As this review deals only with the stocking of freshwater species, the marine stocking trials will not be further discussed in terms of management arrangements (further details on these programs may be found in section B3.3.4).

B1.1.2 Species stocked under the current operation of the activity

Table B1. Species stocked in NSW catchments.

East Coast Catchments	Species Currently Stocked * Indicates whether self-sustaining in this catchment
Tweed River	*Australian bass
Brunswick	*Australian bass
Richmond	*Australian bass, *eastern cod, rainbow trout, brown trout
Clarence	*Australian bass, *eastern cod, rainbow trout, brown trout
Bellinger	*Australian bass
Macleay	*Australian bass, brown trout, rainbow trout
Hastings	*Australian bass, brown trout, rainbow trout
Manning	*Australian bass, brown trout, rainbow trout
Port Stephens	*Australian bass
Hunter	*Australian bass, *golden perch, *silver perch, *brown trout, *rainbow trout
Lake Macquarie	*Australian bass
Hawkesbury	*Australian bass, brown trout, *rainbow trout
Port Jackson	*Australian bass
Lake Illawarra	*Australian bass
Shoalhaven	*Australian bass, *rainbow trout
Clyde	*Australian bass
Moruya	*Australian bass, rainbow trout, brown trout
Tuross	Not previously stocked
Bega	*Australian bass, brown trout, rainbow trout
Towamba	Not previously stocked
Genoa	Not previously stocked

Murray River Catchments	Species Currently Stocked * Indicates whether self-sustaining in this catchment
Murrumbidgee	*Murray cod, *golden perch, *silver perch, *trout cod, Atlantic salmon, *brown trout, brook trout, *rainbow trout
Murray	*Murray cod, *golden perch, *silver perch, *Atlantic salmon, *brown trout, brook trout, *rainbow trout
Lake Hume	*Murray cod, *golden perch, *silver perch, *trout cod, Atlantic salmon, *brown trout, brook trout, *rainbow trout
Lake George	*Australian bass, *golden perch, *silver perch, *Murray cod, *brown trout, *rainbow trout
Lachlan	*Murray cod, *golden perch, *silver perch, *trout cod, Atlantic salmon, *brown trout, brook trout, *rainbow trout
Peacock Creek	*Murray cod, *golden perch, *silver perch

Table B1 cont.

Darling River Catchments	**Species Currently Stocked** *** Indicates whether self-sustaining in this catchment**
Macintyre	*Murray cod, *golden perch, *silver perch, *brown trout, brook trout, *rainbow trout
Gwydir	*Murray cod, *golden perch, *silver perch, brown trout, brook trout, *rainbow trout
Namoi	*Murray cod, *golden perch, *silver perch, *brown trout, brook trout, rainbow trout
Castlereagh	*Murray cod, *golden perch, *silver perch
Macquarie	*Murray cod, *golden perch, *silver perch, trout cod, *brown trout, brook trout, *rainbow trout
Darling	*Murray cod, *golden perch, *silver perch
Moonie	Not previously stocked
Condamine	Not previously stocked

Far West Catchments	**Species Currently Stocked**
Bulloo	Not previously stocked
Cooper	Not previously stocked
Lake Bancannia	Not previously stocked
Lake Frome	Not previously stocked
Lake Victoria	Not previously stocked
Paroo	Not previously stocked
Warrego	Not previously stocked

Montane	**Species Currently Stocked** *** Indicates whether self-sustaining in this catchment**
Snowy	Atlantic salmon, *brook trout, *brown trout, *rainbow trout*

B1.1.3 Current stocking objectives and programs

Table B2. Programs undertaken in the current activity that support conservation and recreational fishing sector needs.

Program Type	**Program Name**
Conservation Stocking Programs	Eastern (freshwater) Cod Recovery Plan Trout Cod Conservation Stocking Program
Recreation Stocking Programs	Australian bass enhancement stockings Dollar-for-Dollar Native Fish Stocking Program Salmonid Stocking Program Snowy Lakes Trout Strategy Access to fish stocking via the permit system (i.e. applications from individuals, organisations, fishing clubs)
Commercial Fishing	No past or present programs to establish or enhance commercial fisheries. The stocking of fish to enhance commercial catches has not been conducted under the current activity other than in two research and development programs.

B1.1.3.1 Conservation stocking programs

Eastern (freshwater) Cod Recovery Plan

The Eastern (freshwater) Cod Recovery Plan was developed in response to the declaration of the cod as a vulnerable species under threatened species legislation requiring the preparation of a recovery plan. Threatened species recovery plans are designed to promote the recovery of a threatened species, population or ecological community, with the aim of returning the species, population or ecological community to a position of viability in nature. A recovery plan must be prepared for each threatened species listed under the FM Act. Stocking of eastern cod back into the fish's natural range is an important aspect of the recovery plan and stocking will continue to supplement stocks until such time as the species has established a viable population capable of natural recruitment.

Trout Cod Conservation Stocking Program

This program has been an ongoing initiative of the NSW Fisheries since 1986. The technology used to breed trout cod was developed at the Narrandera Fisheries Centre (NFC) and was designed to support a Conservation Stocking program in response to the serious decline of the species throughout its natural range in NSW. The species was declared as Endangered on national and international lists in 1998. Categorised as Endangered in Action Plan (Wager & Jackson, 1993), currently listed as Endangered on International Union for the Conservation of Nature (IUCN) Red List, assessed as Critically Endangered against 1994 IUCN criteria by Wager & Jackson (1993) and Brown *et al*, 1998.

NSW Fisheries is currently preparing the Trout Cod Recovery Plan for NSW waters and the Conservation Stocking of the species will no doubt roll-over under the auspices of that plan in due course.

B1.1.3.2 Recreation stocking programs

Native fish stock enhancement program

The NSW Fisheries' Native fish stocking program is conducted annually by the Department as a service to the anglers of NSW. The program stocks Murray cod, golden perch and silver perch into western drainages, golden perch and silver perch into the Hunter catchment impoundments and Australian bass into eastern drainage impoundments.

Funds from the recreational fishing fee have been allocated by RFFTEC to enhance the long term production of native fish. Inland native fish breeding in impoundments is poor due to a lack of environmental triggers, while Australian bass do not breed in impoundments, as they require access to brackish estuarine waters. These impoundments represent significant recreational fisheries worth many millions of dollars to regional NSW, which would either not exist (Australian bass) or would suffer from poor recruitment (Murray cod, golden perch and silver perch) without stocking.

The Dollar-for-Dollar Native Fish Stocking Program

In 1998, the Recreational Freshwater Licence Expenditure Committee (RFLEC) recommended that funds be allocated from the Recreational Fishing (Freshwater) Trust Fund to support the efforts of local stocking groups in the stocking of high priority native recreational species within NSW waterways. In response to this request, NSW Fisheries developed the Dollar-for-Dollar Native Fish Stocking Program, which involves the matching of funding (from the Freshwater Fishing Trust) with those from organisations, such as angling clubs and local councils, that are raising money to purchase fish from private hatcheries to stock into public waters. Dollar-for-Dollar funding is available for Murray cod and golden perch for western drainage waters and Australian bass for eastern drainage waters.

During the 1999/00 stocking season, 40 stocking organisations successfully applied to the program for the western drainage. Over $80,000 was been spent in matching funding and 267,000 golden perch and 150,000 Murray cod were stocked into various waters. For the 2000/01 season, 12 hatcheries and 59 stocking organisations successfully applied for Dollar-for-Dollar funding in the western drainage, $124,000 was spent in matching funding and 407,000 golden perch and 197,000 Murray cod were stocked into various waters.

For the 2000/01 season, 6 hatcheries and 9 stocking organisations successfully applied for Dollar-for-Dollar funding in the eastern drainage and $28,000 was spent in matching funding with 91,500 bass stocked into various waters.

Salmonid Stocking Program (trout and salmon stocking)

As a service to the anglers of the State, NSW Fisheries produces rainbow trout and brown trout fry annually at its two salmonid hatcheries, Gaden (Jindabyne) and Dutton (Ebor) for public stocking. Atlantic salmon and brook trout, produced at the Gaden hatchery, are also stocked but only into select public waterways as these species are more bound by environmental parameters than brown trout and rainbow trout. The Gaden Trout Hatchery produces rainbow trout and brown trout from captive and wild broodfish. The Dutton Trout Hatchery produces rainbow trout from captive broodfish and brown trout from eyed ova, supplied by the Gaden Trout Hatchery.

Public water storages (dams) are stocked with trout, as are lakes, river and streams that offer appropriate environmental conditions for salmonid species. Stocking occurs into streams and impoundments of the New England region, the Central and Southern districts, the Monaro region, and around Orange, with the assistance of the trout acclimatisation societies. These include; New England Trout Acclimatisation Society (NETAS), Central Acclimatisation Society (CAS), Orange Trout Acclimatisation Society (OTAS), Council of Southern Districts Angling Clubs (CSDAC) and the Monaro Acclimatisation Society (MAS). Each of these acclimatisation societies consists of a number of individual branches that concentrate on stocking the streams in their immediate area. An annual stocking program is established at a meeting held prior to the spawning/production season, with representatives of all five acclimatisation societies and recreational fisheries managers. Individual clubs put forward their requests for fry and fingerlings, and also the streams and impoundments they wish to stock. Trout are also produced to support special stocking programs carried out by NSW Fisheries and can include the opportunistic stocking of waters with excess hatchery stock or retired broodstock.

Snowy Lakes Trout Strategy

NSW Fisheries has worked with the local community in the Snowy region to develop the Snowy Lakes Trout Strategy to ensure that the area remains a premier trout fishery. The Snowy Mountains Lakes Working Group was established in December 2000 to assist the Government in the development of this strategy. Anglers had shown concern about declining rainbow trout catches and the lack of formal management arrangements for the trout fisheries in the major Snowy Mountains Lakes (Lakes Jindabyne and Eucumbene, and Tantangara Reservoir). There is also a range of views on how best to manage these trout fisheries to maximise the social and economic benefits that can flow from a well-managed salmonid fishery.

The Strategy sets out a series of goals, objectives and management responses to issues concerning the appropriate and most efficient management of the trout fishery with respect to the aforementioned waterways (see www.fisheries.nsw.gov.au).

Access to fish stocking via permit system

NSW Fisheries provides a service that allows organisations or individuals to apply for a permit to stock fish in NSW waters. This service provides an avenue for the licensing of stocking events that are not part of an existing stocking program. Uses for the service include circumstances where, for instance, local government or community groups seek approval to stock a waterway as part of a environmental rehabilitation program or simply to enrich a community's assets by stocking certain waters with fish. Cultural stocking is also an area supported by this service and caters for religious and ceremonial stocking (release) events such as Buddhist groups who release live fish as part of their annual cultural ceremonies.

Under this system there is no restriction on who may apply for a stocking permit and unless the activity is considered to be potentially damaging to the environment the permits are usually approved and are issued free of charge.

B1.1.3.3 Marine stocking

As previously discussed, the stocking of marine species has only been trialed in a couple of locations and is not part of the current freshwater stocking program. It is not proposed under the draft FMS. Any marine stocking activity proposed in future must be accompanied by an EIS based on the guidelines to which this draft FMS is subject.

B1.1.4 Arrangements for undertaking the activity

B1.1.4.1 The stocking process

Primarily, the concept of fish stocking is applied where it is considered necessary to provide supplementary or entire stocks of hatchery-bred fish to establish or replenish stocks to support a viable fishery or population. A good example is the stocking of an artificial waterbody, such as a dam or other waterway, with a selection of appropriate species so as to establish a recreational fishery. Without a doubt this is the most popular form of large-scale stocking undertaken in NSW, although, rivers and creeks and other watercourses are also stocked regularly across the State to achieve similar outcomes.

Once the desired outcomes of the stocking program are defined (i.e. to establish a recreational fishery) the next step in the process is to select an appropriate species. Several species that may complement the establishment of a stocked fishery are often used to achieve this. Local species are the most obvious choice and in most cases are the only species' approved for stocking due to concerns about releasing fish outside their natural range. This is obviously not practical when considering the non-native salmonid species.

Suitable stock must be produced by a competent hatchery (these arrangements are discussed further in B1.3 - Hatcheries). Stock is sourced from the hatchery (usually by the proponent) and transported to the desired area where the fish are liberated by persons authorised to do so under a stocking permit (see Authorisation of stocking events in this section).

B1.1.4.2 Transport and temporary holding of stock

As most stock ready for release are usually infant fish they are readily transported by tanker or in a large aerated tub (usually <500L). Stock can last in these receptacles for quite a few days if necessary as a temporary holding measure or the fish can be returned to concrete or fibreglass holding/culture tanks if it is necessary that the fish have to be held for an indefinite period prior to release. This may be because of inclement weather or that some other factor has held up the proposed release date.

Small-scale events such as private farm dams stockings can be as rudimentary as the proponent transporting stock in a bucket or other small vessel equipped with an air-stone and battery operated pump or a plastic bag half-filled with water and inflated with oxygen. Providing the distance is not too great and the fish can be protected from extreme temperature fluctuations or violent movements these are usually quite successful operations. Some hatchery operators will deliver stock directly to a property in this fashion.

B1.1.4.3 Stocking methods

Stock may be released through a variety of methods but mainly through broadcast release. This is where the fish are separated from the main consignment in small lots (in plastic bags or buckets) and dispersed throughout the release site by volunteers, usually from fishing clubs and acclimatisation societies. Quite often the release crews use boats to transport the stock to the farthest possible reaches of the waterway. The rationale behind this method is to ensure an even distribution of stock throughout the area and to lessen predation by other fishes and birds if all the stock were released at a single site.

The release of stock is not an overly complex task, however, there are a few critical issues that need to be addressed as far as ensuring the optimal survival of the consignment. Next to predation, thermal shock is probably the next main concern as sharp variations in water temperature (< 3°) can have a devastating effect on juvenile fish.

Where fish are larger and less susceptible to predation and the release site is an enclosed waterbody such as a dam then the release can be undertaken purely by releasing the cock on the tanker and letting the entire consignment flow out. Caution still has to be taken to ensure thermal compatibility so relative temperatures are equalised beforehand by slowly adding water from the release point to the consignment. However, translocation, disease and pollution issues also arise with this method due to the release of large quantities of transport medium along with the stock.

B1.1.4.4 Authorisation of stocking events

The intentional release of fish into any NSW waterway is an offence unless authorised under permit issued under Section 216 of the *Fisheries Management Act 1994*. Stocking permits are available upon written application to NSW Fisheries and are issued free of charge. The permit authorises an individual or nominated members of an organisation (such as a fishing club) to release a specified number of a certain species, or mixture of species into prescribed waters of NSW to support either Recreation Stocking or Conservation Stocking.

Where a stocking is carried out by NSW Fisheries, such as the stocking of a public waterway for recreational fishing, and members of a fishing club, society or other volunteers assist in the release, those persons are authorised by virtue of the stocking permit held by NSW Fisheries.

B1.1.4.5 Involvement in fish stocking events

Fish stocking is seen favourably as a community event and in the days before the Government managed the activity it was members of the angling community in NSW who spent many years importing ova and developing hatcheries and new techniques to get viable stock into the States waters. Over 100 years later, the community is still heavily involved in stocking. Most are involved at the release-end by physically assisting in the actual stocking on a volunteer basis while some others have also taken more of an interest in the management of the activity by joining advisory councils, acclimatisation societies and angling clubs.

Privately owned and operated hatcheries (Private hatcheries) also play a role in the activity with stock produced for NSW Fisheries' managed programs such as the 'Dollar-for-Dollar Native Fish Stocking Program', and some smaller scale events such as stocking private farm dams. One private hatchery also produces stock to support the 'Eastern (freshwater) Cod Recovery Plan'. Before fish produced in these hatcheries can be used for any stocking program, they must be licensed under the aquaculture permit system established under Part 6 of the *Fisheries Management Act 1994* to ensure the proposal meets the minimum criteria. (For more information on associations, contractors, landowners and others involved in the activity see *Groups involved in stocking events* below).

B1.1.4.6 Verification of stocking events

Stocking records held by NSW Fisheries have mapped the activity for many years. Although there are some information gaps in the data through record loss and mismanagement, the stocking records show that over 80 million fish have been stocked since 1960 and in hundreds of waterways across NSW (Appendix B1).

Currently, the verification process is fairly straightforward. Whoever releases the fish, whether they are hatchery staff or angling clubs, must return the data to the central stocking record repository for the purposes of mandatory record keeping. Verification data includes information such as the species stocked, class of stock (age), hatchery producing the stock, group(s) releasing the stock, date of release, waterway and quantity.

B1.1.4.7 Groups involved in stocking events

NSW Fisheries

This agency is the primary producer and stockist under the current activity with few exceptions. The department produces a range of native and non-native species from its five hatcheries and is involved in most stocking events for which the stock is produced. Producing most stocks of salmonids and native species under the current activity and providing management arrangements for all stocking of NSW public waters and aquaculture facilities from where other stocks are produced, NSW Fisheries maintains overall control of the activity including the verification and management of stocking information.

The department also conducts research and monitoring as part of the ongoing management of the activity. Research includes the development of breeding and husbandry techniques, development of marking agents and analysis or recaptured stock. Angler surveys are conducted to determine recapture rates of stocked salmonids while creel surveys and angler knowledge surveys are used for other management arrangements.

Associations

Numerous associations are involved in the activity representing both recreational fishing and conservation interests (Appendix B1). Recreational fishing associations are usually formed to represent a particular discipline within the sport, such as a fly fishing association, but involvement includes numerous fishing clubs who engage in stocking programs for native fish. Fishing associations also assist the department in programs such as Bass Catch, where fishing clubs organise fishing competitions and collect important data on Australian bass taken from certain rivers during fishing competitions. Conservation associations have also had major involvement over the years such as Project Big Fish, a community based organisation committed to improving stocks of eastern cod in the north of the State.

Acclimatisation societies

There are five acclimatisation societies with 46 affiliated groups involved in stocking salmonids in NSW. Acclimatisation societies have played a pioneering role in salmonid production and stocking for over a century and well before the NSW Government had established an agency to manage the resource.

Acclimatisation societies have worked closely with the NSW Government since it took over all the societies' hatcheries and management role and continue to help plan annual stocking events, identify waters to be stocked, provide assistance at stocking events and contribute to management arrangements and policy development.

Until the establishment of the Prospect Hatchery in the 1889, private citizens and angling club members were responsible for introducing brown trout and rainbow trout and Atlantic salmon into NSW. The State established trout hatcheries to import eyed-ova, these facilities were often managed by angling clubs whose members had helped to build the basic infrastructure. Angling clubs also took responsibility for releasing fry, collecting the tiny fish in milk and cream cans from country railway stations, often at night, for immediate release into local waterways. Access to water was often difficult and usually by horse or on foot. Today, angling club members still release trout fry, although plastic containers, oxygenation, four-wheel drives and an established road system have made the task somewhat easier. Until the 1990s, angling club members assisted hatchery staff at both the Gaden and Dutton hatcheries by lending voluntary labour during busy periods such as the stripping of fish for eggs and the laying down of ova.

A forerunner to the acclimatisation societies was the NSW Rod Fishers' Society, formed in 1905 to lobby the Government to improve the trout fishery with regular donations for buying ova. Numerous local branches of the society formed and were active in the development and management of the early hatcheries. It 1924, the society part-funded the construction of the Creel hatchery, which it enlarged at its own expense in 1927. From 1924 onwards, the society was actively co-operating in the construction of six trout hatcheries. By 1938, there were 13 trout angling organisations associated with the Rod Fishers Society.

The acclimatisation societies were registered under legislation passed in 1935 with the objective of hatching, raising and distributing trout fry within particular districts. They received half of the fees from the trout licence (replaced in 1958 by the Inland Angling Licence), allowing the Government to legally devolve the responsibilities of hatchery management to local anglers.

The *Fisheries and Oyster Farms Act* of 1935 recognised five acclimatisation districts: New England, Central Northern, Central Southern, Western and Monaro. In 1937, the Armidale and District

Trout Fishers' Association was the first organisation to register as an acclimatisation society. However, with impetus provided by the Rod Fishers Society and local angling clubs, several more acclimatisation societies were registered in each district.

By the end of the 1930s, the principal acclimatisation societies were New England (NETAS), Central (CAS), Monaro (MAS), and Orange (OTAS), all of which were operating hatcheries in their own districts. These four societies continue to play an important role in the distribution of trout fry from the hatcheries. The efforts of the angling clubs, NSW Rod Fishers Society and acclimatisation societies have made a vital contribution to the development of hatcheries and the trout fishery in NSW.

Contractors

The only form of out-sourcing or contract work involved in the activity is the use of private hatcheries to produce native stocks for the Dollar-for-Dollar Native Fish Stocking Program, one-off stocking events and stock for the Eastern (freshwater) Cod Recovery Plan. All other production work, management arrangements and policy development are conducted by NSW Fisheries.

Landowners

The current activity does not rely on private landowners to provide access to stocked fish or any other involvement in the activity. There are, however, many instances where landowners allow anglers to pass through their property to reach certain waters to fish but this is an individual decision and does not form part of the management arrangements of the fishery. Fish-out operations, where fish are stocked into private waters for angling at a fee as a commercial enterprise, is managed under Part 6 of the *Fisheries Management Act 1994* (Aquaculture Management) and does not form part of the current or proposed operation of the activity.

Ownership of public water storages, where most fish are stocked, are public assets and arrangements are in place, albeit historically, to continue stocking in those areas. Examples are public water storage areas (public dams) and other areas managed by authorities such as the Murray-Darling Basin Commission. Ostensibly, these agencies (landowners) are not involved in the stocking events *per se* with the exception of the Snowy Mountains Hydro Electric Authority who contribute to the management of the Snowy Mountains Trout Strategy through the working group established to improve the management of the salmonid fishery in those waters.

Others involved in fish stocking events

NSW Fisheries as the principal management authority for the activity provides a service whereby any person or group may apply for a permit to stock fish into NSW waters. These provisions do not apply to the stocking of fish into private waters. Groups such as local governments, Landcare groups, non-affiliated fishing clubs, religious groups and individuals have all taken advantage of the fish stocking permit system in the past and this service area of NSW Fisheries has maintained a small but steady clientele.

Volunteers also play a vital part in the stocking events from time to time and can include persons such as volunteers assisting acclimatisation clubs, or assisting NSW Fisheries at fish liberation events.

Aboriginal communities - cultural significance

The Aboriginal communities throughout NSW place strong and continued cultural significance to each of the native species used in stocking programs. These communities have a close affiliation with the native species as an important source of food, a cultural fishing activity and as a focal point for family gatherings and story telling.

B1.1.5 Areas where stocking has been restricted all or some of the time

Historically, fish stocking in NSW has been restricted to the inland waters of the State in areas where environmental conditions are favourable for the proposed species so it can continue to grow and eventually be either taken by an angler as in a Recreation Stocking program, or so the fish can survive and contribute to the viability of a population, as in a Conservation Stocking program.

Restrictions are also in place through current stocking policy that prohibits the stocking of western drainage species into eastern drainage areas and vice versa. Although these types of stocking have been approved in the past (such as the stocking of dams in the Hunter Catchment with golden perch and silver perch), the translocation of species beyond their natural range is restricted to those historically stocked western species into the eastern drainage where acceptable environmental impact has been determined.

The same principle applies to a species that has distinct sub-populations. Golden perch, Macquarie perch, Australian bass and eel-tailed catfish are all believed to have sub-populations within their respective species, and the stocking of a species into any population is restricted to progeny produced from broodfish taken from the original population. Stocking a species from one population to another may cause the loss of genetic variation between the unique populations and therefore the species as a whole.

An area may be reserved from stocking for a variety of reasons, but most commonly due to environmental factors such as the presence of a threatened species. This is the case in the area subject to the Eastern Cod Recovery Plan where certain waters recognised as critical habitat for the cod are precluded from stocking Australian bass (the only recreational species permitted for stocking in that area). This restriction has been in place since the commencement of the recovery plan in 1999 due to the concerns that stocked bass may prey on larval or juvenile cod.

For a number of years, stocking of brown trout has been suspended in waters known to contain the threatened species Macquarie perch. Waters suspended from stocking include Murrumbidgee River above Cooma, Queanbeyan River above Googong Dam, Shoalhaven River and tributaries, Goodradigbee River, Mannus Creek, Abercrombie River and parts of the Hawkesbury River system.

In 2001, stocking of all salmonids was suspended in waters with known sightings of the threatened species Booroolong frog. These streams included Goobarragandra River, Gilmore Creek, Maragle Creek, Turon River, Sewells Creek, Native Dog Creek, Bombowlee Creek and Brungle Creek. After consultation with the NSW National Parks and Wildlife Service, including an eight-part test by NPWS to determine the significance of any impacts, permits were issued to NSW Fisheries to allow stocking in Goobarragandra River, Turon River and Gilmore Creek.

Stocking has not been permitted in Bogong Creek for several years, as it is the only known NSW location of the threatened spotted tree frog.

B1.2 Stocked species and sources of stock

B1.2.1 Native freshwater species used in the current activity

Breeding of Australian native species for Government stockings was first conducted at the Narrandera Inland Fisheries Station (now Narrandera Fisheries Centre) during 1961/62, following construction of the facility in 1960. The first species to be successfully reared was golden perch, now the most stocked native fish in NSW with over 18 million fry released. Technology for breeding a host of native species followed, and standard techniques for producing the majority of recognised angling species and several threatened native species are now well developed.

Native fish breeding technology has successfully provided a consistent source for the main recreationally targeted native species, i.e. Australian bass, Murray cod, golden perch, and silver perch.

Other native species, including the eel-tailed or freshwater catfish and Macquarie perch have been bred and stocked in the past, but not without serious constraints. Hormone induced spawning of catfish was previously not very successful and all catfish produced from the Narrandera Hatchery resulted from natural spawning from broodstock held in ponds. The problems experienced in catfish production combined with low fecundity of the species meant low productivity and an unreliable production of stock. As most public dams had reasonably good populations of catfish and the fact that the species was not at the time all that popular with many anglers, with little potential for aquaculture, catfish production ceased in Government hatcheries around 1963 (NFC Manager S. Thurstan - pers. comm.). In the years since then, some commercial hatcheries have developed technology for breeding this species.

Attempts to spawn pond-reared Macquarie perch at Narrandera in the mid 1980s were also unsuccessful (1,500 eggs on only one occasion). Females did not develop suitable gonads and production was abandoned in the late 1980s. A few successful spawnings of wild fish at Narrandera produced 10,000 fingerlings in 1995 and 51,000 fingerlings in 1998. There has been some successful production of stock achieved by a private hatchery for stocking the Penrith Lakes Scheme just prior to the 2000 Sydney Olympics (Appendix B1).

B1.2.1.1 Australian bass Macquaria novemaculeata

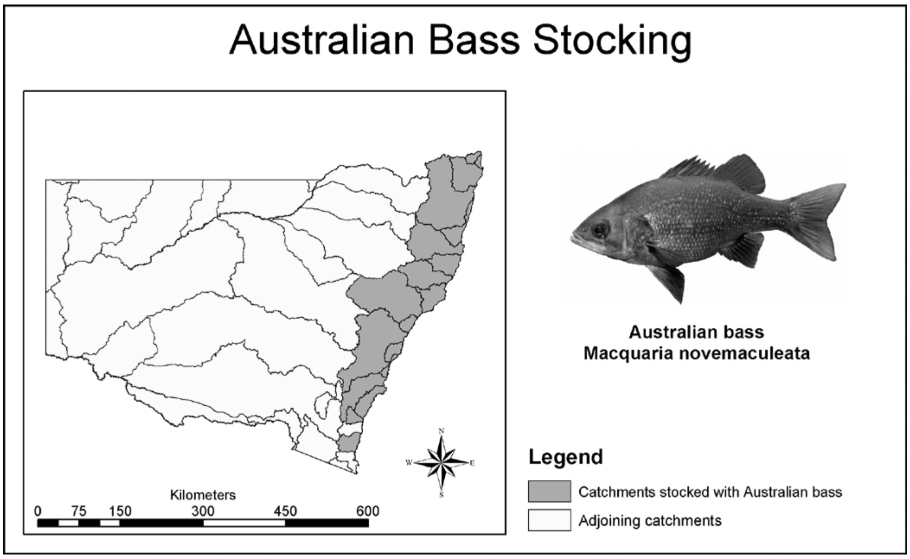


Figure B2. Australian bass stocking in NSW.

History of stocking Australian bass

Populations of Australian bass have declined since European settlement, due mainly to barriers to movement caused by the construction of dams and weirs that have deprived the species of many of its historic spawning and nursery areas. River-flow regulation is also considered to interfere with the species' spawning cues. The loss of bass habitat through de-snagging and the destruction of riparian vegetation causing erosion and siltation have also contributed to the decline. Over-fishing compounded the environmental degradation and there have been serious concerns by fisheries scientists regarding the species' ability to continue to maintain viable populations in certain areas.

Given the factors affecting the populations of Australian bass and its reputation as a tenacious sport fish of excellent table quality, restocking programs were considered an appropriate and timely management tool for this species.

The technology for culturing the Australian bass for stocking was developed at Port Stephens Fisheries Centre and stocking was undertaken primarily to provide better angling opportunities for bass enthusiasts and to re-establish the species within its natural range.

NSW Fisheries records collated since 1980 show that 2,695,983 Australian bass have been stocked into the State's eastern drainages (Appendix B1). Dams and impoundments were also utilised to develop further angling opportunities with this species.

Natural distribution and origin of the Australian bass

Australian bass live in coastal rivers from Mary River and Fraser Island in Queensland south to tributaries of Gippsland Lakes in Victoria. The bass travels extensively upstream, historically reaching altitudes of about 600m in the Hawkesbury River System (McDowall 1996). Australian bass migrate downstream into estuaries to breed from May to August before their return homing migration. They spawn in brackish waters when the water temperature is 11-18º C (McDowall 1996). There is a marked sexual size dimorphism, with females being much larger than males (males mature at 2-4 years, females at 5-6 years).

The Australian bass is classed in the Family *Percichthyidae* (Australian freshwater basses and cods). The estuary perch, *Macquaria colonorum* is a close relative and often misidentified as the Australian bass but has a longer snout that is concave in profile and different spawning and habitat requirements. No stocking programs exist for *M. colonorum* although anecdotal evidence (Bill Talbot, NSW Fisheries, pers. comm.) suggests that on at least one occasion NSW Fisheries produced a batch of estuary perch and stocked them into Glenbawn Dam in the Hunter Valley to help establish stocks for recreational fishing.

Sources of stock

Australian bass are extensively stocked across NSW to satisfy a number of programs relating to recreational fisheries. Stocks are sourced from the Port Stephens Fisheries Centre and a number of private hatcheries to meet the demand for this species.

As described below, sources of stock must be produced in-line with the NSW Fisheries' policy on Australian bass broodstock collection zones. With respect to NSW Fisheries' Australian bass stocking programs, all stock is produced at the Port Stephens Fisheries Centre from broodstock sourced from the appropriate Australian bass zone. Four private hatcheries also produce Australian bass for the Northern, Southern, and Central zones. (These hatcheries are described in full in section B1.3 - Hatcheries).

Sources of broodstock

Under NSW Fisheries' policy all Australian bass broodfish that are used to supply fish for stocking are to be collected from river systems only (not dams or other impoundments). To ensure that the slight genetic variations between populations of this species are not compromised, three Australian bass broodfish collection zones are recognised by NSW Fisheries. When approval is given to stocking a waterway within any of the zones, the supplier is required to obtain at least five breeding pairs of brood fish from the respective zone.

1. Northern zone: All rivers north of the Macleay River
2. Central zone: All rivers between the Macleay River and the Hawkesbury River (both rivers included)
3. Southern zone: All rivers south of the Hawkesbury River

Genetic variations of the species in NSW

The genetic structure of the Australian bass population changes continuously down the NSW coastline with more similar genotypes being found in rivers that are closer together spatially. The three stocking zones arbitrarily split this cline in order to ensure a minimal disruption to the genetic diversity of the population.

Risks to naturally occurring populations of the species from the current stocking activity.

Potential loss of genetic integrity. Genetic integrity could be compromised if bass from one broodstock zone were stocked into another. Introduction of genetic material may reduce the fitness of the local population, and the use of insufficient broodstock within a zone could cause inbreeding and the loss of genetic diversity. This would also lead to reduced fitness and resilience of the population.

Vectors for disease and parasites: Stocking will always carry the risk of translocating live aquatic organisms, and during stocking, there remains the chance of introducing diseases, pathogens, aquatic flora etc. from the source area and hatchery to the release site.

Risks are amplified if an ineffective compliance and monitoring system is in place or where unscrupulous operators provide stock outside the provisions of the broodstock collection policy.

B1.2.1.2 Eastern cod Maccullochella ikei

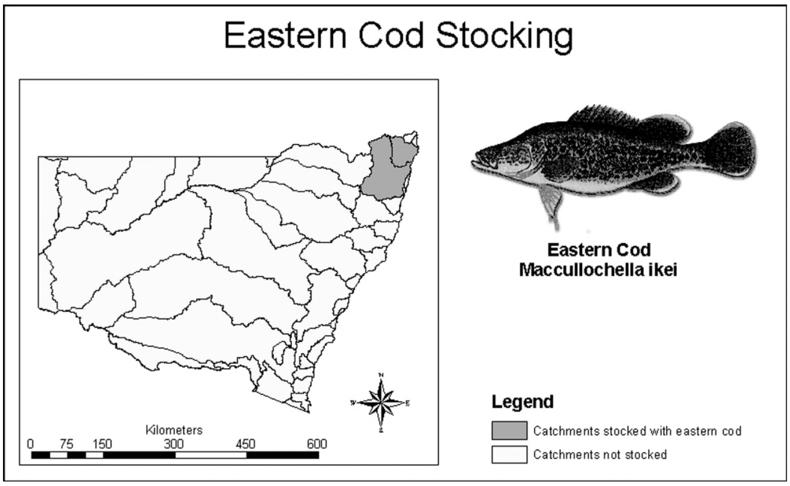


Figure B3. Eastern cod stocking in NSW.

History of stocking

The declining distribution of the eastern cod has been well documented as occurring since European settlement in the Clarence and Richmond catchments, although it is likely that there was a pronounced decline in the genetic diversity in this species around 1000 to 2000 years ago (A. Moore pers. comm.). Rowland (1993) attributed a large portion of the species decline to poor land management practices and over fishing and/or catastrophic events earlier last century such as severe flooding and bushfires.

Captive breeding techniques for eastern cod were developed by NSW Fisheries during 1988-1990 at the Grafton Research Centre and initial stockings of 30,000 eastern cod were made into the Clarence and Richmond catchments at that time. Since then, the only Conservation Stocking programs for eastern cod have been undertaken by private organisations. In 1994, the Booma Fisheries, a privately owned fish hatchery in Dorrigo, NSW, commenced a breeding and Conservation Stocking program approved by NSW Fisheries. Genetic management guidelines were established by NSW Fisheries, and in 1996, Booma Fisheries liberated 660 fingerlings and a further 30,000 in 1997.

In December 1997, the community group Project Big Fish was established with the aim of promoting the recovery of the eastern cod. Project Big Fish stocked 100,000 fingerlings between 1998/99 and between 2000 and 2001, stocked a further 2000 fingerlings.

Natural distribution and origin of the species

The eastern cod is classed in the family *Percichthyidae* (Australian freshwater basses and cods). Historic distribution was considered to be the Clarence River and Richmond River systems downstream of the escarpment of the New England Tablelands. (Rowland (1993) stated "Cod are now considered extinct in the Richmond River system and very rare or absent in the major northern tributaries of the Clarence River system (the Clarence, Rocky, and Cataract rivers)", and are no longer found in the Orara River where they were once very common (Wilcox, 1863). Since the late 1960s, only small numbers of eastern cod (usually less than 5kg) have been caught only from tributaries such as the Nymboida, Little Nymboida, Guy Fawkes, Boyd, and Mann rivers where some pristine habitat still exists.

Source of stock

The only source of stock available for this species is from the private hatchery "Booma Fisheries" at Dorrigo, NSW.

Sources of broodstock

Eastern cod fingerlings for the NSW Fisheries' Conservation Stocking in 1988-90 were bred from broodstock sourced from the remnant cod populations within the Clarence Catchment.

Genetic variations of the species in NSW

Eastern cod are thought to exist as distinct sub-populations within their range. To ensure that sufficient genetic background is provided for the stock used in the recovery, a genetic plan has been devised by NSW Fisheries for the area covered by the recovery plan and conservation stocking sites.

Risks to naturally occurring populations of the species from the current stocking activity.

Potential loss of genetic integrity. Genetic integrity could be compromised during the stocking of eastern cod, as this species already has very low genetic diversity. Studies are currently underway to determine the extent of the remnant populations and the impact of stocking (see B2.5.2).

Vectors for disease and parasites: Stocking will always carry the risk of translocating live aquatic organisms, and during stocking, there remains the chance of introducing diseases, pathogens, aquatic flora etc. from the source area and hatchery to the release site.

Risks are amplified if an ineffective compliance and monitoring system is in place or where unscrupulous operators provide stock outside the provisions of the broodstock collection policy.

B1.2.1.3 Eel-tailed catfish Tandanus tandanus

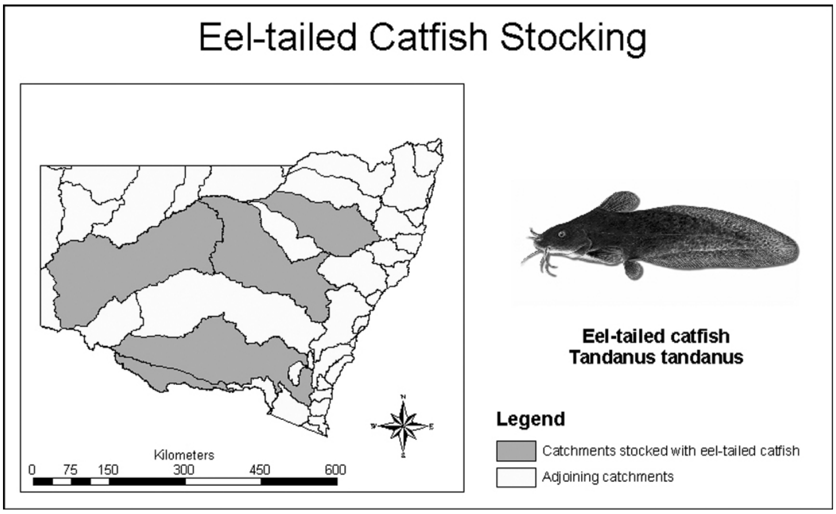


Figure B4. Eel-tailed catfish stocking in NSW.

History of stocking

The first record of stocking this species by NSW Fisheries was in 1963, when 400 fish were liberated into the Yass River (Murrumbidgee River Basin) followed by further stockings until 1978. No further stockings of catfish were recorded until 1992 when stocking resumed. Between 1992 and 1998, small numbers of fish (less than 1,000 fish at each stocking) were carried out in the Wakool, Edward and Namoi Rivers, as well as into waters within Tocal Agricultural College. Stocking ceased for another two years until 1998 when 2,138 catfish were stocked into the Namoi River. In 1999, a further 3,700 fish were stocked into the Macquarie River above Narromine. A few other smaller stockings took place between 1999 and 2000 into Imperial Lake and the Namoi River. Translocations of mature catfish have also occurred in NSW.

Natural distribution and origin of species

The eel-tailed catfish is from the family *Plotosidae* (eel-tailed catfishes), which is found in Australia, New Guinea and the entire Indo-Pacific region. *Tandanus tandanus* is native to Australia and inhabits the warmer waters of the western drainage Murray-Darling River system, including Victoria and South Australia, and on the east coast from the Shoalhaven River (NSW) to the Daintree River in northern Queensland.

Sources of stock

There are no current stocks available for this species in Government hatcheries.

Sources of broodstock

There are no current stocks available for this species in Government hatcheries, although broodstock may be obtained from wild populations other than those in areas where the collection would be prohibited (i.e. areas covered by a management plan or from any impoundment).

Genetic variations of the species in NSW

Catfish are believed to have several sub-populations within NSW, namely an eastern strain and a western strain, although these may yet prove to be different species.

Risks to naturally occurring populations of the species from the current stocking activity.

Potential loss of genetic integrity. Genetic integrity could be compromised if catfish from one broodstock zone were stocked into another. Introduction of genetic material may reduce the fitness of the local population, and the use of insufficient broodstock within a zone could cause inbreeding and the loss of genetic diversity. This would also lead to reduced fitness and resilience of the population.

Vectors for disease and parasites: Stocking will always carry the risk of translocating live aquatic organisms, and during stocking, there remains the chance of introducing diseases, pathogens, aquatic flora etc. from the source area and hatchery to the release site.

Risks are amplified if an ineffective compliance and monitoring system is in place or where unscrupulous operators provide stock outside the provisions of the broodstock collection policy.

B1.2.1.4 Golden perch Macquaria ambigua

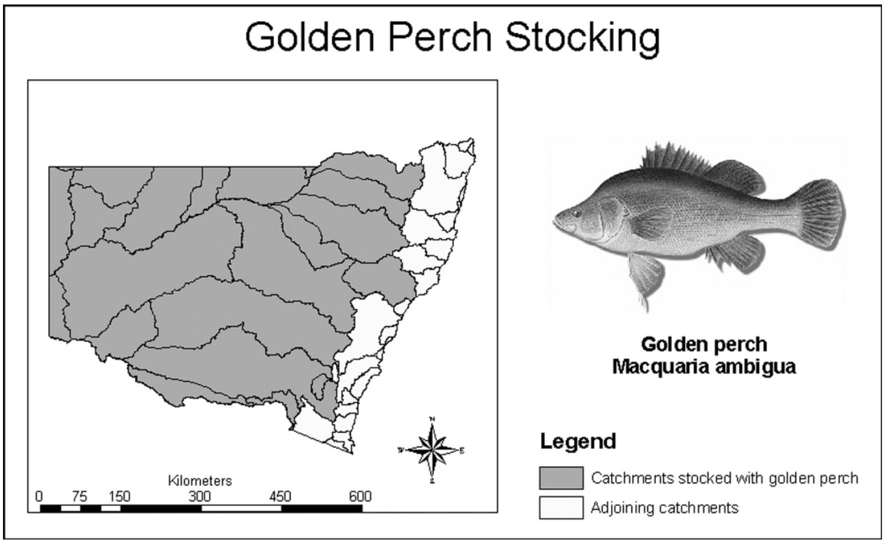


Figure B5. Golden perch stocking in NSW.

History of stocking

NSW Fisheries' records show that stocking of golden perch began in 1960 when the Inland Fisheries Research Centre (NFC-Narrandera) stocked 1,000 fish into each of six impoundments and dams, namely the Hume Weir, Lake Albert, Lake George, Keepit Dam, Lake Burrinjuck and Ben Chifley Dam.

Stocking ceased for three years when between 1963 and 1965, two stockings comprising 600 fish were stocked into Burrinjuck Dam (200) and Burraga Dam (400) by the NFC and Thompsons Fishing Club, respectively.

Records show that stocking ceased in the eight years from 1965 until 1973 when 7,000 perch were stocked into Lachlan River by the Bigga Fishing Club using stock produced at the NFC. The program again resumed in 1976 when the NFC stocked 25,000 fish into Lake Albert.

In 1977, a total of 157,000 golden perch were stocked in two separate events into Glenbawn Dam in the Hunter basin, representing the first large-scale stocking of a western drainage species into the eastern drainage.

By this time, technology had been refined to produce substantial numbers of stock, and in every year since 1977, vast numbers of golden perch have been stocked into rivers, dams and impoundments across the western drainage of NSW. A total of 18,562,127 golden perch have been stocked in NSW waters since 1960 (to June 2002) making it the most-produced native fish used in fish stocking in NSW.

Natural distribution and origin of species

Golden perch is classed in the family *Percichthyidae* (Australian Freshwater Basses and Cods). It is found throughout the Murray-Darling Basin (other than the elevated headwaters). The population declined in the 1950s and is today considered to be moderate to low. Other populations exist in the eastern drainage of south-east Queensland, in the Dawson River including the Fitzroy River systems, and in Central Australia.

Sources of stock

Golden perch have been produced at the NFC for more than 40 years. Today, the stock produced by the Centre are used mainly for the purposes of enhancing the native fish recreational fishery across the State, although some quantities excess to the requirements of these stocking programs are tendered to the aquaculture industry for grow-out.

Several private hatcheries also provide golden perch stock for the Dollar-for-Dollar Native Fish Stocking Program. These hatcheries produce stock for their respective areas, northern, central and southern, but this is related merely to the logistical aspects of supplying the stock to those areas rather than due to any genetic management, recognised genetic zones, or stocking protocols. (More information on the Private hatcheries producing golden perch for stocking are detailed in section B.6 - Hatcheries).

Sources of broodstock

Broodstock used to produce stock for NSW Fisheries stocking programs at the NFC are sourced from a number of river systems including Murray and Murrumbidgee rivers. Broodstock kept on site at NFC are housed and fed in indoor hatchery tanks. The fish are catalogued and rotated regularly (after 5 years) to ensure high fecundity exists within the broodstock. Where private hatcheries produce golden perch for stocking programs such as the Dollar-for-Dollar Native Fish Stocking Program, the broodstock are sourced from the area where the stock are to be placed (see Private Hatcheries).

The three golden perch broodstock zones are listed as follows:

- northern zone: all rivers and tributaries connected with the Darling River (*excludes the Paroo River, even though it is acknowledged that fish stocked into the Darling are likely to move into the Paroo during floods)
- central zone: all rivers and tributaries connected with the Lachlan River
- southern zone: all rivers and tributaries connected with the Murrumbidgee and Murray rivers.

Genetic variations of the species in NSW

Golden perch have been recently considered to comprise several separate sub-species in addition to the Murray-Darling and Queensland species (*M. ambigua ambigua*) by Musyl & Keenan (1993). Although not described, at least two subspecies are believed to exist, one restricted to the Lake Eyre Drainage in South Australia (Lake Eyre golden perch) and another that is restricted to the Bulloo River System (southwest Queensland). No broodstock used for NSW Fisheries stocking programs were sourced from either of the areas.

Risks to naturally occurring populations of the species from the current stocking activity.

Potential loss of genetic integrity. Genetic integrity could be compromised if golden perch from one broodstock zone were stocked into another. Introduction of genetic material may reduce the fitness of the local population, and the use of insufficient broodstock within a zone could cause inbreeding and the loss of genetic diversity. This would also lead to reduced fitness and resilience of the population.

Vectors for disease and parasites: Stocking will always carry the risk of translocating live aquatic organisms, and during stocking, there remains the chance of introducing diseases, pathogens, aquatic flora etc. from the source area and hatchery to the release site.

Risks are amplified if an ineffective compliance and monitoring system is in place or where unscrupulous operators provide stock outside the provisions of the broodstock collection policy.

B1.2.1.5 Murray cod **Maccullochella peelii peelii**

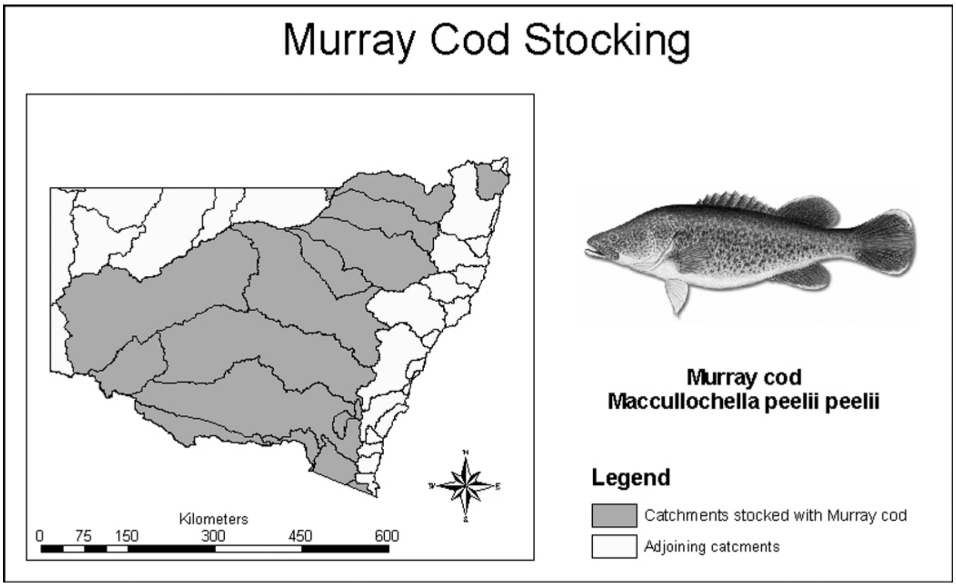


Figure B6. Murray cod stocking in NSW.

History of Stocking

Stocking of Murray cod was first recorded by NSW Fisheries in 1977 when 2,000 fish were released into Toonumbar Dam (Richmond River System) by the Kyogle Fish Acclimatisation Society. In hindsight, the stocking of this species into the Richmond River system was an erroneous decision given that that area is within the range of the now threatened species, eastern cod. However, little was known about the eastern cod then and it was considered to be an eastern form of Murray cod before being later described as *Maccullochella ikei* (Rowland 1988).

Between 1978 and 1979, only a further 2,400 Murray cod were recorded as being stocked in NSW at Sandy Creek, the Abercrombie River and the Lachlan River. No stockings were recorded between 1979 and 1982.

In 1983, the Inland Fisheries Research Station (now NFC) stocked 48,000 Murray cod into the Wyangala Dam in two separate events. Ben Chifley Dam was stocked with 2,000 fish by the Bathurst Fishing Club while two other releases were undertaken by fishing clubs into Lachlan River (200) and Severn River (300). Sporadic stockings continued of small to medium sized releases (between 200 – 10,000 fish) carried out mainly by fishing clubs throughout the early eighties using stock produced at the NFC.

In the late 1980s, more regular stockings occurred in the range of 500 to 15,000 fish in the Gwydir, Lachlan, Macquarie, Macintyre and Mole rivers, while similar quantities were stocked into many dams and impoundments.

In 1990, the NFC undertook the largest single stocking up until that time with 25,000 cod into the Copeton Dam at Inverell. In every year since 1990, Murray cod stockings were regularly undertaken across NSW and in 2000, with the introduction of the Dollar-for-Dollar Native Fish Stocking Program, more emphasis was placed on stocking this species as one of the three approved native species under that program.

Stocking Murray cod continues today by the NFC (aided by stocking clubs) and to date, 2,849,923 Murray cod have been stocked into NSW waters making it the 3rd most stocked native species in NSW.

Natural distribution and origin of species

The Murray cod is classed in the family *Percichthyidae* (Australian Freshwater Basses and Cods). The species *Maccullochella peelii* has two subspecies, *M. peelii peelii* (Murray cod) and *M. peelii mariensis* (Mary River cod) from Queensland's Mary River. The latter is not used in any NSW Fisheries stocking programs.

The Murray cods natural range is throughout the entire Murray-Darling system. Populations have been in serious decline throughout this range due to a host of impacts, including regulation of the majority of the rivers in the Murray-Darling basin causing intolerable alterations to the natural flow regimes required by the Murray cod for breeding triggers, and other impacts such as snag removal, construction of weirs and dams and exploitation by fishing activities.

Sources of stock

Murray cod bred for stocking by NSW Fisheries are produced by the NFC at Narrandera. Several private hatcheries also provide Murray cod stock for the Dollar-for-Dollar Native Fish Enhancement Program. These hatcheries produce stock for their respective areas, northern, central and southern, but this is related merely to the logistical aspects of supplying the stock to those areas rather than as genetic resource management (More information on the private hatcheries producing Murray cod for stocking is detailed in B6).

Sources of broodstock

Broodstock used to produce stock for NSW Fisheries stocking programs are kept at the Narrandera Fisheries Centre (NFC, formerly known as the Inland Fisheries Research Centre) and are sourced from a number of river systems including Murray and Murrumbidgee. Broodstock kept on site at NFC are housed and fed in earthen ponds. The fish are catalogued and rotated regularly to ensure an appropriate genetic variation exists within the broodstock. Private hatcheries source broodstock from the area into which the stock are to be placed under broodstock collection permit issued by NSW Fisheries.

The three Murray cod broodstock zones are listed as follows:

- northern zone: all rivers and tributaries connected to Darling River (*excludes the Paroo River)
- central zone: all rivers and tributaries connected to Lachlan River
- southern zone: all rivers and tributaries connected to Murrumbidgee and Murray rivers.

Genetic variations of the species in NSW

Murray cod are thought to comprise one species, but is closely related and able to cross-breed with eastern cod *M. ikei*, Mary River cod *M. peelii mariensis,* and trout cod *M. macquariensis.*

Risks to naturally occurring populations of the species from the current stocking activity.

Potential loss of genetic integrity. Genetic integrity could be compromised if Murray cod from one broodstock zone were stocked into another. Introduction of genetic material may reduce the fitness of the local population, and the use of insufficient broodstock within a zone could cause inbreeding and the loss of genetic diversity. This would also lead to reduced fitness and resilience of the population.

Vectors for disease and parasites: Stocking will always carry the risk of translocating live aquatic organisms, and during stocking, there remains the chance of introducing diseases, pathogens, aquatic flora etc. from the source area and hatchery to the release site.

Risks are amplified if an ineffective compliance and monitoring system is in place or where unscrupulous operators provide stock outside the provisions of the broodstock collection policy.

B1.2.1.6 Macquarie perch Macquaria australasica

History of stocking

The first recorded Macquarie perch stocking by NSW Fisheries occurred in 1988 when two events comprising 24,000 fish each were liberated into the Upper Murray River Basin at Geehi and Khancoban Pondage, Khancoban, by the NFC. In the same year, the NFC stocked the Murrumbidgee River Basin with 1,300 fish into the Batlow River at Batlow and 2,000 fish into the Yass River at Gundaroo. No further stockings of Macquarie perch were recorded between December 1988 and 1995 until the NFC stocked Talbingo Pondage on the Tumut River with 10,000 fish bred at Snobbs Creek.

The next recorded stocking occurred in 1998, when the Ashford Amateur Fishing Club stocked 100 specimens into the Severn River at Ashford.

In January 2000 the Penrith Lakes Development Corporation stocked the four man-made lakes of the Penrith Lakes Scheme with 15,000 Macquarie perch bred at the Dilger's Hatchery. The Penrith Lakes Scheme was used as a Rowing Regatta venue during the 2000 Sydney Olympics.

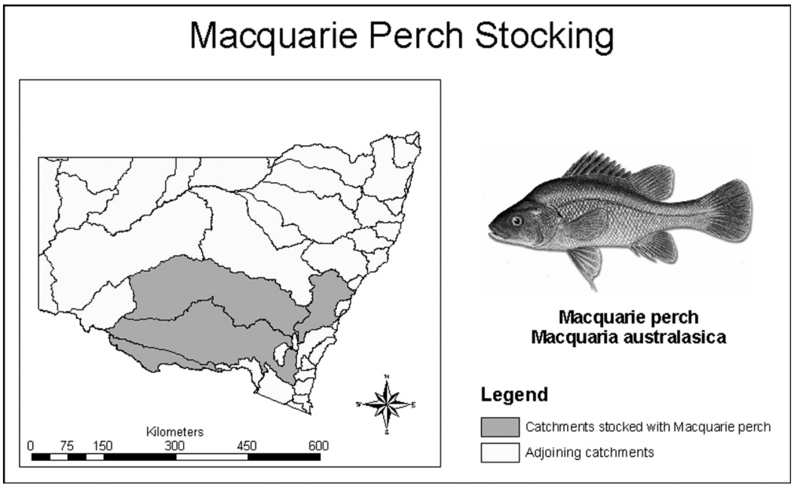


Figure B7. Macquarie perch stocking in NSW.

Natural distribution and origin of species

The Macquarie perch is classed in the family *Percichthyidae* (Australian Freshwater Basses and Cods). The natural distribution of Macquarie perch extends from the middle to upper reaches of the Murray River and its tributaries in both NSW and Victoria with further populations found in the Shoalhaven and Hawkesbury rivers (NSW).

Sources of stock

All stock produced for this species emanated from the NFC at Narrandera and the Dilger's Hatchery, although anecdotal evidence suggests that a small liberation of Macquarie perch from Snobbs Creek Hatchery (Victorian Government Hatchery) into the Seven Rivers in Victoria. There are no current stocking programs for this species.

Sources of broodstock

There are no current stocking programs for this species.

Genetic variations of the species in NSW

There is current debate as to whether the Macquarie perch comprises two or three subspecies. It is believed that the species found in eastern drainages (Hawkesbury and Shoalhaven catchments) is distinct from the western drainage species, although no description of a subspecies has been made. Nevertheless, the populations are considered two separate forms with a possible third existing in the Shoalhaven catchment (Morris *et al.*, 2001).

Risks to naturally occurring populations of the species from the current stocking activity.

Potential loss of genetic integrity. As with previously listed species considered to have sub-populations, a potential loss of genetic integrity could occur if Macquarie perch from one population were stocked into the range of another. As these populations are locally adapted to their native streams, introduction of genetic material may reduce the fitness of the local population. This has occurred in the past and efforts should focus on ensuring such stockings are prohibited in future so as to avoid taxonomic confusion and possible inbreeding (Cadwallader, 1981). The use of insufficient broodstock can also cause inbreeding and the loss of genetic diversity and lead to reduced fitness and resilience of the population.

Vectors for disease and parasites: Macquarie perch are susceptible to the epizootic haematopoietic necrosis virus (EHNV) carried by redfin perch (Wager & Jackson, 1993). Stocking will always carry the risk of translocating live aquatic organisms, and when stocking Macquarie perch from an area where EHNV is known to exist, there remains the chance of introducing the disease or other pathogens and aquatic flora from the source area to the release site.

Risks are amplified due to information gaps in the description of separate species or where ineffective compliance and monitoring system is in place or where unscrupulous operators provide stock outside the provisions of the broodstock collection policy.

B1.2.1.7 Silver perch **Bidyanus bidyanus**

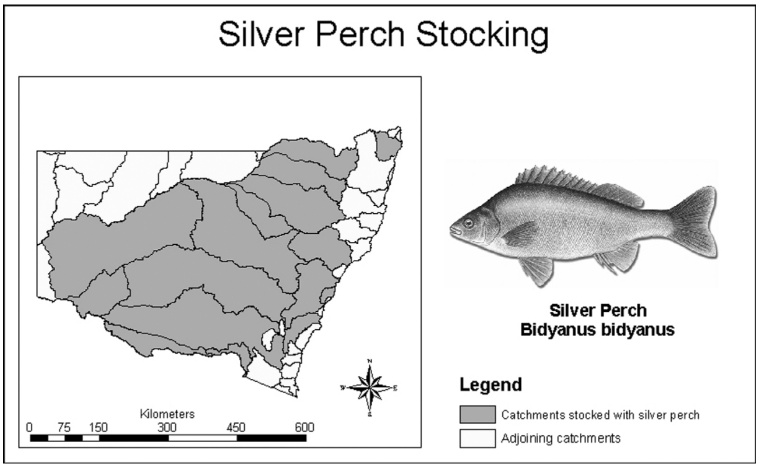


Figure B8. Silver perch stocking in NSW.

History of stocking

The first recorded stocking of silver perch in NSW occurred in 1960 when 200 fish were released by the NFC into Lake Bathurst, within the Shoalhaven River Basin. The NFC undertook several other small-scale stockings that year in the Macintyre River (400), Tenterfield Creek (200) and the Queanbeyan River (300). In December 1960, 106,000 fish were released into Wyangala Dam, in the Lachlan River System, in an effort to enhance silver perch stocks for recreational fishing in the popular dam. Around 80,000 fish were released into the same dam in 1963, while a handful of small-scale releases took place during 1962 and 1963.

NSW Fisheries records indicate that from January 1963, no stocking of silver perch took place until January 1977 when Glenbawn Dam, in the Hunter River Basin, was stocked with 68,500 silver perch and Lake Wyangan, in the Murrumbidgee River Basin, was also stocked with 12,500 fish.

In 1978, the Kyogle Fish Acclimatisation Society stocked 200 fish into Toonumbar Dam (Richmond River Basin), while the NFC stocked 54,700 into Lake Burrendong.

In every year since 1980, silver perch have been stocked extensively in dams and rivers across NSW, totalling 8,224,457, making it the 2nd most stocked native fish in NSW. Primarily, the stockings were undertaken directly by the NFC or by local angling clubs, depending on where the events took place.

In 1994, the NSW Fisheries' Grafton Research Centre began stocking silver perch from stock derived from the GRC breeding lines used in aquaculture trials. Between 1994 and 1998, the GRC engaged in 11 stockings of silver perch in the New England area, stocking over 900,000 fish into the Pindari, Chaffey, Copeton and Keepit dams. In 1999, NSW Fisheries released 3,200 fry from the Narrandera Fisheries Centre into Dumaresq Dam, which is on the Macleay River.

Natural distribution and origin of species

The silver perch, *Bidyanus bidyanus* (Mitchell 1838) is classed in the family *Terapontidae* (grunters). The family also includes other species such as the spangled perch and the Barcoo grunter. The silver perch is endemic to the Murray-Darling river system, although this range has been greatly reduced over the past 60 years and it is either locally extinct or extremely scarce is many areas due to a host of impacts. These include regulation of the majority of the rivers in the Murray-Darling basin causing intolerable alterations to the natural flow regimes required by the silver perch for breeding triggers, and other impacts such as snag removal, construction of weirs and dams and overfishing.

Sources of stock

Silver perch breeding technology was developed at the NFC in the early 1960s, and early successes showed that the species had immense potential for stock enhancement for angling and for aquaculture in NSW. In 1990, the Grafton Research Centre was established as the Eastern Freshwater Fish Research Hatchery, and silver perch were grown in substantial quantities at that site generally as a result of research into commercialisation of the species for aquaculture.

Today, both the NFC and the GAC produce substantial numbers of silver perch to meet the demand for recreational stocking, conservation stocking and aquaculture research. Although some 50 aquaculture permit holders are licensed to grow silver perch in NSW, none are utilised to produce stock for Recreation Stocking or Conservation Stocking programs managed by NSW Fisheries.

Sources of broodstock

Adult silver perch broodstock for the breeding program at NFC and GAC are collected from the wild. Most fish are caught with gill netting or are trapped in fishways by NSW Fisheries staff. Broodstock are typically collected from the Murray River and from a translocated population in Cataract Dam (Nepean catchment).

Silver perch broodfish are held in earthen ponds for at least seven months prior to the breeding season. Following acclimatisation, the fish are recovered from the ponds, anaesthetised with benzocaine, and induced to breed using hormones. After five years, the broodstock are replaced due to decreasing number of eggs produced by broodstock held longer than this.

Genetic variations of the species in NSW

Silver perch are believed to comprise one species throughout NSW (Keenan *et al.* 1995).

Risks to naturally occurring populations of the species from the current stocking activity.

Potential loss of genetic integrity. Silver perch are considered to be susceptible to genetic loss from escaped aquaculture specimens. Genetic integrity could be compromised if aquaculture lines of silver perch were stocked or escaped into the wild. As wild populations are locally adapted to their native streams, introduction of genetic material may reduce the fitness of the local population. The use of insufficient broodstock can also cause inbreeding and the loss of genetic diversity. This would lead to reduced fitness and resilience of the population. The problem is compounded due to the fact that it is very difficult to determine whether broodstock captured for use for stocking are from naturally occurring populations or from a hatchery where the genetic background and proportion of individuals from a species present from a similar background are present in any particular area. This could pose serious problems with regard to loss of overall genetic fitness if stocked fish possess insufficient genetic background and eventually enter the natural breeding population. Risks are amplified if an ineffective compliance and monitoring system is in place and where unscrupulous operators provide stock outside the provisions of the broodstock collection policy.

Vectors for disease and parasites: Stocking will always carry the risk of translocating live aquatic organisms, and when stocking silver perch, there remains the chance of introducing diseases, pathogens, aquatic flora etc from the source area to the release site. Silver perch are susceptible to EHN disease (Inland Rivers Network, 1999), and the Goldfish Ulcer Disease (GUD) (Humphrey & Ashburner, 1993). The Asian fish tapeworm is also considered a threat to the species and could be translocated to populations of silver perch through stocking.

B1.2.1.8 Trout cod **Maccullochella macquariensis**

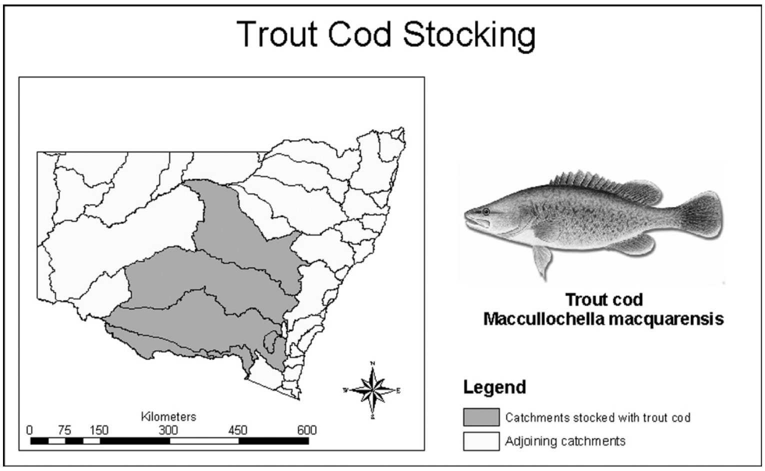


Figure B9. Trout cod stocking in NSW.

History of stocking

Hatchery bred trout cod were first produced and stocked into NSW waters in 1987 when the NFC released 1,000 fish into the Hume Weir at Talmalmo. The technology used to breed trout cod was developed at the NFC and was designed to support a Conservation Stocking program in response to the serious decline of the species throughout its natural range.

During 1988, two stockings of 2,000 specimens each were made in the Upper Murray at Jingellic and Tintaldra, and a third event of 2,000 fish into the Murrumbidgee River at Cooma. In 1989, 740 fish were stocked into the Bendora Dam at Canberra.

During the 1990s, hatchery technology was advanced enough for significant numbers of stock to be bred for Conservation Stocking. In December 1990, the NFC released 15,000 fish into the upper Murray above the Hume Weir.

With the exception of 1995, substantial stockings (up to 18,000) were undertaken each year of that decade, with the single largest stocking of trout cod taking place in 1998 where 46,000 fish were released by the NFC into the Macquarie River between Dubbo and Burrendong.

The NFC has undertaken every stocking event over the past 14 years with the exception of two events in 1991, when the Central Acclimatisation Society released 1,800 and 1,700 fish into Ophir Creek at Hill End and the Turon River at Turondale, respectively, as part of the conservation program.

To date, hatchery-produced trout cod have been stocked for conservation purposes within the Abercrombie River, Bendora Dam, Berembed Weir, Bumbuggan Creek Weir, Crudine Creek, Murray River, Murrumbidgee River, Macquarie River, Ophir Creek, Talbingo Dam, Turon River and Yanco Weir.

Natural distribution and origin of species

Trout cod are endemic to the Murray-Darling Basin. The species belongs to the family *Percichthyidae* (Australian Freshwater Basses and Cods). Within NSW, trout cod previously occurred in the upper reaches of the Macquarie, Murrumbidgee and Murray Rivers and their tributaries. The species also occurred in the Murray-Darling Basin Rivers of Victoria, and had been recorded as far downstream as Mannum in South Australia. Populations have been in serious decline throughout this range, due to a host of impacts including river regulation causing intolerable alterations to the natural flow regimes required by the trout cod for breeding triggers; river ‘improvement’ works such as snag removal; over-exploitation by fishing activities and the impacts of introduced species. Today, trout cod are an endangered species with the only natural self-sustaining population existing in the Murray River between Mulwala and Tocumwal.

Sources of stock

The only source of stock for this species in NSW is from the NFC at Narrandera. As a threatened species and subject to an ongoing Conservation Stocking program, the trout cod has not been approved for breeding in any other hatchery in NSW for Conservation Stocking or aquaculture.

Sources of broodstock

Trout cod are an endangered species with the only natural self-sustaining population existing in the Murray River between Mulwala and Tocumwal.

Genetic variations of the species in NSW

Trout cod are believed to comprise one species in NSW, only relatively recently described as a separate species from the Murray cod (Berra & Weatherly, 1972). The trout cod is now so severely affected by low numbers that the genetic diversity of the species is probably already compromised.

Risks to naturally occurring populations of the species from the current stocking activity.

Potential loss of genetic integrity. Genetic integrity could be compromised if trout cod from one broodstock zone were stocked into another. As these populations are locally adapted to their native streams, introduction of genetic material may reduce the fitness of the local population. The use of insufficient broodstock can cause inbreeding and the loss of genetic diversity. This could lead to reduced fitness and resilience of the population. The continual decline in trout cod numbers is also attributed to the hybridisation of the species with Murray cod. Stocking of species that compete for habitat and food of the trout cod is also a concern.

Vectors for disease and parasites: Stocking will always carry the risk of translocating live aquatic organisms. Trout cod are known to be affected by protozoan parasites found in aquaculture facilities, and the transfer of these by translocation remains a threat. It is also accepted that alien species may transfer parasites and diseases to this species (Ingram & Rowland, 1990).

Risks are amplified if an ineffective compliance and monitoring system is in place and where unscrupulous operators provide stock outside the provisions of the broodstock collection policy.

B1.2.2 Salmonid species used in the current activity

B1.2.2.1 History of salmonid stocking

The history of salmonid stocking in Australia dates back as far as the 1800s, and information on the efforts by acclimatisation societies and other pundits to introduce these species is documented in numerous volumes attributed to those early attempts. However, as this review is considered in respect of NSW Fisheries' management of the activity, the national history of these accounts will only be briefly discussed (see References for further reading).

The trout stocking activity in Australia evolved largely through the perception of many English colonists that the local fish were of poor quality and little sporting value. This prompted keen anglers to form clubs to try and establish trout and salmon fisheries in Tasmania, Victoria and NSW. However, in the 1800s, transporting ova to Australia was an arduous process involving long journeys by sea. After many failures, Englishmen James Youll, devised a method of delaying the ova from hatching and overcame other problems to successfully import trout and salmon ova from England to Tasmania, where the first brown trout hatched in Australia in 1864.

The history of trout in NSW waters starts in the 1870s, and 1880s, when several people stocked brown trout fry hatched from ova obtained from Victoria and Tasmania, into rivers in the Sydney, Shoalhaven, New England, Hunter and Monaro regions. In 1889, brown trout eggs from Geelong in Victoria were hatched in the offices of the Fisheries Commissioners for the colony of NSW, in Phillip Street, Sydney. In 1890, importation of trout eggs from New Zealand commenced, with the initial shipment containing both brown and brook trout eggs.

In NSW, the first record of salmonid stocking is attributed to Messrs Brown, Gill and probably Keys around 1877 (Brinsley, 1999). Other records purport that the first stocking was in fact carried out by Messrs Gale and Campbell in 1888, although Brinsley's research for a book on the history of trout in NSW shows the former occurred some 11 years prior. Suffice is to say that trout stocking in NSW has occurred since the late 1800s. Brinsley's research also revealed that a fire had consumed the only records on the first stockings in NSW along with other historical data in 1882.

In 1880, the NSW Government held a Fishery Inquiry Commission. There being no official government agency in NSW at that time, the inquiry instigated the establishment of the NSW Fisheries Board in 1883, ultimately leading to the organisation known today as NSW Fisheries. The first reported involvement by the NSW Fisheries Board in fish acclimatisation was conducted in November 1888 when the Victorian Government, supported by the Geelong Acclimatisation Society, donated over 1000 trout fry (thought to be brown trout) for stocking into NSW rivers and waterways. The fry were reputedly liberated into the Upper Shoalhaven, Wollondilly, Upper Nepean and Nattai rivers as well as Picton Lakes, and in streams along the western mountain ranges. Quantities of fry from the same stock were consigned to Armidale and to the south coast near Eden (for Brogo River).

Several more importations of trout occurred in the early 1890s, with brown trout stock arriving from New Zealand and Tasmania. Numerous attempts were made over the next few years to establish a purpose-built and government-owned hatchery, and in 1894, a state-owned hatchery was developed at Prospect and the hatching boxes from the Phillip Street hatchery were transferred there.

In June 1894, an importation of 48,000 ova arrived at the Prospect hatchery from New Zealand and included brown trout, lake trout and rainbow trout varieties. Around 30,000 fry were retained at the hatchery while the remainder of the consignment was liberated in the rivers of the southern highlands. Even though the hatchery site was best described as marginal, it continued to produce reasonable batches of stock for nearly 50 years until 1942 when production ceased.

In 1947, two new trout hatcheries were constructed, one at Thredbo and the other at Thompsons Creek at Burraga. In 1951, a third hatchery was constructed at the Serpentine River near Armidale (Dutton Hatchery). The hatcheries were all government-owned but managed mainly by acclimatisation societies who also ran several private hatcheries themselves. Ova were sourced annually from New Zealand, Tasmania and, to a lesser extent, Victoria. By now species being cultivated included Atlantic salmon *Salmo salar*, brook trout *Salvelinus fontinalis*, brown trout *Salmo trutta* and rainbow trout *Oncorhynchus mykiss*.

In 1957, the operations of all three hatcheries were consolidated and thereafter managed wholly by the NSW Government, as is the case today.

Trout and salmon belong to the family *Salmonidae* and none of the four species found in NSW are native to Australia, having been introduced from the Northern Hemisphere.

Rainbow trout were introduced into NSW in 1894, coinciding with the establishment of hatching ponds at the Prospect Reservoir. By 1907, rainbow trout were the only fish being hatched at Prospect as they had been recognised as easier to rear than brown trout. Broodstock had been established, yielding the first locally-stripped ova in NSW in 1907.

The period between 1924 and 1931 saw many permanent and temporary hatcheries established in NSW, often in areas unsuitable for trout production. The hatcheries obtained ova from interstate, usually Tasmania or Victoria, or overseas from New Zealand. Hatching rates were low – often below 50% - increasing the demand for locally stripped brood stock, which had higher hatch rates. However, demand for trout stock and unreliable water supplies ensured that ova continued to be imported in large numbers until well into the 1950s.

The time spanning 1900 to 1930 has been referred to as “The Golden Years” in trout fishing folklore, so called because of the numbers of trout which had prospered in NSW rivers, their large size and the almost unlimited access that anglers had to stocked waters. Reports of trout between 2kg and 4kg were common and bags could be easily filled. By the 1930s, the mean size of the fish had diminished considerably with increasing stock densities and competition for food. It was not until the completion of Eucumbene Dam in 1957 that fish of such size were regularly seen again (Brinsley 1999).

Records of salmonid stocking in NSW held by NSW Fisheries commence from 1960 and the following section shows a synopsis of each salmonid species stocked in NSW since then. See Appendices for a complete record of stocking in NSW.

Note: Catchments highlighted in trout stocking maps show that the species was stocked into some part of the catchment but not necessarily the entire catchment.

B1.2.2.2 Atlantic salmon Salmo salar

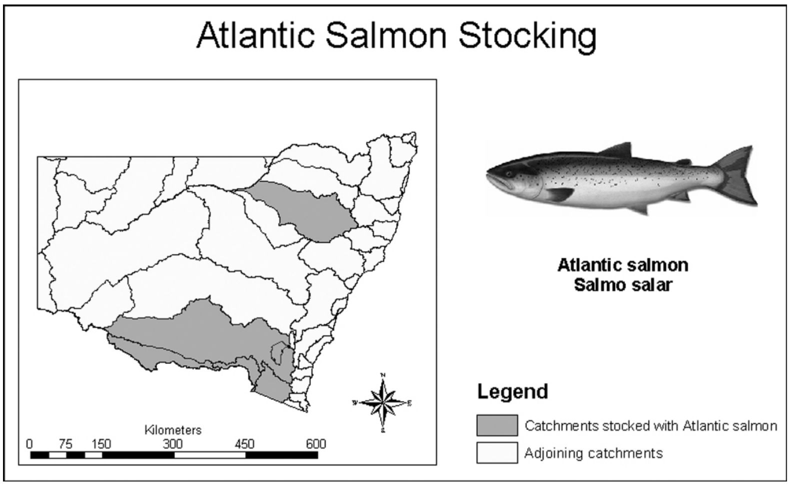


Figure B10. Atlantic salmon stocking in NSW.

History of stocking

In February 1963, the NSW Fisheries Board imported 100,000 Atlantic salmon ova from Canada (Nova Scotia) to a hatchery purpose built at Jindabyne. Of these, 65,000 fry were reared and transferred to the Gaden Hatchery. In October that year, 9,000 young salmon were released into Micalong Creek with the remainder held at Gaden and Dutton hatcheries for future stock. In 1964 and 1965, consignments of 100,000 ova were again received from Canada, resulting in 79,000 and 55,000 fry, respectively. Of these, 18,000 yearlings and 18,000 fingerlings were released into Micalong Creek. In 1969, around 15,000 ova from the stock fish produced 1,940 fingerlings and were retained for future stock.

Even though it is known that the species has been stocked since 1969, departmental records for this species did not commence until 1975, when 14,000 yearling salmon were released into Lake Jindabyne from the Gaden Hatchery. Between 1975 and 1977, a total of 130,584 salmon were released into the Lake.

In 1978, a total of 38,389 salmon were released into Copeton Dam by the New England Trout Acclimatisation Society, from the fish reared at the LP Dutton Hatchery.

From 1978 to 2002, the Gaden Hatchery salmon were stocked predominantly in Burrinjuck Dam and Lake Jindabyne, and a number of releases in the Thredbo River and Murray River. Substantial stockings were carried out into Burrinjuck Dam in the mid to late 1980s, with numerous events exceeding 250,000 fry and one event of 400,000 fry (a total of 2,658,920 salmon have been stocked into Burrinjuck Dam since 1975).

In total, there have been a recorded 7,936,030 Atlantic salmon stocked in NSW, making it the 2^{nd}-most stocked salmonid species in the State.

Natural distribution and origin of species

Atlantic salmon originate from the North Atlantic Ocean from the north of Spain and through eastern Europe and Iceland, Greenland and the north east coast of North America (Jones 1959, Scott and Crossman 1973, Mills 1980). Atlantic salmon were first introduced into southern Australia in the 1860s, at the same time as brown trout. However, early efforts to establish an Atlantic salmon fishery in rivers in the southern states in the 1800s failed. It was not until 1963 that any real effort was made to establish the species in NSW.

Salmon are anadromous, meaning they undertake extensive migration from the sea to freshwater to spawn (this does not occur with NSW stocks). They are much larger than trout and can live to 10 or 11 years, spawning successively, unlike their Pacific counterparts. In NSW waterways, they generally only live to 3 or 4 years of age. Atlantic Salmon also require different hatchery conditions to trout as the fry will not feed in water temperatures of less than 10°C and colder water will cause losses from starvation.

Sources of stock

The only source of stock in NSW is from specimens held at the Gaden Hatchery from the original stock imported from Canada in the 1960s, and 1970s. A substantial aquaculture industry based on the species is contained in sea cages in Tasmania. Due to restrictions placed on the importation of salmon species into Australia, Atlantic salmon stock can no longer be sourced from overseas suppliers due to the risk of introducing diseases found in similar operations around the world that may affect the salmon aquaculture industry in Tasmania.

Sources of broodstock

The only source of broodstock for Atlantic salmon used for stocking in NSW is held by NSW Fisheries at the Gaden Hatchery.

B1.2.2.3 Brook trout **Salvelinus fontinalis**

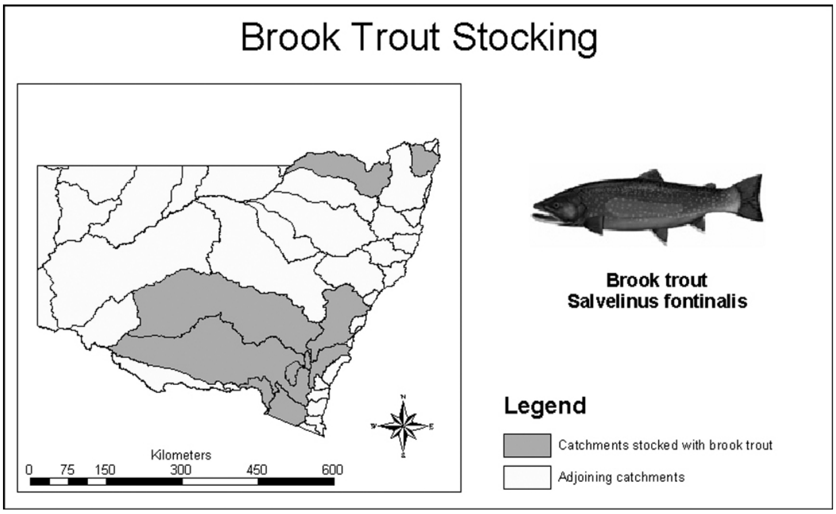


Figure B11. Brook trout stocking in NSW.

History of stocking

The first recorded importation of brook trout into NSW occurred in 1890 when a shipment of ova and fry arrived from Wellington, New Zealand. This importation was recorded in the Parliamentary Papers of 1890, (Brinsley 1999) which further stated that 200 of the fry were released into Barbers Creek Reservoir. The release appeared to fail, and for one reason or another, brook trout production and stocking all but seemed to vanish until 1968 when the Tasmanian Inland Fisheries Commission presented 5000 fry to the NSW Government. Gaden hatchery kept 4000 of these on hand while 1000 fry were consigned to the Dutton Hatchery. The opportunity to establish a reliable broodstock for the species was undertaken, and by 1970, the hatcheries were successfully hatching and stocking brook trout in NSW.

Since 1970, a total of 991,408 brook trout have been released making it the 4th and least most stocked salmonid species in NSW. It has been predominantly stocked in the Snowy River, Murrumbidgee and Shoalhaven catchments, with lesser quantities recorded for the Lachlan, Richmond and Macintyre catchments. There are also anecdotal reports of brook trout being stocked into the Macquarie River, although there are no official records on the NSW Fisheries database.

Natural distribution and origin of species

Brook trout are native to the east coast of North America, from the Atlantic Ocean to the New England south to Cape Cod. They are also found naturally in the mountain waters of this range as far south as Georgia and in the Great Lakes of Michigan.

The brook trout is not a true trout, but rather a 'char', distinguished by their teeth arrangement and smaller scales. In their natural range the fish will grow in excess of 6kg, but rarely exceed 2kg in Australia. The species has been transplanted throughout the world, including New Zealand, South America, Europe, Japan, Africa, and western-North America. A strikingly attractive fish, it lives and reproduces in small, cold streams and spring-fed waters. Optimum water temperature range is from 11-16 degrees Celsius. As with the Atlantic salmon, after 30 years of stocking there has been little or no reliable evidence of these fish spawning in the wild in Australia.

Sources of stock

The only source of stock in NSW is from specimens held at the Gaden Hatchery from the stock imported from Tasmania in the 1970s. Fish are stripped of their eggs at Gaden during early June each season and reared at the hatchery. Eggs may take from 3 to 12 weeks to hatch depending on water temperature.

Sources of broodstock

The only source of broodstock in NSW is from specimens held at the Gaden Hatchery originating from the stock imported from Tasmania in the 1970s.

B1.2.2.4 Brown trout **Salmo trutta**

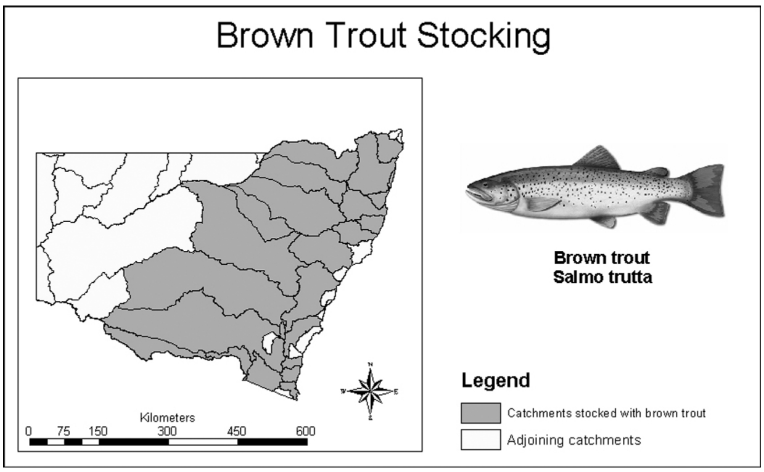


Figure B12. Brown trout stocking in NSW.

History of stocking

Brown trout was the first salmonid species to be introduced into NSW, circa 1888, when 300 or more brown trout were received by early stockists in Queanbeyan from the Ballarat Acclimatisation Society. The fish were liberated into the Cotter, Queanbeyan, Molonglo, Yass, Naas, Little and Bibbenluke rivers. Also in 1888, the NSW Fisheries Board began receiving consignments of brown trout from Ballarat, and stockings were undertaken near Armidale in the mid-northwest of the State and later in the Brogo, Berrima, Colo and Nepean rivers. Other streams in the Cooma and Bega area were also stocked with brown trout.

By 1890, consignments of brown trout were being received from New Zealand and Tasmania and for many years, the species was being cultivated by numerous acclimatisation societies across NSW. Available records since 1965 show that over 5.5 million brown trout have been stocked, making it the 3rd most stocked salmonid in NSW.

Natural distribution and origin of species

Brown trout are native to Europe, Iceland, western Asia and northern Africa, although they have been introduced to many countries around the world including America, New Zealand, Japan and Australia. Overseas, the species utilises both fresh and saltwater for feeding and spawning (in brackish water), and are often partially migratory. The brown trout preys on fish as well as insects. It prefers water temperatures between 10°and 20°C. Brown trout are known to have established self-sustaining populations in NSW, and spawning fish migrate upstream to gravel-bottom stretches of river. The eggs generally hatch after 1 month, depending on water temperature, and hatchlings stay in the gravel feeding off their yolk sacs until they emerge as fry. They initially form schools, but over the next year or two, become solitary and territorial as they move into deeper water.

Sources of stock

Stocks of brown trout are produced predominantly at the Gaden Hatchery and to a lesser extent at the Dutton Hatchery. During the 1980s, a number of acclimatisation society branches including the Walcha Trout Club Hatchery, the Crookwell Hatchery and the Upper Murray Fish Farm were operating their own trout hatcheries and producing stock for release. This arrangement has significantly declined, and the last recorded trout stocking by any of these hatcheries occurred in the mid-1990s.

Sources of broodstock

Wild trout are trapped in the Eucumbene and Thredbo rivers and stripped of ova and milt by hatchery staff for breeding programs at the Gaden Hatchery. A portion of the fish are relayed to the Dutton Hatchery as a readily available source if wild broodstock is not available in that region.

B1.2.2.5 Rainbow trout Oncorhynchus mykiss

History of stocking

The first introduction of rainbow trout into NSW occurred around 1894 from stock sourced in New Zealand. About 3000 rainbow trout ova arrived in Sydney from the Wellington Acclimatisation Society amongst a larger consignment of brown trout ova (Fisheries of NSW Parliamentary Report 1894). By the 1900s, hatchery techniques had developed sufficiently by the acclimatisation societies who produced large numbers of rainbow trout fry, and the species has since been stocked into virtually every waters in NSW capable of sustaining them. NSW Fisheries records held since 1968 show that over 32 million rainbow trout have been released into NSW waters making it by far the most-stocked salmonid in the State.

Rainbow trout spawn between August and September in waters between 10° and 20°C. The species is known to have readily adapted to Australian conditions and many self-sustaining populations exist today in areas offering optimal conditions. Their life expectancy ranges from three to five years or more.

Returns of large fish were taken in the early days in NSW, but high-volume stocking has increased populations and reduced their average size to between 1kg and 2.5kg.

A native of North America, releases of rainbow trout into NSW waters commenced several years after that of brown trout. The rainbow trout is a spectacular fighting fish but easier to catch than the brown. Although known to reach more than 18kg, fish larger than 4kg are exceptional in NSW.

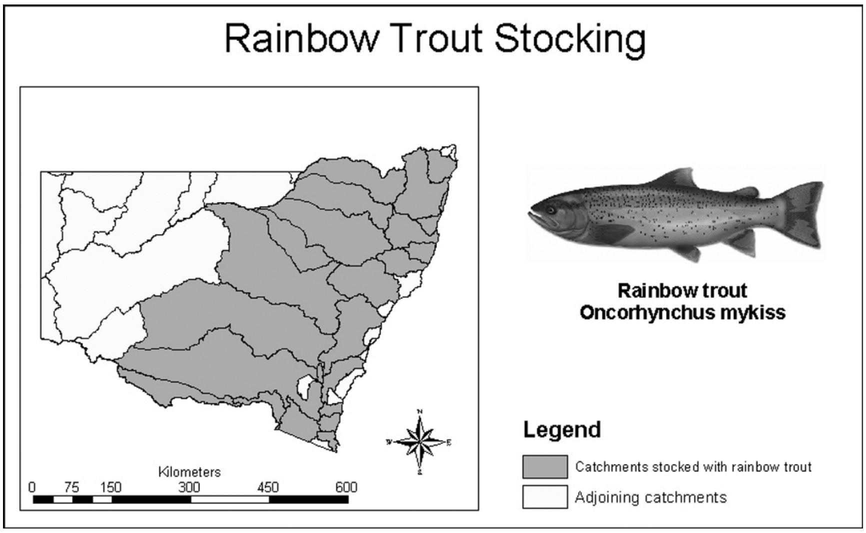


Figure B13. Stocking of rainbow trout in NSW.

Natural distribution and origin of species

Rainbow trout are native to the northeastern Pacific along the west coast of North America, from the north-western portion of Mexico upward to Alaska, and generally west of the Rocky Mountains Range. Introduced to many countries throughout the world including New Zealand, South America, Europe, Asia, Japan, Africa and Hawaii, rainbow trout are also now widespread in the colder rivers and dams throughout NSW and temperate Australia.

Sources of stock

Sources of stock for rainbow trout are produced at both the Dutton and Gaden hatcheries while several private hatcheries have produced this species for smaller-scale stocking events.

Sources of broodstock

Wild trout are trapped in the Eucumbene and Thredbo rivers (in the south of the State) and stripped of ova and milt by hatchery staff for breeding programs at Gaden Hatchery. A portion of the fish is relayed to Dutton Hatchery (in the north) as a readily available source of wild broodstock.

B1.3 Hatcheries

B1.3.1 Definitions

For the purposes of this section, hatcheries are defined as either Government-owned and operated hatcheries managed by NSW Fisheries (*Government hatcheries*) or privately owned and operated hatcheries (*Private hatcheries*) licensed under Part 6 (Aquaculture Management) of the *Fisheries Management Act 1994*.

B1.3.2 History of early trout hatcheries

NSW Fisheries operates five hatcheries producing salmonid and native fish for Recreation Stocking and Conservation Stocking programs.

As noted earlier, the first hatchery in NSW was established in a disused kitchen in the offices of the Fisheries Commissioner for the colony of New South Wales in Phillip Street, Sydney in 1889. The room measured $16m^2$ and town water cooled by ice was used to hatch the eggs. The hatchery imported ova from interstate and overseas, reared the fry and released them into streams in the Cooma, Bega and Armidale districts.

By 1892, high temperatures, lack of capacity for expansion and uncertain water quality had the department searching for a new site. This was found at Prospect Reservoir, near Blacktown in Sydney's west. Custom-built ponds were completed in 1894 and stocked with yearling brown trout from Ballarat and ova from New Zealand. The full hatchery was completed in 1896 and, while the importation of ova continued, low survival rates drove the development of spawning ponds to breed and strip local fish. In 1902, the first ova were stripped from brood fish reared at Prospect and, by 1906, breeding was well established with the construction of a spawning pond on the Jenolan River to catch and strip wild fish.

Again, lack of water, disease and high temperatures forced the department to look for alternative places to rear trout fry to fingerling size before they were released. Five ponds were set up near Talbingo in 1907 to grow out fry hatched at Prospect. The ponds were frequently raided by birds and survival rates were low. Use of the ponds discontinued and, in 1968, they were submerged beneath the waters of the Jounama Pondage, built as part of the Snowy Mountains Hydro-electric Scheme.

In 1919, the hatchery at Prospect underwent the first of a series of upgrades culminating in a large reconstruction in 1939 to provide it with the capacity to produce one million fish. Hatching operations continued until 1942 when the war intervened. Prospect, the State Governments principal hatchery for almost 50 years, was never re-opened and in 1948, the buildings, troughs and fittings were transferred to a hatchery at Burraga and eventually on to Gaden Hatchery.

Pressure to establish hatcheries in the Monaro-Snowy Mountains region, regarded as the area offering greatest potential for trout production, led to the construction of a small temporary hatchery, 'the Hospice', on Diggers Creek near the Kosciusko Hotel which quickly went out of production after all the fry died in 1910. In 1924, 'the Hospice' was dismantled and re-erected on the site of the new Creel Hatchery, close to the junction of the Thredbo and Snowy Rivers. This hatchery was a cooperative venture between the NSW Government, the NSW Rod Fishers' Society and the NSW Tourist Bureau.

Enlarged in 1927, the Creel Hatchery played an important role in the propagation and distribution of trout in the Monaro region until 1941, when the war caused it to close. In the early 1950s, the Creel hatchery building was dismantled and re-erected on the site of the new Gaden hatchery. It served initially as emergency accommodation for the supervisor and then as a storeroom until 1998 when it was demolished.

Following the disappointing experimental opening of the Talbingo Ponds in 1924, a movement began in Tumut for the construction of a hatchery in the town. In 1929, the Tumut Shire Council opened a hatchery with the capacity of 500,000 ova. It produced fish for two years until the Depression followed by the war caused operations to cease. In 1949, the hatchery briefly re-opened, but in the early 1950s, the main building was dismantled and transported to Gaden where it is used today as a machinery shed.

Around 1929, the Cooma Fishermen's Club and Fisheries Department built a small hatchery below Corbetts Springs near the Cooma Rifle Range. From the outset it experienced problems with inadequate water, and produced very few trout. In 1939, the hatchery was relocated at a cost of £300 to a site at Peaks Creek off the McLaughlin River near Bungarby, donated by Mrs A Caldwell. The Monaro Acclimatisation Society organised the removal of the buildings to the new Cooma Hatchery, which laid down brown and rainbow trout ova in 1939, 1941 and 1942. Production was suspended during the war, and resumed in 1946 until the early 1950s, when the hatchery closed down and the building was transferred to the new site at Gaden where it remains in use today as a workshop.

Following the registration of the Central Acclimatisation Society (CAS) in the late 1930s, a hatchery was built at Boggy Creek, on the road between Oberon and Hampton. The hatchery did not operate until after the war, when it started importing ova from New Zealand to produce fingerlings for liberation in the Central Tablelands area. Despite losses of up to 50% of ova in the beginning, the hatchery had soon reduced its mortality rate to 5% according to CAS records. However, demand for fish to be stocked into local rivers proved greater than the small hatchery could supply and the Government was lobbied for £6000 to build a new facility on the site of a disused dam at Burraga on Thompson's Creek.

The Burraga Hatchery was completed in 1948 and was one of three to survive the rationalisation of the hatchery production of trout in 1959 when the Government took over the facilities from the acclimatisation societies. Water quality and high summer temperatures continued to be a serious problem for the hatchery, precluding the raising of ova beyond fry stage for rainbow trout and early fingerling stage for brown trout. By 1962, the Burraga Hatchery was closed and the main building and troughs relocated to Gaden.

B1.3.3 Government hatcheries

Table B3. Locations of Government hatcheries.

Government Hatchery	Location
LP Dutton Trout Hatchery (DTH)	Point Lookout Road, Ebor NSW 2453
Gaden Trout Hatchery (GTH)	Kosciusko Road, Jindabyne NSW 2627
Grafton Aquaculture Centre (GAC)	Grafton Agriculture Research Station Trenayr Road, Junction Hill Grafton NSW 2460
Narrandera Fisheries Centre (NFC)	Buchingbong Road, Narrandera NSW 2700
Port Stephens Fisheries Centre (PSFC)	Taylors Beach Road, Taylors Beach NSW 2316

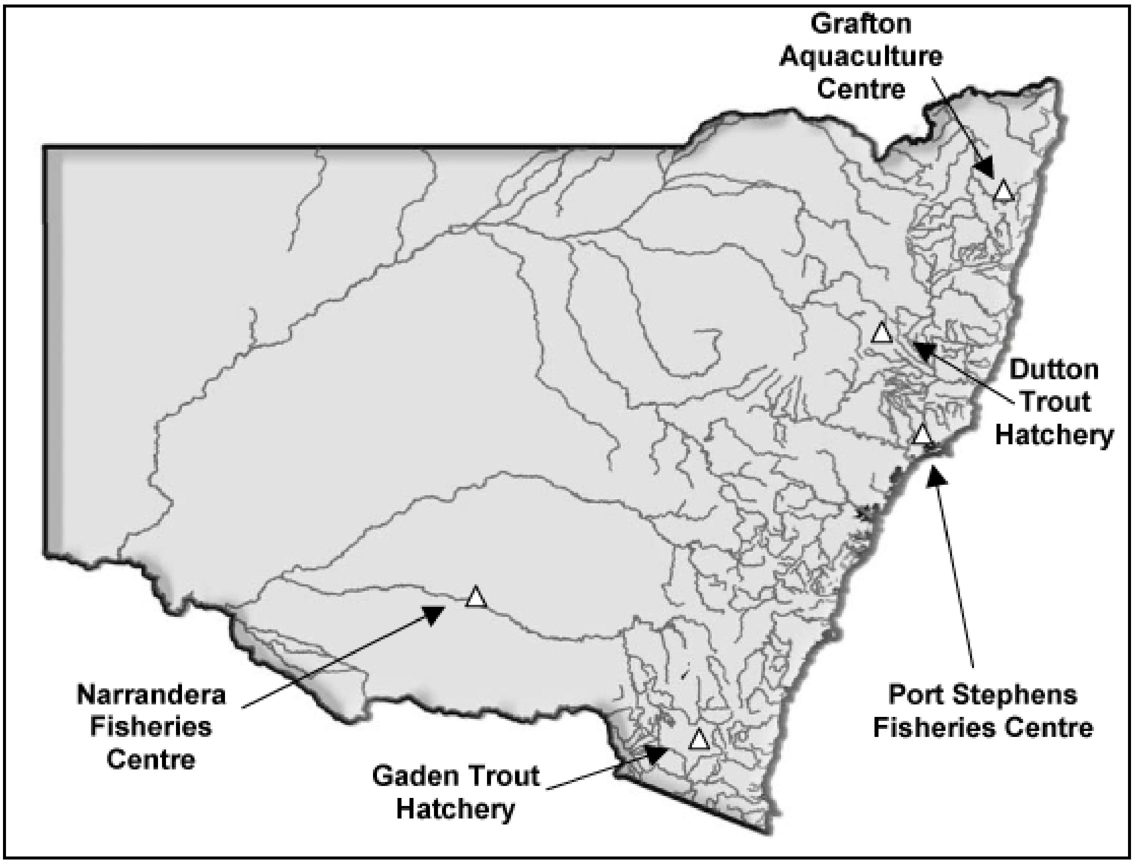


Figure B14. Map showing locations of Government hatcheries.

Table B4. Native species grown in Government hatcheries.

Species	Source of stock
Murray cod *Maccullochella peelii*	NFC
Australian bass *Macquaria novemaculeata*	PSFC
Trout cod *Maccullochella macquariensis*	NFC
Silver perch *Bidyanus bidyanus*	NFC & GAC
Golden perch *Macquaria ambigua*	NFC
Eastern cod *Maccullochella ikei*	Private hatchery under NSW Fisheries permit (formerly bred from GAC lines)
Catfish *Tandanus tandanus*	NFC (no current stocks produced)

Table B5. Salmonid species produced at Government hatcheries.

Species	Source of stock
Rainbow trout *Oncorhynchus mykiss*	DTH & GTH
Brown trout *Salmo trutta*	DTH & GTH
Brook trout *Salvelinus fontinalis*	GTH
Atlantic salmon *Salmo salar*	GTH

B1.3.3.1 The L.P. Dutton Trout Hatchery

Location

The L.P. Dutton Trout Hatchery (Dutton Hatchery) is located on the Serpentine River at the eastern edge of the New England region in northern NSW. It is located 70km east of Armidale and 130km west of Coffs Harbour, the closest settlement being the village of Ebor, 14km to the east.

History

The Dutton Hatchery is named after Mr Leslie Dutton, the first person to build a trout hatchery in the New England region. He built a hatchery on his property 'Urandangie' near Guyra in 1925, which produced more than 200,000 trout fry in its first year of operation. Mr Dutton quickly followed his initial venture with a second hatchery, built on adjoining land and known as the Glen Innes Hatchery. Both hatcheries were operated by the Guyra and Glen Innes' Rod Fishers' Associations and produced close to 500,000 trout fry a year, usually from ova imported from overseas or interstate.

In 1930, a third trout hatchery was built in Armidale with materials supplied by the Fisheries Department and labour from local tradesmen and members of the Armidale and District Rod Fishers' Association (ADRFA). In its first year of operation, the Government-owned, but ADRFA-operated, Armidale State Hatchery released 144,000 rainbow trout fry.

In 1932, the Armidale, Glen Innes and Guyra Rod Fishers' Associations met at 'Urandangie' and formed the New England Trout Acclimatisation Society (NETAS) to operate the Urandangie and Glenn Innes hatcheries.

Following the Depression years in which all the hatcheries had struggled to produce fish, improvements in the economy in 1937/38 saw the Armidale Hatchery lay down 121,000 ova, but hatch fewer than 20,000. Urandangie Hatchery was re-opened for several years in the late 1930s, and early 1940s, although Glen Innes was not able to continue operating. Production at all hatcheries ceased between 1943-46 due to the Second World War.

In 1948, NETAS members reconstituted the organisation and recommenced trout breeding. One of its first actions was to advise the Government that the Armidale Hatchery was to be re-located to Guyra. This prompted some swift action from the Fisheries Department who decided 'Urandangie' was unsuitable for expansion due to an unreliable water supply and a site for a new larger State hatchery should be found where brood fish could be held to provide locally stripped ova. In 1949, it was decided to build a trout hatchery on the Serpentine River near Ebor to replace the three smaller hatcheries.

The Dutton Hatchery was opened in September 1952 and operated by NETAS until 1959, when NSW State Fisheries assumed control of all hatcheries run by acclimatisation societies following the 1958 introduction of the Inland Angling Licence.

Staff and volunteers

Volunteers from angling clubs and NETAS managed the state-owned hatchery at Armidale and private facilities at Urandangie and Glen Innes. Under legislation passed in 1935, the acclimatisation societies received funding from the Trout Licence to run the hatchery and employ occasional staff – often members of the society. From 1952 to 1959, NETAS managed the Dutton Hatchery, employing a full-time manager who remained in the position when the State Government assumed control of the hatchery.

Between 1952 and 1965, the manager was the sole staff member at Dutton Hatchery, producing around 200,000 rainbow trout for stocking each year with the assistance of acclimatisation society members. There have been only five managers of the Dutton Hatchery in its 50-year history:

Table B6. Managers of the LP Dutton Hatchery

Hatchery manager	Year	Hatchery manager	Year
John Sheather	1982 – 2002	Ken Heffernan	1967 – 1975
John Sheather (acting manager)	1980 – 1982	Neville Fenton	1961 – 1967
Colin Woodhouse	1976 – 1980	John Duncan	1952 – 1961

In 1965, an assistant manager (John Sheather) was appointed and production expanded. In 1975, guided tours of the hatchery commenced and public admission charges were introduced, necessitating the employment of two guide attendants. These four positions plus a part-time clerical officer remain the core staff at the hatchery.

Facilities

The hatchery infrastructure has grown progressively since 1952, and the facility now has a large storage dam, five brood ponds, two smaller fish-out ponds, 20 circular cement ponds, four cement raceways, a well-equipped hatchery breeding shed, a machinery shed and a managers residence.

Visitors Centre

The Visitors Centre was constructed in 1986, and officially opened in May 1987. It includes aquarium displays, a theatrette with video show, static display, kiosk, staff meal room, toilet facilities and a bunkhouse. The centre is open from 9.30am to 4.30pm seven days a week.

Operations

The Dutton Hatchery has developed from a small facility producing approximately 200,000 trout fry in 1959, to one which stocks annually more than two million fry into waters in the New England, Hunter and Central Tablelands regions. This has been made possible by advances in trout breeding, new infrastructure and improved technology. In recent years, the Recreational Freshwater Fishing Trust has assisted the hatchery with funding to increase stocking programs and purchase capital items, such as an egg picker that has mechanised the once time-consuming manual work.

The Dutton Hatchery produces only rainbow and brown trout as they are less susceptible to high water temperatures than brook trout and Atlantic salmon, which are bred at Gaden Trout Hatchery in the south of the State. While brown trout are a hardier species in the wild, there has traditionally been little angler demand for them in the New England region. Under hatchery conditions, brown trout also spawn earlier and for longer (May – September) than rainbow trout (May - July) and are more difficult to rear.

The Dutton Hatchery holds 3000 female and 500 male rainbow trout aged one to four years in large earthen ponds on site. In the warmer pond water the trout tend to ripen and spawn in July, earlier than in the wild. Trout also mature earlier in a hatchery environment and are stripped when aged two and older, yielding approximately three million eggs. When the broodstock trout reach four years old they are released into local streams and impoundments for recreational fishing.

Some years ago, an earlier-spawning strain of rainbow trout spontaneously developed at Dutton Hatchery, resulting in reduced ova fertility and losses of up to 80% of fry. A crossbreeding program with wild spawning stock from Gaden Trout Hatchery has been implemented to return the trout to their July spawning. The hatchery also uses a saline-based chemical solution to improve fertilisation. This has only been trialed in fish stocked in the 2001/2002 season, and in conjunction with the new breeding program, is producing survival rates of 80%.

Dutton does not retain brown trout broodstock on site, keeping only a few adults for display purposes. It receives approximately one million brown trout ova stripped from wild-caught stock at Gaden Hatchery each year, which it rears to fry stage.

Gaden also supplies Dutton with replacement brood rainbow trout stock when numbers are low and to ensure sufficient genetic diversity is maintained at the site. When Dutton hatchery lost a large quantity of brood fish during a flood in March 2001, Gaden sent approximately 1000 broodstock to replace them.

The greatest obstacle to the viability of Dutton Hatchery is relatively poor water supply, especially in summer. The flow from the Serpentine River is inadequate to keep large numbers of brood stock over summer months. At times of low water flow and in summer, water temperatures can rise well above 20°C and dissolved oxygen levels fall below optimum levels for trout. There are no real affordable options for improving the water supply.

Limited water availability is a key reason the hatchery only produces fry for stocking. In the 1960s, attempts were made to breed fingerlings at the request of acclimatisation society members, who thought the survival rate of larger fish would be higher. However, the high water temperatures, over-crowding and additional cost of food made this unsustainable.

Dutton Hatchery provides the New England, Central, Orange and Southern Districts acclimatisation societies with fry for stocking between August and November each year.

Table B7. Average annual production and allocation of stock from Dutton Hatchery (2002 figures).

Species	**Stocking organisation**					
	Acclimatisation Societies				NSW Fisheries	Total
	CAS	CSDAC	NETAS	OTAS		
Brown trout	135,000	83,500	414,000	6,000		638,500
Rainbow trout	301,000	234,000	1,491,000	14,000	181,050	2,040,000
Total	436,000	317,500	1,905,000	20,000	181,050	2,859,550

B1.3.3.2 The Gaden Trout Hatchery

Location

The Gaden Trout Hatchery is located on the Thredbo River, in the Snowy Mountains region of southern NSW. It lies 10km north west of Jindabyne and 180km south of Canberra.

History

Gaden Hatchery is the epitome of trout hatcheries in southern NSW. Buildings and other structures from eight former hatcheries still stand at Gaden, serving as an historic reminder of the past. Built between 1949 and 1951 in an attempt to rationalise trout production in the area, Gaden Hatchery was opened in 1953 and named after Mr Jim Gaden, a pioneer in trout acclimatisation in the region.

Staff and volunteers

Volunteers from angling clubs and the Monaro Acclimatisation Society (MAS) managed the small hatcheries that preceded the Gaden Hatchery. In 1948, when representatives from Government, MAS and council identified a site on the Thredbo River to build a hatchery, a supervisor was employed to oversee the project and lay down the first ova. There have been 10 managers of the Gaden Hatchery in its 49-year history. An assistant managers position was introduced in 1967, and two guide attendants in 1969. Guided tours of the hatchery started in 1975 when admission fees were also introduced.

Table B8. Managers of the Gaden Trout Hatchery

Hatchery manager	Year	Hatchery manager	Year
Sam Crocker	1997 – 2002	David Lane	1967 – 1972
Mel Lockhart	1993 – 1997	DJ McDermott	1965 – 1967
Sam Crocker (acting manager)	1992 – 1993	David Kerr	1964 – 1965
David Stock	1979 – 1992	Herbie Butler	1961 – 1964
Sam Crocker (acting manager)	1977 – 1979	Edgar Blau	1959 – 1961
Ray Symons	1973 – 1977	Charlie Bell	1959 – 1969
Bob Leech	1972 – 1973	Fred Ness	1957 – 1959
John Smith (acting manager)	1972 – 1972	Reuben Payten	1949 – 1957

Operations

The Gaden Hatchery is built on the banks of the snow-fed Thredbo River and has a constant supply of good quality, cold water. It produces approximately two million brook trout, Atlantic salmon, rainbow trout and brown trout for stocking each year.

The hatchery keeps approximately 200 rainbow trout and 200 brown trout brood stock on site as insurance against the rare occasions when it is difficult to capture wild fish. The brood fish are replaced regularly to ensure the widest possible gene pool is maintained. Hatchery staff trap brown and rainbow trout when the fish migrate from Lake Jindabyne between May and September each year. The trout are stripped and then released back into the river.

The hatchery supplies the Monaro and Southern Districts Acclimatisation Societies with brown trout and rainbow trout fry for stocking in local waterways. The hatchery retains one-fifth of its brown trout fry and half of its rainbow trout fry to grow out to fingerling size for stocking into the Monaro and other districts. Ova are allocated to the smaller acclimatisation society hatcheries for approved stocking into local rivers.

The fingerlings are clipped on a different fin each year to enable identification and assessment of the success of the stocking program. Fin-clipped fish from previous years regularly appear in the fish trap during spawning.

The hatchery retains two generations of brook trout, approximately 150 in total, and 1000 brook trout fingerlings. These are used to produce around 150,000 advanced fry for release into a limited number of colder alpine streams and impoundments and for sale to landowners for stocking private dams.

The Gaden Hatchery was the first facility in Australia to breed Atlantic salmon and currently holds five generations of brood stock for cross breeding. An indirect consequence of the stock enhancement program for Atlantic salmon in NSW waterways has been the development of a thriving aquaculture industry in Tasmania based solely on broodstock from the Gaden Hatchery. The genetic stock is maintained at Gaden in the event of a crisis in the Tasmanian industry.

Facilities

Gaden Hatchery contains many older wooden buildings from its predecessor hatcheries, although the original ponds and troughs have all been enlarged and updated with new drainage, lining and pipeline intake systems. In addition, the hatchery has a new machinery shed, two residences, nine covered fibreglass raceways, 10 large fibreglass circular ponds, six fenced earthen fry ponds, five large earthen ponds for broodstock and a wooden hatchery shed containing 25 fibreglass troughs, five incubation bins and 36 incubating buckets.

Visitors Centre

The Visitors Centre was constructed in 1985 with static displays, theatrette with slide/video show and aquarium tanks. When it first opened, the centre was averaging 25,000 visitors a year, due to its location near several popular ski fields. It was subsequently privatised, closed for a time in the 1990s, and re-opened by the State Government in 2000.

Hatchery production

In 2002, the Gaden Trout Hatchery produced 694,000 trout fry and fingerlings (a below average year) for stocking by acclimatisation societies and 928,440 for stocking by hatchery staff.

Table B9. Fish production data for Gaden Trout Hatchery in 2002.

Species	No. of female fish stripped	Ova produced	Ova survived
Atlantic salmon	169	715,00	480,000
Brook trout	74	230,000	123,000
Brown trout	758	1,897,000	1,840,090
Rainbow trout	691	1,022,000	766,500
Total	1,692	3,864,000	3,209,590

Table B10. Production and allocation figures for Gaden Hatchery in 2002.

Species	Organisation		
	MAS	NSW Fisheries	Grand Total
Brown trout	405,000	54,000	459,000
Rainbow trout	289,000	294,620	583,620
Atlantic salmon		469,320	469,320
Brook trout		110,500	110,500
Total	694,000	928,440	1,622,440

Trout hatchery production schedule (Dutton and Gaden)

Table B11. Production schedule at Gaden and Dutton Trout Hatcheries.

Month	Dutton	Gaden
March	Annual allocation meeting with five acclimatisation societies sets stocking target for following season and determines number of fry and fingerlings required.	
April	Earthen brood ponds drained and mature rainbow trout moved to raceways. Trout are sexed and males removed to circular cement ponds.	
May to July	Females are checked weekly and stripped when ripe. The ova is fertilised and laid down in troughs to hatch. Rainbow trout brood fish are returned to their ponds. First batch of fertilised brown trout ova are delivered to Dutton and laid down in troughs to hatch.	Female brook trout and Atlantic salmon are stripped and fertilised ova is laid down for up to three months. Screens are placed in the trap in the river to catch brown trout moving upriver to spawn. Brown trout are sexed and held in separate ponds. Females are stripped and the ova fertilised and laid down in troughs to hatch. Ova stripped from brown trout are sent to Dutton Trout Hatchery.
May to July cont.		Brown trout are released back into the river or kept as replacement brood stock.
August to October	Rainbow and brown trout ova hatch and are reared to fry stage. Stocking of rainbow and brown trout fry into dams and waterways in the New England and Central Tablelands regions commences.	Brown trout ova start to hatch. Screens are removed from the river and replaced when rainbow trout start moving upriver to spawn. Female rainbow trout are stripped and the ova fertilised and laid down in troughs to hatch. Rainbow trout are released back into the river or kept as replacement brood stock. Brook trout and Atlantic salmon ova hatch.
November	Final stocking of rainbow and brown trout fry.	Brook trout stocked. Atlantic salmon stocked.
December to January		Rainbow and brown trout fry are stocked. Approximately half are kept to grow out as fingerlings.
February to April		Rainbow and brown trout fingerlings stocked.

B1.3.3.3 The Narrandera Fisheries Centre

Location

The Narrandera Fisheries Centre is located 5km east of Narrandera on the Sturt Highway in southwestern NSW. The 36ha hatchery site is located about 1km from Murrumbidgee River. The nearest major centres are Wagga Wagga, 100km to the southeast, and Griffith, which is approximately the same distance to the northwest.

History

Towards the end of the 1950s, freshwater fisheries scientists were aware of the need for a greater understanding of the biology of Australia's inland fish. Of particular importance were the reproductive habits of the four main recreational and commercial species in western rivers, Murray cod, golden perch, silver perch and catfish, which were observed to be in decline. The first research was funded from the Inland Angling Licence introduced in 1958 and a grant from the NSW State Treasury. It was carried out by John Lake, a freshwater biologist employed by the fisheries branch of the Chief Secretaries Department in Sydney, at the Inland Fisheries Research Station (as it was known then) set up for the purpose at Narrandera, which officially opened in 1962.

Initial research into the reproductive biology of native fishes suggested that rising water temperature levels in spring and summer triggered Murray cod, golden perch and silver perch to spawn. Using this knowledge, a native fish-breeding program was introduced at Narrandera in the 1960s, using natural spawning techniques. However, the environmental manipulation method used by John Lake had a number of practical difficulties, such as delays caused by cold weather, adult fish which were not sexually mature, poor food sources for larval fish, low survival of larvae and the failure of some fish to produce fertile eggs. Consequently, survival rates were low and the department resolved that artificial breeding should be investigated.

The artificial breeding program at Narrandera commenced under the direction of American scientist, Lee Wyse, in 1971 and was later taken over by fellow compatriot, Karl Shearer, who were both brought out by the NSW Government for their expertise. Basically, the program involved collecting sexually mature fish and inducing them to spawn using hormone injections, in place of an environmental trigger. The use of hormones allows the breeding to be carefully controlled, enabling higher survival of fingerlings. Hormones derived from the pituitary gland of European carp and human chorionic gonadotrophin (CHG) – a basic female hormone - are injected into female fish to stimulate final egg maturation and ovulation. The eggs are artificially fertilised and the larval fish subsequently reared in the hatchery.

This technique revolutionised native fish production at Narrandera and, in 1972, the Inland Fisheries Centre produced 1,270 Murray cod and 270 catfish and the following year added 55,882 golden perch. These are small numbers by today's standards, but at this time the artificial breeding of native fish was a new industry worldwide. In 1976, more than 500,000 fingerlings were produced from only 20 pairs of golden and silver perch. These fish were released into Glenbawn Dam (Scone), Lake Albert (Wagga) and Lake Wyangan (Griffith) and were the first native fish stocked into public impoundments in NSW.

After the success in 1976/77, major difficulties were encountered and lower numbers produced in 1977/78. In the following years, Dr Stuart Rowland conducted numerous hormone-induced spawning and larval rearing experiments that led to the development of reliable techniques for then large-scale production of Murray cod, golden perch and silver perch.

In 1979, more than one million native fish, including 876,000 golden perch, were produced. The stocking program was significantly expanded to include Copeton Dam (Inverell), Burrendong Dam (Wellington), Wyangala Dam (Cowra) and Gillenbach Lagoon (Narrandera).

Until 1982/83, the Inland Fisheries Research Station was the only native fish hatchery in Australia. It sold Murray cod, silver perch and golden perch fingerlings to angling groups and landowners for stocking in private waters (eg farm dams) and public waterways. Clients included the Victorian, Queensland and ACT Governments who were purchasing native fish for conservation stocking in their own jurisdictions. By the early 1980s, Narrandera had developed the capacity to produce large numbers of native fish using artificial spawning techniques and was ready to transfer the artificial breeding technology to private industry.

In 1982, it handed the responsibility for the sale of native fish to the four private hatcheries in NSW and concentrated on breeding Murray cod, silver perch and golden perch to stock into public impoundments and waterways.

With hatchery breeding programs established for Murray cod and golden perch and silver perch, attention turned to trout cod and Macquarie perch in the mid-1980s. A conservation-breeding program was set up in 1984 to try and halt the significant population decline in both fish species. However, Macquarie perch proved difficult to breed as female fish did not develop ripe gonads in the ponds, nor did they respond well to hormone stimulation and, for ova to be collected, wild ripe fish had to be caught and stripped. This was a labour-intensive process, problematic in its application and without any guarantee of success. Consequently, the Macquarie perch program was abandoned in 1987 and the species is now declared vulnerable. Successful techniques were developed for trout cod, resulting in an ongoing breeding program. More than 500,000 fry were released into waterways between 1985 and 2001.

Staff

Table B12. Hatchery managers at Narrandera Fisheries Centre

Hatchery manager	Year
Steve Thurstan	1984 – 2002
Scientist in Charge	
Stuart Rowland	1978 – 1984
Karl Shearer	1974 – 1978
Lee Wyse	1971 – 1973
Leighton Llewellyn	1967 – 1971
John Lake	1961 – 1967

Facilities

The hatchery at Narrandera is a multi-functional site, serving as the western base for NSW Fisheries conservation and general operations as well as the hatchery. It is well equipped with an administration centre, three residences, machinery shed, 23 brood ponds, 11 rearing ponds, a 4ML storage pond and three food production ponds. It also has a breeding shed with a number of troughs and fibreglass tanks for breeding fish and rearing eggs and larvae and a new broodfish holding-shed with eight 2000L tanks and four 5000L tanks. The site is supplied with river and bore water.

Visitors Centre

The John Lake Centre was constructed in 1983 as an interpretive centre for native fish species. It contains a theatrette with video show, static displays, display ponds and aquariums with many species of native fish, including a giant Murray cod. The centre is open during office hours in summer when visitation is highest.

Operations

The Narrandera Fisheries Centre breeds four native fish species; Murray cod, trout cod, golden perch and silver perch, for Conservation Stocking and Recreational Stocking purposes. This requires the maintenance of four separate breeding programs at the centre and an intensive production system.

Unlike trout at the Dutton and Gaden Hatcheries, the fish at Narrandera are stocked in earthen ponds, which recreate as much as possible their natural brood environment. Species such as Murray cod, breed in pairs, so the ratio of males to females must be equivalent. The ponds are aerated with paddle wheels and the brood fish feed on native vegetation, zooplankton and small crustaceans which grow in the ponds, as well as live food, such as gudgeons, yabbies, shrimps, rainbow fish and herring. In the past, much of this live food was collected from local waterways. However, on-site food production of yabbies and fish is being developed to reduce the risks of introducing diseases and to protect the fish by making the hatchery self sufficient. A good diet, based on natural food sources, is vital to the health of the native fish and to the production of large amounts of high quality ova during spawning. From 2001, the only supplementary live food brought into the hatchery has been carp and yabbies.

The fish care program at Narrandera requires the 39 brood ponds to be cleaned and sprayed annually to prevent parasites and fish diseases. The fish are rotated annually and female golden perch and all Murray cod and trout cod are tagged with microchips to monitor individual performance and ensure different fish are paired each season. This enables poor producers to be replaced and facilitates better husbandry practices. Brood fish from different drainages can be separated and their progeny identified so they can be released back into the same system. The majority of brood fish come from local catchments with only a few Murray cod from the Macquarie River.

Each year, approximately 20% of broodstock are replaced from wild populations in local rivers, through electro-fishing and various netting techniques, so that the genetic pool is widened and fish aged between five and seven years can be released back into the wild. The new broodstock are transported to the hatchery and kept in fibreglass tanks under quarantine until they acclimatise to their new surroundings and can be released into ponds. The micro-chipping program ensures old broodstock is not recaptured.

Until recently all brood fish on site were injected with hormones to make them spawn in the hatchery so the eggs could be cared for properly. This replaces a natural spawning process and induces final egg maturation, ovulation and spawning. In the case of golden perch and silver perch, the fish are harvested from the brood ponds and hormone induced to spawn in fibreglass ponds in the hatchery shed. They have pelagic eggs, which harden and float in the water column until they hatch.

In the case of Murray cod, some of the fish pairs spawn in the ponds in specially constructed drums. The ponds are checked each day and, when the 10 – 15kg females deposit 20,000 to 30,000 eggs and they are fertilised by the male partner, the screen is removed and the ova taken to the hatchery. This method has proven to require less labour and is more cost efficient.

Once the ova hatch, the larvae in the hatchery are fed on zooplankton and rotifers, which grow in special tanks on site. These food source populations can crash very easily, so great care must be taken in their production. The larval fish are then stocked in rearing ponds, which also contain zooplankton and other, larger food-sources.

Trout cod at the hatchery are induced to spawn when water temperatures in their ponds reach 16°C and are stripped 51 hours later. The eggs are fertilised with milt from the males and hatch when the water temperatures reach 20°C. In 1998, the trout cod was listed as an endangered species with only two known self-maintaining wild populations – in the Murray River below Yarrawonga Weir and in Seven Creeks below Polly McQuinns Weir in Victoria. The Yarrawonga population has provided Narrandera Fisheries Centre with wild brood stock for the Conservation Stocking program, which sees trout cod released into waterways in the Murray Darling system within their natural range each year.

Production schedule

The production cycle for native fish depends on water temperatures in the ponds. The following is a general guide only to the schedule for native fish at Narrandera.

Table B13. Production schedule at the Narrandera Hatchery.

Month	Event
September	Trout cod are induced to spawn and ova is stripped and hatched.
October	Trout cod larvae are stocked into rearing ponds. Murray cod pond spawn and eggs are collected. Murray cod larvae are stocked into rearing ponds.
November	Murray cod finish spawning. Golden perch are induced to spawn and larvae stocked into rearing ponds.
December	Silver perch are induced to spawn and larvae stocked into rearing ponds. Trout cod fry are stocked into local waterways. Murray cod fry are stocked into impoundments.
January	Golden perch complete spawning. Trout cod fry are harvested and stocked into local waterways. Murray cod fry are harvested and stocked into local waterways.
February	Silver perch complete spawning.
March – May	Golden and silver perch fry stocked into impoundments.

Table B14. Fish produced for stocking from Narrandera in 2002.

Species	Number
Golden perch	1,012,000
Murray cod	311,000
Silver perch	451,000
Trout cod	17,000
Total	1,791,000

B1.3.3.4 Port Stephens Fisheries Centre

Location

The Port Stephens Fisheries Centre is located at Taylors Beach, 5km west of Salamander Bay in the inner estuarine section of Port Stephens. Additional outlying facilities include an abalone hatchery located at Tomaree Headland at the mouth of Port Stephens, and a field nursery for rearing juvenile oysters located at Wanda Head (recently decommissioned). Both of these sites lie in the outer high-salinity section of Port Stephens.

History

In 1970, the mining company VAM Limited donated the current site of the Port Stephens Fisheries Centre to the NSW Government to build an aquaculture research facility to develop prawn-farming techniques. The facility was originally called the Brackish Water Fish Culture Research Station (BWFCRS), then the Port Stephens Research Centre and is now the Port Stephens Fisheries Centre (since 2001). It is a large regional office and headquarters for the Aquaculture Division, which carries out research into the culture of marine molluscs and finfish, and provides policy and management direction for the aquaculture industry.

In 1971, research into the feasibility of farming greasy back prawns commenced at the BWFCRS. Research was also carried out on the black tiger prawn, which became the basis of the industry now established on the banks of the Clarence and Richmond rivers in northern NSW.

The 1970s, also saw the commencement of research into the breeding and larval culture of Sydney rock oysters and Pacific oysters. Techniques for breeding and growing out single-seed oysters were developed and transferred to industry.

In the late 1970s, research to develop technology for breeding native Australian bass for restocking commenced. The program was developed to prevent people stocking Murray cod and other species outside their natural range, as the success of the conservation-breeding program at Narrandera had prompted people in the northern part of the State to ask for native species to be stocked into farm dams and streams in the eastern drainage. This was the initial driver for stocking dams with species such as golden perch and silver perch, which are both western drainage species. Bass are bred using the artificial hormone-induced spawning techniques developed at Narrandera.

Staff

Table B15. Hatchery managers at the Port Stephens Fisheries Centre.

Year	Manager (Scientist-in-charge)
1995 - current	Stewart Fielder
1986	Stephen Battaglene
Before 1985	Baughan Wisely
1983	Peter Selosse
Before 1983	Eric Van der Wal

Facilities

Port Stephens Fisheries Centre is equipped with:

- a mollusc hatchery with four 20,000L rearing facilities plus many 1,000L tanks
- an algal unit capable of producing 20 000L of algal culture per week (usually from about six different species)
- an abalone hatchery capable of routinely producing up to 500 000 abalone per year
- a fish hatchery capable of producing approximately 1 million fingerlings per year of three species
- 10 above ground, plastic-lined ponds all with aeration and drainage sumps, and 2 covered with plastic hot houses to raise winter water temperatures

- a plastic covered hothouse that houses two demonstration re-circulation units (both with two 20 000L tanks, drum filters and biological filters), and another 12 X 10 000L tanks used for nutrition experiments
- experimental laboratories for nutrition research, fish larval rearing and growth experiments with crustaceans and fish, and
- analytical laboratories, workshop facilities, boat shed, bunkhouse and administration buildings.

Operations

The Australian bass is bred at the Port Stephens Fisheries Centre for stocking into impoundments on the eastern drainage of the Great Dividing Range. Each year, approximately 12 pair of wild brood fish are netted out of the Clarence, Hunter and Shoalhaven Rivers (broodstock collection zones) and transported to the Port Stephens Fisheries Centre. The female bass are induced to spawn using hormones and release up to half-a-million microscopic eggs that are fertilised by male fish. The eggs are removed into separate grow-out tanks full of 'green water' containing algae cultures and 36 hours later hatch into larvae and start to feed. The bass take three months to reach 25mm in length, at which point they are released into dams and lakes. The broodstock are released back into the wild, although breeding facilities are being constructed at Port Stephens to accommodate broodstock for long-term access.

Australian bass breeding commenced at Port Stephens in the late 1970s, and reliable hatchery techniques were developed to pass onto the commercial sector. Bass breeding at Port Stephens continues today principally for stock enhancement purposes, with 300,000 fish produced annually for stocking into rivers and impoundments along the eastern drainage, although only 96,000 were produced in 2002 due to low demand. Australian bass production and stocking data from PSFC from 1980 is set out in the appendices to this section.

B1.3.3.5 The Grafton Aquaculture Centre

Location

The Grafton Aquaculture Centre (GAC) is located on the Grafton Agricultural Research and Advisory Station, 3km east of the city of Grafton in the northern rivers region of NSW.

History

The Grafton Aquaculture Centre, then known as the Eastern Freshwater Fish Research Hatchery, was constructed under a Commonwealth Government Community Employment Program in 1984/85 to breed the endangered eastern cod. The centre was modelled on the Narrandera Fisheries Research Station where techniques for large-scale production of Murray cod, silver perch and golden perch had been developed.

The facility was completed in 1986 and broodstock collection and experimental trials commenced in 1986/87. In 1988 and 1989, more than 30,000 eastern cod were stocked in areas of its former range. In 1990, the Conservation Stocking program for eastern cod ceased and the facility was turned over to research and development for the commercial aquaculture of silver perch. Eastern cod continues to be stocked into rivers under a NSW Fisheries' funded Conservation Stocking program using a private hatchery to supply stock.

Staff

Dr Stuart Rowland, Scientist in Charge, 1985 – present

Facilities

The infrastructure established for the Eastern Freshwater Fish Research Hatchery has been significantly improved from 1990, when the facility became the Grafton Aquaculture Centre. It currently consists of 19 earthen ponds, two reservoirs, an effluent/settlement dam, a hatchery/ office/ laboratory complex, large workshop/storage shed and associated equipment such as aerators, tractors and other vehicles. The main water supply is the Clarence River and all effluent water is stored, settled and either re-used for fish culture or for irrigation by NSW Agriculture.

Operations

In 1990 the Grafton Aquaculture Centre implemented a large-scale silver perch research program. The species had been identified as a warm-water finfish with high biological potential for commercial aquaculture, and the capacity to form a large industry (>10,000 tonnes p/yr) based on high-volume and low-cost production.

Silver perch has a number of biological characteristics that make it highly suited to intensive culture. These include its ability to be raised in high densities, general hardiness and high survival (>90%) in a hatchery environment, rapid and uniform growth, tolerance of relatively poor water quality, willingness to accept artificial feeds, non-cannibalistic nature, high meat recovery (40%), excellent eating qualities, and ability to utilise a number of natural food sources (omnivorous). Silver perch are also a gregarious species and will readily school.

Between 1990 and 1994, research focussed on fish husbandry, pond management, water quality and disease. Once farming techniques were established, research to develop practical, low-cost diets and feeding strategies was undertaken. In 2000, the research focus shifted to evaluation of the genetic strains most suited to commercial production.

Most of the research into silver perch production has focused on pond-based culture, although some research into cage culture and intensive tank culture in now being conducted at Grafton.

The Grafton Aquaculture Centre breeds approximately half a million silver perch each year for research purposes, with 509,600 produced in 2002. Excess fish are released into impoundments in the western drainage for Recreation Stocking.

Production schedule

Table B16. Production schedule at the Grafton Aquaculture Centre.

Month	Event
October - November	Recapture broodfish from ponds and inject with hormone (HCG). Spawning and incubation of eggs. Prepare and stock larval rearing ponds. Quarantine broodfish and restock into ponds.
December	Monitor and manage larval rearing ponds (fertilise, test water quality and check for disease). Harvest fry from the ponds and quarantine.
January - March	Fry stocked into ponds for research. Excess fry stocked into western impoundments.

B1.3.3.6 Government hatchery stocking programs

Table B17. Outline of the typical annual government hatchery stocking programs

Hatchery	Species	Purpose	Stocking period	Locations
Narrandera Fisheries Centre	trout cod	Conservation	Early Dec	Upper Murray, Murrumbidgee and Macquarie rivers.
	Murray cod	Conservation / stock enhancement	Dec - Jan	Impoundments and small dams west of the Dividing Range.
	golden perch	Conservation / stock enhancement	Late Dec - Feb	Impoundments & small dams west of dividing range & impoundments in Hunter catchment.
	silver perch	Conservation / stock enhancement	Feb - April	Impoundments and small dams west of dividing range and impoundments in the Hunter catchment.
Gaden Trout Hatchery	Atlantic salmon	Stock enhancement	Oct/Nov - April	Lake Jindabyne, Burrinjuck Dam
	brook trout	Stock enhancement	Nov – April (fry, fingerlings & excess broodstock)	Lake Jindabyne, Pinch and Jacobs Rivers.
	rainbow trout	Stock enhancement	Dec (fry) Mar- April (fingerlings)	Snowy Mountains streams, Lakes Eucumbene, Jindabyne and Oberon, Pejar Dam and Googong Dam.
	brown trout	Stock enhancement	Dec (fry)	Snowy Mountains' streams.
Dutton Trout Hatchery	rainbow trout & brown trout	Stock enhancement	Aug – Oct (fry)	Streams in New England, Orange, Bathurst and Goulburn areas.
Port Stephens Fisheries Centre	Australian bass	Stock enhancement	Sep - Oct	Impoundments and small dams east of the Dividing Range.
Grafton Aquaculture Centre	silver perch	Conservation / stock enhancement	Dec - April	Impoundments and small dams west of dividing range and impoundments in the Hunter catchment.

B1.3.4 Private hatcheries

B1.3.4.1 Licensing of private hatcheries

Private hatcheries, as with other forms of aquaculture in NSW, are managed by NSW Fisheries under Part 6 (Aquaculture Management) of the *Fisheries Management Act 1994.* This legislation sets out classes of aquaculture permits and these are complemented by permit requirements and other regulatory instruments for the management of the aquaculture industry.

The following classes of aquaculture permits are prescribed for the purposes of section 144 (2) of the *Act*.

Class A permit authorising extensive aquaculture on public water land,

Class B permit authorising intensive aquaculture on public water land,

Class C permit authorising extensive aquaculture to be undertaken otherwise than on public water land,

Class D permit authorising intensive aquaculture to be undertaken otherwise than on public water land,

Class E permit authorising extensive freshwater aquaculture to be undertaken at 2 or more privately owned locations otherwise than on public water land,

Class F permit authorising a person to operate a fish pond, tank or other structure with a view to charging members of the public for the right to fish in the pond, tank or structure,

Class G permit authorising experimental aquaculture to be undertaken,

Class H permit authorising a fish hatchery to be operated,

Class I permit authorising aquaculture to be undertaken for a charitable or non-profit making purpose.

Note: Intensive aquaculture involves nutrient input to feed the stock whereas extensive aquaculture has no nutrient input such as in yabby culture in ponds where the stock feed on naturally available food sources. Some hatcheries may also hold a class F (fish-out) permit allowing them to charge the public to come and fish on their property.

Several unlicensed hatcheries are operated by acclimatisation societies or fishing clubs and they produce salmonid stocks for smaller scale trout stockings. The unlicensed hatcheries are not required to obtain an aquaculture permit, as the fish they produce are not cultivated with a view to sale. This sector is the most unquantifiable and unregulated group engaged in the activity.

Fish liberation events in natural waters using stock from all hatcheries are subject to the provisions of Part 7, (Protection of Aquatic Habitats), Division 7, section 216 of the FM Act (Releasing live fish into waters prohibited). These permits are assessed and issued by the Scientific Research and Miscellaneous Permits Administration Branch at the Port Stephens Fisheries Centre.

A number of private hatcheries are engaged by NSW Fisheries to produce stock for the Dollar-for-Dollar Native Fish Stocking Program and one other hatchery in the north of the State is contracted to produce stock for the Eastern Cod Recovery Plan. The use of private hatcheries for these programs is supported by NSW Fisheries as a way to increase fish production to provide better recreational fishing and stimulate regional economies.

B1.3.4.2 Stocking programs involving private hatcheries

The Dollar-for-Dollar Native Fish Stocking Program

In 1998, the Recreational Freshwater Licence Expenditure Committee (RFLEC) recommended that funds be allocated from the Recreational Fishing (Freshwater) Trust Fund to support the efforts of local stocking groups in the stocking of high priority native recreational species within NSW waterways. In response to this request, NSW Fisheries has developed the Dollar-for-Dollar Native Fish Stocking Program, which involves matching funding for those organisations, such as angling clubs and local councils that are raising money to purchase fish from Private Hatcheries to stock into public waters.

The program has several aims that are designed to:

- increase the stocking of high priority native recreational species
- support the efforts of local stocking groups
- increase the production and sales from private hatcheries in NSW to boost local business and regional economies, and

- enhance recreational freshwater fishing opportunities.

Dollar-for-Dollar funding is available for Murray cod and golden perch for western drainage stockings and Australian bass for eastern drainage stockings.

The Eastern Cod Recovery Plan

The recovery plan is supported by the stocking of eastern cod back into its natural range to help expand the size and range of the existing population. Only one private hatchery, Booma Fisheries at Bostobrick near Dorrigo, is permitted to produce this species on behalf of NSW Fisheries and it is the first such operation to be licensed to produce a threatened species for Conservation Stocking in NSW (see Private Hatchery Operators).

Salmonid stocking

Periodically, NSW Fisheries has permitted the use of private hatcheries to produce trout to supplement the salmonid stocking program. Details of such occurrences can be found in the appendices to this section.

B1.3.4.3 Private hatchery operators

The following tables describe the private hatchery operators primarily engaged in the activity of fish stocking. One-off contributors to stocking are provided in Appendix B1. WSPA means Water Surface Production Area – the area of water under cultivation excluding evaporation/effluent ponds.

Table B18 (a). Private hatcheries – northern.

Name	Booma Hyland Aquaculture Pty Limited (formerly Booma Fisheries Pty Ltd)
Operator	A & M Gilbert Pty Ltd
Location	Bostobrick, NSW
Permit number	F92/1862
WSPA	6.200 ha
Permit Class	Class D (Intensive), Class H (Hatchery), Class F (fish-out)
Species produced	Eastern cod, Australian bass, golden perch and silver perch
Program	Eastern Cod Recovery Plan (production of stock)
History	This hatchery commenced hatchery production in July 1993. A Class G Experimental permit (AP5422) was granted to F92/1862 on 3/7/97. Class D & H permit amended to include eastern cod to be farmed at this site on 07/03/02. Business rationalised and name changed to Booma Hyland Aquaculture Pty Limited on 12/11/02.

Name	Glen Searle Aquaculture
Operator	Glen Searle
Location	Palmers Island, NSW
Permit number	F86/1457
WSPA	6.620 ha
Permit Class	Class C (extensive), Class D (Intensive), Class H (Hatchery)
Species produced	Australian bass, eel-tailed catfish, silver perch, golden perch, mulloway, sand whiting, snapper, estuary perch
Program	Dollar-for-Dollar Native Fish Stocking Program
History	This hatchery commenced fish production in 1989

Table B18a cont.

Name	R H Mepham
Operator	R H Mepham
Location	Elsmore, NSW
Permit number	F84/197
WSPA	2.000 ha
Permit Class	Class D (Intensive), Class H (Hatchery),
Species produced	Murray cod, golden perch, silver perch, eel-tailed catfish
Program	Dollar-for-Dollar Native Fish Stocking Program
History	Mr Mepham was granted a permit for experimental fish breeding on 18.1.1972. Hatchery commenced production in January 1974.

Name	Gwydir Fisheries Pty Ltd
Operator	Ron Randall
Location	Invirkip (via Inverell)
Permit number	F93/571
WSPA	3.000 ha
Permit Class	Class D (Intensive), Class H (Hatchery), Class F (fish-out)
Species produced	Murray Cod, Golden Perch and Silver Perch
Program	Dollar-for-Dollar Native Fish Stocking Program
History	This hatchery commenced hatchery production in December 1994

Name	Bingara Anglers Club
Operator	Christina Riley
Location	Bingara, NSW
Permit number	F81/678
WSPA	0.500 ha
Permit Class	Class D (Intensive), Class H (Hatchery)
Species produced	Murray cod, golden perch and silver perch
Program	Dollar-for-Dollar Native Fish Stocking Program (Northern)
History	This hatchery commenced production in February 1982.

Name	P & J Orman
Operator	P & J Orman
Location	Narrabri, NSW
Permit number	F92/2035
WSPA	1.700
Permit Class	Class D (Intensive), Class H (Hatchery)
Species produced	Murray cod, silver perch, golden perch, eel-tailed catfish
Program	Dollar-for-Dollar Native Fish Stocking Program
History	This hatchery commenced production in 1992.

Table B18 (b). Private hatcheries – central.

Name	Crayhaven Aquaculture Industries
Operator	R B McCormack
Location	Karuah, NSW
Permit number	F84/1041
WSPA	20.1 ha
Permit Class	Class C (extensive), Class D (Intensive), Class H (Hatchery)
Species produced	Silver perch, Australian bass, eel-tailed catfish, golden perch, Pacific blue eye, cod, mulloway, brine shrimp, yabby, long-finned eel, short-finned eel, freshwater prawn, mussels, redclaw, freshwater shrimp, strong crayfish, freshwater shrimp, mullet, bullrout, climbing galaxias, common jollytail, dwarf galaxias, striped gudgeon, Mulgoa gudgeon, firetail gudgeon, big-headed gudgeon, eastern king prawn, brown tiger prawn, greasyback prawn, school prawn, rainbow trout
Program	Dollar-for-Dollar Native Fish Stocking Program (Central)
History	This hatchery commenced production in 1996.

Name	O'Donohue Filter Sand & Gravel P/L
Operator	Anthony O'Donohue
Location	Millers Forest, NSW
Permit number	A97/19
WSPA	0.4000 ha
Permit Class	Class D (Intensive), Class H (Hatchery)
Species produced	Aust Bass, Mulloway, Snapper
Program	Dollar-for-Dollar Native Fish Stocking Program
History	This hatchery commenced production in June 1999. A97-19 was registered to Mr O'Donohue on 12 April 1999 in order to allow cultivation of marine finfish under the authority of class D permit AP5487. A class H permit issued on 25/6/99.

Name	Cascade hatchery.
Operator	Lance Parker
Location	Cascade Hillston, NSW
Permit number	F85/713
WSPA	1.600 ha
Permit Class	Class D (Intensive), Class H (Hatchery)
Species produced	Murray cod, golden perch and silver perch, eel-tailed catfish
Program	Dollar-for-Dollar Native Fish Stocking Program
History	This hatchery commenced hatchery production in August 1974

Table B18 (c). Private hatcheries – southern.

Name	Lachlan Valley Fisheries
Operator	Chris Lawson
Location	Condobolin
Permit number	A96-16, AP5549 and AP5550
Permit Class	Class D (Intensive), Class H (Hatchery)
Species produced	Murray cod, silver perch, golden perch, eel-tailed catfish
Program	Dollar-for-Dollar Native Fish Stocking Program
History	This hatchery commenced production in December 1980.. Original permit holders operating this farm were Lishmyn Pty Ltd, Site sold to Aqua Culture Holdings Australia and new permits issued to farm the site on 24/12/99. Addition of Murray cod to AP5549 and AP5550 on 7/6/2000.

Table B18c cont.

Name	Uruaha Fisheries
Operator	Bruce Malcolm
Location	Grong Grong, NSW
Permit number	F85/1490 (76/1954)
WSPA	15.000 ha
Permit Class	Class D (Intensive), Class H (Hatchery)
Species produced	Murray cod, silver perch, golden perch, eel-tailed catfish
Program	Dollar-for-Dollar Native Fish Stocking Program
History	This hatchery commenced production in July 1978

Name	Narooma Freshwater Aquaculture Pty Ltd
Operator	Bruce Lawson
Location	Narooma, NSW
Permit number	A99/43
WSPA	1.9000 ha
Permit Class	Class D (Intensive), Class H (Hatchery), Class F (fish-out)
Species produced	Silver perch, golden perch, Australian bass
Program	Dollar-for-Dollar Native Fish Stocking Program
History	This hatchery commenced production in January 2000

Name	Murray Darling Fisheries Pty Ltd
Operator	Noel Penfold
Location	Gumly Gumly, NSW
Permit number	A99/10
WSPA	3.600 ha
Permit Class	Class D (Intensive), Class H (Hatchery)
Species produced	Murray cod, silver perch, golden perch, eel-tailed catfish
Program	Dollar-for-Dollar Native Fish Stocking Program
History	This hatchery commenced production in April 99

Name	Murray Cod Hatcheries
Operator	Greg Semple
Location	Gumly Gumly, NSW
Permit number	F85/1473 (77/609)
WSPA	5.000 ha
Permit Class	Class D (Intensive), Class H (Hatchery), Class F (fish-out)
Species produced	Murray cod, silver perch, golden perch, eel-tailed catfish
Program	Dollar-for-Dollar Native Fish Stocking Program
History	This hatchery commenced production in circa 1985. F85/1473 was "transferred" from Mr Noel Penfold (D925188, AP5237 AP5235 AP5236) to Mr Greg Semple (D925327, AP5425, AP5426 AP5427) on 7/8/1997.

Table B18c cont.

Name	Shoestring Fisheries
Operator	Peter Moore
Location	Hopefield, NSW
Permit number	A9810
WSPA	0.6750 ha
Permit Class	Class D (Intensive), Class H (Hatchery)
Species produced	Silver Perch, golden perch, eel-tailed catfish
Program	Dollar-for-Dollar Native Fish Stocking Program
History	This hatchery commenced production in September 2000

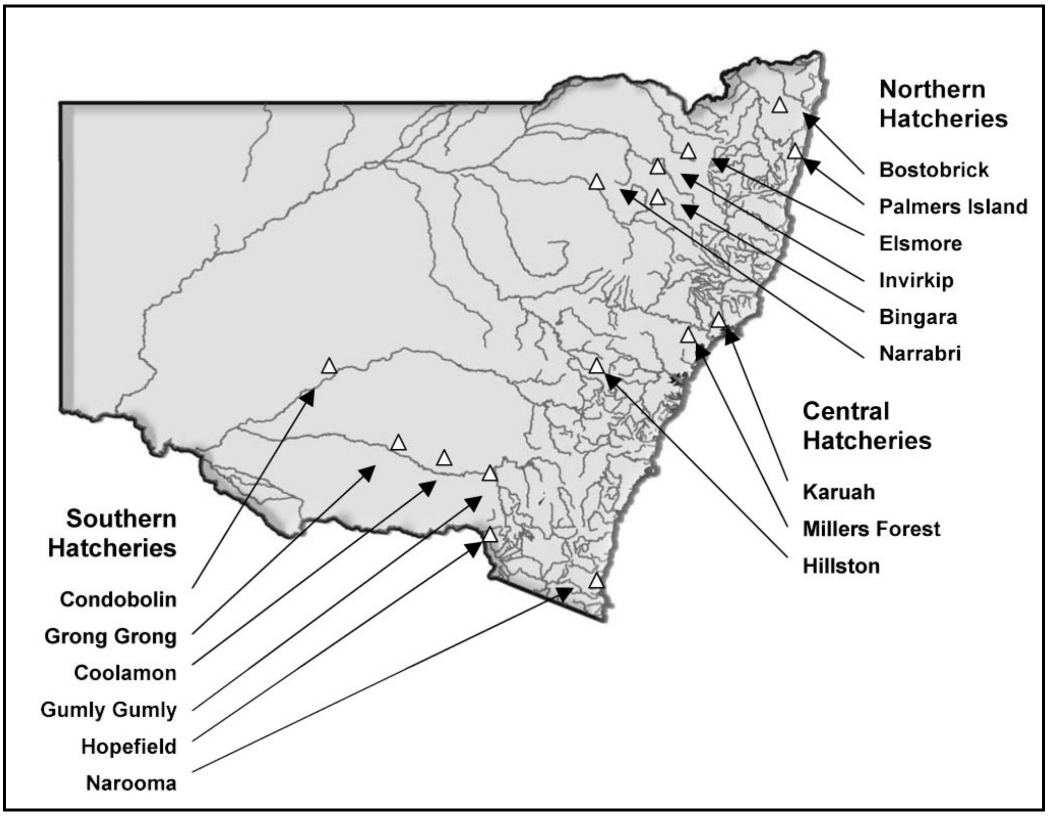


Figure B15. Map showing locations of private hatcheries engaged in the Dollar-for-Dollar program.

B1.3.4.4 Private hatchery production

Table B19. Private hatchery production 1998 to 2002.

Species	Ova	Larvae	Fry	Fingerling	Dollar-for-Dollar program 2002
Murray cod	160,900	350,000	1,756,380	3,050,467	154,449
Golden perch	3,500,000	812,000	14,851,200	7,619,717	601,897
Australian bass	20,000	1,500	112,000	617,200	183,500
Eastern cod				406,060	
Total	14,705,455	3,159,110	27,647,986	27,279,037	939,846

Note: Due to the provisions of privacy legislation, only a collective total may be given for private hatcheries production. There are no figures available to indicate whether fish were produced for aquaculture or stocking.

B1.4 Policies, management plans and administration

NSW Fisheries and its organisational predecessors have been the primary agencies for the management and further development of fish stocking in New South Wales. Due to increasing emphasis on environmental factors over the years (including policy development and implementation), management of the current activity now involves several departmental divisions, namely the Aquaculture and Sustainable Fisheries Division (incorporating the former Office of Conservation) and the Fisheries Services Division. Consultation on the direction of the activity is also undertaken with relevant stakeholders such as acclimatisation societies and the Recreational Fishing Freshwater Trust Expenditure Committee (RFFTEC) and more recently the Recreational Fishing Freshwater Management Planning Committee (RFFMPC - formerly the Freshwater Fishing Review Committee).

B1.4.1 Existing policies

The following tables briefly describe the provisions of existing policies, management plans and administrative arrangements and their objectives that direct the States current fish stocking activities.

Table B20. Policies affecting fish stocking in NSW.

Policies	Objectives
Aquaculture Industry Development Plans (AIDP)	Promote and guide the development of sustainable aquaculture practices (including those relating to stocking) within regional NSW Provides management arrangements for acquisition and maintenance of broodstock Provides management arrangements for the culture of high-security species
Aquaculture Policy - NSW Fisheries 1999	Promote the orderly management of aquaculture in NSW in accord with Part 6 of the *Fisheries Management Act 1994* Provide policy on the establishment and operation of hatcheries
Broodstock Collection Policy - NSW Fisheries 1999 -draft	Promote the appropriate management of brood fish resources in NSW in accord with section 37 of the *Fisheries Management Act 1994.*
Introduction and Translocation - NSW Fisheries Policy Paper– Feb 1994 (R94/1)	Protect aquatic biodiversity and aquaculture ventures by minimising potential undesirable ‘translocation’ of species Restrictions on species that may be stocked and where Restrictions on whom may undertake the activity
National Policy for the Translocation of Live Aquatic Organisms - Ministerial Council on Forestry, Fisheries and Aquaculture (1999)	Provide a national strategic approach to the management and assessment of the translocation of live aquatic organisms while respecting the sovereignty of each state Provide risk assessment guidelines for stocking open waters and aquaculture in closed and semi-closed systems
Trout Stocking Policy - NSW Fisheries (F85/1620)	Provide salmonids of a species, quality and quantity appropriate to the needs of waters in which they are stocked Provide salmonids for stocking of impoundments where inadequate natural reproduction and irregular environmental factors have had a significantly detrimental effect on the population To ensure the disease-free status of all salmonids stocked in NSW

Table B21. Management plans affecting fish stocking in NSW.

Management Plans or Programs	Objectives
Snowy Lakes Trout Strategy	Promote improved catch rates and sustainable use of trout resources in that area to ensure it remains a premier trout fishery by establishing appropriate stocking regimes Create cross-jurisdictional management arrangements between NSW Fisheries and the Snowy Hydro-Electric Authority for mutually beneficial outcomes Identify research requirements to gauge the success of the strategy A vision to provide high quality sustainable trout fisheries that provide positive angling experiences for all anglers
Fish Stocking Plan - Australian Capital Territory 2001 - 2005	Joint management arrangements between NSW Fisheries and Environment ACT for salmonid and native stocking in some ACT waters.
Threatened Species Recovery Plans - Part 7A of the *Fisheries Management Act 1994*	Support recovery of threatened species population in NSW Meet requirement of state and national legislation for the conservation of threatened aquatic species
Species Impact Statements	Determine the level of potential impact on aquatic ecological communities from an activity Present strategy options for mitigation of impacts including, use of or restrictions on stocking Provide ecological data for assessment of fishing activities (including stocking)
Habitat Protection Plans	Develop management strategies for particular habitats where the habitat is critical for the survival of a species or otherwise vital to maintain sustainable harvesting of populations of fish
Draft Native Fish Strategy for the Murray-Darling Basin 2002-2012	To rehabilitate native fish communities in the Murray-Darling Basin back to 60% of their estimated pre-European settlement levels within 50 years of implementation
Anglers Catch Research Program	Monitoring a wide range of freshwater fishing events throughout NSW Used to determine an angling catch rate at competitions in specific dams Provides a picture of the condition of fish stocks and their habitats

Table B22. Administrative procedures.

Administrative Procedures	Objectives
Aquaculture Administration Policy Manual NSW Fisheries - 1999	Outlines administrative procedures for - issuance of stocking permits - issuance of broodstock collection permits - issuance of aquaculture permits
Broodstock Collection Permits Section 37 of the *Fisheries Management Act 1994*	Authority to take fish for use in the hatchery industry for use as broodstock Provides for a fee by way of regulation (clause 61 of the *Fisheries Management (Aquaculture) Regulation 2002* (currently $161.00)
Fish Stocking Permits Section 216 of the *Fisheries Management Act 1994*	Authority for release of fish into NSW waters (other than farm dams or other private waters)
Fish Stocking database	To monitor the numbers of fish stocked in NSW including species, number, area, by whom, and when

B1.4.2 Management of stocking activities by NSW Fisheries

The following section describes the individual involvement of the relevant divisions of NSW Fisheries and how resources are orchestrated to manage the activity.

B1.4.2.1 Aquaculture and Sustainable Fisheries division

This division of NSW Fisheries provides basic services supporting the licensing of the activity. The Division is made up of several branches, each playing a role in the delivery of the service. The division also includes two important conservation branches that affect the management of the activity, the Threatened Species and Biodiversity Unit and Conservation Research Branch (formerly of the Office of Conservation).

Aquaculture Administration Section (AAS)

Based at Port Stephens Fisheries Centre, the AAS provides licensing arrangements for hatcheries and other related functions such as annual production reporting, accounting and record keeping systems as required under Part 6 (Aquaculture Management) of the Act.

The Scientific Research and Miscellaneous Permit Administration (SRMPA)

This service branch provides the main permit system for the activity. Based at Port Stephens Fisheries Centre the SRMPA deals with all stocking applications, assessments protocols, permit issuance under section 216 of the Act and maintains a central registry of stocking permits (including NSW Fisheries' own stocking permits).

The SRMPA is also responsible for the assessment and issuance of the following permits under the *Fisheries Management Act 1994*:

- scientific research permits issued under section 37
- broodstock collection permits under section 37
- aquarium collection permits under section 37
- possession and sale of noxious fish permits (generally Pacific oysters) under sections 210, 211
- fish importation permits under section 217

Aquaculture Management Branch

This branch provides aquaculture policy and planning designed to establish sustainable aquaculture practice in NSW. Policy that affects the activity includes the Class H (hatchery) aquaculture permit policy, established under the NSW Aquaculture Policy, setting hatchery standards (including disease and genetics), Broodstock Collection Policy, management of translocation issues and high-risk species.

Aquaculture Research Branch provides some of the stock produced for the activity from the Port Stephens Fisheries Centre (see Hatcheries), although several other functions of the Branch are used to support the management of the activity indirectly, such as hatchery technology for breeding native fish, development of stocking techniques, fish health research and veterinary services, aquaculture nutrition and technology transfer to industry. The Branch also convenes the Animal Care and Ethics Committee (ACEC), designed to ensure the humane treatment of fish held by NSW Fisheries for fisheries research programs.

The Threatened Species & Biodiversity Unit (TSBU)

The role of the TSBU is to develop and implement management arrangements and strategies such as species recovery plans for threatened species under Part 7A of the FM Act. As recovery plans often involve stocking techniques to meet conservation objectives, the unit has refined genetic management protocols for conservation stocking and has been instrumental in developing stocking policy to limit affects on biodiversity, threatened species, critical habitats and endangered communities.

Conservation Research Branch

This branch assists in the assessment of stocking proposals, their potential effects where any endangered species or communities are present in the area proposed for stocking, and is the department's principal environmental monitoring and research authority for waters in which stocking occurs. The Branch conducts surveys and scientific research (e.g. Bass Catch Program, NSW Rivers Survey, and pest species eradication and research), the results of which are used to help develop stocking policy and conservation measures.

B1.4.2.2 Fisheries Services division

The Fisheries Services division manages the Government Hatcheries that produce fish for NSW Fisheries' stocking programs (see Government Hatcheries). The division also provides a range of compliance and customer-related services as the first point of call for the activity (other than PSFC) and as information service providers through fisheries offices.

Field Services Branch

Fisheries officers undertake site assessments of aquaculture proposals to ensure that all new aquaculture developments comply with NSW Fisheries' Aquaculture Policy. Fisheries officers carry out compliance inspections of hatcheries, fish stocking events and recreational fishing areas where fish are stocked and specific regulations pertaining to those stocked fish.

Each stocking permit issued under section 216 of the Act is developed in consultation with the relevant district office of NSW Fisheries where the District Fisheries Officer is nominated as the Ministers delegate. The Officer has the power to discontinue or alter the event to minimise any potential impacts should the officer discover the stock is diseased or otherwise inappropriate.

Recreational Fisheries Branch

Recreational Fisheries Branch develop the general stocking policies under the activity determining where and when Recreation Stocking activities take place in NSW following consultation with relevant stakeholders. The Recreational Fishing Freshwater Trust Expenditure Committee (RFFTEC), formerly known as the Recreational Fishing Licence Expenditure Committee agree on expenditure priorities for the funds raised by the licence.

Several NSW Fisheries programs are supported by funds allocated by the committee, including the Dollar-for-Dollar Native Fish Stocking Program and conservation measures such as the NSW weir removal program, fishway assessment projects and community education initiatives, although most funds are expended on stocking programs to enhance recreational fishing opportunities. Research and monitoring of the current activity is primarily undertaken by this Division.

B1.4.3 Restrictions on species that can be stocked

Stocking policy in NSW defines the native species and salmonids species that can be used in the activity and where they may be stocked. These arrangements are designed to ensure that appropriate stockings are carried with regard to translocation and introduction principles. Specific populations of species in known genetic regions (areas that contain distinct or discrete populations) or where stocking of a certain species, even within its natural range, may cause undesirable effects on another species or ecological community is also managed under stocking policy.

Table B23. Permitted species and their approved stocking locations for native species.

Species	Eastern Drainage	Western Drainage	Areas within range where species is excluded from stocking
Australian bass	Yes	Impoundments and farm dams only	Excluded from critical habitat of eastern cod subject to recovery plan
Eel-tailed catfish	Yes	Yes	None
Eastern cod	Yes	No	None
Golden perch	Impoundments in the Hunter catchment and farm dams*	Yes (relevant strain only)	Excluded from critical habitat of trout cod subject to recovery plan
Macquarie perch	Yes (eastern strain only)	Yes (western strain only)	None
Murray cod	No	Yes	Excluded from critical habitat of trout cod subject to recovery plan
Silver perch	Impoundments in the Hunter catchment and farm dams*	Yes	Excluded from critical habitat of trout cod subject to recovery plan
Trout cod	No	Yes	None

Note: * denotes that farm dams must be above the 1-in-100 year flood range (NSW Fisheries Translocation Policy 1994).

Table B24. Stocking table showing permitted species and approved stocking locations for salmonid species.

Species	Eastern Drainage	Western Drainage	Areas where stocking is not permitted
Atlantic salmon	Yes	Yes	Some streams inhabited by threatened species
Brook trout	Yes	Yes	Some streams inhabited by threatened species
Brown trout	Yes	Yes	Some streams inhabited by threatened species (Lake Eucumbene and Tantangara Reserve reliant on natural recruitment)
Rainbow trout	Yes	Yes	Some streams inhabited by threatened species

B1.4.4 Restrictions on whom may undertake the activity

In NSW, there are no restrictions on any person or any class of persons whom may apply to undertake the activity. Stocking fish in NSW is subject to the provisions of section 216 of the *Fisheries Management Act 1994* (see below). Providing the proposal to stock meets the requirements of the stocking policy, environmental assessment and any relevant management plan in force, the permit is usually approved.

Excerpt from Fisheries Management Act 1994

216 Releasing live fish into waters prohibited

(1) A person must not release into any waters any live fish except under the authority of a permit issued by the Minister or an aquaculture permit.

Maximum penalty: In the case of a corporation, 100 penalty units or, in any other case, 50 penalty units.

(2) This section does not apply to the immediate return of fish to waters from which they were taken.

(3) This section applies only to the release of fish into the sea, into a river, creek or other naturally flowing stream of water or into a lake.

(4) In this section, release a fish, includes depositing them or permitting them to escape.

Note: No permit is required in NSW to stock private waters (i.e. farm dams).

B1.4.5 Controls on stocking levels

NSW Fisheries relies on historically successful levels of stocking by Government and private hatcheries, anticipated levels of fishing effort in the fishery and reported returns to anglers to determine stocking rates. Due to the enormity and amount of systems stocked in NSW, there has not been any definitive research to determine the actual carrying capacity of the systems (for stocked fish) and, therefore, the scientifically recommended stocking rate of each body of water. Even if these studies were undertaken, they would take years of expensive research and may result in only a static representation of otherwise dynamic systems that vary their carrying capacity in response to climatic (e.g. drought, flood) and other forces.

B1.4.5.1 Australian bass

The amount of Australian bass produced for stocking at the Port Stephens Fisheries Centre is determined by the capacity of the hatchery (approximately 300,000 bass fry max) and this number can vary considerably. There are also several private hatcheries that produce Australian bass for release into rivers through the Dollar-for-Dollar scheme, and production is largely driven by demand.

Once the amount of stock available is known, the Senior Manager (Inland Fisheries) considers applications for fry from stocking groups and makes an assessment of each nominated waterway. Items taken into consideration when determining an allocation of stock include the manager’s experience regarding the size of dam and the capacity of the waterway, the expected participation of recreational angling in the area and the frequency of stocking for the waterway. Stock is divided into equitable portions for distribution to the nominated waterways.

B1.4.5.2 Golden perch, silver perch and Murray cod

The NFC produces fish predominantly to stock impoundments across the State. Very rarely are fish from the NFC stocked into rivers, although several experimental trials have been undertaken to gauge the success of stocking rivers. Numerous private hatcheries produce the majority of native fish for release into rivers through the Dollar-for-Dollar scheme, as well as into impoundments when necessary to meet demand.

NSW Fisheries managers determine stocking allocations of native fry to be stocked into dams for recreational purposes by assessing a number of factors including the size of the dam, how well each available species goes in a particular dam, and how much stock is available for release (numbers can vary considerably season to season). The maximum number of stock released into any dam based on a theoretical recommended rate (USA data) of around 100/ha. Allocations into rivers are determined by stocking requests, stock availability and the conditions of the waterways at the time of the request.

Other issues that affect the amount and distribution of stock include items such as whether sufficient travel funds are available (if funds are low, fish have been stocked close by). Availability and capacity of the transport vehicles can also affect numbers stocked from time to time. These factors and staff availability have limited a more even spread of fish to more remote locations.

Where dams are at low water levels, allocations are cut back accordingly. Dams that have proven successful in past stockings (such as Windamere Dam) often get more fish than dams that do poorly (such as Burrendong Dam). Sometimes certain species are not stocked at all (such as silver perch into Blowering Dam).

B1.4.5.3 Silver perch from Grafton Aquaculture Centre

Silver perch are produced at the Grafton Aquaculture Centre at a rate of approximately half a million silver perch each year for research purposes. Excess fish are released into impoundments in the western drainage (Chaffy, Copeton, Keepit and Pindari dams). This is generally seen as an opportunistic stocking regime and numbers ranging from 1,000 fingerlings to 150,000 can be stocked into these waters. Amounts available for stocking vary considerably each season and an allocation process similar to the NFC is undertaken.

B1.4.5.4 Trout cod and eastern cod

Unlike the other native species that are produced for recreation stocking purposes, trout cod and eastern cod are produced for the Conservation Stocking program. Stocking levels for these species are determined by a number of factors including recovery programs, availability of broodstock and survival of fry. Trout cod are produced at the NFC, and are released into waterways within their historical distribution. Eastern cod are produced by a private hatchery, Booma Hyland Aquaculture Pty Ltd, according to NSW Fisheries protocols. They are also released into rivers and impoundments within their historical distribution.

B1.4.5.5 Salmonids

The current rates of stocking salmonids in large impoundments such as Lake Eucumbene has been long considered appropriate at around 300,000 fish over three years and this has worked well in the past. Smaller impoundments may receive only 20,000 to 30,000 fish per year to maintain acceptable catch rates.

B1.4.6 Monitoring and research to evaluate stocking programs

NSW Fisheries evaluates the effectiveness of stocking natives and salmonids primarily through the Assessment of Stocked Fish program, which is research-orientated, and the Anglers Catch Research Program, which is based on data collected at recreational fishing competitions. Mark-recapture methods have traditionally been used to investigate the effectiveness of stocking programs in impoundments, and some of the broad results from these studies are discussed in B1.4.6.4. Finclipping used to be the widely accepted practice, as it also allowed for *in situ* determination, but more recently, technological advances have allowed for non-harmful marking of otoliths (ear bones) of fish, which greatly improves survival rates of marked fish. These recent research techniques are described below, but as they are ongoing, no results are available. Conservation stocking programs are also monitored and research into the genetics of threatened species trout cod and eastern cod are continuing.

In addition to scientific monitoring and research to determine the effectiveness of stocking, NSW Fisheries contracted a consultant to provide a socio-economic analysis of the trout fishery in the Snowy Mountains region (Dominion 2001). The project ostensibly confirmed the importance of the recreational fishery in the Snowy economy, worth approximately $46.5M annually, and provided valuable information to fishers, fisheries managers and the Snowy community who are concerned with maintaining and increasing the value of the trout fishery and developing tourism opportunities. The project was also developed as a surveying template for examining the regional economic significance of recreational fishing activities in NSW.

B1.4.6.1 Assessment of Stocked Fish research program

Species included in the Assessment of Stocked Fish program include rainbow trout, Australian bass, golden perch and Murray cod. Initial research involved developing a method of marking fish at the size that they are released from the hatchery. This was to identify them at a later date and to distinguish stocked fish from wild spawning fish. Two methods were successful at marking hatchery fish. One method involved marking the otoliths (ear bone) of the fish by depressing the temperature of the water in which they swam for a fixed time and returning the water to a fixed higher temperature for several time cycles. The method was successful but time-consuming, and difficult to scale up to mark large numbers of fish in a hatchery environment. Details of the method have been published (van der Walt and Faragher, 2002). Another method involved determining a concentration and time period to mark the otolith with a chemical, alizarin complexone. The method involves immersing the fish in an appropriate concentration of the chemical for a set time. The method was successful in marking all three species tested. Several batches of golden perch, rainbow trout and Australian bass have been stocked in different waterways and monitoring has commenced. For both methods, subsequent sampling has to be destructive and can only be determined in a laboratory,

The work has been accepted for publication (van der Walt and Faragher 2003). This method adds a powerful tool to the management and tracking of stocked fish for specific research programs. It allows stocked fish to be identified and separated from wild stock in both native species and trout. Marking the fish in this way also enables batches of fish to be identified so that different stocking techniques can be assessed.

B1.4.6.2 Anglers Catch Research Program

The aim of the program is to monitor the status of freshwater fish populations using angler-generated data. Catch information is collected at organised freshwater angling events and competitions and recorded on catch cards by freshwater fishers during their fishing outings. Completed catch cards are returned to NSW Fisheries researchers for data analysis. These programs avoid destructive sampling and allow for interaction and feedback between fishers and researchers.

B1.4.6.3 Conservation stocking

Trout cod monitoring

An artificial breeding and stocking program was adopted as a species recovery strategy for the endangered trout cod (*Maccullochella macquariensis*). Hatchery-reared juvenile trout cod continue to be introduced into suitable habitat within their former range. Approximately 650,000 trout cod from Narrandera Fisheries Centre have been released into NSW waterways since 1986.

NSW Fisheries undertook monitoring of restocked trout cod populations between 1990 and 1993 at two sites in the upper Murrumbidgee and two sites in the Upper Murray Rivers (Faragher *et al*., 1993). Between 1993 and 1995, surveys at a number of stocking sites continued to assess survival of stocked fish. Between 1998 and 2000, 17 uniformly spaced sites within a 450km stretch of the Murrumbidgee River were monitored to assess dispersal from stocking locations. Aims of the various surveys were to assess survival and abundance of restocked populations, investigate dispersal of trout cod from stocking sites, to identify micro-habitat requirements at different life history stages, and to investigate the size-structure of populations. Larval fish capture techniques were first employed in 1994 to identify whether restocking had created self-sustaining populations of trout cod. Recently, larval fish sampling techniques have been refined and cod larvae (larval trout cod being indistinguishable form those of Murray cod) have been sampled from the Murrumbidgee River and mtDNA analysis used to positively identify the larvae. All cod larvae sampled from the Murrumbidgee population have been those of Murray cod, with no trout cod larvae sampled to date.

All trout cod stocked in NSW waters since 1993 have been chemically batch-marked using either strontium chloride, oxytetracycline or alizarin complexone. This enables identification of hatchery-reared fish as opposed to those bred naturally in the wild. The method of detection of hatchery batch marks is through otolith examination (described above). On-going investigations have been conducted into refining mark persistence and identification techniques, a common problem experienced in monitoring hatchery-released stock. Very high survival of hatchery-reared trout cod has been observed at a number of sites, although the lack of specific funds for monitoring has meant that such work has been done in an ad-hoc manner.

Obtaining suitable brood stock and seasonal variability affects the number of fingerlings produced each stocking season. However, NSW Fisheries has refined their hatchery practices, stocking 506 000 fish in the last seven years as compared to 143 000 trout cod stocked in the ten years of production from 1986-1995.

Originally, fish were stocked at low densities at a large number of sites. Since 1996, fewer sites have been stocked but at higher densities. Sites where survival of trout cod had not been detected within three years of the commencement of stocking were discontinued. Further, new sites were chosen to link up surviving stocked populations or extend their range into areas of their former distribution. Anecdotal angler reports indicate that stocked trout cod have dispersed along the river reaches from where they have been released, with some fish surviving to maturity. Survey data supports this information.

The sexual maturity and gonadal maturation of stocked fish has been observed during recent samples. As a result, detecting wild recruitment is now one of the highest priorities for the recovery program. A cessation of trout cod stocking in the upper Murray River (no stocking since 1997) and the middle Murrumbidgee River (no stocking since 2001) will allow assessment of natural recruitment in these populations.

Eastern cod monitoring

One of the key components of the species recovery plan for the endangered eastern cod (*Maccullochella ikei*) is a restocking program within its former range in the Clarence and Richmond River systems, with the aim of establishing at least two self-sustaining populations in each catchment. An initial hatchery production program began in the early 1980s, following the development of artificial rearing techniques by NSW Fisheries. Following their release, several sites have been monitored with the aim of providing information on the success of these preliminary stockings. To date, results have shown that stocked eastern cod had survived, though in relatively low abundance (Faragher *et al*., 1993; Faragher and Harris, 1994).

A subsequent restocking program was initiated in 1997. Fingerlings are currently produced by a commercial hatchery, Booma Fisheries, and are stocked into numerous locations with the assistance of the community-based group ‘Project Big Fish’. To date, approximately 300,000 fingerlings have been stocked at sites within the species historical distribution (but outside the range of extant remnant populations). Pollard and Wooden (2002) conducted field surveys with the aim of examining the distribution and relative abundance of sub-populations of eastern cod, examining both stocked and remnant populations. Field surveys conducted at previously stocked sites recorded low numbers of eastern cod at five of eleven sites surveyed. Prior to 2002, chemical batch marking of hatchery-reared eastern cod was not undertaken. As a result, it is not possible to determine whether these fish are remnant natural populations or had been restocked at some time in the past. Confirmed survival of stocked fish was evident in two impoundments. Reports of increased captures of eastern cod within remnant populations possibly reflects the introduction of the regulations prohibiting the taking of the species.

B1.4.6.4 Results from traditional monitoring programs

First formed in 1957, Lake Eucumbene was not stocked with trout until 1982. Prior to that, the Lake supported an excellent trout fishery based on stocks of brown and rainbow trout derived from fish in the dammed river system. Initially the catch was dominated (70-80%) by rainbow trout. This proportion was gradually reduced, so that by the mid-1970s, and early 1980s, the percentage of rainbow trout in the catch was around 30% of the catch. (Faragher1993). Initial high catches and growth rates are typical in new or enlarged impoundments and are followed by declines in catches and mean weight of fish. (Davies and Sloane, 1988, Stables *et al*., 1990, Tilzey, 1979).

In 1981, an estimated 300,000 yearling rainbow trout were stocked and the percentage of rainbow trout in the angler catch rose from 32% in 1981/82 to 80% in 1982/3. This single stocking instigated a cycle that maintained high rainbow trout numbers for the next ten years. Brown trout have never been stocked into Lake Eucumbene.

In a Lake Eucumbene study (1985-89), fin-clipped rainbow trout were stocked (105,700 over three years) and used for age validation data. These fish were also monitored in the spawning migration and showed that the stocked fish contributed to the spawning migration mainly in their third year. Very few fish were recaptured after their third year in this study (Faragher, 1992).

Annual rates of exploitation found in a tagging study in the Lake found that rainbow trout had an exploitation rate of 27%, whereas brown trout had an exploitation rate of 9%. An example of the significance of the findings in this study is that only 1% of the rainbows trout survived from 3 to 6 years old compared with 14% of the brown trout (Faragher and Gordon, 1994).

Lakes Eucumbene and Jindabyne in the Snowy Mountains are currently being stocked annually with 150,000 and 50,000 rainbow trout, respectively, and have been stocked in 2001 and 2002. Monitoring of these fish will continue using angler catch data and trapping of the spawning migrations.

B1.4.6.5 Potential problems with current monitoring and research programs

Assessment of Fish Stocking program

Since the development of the otolith marking technique, there have been very few problems associated with the monitoring for the Assessment of Fish Stocking program. Whilst it does not allow for anglers to make an *in situ* assessment of whether or not they have caught a stocked fish, and requires laboratory analysis, it is seen as the most cost-effective and reliable technique. Rather than mark every fish that is stocked into waterways, which would be cost-prohibitive, it is more desirable to mark particular batches of fish and to monitor their progress. Unfortunately, this method is likely to be only applicable to the confined environments of impoundments. As such, there is a need to develop appropriate techniques for monitoring the effectiveness of stocking into rivers beyond angler catch data obtained from competitions.

Conservation stocking

Monitoring of stocked eastern cod has reported significant problems with either the early genetic protocols or their implementation, resulting in the loss of genetic biodiversity. This is an unacceptable risk for an endangered species. The monitoring has highlighted the importance of undertaking pre-stocking assessments, which have not been done in the past for either conservation stocking or stocking of other natives into rivers. Pre-stocking assessments are an important tool in assessing the effectiveness of fish stocking programs as they provide a baseline against which effectiveness can be measured and also give insight into the effects of the stocked species on resident fish communities.

In an effort to maintain biodiversity (of which genetic diversity is an integral part), and avert the risk that may be posed to a species, stocking programs should be preceded by an assessment of the population genetics of the intended species. A population genetics study would ensure that genetic biodiversity is not lost as a result of the stocking program (i.e. appropriate sources of broodstock and appropriate stocking locations are identified).Baseline genetic studies have not begun in a formal manner for most native species (with the exception of Australian bass), but hundreds of samples have been collected as part of other sampling programs and could provide the basis for a comprehensive study of population genetics of western drainage species.

Record keeping of stocking activities needs to be accurate, ensuring that necessary information is available for monitoring programs or other research activities that may be conducted in stocked waters. Records are often treated as secret documents within hatcheries, preventing the dissemination of information about broodstock collection and the subsequent release of progeny. A coherent set of guidelines about management and administration are required, in addition to a centralised database that should be developed and maintained by NSW Fisheries. This should monitor all stocking events and hatcheries, not just those for conservation stocking.

Thorough assessment of the adopted recovery strategy needs to be made before commencing a stocking program for threatened species. Stringent scientific monitoring programs need to be established in conjunction with the commencement of threatened species stocking so that repeatable assessments can be conducted to assess the relative success of releases. Research is also required into the conditions and level of stocking required to establish a self-supporting population. This includes the number of years to stock, numbers of fish and number of sites for a given water body. The establishment of funding for monitoring stocked fish and research into improving success and the impacts of stocking should be part of threatened species stocking programs.

Receiving environment

One thing that it is clear from the review of existing NSW Fisheries monitoring and research programs done is that none have been conducted on the impacts of stocking on the receiving environment. This is more important for rivers than for impoundments, which are already highly modified environments, but as a minimum should include an assessment of fish movement post-stocking to determine the potential extent of impact upstream of impoundments. Investigations into the effectiveness of stocking need to assess the impacts of stocking on a community level, i.e. all species, not just those that are being stocked.

B1.4.7 Techniques to eradicate diseases in stocked and wild fish

To ensure stocks are reliably free of diseases that may be transmitted to wild stock, NSW Fisheries manages the issue through a number of active arrangements.

B1.4.7.1 Legislation

The *Fisheries Management Act 1994* sets out arrangements for the declaration of declared diseases and quarantine areas and places certain responsibility on all hatchery operators (aquaculture permit holders) to be diligent with regard to aquatic diseases, by setting out mandatory reporting requirements in the event of a suspected declared disease event. A declaration may be made under this legislation in respect of a disease (including a pest or parasite) that kills or causes illness in fish or marine vegetation (or a particular species of fish or marine vegetation) or that kills or causes illness in people who eat the infected fish or marine vegetation. A declaration may provide for different classes of declared diseases and may exclude specified provisions in respect of any class of those diseases.

If the Minister considers that a disease declaration is required urgently, the declaration may be made by the Minister by publishing notification of the declaration in a newspaper circulating generally in the State, or by radio or television broadcast. The Minister may declare any area specified in the order to be a quarantine area because of the presence or suspected presence of a declared disease. An area may be declared a quarantine area if it is subject to an aquaculture permit or if it is an area of water or in the immediate vicinity of an area of water.

An order declaring a quarantine area may prohibit the taking of fish or marine vegetation or specified fish or marine vegetation in or from the quarantine area. In the case of an area subject to an aquaculture permit, the holder may be required to take such action as is specified in the order or directed by a fisheries officer (including the destruction or treatment of fish or marine vegetation cultivated or located in the area).

The intentional or reckless communication of declared disease to live fish or marine vegetation is also an offence in NSW by virtue of section 184 of the Act. A person must not intentionally or recklessly communicate a declared disease to any other live fish or marine vegetation.

The sale of diseased fish or marine vegetation prohibited by virtue of section 185 of the Act. A person must not sell any fish or marine vegetation (whether it is live or dead) if the person knows or has reason to suspect that it is infected with a declared disease. Further, by virtue of section 186 of the Act, a person must not deposit in any waters any fish or marine vegetation (whether live or dead) if the person knows or has reason to suspect that it is infected with a declared disease.

The *Fisheries Management (Aquaculture) Regulation 2002* may make provision for or with respect to eliminating or preventing the spread of declared diseases, including the destruction or treatment of fish or marine vegetation that is infected or suspected of being infected with a declared disease, the examination, testing and treatment of fish or marine vegetation in a quarantine area, and the notification to the Minister or a fisheries officer of the infection or suspected infection with a declared disease of fish or marine vegetation in an area subject to an aquaculture permit, pet shop, aquarium or other place.

These provisions are made so as to ensure that diseases are effectively identified quickly and appropriate action is taken by the hatchery operator to stop any such diseases from entering other establishments or open systems.

Declared diseases prescribed in the Fisheries Management (Aquaculture) Regulation 2002

Table B25. Declared diseases (aquatic) in NSW.

In relation to finfish: class A diseases epizootic haematopoietic necrosis infectious haematopoietic necrosis viral haemorrhagic septicaemia bacterial kidney disease epizootic ulcerative syndrome infectious pancreatic necrosis *Aeromonas salmonicida* infection viral nervous necrosis yersiniosis whirling disease	**In relation to molluscs: class A diseases** bonamiosis haplosporidiosis marteiliosis mikrocytosis perkinsosis iridoviroses
In relation to crustaceans: class A diseases baculoviral midgut gland necrosis crayfish plague infectious hypodermal and haematopoietic necrosis baculovirosis infection yellowhead disease white-tail disease	**The following are declared to be class B organisms:** Northern Pacific sea-star toxic dinoflagellates

Notification of diseases

If the owner or occupier of any place to which these provisions apply becomes aware that any stock may be infected with a class A or class B disease, the owner or occupier must notify a fisheries officer as soon as practicable of the infection or suspected infection.

These provisions apply to an area to which an aquaculture permit relates (i.e. hatchery), a pet shop, an aquarium kept for commercial purposes, a research establishment (including NSW Government Hatcheries), or a farm containing a dam or other impounded waters.

B1.4.7.2 Policy

The potential transmission of diseases is also managed through policies relating to translocation of live aquatic organisms and aquaculture management. The Introduction and Translocation Policy (NSW Fisheries 1994) is designed, among other translocation issues, to minimise the communication of disease while the NSW Fisheries' Aquaculture Standard Conditions sets out restrictions on aquaculture facility design and other provisions to avoid escape of diseases from aquaculture operations.

Excerpt from NSW Fisheries' Aquaculture Standard Conditions

Disease

21. The permit holder shall notify the Department within 24 hours of the discovery of any Declared Disease unusual disease or any significant event associated with the welfare of the fish on the premises' (eg unexplained or significant fish mortalities, >5% of fish stock loss in a week).

22. Where any Declared Disease or other disease exists, or is reasonably suspected of existing on the farm premises covered by a permit, a permit holder shall carry out any directions so ordered by the Director-General of Fisheries for the treatment or destruction of fish including quarantine of the premises. Any such order shall remain in effect until revoked by the Director-General of Fisheries in writing.

23. The permit holder must not sell, give away or release to waterways, any fish if it is known or suspected to be infected with a Declared Disease. The holder shall take precautions specified in writing by the Director-General of Fisheries to prevent the escape of fish or disease from the farm.

24. All outlets must be screened to prevent the escape of fish. A screen no greater than 1mm must be used for eggs and fry, a screen no greater than 5mm for fingerlings, and a screen no greater than 15mm for post-fingerling fish.

24a. No effluent is permitted to reach any waterway except for farms licensed by the EPA to discharge effluent into waterways.

B1.4.7.3 Strategic response to disease outbreak

AQUAVETPLAN, a Commonwealth Government initiative, has been established to address national preparedness and response capabilities in the event of an outbreak of an aquatic animal disease. AQUAVETPLAN, developed under the national AQUAPLAN (Australia's National Strategic Plan for Aquatic Animal Health 1998-2003), consists of a series of operations manuals that are being progressively developed in-line with priorities set out to respond to disease incursions in aquaculture and fisheries in conjunction with state and commonwealth agencies and relative industries.

NSW Fisheries negotiated with NSW Agriculture with a view to becoming a participating organisation under the Agricultural Services Functional Area Supporting Plan, which is part of the NSW State Disaster Plan. Under this arrangement, NSW Fisheries gained access to the pool of experience and resources available within the State for deployment in an animal emergency. NSW Fisheries and NSW Agriculture has engaged in preliminary training exercises during 2002 (ongoing in 2003), dealing with implementation of the Agricultural Services Functional Area Supporting Plan, focussing on aquatic animal disease emergencies.

Disease identification and response instructions are managed by the NSW Fisheries' Aquatic Animal Health Unit (Wollongbar, NSW) and this unit is the first reference point following any disease notification or other disease incidence.

B1.4.7.4 Operations

All Government hatcheries are checked regularly for diseases to:

- minimise the risk of introducing major pathogens to the hatcheries
- minimise the risk of disseminating major pathogens via translocated fish, and
- maintain the health of fish at the hatcheries.

Native fish

Stocks produced at the three native fish Government hatcheries (Grafton, Narrandera, and Port Stephens) undergo regular disease testing procedures. Stock is regularly examined for signs of clinical disease and affected fish are submitted for laboratory examination. Fish are submitted for examination whenever morbidity or mortality rates rise significantly above background levels.

Native fish consigned for stocking are purged for 24 to 48 hours and placed in fresh water (usually bore water) that has been filtered to one micron to remove impurities and parasites. Stock may be treated with oxytetracycline (OTC), which acts as an antibiotic (as well as a marking agent) and formalin to act against infectious agents when the stock is susceptible under stress and crowded conditions.

Consignments of stock are checked prior to leaving the hatchery with a microscopic examination of gill and skin tissue to check for parasites. Before fish are released from the transport medium into an open system, they are again checked for signs of clinical disease, flashing, abnormal colouring, fungal lesions, lesions or ulcers, visible external parasites.

If the fish are in good health, the hatchery manager consigns the stock, although the stock is not certified as disease-free.

Salmonids

NSW Fisheries conducts a disease-monitoring program for salmonid diseases at the two salmonid hatcheries, namely Gaden (program introduced in 1998) and Dutton (introduced in 1990).

The sample sizes taken from the populations (on hand) provide for 95% certainty of detecting at least one positive animal found at 2% disease prevalence. Testing procedures used include standard microbiological techniques and the ELISA test (substituted for cell culture method in 1996) for the presence of Epizootic Haematopoietic Necrosis Virus (EHNV).

All stock at both salmonid hatcheries are regularly examined for signs of clinical disease and any affected fish are submitted for laboratory examination. Fish are submitted for examination whenever morbidity or mortality rates rise significantly above background levels.

Since the program began, no significant clinical disease outbreaks have been seen at Gaden or Dutton, with the exception of an outbreak of streptococcisis associated with abnormally high water temperatures at Dutton. No EHNV infection, other viral infection, *A salmonicida* infection or *Y. ruckeri* infection has been detected at either hatchery up to the time of this review (March 2003).

B1.4.7.5 Disease zoning

NSW has proclaimed a disease control zone in the southeast region of the State where Epizootic Haematopoietic Necrosis Virus (EHNV) is endemic. Movements of salmonids to or from this region and to the designated EHNV-free remainder of the State are controlled through a process of certification testing.

Certification testing for pathogens in translocated salmonids in NSW
1. Samples of salmonid fish imported from endemic interstate zones for grow-out in NSW outside the designated endemic area must test free for EHNV by the ELISA test.
2. Samples of salmonid fish translocated for grow-out from NSW endemic area (defined catchments in the southeast) to other parts of the state must test free from EHNV by the ELISA test.
3. Samples of salmonid fish translocated for restocking into public water bodies must test free of EHNV by ELISA test, and *Yersinia ruckeri* and *Aeromonas salmonicida* infection by conventional bacteriological methods.

B1.4.7.6 Surveillance of diseases in NSW (monitoring)

NSW Fisheries reports on diseases on a quarterly basis to Australian Fisheries Forestry and Agriculture (AFFA) who then correlate reports from all states to the Office Internationals Epizootics (OIE). The quarterly report to AFFA advises on incidences of 20 declared diseases in finfish, seven aquatic mollusc diseases and eight crustacean diseases. NSW Fisheries' Senior Aquatic Veterinary Officer from the Aquatic Animal Health Unit completes the report to AFFA.

B1.4.8 Protocols to maintain genetic integrity of stocked and resident species

NSW Fisheries uses a number of processes to ensure appropriate management of genetics in stocked fish. All fish produced by NSW Fisheries are bred using genetic guidelines that result from appropriate selection of broodstock, reliable husbandry techniques and appropriate allocation of stock within genetic regions.

Fish produced in hatcheries for aquaculture are developed for different purposes than for stocking in that the fish are bred to be quick growing as a food product and this is achieved with less regard to genetic variation required for fish used in stocking (Rowland, 2003). Essentially, a run of fish bred for aquaculture may include the production of many fish that are the progeny of only select parents with the desired attributes (quick growing, vigorous), rather than being stock that are bred from a broader genetic background similar to that of wild populations. The use of crossbreeding to create a hybrid species is another technique practiced by the aquaculture industry to produce vigorous stock with efficient food conversion rates. These techniques are not suitable for the production of fish destined for release into a natural population.

B1.4.8.1 Broodstock collection

All stock used in the activity are produced from sufficient quantity of broodstock taken from the area into which the stocking is to take place, with the exception of golden perch and silver perch produced at Grafton for stocking into impoundments of the Hunter catchment. This is designed to ensure that local species are used and that adequate parentage provides the necessary genetic background compatible with wild fish from the same area. NSW Fisheries' current broodstock policy is set out below.

Excerpt from NSW Fisheries' Broodstock Collection policy.

The collection of finfish for use as broodfish from NSW waters requires authorisation from NSW Fisheries.

To obtain a broodstock collection permit the applicant must provide NSW Fisheries with details of:

The species and number of broodfish required,

The exact location(s) that the broodfish will be sourced from,

The proposed broodfish catching methods (exact dimensions of equipment to be utilised),

The applicants or any nominated agents experience in handling fish,

The facilities of the hatchery, including broodfish holding and larvae rearing facilities,

The application fee (currently $161).

Assessment of the application will involve liaison with: NSW Fisheries Aquaculture Division, NSW Fisheries Office of Conservation, NSW Fisheries Field Service Officers, Environment Australia for threatened species, Local community groups, where appropriate

Where a permit is required then: the permit will remain valid for one year from the date of issue unless otherwise specified. During this period the permit may be amended.

Permit holders must notify the District Fisheries Office within 48hrs of their intent to collect broodfish, and give details of the intended collection location.

During broodfish collection activities permit holders are obliged to carry their broodfish collection permit and display a sign in plain view, with the permit number on it with letters no less than 15cm high.

Any fish caught in excess of the number provided within the permit must be immediately returned to the waters of capture.

Broodfish captured may not be used for the purpose of human consumption, sale, trade or barter.

The exchange of broodfish may be allowed between hatchery facilities, provided both recipients hold a current Class H aquaculture permit and NSW Fisheries is notified of the exchange.

Special provisions concerning the type of equipment to be used in broodstock collection and monitoring of equipment will be made on a case-by-case basis.

To minimise the risk of translocation of pathogens, all equipment used for the collection of broodfish must be thoroughly cleaned and dried before use at any location.

The holding of a broodfish collection permit does not give right of access to private property. Access permission must be obtained from the landowner or occupier.

Collection of broodfish by the hatchery owner/operator using legal recreational methods will be permitted, providing NSW Fisheries (aquaculture administration) is notified of the addition of broodfish to broodfish holding facilities, and a file note made on the permit file, and providing the hatchery owner/operator complies with all recreation size limits, bag limits, and closures.

Recreational fishing possession limits will not apply to live fish held on a licensed hatchery premises, provided the fish are held for the purpose of using as broodfish.

Any hatchery operator nominated to receive broodfish of a species listed as threatened must have appropriate facilities to comply with recommended genetic guidelines for conservation stocking programs.

Progeny of Murray cod (*Maccullochella peelii peelii*) and golden perch (*Macquaria ambigua*) should only be stocked back into natural waters from which the broodfish were captured.

Progeny of Australian bass (*Macquaria novemaculeata*) must only be stocked into waters as specified by NSW Fisheries.

Hatcheries producing fish for river stockings may be audited to establish the specific source of broodfish and the location of the broodfish on farm and matter related to genetic diversity.

Broodfish that are rotated at the end of a breeding program must be placed back to waterways, and this will require a stocking permit issued by NSW Fisheries. Except for condition (9) broodfish must not be sold, traded or bartered under any circumstances.

A fisheries officer may examine the broodfish for any obvious signs of disease prior to stocking, and reserves the right to destroy any fish that are diseased.

Upon expiry of the broodfish collection permit, the permit holder must provide NSW Fisheries with a summary of collection activities.

Government hatcheries that produce stock for public waters and private hatcheries engaged in the Dollar-for-Dollar Native Fish Stocking Program or any other program (other than salmonids) are required to observe broodstock policy requirements for the production of fish for public stocking.

Australian bass broodstock

All Australian bass broodstock are to be collected from river systems only. There are three Australian bass broodstock zones; northern, central and southern. If an organisation wishes to stock a waterway in the northern zone, for example, then the supplier needs to have obtained at least five breeding pairs of broodstock from that zone, and have used that broodstock to produce fry for stocking back into the zone.

Murray cod and golden perch brood fish

All Murray cod and golden perch brood fish are to be collected from river systems only. There are three Murray cod and golden perch brood fish zones; northern, central and southern. If an organisation wishes to stock a waterway in the central zone, for example, then the supplier needs to have obtained at least 5 breeding pairs of brood fish from that zone, and have used that brood fish to produce fry for stocking back into that zone. Similar provisions are applied to any other species used in stocking in NSW.

B1.4.8.2 Genetic guidelines

Following the collection of broodstock, hatchery managers are then required to produce the fish in line with basic genetic guidelines to ensure the appropriate level of genetic fitness is established in the stock.

Conservation stocking

When the species to be stocked is a threatened species and subject to a Conservation Stocking program, a specific genetic plan is drawn up by NSW Fisheries' managers and geneticists. Following are the details of the genetic guidelines of the Conservation Stocking program for eastern cod.

1. MINIMUM of 25 pairs of broodfish to be used within 5 consecutive breeding seasons. This number of pairs per generation should prevent loss of fitness through inbreeding depression and will result in an approximate loss of 1% of genetic variation.
    a. Progeny from AT LEAST 5 pairs to be stocked at each site
    b. This requires that eggs from each pair be incubated separately
    c. Stock the larvae from 5 pairs into each pond, or
    d. Pool the fry from 5 pairs after harvest.
2. As far as is practically possible, the same number of offspring from each pair should be stocked into the wild. Equalising family sizes effectively doubles the available genetic variation in the recovering population. It would be beneficial for us to adapt a strategy that equalised family sizes. This would require that offspring from all pairs be kept independently throughout the entire breeding process. The same number (roughly) of offspring from each pair could then be stocked at each re-introduction site. However to incorporate equalised family sizes into the recovery plan is logistically difficult.

3. Use single cross matings (1 Female x 1 Male) or cross every female with every male. DO NOT mix eggs from several females or milt from several males. Divide eggs of each female into the same number of portions as the number of males in the breeding program. Each portion of eggs should be the same size. Do the same with males (quantities of milt not important, as eggs are the limiting factor). Fertilise each portion of eggs from individual females with milt from each of the males. (*Genetically more beneficial but very hard to achieve*).
4. If males do not produce enough milt for fertilisation they should not be used that season. If they again fail to produce sufficient milt the following season they should not be used in the program. Therefore a few excess males may be required as backups.
5. Ideally NO individuals will be bred from more than once in the program. Therefore all broodstock should be replaced each year (assuming no recapture of broodfish). However, as a minimum, AT LEAST some broodfish should NOT have been used in a previous season. This number depends on the length of the breeding program. The minimum number to be replaced each year is given.
6. Collect broodfish from 3 or more sites. As far as possible, set up pairs with individuals from different locations. Collect broodfish before May.

Salmonids

Even though salmonid species used in the activity are not indigenous to Australian waters, sufficient care has to be taken to ensure adequate genetic variation exists within the stocks to ensure the stocks remain healthy and viable.

Rainbow trout and brown trout

Both rainbow trout and brown trout broodstock are trapped from wild fish taken in rivers as they attempt to travel upstream to spawn. This ensures that the fish used are mature and have displayed sufficient health in the wild to achieve an appropriate level of genetic fitness (poor genetic stocks rarely survive for long in the wild). Wild stocks produce around 90% fertilisation rates, further demonstrating viable genetic material.

Brook trout

Brook trout are bred using broodstock held at the Gaden Hatchery. Brook trout greater than two years old are unsuitable for broodstock, so a constant cycle of breeding is undertaken to ensure sufficient quantities of broodstock are available within the two-year or less stage of development. Brook trout are crossed by year classes (1year old X 1 year old) and (2 year old males with 1 year old females). These procedures have provided an acceptable class of genetically sound stock. Brook trout fertilisation rates are as low as 50%.

Atlantic salmon

As with brook trout, Atlantic salmon are bred using age-crossing techniques. Adequate stocks are produced from using 2 year-old stock crossed with 2 year-old stock, although with age classes on hand including fish of 3, 4, and 5 years of age, up to 9 crosses are used to keep salmon genetic lines suitably diverse. Fertilisation rates for Atlantic salmon are around 70%.

All salmonids considered for breeding purposes are thoroughly checked for deformities or any expression of inbreeding, and any specimen displaying any such abnormalities are rejected from the breeding program and destroyed.

The use of broodstock from interstate is an option available to hatchery operators to further spread the genetic base of the stock, although this technique is not utilised very often. The last occasion broodstock were brought into a Government Hatchery from interstate was in 1995 when broodstock were imported from Victoria (Gary Green, Assistant Manager Gaden Hatchery, pers. comm.).

B1.4.8.3 Triploids

The use of non-breeding fish (such as triploidy stock) has never been used in the current activity. The triploid technology creates stock whereby the gonads of the fish do not complete the sexual cycle. Instead of spawning, the ripened gonads are absorbed back into the fish and converted into body weight, thereby allowing the fish to grow much faster than non-triploid stock. As triploids are unable to breed, there is an opportunity to stock waters without introducing a self-sustaining population and associated problems created by inbreeding. The use of this technology to create faster growing non-breeding fish has not been officially considered by NSW Fisheries as a management option to date.

B1.5 Factors affecting management of fish stocking

B1.5.1 Current management of the State's water resources

The manipulation of the States waters through the development of dams and weirs, compounded by poor land and water management, have significantly affected the viability of most freshwater fish populations and where once thriving populations existed, now only remnant populations occur. Throughout NSW, over the past 200 years or so there has been a high level of degradation and physical change to the critical environment required for natural fish breeding, such that historically fish stocking was seen as the most reliable way to maintain or reintroduce viable stocks until environmental issues are resolved or improved. An ever-increasing environmental awareness in recent years, however, has seen more emphasis on habitat restoration and appropriate resource management, rather than a quick-fix approach of mass stockings.

Management plans and other initiatives (described below) are now being progressively developed by NSW Fisheries and other management authorities to improve fish habitat. These strategies are now evolving at a steady rate and include initiatives such as the creation of environmental flows and water allocation regimes that are more habitat-oriented, wetlands protection, riverine aquatic habitat and foreshore protection. These programs have all been either instigated or planned for future deployment across the State to meet a range of environmental problems. These plans and initiatives are unlikely to reduce the need for ongoing supplementation of fish populations through stocking well into the foreseeable future, although it will be important to measure any change in fish assemblages following rehabilitation efforts to determine the most suitable method or suite of methods to improve fish stocks.

NSW Fisheries is responsible for the implementation of a number of these initiatives through its own programs. The following section outlines the management plans and initiatives that have affected fish stocking management now and in the past.

B1.5.1.1 Weirs and fishway development

Weirs and other barriers to fish passage have caused many natural populations to be severely affected across the State, as they restrict migration of fish for spawning, reduce the dispersal of juvenile fish, create isolated populations, reduce gene flow between fish populations, limit passage of fish, cause fish to congregate at barriers leaving them open to disease or predators, alter species diversity because of the local disappearance of some species and change the abundance of remaining species. Stocking has been used as a management tool to address these issues in the past by restocking areas affected by impediments to fish passage. Examples are the restocking of Australian bass above barriers to movement on the eastern drainage, and other native species on the western drainage, for similar reasons.

Ongoing management of these issues is underway, with several management plans and initiatives such as the NSW Weirs Policy. The aim of the NSW Weirs Policy is to halt and, where possible, reduce and remove the environmental impact of weirs. The policy contains three main components that limit approvals for new or expanded weirs, requires a review of all existing weirs and provides for consideration of the need for a fishway at each structure. The State Weir Review is another program designed to make an assessment of all licensed barriers within NSW with regard to potential for removal, fishway installation or other management arrangements.

Fishways are another management tool used to remove barriers to fish passage and improve natural populations. The State Water Assets Management Program (SWAMP) is an upgrade to the State Water instream assets to incorporate up to 15 fishways, with an accompanying monitoring program to determine design efficiency. The Murray Darling Basin Commission's Murray Fishways Assessment Program aims to install fishways at 11 barriers over four years, complete with integrated monitoring program.

Funds from the Recreational Fishing Freshwater Trust have been provided to supplement the Natural Heritage Trust (NHT)-funded Innovative Fishway Developments project, to apply a different method of monitoring to fish passage research. PIT-tagging is now widely used as a tool to quantify migrations of fish species. It involves the attachment to a fish of a microchip providing data when scanned to allow the position of that fish to be accurately determined at a later date. This methodology is to be employed at Euston weir and will investigate travel times and destinations of native fish once they have passed through the fishway. The PIT-tagging project will provide definitive information as to the movement of key migratory species throughout inland rivers, and their utilisation of innovative fishway designs.

B1.5.1.2 Wetlands

Wetlands and floodplains remain one of the States most threatened resources. Wetlands have been degraded in a number of ways, reducing their effectiveness as fish habitat. In the Murray-Darling Basin the number and condition of wetlands has declined considerably. It is estimated that the Macquarie marshes have reduced in area by at least 40-50%. Along the coastal region of NSW, 75% of the original wetlands have been lost while more than 45% of the area of NSW River Murray wetlands have been degraded by regulated flows. The Lowbidgee wetlands have been reduced by 18% of its original area and on the Murray floodplain of NSW, many wetlands have also been degraded by permanent inundation. There are 178 sites in the Directory of Important Wetlands in NSW totalling 2.3 million hectares.

The loss of important wetland areas has caused permanent reductions in the number of fish breeding grounds and hence, overall fish populations. Compounded by ever increasing fishing pressure, stocking has been historically used as a management response and remains an important way to supplement those losses.

The NSW Wetlands Management Policy, established by the State Government in 1996, seeks to ensure "the ecologically sustainable use, management and conservation of wetlands in NSW for the benefit of present and future generations" (NSW Government, 1998). Management options, such as increasing environmental flows to mimic natural flooding events that trigger fish spawning and rehabilitation of wetland species biodiversity, are just some of the principles of this policy.

Floodplain management plans are being developed by the Department of Infrastructure, Planning and Natural Resources (DIPNR, formerly the Department of Land and Water Conservation) in conjunction with local communities for many floodplain areas, especially in areas of intensive agriculture and development. The main aim of these plans is to assess the impact of existing and proposed structural works on the floodplain and develop management options. Floodplain plans also have a conservation aim, attempting to balance the natural state of the floodplain and the function it performs with development.

B1.5.1.3 Water supply

In 1997, the NSW State Government announced the NSW Water Reform Package. The aim of the water reform process is to secure fair shares of water for the environment, agriculture, community and industry. This process will have benefits for fish conservation, allowing secure allocations for environmental flows to provide healthy ecosystems. As part of this package, the Government, in consultation with the community, developed interim flow objectives for all rivers in the state. Their goals are to protect natural water levels in pools in creeks and rivers and wetlands during periods of no or low flows, protect or restore a proportion of moderate flows (‘freshes’) and high flows, maintain or restore the natural inundation patterns and distribution of floodwaters supporting natural wetland and floodplain ecosystems, mimic the natural frequency, duration and seasonal nature of drying periods in naturally temporary waterways, maintain or mimic natural flow variability in all streams and maintain natural fluctuations in water levels.

B1.5.1.4 Cold water pollution

Cold water released from dams can have several impacts, including depressing natural temperatures by 8-12°C in spring and summer, reducing annual temperature ranges, and delaying summer peaks in temperatures (Astles *et al*., 2003). These can affect temperatures in river systems many hundreds of kilometres downstream from the storage. Initial research has indicated that cold water pollution can result in the death of juvenile native fish and reductions in growth rates. Results from a NSW study on the topic showed 100% survival in the warm channels (18 to 24°C) compared to 25% survival in the cold channels (12 to 14°C). Growth and weight responses were similar to those for survival, with fish in the warmer channel growing significantly better.

With its potential to affect both natural fish populations, and the success of stocking programs, the issue of cold water pollution continues to be of serious concern to both conservationists and stockist, although management of the issue is the responsibility of the DIPNR. To address the issue, the State Water Management Outcomes Plan, developed under the *Water Management Act 2000*, should see the modification of least two priority dams between December 2002 and December 2007. Efforts to mitigate cold water pollution affecting the Snowy Mountains trout fishery, through joint management arrangements resulting in mutually beneficial outcomes, are underway with the Snowy Mountains Trout Stocking Strategy.

B1.5.2 Management of recreational fisheries

Fish stocking in NSW is affected by recreational fisheries management programs and by regulation of the sport by virtue of the *Fisheries Management (General) Regulation 2002.* The main management tools applied to recreational fishing in NSW are the recreational fishing licensing system (from which the recreational fishing trust funds are established), and the provisions of the general regulation (relating to methods of capture and gear restrictions, bag and size limits, closed waters and closed seasons and species protected from fishing).

B1.5.2.1 Recreational fishing activity and its level

NSW Fisheries commissioned a twelve-month survey of recreational fishing in New South Wales in 2000-01. The survey was part of a broader national initiative to obtain fisheries statistics on non-commercial components of Australian fisheries (Henry and Lyle, 2003). The survey obtained estimates of the level of participation, fishing effort and catch by recreational fishers.

NSW had an estimated 998,501 recreational fishers and the proportion of the NSW population that participated in recreational fishing was 17.1%. Almost 24% of the NSW male population went fishing while about 10% of females fished.

More than 7.7 million recreational fishing events were reported in NSW during the survey period. These fishing events were conducted on 6.9 million days. The estimated time spent recreational fishing in NSW was 30.4 million hours. Interstate patterns in fishing effort indicated that about 1.5 million fishing events were undertaken in NSW by fishers from other states.

NSW recreational fishers used a range of fishing platforms including boats (private, hire and charter) and shore (ocean beach and rocks, man-made structures) during the survey year. Fishing from the shore attracted a greater level of activity (59% of events) than fishing from boats (41% of events). Of the boat-based fishing effort, more than 92% of fishing events were conducted from private fishing boats as opposed to 4% from charter vessels and 4% from hire boats. Freshwater fishing accounted for approximately 24% of the effort in NSW, compared to about 20% of the national effort.

Recreational fishers in NSW harvested approximately 14 million finfish comprising about 200 species. Most of the key recreational species were harvested from estuarine or coastal waters, although, the current survey provided the first like-for-like comparison of saltwater and freshwater recreational harvests.

A number of freshwater species including European carp, redfin, golden perch and trout were prominent in the NSW harvest despite past assumptions regarding the overall prominence of saltwater species in State recreational fisheries. Freshwater species accounted for at least 17% of the State harvest (Table B26). Two species, European carp and redfin, neither of which are stocked, were harvested in substantial numbers by recreational freshwater fishers and are considered by NSW Fisheries and many fishers to be pest species. Many other commonly caught freshwater fish are supplemented by stocking, such as golden perch, or reliant on stocking, such as salmonids.

Table B26. Estimated catch of popular freshwater recreational angling species in 2000-01, and their relative proportions of the total harvest for NSW (Source: Henry and Lyle, 2003).

Species	Number	Accuracy (+ or -)	Proportion of State harvest	Weight (tonnes)	Stocked	Reliant on stocking
European carp	1,168,881	10%	8.1%	876	No	No
Golden perch	542,107	9%	3.8%	325	Yes	No
Redfin perch	244,596	19%	1.7%	61	No	No
Salmonids	244,470	11%	1.7%	122	Yes	Yes (other than self-sustaining populations of brown and rainbow trout)
Murray cod	93,973	7%	0.7%	94	Yes	No
Australian bass /perch	93,150	11%	0.7%	46	Yes	No (yes in impoundments)

B1.5.2.2 Recreational fisheries licensing

To take or attempt to take fish for recreational purposes in NSW requires a recreational fishing licence. Licensing of recreational fishing was first implemented for the trout fisheries in 1936 following the introduction of the *Fisheries and Oyster Farms Act 1935*. Half of the funds raised from the licence were reverted back into the cost of stocking and management. The trout licence was replaced in 1958 with the Inland Angling Licence that covered the taking of all freshwater angling species. The Inland Angling Licence was abolished in 1988, but replaced in 1998 by the Inland Fishing Fee. Funds raised by the fee have since reached $6.4M.

Amendments to the *Fisheries Management Act 1994* were passed by the NSW Parliament in November 2000, and the recreational fishing licence was introduced in March, 2001. Known as the General Recreational Fishing Licence (GRFL), the licence is required for all recreational angling in both inland and marine waters in NSW. Existing inland angling licences were honoured in inland and also marine waters until their expiry date. Recreational fishing in saltwater areas (offshore, coastal and estuarine waters) accounts for 76%of the State's angling activity.

A range of exemptions apply to the licence in inland waters (under 18 years of age, Indigenous persons, pensioners etc.) and a 50% concession applies to people fishing in the tidal waters of the Tweed River and prescribed adjacent beach areas. The Tweed Concessional Area is a transitional arrangement pending Queenslands introduction of an equivalent licensing scheme. Other arrangements for licensing in Lake Hume and Lake Mulwala are still under consideration due to their proximity to Victoria.

Licences fees pricing and duration:

- $5 for three days
- $10 for one month
- $25 for one year
- $70 for three years

B1.5.2.3 Bag and size limits

These restrictions apply to most recreationally targeted fish taken in NSW inland waters and to all species stocked for recreational purposes. Size restrictions are in place to ensure that the species is of an age class such that the fish has had a reasonable chance of breeding at least once before it can be legally taken by an angler. Bag limits ensure that anglers only take a reasonable share of the resource at any one time.

A number of species of freshwater fish are classed as protected and may not be taken recreationally or otherwise. All freshwater species in this class are stocked in NSW as either part of a recovery plan or through enhancement stocking while others are protected from commercial fishing (historically and now as the inland commercial fishery is being phased out). The following table describes the bag and size limits of all stocked species and the protection status of each.

Table B27. Bag and size limits of stocked fish in NSW.

Species stocked	Size limit	Bag limit	Protection status
Australian bass	None (only one over 35cm if taken in streams)	2	Protected from commercial fishing including coastal/tidal waters
Eastern cod	N/A	N/A	Totally protected in all NSW waters
Eel-tailed catfish	30cm	2	Zero bag limit in the Lower Murray
Golden perch	30cm	5	Commercial fishing phased-out
Macquarie perch	N/A	N/A	Totally protected in all NSW waters
Murray cod	50cm (only 1 over 100cm)	2	Closed season Sept - Nov
Silver perch	25cm	Zero in streams, 5 in dams	Protected in all NSW waters (other than in dams stocked for angling)
Trout cod	N/A	N/A	Totally protected in all NSW waters
Atlantic salmon	25cm	Variable	Protected from commercial fishing
Brook trout	25cm	Variable	Protected from commercial fishing
Brown trout	25cm	Variable	Protected from commercial fishing
Rainbow trout	25cm	Variable	Protected from commercial fishing

Note: Trout size and bag limits vary depending on the classification of the waters from which they are taken. See "Notified Trout Waters" below.

B1.5.2.4 Notified Trout Waters

To protect breeding populations of stocked salmonids and to promote fair sharing of the catch amongst anglers, certain streams have been classified as 'notified' trout waters. These waters, of which there are several types, have special regulations on gear and seasons.

Trout spawning streams

Fishing season: From 1 May each year until the end of the June long weekend. Bag limit: one over 50cm only (two in possession). Permitted gear: One attended rod and line with up to two hooks with artificial flies or lures. Gear rigged for bait fishing is prohibited.

Blue ribbon streams

Fishing season: From the start of the October long weekend to the end of the June long weekend (this means that you can commence fishing on Saturday morning and must cease fishing on Monday night). Bag limit: two (four in possession). Permitted gear: One attended rod and line with up to two hooks with artificial flies or lures. Gear rigged for bait fishing is prohibited.

Catch & release streams

Fish must be returned to the water immediately with least possible harm. Fishing season: From the start of the October long weekend to the end of the June long weekend (this means that you can commence fishing on Saturday morning and must cease fishing on Monday night). Permitted gear: One attended rod and line with up to two hooks with artificial flies or lures. Gear rigged for bait fishing is prohibited.

General trout streams

Fishing season: From the start of the October long weekend to the end of the June long weekend (this means that you can commence fishing on Saturday morning and must cease fishing on Monday night). Bag limit: five (10 in possession) Permitted gear: One attended rod and line with no more than two hooks attached.

General trout dams

Fishing season: All year Bag limit: 10 (20 in possession). Permitted gear: Two attended rods each with a line and no more than two hooks attached.

Trophy trout dams

Fishing season: All year Bag limit: two (four in possession). Permitted gear: Two attended rods each with a line and no more than two hooks attached. Black Lake- bait, artificial fly and lure fishing permitted. Thompsons Creek Dam- artificial fly and lure fishing only, from shore areas only, during the period from one hour before sunrise to three hours after sunset.

Lake Jindabyne and Eucumbene Dam

Fishing season: All year Bag limit: five (10 in possession) Permitted gear: Two attended rods each with a line and no more than two hooks attached.

Lake Jindabyne and Eucumbene Dam (yabbies)

Fishing season: All year Bag limit: Bag and possession limits for freshwater yabby: 200 Permitted gear: Permitted gear: five hoop or lift nets per person.

Closed waters - trout and salmon

All notified Trout Streams are closed to fishing from the end of the June long weekend to the start of the October long weekend.

B1.5.2.5 Operation of the recreational fishing trusts

In the first year of the GRFL, over 490,000 licences were sold. Monies raised under the scheme are placed into either one of two trust funds called the Recreational Fishing Fee Trusts (one each for saltwater and freshwater) and used specifically for improving angling opportunities in NSW.

To date, the expenditure committees have supported spending the fishing fee money on:

- buying out commercial fishing effort to create saltwater Recreational Fishing Havens
- ending the commercial fishing of freshwater native finfish
- conservation and fish habitat restoration programs
- recreational fisheries research
- the Fish Care Program
- additional compliance officers, and

- fish stocking (of which $500,000 was allocated from the freshwater trust in 2001).

The following section is a brief description of the projects funded from the Recreational Fishing (Freshwater) Trust in 2001/02 (Table B28). A number of these programs marked with * directly relate to fish stocking and are further described below the table.

Table B28. Expenditure from the Recreational Fishing (Freshwater) Trust in 2001/02.

Project	Total available 2001/02 ($)	Total expenses 2001/02 ($)	Carried forward ($)
Angler catch monitoring program	316,000	161,000	155,000
Bass habitat	100,000	68,000	32,000
Carp assessment and reduction program	164,000	113,000	51,000
Effectiveness of stocking research	319,000	230,000	89,000
Enhanced Departmental government fish production	379,000	355,000	24,000
Field operations staff	609,000	610,000	
Fish passage/weir removal	69,000	73,000	
Fishcare Volunteer Program	356,000	244,000	112,000
Fishing information (shared program)	60,000	29,000	31,000
Impoundments access program	69,000	26,000	43,000
Purchase of native fish from private hatcheries	218,000	149,000	69,000
Recreational advisory and education program	264,000	214,000	50,000
Recreational fishing expenditure survey	71,000		71,000
Regional fish habitat	269,000	276,000	
Small project enhancement program	20,000	2,000	18,000
Statewide angler survey	14,000	1,000	13,000

Angler catch monitoring

The Trust provided funds for monitoring of the angler catch at selected fishing competitions and special Angler Catch Research Program events, analysis of catch rates, species compositions and size distributions, and comparisons to information relating to the success of stocking programs from previous events.

Bass habitat

This new project involves anglers in the mapping of habitats of three key bass rivers, the Macleay, Hawkesbury and Shoalhaven rivers, in order to establish a baseline for a long term monitoring project of these environments.

Carp assessment and reduction program (not fully licence funded)

The Carp Assessment and Reduction Program includes the Carp Production Incentive Scheme which boosts the commercial harvest of carp, research into carp control, and provision of advisory information on carp impacts and control.

Effectiveness of stocking research

This encompassed research into effective marking techniques for hatchery produced fish, surveys of fish populations in key impoundment fisheries, trial stocking programs and presentation of results at angling group meetings, committee meetings and conferences.

Enhanced departmental fish production

Government hatcheries at Narrandera Fisheries Centre, Gaden Trout Hatchery, Dutton Trout Hatchery and Port Stephens Fisheries Centre received funding to boost production of native fish species (trout cod, Murray cod, golden perch, silver perch and Australian bass) and salmonid species (Atlantic salmon, brook trout, brown trout and rainbow trout). Funds were used for additional staffing, additional operational expenditure and for capital items including a new broodstock shed, pond construction and equipment.

Impoundment access program

Increased access to impoundments for anglers will increase angling opportunities, decrease pressure on wild fish stocks and stimulate regional employment and economic activity. A project officer was part-funded to negotiate improved access to major impoundments that are currently ‘out of bounds’ for anglers. Access to Thompsons Creek Dam near Lithgow and Imperial Lake, near Broken Hill, was arranged for recreational fishers. Another opening, for Umberumberka Lake, near Broken Hill will commence in two years time. NSW Fisheries is in discussions with key NSW Government agencies to obtain access for recreational fishers to other major water storages in the Wollongong, Sydney and Newcastle metropolitan areas. The information derived from this program will assist managers in determining whether an area provides necessary access for anglers and therefore whether the area should be stocked.

Purchase of native fish from private hatcheries

Angling clubs, councils and community groups received Dollar-for-Dollar funding to increase the numbers of Murray cod, golden perch and Australian bass stocked in NSW. The program supported private hatcheries, increased stocking rates and increased compliance with reporting requirements for stocking groups.

Recreational fishing expenditure survey

This program investigated the value of the recreational fishery in the Snowy Mountains region, a fishery substantially based on stocked salmonids. The project provided detailed estimates of expenditure by anglers in the Snowy Mountains region, as well as some estimates of involvement in the trout fishery and other freshwater fisheries in NSW.

Regional fish habitat

Protection, restoration and rehabilitation of fish habitat will enhance the sustainability of recreational fisheries in inland regions. Two conservation managers were funded to ensure that the habitat implications of modifying bridges, causeways, roads and culverts, and water releases from dams were considered in a range of activities, including development approvals, water management plans and riverine management.

Statewide angler survey

A twelve-month survey of recreational fishing in New South Wales was conducted in 2000-01. The survey was part of a broader national initiative to obtain fisheries statistics on non-commercial components of Australian fisheries. The survey obtained estimates of the level of participation, fishing effort and catch by recreational fishers.

B1.5.2.6 Recreational fishing havens

Along the NSW coast, 30 locations were set aside and protected from commercial fishing. These areas now represent 27% of estuarine waters substantially reserved from commercial fishing (previously only 3% were reserved). Commercial fishing was banned from these areas from 1 May 2002, except for the Clarence River haven, which came into effect on 1 September 2002. The purpose of these areas is to improve recreational fishing. Commercial fishers entitlements were withdrawn through a buy-back process where commercial fishing entitlements were surrendered in exchange for fair compensation. The compensation is being paid by the Recreational Fishing Saltwater Trust, which is funded by the GRFL fee. The 30 locations were chosen through a transparent selection process, which ensured that the community's social, economic and ecological issues were considered.

There is no recreational fishing haven proposed for inland waters of NSW, due to the cessation of the inland native fish commercial fishery.

B1.5.2.7 Fishing in the Lower Murray River catchment

Following recommendations from the Species Impact Statement for the lower Murray (Sanger *et al.,* 2002) a number of changes were made to recreational fishing in that area. The Lower Murray River catchment includes a wide range of aquatic species in all natural creeks, rivers, and associated lagoons, billabongs and lakes of the regulated portions of the Murray River below the Hume Weir, the Murrumbidgee River below Burrinjuck Dam, the Tumut River below Blowering Dam and all their tributaries (excluding the Lachlan and the Darling rivers).

The new rules, aimed at ensuring recreational fishing in the area remains sustainable, include:

- a zero bag limit for eel-tailed catfish and river blackfish for the Murray and Murrumbidgee rivers and their tributaries
- a reduction in the bag limit of Murray crayfish from ten per day to five per day, with only one greater than 12cm allowed
- Murray crayfish to only be taken during the months of May, June, July and August, and
- a ban on taking Murray crayfish in notified trout waters.

Note: Recommendation 17 of the Species Impact Statement supports the continued stocking at historic levels of recreationally important species, especially into off-stream impoundments to address the declining abundance of these species in the area.

B1.5.3 Management of commercial fisheries

The NSW Inland Restricted Fishery (previously Inland Commercial Fishery) has operated for well over 100 years. The major targeted species are Murray cod and golden perch, with catches of carp and particularly yabbies increasing over recent decades. Over time, areas open to commercial fishing have gradually decreased to approximately 5% of inland waters, focused on the southwest and the northwest of the State.

In 1997, the NSW Rivers Survey reported that native fish were under threat from habitat degradation, fishing pressure, disease, and introduced species. A review of the inland commercial fishery followed in early 1998. Given opposition to the continued existence of the commercial fishery, particularly from the recreational fishing sector, and scientific concern about the viability of native fish stocks, it was determined that commercial fishing for native finfish would cease as of 1 September 2001, and fishing effort would be redirected towards under-utilised yabby and carp resources.

A structural adjustment package was developed to enable transition from native finfish to the yabby and carp fishery. Under this structural adjustment package, commercial fishers could surrender their licence in exchange for an ex-gratia payment, or continue fishing under a transferable yabby and carp endorsement. Payments for the surrender of commercial fishing gear were made possible by the re-introduction of the Freshwater Recreational Fishing Licence in 1998.

B1.5.4 Interaction with past or existing aquaculture activities

The activity of fish stocking and the aquaculture industry have long shared some common ground in the area of fish production through hatchery technology and indeed most commercial hatchery techniques used in NSW today were derived from Government Hatcheries through the development of native fish breeding and stocking programs. However, aquaculture operators (Private Hatcheries) have only a relatively recent formal involvement in the activity with the introduction of the Dollar-for-Dollar Native Fish Stocking Program. Prior to the program, most fish stocked in NSW had been the exclusive domain of Government hatcheries for about 60 years. Although small scale stocking of native fish were sourced from private hatcheries in the 1980s, and 1990s, the use of private hatcheries to produce stock for the activity is now commonplace and interaction of this kind is expected to increase in future.

NSW Fisheries has been aware that private hatcheries have sold fish to the public for private water stockings such as in farm dams for many years. Species including trout, Australian bass, golden perch, silver perch, Murray cod and yabbies are believed to have been popular for stocking private waters. As this aspect of the aquaculture industry is unregulated and, therefore, never recorded, it is impossible to gauge the amount or extent of this trade or any subsequent impacts.

The main issue of concern that arises is the potential of fish (and associated diseases and parasites) escaping farm dams outside their natural range. NSW Fisheries' Aquaculture Policy has attempted to address this issue by way of standard aquaculture permit conditions.

Excerpts from NSW Fisheries' Aquaculture Standard Condition.

Conditions Relating to the Sale and Stocking of Indigenous Freshwater Fish of NSW

25. Live fish may be sold to other farmers holding a current permit authorising the farming of that particular species of indigenous fish; or to a fish wholesaler, retailer or restaurant for human consumption; to a registered wholesaler or retailer of aquarium fish; or to a recognised outlet authorised under State and/or Commonwealth legislation.

26. Live fish may also be sold to farm dam owners for stocking farm dams. Of the western drainage species, only silver perch (*Bidyanus bidyanus*), golden perch (*Macquaria ambigua*) and eel-tailed catfish (*Tandanus tandanus*) may be sold for stocking farm dams on the eastern drainage. Permit holders must advise people purchasing fish for stocking farm dams on the eastern drainage that dams must be above the 1 in 100 year flood level and not be susceptible to overflow that would allow fish to escape.

26a. Murray cod (*Maccullochella peelii peelii*) may only be cultured or stocked in farm dams on the western drainage.

26b. Silver perch may not be grown for sale in farm dams (See 'Aquaculture Permits for Silver Perch' Policy).

27. No fish may be sold for the purpose of stocking natural waterways and public impoundments without first

obtaining a Fish Stocking Permit issued for those waters by the Director-General of Fisheries.

Conditions Relating to the Sale and Stocking of Salmonids

40. The permit-holder shall not use on their premises any eggs taken from wild trout nor shall the holder have wild trout on the premises.

41. Live fish may be sold to other fish farmers holding a current permit authorising the farming of salmonids; to a fish wholesaler, retailer or restaurant (authorised under State and/or Commonwealth legislation) for human consumption; or to a registered wholesaler or retailer of aquarium fish.

42. Live fish may also be sold to farm dam owners for stocking farm dams. Farm dams must be located above the 1 in 100 year flood level in catchment areas where trout have been traditionally stocked and not be susceptible to overflow that would allow fish to escape.

Conditions Relating to the Sale and Stocking of Freshwater Crayfish

51. Live yabbies, *Cherax destructor*, may be sold to farm dam owners for stocking farm dams, or to a registered wholesaler or retailer of aquarium fish. The permit holder must advise people wishing to stock yabbies into eastern drainage dams that they can not stock yabbies where there are known populations of other species of freshwater crayfish that could be threatened by their introduction. This information is available from the NSW Fisheries. In addition, the dams must be above the 1 in 100 year flood level and not susceptible to overflow.

52. Live crayfish may only be sold to other fish farmers holding a current permit authorising the farming of that species, to a fish wholesaler, retailer or restaurant (authorised under state and/or Commonwealth legislation) for human consumption or to a registered wholesaler or retailer of aquarium fish. The permit-holder must advise the aquarium dealer that only the yabby *Cherax destructor* may be stocked into NSW waters.

52a. Freshwater crayfish of a species not indigenous to NSW may not be stocked into New South Wales' waters.

53. All ponds, raceways or other tanks containing marron (*Cherax tenuimanus*) or redclaw (*Cherax quadricarinatus*), or any species of crayfish not native to the area where the fish farm is located, must be surrounded by an unbroken fence extending at least 60cm above ground and 30cm below ground, and constructed of a smooth material (e.g. plastic sheeting, galvanised iron) to prevent the escape of stock. Fences will be required where yabbies are to be grown on the eastern drainage in areas where native species of crayfish are present, as the introduction of yabbies may present a threat to native crayfish stocks.

B2 Environmental Risks of the Current Activity

Introduction

The aim of this section of the EIS is to describe and evaluate the potential environmental impacts arising from the current manner in which stocking is conducted. The principles of risk management have been used to identify those aspects of the existing activity (described in Chapter B1) that are thought to be responsible for the impacts. Those aspects of the current activity that are assessed as posing the greatest threat to ecological sustainability will be highlighted as issues that require significant modification or change through the draft FMS (Chapter D). Those aspects assessed as posing little or no risk may receive little, if any, modification in the draft FMS. In effect, the draft FMS becomes an environmental risk management strategy.

This section begins with a discussion and definition of risk, followed by the risk management framework used to determine the risks associated with fish stocking. It then defines the terms used throughout the methodology and within this chapter. The preliminary or first stages of the risk management framework are then presented. The preliminary stages are a very broad scale, rapid assessment that compares the components of the environment against the aspects of fish stocking that are thought to be the sources of risk. At that point, a decision is made as to which components will be reviewed in more detail as they are thought to be at risk yet cannot be sufficiently well understood at the broad level. The components that are assessed in more detail comprise sections B2.1 to B2.6. Those components that can be rapidly dismissed as not at risk due to fish stocking are not considered further, and a justification for that decision is provided.

As an overview:

- this section (B2) highlights the risks and sources of risk associated with the current activity of fish stocking
- Chapter C provides some alternatives to the current activity
- Chapter D presents the draft fishery management strategy that includes the measures proposed to address the risks discussed in this section (B2) and
- Chapter E assesses the proposed management strategy to determine whether its management measures can effectively reduce the risks to the environment that were highlighted in this section (B2) to ensure that the activity is conducted in an ecologically sustainable manner.

Risk

Risk has numerous definitions within the risk assessment literature, and even more ways of determining that risk (Francis and Shotton, 1997). This is not surprising given the broad range of environmental impacts that are possible and the number of aspects that can be responsible for the impacts. Levels of risk can be determined using quantitative or qualitative assessments. As there is insufficient data upon which to develop a quantitative risk management framework for fish stocking, a qualitative risk assessment will be undertaken using the following categories: low, medium and high to describe risk. There are generally two definitions of risk in ecological and fisheries literature:

1 Risk is defined as an expected loss (or impact) and calculated by incorporating both the probability (or likelihood) and severity (or consequences) of the loss (Rosenberg and Restrepo, 1994)

2 **Risk** is defined as the likelihood of an undesired event (or impact) occurring as a result of some behaviour or action (in this case, fish stocking) (Francis, 1992 & 1997; Hayes, 1997).

In the first definition, which originates from the Occupational Health and Safety setting and later modified for ecotoxicological studies, the consequences are generally consistent, well documented and determined in controlled environments, e.g. laboratories. The frameworks used to determine the risk are often referred to as decision-theoretic frameworks and the consequences are independent of any future occurrences of the event. This definition of risk cannot be used to assess the activity of fish stocking because the consequences of stocking are not well documented. Impacts from one stocking event only offer a hint as to what might happen in another, very similar event, but offer nothing for very different stocking events. Further, the actual impacts of fish stocking have not been sufficiently well studied or documented to allow definitive conclusions to be drawn for all species and locations. This means that the consequences cannot be evaluated independently of their probability as each stocking event is unique in terms of species and locations, and each event has its own set of potential impacts.

The second definition is more often used for fishery and fishing-related assessments (Francis and Shotton, 1997; FAO, http://www.fao.org/fi/glossary), and will be used in this assessment to define the issues of the current activity that need to be addressed in the draft FMS. This definition requires that an *a priori* definition of consequence be given for the undesirable event that is being analysed. In this way, the definition of risk combines the consequence and likelihood of an undesirable event happening, and avoids the confusion associated with trying to select the appropriate combination of the often non-independent variables of consequence and likelihood. This definition implies that the undesired event or impact includes a suite of negative changes or consequences, and they are expressed in terms of assessment endpoints. They are simply an expression of the values that one is trying to protect by undertaking the risk assessment procedure (Hayes, 1997). For example, if our endpoint is habitats, then risk is defined as the likelihood of habitat damage as a result of stocking. By clearly defining the risk in this manner, it also says that the concern is not that stocking (in this example) is taking place, but that it is also damaging habitat. If we were able to guarantee that stocking was not damaging the habitat, then there would be no risk. The inability to make that guarantee, and the lack of data, means that there is some immeasurable level of uncertainty associated with assessment, and it is important for that to be presented. Quantitative methodologies can rely on formulae to calculate that uncertainty, but as a qualitative method has been used here, uncertainty will presented as low, medium or high, and will be based on the amount and "value" of data used in the assessment. Presenting the information in this fashion means that the risk will have been assessed, the uncertainty associated with it communicated in a transparent fashion, and then the acceptance or otherwise of the risk gauged by those whom review the EIS. The ecological risk management framework that was used in this EIS to determine risk as defined above is explained below.

Ecological Risk Management

Risk management is the culture, processes and structures that are directed towards the effective management of potential opportunities and adverse effects (AS/NZS 4360). It is an iterative process that combines risk identification, assessment, management and communication (see Figure B16). The risk management process is intended to provide insights about sources of risk and their potential impacts, which then enables managers to take mitigative action against undesirable outcomes.

A broad range of risk analysis, risk assessment and risk management information and literature was reviewed in order to determine the most appropriate method for determining the ecological risks associated with fish stocking. This information and literature covered generic principles of risk management (Standards Australia/Standards New Zealand, 1999), generic principles of environmental risk management (Standards Australia/Standards New Zealand, 2000), a risk analysis and reporting framework for ecologically sustainable development in fisheries (Fletcher *et al*., 2002), a comprehensive review of risk assessment terminology for the fields of chemistry and toxicology (Duffus, 2001), the risk analysis terminology provided by the Food and Agriculture Organisation of the United Nations (FAO) in their online glossary of fisheries terms and definitions (http://www.fao.org/fi/glossary), and relevant publications in the aquatic sciences dealing with quantitative and qualitative risk analyses and assessments (Pearsons and Hopley, 1999; Hayes, 1997; Francis, 1992; Francis and Shotton, 1997; Lane and Stephenson, 1998).

The practical application of the risk management process for assessing and treating risks in the activity of fish stocking was made difficult because of:

a) the different risk management methods and frameworks that are in usage among and within different fields of research and resource management

b) inconsistent usage of risk management terminology throughout the literature (Hayes, 1997)

c) complex relationships that exist between assemblages of species, habitats and ecological processes in the aquatic environment (Dayton *et al*., 1995; Hall, 1999; Jennings *et al*., 2001, Polunin and Pinnegar, 2002)

d) lack of detailed biological and ecological data for many species and

e) a lack of experimental data, but an abundance of anecdotal information and circumstantial evidence about the ecological effects of fish stocking in Australia.

These difficult issues were resolved by modifying and integrating the general concepts and principles that had been previously used across the different areas of risk management, primarily the Standards Australia/Standards New Zealand manual for Environmental Risk Management - Principles and Processes - HB 203:2000. A description of the resulting risk management framework, its relationship to the broader framework under which this environmental impact statement was written, and the definitions (based on HB 203:2000) of most of the terms used throughout this chapter are provided below.

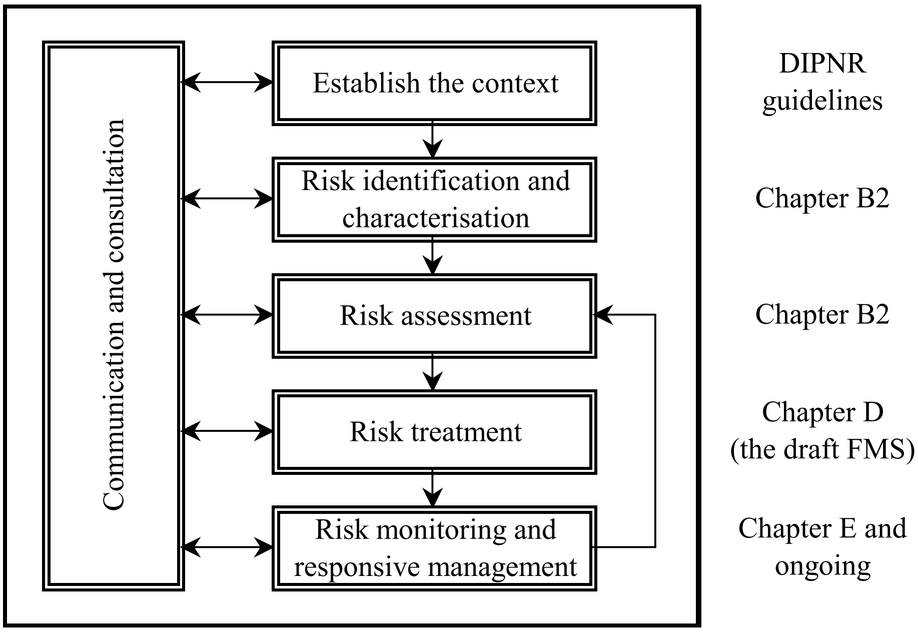


Figure B16. The risk management framework adopted for this EIS and the location of its components within this EIS. (Source: based on AS/NZS 2000)

Context is the determination of the strategic, organisational and risk management arrangements, and establishes the structure of the analysis and the criteria against which risk will be assessed. It identifies stakeholders and defines the communication and consultation policies. The context for this assessment has been established by the Guidelines for the Environmental Impact Assessment of the Draft Fishery Management Strategy for Fish Stocking issued by DIPNR, which includes criteria under the FM Act and EP&A Act. The criteria against which risk must be assessed are thus largely legislative, e.g. preventing the recovery of a threatened species listed under the TSC Act or FM Act, but must also use broader guiding principles such as Ecologically Sustainable Development, incorporating the Precautionary Principle, when determining the impact on other components.

Risk identification and characterisation aims to generate a comprehensive list of sources of risk due to the activity of fish stocking. This can be done using a variety of methods that include literature reviews, examination of historical records, expert panels, brainstorming, and consultation meetings to discover stakeholder opinions and perceptions. For this EIS, NSW Fisheries consulted with the Department of Infrastructure, Planning and Natural Resources and conducted internal workshops and numerous stakeholder meetings with the Recreational Fishing Freshwater Management Planning Committee (RFFMPC) to help identify areas and sources of risk due to stocking. The results of this risk identification step are often presented as lists, tables or as component trees (see Fletcher *et al*., 2002). The Guidelines for the Environmental Impact Assessment of the Draft Fishery Management Strategy for Fish Stocking issued by DIPNR provide a broad overview of the components at risk, and these will be compared to the elements that comprise the activity of stocking as the basis for further assessment (Table B29). In other words, risk characterisation is done initially at the broad ecosystem level to identify those areas at highest risk, and then those areas are assessed at a finer resolution for species (or other ecological component) impacted by the fishery. Those components of the ecosystem determined to be at low risk at the broad ecosystem level will be eliminated from the subsequent assessment, and a justification as to why they were eliminated will be provided. Both the risk identification and characterisation are contained within this section.

Risk assessment is the detailed analysis of those components of the ecosystem thought to be at greatest risk due to fish stocking that were identified in the previous step and may also elucidate other areas of risk. In many risk management frameworks, it involves two sub-components of risk analysis and risk evaluation. Risk analysis involves consideration of the consequence and likelihood of impacts, and risk evaluation is the comparison of those estimated levels of risk against pre-determined criteria. As discussed above, owing to the origin of the 'consequence x likelihood' method for determining risk and its application, risk analysis and evaluation have been combined in this framework by using a definition of risk that incorporates the likelihood of failing to meet the pre-determined criteria. For example, for threatened species, the risk is defined as the likelihood of preventing the recovery of the species, and for wilderness areas, risk is defined as the likelihood of altering the natural state of those areas. The risk assessment step is contained within this chapter and guides the content of subsequent chapters. Those aspects that are assessed as medium to high risk must be addressed in the draft FMS (Chapter D), through either direct or indirect management responses and associated monitoring and review. Areas of low risk can be accepted without management changes but may require periodic reviews.

Risk treatment (also often referred to as risk management) involves the development and implementation of what is generically termed a management plan (not to be confused with a share management plan under the FM Act), in this case the draft Fishery Management Strategy for Fish Stocking (Chapter D). It details the programs, management measures and monitoring programs designed to mitigate the risks associated with fish stocking.

Risk monitoring and responsive management aims to collect information to determine whether the management initiatives that were implemented through the draft FMS were effective in minimising the risks. Risk monitoring is useful for validating management actions when they have been effective, and highlighting areas that need stronger management when previous initiatives have been shown to be ineffective. Risk monitoring and responsive management should be regarded as a practical appraisal of management initiatives and an opportunity to modify management arrangements in a timely manner. This takes place over the life of the management strategy, and as such the results will not be presented in this EIS, although a theoretical appraisal of the draft FMS is provided in Chapter E. Basically, the role of that chapter and the theoretical appraisal is to determine whether the draft FMS appears to mitigate the medium to high risks. It is theoretical because there are no data upon which to more accurately determine the extent or magnitude to which the risks are mitigated.

Communication and consultation occurs throughout the risk management process because it provides the basis for information flow among stakeholders, fisheries managers, scientists and consultative committees. This EIS has involved extensive consultation and communication, including a stakeholder committee and internal workshops to assist in the identification of sources of risk and formulation of the draft FMS, DIPNR to develop the guidelines upon which this EIS is based, regional meetings to discuss the development and content of the draft FMS and EIS, targeted surveys of businesses groups, Aboriginal groups and the broader community about fish stocking, peer reviews of draft documents, consultation with Ministerial advisory councils, and finally public exhibition of this EIS. Consultation will also continue during the refinement of the FMS until its approval.

Ecosystem encompasses all ecological, physical and other processes that affect or are influenced by fauna and the operation of the activity. Therefore, ecological risk assessment must recognise all actions that influence all relevant processes that may affect the ecology of finfish and the environment in which they live. These include, for example, hydrological and geomorphological factors and biological factors, such as food-webs, interactions among species, interactions with habitats and processes of spawning, dispersal and recruitment and natural variability in population abundance (Underwood and Chapman, 1995; Underwood, 2000; Brodziak and Link, 2002; Heino and Godo, 2002).

Components of an ecosystem are the different aspects of the environment relevant to the activity of fish stocking being examined by the risk assessment. For the activity of fish stocking, the components are ecological relationships, threatened and protected species, other aquatic species that could be affected by fish stocking, habitats, genetic integrity of wild populations, fish health and disease, water quality, noise, light, air and energy. These components were identified in the guidelines for this EIS and during internal and external consultation. Components are used to systematically break down the ecosystem into manageable units and to ensure that no relevant component to the risk assessment is overlooked (Fletcher *et al*., 2002).

The identification and characterisation of risk due to stocking

To identify areas of risk, the activity of fish stocking was divided into its individual elements. The link between these elements and the broad components of the ecosystem was examined and broad-scale levels of risk assigned (Table B29). The components and elements were determined using a combination of the DIPNR guidelines and the consultation process involving internal staff and the RFFMPC. It is important to note that the elements of the activity can affect the environment both directly and indirectly and the risks of all of these effects need to be considered.

Some components of the environment were characterised at negligible risk due to the various elements of the activity of fish stocking. Justification of the risk levels for these components is given below, and they will not be considered in the more detailed risk assessment stage.

Table B29. Links between the elements of fish stocking and broad components of the environment. Where N = negligible, L = low, M = medium and H = high

	Elements of the activity of fish stocking							
Environmental components	Broodstock collection	Species to be stocked	Hatchery protocols	Information management	Stocking locations	Release of fish	Compliance	Lack of research and monitoring
Ecological processes	L	M	M	L	L	M	L	H
Threatened species	L-M	H	H	M	H	M	M-H	H
Other species	L	M-H	M	M	M	M	M	H
Protected areas or habitats	L-M	M	L	M	H	M	L-M	H
Other habitats	L	L	L	L	L	L	L	L
Genetic diversity	H	M	H	H	M-H	N	H	H
Diseases and pests	H	M	H	H	M-H	N	H	H
Water quality	N	N	L	L	L	L	L	L
Noise	N	N	N	N	N	N	N	N
Light	N	N	N	N	N	N	N	N
Air	N	N	N	N	N	N	N	N
Energy	N	N	N	N	N	N	N	N

It is not known to what extent ecological processes are affected by fish stocking, but given the current lack of research in such areas it is possible that it is having some as yet unknown effect. As stocking has been fairly widespread to date, it is also likely that effects could be widespread. For these reasons, the potential impacts of stocking will be reviewed in more detail in the risk assessment, as will any literature describing any effects of stocking on ecosystem structure or functioning.

All aspects of fish stocking are considered likely to place threatened species at risk and so this component will be covered in more detail in the risk assessment. Even the most apparently benign element of physically releasing the fish could affect these and other species, as well as ecological processes, as we do not know the fate and impacts of the released fish. The stocking database provides very little information about where fish are actually released. Releasing large numbers of fish into the modified environment of a dam may have limited ecological consequences, but they may be very different for more pristine or unmodified waterways.

It is not known to what extent fish stocking affects other species, but it is considered likely that numerous species other than threatened species are also at risk from stocking. Those species, loosely termed unlisted species or those of conservation concern, will be covered in more detail in the risk assessment. For brevity and to allow some degree of targeting at the species rather than faunal group level (e.g. fish), the assessment will focus on those aquatic species that are thought to have restricted distributions or reported declines in their abundance or distribution due to competition with, or predation by fish. If such declines were to continue, those currently unlisted species for which some information exists (thus primarily fish and frogs) could become listed. The risk assessment will determine the potential for fish stocking to cause or contribute to such an outcome. For a variety of other fauna, such as waterbirds, piscivorous bats, insectivorous bats that feed above waterways, as well as a plethora of invertebrates, the impacts due to stocking are likely to be extremely difficult to separate from numerous other factors responsible for their reported declines. Although a source of potential competition for some species, stocking fish into waterways may actually assist others, such as tortoises and piscivorous bats and birds, by providing a source of food that may have otherwise been unavailable. Such speculation or conjecture provides unnecessary complication into the risk assessment. That said, however, the draft FMS should consider research into whole-of-ecosystem impacts to better understand these potential impacts.

The review of the existing operation of the activity suggests that stocking is widespread, but it is not known how extensively or intensively stocking is conducted in protected areas or what effects it could have on the overall status of the area. There are a variety of areas broadly referred to as protected areas, ranging from those listed under relevant legislation, such as aquatic reserves, through to non-regulatory areas considered important habitats under State or Commonwealth policies or international agreements. Many of the latter areas that cannot be specifically defined, such as habitats thought to be important for migratory birds protected under the Japan-Australia or China-Australia Migratory Bird Agreements (JAMBA and CAMBA, respectively), are considered to be at low risk from stocking. These areas are primarily coastal and estuarine waters that are not part of the existing activity of fish stocking. The period of any interaction and overlap between any species that are common to inland waters and stocked fish, or a stocking event, is also likely to be minimal to negligible. Further, those inland areas that may be of some minor concern are likely to be well defined and thus covered under some other criteria, such as a Ramsar wetland.

The management of areas listed on the register of the National Estate is not affected by the listing, as the Commonwealth Government is the only body whose actions are constrained as a result of the listing. As such, those areas are considered to be at low risk due to fish stocking and will not be considered in the detailed risk assessment. Of the more than 1500 areas listed on the State Heritage Register, only 12 are considered 'natural landscapes' under the search criteria provided at the website (http://heritage.nsw.gov.au). Of those 12, only one appears to have been stocked in the past, and as a world heritage area, will be covered in more detail in the risk assessment. The other areas on the State Heritage Register are considered to be at low risk and will not be considered further.

Of the variety of protected areas that exist, only areas protected under the FM Act, NSW National Parks and Wildlife Act, Wilderness Act, Ramsar sites or world heritage areas are thought to be potentially at risk due to stocking and will be covered in more detail in the risk assessment.

Aquatic habitats in general are not considered to be at risk due to stocking. This is because the species that are currently stocked are not considered likely to significantly modify the habitats into which they are released. The species that are used in the existing stocking programs consist of natives and some salmonids. Introducing native species into their natural habitats or into the modified environments of dams and impoundments is generally considered to be a low risk activity. Salmonids are stocked into either dams or flowing waters, primarily with a rocky or gravel substratum, and some are able to establish spawning beds. Relative to other riverine impacts and natural changes in morphology, any potential modification would be limited in both its temporal and spatial magnitude. Salmonids are carnivores, feeding on a wide variety of aquatic crustaceans, molluscs, insects and fishes and terrestrial insects. As they do not primarily consume plant material, if ever, they will not be modifying aquatic flora, although consuming stream invertebrates that might otherwise consume algae or other plant material could have some effect on the floral character of waterways. If there were such an effect, it is likely to be highly localised and insignificant when compared to the many other factors that determine the distribution of aquatic flora. Overall, fish stocking is considered a low risk to aquatic habitats and so will not be considered in the risk assessment, however, the draft FMS should consider such issues within any whole-of-ecosystem research.

Almost all elements of fish stocking are considered to be a source of risk to genetic diversity of both stocked and wild populations of fish. This is particularly so for broodstock collection, hatcheries, information management by hatcheries and NSW Fisheries and the limited understanding of population dynamics of those native species currently stocked. This component will be reviewed in more detail in the risk assessment.

The transmission of diseases, pathogens and pest organisms is also highly probable during fish stocking, and it is broadly considered that the hatchery environment is the greatest source of this risk, along with the initial broodstock collection. Some fish diseases are already reported in NSW, such as the virus epizootic haematopoietic necrosis, which was probably introduced with redfin perch, has been found to infect native species. Redfin perch are not part of the current activity, but they serve to highlight the potential for disease transmission during stocking. These components will be reviewed in more detail in the risk assessment.

Water, noise, light and air are considered to be at low risk due to fish stocking. These aspects are generally covered under the aquaculture licence for hatcheries. Beyond that, most concerns about water pollution relate to the transmission of organisms, which will be addressed as described above. The release of contaminants that might have some environmental impact is considered highly unlikely as stockists should be able to notice that their consignment of fish appear unhealthy or stressed or that the water appears irregular in colour. Potential issues related to these aspects should be addressed in any management measures designed to mitigate other environmental risks. Any effects on the surrounding environment due to emissions of noise, light or airborne particulate matter are also considered to be negligible. These components will not be considered in the risk assessment.

In summary, the risk identification at the broader level suggests that all aspects of fish stocking are likely to be having some degree of environmental impact. Those environmental components deemed to be at the greatest risk and thus warranting finer detailed risk assessments are ecological processes/ecosystem functioning, threatened species, other unlisted species that are of conservation concern, protected areas, genetics and disease. These components and their risk assessment are presented in sections B2.1 to B2.6 below.

B2.1 Overview of the environmental impacts of fish stocking

Fish stocking has been occurring throughout the world for many decades, or even centuries, although it is only recently that a general awareness has been raised about the environmental and ecological effects of stocking fish (Taylor *et al.*, 1984; Allendorf, 1991; Krueger and May, 1991; Ham and Pearsons, 2001; Harris, 2002). The purpose of this overview is to critically evaluate the available information on the ecological impacts of fish stocking and the underlying mechanisms by which impacts occur. An understanding of these mechanisms is important for the evaluation of future impacts of fish stocking (Pearsons and Hopley, 1999), and for evaluating the extent and magnitude of existing impacts.

Many authors acknowledge that much of the evidence of impacts is anecdotal or circumstantial. This review begins by examining the utility of such evidence. The evidence for ecological impacts of stocking on the Australian biota is then reviewed separately for introduced salmonid stocking and native fish stocking, and the role of various ecological processes such as competition and predation are discussed.

B2.1.1 The nature and utility of evidence

In reviewing the evidence for impacts and the underlying mechanisms of those impacts, it is important to carefully evaluate the available evidence and the inferences or conclusions that can be validly drawn from it. Three sorts of evidence are considered:

Anecdotal: any evidence that is not backed up by data. Anecdotal evidence is subject to a large amount of uncertainty, but in many instances it is the only form of evidence available. For example, much evidence cited on the historical distribution of fishes is anecdotal.

Circumstantial: Any evidence cited in support of a theory that is backed up by data, but which is not inconsistent with other theories. Correlations are an example of circumstantial evidence, but correlations do not demonstrate causation. For example, if a native fish occurred in an area before stocking was done, but disappeared shortly after stocking it can be inferred that stocking might be a cause of the observed decline, but other causes cannot be ruled out. Other types of circumstantial evidence include observations such as similar diets between species, from which it could be inferred that competition between species is possible.

Experimental: only a well designed experimental manipulation with appropriate controls can unambiguously determine the ecological impact of fish stocking by explicitly ruling out the effects of all other factors. Very few such studies have been attempted anywhere in the world.

Most of the evidence cited in support of impacts of fish stocking is anecdotal or circumstantial. From a scientific viewpoint, circumstantial evidence is generally not considered sufficient to demonstrate an impact. Thus it is often stated that there is very little scientific evidence for impacts of fish stocking. It must be remembered, however, that the reason for lack of scientific evidence of impacts is that few experimental studies have been done, not that there are no impacts.

In the absence of experimental data, it is necessary to examine circumstantial evidence. Care must be taken in evaluating anecdotal and circumstantial evidence, because such evidence is open to a range of interpretations. Circumstantial evidence can provide necessary support for a particular explanation of observed events. Where circumstantial evidence runs contrary to a particular explanation, it may allow that particular explanation to be ruled out. Taken individually, circumstantial observations mean little. A large collection of independent circumstantial observations can, however, provide stronger (though still not unequivocal) support for a general conclusion because the greater the number of similar, independent observations, the smaller the probability of coincidence. Furthermore, circumstantial evidence of impacts of stocked fish is an important way of identifying areas where experiments are necessary to establish causality (Taylor *et al.*, 1984).

B2.1.2 Mechanisms of impacts

Australian and overseas studies have cited a range of mechanisms by which fish stocking may affect the ecology of aquatic systems. These include predation, competition, provisioning of fish, habitat alteration, incidental capture, loss of genetic diversity, and the introduction of diseases and pest species (Moyle, 1976; Taylor *et al.*, 1984; Fletcher, 1986; Cadwallader, 1996; Pearsons and Hopley, 1999). There are no published data on the frequency or impact of incidental capture on fish. The possible impacts of incidental capture are evaluated in sections B2.2 and B2.3 with respect to particular non-target native species. Loss of genetic diversity and diseases and pests are discussed in section B2.5.

B2.1.2.1 Competition

Competition has been suggested by several authors as a possible mechanism by which salmonids may impact native species (including threatened species). A widely accepted definition of competition is given by Andrewartha and Birch (1954): "...competition occurs whenever a valuable or necessary resource is sought together by a number of animals (of the same or different kinds) when that resource is in short supply; or if the resource is not in short supply, competition occurs when the animals seeking that resource nevertheless harm one or another in the process". Competition is generally thought of in terms of food or space/habitats. The ecological consequences of competition between species can include shifts in patterns of resource use, reduction in growth, reproductive, output or survival, or (in theory) complete competitive exclusion of one species.

All of the evidence cited for competition between stocked salmonids and native fish is based on overlapping diets, sometimes in combination with negative correlations in patterns of distribution (McKeown, 1934; Butcher, 1945; Jackson, 1976). While the demonstration of common resources is necessary for competition to be inferred, it is not sufficient to demonstrate that competition has either occurred or is important (i.e. competition may occur, but may not be the process responsible for the observed negative correlation (Underwood, 1986). Ideally, evidence of an impact due to competition would come from field experiments designed specifically to detect competition, but unfortunately no such studies have been done on stocked fish.

Competition for food

Competition for food with salmonids is thought to be responsible for the decline of the Macquarie perch in some areas (Butcher, 1945; Cadwallader and Rogan, 1977). This suggestion is based on the considerable dietary overlap and distributional overlap of these species, coupled with observed declines following the introduction of trout.

Tilzey (1976) reported significant dietary overlap between *Galaxias olidus* and rainbow trout in the Eucumbene catchment. Jackson (1978a) and Butcher (1945) reported overlap in the diets of river blackfish and trout in the Aberfeldy river, northern Victoria. Cadwallader (1978), suggested that *G. olidus,* golden perch, Macquarie perch and river blackfish all have similar diets to brown trout.

Fletcher (1979) examined brown trout and *G. olidus* diets in four rivers and found that they were quite similar. In an experimental addition of trout to a 70m length of one stream, the two species consumed similar foods. During the course of the experiments the galaxiids in the trout section lost condition (= weight x 10^5/ length^3) relative to those in the control section. It was inferred that competition for food was responsible for the loss of condition. Fletcher suggested that both exploitation and interference competition could be responsible, although she did not find evidence that food was in short supply. Interference competition is possible, where trout defend areas of the stream against intruders, resulting in galaxiids being relegated to less favourable habitats.

Similar data on the overlap of diets between New Zealand natives and introduced salmonids is reviewed by Crowl *et al*. (1992).

Competition for space

Information about competition for habitats from Australia is sparse. Overseas studies have shown that salmonids compete vigorously for space, displacing other species and smaller individuals of their own species through aggressive behaviour (e.g. Taylor *et al.*, 1984; Krueger and May, 1991; McMichael *et al.*, 1999). In a New Zealand study, trout displaced galaxiids from their optimal feeding locations in stream channels (McIntosh *et al.*, 1992). Little is known about such interactions in Australia, but they are possible where fish have similar habitat requirements. Cadwallader (1978) reported that trout cod (a native and not related to trout) establish territories in suitable habitats and defend them vigorously. This may lead to competition between salmonids and trout cod where their distributions overlap. Many of the other non-migratory native species are also very territorial, particularly at breeding times. River blackfish in particular, are very territorial during spawning, and also share similar depth and velocity requirements with brown trout.

B2.1.2.2 Predation

For the purpose of this assessment, predation is defined as the consumption of all or part of one animal (prey) by another (the predator), resulting in death of the prey. The most obvious ecological consequence of predation is the decline in the abundance of prey species. There is ample evidence that salmonids are predators of native species. For example, Butcher (1945) reported that trout stomachs contained Macquarie perch, galaxiids and river blackfish. Butcher (1967) reported that trout consumed small trout cod. Cadwallader (1979) found river blackfish and southern pygmy perch in trout stomachs, along with numerous unidentified tadpoles. Jackson (1978b) reported the consumption of river blackfish by trout in the Aberfeldy River, Victoria. Cadwallader and Eden (1982) reported an average of 10 galaxiids (*G. maculatus*) per rainbow trout stomach from Lake Purrumbete in Victoria. These authors also cited data from 1967 that showed 25 galaxiids per trout stomach, and suggested that a documented decline in the growth of trout was caused by the decline in galaxiids. Similar reports of decline in native fish prey abundance followed by decrease in growth rate of trout in New Zealand are reviewed by Crowl *et al*. (1992).

Impacts of introduced salmonids on native frogs are most likely to be due to predation on the tadpoles. The tadpoles of some frog species have chemical defences against predation, which make them unpalatable to predatory native fish. It is argued that such defences are likely to have evolved in response to particular predator species, and thus are unlikely to be effective against recently introduced predators, such as salmonids (reviewed by Gillespie and Hero, 1999). There is some evidence consistent with this hypothesis for Australian frogs. Gillespie (2001) conducted experiments in which either native fish (mountain galaxias or river blackfish) or brown trout were placed in containers with tadpoles of one of four species. Three of the frogs were stream dwelling species that occur naturally with native fish. The fourth was a species that occurs in ephemeral pools not normally occupied by fish, and was used as a known palatable control. It was predicted that after 24 hours, the stream frogs would be consumed in very low numbers if at all by native fish, while the non-stream species would be consumed in large numbers, and that the trout would consume all of the frog species. The results were consistent with this prediction, supporting the hypothesis that the frogs' defences were ineffective against trout. Similar results have recently been obtained from experiments on the Booroolong frog (David Hunter, University of Canberra, pers. comm. 2003).

Where it has been estimated experimentally (for *G. olidus* and spotted tree frogs), the magnitude of predation effects has been found to be large. Lintermans (2000) reported a 15-fold increase in mountain galaxiid numbers following trout removal. Gillespie (2001) reported 50% mortality of spotted tree frogs over 4-6 days, and Fletcher (1979) reported a 60% decline in *G. olidus* over 4 months when trout were introduced. Garman and Nielsen (1982) found a 30% decline in prey population over 7 months. For other native species such as galaxiids other than *G. olidus*, river blackfish, Macquarie perch, southern pygmy perch, trout cod and other frog species, the magnitude of predation effects is unclear. The larger species such as blackfish, Macquarie perch and trout cod may only be vulnerable as juveniles. The other fish species would be vulnerable throughout their life history, while the frogs are most vulnerable during the tadpole stage.

B2.1.2.3 Provisioning

Stocked juvenile fish may constitute a source of food for naturally occurring wild fish and for previously stocked fish. No information is available on the ecological effects of such provisioning in Australia, although it has been reported to occur in North America (Pearsons and Hopley, 1999). Provisioning may be mitigated in some cases if stocking is avoided in areas where predators are abundant. For example, trout are stocked in montane areas where other predatory fish are scarce, and Australian bass are not stocked into eastern cod areas. Provisioning of birds, particularly cormorants, is possible. Provisioning of pest species, such as redfin perch, is another aspect that has not been considered in the literature. This may enhance the abundance of the pest species, thereby limiting the viability of future stocking events. The effect of provisioning is likely to be small, due to the small biomass of fish involved and its relative infrequency. Therefore, provisioning seems unlikely to cause a negative impact.

B2.1.2.4 Habitat alteration

There is no information on habitat alteration by stocked fish, nor are any stocked fish known to physically alter their habitat. Salmonids may alter part of their habitats during spawning, by digging up spawning sites ("redds"), but there are only a few trout spawning streams in NSW, thus limiting the potential for such an impact. In one North American study, massive stocking of Coho salmon led to exceptionally large spawning runs, which reduced benthic invertebrate density by 66% and biomass by 78% relative to replicate control sites (Hildebrand, 1971). Five months later, the density of invertebrates was still 39% lower at the spawning site than at the controls. Huryn (1996), in a study in New Zealand streams of the effects of trout on stream invertebrates, reported a similar result. Huryn suggested that in productive trout streams (i.e. >100kg wet mass trout/ha/year), trout may consume most (>80%) benthic prey production. Such impacts have not been investigated in Australia, but they are possible. Brown trout and rainbow trout dig similar sized redds to those of Coho salmon (Crisp and Carling, 1989).

B2.1.3 The impacts of fish stocking

Almost all of the work published on impacts of fish stocking in Australia and overseas has focused on salmonids. This is because salmonids have a much longer history of stocking in Australia than native fish, and comprise the majority of the fish stocked in NSW (see Chapter B1) and overseas. Furthermore, as an introduced species, the stocking of salmonids has historically been of greater concern to conservationists and scientists than stocking of native fish. Moreover, stocking of salmonids is geographically separated from stocking of native fish – salmonids are stocked only in montane areas, whereas natives are generally stocked at lower altitudes. Therefore, this review of ecological impacts of fish stocking is divided into two sections: impacts of stocking salmonids and impacts of stocking natives.

B2.1.3.1 Impacts of salmonid stocking

Impacts of salmonid stocking in Australia have been reviewed a number of times (Butcher, 1967; Weatherly and Lake, 1967; Arthington, 1991; Crowl *et al.*, 1992; Cadwallader, 1996; Gillespie and Hero, 1999). Most authors conclude that although the evidence is mostly circumstantial, there is little doubt that the stocking of salmonids has contributed to observed declines of native fish and frogs in Australia (Arthington, 1991; Crowl *et al.*, 1992; Cadwallader, 1996). There is great uncertainty, however, as to the relative contribution of salmonid introductions and other factors such as land use, to the decline of native species remains. Until there is more experimental and less reliance on circumstantial evidence, it is unlikely that this controversy will be resolved.

Evidence for impacts of salmonid stocking are divided into four categories (following Cadwallader, 1996): spatial patterns; before/after studies; habit modelling studies; and experiments.

Evidence from spatial patterns

Several authors have reported observations of non-overlapping distribution between salmonids and native fish, primarily galaxiids, as evidence in support of salmonid impacts. It is assumed that the native fish formerly occupied the waters occupied by trout, and it is inferred that trout are responsible for the decline or disappearance of the native species. Whilst it is easy to see how such conclusions might be reached, there are weaknesses in this approach. First, it makes an untested assumption about the distribution of the native species, and second, it fails to rule out alternative explanations for the decline of native species. Nevertheless, such information can be useful in indicating areas for further investigation (Taylor *et al.*, 1984). Here the evidence from Australia is briefly reviewed. Similar studies from New Zealand are reviewed by Crowl *et al.* (1992) and to a lesser extent by McDowall (1989). In common with the studies described below, the New Zealand studies report significant impacts on native galaxiids and grayling, as well as a variety of other species of fish, due to the introduction of salmonids. They are reported by some authors (Rutherford, 1901 and Donne 1927, in McDowall 1989) as being partly responsible for the extinction of New Zealand grayling (*Prototroctes* *oxyrhynchus*), although the exact causes are not understood and the species is thought to have been in decline prior to the introduction of salmonids.

Frankenberg (1966) reported that galaxiids in the headwaters of the Kiewa River were found only in areas inaccessible to the brown trout which occupied the main body of the stream. It was concluded that trout had caused the fragmentation of the galaxiid populations (Frankenberg, 1966). Tilzey (1976), surveyed 27 streams in the Eucumbene catchment. Trout occurred in 26 streams and the native fish, *Galaxias olidus*, only occurred in the one stream not occupied by trout. *G. coxii* (now recognised as *G. brevipinnis*) occurred with trout but was only found in three streams. Although historical data were lacking, it was assumed that trout were responsible for fragmentation of the galaxiid population. Similarly, Fulton (1978) reported that *Galaxias fontanus* only occurred in the absence of brown trout in the Swan River, Tasmania. Cadwallader (1979) found that although *G. olidus* was widespread in the Seven Creek System, Victoria, it only occupied the upper reaches of streams above waterfalls that trout could not pass. Trout occurred immediately below these barriers. In concluding that trout had caused the fragmentation of these populations, it was presumed that *G. olidus* formerly occurred throughout the system. It was also speculated that the limited distribution of trout cod and river blackfish in that system might also have been partly caused by trout (Cadwallader, 1979).

Fletcher (1979) sampled above and below barriers (waterfalls) to trout movement in four Victorian streams. Two of the streams were sampled four times, one was sampled once and the fourth twice. Brown trout occurred below the barrier in all streams. In three of the streams *G. olidus* only occurred above the waterfalls. In the fourth stream, it was present above and below the waterfalls, but at very low density below the falls.

Jackson and Williams (1980) surveyed three areas in Victoria, two of which contained brown trout. At the two sites where trout were present, they were negatively correlated with the distribution of galaxiids. In the upper Yarra, the abundance of *G. olidus* was negatively correlated with trout abundance. In the Otway ranges, *G. brevipinnis* was only found in the absence of brown trout. *G. truttaceus* and *G. maculatus* occurred with trout, but only where trout were not abundant. At Wilsons Promontory, where trout were not found, galaxiids occurred at all sampling stations. Jackson and Davies (1983) found that *G. olidus* and brown trout did not coexist in the Grampians, Victoria.

Similar observations have been made for some high country frogs, namely the spotted tree frog and Booroolong frog. Both of these species are listed as endangered under the Threatened Species Conservation Act, and although trout are considered one of numerous threats to both species, trout *per se* are not listed as a Key Threatening Process under the Act. The spotted tree frog breeds in montane streams. It occurs in high densities in only one location of the fourteen currently known, and this is the only site that is free of salmonids (Gillespie, 2001). The Booroolong frog also breeds in trout streams in New South Wales, and has declined in numbers (Gillespie and Hero, 1999). In NSW, the Booroolong frog was known to occur predominantly along western-flowing streams of the Great Dividing Range, from catchments draining the Northern Tablelands, to Tumut River in the Southern Highlands, and other tributaries of the Murrumbidgee River. In the past ten years, there have been very few sightings. Its distribution overlaps most of the trout streams in NSW, and as an introduced predator, they are listed as threat to the species.

Before/after studies

Some studies have demonstrated a decline in abundance of native species immediately following the introduction of salmonid species. It is argued that such studies provide stronger evidence for impacts of salmonids than those that describe disjunct distributions, such as those described above (Crowl *et al.*, 1992). This is presumably because the short time frame and small spatial scale of the observations rule out other processes such as changes in land use, which generally operate on larger spatial and temporal scales than fish introductions.

Frankenberg (1966) reported the disappearance of *G. coxii* (now *G. brevipinnis*) from Lake Tarli Karng in Victoria following the introduction of brown trout. Tilzey (1976) reported a rapid decline in *Galaxias olidus* in a section of stream below a waterfall following the introduction of trout. Trout were initially absent from the stream. Three years after their introduction, trout occupied the area below the waterfall and *G. olidus* were absent, but were still present in the trout-free area above the waterfall. Closs and Lake (1996) observed the progressive decline of *G. olidus* over four years as brown trout recolonised a river in Victoria following a drought. Similar observations have been made in numerous studies in New Zealand (reviewed by Crowl *et al.*, 1992).

Similar observations have been made for frogs. The spotted tree frog was observed to disappear from one Victorian site following the arrival of trout (Gillespie, 2001). Trout are known to occur in all sites from where the spotted tree frog has disappeared (Gillespie and Hollis, 1996), although frogs also disappeared from some sites with no trout. Similar observations of amphibian declines coinciding with salmonid introductions have been made in Europe, Britain, North America, South America and Canada (reviewed by Gillespie and Hero, 1999).

While the circumstantial evidence discussed above does not provide conclusive evidence that the observed changes were caused by salmonids, it does implicate salmonids as a likely cause, and indicates that further investigation needs to be done into salmonid impacts. These distributional and before/after studies are often the results of general fish surveys and are not designed specifically to test hypotheses about impacts of stocked salmonids. Studies designed to detect specific hypotheses are discussed below.

Habitat modelling studies

Townsend and Crowl (1991) surveyed 198 sites in New Zealand for the presence of *Galaxias vulgaris* and brown trout. The galaxiid is very similar in its biology to Australia's mountain galaxias (*G. olidus*). Their survey examined equal numbers of sites in undisturbed and disturbed (by agriculture and forestry) catchments and with and without trout in order to separate the possible effects of trout and land use. At each site, 23 physical, chemical and biological variables were measured. The major findings were that a negative association existed between galaxiids and trout, that both galaxiid and trout numbers were smaller in degraded habitats, and that the best biological predictor of galaxiid presence was the absence of trout. The best physical predictor was the number of waterfalls greater than 3m in height present downstream of the survey site. These waterfalls are known to be a barrier to trout movement. The conclusion was that trout were the most important cause of galaxiid decline. The authors speculated that predation was the most likely process by which trout had reduced the distribution and abundance of the galaxiid.

In a similar study done in Tasmania, Ault and White (1994) used population abundance models based on habitat variables from 35 sites without brown trout and then attempted to predict the abundance of *Galaxias truttaceus* in sites with trout. They found that actual galaxiid abundances in the presence of trout were far smaller than those predicted by the model. Unfortunately, the reliability of the model was not evaluated by making predictions for additional trout free sites, although the authors stated that trout sites were "not atypical" of those used to derive the models.

Experimental manipulations

The best evidence for impacts of salmonids comes from manipulative experiments designed to test specific hypotheses. Unfortunately, few such studies have been done either in Australia or overseas. The findings of four experiments are discussed below, followed by a discussion of the limitations to interpretation of their results.

Fletcher (1979) conducted a trout addition experiment in a section of Watchbox Creek in the Strathbogie Ranges, Victoria. The creek had a self-sustaining population of brown trout below a waterfall and galaxiid (*G. olidus*) population above the waterfall. Trout were stocked into a fenced off 70m long section of the stream containing *G. olidus* above the waterfall, and a 70m section upstream of the trout section was used as a control. After four months, galaxiid numbers in trout section were 40 % of those in control section. Galaxiid condition factor (= weight x 10^5/length^3) was significantly lower in the trout section. The abundances of some aquatic invertebrate taxa also differed between trout addition and control treatments at certain times during the experiment. For example, two ephemeropteran species increased in the trout section, consistent with observations of greater abundance in pre-existing trout areas. Chironomids, stoneflies and mayflies were more abundant in non-trout areas (containing galaxiids) and trichopteran species were more abundant in the trout sections. Chironomid diversity was lower in the galaxiid section, and one species, *Cricotopus* sp. appeared to decline in the trout section. A hydroptilid beetle and a trichopteran both had greater abundances in the control section at various times during the experiment. Differences in invertebrate numbers between stream sections with or without trout were generally consistent with observations on natural trout and non-trout sections of the stream.

Garman and Nielsen (1982) divided a reach of montane stream in Virginia, USA, into three sections separated by barriers to fish movement to examine the impact of non-native brown trout on the fish assemblage. Sections 300m long were stocked with 100 small (200-250mm) or 150 large (300-305mm) brown trout, and the third section (100m) was not stocked. Stomach content analysis showed that both large and small trout consumed native fish, but fish were a negligible part of the diet of small trout. Assemblages of fish changed dramatically in the large trout treatment, with the main prey species declining by 30% over seven months.

Lintermans (2000) performed a trout removal experiment in Lees Creek, a tributary of the Cotter River in the ACT. Rainbow trout were removed from a site above the weir using rotenone and stop-nets, while two sites downstream of the weir were used as instream control sites. Two other streams containing rainbow trout were also monitored as external control streams. It was predicted that following the removal of trout from above the weir, *G. olidus* would re-colonise from further upstream and be found in greater numbers than at sites below the weir or in the external control sites. The hypothesis was supported by the data, and it was concluded that the absence of trout was responsible for the increase in galaxiids above the weir over four years of monitoring. Lintermans (2000) demonstrates that galaxiids were not absent from the trout removal section because of unsuitable habitat, but due to the presence of trout. Furthermore, it demonstrates the impacts due to salmonids are reversible.

Gillespie (2001) experimentally introduced rainbow trout into a section of stream containing tadpoles of the spotted tree frog and the leaf green tree frog. Trout were left in the experimental pool for four to six days, and the survival of tadpoles was recorded at the end of each trial. The presence of trout significantly reduced the survival of both species, by 50% in the case of spotted tree frog.

Limitations of studies that have examined the effects of stocking salmonids

The ability to generalise from the results of each of these four experiments may be constrained because of some limitations of their designs, which are discussed below. Such limitations are largely due to the numerous constraints of doing large-scale, manipulative field experiments in rivers and streams, but may also reflect a lack of understanding of experimental designs that are required to detect environmental impacts (see Underwood, 1991).

Lack of replication

Fletcher (1979) and Lintermans (2000) used only one experimental treatment site (i.e. trout removal or addition). Garman had two trout addition sites, but each represented a different intensity of stocking and is thus a different treatment. This lack of replication means that the results cannot be unambiguously attributed to the effects of adding trout, but may be due to inherent differences between the creek sections themselves - for example in Fletcher's case an unidentified disturbance unique to the downstream (trout) section could have been responsible for the decrease in galaxiid numbers. Similar issues occur in each of the experiments described above. Nevertheless, the fact that these four independent experiments, each testing the same general hypothesis, all reached the same conclusion suggests strongly that the presence of trout was responsible for the observed differences between treatments.

Lack of independence

The stream studies had experimental and control sites within a single stream, with the sites arranged along the stream. Such sites cannot be considered to be independent because one is directly downstream of the other, meaning that there is likely to be a positive correlation between the treatments (Downes *et al.*, 2002). For example, in Fletcher (1979), invertebrates may be washed downstream from the control site to the trout site, making the two sites more similar than they would have been if trout were reducing the invertebrate abundance. Such non-independence would therefore decrease the probability of detecting a significant difference, thus the finding of difference a between the sites is not erroneous, but the magnitude of the difference may be underestimated (Underwood, 1997; Downes *et al.*, 2002).

Lack of procedural controls

Experimental manipulation of fish density involves various procedures such as removal of fish or fencing off areas of stream, which in themselves could cause changes to the abundance of fish. In Lintermans' (2000) case for example, the recolonisation by galaxiids could be an artefact of the rotenone and netting treatment, and nothing to do with trout removal. While this seems improbable, it must be considered as a possibility. Nets placed across streams may prevent the natural migration of animals, causing them to accumulate upstream of the net. Such experimental artefacts were not discussed in any of the above studies.

Despite their limitations, when considered together, the experiments all suggest that trout are capable of having a substantial and rapid impact on smaller native fish and tadpoles.

B2.1.3.2 Impacts of stocking native fish

There are few ecological studies on the impacts of stocking native fish within their natural range and there is very little consideration of such impacts in the Australian literature. This is probably because widespread stocking of native fish into rivers is a relatively recent phenomenon, and also because stocking natives within their natural range is perceived by many as an ecologically benign activity. In the following section, the potential impacts and mechanisms are proposed based on overseas experience, theoretical considerations and knowledge of the basic biology of the species concerned. Much of the concern associated with stocking native fish has to do with the genetic consequences for wild populations (see section B2.5).

Competition

Dietary studies indicate that competition between stocked and wild native fish is possible where their distributions overlap. For example, the diets of Australian bass, Macquarie perch, Australian grayling, and catfish overlap to some extent (Harris, 1985). Similarly, there is overlap between diets of golden perch, Murray cod, trout cod and, to a lesser extent, silver perch. Competition between native species that naturally co-exist would normally be regarded as a natural process, although in the case of fish stocking where large numbers of similar aged fish are released into a small area, the effects of competition could be greater than would occur naturally and could, therefore, have an effect on native species over and above what would be considered natural. The intensity of competition could be further increased if the habitat is degraded such that resources are not abundant (Fletcher, 1986). The possible occurrence and implications of competition between stocked and wild native species is discussed with detailed reference to particular species in sections b and c of this chapter.

Overseas studies have found that hatchery-reared fish are more aggressive, grow faster and tend to dominate competition for space and food with wild fish (McMichael *et al.*, 1999; Reinhardt *et al.*, 2001). Aggressiveness in hatchery-reared Australian natives is not known, primarily because it has not been studied, but native fish reared in hatcheries may become domesticated (Stuart Rowland, NSW Fisheries, pers. comm.). It is not known how this affects their survival or interactions with wild fish in Australia.

Predation

All of the native species currently stocked (except silver perch) are predators on other fish, and impacts on wild fish due to predation must be considered possible, although no information is available on the effects of predation by stocked natives on wild fish in Australia. Predation of native fish by native fish is a natural process and would not normally be considered an impact. In the case of stocking, however, where large numbers of hatchery-reared fish are released, predation by the stocked fish could have an impact on wild fish. This is particularly pertinent for the smaller prey species and/or wild juveniles of the stocked species. It is further acknowledged that stocked fish, of either native or non-native species, may prey on or compete with pest species, such as redfin perch or carp. The possibility and effects of such interactions are discussed with respect to particular species in sections b and c of this chapter.

B2.1.3.3 Impacts of stocking on ecological communities

For this assessment, the term ecological community is taken to mean the assemblage of animals and plants that occupy a given area of study. As well as having direct impacts on other species through interactions such as competition and predation, fish stocking may affect a range of other species in the ecological community through indirect interactions. For example, Garman and Nielsen (1982) found effects of large brown trout (> 300mm long) on four fish species. Two prey species decreased, which was attributed to the effects of predation, while two non-prey species increased, relative to a control area. This increase may have been due to an indirect effect of the reduction in prey species abundance, such as reduced competition with the prey species.

Mechanisms of impacts on multiple species could be the result of simultaneous direct interactions, such as competition and predation, or the result of indirect species interactions mediated by other species. The trophic cascade is the best known example of indirect species interaction in aquatic systems. In some temperate lowland streams and lakes of North America, a four-tiered cascade operates in which top predators suppress the smaller fish and insect predators, allowing grazers to flourish, thereby decreasing the abundance of primary producers (Power, 1990). Similarly, a three-tiered cascade involving predatory fish, grazing invertebrates and algae has been demonstrated in fast-flowing montane streams in Canada (Rosenfeld, 2000) and New Zealand (reviewed by McDowall, 2003). Most such trophic cascades have algae as the primary producer, are characterised by low species diversity, and are isolated discrete freshwater habitats, streams and mesotrophic lakes (Strong, 1992). In such systems, the impact of fish introduction on the broader ecological community could potentially be large.

Work on trophic cascades in Australia has focused on the potential for control of blue green algae through manipulation of the food web (Boon *et al.*, 1994; Gehrke and Harris, 1994; Matveev, 1995; Matveev and Matveeva, 1997; Matveev, 1998)). Matveev and Matveeva (1997) found that in Lake Hume and Lake Dartmouth, zooplankton could exert significant effects on phytoplankton, accounting for a significant proportion of the residual variance in the chlorophyll *a* - total phosphorus relationship. There is, however, insufficient data to answer the question of whether planktivorous fish regulate zooplankton communities in Australian impoundments (Gehrke and Harris, 1994).

Very little work has been done on trophic cascades in Australian streams. Closs and Lake (1994) found that manipulating the density of *Galaxias olidus* had little effect on the abundance of benthic invertebrates in a Victorian upland stream. This result is consistent with that of Flecker and Townsend (1994) in New Zealand, where galaxiids had little effect on invertebrate numbers or algae.

The effect of salmonids on trophic cascades in Australia has not been examined, but similar results to those found in New Zealand are likely given the similarity between the Australian and New Zealand stream faunas. Flecker and Townsend (1994) induced a trophic cascade in an artificial stream channel experiment in New Zealand. Replicate stream channels (5m by 0.38m) containing natural substrata were placed in a stream, and invertebrates and algae allowed to colonise them over ten days. Three treatments were used, no fish, 10 galaxiids or 10 juvenile trout, were placed into each channel. Fish in each treatment were similar in size, and the densities used were within the natural range of densities found in the area. The invertebrate fauna and algae were sampled after a further 10 days. In the presence of trout, the abundance of invertebrate grazers and predators decreased, and the abundance of algae increased. In contrast the galaxiid and control channels were similar to each other and had more insects and a smaller biomass of algae. Thus, a trophic cascade occurred in the presence of trout but not galaxiids. It was concluded that the introduction of trout had community-wide effects.

Huryn (1998) found evidence of a trophic cascade in a New Zealand stream. He compared two adjacent tributaries, one containing trout and the other containing galaxiids (*G. eldoni*). In the galaxiid stream, only 18% of invertebrate prey production was required to support the fish population, and the invertebrates consumed 75% of the primary production (periphyton). In contrast, trout consumed almost the entire invertebrate production, and the remaining invertebrates consumed only 21% of the primary productivity. The smaller invertebrate abundance and greater periphyton abundance was attributed to the presence of trout. This is consistent with observations from other areas where trout streams had more periphyton than galaxiid streams (Biggs *et al.*, 2000).

Such impacts may be caused by direct effects of trout predation on invertebrates, and also by alterations in the behaviour of invertebrate prey species in the presence of trout. McIntosh and Townsend (1996) found that when trout were present, insects spent more time beneath the cobbles and less time feeding on periphyton than they did in the presence of galaxiids. This behavioural change in the presence of trout contributed to decreased periphyton through suppression of grazing, and could impact on galaxiids by making their food less accessible.

After reviewing the recent literature on salmonid-galaxiid interactions in New Zealand, McDowall (2003) concluded that in addition to direct interactions such as competition and predation, salmonid stocking in New Zealand has had an impact on native fish through a feedback loop in which native fish are less able to obtain food due to changes in their own behaviour, insect behaviour and insect abundance, all of which are induced by trout predation.

B2.1.4 Discussion – the role of fish stocking in ecological change

It is clear from the above review that the impacts of fish stocking and their underlying mechanisms are poorly understood, despite a strong circumstantial case for the occurrence of impacts attributable to stocking. It can be concluded that fish stocking has probably had a significant impact on the distribution and abundance of some native fish and frogs. Further, in the case of the spotted tree frog, these impacts are thought to be one of the causal factors in the decline in distribution and abundance of the species. Predation is a likely ecological mechanism of impact of salmonid stocking, and while competition is possible, its relative importance is not known. There is even less information for stocked native species, and the likely ecological impacts of stocking these species are largely speculative.

Several processes have contributed to the observed declines in faunal abundance. Such processes include alteration of flow regimes, loss of riparian vegetation, land clearing and mining leading to siltation, species introductions and removal of woody debris and fish stocking. The causes of any given faunal decline are likely to be complex, involving several different processes operating at different spatial and temporal scales. It is difficult to evaluate the relative contributions of these processes versus fish stocking to the decline of native fauna for two main reasons. First, fish stocking and other activities pre-date comprehensive surveys of native aquatic fauna. Second, very little quality research has been specifically directed at either the impacts of fish stocking or the impacts of the other activities listed above (Mallen-Cooper, 1992). This second point urgently needs to be addressed in order to ensure that stocking will not contribute to further declines in native fauna.

The implications of the lack of research for this EIS are that assessments of ecological risks posed by stocking must, for the most part, be done without even the most basic knowledge of species interactions. For this reason, the risk assessment must necessarily err on the side of conservatism with regard to environmental concerns, in line with the object of ecologically sustainable development given by the *Fisheries Management Act 1994* (section 3(2)(c)). It is highly undesirable, however, to continue to rely on the precautionary principle to argue for or against stocking - more research into the ecological effects of fish stocking is essential if management practices are to improve. Dismissing circumstantial evidence and then citing lack of scientific evidence of any impacts of past stocking as a reason to continue current stocking practice is not a justifiable position. Only when the underlying causes of the large body of circumstantial evidence for impacts of stocking have been investigated in a scientifically rigorous manner can either claim of impact/no impact be substantiated.

B2.2 Threatened and protected species or habitats

For this assessment, 'threatened species' refers to any species, populations or ecological communities and their habitats as defined and listed under Schedules 4 or 5 of the *Fisheries Management Act 1994* (FM Act), Schedules 1 or 2 of the *Threatened Species Conservation Act 1995* (TSC Act) or subdivisions C or D of the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). This assessment also includes any species of fish listed as protected under Sections 19 (totally protected – not to be taken) or 20 (not to be taken by commercial fishers) of the FM Act, with the exception of salmonids.

The species listed below have been selected from their respective schedules because an assessment of their distribution and other ecological aspects suggest that they could be affected in some way by the activity of fish stocking (Tables B29 to B31). Twenty-five threatened species, one larger threatened group (the freshwater crayfish) and one endangered ecological community are identified as being potentially affected by fish stocking (Tables B32 and B33).

B2.2.1 Evaluation of risks to threatened species from fish stocking

Threatened species are protected by state and federal legislation that aims to conserve and promote their recovery. The risk ratings given below, therefore, refer to the risk that any aspect of stocking would impede the conservation and recovery of a threatened species.

The general approach for the assessment of risk to threatened species due to fish stocking follows that of Pearsons and Hopley (1999). The overlap and ecological interactions with stocked salmonids and stocked native fish are evaluated for each threatened species. Overlap and interaction effects are each assigned a value of low, medium or high, based on a set of rules given below. Risk is defined as the probability that stocking would impede the recovery of the species. The level of risk is assigned according to a matrix (Table B29), which takes into account both the overlap and likely interactions between the species. Thus, a species that is highly vulnerable to predation, but has only a small geographical overlap with a stocked species, would be assigned a lower risk than a similarly vulnerable species with large geographical overlap.

Two caveats apply to the interpretation of the assigned risk levels. First, it should be noted that the risk assigned to a species pair is not necessarily indicative of the cause of decline of the species. For example, the western population of the purple spotted gudgeon is considered to be at high risk from stocking of golden perch and Murray cod. This does not necessarily mean that stocking these species has contributed to the historical decline of the gudgeon throughout the Murray-Darling basin (and, therefore, to its status as an endangered population), but merely that stocking under current management arrangements poses a risk to the species. The risk arises because the species is known from a small number of locations, all of which may be subject to stocking, and is vulnerable to predation by the stocked species.

Second, it is recognised that processes other than fish stocking pose a risk to threatened species. While the risk assessment provided here considers the risk to the species in the context of these other processes, it does not provide an assessment of risk for those processes, as they are beyond the control of the draft FMS, which are the management measures that this assessment will influence. Thus, a species assigned a low risk from stocking may still be at high risk from other factors.

Importantly, however, it is because there are multiple anthropogenic impacts that affect species that any potential impacts due to stocking need to be addressed more cautiously, mindful of the collective or cumulative impacts.

B2.2.1.1 Evaluation of overlap

Overlap is considered on a broad, geographic scale (10s to 100s of km) and on a microhabitat scale. At the geographic (or reach) scale, it can be difficult to precisely quantify the degree of overlap between fish species. For many threatened species, there are relatively few records of geographic distribution, and many of these are too old to be considered representative of current distributions. Where no information is available on microhabitats of the species, it is assumed that the species occupy the same habitats. This is reasonable, because most fish utilize a diverse range of different habitats in Australia's variable and unpredictable drainage systems (Morris *et al.*, 2001).

Further, historical distributions of most native species, but particularly threatened species, are rarely based on comprehensive faunal surveys over extended periods. For this reason, despite any findings in the risk assessment, the draft FMS will need to be precautionary and consider measures that allow those species to expand their current range.

Four broad categories of overlap are used. These correspond to approximately 0%, >0-20%, 20-50% and 50-100% overlap of the threatened species range with waters eligible to be stocked with a certain species under consideration.

The categories of overlap are:

None: there is no geographic overlap between the stocked and threatened species. For example Australian bass are stocked only in eastern drainages, and thus, do not overlap with threatened species that only occur in western drainages

Low: limited overlap between the stocked species and the range of the threatened species. For example, if the overlap occurs at the geographical limits or marginal habitats of the species distributions, it would be considered small. Overlap may also be small if it can be demonstrated that although the species geographic ranges overlap, they occur in distinctly separate habitats

Medium: some overlap within the main core of the species current or former range, but probably less than half of the area occupied (or formerly occupied) is stocked or eligible for stocking

High: the majority of the species current (or former) range is eligible to be stocked, and the species occur in the same habitats.

B2.2.1.2 Evaluation of the effects of ecological interactions

The ecological interactions with stocked fish considered most likely to affect threatened species are predation and competition (see section B2.1). Genetic, disease and species translocation impacts are considered elsewhere (Sections B2.5 and B2.6).

There is limited data on the interactions between Australian freshwater fish. Therefore, in many, the potential for interactions and their likely effects on the threatened species are inferred from knowledge about the biology, feeding habits and other resources used. Data are used where available. Species are assigned interaction scores based on the predicted or actual (where data are available) consequences of their interactions with the threatened species under consideration. Interaction scores are assigned according to the following criteria:

Low: predation by stocked fish on the threatened species is unlikely given the size of the threatened species, or because the stocked species is not a predator. Competition is considered to be unlikely because the resources used by the species (e.g. habitat, food) are different

Medium: predation and/or competition are likely, but the consequences of these interactions may be considered to be moderate for various reasons. For example, the potential for predation and/or competition may be great, but research has shown that the effects are not as serious as predicted. Predation or competition may only occur during part of the lifecycle of the threatened species. Resources used by the species may overlap only partially

High: the potential for predation and/or competition is high, and is considered likely to impact on the species. Where no data are available, a precautionary approach is taken.

B2.2.1.3 The risk matrix

The risk matrix in Table B30 provides a means of assigning one of five risk levels to a threatened species/stocked species pair. The implications of, and appropriate management responses to the various levels are given in Tables B31 and B32, respectively.

Table B30. Risk matrix for the impacts of fish stocking on threatened species.

Risk matrix		**Overlap rating**			
		None	**Low**	**Medium**	**High**
Ecological interaction rating	**Low**	L	L	L-M	M
	Medium	L	L-M	M	M-H
	High	L	M	M-H	H

Table B31. Interpretations of risk ratings in terms of the predicted outcome for threatened species.

Risk	**Outcome for threatened species**
Low	Species unlikely to be affected
Low-medium	Possible small effects, but populations unlikely to be affected. Impacts may occur under future changes to stocking activity (e.g. expansion of area eligible for stocking)
Medium	Recovery impeded, further population declines in medium-long term under existing stocking strategy
Medium-high	Recovery impeded, further population declines in short-medium term under existing stocking strategy
High	Recovery impeded, further populations declines or extinctions imminent under existing stocking strategy

Table B32. Examples of management actions required to adequately address the risks to threatened species from fish stocking.

Risk	Management response required
Low	None
Low-medium	None at present, but future changes to stocking activity (e.g. expansion of area eligible for stocking) require reassessment of risk.
Medium	Suspension of stocking in the area(s), pending research into impacts and/or implementation of other risk minimisation actions
Medium-high	Suspension of stocking in the area(s), pending research into impacts and/or implementation of other risk minimisation actions
High	Suspension of stocking in the area(s), pending research into impacts and/or implementation of other risk minimisation actions

B2.2.2 Risks to species listed under the FM Act

B2.2.2.1 Species that may be at risk from stocking

Eighteen species, populations, communities or groups of fish and aquatic invertebrates in NSW are listed as threatened or protected under the FM Act and/or EPBC Act and are, therefore, likely to interact with stocked fish.

Of those 18 species, six are endangered, including eastern cod, Oxleyan pygmy perch, trout cod, Murray hardyhead, river snail and Adams emerald dragonfly.

Three species are listed as vulnerable under the FM Act, including Macquarie perch (endangered under the EPBC Act), silver perch and southern pygmy perch, and Murray cod is listed as vulnerable under the EPBC Act.

Four species and one taxonomic group are protected from fishing under the FM Act, including Australian grayling, estuary perch, eel-tailed catfish, freshwater crayfish of the genera *Euastacus* and *Cherax* (except *Cherax destructor*) and the isopod *Crenoicus harrisoni*.

There are two species, purple spotted gudgeon and the olive perchlet, for which the western populations of the species are endangered.

There are also two Endangered Ecological Communities under the FM Act that could be affected by stocking. These are the communities of the Lower Murray River and Lower Darling River. Under the FM Act, the Endangered Ecological Community refers to all of the aquatic species within a given area, with the exception of mammals, reptiles, birds and amphibians.

B2.2.2.2 Sources of risk

It is important to recognise that several processes may pose a risk to threatened species. Key Threatening Processes (KTP) are listed under Schedule 6 of the *Fisheries Management Act 1994* because they are implicated in the decline of threatened fish species and ecological communities. The object of Part 7A of the FM Act with respect to KTP is to manage and/or eliminate their impacts. The four KTP listed under the FM Act are:

- degradation of native riparian vegetation along New South Wales water courses (henceforth, referred to as "degradation of riparian vegetation")

- installation and operation of instream structures and other mechanisms that alter natural flow regimes of rivers and streams (henceforth, "river regulation")
- introduction of fish to waters within a river catchment outside their natural range (henceforth, "fish translocation"), and
- removal of large woody debris from New South Wales rivers and streams (henceforth, "removal of woody debris").

In addition to the Key Threatening Processes, other processes that have been suggested in the literature to pose a threat to particular threatened species are described below. The risk level assigned to each species in Table B33, based on the evaluation process described in B2.2.1, only considers the risk posed by fish stocking. Assessment of the risks posed by other processes is beyond the scope of this EIS.

B2.2.2.3 Species information and risk summaries

Risk due to stocking salmonids

Of the eighteen fish and invertebrates listed under the FM Act and/or the EPBC Act, eleven species and one population are considered to have low or low-medium risk levels from salmonid stocking as practiced under current management arrangements. Three species, one population and the freshwater crayfish group (~24 species) are considered to be at medium or greater risk levels from salmonid stocking. The risk level for the endangered Lower Murray ecological community was indeterminate as there was too little information available to assess the impacts of stocking at the community level.

Low and low-medium risk species are not likely to be impacted, but medium, medium-high and high risk species are considered likely to suffer further population declines and possible local extinction due to fish stocking as carried out under the present management arrangements.

The medium to high risk species are Macquarie perch, southern pygmy perch and Australian grayling; the medium to high risk population was the western population of purple spotted gudgeon; and the group at medium risk due to salmonids was the freshwater crayfish group. Risks to these species arise because they have a medium to high level of geographic and habitat overlap with stocked salmonids.

Of the eleven species and one population at low and low-medium risk, nine species are at low risk, and the other two species and the population are considered to be at low-medium risk from salmonid stocking. The species are generally at low risk because they have little if any geographic overlap with stocked salmonids.

Risk due to stocking native species

Six species are considered to be at medium to high risk from stocking of native fish. Most of the risk to these species arises because of the large overlap with native species. For the smaller fish (Murray hardyhead, southern pygmy perch, olive perchlet, purple spotted gudgeon), predation by the larger, piscivorous stocked native species is considered likely. For the other species, a combination of predation by stocked fish on the juvenile stages of the threatened species and competition between the species are sources of risk. Detailed information on the risks to the various species is given in the next section.

Table B33. Summary of the risks of stocking salmonids and native fish to species listed under the *Fisheries Management Act 1994* and/or the *Environment Protection and Biodiversity Conservation Act 1999*, that could be directly or indirectly affected by fish stocking activities.

* Denotes species also listed as vulnerable under the EPBC Act
** Denotes species considered vulnerable under the EPBC Act and protected under section 19 of the FM Act
Overlap and interaction scores: 0 - no overlap, L - low, M - medium, H - high, U - unknown. See text for further details.

Common name	Species name	Region where threatened species currently occurs	Salmonid risk evaluation			Native risk evaluation		
			Overlap	Interactions	Risk	Overlap	Interactions	Risk
Endangered species								
River snail	*Notopala sublineata*	Darling, Far west	0	L	**L**	L	L	**L**
Eastern cod	*Maccullochella ikei*	East Coast (North)	L	M	**L-M**	L	M	**L-M**
Trout cod	*Maccullochella macquariensis*	Murray	L	M	**L-M**	L	M	**L-M**
Oxleyan pygmy perch	*Nannoperca oxleyana*	East coast (North)	0	L	**L**	L	M	**L-M**
Murray hardyhead*	*Craterocephalus fluviatilis*	Darling	0	L	**L**	H	H	**H**
Vulnerable species								
Adam's emerald dragonfly	*Archaeophya adamsi*	East Coast (Central)	L	L	**L**	L	L	**L**
Murray cod* EPBC only	*Maccullochella peelii peelii*	Murray, Darling	L	M	**L-M**	H	L	**L**
Macquarie perch	*Macquaria australasica*	Murray	M	M	**M**	M	M	**M**
Silver perch	*Bidyanus bidyanus*	Murray	L	L	**L**	L	M	**L-M**
Southern pygmy perch	*Nannoperca australis*	Murray, Montane	L	H	**M**	H	M	**M-H**
Australian grayling**	*Prototroctes maraena*	East Coast	M	M	**M**	H	L	**M**
Endangered populations								
Olive perchlet	*Ambassis agassizii*	Darling	L	M	**L-M**	H	M	**M-H**
Purple spotted gudgeon	*Mogurnda adspersa*	Darling	M	H	**M-H**	M	H	**M-H**
Endangered ecological communities								
Lower Murray		Murray	0	L	**L**	H	H	**U**
Protected species (Section 19)								
Isopod	*Crenoicus harrisoni*	Montane (upper Hunter)	0	L	**L**	0	L	**L**
Protected species (Section 20)								
Eel-tailed catfish	*Tandanus tandanus*	Murray, Darling, Far West	L	L	**L**	H	L	**L-M**
Estuary perch	*Macquaria colonorum*	East Coast	0	L	**L**	L	M	**L-M**
Freshwater crayfish	*Euastacus* spp. & *Cherax* spp. (not *C. destructor*)	All	M	M	**M**	L	M	**L-M**

B2.2.2.4 Detailed information supporting the risk assessments

Endangered species

River snail (*Notopala sublineata*)

Conservation status: The river snail, *Notopala sublineata* is listed as Endangered under the FM Act.

Distribution and decline: formerly common and widely distributed in Murray-Darling system. Two subspecies are recognised: *N. sublineata sublineata*, which is restricted to the Darling river and its tributaries and *N. sublineata hanleyi*, which is restricted to the Murray and Murrumbidgee drainages (NSW Fisheries Scientific Committee, 2000a). The species is apparently now extinct in natural habitats in NSW, but persists in underground irrigation pipelines where it is sometimes considered a pest. A natural population occurs in the Lake Eyre Basin, South Australia (Sheldon and Walker, 1997), and small, isolated populations also exist in some western Queensland catchments of the Murray-Darling Basin (G. Wilson, Murray-Darling Freshwater Research Centre, pers. comm.).

Key Threatening Processes: It has been suggested that changes in biofilms caused by river regulation in the lower Murray have caused the decline of *N. sublineata* (Sheldon and Walker, 1997).

Other threatening processes: Deliberate removal from pipelines using chemicals has been cited as a threat to *N. sublineata* (NSW Fisheries Scientific Committee, 2000a). Though circumstantial, reductions in littoral primary production due to carp foraging may also be a threatening process. For example, in Ambathalla Creek of the upper northwest corner of the Warrego catchment (Qld), *Notopala* appear to exist in the absence of carp, in stark contrast to elsewhere along the same river system (G. Wilson, Murray-Darling Freshwater Research Centre, pers. comm.).

Habitat: the species has been collected from shallow snag and leaf litter habitats along the edge of rivers, and also in underground pipelines. The subspecies *N. sublineata hanleyi* is also known to occur in underground irrigation pipelines (Sheldon and Walker, 1997).

Recovery plans: None.

Assessment of risk to river snail

Species stocked: Golden perch, silver perch, Murray cod and trout cod may be stocked within the former range of *N. sublineata*.

Overlap: Stocked fish may occur throughout the entire former range of *N. sublineata*.

Ecological interactions: All of the stocked species consume invertebrates, including snails, but there is no specific information on consumption of *N. sublineata* by fish, however, the habitat of the species is in shallow littoral areas and underground pipes, which may provide refuge against predation by fish.

Risk: Low. It is unlikely that fish stocking would inhibit recovery of the river snail.

Eastern cod (*Maccullochella ikei*)

Conservation status: The eastern cod is listed as Endangered under the FM Act and the EPBC Act, and is also a Protected Fish under section 19 of the FM Act.

Distribution and decline: Once common in the Richmond and Clarence Rivers, the population of eastern cod has declined dramatically since European settlement of these areas. It is now found only in some tributaries of the Clarence River such as the Nymboida, Little Nymboida, Boyd and Mann rivers. The natural population is thought to have become extinct in the Richmond drainage basin, with no confirmed records since 1971 (Rowland, 1993).

Key Threatening Processes: All four Key Threatening Processes listed under the FM Act may affect the eastern cod (NSW Fisheries, 1999; NSW Fisheries Scientific Committee, 2001a; NSW Fisheries Scientific Committee, 2001b; NSW Fisheries Scientific Committee, 2001d). Fish translocation threatens the species through loss of genetic variation and hybridisation with translocated, hatchery-reared Murray cod that were introduced into the area (Rowland, 1993; NSW Fisheries Scientific Committee, 2001c).

Other threatening processes: Historical factors contributing to the decline include fishing, several fish kills during the late 1920s and 1930s associated with railway construction, clearing of timber and extreme climatic events, and release of contaminated water from tailings dams (Rowland, 1993). The species is also threatened by illegal recreational fishing (NSW Fisheries, 1999).

Habitat: The eastern cod inhabits clear, slow flowing rivers or creeks, with rocky or gravel bottoms and abundant instream cover of rocks, timber or tussocks (Rowland, 1996). At present, natural populations of freshwater cod occur in isolated parts of the Clarence river system that contain pristine habitat (Rowland, 1993). There is a stocked population in the Richmond river system.

Recovery plans: A draft recovery plan has been prepared by NSW Fisheries (NSW Fisheries Threatened Species Recovery Planning Program, 2003). The recovery plan sets out a range of measures including protection and enhancement of habitat, establishment (through stocking) of new populations within the former range, research on the ecology, genetics and threats to survival of the species, coordination of community and government actions to provide a strategic approach to management, and ongoing monitoring to evaluate the success of recovery actions.

Assessment of risk to eastern cod

Species stocked: Under current arrangements, Australian bass, salmonids and eastern cod may be stocked within the range of the eastern cod.

Salmonids

Overlap: Salmonids (brown trout and rainbow trout) have been extensively stocked within the upper Clarence, although these fish are generally only stocked in the upper reaches of the catchment and, thus, have a very limited overlap with eastern cod (John Pursey, NSW Fisheries, pers. comm.). Salmonids are not stocked into waters containing natural or stocked populations of freshwater cod.

Ecological interactions: There are no data on interactions between these species. Competition between the species could occur (inferred from biological data on diet), and predation of juveniles of either species by adults of the other is likely to occur where they do overlap.

Risk: Low-medium. Due to the limited geographical overlap between these species, the risk is considered to be low.

Native fish

Overlap: Australian bass are stocked into the lower reaches of rivers where eastern cod do not occur. Some bass may migrate up rivers, however overlap between the species is probably negligible. At present, NSW Fisheries does not permit the stocking of bass in natural eastern cod populations, or in eastern cod recovery areas. Stocking of eastern cod for conservation has been done at various times, initially by NSW Fisheries, with later involvement from a private hatchery and community group (see Chapter B1).

Ecological interactions: Competition and predation between freshwater cod and bass is possible (inferred from biological information on the diet of these species). In particular, adult bass may prey on the juvenile eastern cod.

Risk: Low-medium. Bass stocking poses a low risk to eastern cod due to the limited overlap between the species. Stocking of eastern cod for conservation purposes carries a high risk of genetic impact and must, therefore, be carefully managed (see B2.5).

Trout cod (*Maccullochella macquariensis*)

Conservation status: The trout cod is listed as endangered under the FM Act and EPBC Act, and is also protected under section 19 of the FM Act. It is also listed as threatened in Victoria, and protected in the ACT and SA. The IUCN lists trout cod as endangered on its Red List of threatened flora and fauna.

Distribution and decline: According to museum records, the trout cod was formerly found in many locations throughout the Murray-Darling system, and was sympatric with Murray cod (Berra, 1974). The only remaining natural population of trout cod occurs in the Murray River between the Yarrawonga weir and Tocumwal. Conservation stocking of trout cod has been done since the late 1980s in many sites within the presumed natural range of the species and at a couple sites outside the natural range (Douglas *et al.*, 1994). In NSW, stocked populations occur in the upper Murray above Hume Dam, upper Murrumbidgee River between Adaminaby and Murrells Crossing, sections of the Murrumbidgee from Burrinjuck to Yanco weir, the Macquarie River at Dubbo and Talbingo Dam in the Kosciusko National Park (NSW Fisheries, 2001). There is also a self-sustaining stocked population in Cataract Dam (Dean Gilligan, NSW Fisheries, pers. comm., 2003). Stocking in some sites, such as the Murrumbidgee near Cooma, Childowla, near Burrinjuck dam have been unsuccessful. In contrast, anecdotal reports from anglers indicate that large numbers of trout cod are present at stocking sites ranging from Narrandera on Murrumbidgee River, to Gundagai in the upper Murray River (Ian Wooden, NSW Fisheries, pers. comm. 2003). These fish are of reproductive size, but it is not known whether they have bred successfully. Earlier surveys failed to find convincing evidence of reproduction by stocked trout cod (Brown and Nicol, 1998). A self-sustaining stocked population occurs in the Seven Creeks system, northern Victoria (NSW Fisheries, 2001).

Surveys conducted between October 1990 and March 1993 found evidence for survival beyond 1 year at only two sites, and evidence of possible recruitment at only one site (Faragher *et al.*, 1993). Later surveys also revealed little evidence of reproduction by stocked fish. The main reason cited for lack of success was poor site selection due to inadequate knowledge of the species' requirements (Brown *et al.*, 1998). These fish are of reproductive size, but it is not known whether they have bred successfully. Predation of young trout cod by rainbow trout and brown trout at Cooma has also been cited as a threat to conservation stocking (Faragher *et al.*, 1993). Trout are known to prey on trout cod (Butcher, 1967; ACT Government, 1999c).

Key Threatening Processes: All of the key threatening processes listed under the FM Act apply to the trout cod (NSW Fisheries, 2001; NSW Fisheries Scientific Committee, 2001c; NSW Fisheries Scientific Committee, 2001a; NSW Fisheries Scientific Committee, 2001b; NSW Fisheries Scientific Committee, 2001d).

Other threatening processes: Habitat degradation through siltation and water pollution, and overfishing are also likely contributors to the decline of the trout cod (NSW Fisheries, 2001), as are diseases and parasites and recreational fishing practices. Several authors list interactions with brown and rainbow trout as threats to trout cod populations. Trout may compete with trout cod for food resources, and also prey on juvenile trout cod (Jackson *et al.*, 1992; Faragher *et al.*, 1993; Douglas *et al.*, 1994; NSW Fisheries, 2001). There is evidence of hybridisation between trout cod and Murray cod, but the incidence of hybrids is low and there is no evidence for genetic impacts from introgression (i.e. homogenisation of the two species' genetic makeup Douglas *et al.*, 1995).

Habitat: The two known self-sustaining populations occur in quite different habitats. The naturally occurring Murray River population is associated with various substrata and around instream cover of snags and woody debris (Harris and Rowland, 1996). In the stocked Seven Creeks population, the species occurs in fast flowing water over bedrock, boulder and gravel, as well as in pools mixed with rapids and cascades (Jackson *et al.*, 1992; Harris and Rowland, 1996).

Recovery plans: A national research and recovery plan was prepared for trout cod (Douglas *et al.*, 1994), with the aim of securing critical habitat and establishing new populations. At the time the plan was prepared, very little was known about the biology and habitat requirements of trout cod. Research done as a result of this recovery plan has greatly improved knowledge of the species. A second national recovery plan, effective for the years 1998 to 2005 has also been prepared (Brown *et al.*, 1998).

Assessment of risk to trout cod

Species stocked: Present management arrangements provide for the stocking (subject to issue of a stocking permit) of golden perch, silver perch and trout cod within the area of the naturally occurring trout cod population in the Murray River. These species, as well as Murray cod and salmonids, may also be stocked within the broader historical range of trout cod. NSW Fisheries does not permit stocking of Murray cod in waters that contain trout cod.

Salmonids

Overlap: Salmonids may overlap with restocked trout cod in certain areas where there is suitable habitat and conditions, including limited numbers of predators, for survival of trout cod (e.g. the upper Murray near Towong and Talmalmo). In other areas where conditions are less suitable and other fish have been stocked or established, such as the Murrumbidgee River near Cooma, overlap would be significant and may have impeded the success of stocking trout cod (Faragher *et al.*, 1993). In impoundments such as Talbingo Dam and Bendora Dam, overlap is likely to occur all the time, and the success of trout cod stocking is unknown (Ian Wooden, NSW Fisheries, pers. comm. 2003). Stocking has been unsuccessful at Childowla downstream of Burrinjuck Dam, although stocked fish have survived in the middle reaches of the Murrumbidgee River (Ian Wooden NSW Fisheries, pers. comm. 2003). In Victorian impoundments, trout cod are believed to have survived but moved into deep water and, hence, been difficult to detect (Brown and Nicol 1998).

Ecological interactions: Several authors list interactions with brown and rainbow trout as threats to trout cod. Trout may compete with trout cod for food resources, and also prey on juvenile trout cod (Jackson *et al.*, 1992; Faragher *et al.*, 1993; Douglas *et al.*, 1994; NSW Fisheries, 2001). Trout are known to prey on trout cod (Butcher, 1967; ACT Government, 1999c). It was suggested that trout stocking would pose a risk to any attempts to re-establish populations of trout cod within their former habitat in the montane zone (Faragher *et al.*, 1993).

Risk: Low-medium. Re-stocked trout cod may interact with salmonids in some areas such as the upper Murray and Murrumbidgee rivers. In one such area near Cooma, trout cod became established through stocking, but have since disappeared.

Native fish

Overlap: Murray cod are not stocked into naturally occurring trout cod areas (Craig Watson, NSW Fisheries, pers. comm.). Stocking of Murray cod is not done in Lake Mulwala, upstream of the trout cod area, although stocking of golden perch and silver perch may be permitted in this area (Cameron Westaway, NSW Fisheries, pers. comm.). Golden perch are also stocked in other trout cod recovery areas such as the Murrumbidgee near Narrandera (e.g. 45,000 fry in 2002, NSW Fisheries fish stocking database). Trout cod and golden perch may occupy similar habitats.

Ecological interactions: Stocked golden perch may interact with the naturally-occurring trout cod population. Competition for food may be inferred, based on the diets of the two species. Predation is also possible, although this is more likely to have an impact on the stocked fish than on trout cod, as the latter are larger and more aggressive predators. Incidental capture of trout cod is likely, due to their highly aggressive nature and the ease with which they can be caught using rod and line.

Risk: Low-Medium. Within the natural population of trout cod in the Murray, interactions with native fish seem unlikely to affect trout cod. Evidence suggests that restocking of trout cod has been successful in establishing some new populations, although it remains to be seen whether these populations become self-sustaining.

Oxleyan pygmy perch (*Nannoperca oxleyana*)

Conservation status: The Oxleyan pygmy perch is listed as Endangered under the FM Act.

Distribution and decline: The Oxleyan pygmy perch has been recorded from only four locations in NSW: North Range Lake within Bundjalung National Park, the Richmond river at Coraki and Lake Hiawatha (Arthington, 1996), and from coastal creeks and lakes around Broadwater National Park (Knight 2000, cited by Morris *et al.*, 2001). Extensive surveys on the NSW north coast have failed to locate this species. Arthington (1996) notes that detecting such small fish in large water bodies is challenging. The species is also known from 17 locations in Queensland. Genetic analysis found that populations of Oxleyan pygmy perch are genetically distinct and have probably been isolated from one another for a considerable period of time (Arthington, 1996).

Key Threatening Processes: Degradation of riparian vegetation and fish translocations are key threatening processes likely to affect the Oxleyan pygmy perch (Arthington, 1996; NSW Fisheries Scientific Committee, 2001c; NSW Fisheries Scientific Committee, 2001a; Morris *et al.*, 2001).

Other threatening processes: Other processes implicated in the decline of the species include habitat degradation (removal of instream vegetation, alteration of pH and turbidity, reduction of invertebrate prey) caused by housing developments, road and forestry operations, water pollution, mining and agriculture (Morris *et al.*, 2001).

Habitat: The Oxleyan pygmy perch is found in coastal heathland or “Wallum” ecosystems of south-eastern Queensland and northern NSW. It is restricted to creeks, swamps and dune lakes with low pH, low conductivity in areas of little or no flow with abundant aquatic macrophytes (Arthington, 1996).

Recovery plans: A recovery plan for the species in NSW is currently in preparation. The national recovery plan for the Oxleyan pygmy perch calls for the conservation of all the separate subpopulations as well as protection of large tracts of coastal heathland and the water bodies therein (Arthington, 1996). Specific recovery actions include restricting access to known populations of Oxleyan pygmy perch, protecting water quality, monitoring and investigating the possible eradication of *Gambusia holbrooki*.

Assessment of risk to Oxleyan pygmy perch

Species stocked: Australian bass is the only species currently stocked within the geographic range of the Oxleyan pygmy perch.

Overlap: There are no records of overlap between these species. It is possible that some bass may move into Oxleyan pygmy perch areas in the Richmond River area. However, based on the known habitats of the species, this seems unlikely.

Ecological interactions: No information is available in interactions between these species. If they did overlap, Australian bass could compete with and prey upon Oxleyan pygmy perch.

Risk: Low-Medium. Because these species are unlikely to encounter one another, the risk of impact from stocking of Australian bass is considered low-medium.

Murray hardyhead (*Craterocephalus fluviatilis*)

Conservation status: The Murray hardyhead is listed as Endangered under the FM Act and Vulnerable under the EPBC Act.

Distribution and decline: The Murray hardyhead was formerly widespread throughout the lower Murray and Darling Rivers, but is now restricted to a few sites in Victoria and possibly NSW, although recent records for NSW are uncertain. According to Ivantsoff (1996), no populations are known in NSW. A single was individual collected during the NSW rivers survey at Bundidgerry Creek, a tributary of the Murrumbidgee near Narrandera (Schiller *et al.*, 1997). The species was collected from the lower Murray River in 1986 (Wager and Jackson, 1993), but no location was given. Very little is known about this species, possibly because of difficulties with its identification (Brendan Ebner, Environment ACT, pers. comm. 2003).

Key Threatening Processes: The causes of decline of this species are unknown, but river regulation, fish translocation and degradation of riparian vegetation are likely key threatening processes (Ivantsoff and Crowley, 1996; NSW Fisheries Scientific Committee, 2001c; NSW Fisheries Scientific Committee, 2001a; NSW Fisheries Scientific Committee, 2001b).

Other threatening processes: Other threats include salinisation, habitat changes due to agriculture and spawning failures due to cold-water release from dams (Morris *et al.*, 2001).

Habitat: The Murray hardyhead occurs at the margins of slow, lowland rivers and in lakes, billabongs and backwaters. It is found amongst aquatic plants, and over gravel beds in fresh and saline waters (Wager and Jackson, 1993).

Recovery plans: There is currently no recovery plan for the Murray hardyhead. The national action plan for freshwater fishes calls for basic research on the species to determine its distribution and reasons for decline (Wager and Jackson, 1993).

Assessment of risk to Murray hardyhead

Species stocked: Golden perch, silver perch, Murray cod and trout cod may be stocked (subject to approval) within the current and former range of the Murray hardyhead.

Overlap: Fish may be stocked within the entire range of the Murray hardyhead. The species occurs in similar habitats to the much larger native predatory species golden perch and Murray cod. The cryptic nature of the species means that if it were present in an area proposed for stocking, it probably would not be noticed.

Ecological interactions: Predation by stocked fish is considered likely, based on the small size of the Murray hardyhead and the predatory nature of the stocked species.

Risk: Medium. Due to the extremely limited known range and cryptic nature of the Murray hardyhead in New South Wales, combined with the likelihood of predation by stocked fish, this species is assigned a high risk from fish stocking. Although the native fish species that are stocked would naturally co-exist with the Murray hardyhead, and predation by these species is a natural process, the status of the species in NSW warrants a high degree of caution.

Vulnerable species

Adams emerald dragonfly (*Archaeophya adamsi*)

Conservation status: Listed as vulnerable under the FM Act

Distribution and decline: Despite considerable survey efforts, Adams emerald dragonfly is known from only four locations: Brisbane Waters National Park (Somersby Falls & Floods Creek), Tunks Creek near Berowra, Bedford Creek (lower Blue Mountains) and Hungry Way Creek in Wollemi National Park.

Key threatening processes: Unknown.

Other threatening processes: Changes to water quality due to agricultural development around the headwaters of Floods Creek and housing development near Berowra may threaten Adams emerald dragonfly (NSW Fisheries Scientific Committee, 1999b).

Recovery plans: None.

Assessment of risk to Adams emerald dragonfly

Species stocked: Australian bass may be stocked into areas within the likely range of Adams emerald dragonfly.

Overlap: Fish were not observed at the Tunks Creek, Hungry Way Creek or Somersby Falls sites. The habitat at these sites consisted of small cascades and very shallow riffles, probably unsuitable as habitat for Australian bass (Gunther Theisinger, EPA, pers. comm. 2003).

Ecological interactions: No interactions have been recorded. Australian bass are known to prey on dragon fly nymphs (Harris, 1985), so predation would be likely if the species did overlap.

Risk: Low. Adams emerald dragonfly occurs in habitats unsuitable for stocked fish.

Murray cod (*Maccullochella peelii peelii*)

Conservation status: The Murray cod is listed as vulnerable under the EPBC Act.

Distribution and decline: The Murray cod was formerly distributed throughout the Murray-Darling system, except for the upper reaches of some of the southern tributaries. NSW Fisheries data shows a steady decline in recreational and commercial catches of the species since the 1950s (Rowland, 1988). The species has declined dramatically in geographic distribution and abundance and is considered uncommon in most areas and rare in Victoria (Harris and Rowland, 1996). The NSW

Rivers Survey sampled 15 sites on four occasions over two years across the lower Murray drainage where the species was expected to occur and found no Murray cod (Harris and Gehrke, 1997). The species was still locally abundant in some areas of the Murray, however, where it is regularly caught by recreational and commercial fishers (Schiller *et al.*, 1997). Fifty-two specimens were caught at seven sites (of 15 where the species would be expected) in the Darling (Schiller *et al.*, 1997).

Key Threatening Processes: The effects of river regulation, removal of woody debris and fish translocations are believed to have affected the recruitment of juveniles (Harris and Rowland, 1996; Humphries and Lake, 2000).

Other threatening processes: Recreational and commercial fishing, siltation, pollution and the release of cold water from dams have also been suggested as likely causes of decline of the Murray cod (Harris and Rowland, 1996; Morris *et al.*, 2001; Threatened Species Scientific Committee, 2003).

Habitat: Habitats range from small, clear, rocky streams in the upper western slopes of NSW to the turbid, slow-flowing rivers and creeks of the western plains. Found in or near deep holes, often around cover such as rocks, fallen trees, stumps, clay banks or overhanging vegetation (Harris and Rowland, 1996).

Assessment of risk to Murray cod

Species stocked: Salmonids, golden perch, silver perch, Murray cod and trout cod may be stocked within the range of this species.

Salmonids

Overlap: Low. Murray cod may overlap with salmonids on the western slopes of the Great Divide, although this represents a very small part of the species' range.

Ecological interactions: There is no information on interactions between these species. Competition and predation are possible between salmonids and juvenile Murray cod, but adult cod are unlikely to be vulnerable.

Risk: Low-medium. Due to the low geographical overlap, the risk to Murray cod from salmonid stocking is considered to be low-medium.

Native species

Overlap: Native fish species may be stocked throughout the range of the Murray cod.

Ecological interactions: Trout cod and Murray cod were formerly sympatric and, therefore, the species would be expected to coexist under ordinary circumstances. However, regular stocking of trout cod in some areas could overwhelm local resident Murray cod populations through competition for habitat. Murray cod is by far the largest predatory freshwater fish species in NSW (Rowland, 1988) and is, therefore, unlikely to be affected by stocking of golden perch or silver perch.

Risk: Low. The risk of fish stocking having an impact on Murray cod through ecological interactions is low because of the large size of the species. There is a greater risk from genetic impacts due to stocking of genetically unsuitable Murray cod (see section B2.5).

Macquarie perch (*Macquaria australasica*)

Conservation status: The Macquarie perch is listed as Endangered under the EPBC Act and Vulnerable under the FM Act. It is also a protected fish under section 19 of the FM Act.

Distribution and decline: The Macquarie perch previously occurred throughout the cooler reaches of the Murray-Darling system in NSW and Victoria. It is also known from six major coastal drainages including the Hawkesbury and Shoalhaven (Cadwallader, 1981). Poor documentation of past stocking of Macquarie perch, and misidentification by observers, has led to confusion over distribution and relationships among various stocks. Stocking of western drainage fish into eastern drainages has occurred, but there are thought to be two or three distinct species: one in the Murray-Darling, one in the Shoalhaven basin and possibly a third in the Hawkesbury. Wild populations of western drainage fish are very restricted and fragmented, and absent from much of the former range. The species is known from the upper reaches of the Abercrombie, Murray, Goodradigbee, Kangaroo, Mongarlowe, Nepean (and all tributaries), Lachlan and Murrumbidgee Rivers.

Key Threatening Processes: All of the key threatening processes listed under the FM Act apply to the Macquarie perch (NSW Fisheries Scientific Committee, 2001c; NSW Fisheries Scientific Committee, 2001a; NSW Fisheries Scientific Committee, 2001b; NSW Fisheries Scientific Committee, 2001d).

Other threatening processes: The decline of Macquarie perch has been attributed to overfishing by recreational anglers, EHN disease (carried by introduced redfin perch), habitat degradation (erosion leading to siltation and narrowing of channels), destruction of invertebrate food fauna and the infilling of deep holes and snag removal (Wager and Jackson, 1993). Competition with and predation by trout, carp and redfin perch have probably also led to the decline of Macquarie perch populations (Cadwallader, 1981; Harris and Rowland, 1996; NSW Fisheries Scientific Committee, 1999a). Barriers have fragmented populations and prevented successful spawning in several locations (ACT Government, 1999a).

Habitat: The Macquarie perch occurs in the upper reaches of rivers with light siltation loads, where there are deep, still holes interspersed with shallow riffles (Cadwallader, 1981).

Recovery plans: There is no recovery plan for the Macquarie perch.

Assessment of risk to Macquarie perch

Species stocked: Fish that may be stocked (subject to approval) within the range of western populations of the Macquarie perch are salmonids (but see below), golden perch, silver perch, Murray cod, and trout cod. Australian bass and salmonids may be stocked within the range of the eastern drainage populations.

Salmonids

Overlap: NSW Fisheries records from 1980 onwards indicate that the Macquarie perch is known from approximately 42 sites in NSW, approximately 14 of which are eligible to be stocked with salmonids under current management arrangements (the Upper Murrumbidgee, Queanbeyan, Abercrombie, Lachlan, Shoalhaven and Mongarlowe, Goodradigbee, Murray and Coxs rivers). Several of these waters currently have stocking restrictions, meaning that that brown trout are not permitted to be stocked (Murrumbidgee River above Cooma, Queanbeyan River above Googong Dam, Goodradigbee River, Mannus Creek, Abercrombie River, Shoalhaven River and Mongarlowe River). Rainbow trout are still stocked in those waters. Anecdotal reports suggest that rainbow trout are less of a threat to Macquarie perch than brown trout because they tend to be more easily caught and, hence, get fished out before they become large enough to pose a threat (Andrew Sanger, NSW Fisheries, pers. comm.). In contrast, brown trout are more difficult to catch and are likely to persist for several years and attain a large size (Butcher, 1967).

Biological interactions: Some authors list interactions with trout among factors threatening the survival of the Macquarie perch (Harris and Rowland, 1996). These threats are inferred from the biology of the species, since little data are available on the biological interactions between Macquarie perch and salmonids. The possibility of competition between Macquarie perch and salmonids may be inferred from dietary overlap from stomach content analysis. Macquarie perch eat mainly benthic invertebrates, particularly insects, which are also consumed by trout (McKeown, 1934). Butcher (1945) reported, based on stomach content analysis, that rainbow trout may compete with Macquarie perch for food, but that brown trout are less likely to do so. Predation of small Macquarie perch by rainbow trout is known to occur in Victoria, although it is not known how frequently (Butcher, 1945). Furthermore, Macquarie perch have been observed to decline in areas heavily stocked with trout (Cadwallader and Rogan, 1977). This evidence, though circumstantial, suggests that Macquarie perch could suffer from competition and predation from stocked salmonids.

Risk: Medium. Based on the distributional overlap in NSW, the ecological interactions discussed above and the grave concerns held for the conservation of Macquarie perch, it is concluded that stocking of salmonids in NSW poses a medium level of risk to the Macquarie perch.

Native fish

Overlap: Murray cod and golden perch in particular occur in similar habitats to Macquarie perch in the headwaters of rivers. Trout cod, Murray cod, golden perch or silver perch may be stocked into waters containing Macquarie perch. These waters include the Murrumbidgee River above Canberra, Wyangala Dam and tributaries, Queanbeyan River (where stocking is done in conjunction with ACT Government) and Burrinjuck Dam (Cameron Westaway, NSW Fisheries, pers. comm. 2003).

Ecological interactions: Competition between stocked native fish and Macquarie perch is considered possible based on the diets of the species. Predation by Murray cod and golden perch on juvenile Macquarie perch is also possible.

Risk: Medium. Due to the overlap between stocked fish and the Macquarie perch, and the probability of competition and predation by native species, there is a medium risk that stocking would impede the recovery of the Macquarie perch.

Silver perch (*Bidyanus bidyanus*)

Conservation status: The silver perch is listed as Vulnerable under the FM Act and protected under section 20 of the FM Act.

Distribution and decline: The silver perch formerly occurred throughout the lowland areas of the Murray-Darling basin, but has declined over most of this. One natural population is known from waters between Torrumbarry and Euston weirs on the lower Murray (Morris *et al.*, 2001; FSC, 1999). However, recent surveys have only caught isolated individuals. The NSW Rivers Survey found seven in the Darling area at three sites, two of which are often stocked with hatchery-reared fingerlings. In the Lachlan two specimens were caught above Wyangala Dam (Abercrombie River), which is regularly stocked with silver perch and other native fish by NSW Fisheries (Harris and Gehrke, 1997). Recent captures have also been recorded in the Macquarie River near Wellington and the Macintyre River near Goondiwindi (G. Wilson, Murray-Darling Freshwater Research Centre, pers. comm.). Introduced populations of silver perch also occur in some eastern drainages (Merrick, 1996).

Key Threatening Processes: All of the key threatening processes listed under the FM act apply to the silver perch (NSW Fisheries Scientific Committee, 2001c; NSW Fisheries Scientific Committee, 2001a; NSW Fisheries Scientific Committee, 2001b; NSW Fisheries Scientific Committee, 2001d; ACT Government, 2002).

Other threatening processes: The Silver Perch Recovery Team attempted to rank the processes thought to contribute to the decline of silver perch. In addition to those listed above, they included (in order of severity) loss of aquatic plants, parasites and disease, water quality, increased sedimentation, community and food chain changes, stocking (genetic issues), salinity, recreational fishing and commercial fishing (Clunie and Koehn, 2001d).

Habitat: The silver perch occurs predominantly in the warm sluggish waters of turbid lowland rivers (Llewellyn, 1983; ACT Government, 2002). There are also reports that the species occurs in fast flowing waters where there are rapids and races (Merrick, 1996). The species does not occur in cool, fast-flowing, upland rivers of the Murray-Darling system (ACT Government, 2002).

Recovery plans: A national recovery plan for silver perch has been prepared (Clunie and Koehn, 2001c). With regard to fish stocking, this plan recommends a coordinated, large-scale conservation stocking program, following sound genetic principles. Such stocking would only be conducted in areas where a high degree of success is likely. Other measures are aimed at reducing the impacts of all the threatening processes listed above, including relevant research programs (Clunie and Koehn, 2001c).

Assessment of risk to silver perch

Species stocked: Under current management arrangements, Murray cod, golden perch silver perch and trout cod may be stocked within the former range of the silver perch. Salmonids may co-occur with silver perch although their overlap is minor.

Salmonids

Overlap: The distribution of salmonids represents only a small portion of silver perch distribution (Clunie and Koehn, 2001d).

Ecological interactions: Data are not available on interactions between these species, which probably reflects their limited overlap. Competition is unlikely because silver perch have very different diets from trout. Predation by salmonids is possible where they do overlap.

Risk: Low. Due to their negligible overlap, the risk to silver perch from salmonid stocking is considered to be low. Clunie and Koehn (2001d) suggested that “It is unlikely that they [trout] have played an important role in the decline of silver perch since its distribution only represents a small portion of that occupied by silver perch”.

Native fish

Overlap: Given the very wide distribution of this species, overlap with stocked native species is very likely. Silver perch have very similar habitats to the native species that are stocked within its range.

Ecological interactions: There are no data available on interactions between silver perch and other native fish. Dietary overlap with stocked species is minor: silver perch consume small aquatic insects, worms, molluscs and algae (Merrick, 1996), while the other stocked native species consume larger prey or are primarily piscivorous. Competition for food with juveniles of the native species is possible. Competition for space is unlikely because silver perch are not territorial. Predation on silver perch by adults of the native species is possible, and NSW Fisheries staff have observed Murray cod preying on adult silver perch (Dean Gilligan, NSW Fisheries, pers. comm., 2003).

Risk: Low - medium. Given the (inferred) small likelihood of competition for food, the risk posed by stocking other species of native fish is low-medium.

There may be major risks of stocking from spread of EHN disease in certain areas (ACT Government, 2002), and genetic impacts of stocking (see section B2.5).

Southern pygmy perch (*Nannoperca australis*)

Conservation status: The southern pygmy perch is listed as Vulnerable under the FM Act.

Distribution and decline: The former range of the southern pygmy perch included the lower reaches of the Murray River in New South Wales, although the species has declined throughout the Murray River and may be close to extinction in NSW. It is now absent from the Murrumbidgee River and much of the Murray River system and has a restricted distribution elsewhere. It is known to occur in billabongs and creeks around Albury. Recent NSW sightings include Billabong Creek near Holbrook (NSW Fisheries Scientific Committee, 2000b), the Murray River near Gunbower Island and two sites on a small tributary of the Lachlan River near Dalton, just north of the ACT border, (ASFB Threatened Fishes Committee Report July 2002). This is first record for the Lachlan drainage.

Key Threatening Processes: River regulation, fish translocation and degradation of riparian vegetation are considered to be threats to the southern pygmy perch (NSW Fisheries Scientific Committee, 2000b; NSW Fisheries Scientific Committee, 2001c; NSW Fisheries Scientific Committee, 2001a; NSW Fisheries Scientific Committee, 2001b).

Other threatening processes: Other threats to the southern pygmy perch include loss of aquatic vegetation, alienation of floodplain habitats by flood mitigation works, seasonal flow reversal, spawning failure due to cold water releases from dams (NSW Fisheries Scientific Committee, 2000b).

Habitat: Inhabits weedy, slow flowing or still waters, lakes and irrigation channels. It is known to inhabit small creeks in vegetated areas, dams, billabongs and irrigation ditches and other types of wetlands (Kuiter *et al.*, 1996).

Recovery plans: There is no recovery plan for the southern pygmy perch in NSW, though a recovery outline has been prepared for the species in South Australia (Hammer, 2002).

Assessment of risk to southern pygmy perch

Species stocked: Fish stocked within the range of the southern pygmy perch are salmonids (brown and rainbow trout), Murray cod, trout cod, golden perch and silver perch.

Salmonids

Overlap: Although salmonids and southern pygmy perch generally occupy different habitats, these species do interact. Cadwallader (1979) reported trout-pygmy perch interactions in the Seven Creeks system in Victoria, where both species occurred in still waters above a weir. The NSW Fish stocking database shows that salmonids have been stocked in Grabben Gullen Creek, a tributary of the upper Lachlan River, not far from a recently discovered population of southern pygmy perch.

Ecological interactions: Predation of southern pygmy perch by brown trout can be significant in areas where their distributions overlap (Kuiter *et al.*, 1996). In a Tasmanian study, gut contents of brown trout comprised 20% pygmy perch (Kuiter *et al.*, 1996). Pygmy perch were consumed by brown trout in the Seven Creeks system in Victoria (Cadwallader, 1979). A very similar species, the western pygmy perch (*Edelia vittate*), formed a considerable part of the diet of rainbow trout in southwest Western Australia (Shipway, 1949).

Risk: Medium. Given the small, highly fragmented nature of known southern pygmy perch populations, and their susceptibility to predation by brown and rainbow trout, stocking of salmonids poses a medium risk to the recovery of this species.

Native fish

Overlap: Native fish may be stocked anywhere within the current and former geographical range of this species.

Ecological interactions: No data are available on interactions between southern pygmy perch and native fish. Its small size suggests that the southern pygmy perch may be vulnerable to predation by stocked native fish. Competition with juveniles of stocked natives is also possible.

Risk: Medium-high. Given the possibility of predation by stocked native fish on southern pygmy perch, there is a medium-high probability that stocking of native fish near riverine populations of the southern pygmy perch would adversely affect the recovery of the species.

Australian grayling (*Prototroctes maraena*)

Conservation status: The Australian grayling is listed as Vulnerable under the EPBC Act and is protected under section 19 of the FM Act.

Distribution and decline: The Australian grayling occurs in eastern drainages south of the Grose River to the Hopkins River in Western Victoria, and is also widespread in Tasmania (McDowall, 1996). It was formerly considered to be Australia's most endangered fish species (Lake, 1971). Sampling of 312 individuals in the Shoalhaven River below Tallowa Dam in 1976 (Bishop and Bell, 1978), and collection of 1000 specimens in the Tambo River in Victoria have suggested that the species is not as rare as was once thought (McDowall, 1996). Currently it has a discontinuous distribution throughout its former range. The NSW Rivers Survey recorded 64 specimens from 6 different southern New South Wales coastal rivers (Harris and Gehrke, 1997), and it is known to be present in relatively large numbers in several coastal rivers from the Clyde River south to the New South Wales-Victorian border. However, it has not been recorded from the Grose River (part of the Hawkesbury-Nepean River system) since the 1950s, (Gehrke and Harris, 1996).

Key Threatening Processes: Land clearing (as listed under the EPBC Act) affects the Australian grayling. No other key threatening processes listed under the EPBC Act affect the Australian grayling, but all four of those listed under the FM Act apply (Ingram *et al.*, 1990).

Other threatening processes: Agriculture, forestry and sand and gravel extraction have damaged the Australian grayling's habitat through erosion (Wager and Jackson, 1993). Predation by brown trout and rainbow trout may threaten the Australian grayling (Koehn and O'Connor, 1990).

Habitat: The freshwater habitat of this species includes large and small coastal rivers and streams (Wager and Jackson, 1993), generally with gravel substrata and moderate flows, and the species may penetrate upland streams to altitudes of 1000m (McDowall, 1996). It has also been found in some degraded streams, and (as larvae and juveniles) in inshore marine and estuarine habitats.

Recovery plans: There is no national recovery plan for the Australian grayling. The Action Plan for Australian Freshwater Fishes recommended that stocking of brown trout and rainbow trout be restricted in catchments identified as sustaining populations of Australian grayling (Wager and Jackson, 1993).

Assessment of risk to Australian grayling

Species stocked: Salmonids and Australian bass may be stocked in waters that contain the Australian grayling.

Salmonids

Overlap: The Australian grayling occurs in temperate streams south of the Grose River at elevations of up to 1000m (McDowall, 1996), thus there is the possibility of overlap with stocked salmonids. Their habitat descriptions are very similar, with both species found in moderate to fast flowing streams over gravel or boulder substrata (Cadwallader, 1996; McDowall, 1996), but the Australian grayling is generally confined to lowland habitats by the presence of impassable barriers such as waterfalls and impoundments (e.g. Gehrke *et al.*, 2001) and is therefore unlikely to interact with salmonids in NSW (R. Faragher, NSW Fisheries, pers. comm. 2003). However, as fish passage is progressively improved in line with NSW Fisheries policy, there is likely to be greater overlap between grayling and trout.

Ecological interactions: Predation by and competition with salmonids (brown and rainbow trout) are considered threats to Australian grayling (Koehn and O'Connor, 1990). The potential for competition with trout may be inferred from the species' similar habitat requirements (Koehn and O'Connor, 1990) and diet (Jackson, 1976; Bishop and Bell, 1978). Potential for predation is inferred from shared habitat and the fact that trout are piscivorous. There are no data on interactions between salmonids and grayling.

Risk: Medium. Due to the NSW Government initiatives in improving fish passage, the Australian grayling is likely to experience overlap with salmonids as it moves back into its former range in the upper reaches of coastal rivers. Therefore the risk that salmonids will impede recovery of the species is considered medium.

Australian bass

Overlap: Australian bass may be stocked in all NSW rivers within the range of the Australian grayling. The habitats of these two species are fairly similar (Bishop and Bell, 1978; Koehn and O'Connor, 1990; McDowall, 1996).

Ecological interactions: The diets of bass and grayling are very similar, therefore competition is possible (Harris, 1985). Predation by bass on juvenile Australian grayling is also possible. No data are available on the effects of such interactions.

Risk: Medium. The similarity in habitat and likelihood of ecological interactions suggest that stocking of Australian bass poses a medium level of risk to the recovery of the Australian grayling.

Endangered populations

Olive perchlet (*Ambassis agassizii*) (western population)

Conservation status: The western population of this species is listed as an Endangered Population under the FM Act.

Distribution and decline: (from Morris *et al.,* 2000) The olive perchlet's previous range encompassed tributaries of the Murray-Darling River system in western Queensland, western New South Wales, northern Victoria, and south-eastern South Australia. It is also found in coastal drainages east of the Great Dividing Range from Lake Hiawatha in northern New South Wales, northwards to the Mowbray River in north Queensland (Allen & Burgess, 1990). This species has been found in Lake Broa in Queensland as well as along the Severn and Macintyre river systems on the New South Wales/Queensland border (Moffatt *et al.,* 1997). Presently, this species is also known to occur in the Dumaresq River around Bonshaw and in two waterbodies near Charleville in the Warrego River catchment. It is not uncommon in parts of the Condamine River (Unmack, 2000) as well as in rivers in northern coastal New South Wales (Harris & Gehrke, 1997; Gehrke & Harris, 2000). It has also been recorded in very low numbers in the Bogan River near Gongolgon and Nyngan in New South Wales. This species was recorded near Mildura in an irrigation channel in the 1920s, but has not been recorded in Victoria since (T.Raadik, pers. comm. 2000).

Key Threatening Processes: River regulation, degradation of riparian vegetation and fish translocations threaten the western populations of the olive perchlet (NSW Fisheries Scientific Committee, 2001c; NSW Fisheries Scientific Committee, 2001a; NSW Fisheries Scientific Committee, 2001b).

Other threatening processes: Unknown.

Habitat: The olive perchlet occurs in rivers, creeks, drainage ditches, ponds and swamps, and is most commonly found amongst log snags and aquatic vegetation (Allen, 1996). It is usually found in waters ~1m deep, with little or no flow, near overhanging vegetation, and especially in backwaters (Hansen, 1999).

Recovery plans: There is no recovery plan for the olive perchlet.

Assessment of risk to olive perchlet

Species stocked: Fish stocked into waterways known to contain threatened populations of the olive perchlet are golden perch, Murray cod and silver perch. Salmonids (brown trout, brook trout) are stocked in the upper reaches of rivers that contain olive perchlet, namely the Severn and Dumaresq Rivers.

Salmonids

Overlap: There may be a limited overlap between the olive perchlet and salmonids in the upper reaches of the Severn and Dumaresq rivers.

Interactions: In areas where olive perchlet and trout do overlap, predation on olive perchlet could be inferred. No data are available on interactions between these species.

Risk: Low - medium. The risk to olive perchlet from stocking salmonids is considered low-medium because of their limited geographical overlap.

Native fish

Overlap: Golden perch, silver perch and Murray cod may be stocked within the range of western populations of the olive perchlet. Examples of stocking in areas containing populations of the species include the Bogan River at Nyngan, Severn River, Macintyre River and the Dumaresq River near Bonshaw.

Ecological interactions: In the wild, the olive perchlet is an important food for larger predators (Allen, 1996). Due to its small size the olive perchlet is possibly subject to heavy predation by golden perch and Murray cod (Morris *et al.*, 2001).

Risk: Medium-high. Due to the extensive overlap and the possibility of predation, the risk to the olive perchlet is considered to be medium-high.

Purple-spotted gudgeon (*Mogurnda adspersa*) (western population)

Conservation status: The western population of this species is listed as an Endangered Population under the FM Act.

Distribution and decline: Within New South Wales, the former distribution of the purple-spotted gudgeon included the entire Murray-Darling system and also the Murray and Murrumbidgee rivers (Larson and Hoese, 1996). Populations (not threatened) also occur in streams on the far north coast of New South Wales. It is believed to have declined, but little is known of its current distribution (Larson and Hoese, 1996). Populations are known from near Inverell, Deadman Creek (a tributary of Tenterfield Creek) (Briggs, 1998), Severn River at Dundee, Gwydir River at Bingara (Unmack cited by Morris *et al.*, 2001) and Beardy River near Bonshaw (NSW Fisheries Fish Files). No specimens were collected in the NSW Rivers Survey (Harris and Gehrke, 1997). Anecdotal reports suggest that they are regularly seen in some floodplain wetlands and small creeks off the Dumaresq River, upstream of Glenarbon (G. Wilson, Murray-Darling Freshwater Research Centre, pers. comm.).

Key Threatening Processes: River regulation, degradation of riparian vegetation and fish translocation (particularly *Gambusia*) threaten the western populations of the purple spotted gudgeon (Larson and Hoese, 1996; NSW Fisheries Scientific Committee, 2001c; NSW Fisheries Scientific Committee, 2001a; NSW Fisheries Scientific Committee, 2001b).

Other threatening processes: The purple spotted gudgeon was a popular bait species for Murray cod fishers (Briggs, 1998).

Habitat: Slow flowing weedy areas, with suitable areas of hard substratum for spawning (Larson and Hoese, 1996). It occurs amongst benthic structures such as rocks and snags and amongst aquatic vegetation (Wager and Jackson, 1993). The purple-spotted gudgeon thrives at temperatures of 14-25˚C, but can tolerate temperatures as low as 10.5˚C (Briggs, 1998).

Recovery plans: There is no recovery plan for the western populations of the purple spotted gudgeon.

Assessment of risk to western populations of the purple spotted gudgeon

Species stocked: Species stocked within the current range of the threatened population include golden perch, brown trout, brook trout, Murray cod and silver perch. Interactions of this species with stocked fish are unknown, although the purple-spotted gudgeon occupies similar habitats to many stocked species of fish. Due to its small size, the purple-spotted gudgeon is probably subject to heavy predation by both native and introduced fish (Morris *et al.*, 2001).

Salmonids

Overlap: Two of the five recent sightings of the purple-spotted gudgeon were made in montane streams that are stocked with trout (Severn River and Beardy River).

Ecological interactions: Predation on purple-spotted gudgeon by trout is inferred from the small size of this species.

Risk: Medium-high. It is noted that while salmonids may not be responsible for the decline of the species, they are considered to pose a threat to recovery of the remaining population in northern NSW.

Native fish

Overlap: All of the locations from which the species is known may be stocked with native fish under current arrangements. For example, the Tenterfield Creek has been stocked with golden perch and Murray cod. These species are known to occur in similar habitats to the purple spotted gudgeon.

Ecological interactions: Predation by golden perch and Murray cod is possible. Purple-spotted gudgeon was once a popular bait species for Murray cod (Briggs, 1998).

Risk: Medium-high. Given the large overlap of fish stocking with the known current distribution in NSW and the possibility of predation, the risk posed to the recovery of this species by stocking of golden perch and Murray cod is medium-high.

Endangered ecological communities

The aquatic ecological community in the natural drainage of the Lower Murray River and the aquatic ecological community in the natural drainage system of the lowland catchment of the Darling River

Conservation status: The aquatic ecological community of the lower Murray River is listed as an Endangered Ecological Community under the FM Act. Under the FM Act the Endangered Ecological Community refers to all of the aquatic species within a given area, with the exception of mammals, reptiles, birds and amphibians. The aquatic ecological system of the lower Darling River has been nominated as an endangered ecological community under the FM Act and the nomination has been approved by the NSW Fisheries Scientific Committee, although final approval is still pending. Both ecological communities are considered here.

Reasons for listing: Eight of 23 fish species occurring in the endangered communities are listed as vulnerable or endangered. Of the poorly known invertebrate fauna, one species (the river snail *Notopala sublineata*) is endangered and Murray crayfish have documented declines, as do two species of finfish (eel-tailed catfish and Murray cod).

Key threatening processes: All of the Key Threatening Processes listed under the FM Act apply to the threatened ecological communities of the Murray-Darling.

Other threatening processes: Other threatening processes include trampling by stock, clearing of floodplain vegetation, pollution by agricultural chemicals, salinisation and overfishing (NSW Fisheries Scientific Committee, 2001f). Flow regulation and nutrient enrichment are also probable threats to this community.

Recovery plans: A recovery plan has not been prepared for NSW. The Murray Darling Basin Commission has prepared a draft strategy for the recovery of fish in the Murray Darling basin (Murray Darling Basin Ministerial Council, 2002). The draft strategy outlines a broad range of management actions aimed at minimising or eliminating threatening processes. These actions include rehabilitation and protection of fish habitat, management of riverine structures, controlling alien fish, protecting threatened native fish and managing fish translocation and stocking. As an example of actions that affect fish stocking under the strategy, in a case study for the Murray River between the Hume Weir and Barmah, the strategy calls for a halt to all stocking unless it is part of an agreed rehabilitation plan (Murray Darling Basin Ministerial Council, 2002).

Assessment of risk to endangered ecological communities

Species stocked: Golden perch, silver perch, Murray cod and trout cod, may be stocked within the threatened ecological communities of the Lower Murray and lower Darling Rivers. Salmonids are not stocked within the area covered by the listing, but may move into the area from further upstream when conditions are favourable. Salmonids may persist immediately below Hume, Blowering and Burrinjuck Dams where thermal pollution inhibits native fish. It is unlikely that salmonids are resident in the majority of the area covered by this listing (Dean Gilligan, NSW Fisheries, pers. comm., 2003).

An impact on an ecological community is defined here as a change in the relative abundance of species within the area occupied by the stocked fish. By definition, stocking must change the structure of the community; the magnitude of the changes that the stocked species cause to the rest of the community is at issue. Risks to individual threatened, protected and other key species in the endangered ecological community are discussed elsewhere in this section. While risks from fish stocking to particular individual species may be high, the risk to the overall community would not necessarily be considered high. This is because the threatened ecological communities contain more than four hundred species (mostly invertebrates) and a vast majority of species may not be greatly affected by fish stocking.

Likely impacts: The impacts of fish stocking on the broader ecological community, beyond the direct effects on listed species, is extremely difficult to assess. Based on a limited number of overseas studies it is possible that fish stocking in lowland streams would affect the community via a trophic cascade (Power, 1990, 1992; Strong, 1992). This would only occur if stocking caused a significant increase in the size of fish populations, which is unknown for most species. In some cases, such an increase may be a management goal, as in the case of conservation stocking. In other cases, stocked species (i.e. Murray cod and golden perch) are targeted by anglers, so stocking may simply compensate for the removal of fish in some areas. Conversely, angling pressure could increase disproportionately in some stocked areas due to anglers targeting the stocked fish. There is little quantitative information on the effectiveness of stocking native fish (other than threatened species) in NSW or on the relationship between stocking and angling pressure.

Risk: There is too little information on the effect of stocking on fish population sizes, l*et al*one on the functioning of freshwater systems to adequately assess the risk of stocking to threatened ecological communities. The paucity of data on survival and fate of stocked fish is a major knowledge gap that must be addressed in future research programs. Without such knowledge, there can be no serious attempt to use fish stocking as a management tool to help promote recovery of the Murray-Darling threatened ecological communities.

Species protected under section 19 of the FM Act

Isopod (*Crenoicus harrisoni*)

Conservation status: Crenoicus harrisoni is protected under the FM Act.

Distribution and decline: The isopod species is known to occur in Saxby Swamp, Barrington Tops National Park, in the upper Manning River Basin. It has never been recorded anywhere else in the area, despite extensive surveys.

Key threatening processes: Unknown.

Other threatening processes: Unknown.

Habitat: Occurs among the roots of mosses and other aquatic plants in Saxby Swamp, Barrington Tops National Park.

Recovery plans: None.

Assessment of risk to Crenoicus harrisoni

Species stocked: Salmonids have been stocked into rivers in the upper Manning River drainage close to Saxby Swamp such as the Barrington River and Saxby Creek, which runs through Saxby Swamp.

Overlap: Salmonids are likely to occur downstream of Saxby Swamp, although the habitat occupied by the isopod is inaccessible to fish and is unlikely to be suitable for the survival of trout (George Wilson, Australian Museum, pers. comm. 2003).

Ecological interactions: Unknown, but interactions with trout are highly unlikely to occur due to the inaccessibility of the isopod's habitat.

Risk: Low. Given the inaccessibility and unsuitability of the isopod's habitat to salmonids, stocking poses a low risk to the species.

Species protected under section 20 of the FM Act

Eel-tailed catfish (*Tandanus tandanus)*

Conservation status: Protected from commercial fishing under s.20 of the FM Act.

Distribution and decline: Eel-tailed catfish occur throughout the Murray-Darling, and in eastern drainages in NSW and Queensland (Clunie and Koehn, 2001b). Formerly considered very abundant, the distribution and abundance of the species is significantly reduced throughout most of its range (Harris and Gehrke, 1997). The species is more common in eastern drainages, although recent studies on the genetics of eel-tailed catfish has revealed that there are probably three distinct species (Musyl and Keenan, 1996). One of these, the Bellinger catfish (Jerry and Woodland, 1997), is classified as "data deficient" by the Australian Society for Fish Biology (also see section B2.5).

Habitat: The eel-tailed catfish occurs in a wide variety of habitats including rivers, creeks, lakes and billabongs.

Key threatening process: The reasons for the decline of eel-tailed catfish are not well understood, but all of the processes listed under the FM Act are likely to have contributed to the decline of the species (Clunie and Koehn, 2001b).

Other threatening processes: Other processes considered to pose a threat to eel-tailed catfish (ranked in order of importance by the eel-tailed catfish recovery team) are sedimentation, loss of aquatic plants, water quality issues (algal blooms, agricultural pollution), diseased and parasites, recreational fishing, fish stocking (genetic issues), salinity and commercial fishing (Clunie and Koehn, 2001b). Carp are also likely to be a threat to catfish, particularly in western drainages.

Recovery plans: A recovery plan has been prepared for the Murray Darling Basin Commission (Clunie and Koehn, 2001a). The plan calls for the research into the reasons for decline of eel-tailed catfish. It also recommends stocking of eel-tailed catfish into suitable areas, but no stocking between drainages where different genetic stocks occur or are predicted to occur.

Assessment of risk to eel-tailed catfish

Species stocked: Species stocked can include golden perch, silver perch, Murray cod, trout cod, freshwater cod, Australian bass and salmonids.

Salmonids

Overlap: There is very little overlap between the distributions of salmonids and eel-tailed catfish (Clunie and Koehn, 2001b).

Ecological interactions: Where they do overlap, it is possible that eel-tailed catfish could be preyed upon by, or compete with trout.

Risk: Low. Due to the very limited overlap between these species, the risk to eel-tailed catfish of salmonid stocking is considered to be low.

Native fish

Overlap: Native fish are stocked throughout the range of the eel-tailed catfish. Species stocked are golden perch, silver perch, Murray cod, trout cod, freshwater cod and Australian bass.

Ecological interactions: There are no data available on interactions between stocked native fish and eel-tailed catfish. The eel-tailed catfish is an opportunistic carnivore (Davis, 1977), so competition is possible, although the species is still locally abundant in areas that have been heavily stocked (Andrew Sanger, NSW Fisheries, pers. comm.). Predation may also be inferred, but it is not known how these interactions affect populations of eel-tailed catfish.

Risk: Low-medium. Due to co-existence and local abundance, despite large spatial overlap and the possibility of competition and predation by stocked native fish, the risk is considered low-medium.

Estuary perch (*Macquaria colonorum*)

Conservation status: The estuary perch is protected from commercial fishing under s.20 of the FM Act.

Distribution and decline: Estuary perch occurs in coastal rivers and lakes, from the Richmond River south. The species has undergone an apparent decline, but no data are available (Harris and Rowland, 1996).

Key Threatening Processes: None of the key threatening processes listed under the FM Act apply to this species.

Other threatening processes: Overfishing is cited as the main reason for the decline of this species (Harris and Rowland, 1996).

Habitat: Occurs in tidal waters in the north, but moves further upstream in the southern part of its range away from the main distribution of Australian bass.

Recovery plans: None is required, as this species is not listed under Schedule 4 of the FM Act.

Assessment of risk to estuary perch

Species stocked: Australian bass may be stocked within the range of the estuary perch.

Overlap: The estuary perch generally prefers deeper and more saline waters than Australian bass, although it is commonly found in fresh or slightly brackish reaches of estuaries, especially in the southern parts of its range that are further south than the main distribution of bass (Harris and Rowland, 1996).

Ecological interactions: No data are available. Based on their ecological similarity, competition between Australian bass and estuary perch is possible.

Risk: Low. Because these two species occupy different habitats within estuaries, the risk is considered to be low.

Freshwater crayfish of the genera *Euastacus* and *Cherax*, except *Cherax destructor*

Conservation status: protected from commercial fishing. None of the species are listed as threatened in NSW. The Murray River crayfish (*Euastacus armatus*) is listed as vulnerable in the ACT (ACT Government, 1999b). The freshwater crayfish were not listed under as protected out of concern for their conservation status, although the conservation status of most of the species is unknown.

Distribution and decline: This listing covers approximately 3 species of the genus *Cherax* and 24 species of the genus *Euastacus* including the Murray crayfish *Euastacus armatus*. The combined distribution of protected freshwater crayfish covers the entire east coast of NSW inland to the lower western slopes of the Great Divide and throughout the Murray, Lachlan and Murrumbidgee drainages in NSW. Within this large geographic area, most of the species have very restricted local distributions (Morgan, 1997).

E. armatus has undergone a considerable reduction in range, is possibly extinct in the Murray River below Mildura and has become rare in the lower Murrumbidgee. Anecdotal evidence suggests that the average size of individual crayfish caught in the recreational fishery has decreased (Horwitz, 1990). Declines in other *Euastacus* and protected *Cherax* species in NSW have not been reported, although few recent surveys for freshwater crayfish have been undertaken.

Key Threatening Processes: There are little data on the processes that threaten freshwater crayfish. River regulation, loss of riparian vegetation and translocation of fish and other crayfish have all been suggested as potential threatening processes (Merrick, 1993).

Other threatening processes: Overfishing is thought to be a major threat to the *E. armatus* (ACT Government, 1999b). Land clearing and urban development leading to increased siltation threatens the Murray crayfish in the ACT (ACT Government, 1999b), and this may apply to other crayfish species. Pesticides and other contaminants, salinity and disease have also been cited as threats to the Murray River crayfish (Horwitz, 1990).

Habitat: *Euastacus* species other than *E. armatus* inhabit highlands or elevated areas near streams in cool, clear running water (Merrick, 1993, 1995; Morgan, 1997). Some species also occur in streams at lower altitudes near the coast (*E. australiensis*, *E. clydensis*, *E. hirsutus*, *E. spinifer*, *E. valentulus*). The Murray River crayfish lives in the flowing, permanent main channels of rivers west of the Great Divide to altitudes of 700m (Merrick, 1993). *Cherax* species occupy similar habitats in coastal lowlands, and the habitat of *C. rotundus* extends to the northern highlands.

Assessment of risk to freshwater crayfish

Species stocked: All fish stocked within New South Wales may be stocked within the range of the freshwater crayfish covered by this listing. Because the freshwater crayfish covered by the listing are primarily montane in distribution, the potential impacts of stocked native fish are considered to be low. Many species have naturally restricted ranges, which is also taken into consideration in assigning the risk to each species from stocking.

Overlap and range restriction: The overlap and range restriction of the crayfish with salmonid stocking areas is given in Table B34.

Ecological interactions: Freshwater crayfish are eaten by all stocked fish (except silver perch), and can form an important part of the diet of golden perch (Battaglene and Prokop, 1987), eel-tailed catfish (Davis, 1977), cod species (NSW Fisheries, unpublished data) and brown and rainbow trout (Faragher, 1983). However, the ecological interactions between fish and crayfish are complex. Local and overseas evidence suggests that there is an upper size limit beyond which crayfish are not vulnerable to predation (Gowing and Momot, 1979; Faragher, 1983; Hill and Lodge, 1999), so in many cases, juveniles would be susceptible until they reach a certain size beyond which they have a refuge from predation. The refuge size depends on the size of the predator - larger fish will take larger crayfish. The crayfish species considered to be at risk here are all relatively small (maximum length of the largest species = 150mm). Furthermore, the species are considered to be very slow growing (S. Ahyong, Australian Museum, pers. comm.), and the majority of individuals do not reach the maximum size, which would make individuals and populations more vulnerable to the effects of predation.

In the presence of predators that are too small to consume them, crayfish may still respond to visual and chemical cues (odours) by engaging in defensive behaviour such as sheltering or displaying their claws. Laboratory experiments have shown that as a result of such predator avoidance activity, the crayfish may spend less time feeding and suffer reduced growth and increased mortality in the absence of direct predation (Hill and Lodge, 1999).

Some field studies have shown that in lakes, stocked salmonids apparently have little impact on freshwater crayfish populations (Gowing and Momot, 1979; Faragher, 1983). However, the disappearance of the New Zealand species *Paranephrops zealandicus* (similar in size and spination to the smaller *Euastacus* species) was documented following the introduction of salmonids into a small lake in New Zealand (McDowall, 1968). In stream surveys, negative correlations between crayfish and fish abundance have been found, and it has been suggested that predation by fish was responsible for those patterns (Englund and Krupa, 2000; Usio and Townsend, 2000). In Australia, there is anecdotal evidence that freshwater crayfish are less common in areas where large fish are present (J. Merrick, Macquarie University, pers comm.; S. Ahyong, Australian Museum, pers. comm.).

There are no data on impacts of stocked fish on *Euastacus* spp. in Australia. Based on overseas studies, however, the potential for impacts to have occurred is high.

Risk: Eleven *Euastacus* species identified as being at medium risk or greater (Table B34). For the other 13 species and the three *Cherax* species, the risk is considered to be low or low-medium.

Table B34. Distribution and overlap between freshwater crayfish and salmonids.

Range restriction: L = not restricted (>400km n/s) M = restricted (50 - 400km) H = very restricted (< 50km). Distributional, habitat and OCL (occipital carapace length) information is taken from Morgan (1997) unless otherwise stated. Total length data are taken from Merrick (1993).

Species	Distribution	Habitat	Size (mm)		Overlap	Range restriction	Risk
			total	OCL			
Cherax species							
C. cuspidatus	Port Macquarie, north to Brunswick heads (Merrick 1995)				L	L	L
C. neopunctatus	From Coffs Harbour north to Ballina but sites are well separated. Common in upper Coldstream (Clarence) (Merrick 1995)				L	L	L
C. rotundus	Extensive distribution from Newcastle north to the Queensland border. Extends to coastal creeks in south. (Merrick 1995)	Steep muddy banks in upper Gwydir (Merrick 1995)	110		L	L	L
Euastacus species							
Euastacus armatus	Throughout Murray and Murrumbidgee	Flowing, permanent main channels of rivers west of the Great Divide to altitudes of 700m	500		L	L	L
E. australasiensis	Extends for 100km along the coast from Ourimbah, south through Sydney to the Bulli Pass (Nth of Wollongong), inland to the Blue Mountains area from the Newnes Plateau in the north to Kanangra Boyd National Park in the South.	Under rocks and in burrows in permanent, stream fed springs, 50 to 1100m ASL. Sandstone and granite areas with some conglomerates, surrounded by eucalypt forest and heath, with patches of temperate rainforest	140	59.4	M	M	L-M
E. bidawalus	From Mt Imlay, 90km south to Lind National Park	Streams bordered by tree ferns, vines and dry sclerophyll forest or heath on ridges, altitudes from 150-400m ASL			None	M	L
E. brachythorax	Tuross river basin (Brown Mountain area), south to near Victorian border (85km)	Streams in granite country 240 to 1000m ASL, well shaded by tree ferns or temperate rainforest, with sclerophyll forest on upper ridges		35.7	L	M	L-M
E. clarkae	Known only from two tributaries of Cockerawombeeba Ck (a tributary of the Forbes River), Mt Boss State Forest near Mt Werrikembe, 45km SW of Kempsey (Hastings R)	Cool, well shaded streams at or above 670m ASL		33.0	H	H	H
E. claytoni	Craigie area near Vic border, north along the great divide to Captains flat, a distance of 160km	Burrows in stream banks, juveniles in shallows under rocks (Merrick 1995). Type locality (McLaughlin River near Nimmitabel) narrow stream with deep (2m) pools. >800m ASL	145	58.5	H	M	M-H

Table B34 cont.

Species	Distribution	Habitat	Size (mm)		Overlap	Range restriction	Risk
Euastacus cont.							
E. crassus	Along the NSW Alps from ACT, south into Victoria (210km)	Small rocky pools in granite areas with dry sclerophyll and heath. Altitudes 640m - 1200m	130	58.0	H	M	M-H
E. dangadi	Coastal mountains of NSW from Coffs Harbour to Port Macquarie (130km). Clarence, Nambucca, Bellingen	Streams in rainforest with sclerophyll on higher ridges		42.8	L	M	L-M
E. dharawalus	Very restricted - small area in and near the northern section of Morton National Park drained by tributaries of the Kangaroo River (Shoalhaven)	Cleared site with some Eucalypts along the stream banks. Found in a catacomb of holes in the soft stream bed		60.8	H	H	H
E. gamilaroi	Hanging rock reservoir, Near Nundle. (Namoi) - known only from a single site, found in 1954, not collected in 1981	Not known		41.8	None	H	L
E. gumar	Tributaries of Clarence River in the Richmond Range, >300m. Trout stocked in the area (Sandy Ck)	Streams surrounded by rainforest in gullies, with sclerophyll on exposed ridges		37.2	L	H	M
E. guwinus	Tianjara Ck above falls (Shoalhaven) near Tianjara. Known only from the one site	Small creek with sandstone bedrock, lined with dry sclerophyll and heath		29.5	None	H	L
E. hirsutus	Mt Keira near Wollongong, south and west to just northeast of Nowra (55km)	Active burrower in swamp habitats (Merrick). Sedimentary areas with light temperate rainforest bordering on streams and wet or dry sclerophyll above the creeks. 200-600m ASL	95	44.0	L	M	L-M
E. neohursutus	Upper Clarence and Bellinger River systems in Dorrigo area. Coastal mountains 20km north-west of Coffs Harbour, south and west through Dorrigo region to New England National Park (65km)	In the east, occurs in small, cool creeks, generally 480 to 710 m, but has been collected at 70m ASL in a tributary of the Bellinger. In the west (Dorrigo area), is found in streams at 1070-1250m ASL, mostly cleared for agriculture	100	42.8	M	M	M
E. polysetosus	Streams above 1000m ASL in the Barrington Tops area, Upper Hunter and Manning catchments	Streams bordered by forest dry sclerophyll, treeferns, subalpine grassland, with snowgums or beech forest, found under stones in shallows	110	56.6	H	H	H
E. reductus	From near Elands, south-west of Comboyne, 100km south-west to the Barrington Tops area, and also the Myall Range near Bulahdelah	Small streams surrounded by rainforest, from 75-550 ASL	80	34.5	M	M	M

Table B34 cont.

Species	Distribution	Habitat	Size (mm)		Overlap	Range restriction	Risk
Euastacus cont.							
E. rieki	High alpine and semi alpine country of the Snowy Mountains, particularly around Mt Kosciuszko, north to Kiandra and Yarrongobilly areas (100km N/S)	Above 560 m, usually above 1000, and up to 1520 m. creeks lined with dry sclerophyll with heath or tussock grass, moderate to poor shade with clear water and little algal growth. Gravel streams, some loose rocks, and bedrock. Most sites covered with snow or ice in winter		52.7	H	M	M-H
E. simplex	From 25km west of Dorrigo, 90km to the Armidale and Guyra areas and a similar distance south along the Botombulla Range to Yarrowitch. Nymboida, Styx, Guy Fawkes rivers in the North, and Hastings River in the south	small to medium sized, open streams with banks vegetated by dry sclerophyll and heath or cleared, between 1100 and 1380m ASL	135	56.3	H	M	M-H
E. spinichelatus	An area of 20 x 40km on and about the Hastings Range, 70km NW of Port Macquarie, and mountains 30km west of Comboyne (Macleay, Hastings and Manning)	Small streams above 680m ASL surrounded by temperate rainforest and wet or dry sclerophyll		38.8	M	M	M
E. spinifer	From the upper reaches of the Hastings River, NW of Port Macquarie, south through Sydney and the Blue Mountains, to Clyde Mountain bear Brooman, 550km north-south and 100km inland.	Moderate to well shaded streams in dry sclerophyll to heath, vegetation with occasional wet sclerophyll or temperate rainforest. Populations are concentrated in undisturbed areas of National Park, state forest and water catchments. 70 to 800m ASL	240	116.7	L	L	L
E. sulcatus	Limited range from upper Richmond River, north to the Lamington Plateau, and west to the Condamine. A relict population may be present on Mt Warning	Streams bordered by rainforest or wet sclerophyll above 300 m	235		L	M	L-M
E. suttoni	Stanthorpe (southern Qld) south 120km along great divide to Glen Innes and along eastern spur of Gibraltar Range. Occurs in upper parts of Darling and Clarence systems	Streams and swamps above 680 m, bordered by open sclerophyll forest or heath	175		L	M	L-M
E. valentulus	Upper Currumbin Ck (SE Qld) to Ballina area (approx 90km and west to Woodenbong (100km). Tweed, Richmond upper Clarence river systems and adjacent smaller coastal streams in hilly terrain	Small flowing tributaries with rocky substrata, up to 600m ASL			L	M	L-M

Table B34 cont.

Species	Distribution	Habitat	Size (mm)		Overlap	Range restriction	Risk
Euastacus cont.							
E. yanga	From Robertson and Bundanoon to just inside the Victorian border west of Genoa, about 400km. Clyde, Shoalhaven, Tuross, Towamba, Womboyn and Genoa Rivers	Streams bordered by temperate rainforest of ferns, with dry sclerophyll and heath on ridges between 60 and 720m ASL		61.2	L	L	L

B2.2.3 Risks to species listed under the TSC Act or EPBC Act

B2.2.3.1 Species that may be at risk from stocking

Eight species of frogs in NSW are listed as threatened under the TSC and/or EPBC Acts and are stream breeders (i.e. their tadpoles live in streams) so, therefore, are likely to interact with stocked fish. Six species, namely Booroolong frog, spotted tree frog, peppered tree frog, New England tree frog, stuttering frog and the giant barred frog, breed exclusively in streams and are thus referred to as obligate stream breeders.

Two species, namely tusked frog and giant burrowing frog, also breed in standing waters and are less reliant upon flowing waters and are thus referred to as facultative stream breeders (Gillespie and Hines, 1999). Facultative stream breeders are considered less vulnerable to predation by stocked fish because they can breed in areas where stocked fish do not occur.

None of the bird species listed under the TSC Act or the EPBC Act are considered likely to interact with stocked fish. While many threatened birds occupy aquatic habitats, most feed in shallow wetland habitats that are not occupied by the fish species stocked by NSW Fisheries. In general the habitats of stocked fish and threatened birds do not overlap. Occasional predation by fish on birds is known, but has not been reported for any threatened bird species, and is considered too rare an occurrence to pose a threat. There is a remote possibility that some listed ducks (blue billed duck and freckled duck) may compete for food with stocked native fish such as silver perch and golden perch. Both species can occupy similar habitats and consume similar invertebrate foods. There are no data on such interactions, and the risk to threatened birds is considered low. Provisioning of listed birds by stocked fish is unlikely since listed piscivorous birds (e.g. osprey) rarely if ever feed on the stocked freshwater species.

None of the listed mammal, reptile or plant species are considered likely to be at risk from stocked fish.

B2.2.3.2 Sources of risk

Three Key Threatening Processes listed under the TSC Act are applicable to the threatened species discussed below. These are:

- alteration to the natural flow regimes of rivers and streams and their floodplains and wetlands (henceforth, referred to as “river regulation”)
- clearing of native vegetation (as defined and described in the final determination of the Scientific Committee to list the key threatening process) (henceforth, “clearing of native vegetation”), and

- predation by *Gambusia holbrooki* Girard, 1859 (Plague Minnow or Mosquito Fish) (as described in the final determination of the Scientific Committee to list the threatening process) (henceforth, "predation by *Gambusia*").

B2.2.3.3 Species information and risk summaries

Of the eight frog species listed under the TSC Act and/or the EPBC act, six are considered to be at medium or greater risk from direct or indirect effects of stocking salmonids under current management arrangements (Table B35). The risk from stocking arises because their tadpoles inhabit streams exclusively, they have extensive range overlap with areas that are eligible to be stocked with salmonids, and their tadpoles are likely to be subject to predation by salmonids. One species, the giant barred frog, is exposed to a medium level of risk from stocking of native fish. This is because the species occurs in areas stocked, or eligible for stocking, with Australian bass and eastern cod.

Table B35. Summary of the risks of stocking salmonids and native fish to species listed under the *Threatened Species Conservation Act 1995* and/or the *Environment Protection and Biodiversity Conservation Act 1999.*

* Denotes species also listed in the same respective category (Endangered or Vulnerable) under the EPBC Act.
Overlap and interaction scores: 0 - no overlap, L - low, M - medium, H - high, U - unknown. See text for details.

			Salmonid risk evaluation			**Native risk evaluation**		
Common name	**Species name**	**Region where threatened species currently occurs**	**Overlap**	**Interaction**	**Risk**	**Overlap**	**Interaction**	**Risk**
Endangered species								
Booroolong frog	*Litoria booroolongensis*	Montane	H	H	**H**	0	L	**L**
Spotted tree frog*	*Litoria spenceri*	Montane	H	H	**H**	0	L	**L**
Giant barred frog	*Mixophyes iteratus*	Coastal, Montane	M	H	**M-H**	M	M	**M**
Vulnerable species								
Peppered tree frog*	*Litoria piperata*	Montane	H	H	**H**	0	L	**L**
New England tree frog	*Litoria subglandulosa*	Montane	H	H	**H**	0	L	**L**
Stuttering frog*	*Mixophyes balbus*	East Coast, Montane	M	M	**M**	M	L	**L-M**
Giant burrowing frog*	*Helioporus australiacus*	East Coast, Montane	L	L	**L**	L	L	**L**
Endangered populations								
Tusked frog	*Adelotus brevis*	Montane	L	M	**L-M**	0	L	**L**

B2.2.3.4 Detailed information supporting the risk assessments

Booroolong frog (*Litoria booroolongensis*)

Conservation status: The Booroolong frog is listed as Endangered under the TSC Act.

Distribution and decline: In NSW, the Booroolong frog occurs predominantly along western flowing streams of the Great Divide from 200 to 1000m above sea level (Gillespie and Hines, 1999). Survey data indicate marked population declines in the north-east of NSW and the Northern Tablelands, and the species may have declined over its entire range (Anstis *et al.*, 1998, Gillespie, 1999). The Booroolong frog is currently known from approximately 26 streams in NSW (David Hunter, University of Canberra, pers. comm. 2003).

Key Threatening Processes: All three key threatening processes listed above are likely to affect the Booroolong frog (Gillespie and Hines, 1999; NSW National Parks and Wildlife Service, 2002).

Other threatening processes: Other threatening processes include timber harvesting, weed invasion and predation by other introduced fish (including salmonids – see below) (Gillespie and Hines, 1999).

Habitat: Usually found on or under boulders and debris in and beside the rocky beds of mountain streams (Cogger, 1996). The species exists in a range of habitat types from undisturbed upland streams to highly modified reaches in farmland (Gillespie and Hines, 1999). Larvae are always found in streams (Gillespie and Hines, 1999).

Recovery plans: A statewide recovery plan is currently in preparation by NPWS.

Assessment of risk to Booroolong frog

Species stocked: Salmonids may be stocked within the range of the Booroolong frog. At least nine streams known to contain the Booroolong frog have been stocked in the past. Stocking is currently temporarily suspended in six of these. Three known Booroolong frog streams are currently stocked with salmonids under a permit from NPWS.

Overlap: There is extensive overlap between salmonids and the Booroolong frog. Twenty-six streams are known to support the Booroolong frog; trout occur in fourteen of those (David Hunter, University of Canberra, pers. comm., 2003).

Ecological interactions: Trout can consume Booroolong frog tadpoles, and could exert significant predatory pressure on populations of these species, particularly when other food resources are limited (Gillespie and Hero, 1999). Recently, three experiments were undertaken as part of a collaborative project between the University of Canberra, NSW Fisheries and the NSW National Parks and Wildlife Service investigating the impact of trout and trout stocking on the Booroolong frog. The first experiment tested the palatability of hatchling tadpoles of three frog species (two riverine species: Booroolong frog and Leseur's frog, and one pond species: spotted marsh frog) to three fish species (brown trout and two native species: mountain galaxias and two-spine blackfish). The second experiment involved comparing the propensity for wild juvenile trout and hatchery reared juvenile trout to consume hatchling Booroolong frog tadpoles, while the third experiment compared consumption of Booroolong frog tadpoles by larger trout (> 15cm) when rock substrates were either present or absent. Preliminary analysis of the results from these experiments suggest the following: Booroolong frog tadpoles and Leseur's frog tadpoles are unpalatable to mountain galaxias and two-spine blackfish, but are palatable to brown trout. Spotted marsh frog tadpoles were palatable to all fish species tested. Compared to wild trout, the hatchery reared trout displayed a greater propensity to consume hatchling Booroolong frog tadpoles under the experimental conditions. The presence of a rock substrate in the experimental enclosures did not afford the Booroolong frog tadpoles any protection from predation by trout (D. Hunter personal communications). Further field monitoring and *in situ* experiments have been planned for December and January 2003/2004.

Risk: High. Given the susceptibility of Booroolong frog tadpoles to predation, and the significant overlap with salmonid species, the risk that stocking fish will impede recovery of the species is considered to be high.

Spotted tree frog (*Litoria spenceri*)

Conservation status: The spotted tree frog is listed as Endangered under both the TSC Act and the Commonwealth's EPBC Act.

Distribution and decline: In NSW, the species is known from two locations on the Bogong creek and one in the upper Murray River. Only one sub-adult frog was ever found at the Upper Murray site (NSW National Parks and Wildlife Service, 2001a). A population was discovered in 1975 on the Bogong creek but the species has not been recorded at this site since, although a second population at Bourke's Gorge, several kilometres upstream of the historical collection site has been discovered (Gillespie and Hollis, 1996; NSW National Parks and Wildlife Service, 2001a). Between 1993 and 1996, the Bourke's Gorge population consistently exceeded several hundred animals, but since then has declined dramatically with a maximum of two frogs recorded in any year since 1999 (Gillespie and Hollis, 1996; NSW National Parks and Wildlife Service, 2001a). The species has probably always occupied a restricted range, but has undergone a precipitous decline within its historic range (Watson *et al.*, 1991).

Habitat: The spotted tree frog occurs among boulders or debris in or beside fast flowing mountain streams (Cogger, 1996), between 200 and 1100m above sea level (Gillespie and Hines, 1999). Spotted tree frogs are distributed patchily among streams. Most individuals are associated with loose rock substrata, rocky banks and riffles or cascades. Adjacent riparian vegetation is also used for shelter and basking. Spotted tree frog is an obligate stream breeder (Gillespie and Hines, 1999). Eggs are deposited under large boulders in streams and development of tadpoles occurs within streams, in shallow pools or shallow stream margins (Gillespie and Robertson, 1998). The habitat at Bourke's Gorge consists of areas of continuous exposed bedrock with loose rock and small waterfalls (Gillespie and Hollis, 1996).

Key Threatening Processes: River regulation is considered to be a threat to the spotted tree frog (NSW National Parks and Wildlife Service, 2001a).

Other threatening processes: Human disturbances such as gold dredging, forest roads and recreational pressures are correlated with the decline of the spotted tree frog (Gillespie and Hollis, 1996). Increased sediment loads caused by such activities cause reduction in growth and development of spotted tree frog tadpoles (Gillespie, 2002). The species persists along some highly disturbed streams, but has disappeared from at least one near pristine stream, suggesting that factors other than human disturbance may also be responsible for the decline (Gillespie, 2001). Trout occur throughout the range of spotted tree frog, can exert significant predation pressure on their tadpoles, and are believed to be a major cause of population declines of spotted tree frogs (Gillespie and Robertson, 1998).

Recovery plans: Two recovery plans are current for the spotted tree frog in NSW. The national spotted tree frog recovery plan lists trial eradication of trout from selected stretches of streams among its recovery actions (Gillespie and Robertson, 1998). The NSW recovery plan considers that eradication of trout is not economically feasible, but would consider such action if it became cost effective, and if re-establishment of breeding populations turns out to be possible at Bourke's Gorge where trout are absent (NSW National Parks and Wildlife Service, 2001a).

Assessment of risk to spotted tree frog

Species stocked: Salmonids may be stocked within the range of the spotted tree frog in New South Wales.

Overlap: Stocking has been temporarily suspended in the Bogong Creek, although this waterway has been stocked in the past and trout are present in the stream below Bourke's Gorge (NSW National Parks and Wildlife Service, 2001a).

Ecological interactions: Tadpoles are known to be highly susceptible to predation by trout (Gillespie, 2001). Predation by trout is considered a causal factor in the decline of the spotted tree frog (NSW National Parks and Wildlife Service, 2001a; Gillespie 2001).

Risk: High. Because of the known susceptibility to predation, the risk that fish stocking will impede recovery of the spotted tree frog in NSW is considered high.

Giant barred frog (*Mixophyes iteratus*)

Conservation status: The giant barred frog is listed as endangered under the TSC and EPBC Acts.

Distribution and decline: Historical records show that the giant barred frog occurred on the eastern slopes and coastal plains from Narooma on the south coast of NSW to the Colondale Ranges in southeastern Queensland. It has not been found south of the Hastings River in surveys conducted since the early 1990s, (Mahony *et al.*, 1997a). Populations are known from the Watagan Mountains, Mount Seaview, Southern Nambucca catchment, and there is a large population in the Dorrigo-Coffs Harbour area. In the far north east it is known from only three sites, despite intensive survey efforts (Hines *et al.*, 1999). Several populations are known from south-eastern Queensland, where declines have also been observed (Hines *et al.*, 1999).

Habitat: The giant barred frog occurs along small, permanent, fast-flowing streams (Mahony *et al.*, 1997a) and also along deep, slow moving streams with steep banks in lowland areas (Hines, 2002). The species is also found in ponds or ephemeral pools (Mahony *et al.*, 1997a). Eggs are deposited onto streamside vegetation, where early development takes place, and are then washed into the stream by rain. Tadpoles are present in streams throughout the year.

Key Threatening Processes: All three key threatening processes listed above are threats to the giant barred frog (Hines, 2002).

Other threatening processes: Timber harvesting and urban development are likely threats. There are also potential, but unknown threats from feral animals, domestic stock, weed invasion and disturbance (Hines *et al.*, 1999). Pollution of water from pesticides and fertilizers is also possible (Mahony *et al.*, 1997a).

Recovery plans: A recovery plan has been prepared for this species (Hines, 2002). The plan calls for effective management of the recovery process, population monitoring, research, protection of existing populations and education programs.

Assessment of risk to giant barred frog

Species stocked: Fish that may be stocked within the range of the giant barred frog are brown trout and rainbow trout, Australian bass and eastern cod.

Salmonids

Overlap: Given the habitat, altitudes and latitudes over which the species is found, overlap with salmonids is likely. Salmonids were not observed at any sites containing the species in a recent survey (Mahony *et al.*, 1997a). Historical records of the species occur near trout streams (the Timbarra River and Washpool Creek) in northeastern NSW. Trout have been stocked into Wild Cattle Creek

(NSW Fisheries fish stocking database), where the species is known to occur (Lemckert and Brassil, 2000). Overlap with trout would not occur at lower altitudes.

Ecological interactions: Interactions with salmonids have not been documented. Predation by salmonids on the tadpoles can be inferred.

Summary of risk: Medium-high. The stocking of trout in areas of former distribution poses a medium-high risk to the recovery of the species in those areas.

Native fish

Overlap: Eastern cod and Australian bass are likely to overlap with the giant barred frog. Eastern cod have been stocked into the Wild Cattle Creek (NSW Fisheries Fish Stocking Database).

Ecological interactions: Australian bass are not known to consume tadpoles (Harris, 1985), and it is not known whether eastern cod would consume tadpoles. It is, however, possible that being generalist carnivores, both species could consume tadpoles of this species.

Risk: Medium. Considering the overlap and possibility of predation fish stocking poses a medium level of risk to the recovery of the giant barred frog.

Peppered tree frog (*Litoria piperata*)

Conservation status: The peppered tree frog is listed as vulnerable under the TSC Act and the EPBC Act.

Distribution and decline: The peppered tree frog is known from five streams in the east of the Northern Tablelands from the Gibraltar Range to Armidale, at altitudes between 800 and 1120m above sea level. This species has not been sighted since 1973, despite several surveys of the historic collection sites and previously unsurveyed areas of potential habitat (Gillespie and Hines, 1999; NSW National Parks and Wildlife Service, 2001c).

Habitat: The species occurs in or beside rocky streams between 800 and 1120m above sea level (Gillespie and Hines, 1999).

Key Threatening Processes: Predation by *Gambusia holbrooki* has been suggested as a likely cause of decline for this species (Gillespie and Hines, 1999).

Other threatening processes: The reasons for decline are unknown, but may include habitat disturbance through land clearance, grazing and timber harvesting. Predatory fish (*Gambusia* and salmonids) have been introduced to these streams from where the peppered tree frog is known and may have impacted frog populations through predation on larvae (Gillespie and Hines, 1999). Other possible threats include disease, increased UV radiation, drought and chemical pollution (Tyler, 1997).

Recovery plans: The recovery outline (Tyler, 1997) for the peppered tree frog calls for clarification of the taxonomy of this species and notes that any recovery plan would be dependent on resolution of the systematic and nomenclature problem. The recovery plan for the peppered tree frog (NSW National Parks and Wildlife Service, 2001c) calls for research on the distribution of any extant populations and resolution of taxonomic issues, protection of potential habitat, effective protection of any populations which may be discovered in the future and to determine agents which contributed to the species decline (NSW National Parks and Wildlife Service, 2001c).

Assessment of risk to peppered tree frog

Overlap: Salmonids may be stocked within the entire known range of the peppered tree frog.

Ecological interactions: Salmonids are known to consume tadpoles of closely related species and are thus considered likely to prey on tadpoles of this species.

Risk: High. Although there are no recent sightings of this species, the species is not listed as extinct and, therefore, it is assumed that undiscovered populations exist. Stocking of salmonids, which are likely to prey on tadpoles, poses a high risk to the recovery of this species.

New England tree frog (*Litoria subglandulosa*)

Recent work on the taxonomy of this species have found that it actually consists of two different species: *Litoria subglandulosa sensu stricto* and *L. daviesae* n. sp. (Mahony *et al.*, 2001). Threatened species listings have not been updated to reflect the new classification. Information on both species is reported here. In the following discussion, New England tree frog refers to *L. subglandulosa sensu stricto*.

Conservation status: The New England tree frog is listed as Vulnerable under the TSC Act. *L. daviesae* is not listed, but is considered vulnerable (Mahony *et al.*, 2001).

Distribution and decline: The New England tree frog is known from stream habitats on the eastern escarpment of the Great Dividing Range from “The Flags” near Walcha in northern NSW to Girraween National Park, southern Qld, a distance of 250km. The species has disappeared from several areas in the south of its range and is uncommon in the north. The species apparently no longer occurs in the upper reaches of streams that originate on the tablelands (Mahony *et al.*, 2001).

Litoria daviesae occurs further south occupying a 150km band along the eastern edge of the tablelands and great escarpment of the Great Dividing Range, from north of the Hunter River to the catchment of the Hastings River (Mahony *et al.*, 2001). Because this species has only recently been detected, it is difficult to assess its conservation status by comparing present population to past populations. However, due to its limited distribution, apparently small population size and a reported decline in one area (the region between the Hastings and Manning Rivers (Anstis, 1997)), Mahony *et al*. (2001) consider *L. daviesae* to be vulnerable.

Habitat: The New England tree frog is found in or adjacent to well vegetated, upland streams above 600m. Surrounding vegetation may consist of heath or dry open forest with tea tree and tussocks and ferns along the stream. On the edge of the escarpment, streams are surrounded by wet sclerophyll and rain forest vegetation, usually with a rainforest understorey (Mahony *et al.*, 2001). The species has also been recorded along streams running through semi-cleared grazing land (Anstis, 1997).

L. daviesae occurs in similar habitats, but down to 400m elevation.

Key Threatening Processes: Predation by *Gambusia*.

Other threatening processes: The reasons for the decline of both these species are uncertain, but potentially threatening process operating in catchments containing the New England tree frog include timber harvesting, forest grazing and aerial spraying, and predation by exotic fish (Gillespie and Hero, 1999; Gillespie and Hines, 1999). Many of the streams within the species’ range contain exotic fish including carp, trout and mosquito fish, which may have an impact on eggs and larvae (Mahony *et al.*, 2001). The three main rivers near the type locality of the New England tree frog have been stocked with trout, and recent surveys show a drastic decline in frog and tadpole numbers of all species previously known at these sites (New England tree frog, Booroolong frog, stuttering frog and *L. barringtonensis*) (Anstis, 1997).

Recovery plans: There is a recovery plan for Queensland populations of the New England tree frog (Hines, 2002), but none for New South Wales.

Assessment of risk to New England tree frog

Species stocked: Brown and rainbow trout.

Overlap: Salmonids may be stocked within the majority of the range of New England tree frog.

Ecological interactions: Predation on tadpoles may be inferred from work on the closely related spotted tree frog.

Risk: High. Given the known overlap and the likely role of salmonids as predators of tadpoles, there is a high risk that salmonid stocking will impede the recovery of New England tree frog.

Stuttering frog (*Mixophyes balbus*)

Conservation status: The stuttering frog is listed as Vulnerable under the TSC Act (NSW) and Vulnerable under the EPBC Act.

Distribution and decline: Historically, the stuttering frog occurred from East Gippsland in Victoria, along the eastern escarpment of the Great Dividing Range and coastal region to north-eastern NSW (Tyler, 1997). Populations have declined in many areas in which they are known. The species may be extinct in Victoria and parts of NSW, and is extremely rare at most other locations (Gillespie and Hines, 1999).

Habitat: The stuttering frog is typically associated with permanent streams in temperate and subtropical rainforest and wet sclerophyll forest, and moist gullies in dry forest (Gillespie and Hines, 1999). It occurs at altitudes of 50 – 900m ASL (Daly, 1998).

Key Threatening Processes: Clearing of native vegetation and predation by *Gambusia holbrooki* may contribute to the decline of the stuttering frog (Mahony *et al.*, 1997b).

Other threatening processes: Logging, associated forest management practices and forest grazing may threaten the stuttering frog (Mahony *et al.*, 1997b). Interactions with stocked fish are possible (see below).

Recovery plans: A national recovery plan is in preparation for this species.

Assessment of risk to stuttering frog

Species stocked: Salmonids and Australian bass may be stocked within the range of the stuttering frog. Several biological attributes make the stuttering frog susceptible to predation by stocked fish. Breeding occurs in January, coinciding with the timing of stocking events (other than in the north-west of the State where stocking finishes in November). Hatchlings are small (6-7mm long), take a year to metamorphose and reach a maximum total length of around 64mm (Daly, 1998).

Salmonids

Overlap: Salmonids may be stocked in the higher altitude parts of the stuttering frog's range.

Ecological interactions: Salmonids are known to eat frog tadpoles of other species, and it is likely that they would consume stuttering frog tadpoles also. Salmonids have been observed in areas where the stuttering frog has declined (Anstis, 1997). However, the stuttering frog has also disappeared from many streams that do not contain introduced fish (Gillespie and Hines, 1999), suggesting that if stocked salmonids have contributed to the decline, they are not the only factor.

Risk: Medium. Given the partial overlap and likelihood of predation, stocking of salmonids poses a medium risk to the stuttering frog.

Native fish

Overlap: Australian bass may be stocked within the range of the stuttering frog at lower altitudes.

Ecological interactions: Predation on tadpoles by Australian bass is possible, but none were found it the stomachs of 552 Australian bass collected in the Sydney region over a period of four years (Harris, 1985). It has been suggested, however, that the absence of tadpoles in stomach contents does not provide a reliable indication of lack of predation, because digestion of these soft-bodied larvae is rapid. It is possible that tadpoles are chemically defended against predation by native fish (Gillespie and Hero, 1999).

Risk: Low - Medium. Given the partial overlap between Australian bass and the stuttering frog, and the possibility of predation on the tadpoles of the species, the risk of stocking is considered to be low-medium.

Giant burrowing frog (*Helioporus australiacus*)

Conservation status: The giant burrowing frog is listed as Vulnerable under the TSC Act.

Distribution and decline: The giant burrowing frog is distributed from Mount Coricudgy and Kings Cross in Wollemi National Park north of Sydney, along the coast and ranges to the eastern highlands of Victoria (NSW National Parks and Wildlife Service, 2001b). The species has undergone a perceived decline in numbers (Recsei, 1997).

Key Threatening Processes: Clearing of native vegetation has been identified as a threat to the giant burrowing frog (NSW National Parks and Wildlife Service, 2001b).

Other threatening processes: Forestry activities, grazing, road works, urban runoff, predation by foxes and cats, housing developments and fires may threaten the giant burrowing frog (Recsei, 1997; NSW National Parks and Wildlife Service, 2001b).

Habitat: In the northern part of its range, the giant burrowing frog occurs in hanging swamps on sandstone shelves and beside perennial non-flooding creeks. In the Shoalhaven area, the species occurs in ephemeral creeks running through heath or tall open eucalypt forest adjacent to heath (Daly, 1996). It occurs at altitudes from 10 to 1000m ASL.

Recovery plans: There is no recovery plan for the giant burrowing frog.

Assessment of risk to giant burrowing frog

Species stocked: Australian bass and salmonid species may be stocked within the range of the giant burrowing frog.

Salmonids

Overlap: The giant burrowing frog overlaps partially with areas that are eligible for salmonid stocking. The species is not an obligate stream breeder, but also breeds in still waters, so its overlap with salmonids at higher altitudes would only be partial. Furthermore, in the Shoalhaven, Illawarra and Southern Sydney regions, breeding sites of the giant burrowing frog were in the upper sections of ephemeral creeks that did not contain fish (Daly, 1996).

Ecological interactions: Salmonids would be likely to prey on tadpoles of the giant burrowing frog if they encountered them.

Risk: Low. Due to limited overlap, tadpoles are unlikely to encounter stocked salmonids.

Native species

Overlap: Australian bass may be stocked within the range of the stuttering frog. In the Shoalhaven, Illawarra and Southern Sydney regions, breeding sites of the giant burrowing frog were in the upper sections of ephemeral creeks and did not contain fish (Daly, 1996).

Ecological interactions: It is possible that tadpoles would be consumed by Australian bass, but they were not found in the stomachs of 552 Australian bass collected in the Sydney region over a period of four years (Harris, 1985). Tadpoles may be chemically defended against predation by native fish (Gillespie and Hero, 1999). Predation is, therefore, considered unlikely.

Risk: Low. Due to the small likelihood of predation by Australian bass on tadpoles, and the absence of fish at known breeding sites the risk to the giant burrowing frog from fish stocking is considered low.

Tusked frog (*Adelotus brevis*)

Conservation status: The tusked frog population in the Nandewar and New England Tablelands Bioregions is listed as Endangered Population under the TSC Act (NSW).

Distribution and decline: The tusked frog occurs along the Great Dividing Range and coastal plain from central Queensland to southern New South Wales (Cogger, 1996). Historical records indicate that the species was formerly widespread throughout the Nandewar and New England Tableland regions (Heatwole *et al.*, 1995), although considerable survey effort throughout the 1990s, resulted in only one record from within the New England Tablelands in 1992 (NSW National Parks and Wildlife Service, 2000). A further two records in 1997 come from just outside the region.

Habitat: The tusked frog occurs in rainforest, wet sclerophyll and open grazing country and is usually found under logs or stones, in cavities and crevices or beside puddles or streams. The species is considered to be a facultative stream breeder (Gillespie and Hines, 1999).

Key Threatening Processes: The key threatening processes affecting this species are unknown, but may include predation by *Gambusia holbrooki* and clearing of native vegetation (NSW National Parks and Wildlife Service, 2000).

Other threatening processes: Other threatening processes that may have contributed to the decline of the tusked frog include chytrid fungal infections (Berger *et al.*, 1999), and predation by introduced fish such as carp and salmonids (Gillespie and Hines, 1999; NSW National Parks and Wildlife Service, 2000).

Recovery plans: There is no recovery plan for the tusked frog.

Assessment of risk to tusked frog

Overlap: Salmonids may be stocked throughout the range of the endangered population in the New England Tablelands. The tusked frog is not confined to streams (Gillespie and Hines, 1999); therefore, its tadpoles will not necessarily encounter stocked fish such as salmonids.

Ecological interactions: Salmonids are likely to be predators of tadpoles of this species.

Risk: Low-medium. Given the partial overlap and the possibility of predation by salmonids, there is a low-medium risk that stocking will impede the recovery of this species.

B2.3 Species not currently listed as threatened

B2.3.1 Species information and risk summaries

Species of fish that are not currently listed under any threatened species legislation are considered in this section. These species have been included because concerns have been raised in the literature about their decline and fish stocking has been suggested as a possible cause of decline. The relevant available information is reviewed for each species, and the risk that fish stocking poses to their recovery is evaluated. The methodology for evaluating risks is the same as that used for the threatened species in sections B.2.1 and B.2.2 above. A summary of the risks to these unlisted species is given in Table B36.

Two galaxiid species are considered to be at high risk from salmonid stocking as practiced under current management arrangements. These species are known prey of salmonids, and abundant circumstantial evidence as well as some experimental data suggests that trout have caused the decline of these species in some areas (see section B.1). The river blackfish is considered to be at low-medium risk despite its considerable overlap with salmonids, because it is apparently able to coexist with salmonid species (see below). Two species (Murray jollytail and Darling River hardyhead) are at medium risk from the stocking of native fish, because they have a medium level overlap and are vulnerable to predation by stocked native fish species.

Table B36. Summary of the risks of stocking salmonids and native fish to species not listed as threatened though potentially directly or indirectly affected by fish stocking activities.

Overlap and interaction scores: 0 - no overlap, L - low, M - medium, H - high, U - unknown. See text for further details.

			Salmonid risk evaluation			Native risk evaluation		
Common name	**Species name**	**Region where species currently occurs**	**Overlap**	**Interaction**	**Risk**	**Overlap**	**Interaction**	**Risk**
Climbing galaxias	*Galaxias brevipinnis*	East coast, Murray	L	H	**M**	L	L	**L**
Mountain galaxias	*Galaxias olidus*	East coast, montane, Murray, Darling	H	H	**H**	L	L	**L**
River blackfish	*Gadopsis marmoratus*	Montane, Murray	H	L	**L-M**	L	L	**L**
Darling River hardyhead	*Craterocephalus amniculus*	Darling	0	L	**L**	M	M	**M**
Murray jollytail	*Galaxias rostratus*	Murray, Darling?	L	M	**L-M**	M	M	**M**
Congolli	*Pseudaphtitis urvillii*	East coast	L	L	**L**	H	L	**L-M**
Non-parasitic lamprey	*Mordacia praecox*	East coast	0	0	**L**	H	M	**M**
Two-spined blackfish	*Gadopsis bispinosus*	Murray, montane	M	L	**L-M**	M	L	**L-M**

B2.3.2 Detailed information supporting the risk assessments for species not listed under threatened species legislation

Climbing galaxias (*Galaxias brevipinnis*)

Conservation status: Not listed. The species is considered here because of fragmentation of the population and probable detrimental interactions with stocked fish.

Distribution and decline: Found in coastal drainages south of and including Sydney, but the distribution is probably fragmented over most of this range. Landlocked populations occur in Curl Curl Creek above Manly Dam and in isolated tributaries of the Nepean River (Morris *et al.*, 2001). The species has also found its way into the Murray-Darling system, probably via the Snowy mountains scheme (McDowall and Fulton, 1996). It has recently been collected at sites in the Snowy, Murray, Darling, Bega, Shoalhaven and Macleay catchments (Hartley and Rayner, 2003). The Australian Museum has 17 recent records of the species from locations in the Snowy, Upper Murray, Murrumbidgee, Shoalhaven, Port Hacking, Georges, Lake Macquarie and Karuah catchments.

Habitat: Clear boulder-filled headwater streams, also in lakes and their tributaries among rocks and other cover (McDowall and Fulton, 1996). Following hatching, juveniles are washed downstream to the sea and subsequently migrate back to the adult habitat as whitebait.

Key threatening processes: All four of the key threatening processes listed under the Fisheries Management Act 1994 apply to the climbing galaxias (Morris *et al.*, 2001).

Other threatening processes: Sedimentation, erosion and residential development have also been suggested as possible causes of decline of the climbing galaxias.

Assessment of risk to climbing galaxias

Species stocked: Salmonids and Australian bass may be stocked within the range of the climbing galaxias.

Salmonids

Overlap: Where climbing galaxias occurs in montane areas it overlaps with salmonids. The species is able to climb barriers, such as waterfalls, that are impassable by salmonids, so may find some refuge in areas inaccessible to stocked fish. Relatively few known sites are eligible to be stocked with salmonids.

Ecological interactions: The climbing galaxias occurs predominantly in areas inaccessible to trout (McDowall and Frankenberg, 1981). Considerable circumstantial evidence suggests that trout have reduced or eliminated climbing galaxiid populations in Victoria, Tasmania and NSW (Frankenberg, 1966; Andrews, 1976; Tilzey, 1976; Jackson and Williams, 1980). Predation by trout is considered the most likely causal mechanism (Tilzey, 1976).

Risk: Medium. Salmonid stocking has probably been responsible for the decline and population fragmentation of the climbing galaxias in some areas, although given the small overlap in NSW, the risk is considered to be medium.

Native fish

Overlap: Australian bass are stocked into the lower reaches of rivers containing the climbing galaxias. Bass and galaxiids are likely to interact only during migrations of galaxiids.

Ecological interactions: Predation on the migrating juveniles stages by bass is possible, but there are no data available.

Risk: Low. Due to the limited temporal overlap of these species, the risk from stocking of Australian bass is considered low.

Mountain galaxias (*Galaxias olidus*)

Conservation status: Not listed. The species is considered here because of documented habitat fragmentation and known interactions with stocked fish.

Distribution and decline: Widespread in eastern Australia at moderate to high altitudes in eastern and western drainages. Populations of this species have become highly fragmented (McDowall and Fulton, 1996). *Galaxias olidus* is highly variable and may actually comprise several different species (Raadik, 2001). Areas of particularly high diversity for this species are known in the Mt Kosciuszko National Park, in the upper reaches of the Bellinger and Clarence systems in the Dorrigo area (T. Raadik, pers. comm. 2003).

Habitat: Primarily found in small streams and sometimes in small tarns and ponds up to 1800m ASL (McDowall and Fulton, 1996). It occurs primarily in montane areas, but has been recorded at lower altitudes (McDowall and Frankenberg, 1981).

Key Threatening Processes: Loss of riparian vegetation, installation of instream structures that regulate flow and translocation of fish species beyond their natural range (primarily salmonids and redfin), have contributed to the decline of the mountain galaxias (Morris *et al.*, 2001).

Other threatening processes: Increased sedimentation has also been considered a threat to the mountain galaxias (Morris *et al.*, 2001).

Assessment of risk to mountain galaxias

Species stocked: All species are stocked within the range of the mountain galaxias.

Salmonids

Overlap: Most of the waters where the mountain galaxias occurs have been stocked with trout. The species may find some refuge in small headwater streams that are inaccessible to trout and in warmer tributary streams where trout do not survive.

Ecological interactions: There is much circumstantial evidence that trout are responsible for the decline of mountain galaxias (Tilzey, 1976; Jackson and Williams, 1980; Closs and Lake, 1996), and two studies have provided convincing experimental evidence that trout can reduce local populations (Fletcher, 1979; Lintermans, 2000).

Risk: High. Salmonids stocking has probably been important in the decline and fragmentation of the Mountain galaxias population. Continued stocking under the current management arrangements i.e., stocking into most montane streams, is likely to inhibit the recovery of the mountain galaxias. It is noted that the observed fragmentation of the species is reversible through the elimination of salmonids (Lintermans, 2000).

Native fish

Overlap: Native fish are stocked within the range over which the mountain galaxias has been recorded (McDowall and Fulton, 1996), but there is no native stocking within the core montane part of the species' range.

Ecological interactions: Predation and competition are possible.

Risk: Low. Due to the limited overlap between stocked native fish and the mountain galaxias, the risk to the mountain galaxias from fish stocking is considered negligible.

River blackfish (*Gadopsis marmoratus*)

Conservation status: Not listed under the FM Act. This species has undergone a major decline in the Darling River system (Harris and Gehrke, 1997; NSW Fisheries Scientific Committee, 2001e).

Distribution and decline: Occurs in western drainages in New South Wales. In the northern part of its range, it occurs at altitudes above 600-900m ASL, but further south, in the Murray region, it is found down to 150m (Jackson *et al.*, 1996).

Habitat: Occurs in a range of stream types including clear, fast flowing mountain streams and more sluggish lowland rivers in the south, in areas with abundant cover of rocks or woody debris (Jackson *et al.*, 1996). Small numbers occur in some Victorian reservoirs.

Key Threatening Processes: Removal of woody debris (Jackson, 1978b) and reductions in water temperature through river regulation (Jackson *et al.*, 1996) are thought to threaten the river blackfish.

Other threatening processes: The river blackfish is susceptible to increased sedimentation, which kills eggs and juvenile fish (Jackson *et al.*, 1996).

Recovery plans: None. The Species Impact Statement for Fishing in the Lower Murray River Catchment proposes a zero bag limit for the species within the threatened ecological community of the lower Murray. However, this measure would cover only a small part of the species' range, i.e. the Murray, Murrumbidgee, Tumut and Goobarragandra Rivers (NSW Fisheries, 2002).

Assessment of risk to river blackfish

Species stocked: Salmonids are primarily stocked within the range of the river blackfish, as well as some native species.

Salmonids

Overlap: Based on habitat considerations and altitude, overlap with salmonids is likely throughout most of the upper reaches of rivers within the range of river blackfish in NSW. River blackfish are generally found in highest abundances at lower altitudes where trout are not found.

Ecological interactions: In a detailed study of interactions between brown trout and river blackfish, Jackson (1978a) found that these species consume similar food items, and concluded that competition was occurring. The two species were found to occur in different habitats, with river blackfish occurring only in slow flowing pools and flats, while trout occurred in all of the identified habitats and were positively correlated with flow speed. In contrast, Koehn *et al*. (1994) and Davies (1989) found that trout and blackfish abundances were positively correlated, and this was attributed to similar habitat preferences of the two species. These apparently contradictory results may be explained by the difference in relative abundances of the two species in each study. In Koehn *et al*. (1994), blackfish were an order of magnitude more abundant than trout. In Jackson (1978a), trout were approximately twice as abundant as blackfish. Koehn *et al*. (1994) suggested that in Jackson's (1978a) study, a dominance hierarchy among the trout forced most of the smaller trout into the marginal higher flow habitats (which comprised the majority of habitat types), resulting in a positive correlation between flow speed and trout abundance. In contrast, where trout were relatively rare (Koehn *et al.*, 1994), trout were not forced into less favourable high-flow habitats by intraspecific competition. Thus trout and blackfish do occupy similar habitats and consume similar foods, but can apparently coexist. The studies described above were done in a relatively pristine habitat. Fletcher (1979), in a study of the upper Yarra, Victoria, found that river blackfish occurred at much greater densities above a waterfall where trout were absent, than below the waterfall where brown trout were present. It was suggested that competition might be more severe in less pristine habitats with fewer food resources, such as the Yarra River (Fletcher, 1986). Predation of blackfish by salmonids is known (Butcher, 1945; Jackson, 1978a; Cadwallader, 1979), but it is not known whether predation occurs frequently enough to have an impact on blackfish populations.

Risk: Low-medium. Although the species overlap partially, there is evidence that they can coexist in some stream habitats. The risk to river blackfish from stocking of salmonids is therefore considered low-medium.

Native fish

Overlap: Native fish stocking occurs throughout the range of river blackfish in the Murray-Darling system. Some trout cod stocking may be done within the range of the river blackfish.

Ecological interactions: There are no data on interactions between stocked native species and river blackfish. Golden perch and Macquarie perch have similar diets to blackfish, although they occur in different habitats. River blackfish have a strong dependence on instream cover as their preferred spawning and feeding habitat. It spends very little time in open water habitats during the day, but moves into more open water in the evenings.

Risk: Low. The risk that stocked natives would inhibit recovery of the river blackfish is considered to be low due to their limited overlap and specialised habitat preference.

Darling River hardyhead (*Craterocephalus amniculus*)

Conservation status: The Darling River hardyhead is listed as vulnerable by the Threatened Species Committee of the Australian Society for Fish Biology (ASFB).

Distribution and decline: Known from the upper tributaries of the Darling River including the Condamine River, Peel River, Namoi River, Warialda Creek, Macintyre River, Cockburn River and Boiling Down Creek (Ivantsoff and Crowley, 1996). Specimens have also been collected in the Hunter River drainage, but subsequent collecting failed to locate the species there, and it is not clear whether the species occurs there naturally or was translocated (Crowley and Ivantsoff, 1990). The species is reportedly abundant at times, but concern is held for its status (Ivantsoff and Crowley, 1996).

Key Threatening Processes: Unknown, but thermal pollution resulting from river regulation and interactions with translocated fish (redfin and gambusia) may have affected the species (Morris *et al.*, 2001).

Other threatening processes: Habitat changes caused by agricultural practices may also threaten the Darling River hardyhead (Morris *et al.*, 2001).

Habitat: The Darling River hardyhead is found in gently flowing, shallow, clear water (e.g. lakes, billabongs and backwaters) or amongst weed at the edge of such waters (Ivantsoff and Crowley, 1996).

Assessment of risk to Darling River hardyhead

Species stocked: Fish that may be stocked within the range of the Darling River hardyhead are silver perch, golden perch and Murray cod.

Native species

Overlap: The native fish listed are all likely to overlap in distribution with the Darling River hardyhead.

Ecological interactions: Interactions with other species are unknown. Predation by stocked fish is considered likely, based on the small size of the fish and the predatory nature of golden perch and Murray cod.

Risk: Medium. Given the possibility of predation and the high degree of overlap, the risk that fish stocking will impede recovery of the species is considered to be medium.

Murray jollytail (*Galaxias rostratus*)

Conservation status: The Murray jollytail is listed as vulnerable by the Australian Society for Fish Biology (ASFB).

Distribution and decline: Widespread but intermittent at low elevations throughout the Murray and Murrumbidgee rivers, with one isolated record from the upper Darling (McDowall and Fulton, 1996). The species was not recorded in the NSW Rivers Survey. The species is thought to have undergone a significant decline (Dean Gilligan, NSW Fisheries, pers. comm., 2003).

Key Threatening Processes: Processes that may threaten the Murray jollytail are unknown, but may include river regulation and fish translocation (redfin, brown trout, rainbow trout and gambusia, Morris *et al.*, 2001).

Other threatening processes: Habitat changes due to agricultural practices may also threaten the Murray jollytail (Morris *et al.*, 2001).

Habitat: Found in still and gently flowing waters such as lakes, lagoons, billabongs and backwaters (McDowall and Frankenberg, 1981).

Assessment of risk to Murray jollytail

Species stocked: Salmonids, golden perch, silver perch, Murray cod and trout cod may be stocked within the range of this species.

Salmonids

Overlap: There is a minimal amount of overlap in montane areas as Murray jollytail are primarily a lowland species.

Ecological interactions: No data are available. Given that trout are predators of other small galaxiids they are also likely to be predators of this species.

Risk: Low. Due the small area of overlap, the risk to the Murray jollytail is considered to be low. Recovery of the species in montane habitats is unlikely under current stocking arrangements.

Native species

Overlap: Stocked species are likely to occur in those habitats occupied by the Murray jollytail.

Ecological interactions: The Murray jollytail may be consumed by larger native species (McDowall and Fulton, 1996).

Risk: Medium. Due to the overlap with stocked fish and the likelihood of predation, the risk is considered to be medium.

Congolli (*Pseudaphtitis urvillii*)

Conservation status: Not listed.

Distribution and decline: The congolli is primarily a marine species, but is commonly found in fresh water and has been recorded up to 120km inland. It is widespread in coastal NSW south of Bega (Andrews, 1996). In one Tasmanian study, the species became less abundant further (16km) from the coast (Sloane, 1984). The species is not reported to have declined, but is of concern because barriers to migration may have led to reduced upstream abundances in coastal rivers (Morris *et al*., 2001).

Key Threatening Processes: River regulation may impede migration into previous, upstream habitats (Morris *et al*., 2001).

Other threatening processes: Unknown.

Habitat: The congolli is commonly found near the mouths of slow moving streams emptying into estuaries. The species occurs in leaf litter, among rocks, under sunken logs and overhanging banks (Andrews, 1996).

Assessment of risk to congolli

Species stocked: Australian bass and salmonids may be stocked within the range of the congolli.

Salmonids

Overlap: There may be a small amount of overlap in the upper reaches of the Moruya and Tuross Rivers.

Ecological interactions: Unknown. Predation by salmonids is likely given the small size of the species. Competition is also possible, given that the species is a generalist carnivore (Hortle and White, 1980).

Risk: Low. Due to the limited overlap between salmonids and congolli, the risk from stocking this species is considered to be low.

Australian bass

Overlap: Stocked bass are likely to occupy the entire range of the congolli. In estuarine areas, the female bass occur only during the breeding season (winter), while males may be present year-round. Juvenile bass migrate upstream in mid spring (Koehn and O'Connor, 1990).

Ecological interactions: Unknown. Predation and competition are possible. The congolli is a generalist carnivore, consuming benthic invertebrates such as gastropods, amphipods, mayflies, chironomids and trichopterans (Hortle and White, 1980). Australian bass also consumes similar species, although fish are more important in the diet of Australian bass (Harris, 1985), and competition is considered unlikely.

Risk: Low-Medium. Given that the species is considered to be widespread and abundant within its range, stocking of bass is considered to pose a low to medium level of risk to the congolli.

Non-parasitic lamprey (*Mordacia praecox*)

Conservation status: Not listed. Potentially threatened (ASFB).

Distribution and decline: The species has a very limited known distribution. It has been found in the Moruya and Tuross Rivers. The species may also occur in some Victorian streams, but difficulties in distinguishing it from the more widespread shortheaded lamprey make its full distribution difficult to determine (Potter, 1996).

Key Threatening Processes: River regulation has created barriers to the migration of this species.

Other threatening processes: Habitat destruction and agricultural land use practices may also threaten the non-parasitic lamprey (Morris *et al*., 2001).

Habitat: The non-parasitic lamprey occurs in the soft-bottom mud of flowing freshwater and estuarine habitats, including coastal rivers and streams.

Assessment of risk to non-parasitic lamprey

Overlap: High. Australian bass may be stocked within the entire range of the non-parasitic lamprey.

Ecological interactions: Interactions between the species are unknown. The non-parasitic lamprey is a filter feeder and, therefore, is unlikely to compete with bass. Predation is considered possible, given that fish are reported to be the most important component of the diet of Australian bass (Harris, 1985), but no data are available.

Risk: Medium. Given the large overlap and the possibility of predation, the risk to the non-parasitic lamprey is considered to be medium.

Two-spined blackfish (*Gadopsis bispinosus*)

Conservation status: The two-spined blackfish is listed as a vulnerable species in the ACT. It is not listed under the FM Act, TSC Act or EPBC Act.

Distribution and decline: The two-spined blackfish occurs west of the Great Dividing Range from northeastern Victoria into southeastern New South Wales and the ACT. The species occurs in the Murray drainage above Lake Hume, and a few streams in the upper Murrumbidgee (Jackson *et al*., 1996). The species is reported to be very abundant in many parts of its range, but has apparently declined in others (ACT Government, 1999d).

Key Threatening Processes: River regulation is a threat to the two-spined blackfish (ACT Government, 1999d).

Other threatening processes: Other threatening process include loss of instream habitat, reduction in water quality, siltation resulting from land clearing extractive industries, building of dams and urban development (ACT Government, 1999d; Morris *et al*., 2001).

Habitat: The two-spined blackfish occurs in cool, clear streams with gravel, cobble or boulder substrata and is associated with instream habitat such as boulders or woody debris (Jackson *et al*., 1996).

Recovery plans: An action plan has been prepared for the ACT (ACT Government, 1999d). The action plan sets out a range of measures including allocation of adequate environmental flows, maintenance of certain barriers to upstream migration of introduced fish species, appropriate surveys, monitoring and research activities, community education and protection of existing populations.

Assessment of risk to two-spined blackfish

Species stocked: Salmonids may be stocked with the range of the two-spined blackfish. Native fish that may be stocked within the range of the two-spined blackfish are golden perch, silver perch, Murray cod and trout cod.

Salmonids

Overlap: Trout occur with two-spined blackfish at all sites in the ACT and almost all sites in Victoria (ACT Government, 1999d).

Ecological interactions: There is little information on interactions between two-spined blackfish and salmonids. Trout are known to prey on two-spined blackfish. Two-spined blackfish may be able to co-exist with trout in pristine habitats (Jackson *et al*., 1996), but whether this occurs in sub-optimal habitats is unclear (ACT Government, 1999d).

Risk: Low-medium. Given that trout and two-spined blackfish can apparently coexist, and that the two-spined blackfish is considered to be abundant in many parts of its range, risk to this species from salmonid stocking is considered to be low-medium.

Native fish

Overlap: Native fish may be stocked throughout most of the range of the two-spined blackfish. The two-spined blackfish has similar habitat requirements to the river blackfish and restricts the actual overlap with stocked species.

Ecological interactions: Interactions between two-spined blackfish and the stocked native species have not been reported, but competition and predation are considered possible. However, the species are known to occur together and where they do they are still relatively abundant.

Risk: Low-medium. Because the two-spined blackfish is considered to be abundant in many parts of its range, it is considered to be at low-medium risk from the stocking of native species.

B2.4 Areas of conservation significance

There have been very few studies that have examined the biodiversity of freshwater rivers of NSW, and these have generally focussed on a particular aspect, not the entire aquatic community, so do not provide detail of overall conservation significance. The NSW Rivers Survey (Harris and Gehrke, 1997) and ongoing related programs have established that the fish fauna of NSW could be broadly separated into four groups representing montane species, north coast species, south coast species and a combined group of Murray-Darling species, although the latter could also be separated to form a fifth management unit (i.e. Murray and Darling). Detailed analysis of the database established as part of the Rivers Survey could provide some indication of those areas of conservation significance in terms of fish fauna, but is beyond the scope of this EIS. Furthermore, the river surveys done to date, whilst relatively extensive when compared to anything done before it and in so far as it includes waterways across the State, has not yet surveyed all waterways, limiting any comparisons.

Morris *et al*. (2001), did analyse the Rivers Survey database, as well as others maintained by NSW Fisheries and the Australian Museum in an attempt to highlight those areas referred to in the report as diversity hotspots. Those areas were determined as those that maintained populations of several different species of threatened and/or potentially threatened species. A second criterion was that the location also had to be in need of some degree of on-ground management works, such as a fishway or weir upgrade. Whilst relevant to the scope of works for that report, unfortunately it does not provide this assessment with a comprehensive list of waterways that are of conservation significance.

The NSW Stressed Rivers Program (DLWC, 1998) identified those rivers under hydrological stress, environmental stress and of 'high conservation value'. The program was one of a series of steps in the Water Reforms process that was designed to identify catchments in need of immediate management attention or increased protection. The program was run over a limited timeframe, however, and only entailed a desktop analysis of potentially high conservation value rivers as determined by NSW Fisheries and NSW NPWS staff. Effectively ranking catchments against each other, particularly in the absence of recently collected data, meant that the program did not really highlight those waterways of conservation significance. To compound the problem in respect of assessing the potential risk of stocking to such waters, because the program compared sub-catchments to each other based on diversity, most freshwater sub-catchments rated poorly against their more diverse estuarine counterparts. As such, the report does not accurately reflect those freshwaters of conservation significance.

With the exception of those threatened species discussed in B2.2, there have been even fewer studies examining the conservation significance of waterways based on assemblages of invertebrates. Further most such studies have had determining 'river health' or 'condition' as their main aim, e.g. AusRivAS (Davies, 1994), Index of Stream Condition (Ladson *et al*., 1999), RIVPACS (Turak *et al*., 1999) and SIGNAL index (Chessman, 1995). These programs may be useful for providing a general picture of the invertebrate status and thus by default, the 'health' of a waterway, but they do not provide an indication of the conservation significance of waterways in terms of invertebrate assemblages.

In the absence of data about areas of conservation significance and the impacts of stocking, it was decided to examine the movement of fish into such areas, to determine if an overlap and interaction matrix could be used similar to that for threatened species. Unfortunately, it is readily apparent by the few studies described below that very little is known about the movements of stocked fish. Whilst it is acknowledged that in countries in which they are endemic, salmonids undergo extensive (hundreds of kilometres) migrations as part of their life cycle, as do many native fish, including some species that are stocked (e.g. golden perch, Australian bass), what is not understood is the survival rate of stocked fish, nor any migrations that they might undertake over the short and longer term. Brown trout and to a lesser extent rainbow trout, are known to spawn upstream of a limited number of impoundments into which they have been stocked in NSW, but as they have also been stocked into the waterways above those impoundments, it is not known what portion survive nor how far they move. Such data is a necessary first step in trying to determine the potential impacts of stocked fish in areas of conservation significance.

Jackson (1980) examined the movement of brown trout in a Victorian stream using a mark-recapture method and is thought to be the only such study into the movement of salmonids in Australia. Unfortunately, the study was very limited in its scope and methodology, and surveyed a wild (i.e. not stocked for the study but would have originated due to past stockings) population of fish that would have been more mature than those that are stocked into NSW waters. The study reported that the greatest distance travelled from the point of capture was about half a kilometre, although the results were highly variable and reflected a little over 25% of marked fish.

Overseas studies, although providing some indication of salmonid movement, are further limited in that mark-recapture studies are rarely done on stocked fish (especially juveniles), contain very different habitats and assemblages to those of eastern Australian waters, and usually involve a stream reach of 100-150m. Movements are observed within that 150m reach, but not beyond it. For example, Mitro and Zale (2002) used mark-recapture methods to determine the abundance of age 0+ rainbow trout in Snake River, Idaho. They reported that 84% of fish were recaptured in the area where they were marked, suggesting limited movement. Whilst providing a basis for abundance determinations, such studies provide little information for determining the overall movements of stocked fish. In another North American study, Sweetser *et al*. (2002) examined the movement of non-native rainbow trout (*Oncorhynchus mykiss*) that are stocked into several reservoirs in the range of the federally (United States of America) threatened Little Colorado spinedace (*Lepidomeda vittata*). They examined rainbow trout escapement from Nelson Reservoir into Nutrioso Creek, critical habitat for *L. vittata*. They did not record any movement of rainbow trout out of Nelson Reservoir over 4 years of study, and concluded that other native salmonids were a greater threat than the non-native salmonid.

As previously stated, such studies in overseas environments are very restricted in their nature, are conducted in an environment in which some species of salmonid are endemic, utilise very different environments and assemblages to NSW waters and overall offer little in the way of determining the impacts of stocking on conservation areas.

Although the stocking database maintained by NSW Fisheries suggests that stocking, and by default any potential impact, has been very widespread across the State, there are numerous waterways that do not appear to have been stocked. There are also many that have either been stocked very infrequently, with limited numbers of fish, or in which stocking has not taken place for a considerable period of time. The faunal communities of those waterways could be reasonably expected to show little or no impacts due to stocking, although they may have been impacted by other anthropogenic factors. Those waterways with minimal stocking or external impacts could contain unique or pristine faunal assemblages and thus represent areas of conservation significance. Further, such areas would provide baseline conditions against which to compare the impacts of stocking. The draft FMS should consider direct or indirect measures to retain those areas not previously stocked and/or that have not been subject to significant anthropogenic impacts.

Complicating any evaluation of the risks that fish stocking could pose to areas of conservation significance is that current research into the effectiveness of stocking has been restricted in terms of its spatial and temporal extent and the species that have been considered. A limited understanding of how many salmonids survive to spawning age within some impoundments and their associated upstream area provides no indication of the potential effects on instream biota and habitats or adjacent water-dependent terrestrial biota. Even if some studies had been done, unless they covered all types of rivers and assemblages within rivers, it may not be readily possible to extrapolate effects between assemblages in different conservation areas or among them within a conservation area.

The evaluation of risk procedure described above for threatened species is thus not applicable in this instance, because as with the threatened ecological community, the potential extent of impact is both too large and poorly understood to assess the risk due to stocking. In the absence of data, it would be convenient to develop some kind of surrogate assessment tool, such as the spatial overlap and ecological interactions determined for stocked species and threatened species. The equivalent for conservation areas could be an assessment of stocking pressure (for overlap), but there would not be an equivalent for interactions. Further, without information about the effectiveness of stocking for each species within each catchment, it is not possible to accurately determine stocking pressure. For example, 10000 fish put into one stretch of river may have no discernible impact on biota, but 10000 of the same fish may have a completely different result in another river or area of the same river. It could be that the periodicity of stocking has a greater influence than number or area, such that annually stocking an area with 1000 fish in each of ten years could be more detrimental than stocking 10000 fish every ten years. This kind of information is not currently available and thus any assessment of risk to areas of conservation significance is severely limited.

In the absence of any data, for the purpose of this assessment, risk to conservation areas will be defined as the likelihood of undermining the criteria upon which the conservation area was determined.

To assist in the determination of conservation areas that could be affected by the current activity of stocking, beyond allotting any protected area that existed within a stocked catchment as potentially affected, any protected or conservation areas that occur within approximately 5km by river of stocking events have been listed in Table B37. This fairly arbitrary distance was established by applying a precautionary factor of 10 to the half a kilometre recorded for the movement of brown trout by Jackson (1980) in a Victorian stream. Stocking may not actually take place within any protected areas, but the stocking database maintained by NSW Fisheries is not detailed enough to accurately determine precise stocking locations. The assumption here is that stocking into such areas could have an impact, albeit undefined in terms of its extent or magnitude.

B2.4.1 Fisheries Management Act 1994

The same provisions in the FM Act that have so far created more than 20 marine protected areas have not been utilised for the establishment of freshwater aquatic reserves or protected areas. As such, beyond those areas discussed above (B2.2) in relation to threatened species, there are no other areas that have been clearly defined as of conservation significance under the FM Act. Further, critical habitat has not been defined for any of the threatened species listed under the Act.

NSW Fisheries is currently considering the establishment of Riverine Management Zones as recently proposed by the Murray-Darling Basin Commission (MDBMC, 2002), which could include areas of limited use or fauna and habitat protection. No such areas had been identified at the time of this report.

B2.4.2 National Parks and Wildlife Act 1974

There are several types of parks and reserves that can be established under the NPW Act to protect terrestrial flora and fauna, but at the same time provide for a variety of permitted recreational opportunities. These activities range from bushwalking to four-wheel driving. Despite being a form of hunting, which is banned within all estates listed under the NPW Act, fishing is permitted and encouraged in many such estates because it is viewed as a low impact activity in terms of the terrestrial biota that the parks are designed to protect. The broad range of permitted activities, the often high visitor usage associated with most parks, and its restricted potential for impacts, beyond occurrences of aquatic threatened species described in section B2.2, suggests that the activity of fish stocking would pose a low risk to estates gazetted under the NPW Act.

The potential for impacts to such areas is restricted both by the nature of the organism being stocked and the relatively limited spatial extent of stocking compared to the area and number of estates. The stocking of fish is only going to directly affect a limited number of animals protected within an estate, primarily frogs, but could also have some indirect impact on an even smaller number of other aquatic dependent fauna. These effects could be both positive and negative. The introduction of juvenile fish could provide a food source for other fish, birds and the fish-eating bat, or could compete with other fish, bats and birds for aquatic invertebrates. Some of the studies described in Section B2.1 suggest that in highly productive trout streams of New Zealand, this competition could be intense (see Huryn 1996). There is no equivalent data for stocked streams in NSW.

Of the more than 200 estates reserved under the NPW Act, fish stocking currently occurs within or adjacent (within 5km by river) to 45 national parks and seven nature reserves (Table B37). This represents less than 25% of estates under the Act, and an undescribed but even smaller amount of riverine corridor. This limited spatial extent, the terrestrially benign nature of stocking and the types of other activities that are permitted within estates gazetted under the NPW Act suggests that the activity of fish stocking is posing a very low risk to such estates.

B2.4.3 Wilderness Act 1987

Wilderness areas are invariably an overlay on existing national parks or reserves, but can also be declared over freehold or Crown leasehold land following written consent of the occupiers. Under the Act, a wilderness area is defined as "an area of land, that together with its plant and animal communities, is in a state that has not been substantially modified by humans and their works or is capable of being restored to such a state; and that it is capable of providing opportunities for solitude and appropriate self-reliant recreation". Mindful of these criteria, under the Act "wilderness areas are to be managed so as to restore (if applicable) and to protect the unmodified state of the area and its plant and animal communities; to preserve the capacity of the area to evolve in the absence of significant human interference; and to permit opportunities for solitude and appropriate self-reliant recreation". Broadly this means that vehicles (except for management purposes) and horses are not permitted and that bicycles are only allowed on a small number of approved management trails. Almost all declared non-coastal wetland wilderness sites are in the headwaters of rivers that originate along the Great Dividing Range, and are typified by steep gorge country, rugged bushland, and few if any vehicular trails except in former State Forest areas.

Of the approximately 4-5% of land in NSW that has been identified as wilderness, approximately 70% has been legally declared as wilderness following the recent Wilderness Assessments in southern and northern NSW (NPWS, 2001; NPWS, 2002). That process increased the total number of wilderness areas from 32 to 47 and made additions to 16 existing areas.

The NSW Fisheries stocking database, CMA topographic maps, NSW NPWS Northern and Southern Wilderness Assessment Reports and subsequent Fact Sheets for Wilderness Declarations were used to determine how many wilderness areas fish stocking could affect. As discussed previously, in the absence of any information about the movements of stocked fish that might provide for a more accurate analysis of affected areas, this assessment has included any stocked waterways within or adjacent (within 5km by river) to wilderness areas. This conservative estimate was considered necessary both because of the lack of information about fish movements and the lack of detail about exact stocking locations within the NSW Fisheries stocking database. It is probable that the estimate provided below overstates the number of areas that could be affected, but it is important to remember that the risk being considered to these areas is the likelihood of undermining the criteria upon which they were determined, not how many are affected.

Wilderness areas include the rivers that run through them, and thus the plant and animal communities of the river. Ideally, the assessment should be done against individual areas and their plant and animal communities, but without information about post-stocking survival, interactions between stocked fish and the existing biota, and movements into and out of areas, it is not possible to apply that more rigorous assessment. On that basis, stocking fish into any wilderness area is going to modify its plant and animal communities, and even though we do not know to what extent the community will be modified, stocking must be considered a medium risk to those areas. A complete lack of any information means that there is a high degree of uncertainty associated with assigning the level of risk, but as a medium risk it ensures that the draft FMS needs to address the issue of stocking into wilderness areas. Management measures could range from a precautionary approach of continuing stocking whilst research programs are initiated to more thoroughly understand the interactions between stocked fish and the receiving environment, through to stopping stocking in wilderness areas. The latter approach is the preferred measure, as it avoids any immediate impact on the aquatic component and does not encourage people into such areas, which is consistent with the management principles for wilderness areas.

According to the fish stocking database maintained by NSW Fisheries, fish stocking currently occurs within or adjacent (within 5km by river) to 31 of those 47 wilderness areas (Table B37), or more than 60% of wilderness areas. As discussed above, it is not known to what magnitude individual areas are affected, but at 60% the potential extent of impact is relatively large. It is likely that a more detailed analysis and/or better understanding of the fate and movement of stocked fish, would reduce that figure and provide a better idea of how much of each wilderness area was affected. To enable such an analysis, the draft FMS should include a management response or measure that addresses the usefulness of each waterway for stocking purposes. This should include aspects such as the location and extent of wilderness areas that could be affected, but should also consider physical factors such as topography, water temperatures, and instream and riparian habitat.

B2.4.4 World Heritage

The Convention Concerning the Protection of the World Cultural and Natural Heritage (the World Heritage Convention) was adopted by the UNESCO General Conference at its 17th session in Paris on 16 November 1972. The Convention aims to promote cooperation among nations to protect heritage from around the world that is of such outstanding universal value that its conservation is important for current and future generations. The Convention has established a list of properties of outstanding universal value and is called the World Heritage List. To qualify for inscription, properties must meet a range of cultural and/or natural criteria.

There are currently 14 Australian properties on the World Heritage List, three of which are found in NSW, namely Willandra Lakes Region, the Greater Blue Mountains (GBM) area and the Central Eastern Rainforest Reserves of Australia (CERRA). Willandra Lakes is a semi-arid landscape comprising dried saline lakebeds and is not affected by fish stocking and will not be discussed in further detail.

The GBM area consists of over 1 million hectares of mostly forested sandstone escarpments dissected by waterways and valleys. It includes numerous conservation reserves, including Kanangra-Boyd Wilderness area. It is not known to what extent stocking is done within the boundaries of the

World Heritage area, and although it is likely to be minimal due to access limitations, the stocking database suggests that stocking has taken place within several waterways that run through the area. The current activity of fish stocking could, therefore, have some as yet unknown impact on the area.

The CERRA comprises more than 50 separate conservation reserves located between Newcastle and Brisbane, about 30 of which are located in NSW. The major reserves include Barrington Tops NP/Wilderness, Werrikimbe NP/Wilderness, Kunderang NP/Wilderness, Oxley Wild Rivers NP, New England NP/Wilderness, Dorrigo NP, Gibraltar Range NP, Washpool NP/Wilderness and Border Ranges NP/Lost World and Warrazambil Wilderness areas. As discussed above, most of these wilderness areas contain waterways that have been stocked and could thus be affected.

Both the GBM area and the CERRA are listed as World Heritage Properties under the criteria for natural heritage. The four natural criteria are that a site must:

i. be outstanding examples representing major stages of earth's history, including the record of life, significant ongoing geological processes in the development of landforms, or significant geomorphic or physiographic features, or

ii. be outstanding examples representing significant ongoing ecological and biological processes in the evolution and development of terrestrial, freshwater, coastal and marine ecosystems and communities of plants and animals, or

iii. contain superlative natural phenomena or areas of exceptional natural beauty and aesthetic importance, or

iv. contain the most important and significant natural habitats for *in situ* conservation of biological diversity, including those containing threatened species of outstanding universal value from the point of view of science or conservation.

The Greater Blue Mountains area meets criterion 2 and 4, and the CERRA criterion 1, 2 and 4. As discussed above for national parks and wilderness areas, the terrestrial components of these reserves are at low risk from the current activity of stocking. For the GBM, that includes criterion 2, the values of which are related to the significance in terms of the evolution of plant life (e.g. the Wollemi pine) and as a centre of diversification of eucalypts. Criterion 4 values, for both the GBM area and the CERRA, include endemic species, relict species, species with restricted ranges and rare or threatened species. Any of those species that are aquatic, primarily fish and frogs, are likely to be affected by fish stocking, although as discussed previously, the extent and magnitude of this impact is as yet unknown. The potential for an impact in the absence of evidence to the contrary suggests that stocking is likely to undermine the basis of criterion 4, and is thus considered to be at medium risk.

For the CERRA, criterion 1 includes both terrestrial and aquatic components. Consistent with the previous assessments, the terrestrial components are at low risk. The previous species-specific discussions (section B2.2 and B2.3) suggest that the aquatic components, in particular frogs and crayfish, are at medium to high risk due to stocking, and on that basis criterion 1 could be undermined by stocking and by inference is also considered to represent a medium risk. Criteria 2 and 4 also list numerous frogs and crayfish amongst the World Heritage values for the CERRA and so are also at medium risk due to stocking.

It is important to note that the lack of data has meant that these have necessarily been very theoretical assessments and that there is a high degree of uncertainty associated with assigning the levels of risk. The assessment acknowledges that uncertainty, but must apply the precautionary principle in the absence of data that might allow for a more rigorous and precise assessment. Accepting that the assessment is erring on the side of caution, necessitating that the draft FMS implements some measures to address the risk to conservation areas, is considered to be more appropriate than rejecting the potential for an impact due to stocking and thus continuing with existing management arrangements. Any measures that are developed for wilderness areas are likely to be readily transposed over World Heritage areas, as there is significant overlap between the two conservation areas. As a minimum, the draft FMS needs to implement indirect measures to address conservation areas, but direct measures are more likely to be both effective and provide all stakeholders with greater certainty.

B2.4.5 Ramsar

The Convention on Wetlands of International Importance, signed in the Iranian town of Ramsar in 1971, aims to halt the loss of wetlands and to conserve remaining wetlands. Countries that are party to the Convention nominate wetlands to be listed, and following acceptance they become known as Ramsar wetlands. Countries are expected to manage their Ramsar sites to preserve their unique ecological characteristics, and in Australia are protected under the EPBC Act.

The five major causes of change in ecological character of wetlands are changes to water regime, water quality, physical modification, exploitation of biological products and the introduction of exotic species. The activity of fish stocking could be regarded as a form of physical modification, an exploitation of biological products and may involve the introduction of exotic species. On a broad level, any fish stocking done within a Ramsar wetland could be negatively affecting its ecological character. The magnitude of any such impacts is unknown.

The potential extent of any impacts due to the current activity, however, is extremely limited. In NSW, there are currently nine listed Ramsar wetlands, including Blue Lake, Gwydir Wetlands, Kooragang Island Nature Reserve, Lake Pinaroo, Little Llangothlin Nature Reserve, Macquarie Marshes, Myall Lakes National Park, Narran Lakes Nature Reserve, Towra Point Nature Reserve.

Of these, only Gwydir Wetlands, Macquarie Marshes, Myall Lakes NP and Towra Point NR could have been affected by stocking in NSW, as the others have not been previously stocked according to the stocking database. Narran Lakes, however, could be affected by stocking upstream in Queensland. Gwydir Wetlands, Macquarie Marshes and Myall Lakes NP have not been directly stocked, but the waterways running through them have been stocked with native species. It is not possible to determine the extent or magnitude of those stocking events, but stocking native species of fish is likely to have minimised any potential impact. Towra Point NR has been stocked on one occasion with Australian bass, which occurs naturally in the Georges River and is likely to have been the ultimate destination of those fish. Other areas of the Georges River have also been stocked with Australian bass, but this has been primarily in the upper reaches above impoundments. The limited number of stocking events in the catchment, the limited number of fish released, the presence of multiple barriers to fish movement and the fact that they were native species is likely to have had a negligible impact on the wetland.

Ramsar wetlands are considered to be at very low risk due to the current activity of stocking. This is because of the lack of stocking that is thought to have taken place within and even adjacent to wetlands. To ensure that the activity retains this low level of risk, it will be necessary for the draft FMS to continue to not stock Ramsar wetlands, or to initiate site-specific studies to determine the actual impacts of stocking on the ecological characteristics of wetlands.

Table B37. Protected areas potentially affected by fish stocking.

Catchment and aquatic species of conservation significance	Protected area	Stocked species	Stocking period	Total number
Bega	South-East Forests NP / Genoa Wilderness	brown trout	1983	5000
non-parasitic lamprey,		rainbow trout	1993	1000
Australian grayling,	Wadbilliga NP / Brogo Wilderness & SEF	Australian bass	1981-01	130300
congolli, climbing galaxias	NP			
Clyde	Budawang NP / Wilderness	Australian bass	1999	5100
Australian grayling,	Clyde R NP	Australian bass	1999	8500
congolli, climbing galaxias	Morton NP / Budawang Wilderness	Australian bass	1999	2000
Clarence	Bald Rock NP & Boonoo Boonoo NP	brown trout	1984	12000
eastern cod, peppered tree	Cathedral Rock NP & Wilderness	brown trout	2001	4000
frog, New England tree		rainbow trout	1983-01	13710
frog, stuttering frog, giant	Chaelundi NP	eastern cod	1998	900
barred frog, new species of	Coramba NR	eastern cod	1988-97	15007
catfish, *Euastacus gumar*,	Dorrigo NP	eastern cod	1998	1000
new species of *Galaxias*		rainbow trout	1982-86	20880
	Guy Fawkes NR / NP / Wilderness	brown trout	1984-01	86500
		eastern cod	1998	4400
		rainbow trout	1980-01	720615
	Junuy Juluum NP	eastern cod	1998	500
		rainbow trout	1983-01	86417
	Nymboi-Binderay NP	eastern cod	1998	12180
		rainbow trout	1998	8000
	Nymboida NP / Bindery-Mann Wilderness	eastern cod	1997-98	9150
	Sherwood NR	eastern cod	1997-97	15007
	not within 5km of NP estate	rainbow trout	1981-01	604468
		brown trout	1983-01	75200
		eastern cod	1997-98	8200
		Australian bass	2000-02	7000
Georges	Georges R NP	Australian bass	1982-99	55445
landlocked pop. climbing	Towra Pt Aquatic Reserve & NR	Australian bass	1998	5518
galaxias	not within 5km of NP estate	Australian bass	1982-01	62783
		rainbow trout	1996	10000
		silver perch	1992	3000
Hastings	Booragang NP	rainbow trout	1985	3000
giant barred frog	Tapin Tops NP	brown trout	1984-92	42300
		rainbow trout	1981-01	665605
	Werrikimbe NP & Wilderness / Kunderang	Australian bass	1984-00	25750
	Wilderness / CERRA World Heritage	rainbow trout	1981-84	72000
	Willi Willi NP / Wilderness	Australian bass	1984-01	30500
	not within 5km of NP estate	Australian bass	1984-01	27700
		rainbow trout	1985-99	39200
		brown trout	1987-01	33000
Hawkesbury	Kanangra Boyd NP & Wilderness	brown trout	1984-97	43000
Macquarie perch,		rainbow trout	1983-99	9000
landlocked pop. climbing	Blue Mts NP / World Heritage	brown trout	1988-02	19000
galaxias, Adam's emerald		rainbow trout	1983-97	33000
dragonfly	not within 5km of NP estate	Australian bass	1981-01	183600
		brook trout	1997	10000
		brown trout	1988-02	490600
		golden perch	2001	60000
		Macquarie perch	2000	15000
		Murray cod	2001	8000
		rainbow trout	1980-02	2105100
		silver perch	1980-96	146000
Hunter	Barrington Tops NP & Wilderness /	brown trout	1996-01	60000
New England tree frog,	CERRA World Heritage	rainbow trout	1983-01	100000
Euastacus polysetosus	not within 5km of NP estate	Australian bass	1980-01	1189934
		brown trout	1991-01	301000
		golden perch	1977-99	1104510
		Pacific blue eye	1998	200
		silver perch	1977-02	468114
		rainbow trout	1981-01	972260

Table B37 cont.

Catchment and aquatic species of conservation significance	Protected area	Stocked species	Stocking period	Total number
Lachlan	Abercrombie R NP	brown trout	1997	4000
Macquarie perch, silver perch		golden perch	1998	4000
		Murray cod	1978-90	3000
		rainbow trout	1983-96	43000
		trout cod	1993	5600
	not within 5km of NP estate	Atlantic salmon	1989-96	110000
		brook trout	1988	100
		brown trout	1965-01	505000
		golden perch	1965-02	2800685
		Murray cod	1978-02	481775
		rainbow trout	1976-02	2451600
		silver perch	1960-02	1788600
		trout cod	1992	11600
Macintyre	Kings Plains NP	rainbow trout	1984-96	13000
Darling hardyhead, western pop. olive perchlet, western pop. purple spotted gudgeon	Kwiambal NP	golden perch	2001	3000
		Murray cod	2001	1600
	not within 5km of NP estate	Atlantic salmon	1979-78	40910
		brook trout	1974-76	262100
		brown trout	1984-01	49400
		golden perch	1979-02	3200431
		Macquarie perch	1998	100
		Murray cod	1983-02	669360
		rainbow trout	1973-01	4725940
		silver perch	1960-02	1179513
Macleay	Oxley Wild Rivers NP / CERRA World Heritage	Australian bass	1999	3300
peppered tree frog		brown trout	1983-01	393360
		rainbow trout	1984-01	954343
	Carrai NP/Carrai Wilderness	rainbow trout	1982-01	37000
		brown trout	2001	2000
	Cathedral Rock NP & Wilderness	rainbow trout	1983-01	57000
		brown trout	1982-01	127027
	Cunnawarra NP / CERRA World Heritage / Georges Ck NR	rainbow trout	1982-98	122500
	New England NP & Wilderness / CERRA World Heritage	rainbow trout	1982-01	69000
	not within 5km of NP estate	Australian bass	1992-01	17480
		brown trout	1982-01	263670
		rainbow trout	1980-01	1924160
		silver perch	1999	3200
Macquarie	Coolah Tops NP	rainbow trout	1981-99	44300
Murray jollytail, western pop. olive perchlet	Goobang NP	brown trout	2001	1000
	not within 5km of NP estate	brown trout	1982-02	725111
		catfish	1999	3700
		golden perch	1960-02	2206477
		Murray cod	1983-02	473788
		rainbow trout	1980-02	2164929
		silver perch	1962-02	1102150
		trout cod	1991-98	63800
Manning	Barrington Tops NP & Wilderness / CERRA World Heritage	rainbow trout	1981-01	367000
New England tree frog, Isopod *Crenoicus harrisoni, Euastacus polysetosus, Euastacus spinichelatus*	Barakee NP	brown trout	1996-97	110000
		rainbow trout	1982-01	209800
	not within 5km of NP estate	Australian bass	1995	20000
		brown trout	1996-01	93000
		rainbow trout	1981-01	709300
Moruya	Deua NP / Woila-Deua Wilderness	rainbow trout	1980-84	41500
non-parasitic lamprey, Australian grayling, congolli, climbing galaxias				

Table B37 cont.

Catchment and aquatic species of conservation significance	Protected area	Stocked species	Stocking period	Total number
Murray	Kosciuszko NP / Indi Wilderness	brown trout	1996-01	63800
Murray jollytail, Murray		rainbow trout	1981-01	107500
hardyhead, trout cod,	Kosciuszko NP / Jagungal Wilderness	brook trout	1988	4000
Macquarie perch, silver		brown trout	1985-02	40900
perch, southern pygmy		Macquarie perch	1988	24000
perch, two-spined blackfish,				
Murray river crayfish,		rainbow trout	1980-01	66960
spotted tree frog, river snail	Kosciuszko NP / Pilot Wilderness	brown trout	1998-01	7200
		rainbow trout	1998	14000
	not within 5km of NP estate	Atlantic salmon	1994	50000
		brown trout	1985-01	95000
		golden perch	1960-02	1476500
		Macquarie perch	1988	24000
		Murray cod	1987-01	97600
		rainbow trout	1981-02	226390
		silver perch	1983-00	193400
		trout cod	1988-97	63600
Murrumbidgee	Bimberi NR & Wilderness /	Atlantic salmon	1981-95	242750
Murray jollytail, Macquarie	Brindabella NP/ Kosciuszko NP	brown trout	1987-98	12500
perch, silver perch, Murray		rainbow trout	1980-01	132760
river crayfish, two-spined	Kosciuszko NP / Bogong Peaks Wilderness /	Atlantic salmon	1980-82	96000
blackfish, spotted tree frog	Jagungal Wilderness	brook trout	1983	9400
		brown trout	1984-01	127200
		golden perch	1980-00	1007620
		Macquarie perch	1995	10000
		rainbow trout	1980-01	803020
		Murray cod	1988-02	202018
		silver perch	1984-91	313700
		trout cod	1991-96	15000
	Kosciuszko NP / Bogong Peaks	brown trout	2002	10000
	Wilderness / Goobarragandra Wilderness	brook trout	1996	8000
	not within 5km of NP estate	Atlantic salmon	1981-01	2658920
		brook trout	1971-01	154910
		brown trout	1976-01	291050
		catfish	1963-98	900
		golden perch	1960-02	2849443
		Macquarie perch	1988	3300
		Murray cod	1988-02	342740
		rainbow trout	1968-01	1289130
		silver perch	1960-02	1428220
		trout cod	1988-99	325940
Namoi	Warrabah NP	golden perch	1989-01	10196
silver perch		Murray cod	1989-01	6331
		rainbow trout	1989-90	135000
	not within 5km of NP estate	brown trout	1984-01	143821
		catfish	1994-00	5038
		golden perch	1960-02	1896034
		Murray cod	1984-02	359514
		rainbow trout	1981-01	3954806
		silver perch	1985-02	1175760
Richmond	Border Ranges NP / Lost World	eastern cod	1988-97	7816
giant barred frog, Oxleyan	Wilderness / CERRA World Heritage	golden perch	1990	6000
pygmy perch, eastern cod,	Goonengerry NP / Boatharbour NR	Australian bass	1994-96	6850
cascade tree frog, Fleay's		brown trout	1991	1000
barred frog		eastern cod	1997-98	12100
	Nightcap NP / CERRA World Heritage	Australian bass	1994-96	550
	Toonumbar NP / CERRA World Heritage	Australian bass	1981-99	257000
		brook trout	2000	800
		eastern cod	1988-00	17023

Table B37 cont.

Catchment and aquatic species of conservation significance	Protected area	Stocked species	Stocking period	Total number
Richmond cont.	Toonumbar NP/CERRA World Heritage cont.	golden perch	1978-00	5000
		Murray cod	1977	2000
		rainbow trout	2000	30700
		silver perch	1978-00	6000
	not within 5km of NP estate	Australian bass	1988-01	35300
		eastern cod	1988-98	19084
		rainbow trout	1981-85	3500
Shoalhaven non-parasitic lamprey, Australian grayling, Macquarie perch, isolated pop. freshwater catfish, isolated pop. western carp gudgeon	Deua NP / Woila-Deua Wilderness	brown trout	1995-98	1300
		rainbow trout	1983-99	5400
	Monga NP	brown trout	1995-97	6100
		rainbow trout	1984-90	13000
	Morton NP	rainbow trout	1983-89	22000
	Morton NP / Budawang Wilderness	brown trout	1987-92	14000
		rainbow trout	1983-98	61000
	Morton NP / Ettrema Wilderness	Australian bass	1981-99	198620
		brook trout	1973-77	104000
		brown trout	1984-98	21200
		rainbow trout	1973-01	747150
	Morton NP / North Ettrema Wilderness	rainbow trout	1982-87	17000
		Australian bass	1990-98	250775
	Tallaganda NP	brown trout	1994-95	750
		rainbow trout	1983-84	4000
	not within 5km of NP estate	Australian bass	1996-01	21500
		brook trout	1970-72	2400
		brown trout	1991-98	16400
		rainbow trout	1968-01	69740
Snowy congolli, two-spined blackfish, yellow-spotted bell frog	Kosciuszko NP	rainbow trout	1982-99	55500
	Kosciuszko NP / Byadbo Wilderness	brook trout	1981	1450
	Kosciuszko NP / Jagungal Wilderness	rainbow trout	1983	2000
	Kosciuszko NP / Pilot Wilderness	brook trout	1981-01	119538
		brown trout	2001	20000
		rainbow trout	1983-01	42500
	Kosciuszko NP / Western Fall Wilderness	Atlantic salmon	1981-94	486591
		brook trout	1986-98	2243
		brown trout	1992-01	5203
		rainbow trout	1988-01	28500
	not within 5km of NP estate	Atlantic salmon	1975-02	3940859
		brook trout	1981-02	312467
		brown trout	1981-01	980750
		rainbow trout	1980-02	4384220

B2.5 Genetic issues for stocked and wild populations

Parts B2.5 and B2.6 were prepared by Spring Creek Environmental Consulting.

B2.5.1 Genetic implications of stocking

B2.5.1.1 Reductions of genetic diversity from the hatchery process

Genetic diversity is an important element in the management and long-term survival of biological populations (Frankel and Soule, 1981). Genetic diversity gives a population adaptive potential to cope with environmental change, new diseases, parasites, predators, and competitors (Soule, 1980). Moreover, genetic diversity is the fundamental material for evolution and the amount of evolutionary change in a population is proportional to the amount of genetic diversity available (Meffe and Ronald Carroll, 1997). Reductions in genetic diversity have been shown to result in decreased Darwinian fitness, fecundity and growth. Inbred individuals also have a higher probability of exhibiting deformities due to the expression of deleterious recessive alleles and the disruption of stable developmental pathways (Ralls and Ballou, 1983).

It is well recognised that the captive breeding of wild or domesticated fish in hatcheries can result in significant genetic problems when introduced into a receiving population (Allendorf and Phelps, 1980). Genetic problems are most often seen as reductions in genetic diversity through inbreeding, failing to capture remnant genetic variation of the source population and using too few parental stock to counteract genetic drift. Other issues include increasing the frequency of deleterious alleles, domestication, outbreeding depression and the breakdown of evolutionary distinct groups. However, with enlightened genetic protocols and hatchery management these problems can largely be avoided or reduced to acceptable levels.

Genetic problems are likely to affect both native and introduced fishes alike, though the problems are likely to differ. Native fishes are likely to not only suffer problems associated with hatchery production, but also with interactions between stocked species or populations. The most significant genetic problems at this level is hybridisation between species, populations and evolutionarily distinct units (see B2.5.4). Whereas the introduced salmonids, while possibly crossing among their group, are not likely to interbreed with endemic species, as Australia has no native salmonids. Hybridisation at the species level is only likely between closely related species, at the genus level.

B2.5.1.2 Inbreeding

Inbreeding is the mating of closely related individuals that share common alleles by decent. Inbreeding, leads to increased homozygosity compared to an outbred population. The negative effects of inbreeding on domestic, laboratory, and zoo populations are well documented and include reduced fecundity and survival of inbred progeny (Wright, 1977; Kincaid, 1976a,b; Ralls and Ballou, 1983; Miller and Hedrick, 1993). Inbreeding has been shown to increase the frequency of deformed individuals in hatchery populations (Aulstad and Kittelsen, 1971; Kincaid, 1976a,b; Gall, 1987). Inbreeding can lead to decreased Darwinian fitness and increased probability of extinction in wild populations (Saccheri *et al.*, 1998).

Inbreeding increases the probability of recessive deleterious alleles being expressed because inbred lines are more likely to express recessive traits rather than dominant or over dominant forms (Frankel and Soule, 1981). Inbreeding depression is the subsequent decreased phenotypic fitness resulting from the expression of these recessive deleterious alleles (Hartl and Clark, 1997). Severe inbreeding depression and loss of heterozygosity are direct consequences of poorly managed breeding programs (Vrijenhoek, 1998). For example, Keenan (1995) demonstrated that golden perch (*Macquaria ambigua*) populations with higher levels of inbreeding and lower levels of genetic variation are less viable in terms of larval survival, growth and fecundity than those with lower levels of inbreeding and greater heterozygosity. Inbreeding has also been detected in golden perch and silver perch (*Bidyanus bidyanus*) from wild fisheries that were supplemented from hatchery stock. It is believed that the level of inbreeding found in these species is most likely due to interbreeding of stocked fish (which have common parents) and the natural loss of variation as a result of a depletion of breeding adults (Keenan *et al.*, 1995).

Gjedrem (1976) estimated for salmonids that for every ten percent reduction in variation there is a corresponding five to ten percent depression in growth rate. It is widely accepted that to reduce the effects of inbreeding, the inbreeding coefficient should be maintained below 1% (Franklin, 1980; Frankel and Soule, 1981).

Heterozygosity of an individual can be used as an indirect estimator for fitness, because it is well accepted in animal breeding that a reduction in heterozygosity may lead to decreases in viability, vigour, fecundity and fertility. A reduction in heterozygosity of 25% in rainbow trout (*Oncorhynchus mykiss*) as a result of inbreeding was shown to decrease fry survival by 19% and growth by 23% and increase phenotypic deformities by 38% (Kincaid, 1976a,b). Conversely, increased heterozygosity is believed to increase fitness and growth in some situations and is termed heterosis. Factors that reduce heterozygosity are inbreeding, selection and random genetic drift, which are all exacerbated by the use of small numbers of hatchery broodstock. Genetic drift is the per generation change in allele frequencies brought about by reproductive sampling error.

B2.5.1.3 Genetically effective population size

The observation that populations often showed much less genetic variation than predicted led to the development of the theory of genetically effective population size (Wright, 1931). The genetically effective population is the size of an ideal population that is subject to the same degree of genetic drift as an actual population (Hartl and Clark, 1997). Therefore, the effective population is the size of a real population that has been corrected for factors that reduce effective population size such as sex-ratio biases, harem formation, reproductive variance among individuals and inbreeding. In wild populations the genetically effective population is typically much smaller than the census population size (Lande and Barrowclough, 1987).

A recent survey of hatcheries in NSW revealed a practice for hatchery breeding where up to a hundred female rainbow trout were fertilised with the milt from very few males (Moore and Baverstock, 2002). If we compare this hatchery practise to calculations of effective population size it is revealed that for every one hundred females fertilised with a single male the effective genetic contribution of the progeny is the same as if only two males and two females were used. It should be noted that the most effective and practical breeding system for the maintenance of genetic diversity within the hatchery is a one male and one female mating.

Effective population size is also strongly affected by variance in contribution among females. It is a common practice in breeding Australian native fish to use broodstock of different ages (Moore and Baverstock, unpublished). Because the fecundity of fish is almost invariably related to age as well as body size, the egg production among females is likely to be variable (Baltz, 1990). If we take the hypothetical example of ten females, where seven small females produce 1,000 eggs each and three larger females produce 10,000 eggs each, the variation in reproductive contribution between individuals will reduce the effective genetic contribution to the same as if four equally contributing parents were used. Equalising the reproductive contribution of each female to 1,000 eggs will result in approximately 20 effective females (Allendorf and Ryman, 1987). This task can be greatly accelerated with the aid of an egg counter or using a volumetric counting system, which are commonly used in hatcheries already. The important point here is the equalisation of reproductive contribution and not the number of eggs. By separating equal contributions of matings into different tanks or ponds, effective population size within the hatchery can be maximised per generation. It is important to note the reproductive contribution will be reduced to that of the least productive female. A point worth considering when selecting or monitoring broodstock.

The common practice of placing several pairs of fish in a tank or pond for spawning and fertilisation (Thurstan, 2000) is not recommended, as it is impossible to determine contributions or matings among broodstock. Dominant fish are likely to monopolise matings and therefore contribute disproportionately to the next generation, thereby reducing effective population size.

Effective population size is also affected by fluctuations in the number of breeders equal to the harmonic mean of those broodstock across generations, (Hartl and Clark, 1997). Therefore, to maximise effective contributions across generations, the number of broodstock used should not fluctuate significantly over time.

Indeed, by following sound genetic protocols the genetically effective population size can be double the census population or number of broodstock. This occurs when mating designs are implemented that prevent variance in progeny number that survive to become parents of the next generation. Therefore an effective population size of 100 can be achieved from the use of 25 breeding pairs. When effective population size = 100 the expected increase in inbreeding level per generation is 0.5 %, which is well under the threshold of 1% recommended by Frankel and Soule, (1981).

B2.5.1.4 Allelic diversity

Until recently, most genetic breeding programs were designed assuming most loci had very low levels of polymorphism, typically one, two, or three alleles. However, recent advances in molecular biology have shown that most loci are characterised by many alleles. Therefore, an important measure of genetic variation is allelic diversity or more specifically the number of alleles at a locus. Heterozygosity has been widely used as a measure of genetic variation, however, heterozygosity is relatively insensitive to reductions in allelic diversity (Allendorf and Ryman, 1987). It is allelic diversity that is likely to give a population adaptive potential to cope with environmental change over evolutionary timescales (Soule, 1980).

The loss of allelic diversity through captive breeding is usually a result of the failure to successfully capture representative variation of the wild population. The change in allele frequency as a result of this bottleneck is more complicated to predict than its effect on heterozygosity because it depends on the number and frequency of alleles present in the original population (Allendorf and Ryman, 1987). Allelic diversity is much more likely to be lost through a severe population bottleneck than heterozygosity. Heterozygosity levels may recover reasonably quickly after a population bottleneck, whereas allelic diversity is expected to recover much more slowly and may take thousands of years to regain pre-bottleneck levels. Some rare alleles may be lost forever.

To reduce the loss of allelic diversity, a hatchery stock should comprise a sufficient number of individuals to capture representative variation of the wild population. The number of broodstock required will depend on the allelic diversity of the wild population being sampled. The higher the allelic diversity the larger the sample needed in order to have a sufficient probability of capturing that variation. Large samples are also required to capture rare alleles that occur at low frequencies within a population (Allendorf and Phelps, 1980). For example, a sample of 230 individuals would be needed to have a 99% probability of capturing alleles that occurred at a frequency of 0.01 (Brown, 1988). Brown (1988) has suggested the use of 200 broodfish collected over a period of two minimum generation intervals, or about ten years. As a rule of thumb, the broodstock should be sourced from unstocked populations in order to capture remnant variation.

The justification for sampling rare alleles is that although they may occur at a low frequency at present, their potential in the future may be of great importance if environmental conditions change. However, some alleles are likely to be rare within a population because they are deleterious. Therefore breeding and stocking with individuals that carry rare deleterious alleles is likely to increase the frequency of potentially deleterious alleles within the receiving population. Local gene pools are also likely to be swamped by genetically homogeneous offspring if large stockings are made from a single pair mating. The receiving population is therefore likely be compromised after restocking rather than benefiting. These problems can be reduced by changing broodstock regularly, stocking with the progeny of several matings, and limiting the amount of progeny that are stocked into each location.

B2.5.1.5 Monitoring genetic variation

It is important to have baseline data on the number and frequency of alleles in the founding stock if we are to gauge the potential importance of their loss to the species of interest. The development of modern molecular biology and population genetics have provided a suite of techniques to examine the level of genetic diversity and structuring within remnant populations or its loss within captive breeding programs. The most powerful techniques commonly employed today involve the screening or direct sequencing of DNA. The most useful of these techniques for population level analysis include the screening of mitochondrial DNA, and micro-satellites. Methods for both techniques are well developed and sensitive enough to detect single nucleotide differences among individuals. Additionally, consultation with a population geneticist should be considered essential for the design of stock enhancement programs. In NSW, very little genetic information exists for the majority of the species that are currently used for stock enhancement and the genetic profiles of many populations are already likely to be compromised.

B2.5.1.6 Artificial selection

Hatchery stocks are likely to diverge from wild stocks through artificial selection and domestication within the hatchery. Phenotypes that thrive in the relatively stable conditions and relaxed selective pressures of a hatchery may not do so well in the wild (Bryant and Reed, 1999). Domesticated stocks tend to be phenotypically more uniform and behaviourally predictable than their wild counterparts (Vrijenhoek, 1998). This adaptation to captivity and decrease in fitness in wild environments is likely to hinder stocking success. It has been estimated that in highly fecund animals such as fish, up to 90% of selection takes place between fertilisation and the end of the larval stage. Coincidently this is exactly the time that captivity-bred fish spend in the hatchery. The effects of domestication can be reduced in open hatchery systems by using wild broodstock (Harada *et al.*, 1998). However, there remains a conundrum over the age of release to limit domestication. Release the fish too young and natural mortality is very high. Release too late and the probability that fish will become domesticated increases. Despite the problems associated with early release mortality it is still recommended that fish be liberated into the wild as early as possible.

B2.5.1.7 Problems of stocking genetically depauperate fish into the wild

It is clear that unless genetic protocols within the hatchery are sufficient, genetic diversity is likely to be lost. There is little published literature on the effects of stocking genetically depauperate fish into the wild. This lack of information is linked to the difficulties in assessing impacts of fish once they are released. Levels of mortality are often very difficult to estimate in wild aquatic habitats. This problem is compounded by the fact that a reduction in genetic diversity is not likely to kill an individual or population. However, it is likely to reduce the ability of a population to cope with environmental change, therefore limiting its evolutionary potential. As a result, stocked populations are likely to have an increased risk of extinction, compared to unstocked populations, if adequate genetic protocols are not adhered to.

Genetic diversity, which often takes many thousands of years to accumulate, can be eroded very quickly within captive breeding programs. For example, it has been shown that eastern cod have lost up to 70% of their allelic diversity and 78% heterozygosity in a single generation through the captive breeding under the present genetic guidelines in NSW. The loss of genetic diversity can also be seen as a loss of biodiversity (Nock *et al*., 2003).

The problems observed in inbred populations relate to significant reduction in fitness, increases in deformations and sterility and very high extinction rates. Increasing the frequency of deleterious alleles has been shown to significantly reduce fitness in subsequent generations.

B2.5.1.8 Quantitative genetics

While the use of neutral molecular markers is essential for providing information on population distinctiveness, evolutionary lineages, levels of inbreeding and gene flow patterns they cannot provide data on measures of fitness such inbreeding and outbreeding depression or the adaptive potential of populations. Neutral molecular genetic variation is used as definitive tools in conservation biology because it excludes selection from the analyses, which is important to avoid regional selection biases. However, the patterns seen in neutral genetic data are unlikely to accurately reflect what is happening to genes under selection or of ecological importance (Lynch, 1996). Moreover, under some circumstances a hatchery bottleneck may increase additive genetic diversity as portions of epistatic variance in converted to additive variance. Additionally, variance can be maintained by balancing selection or eroded by strong directional selection relatively independent of the forces acting on neutral variation.

The use of quantitated genetic measures will allow for the monitoring of fitness of hatchery progeny and wild populations. New techniques are emerging that may enable both quantitative and molecular genetics to be combined to provide data of the relative adaptive potential of populations (Phillips and Moore, 2002; Phillips and Moore, 2003a; Phillips and Moore, in review). The ability to infer adaptive potential is very important for species of conservation concern and may allow the ranking or prioritising of populations (Phillips and Moore, 2003b). However, the combination on these techniques in fisheries is still at a very early stage and research into this area should be encouraged.

B2.5.2 Genetic structuring of native fish populations in NSW

Due to a paucity of studies on the population genetics of Australian native fish there remains relatively little information on population structuring, population and deme boundaries, and almost no information on distinct evolutionary units, e.g. Evolutionarily Significant Units or Management Units.

Table B38. Genetic studies of population structuring in native freshwater fish that are currently stocked into NSW waters.

Species	Study	Marker	Survey area	Structuring
Australian bass *Macquaria novemaculeata*	Jerry 1997 Jerry and Baverstock, 1998	Allozymes mtDNA	Eastern drainages Eastern drainages	Yes Yes
golden perch *Macquaria ambigua*	Musyl & Keenan 1992 Keenan *et al.,* 1995	Allozymes	Eastern/western drainages	Yes Yes
eastern cod *Maccullochella ikei*	Nock *et al.*2003	Microsatellites	Clarence and Richmond Rivers	Yes
Murray cod *Maccullochella peelii peelii*	Bearlin & Tikel, 2002 Tikel & Nock, unpublished data	MtDNA Microsatellites	Murray/Darling Murray/Darling	Insufficient data Insufficient data
trout cod *Maccullochella macquariensis*	Bearlin & Tikel, 2002	mtDNA	Murray, Ovens, King & Sevens Creeks	Yes
silver perch *Bidyanus bidyanus*	Keenan *et al.,*1995	Allozymes	Murray/Darling	Insufficient data
eel-tailed catfish *Tandanus tandanus*	Keenan, *et al* 1995 Musyl and Keenan 1996	Allozymes Allozymes	Murray/Darling Eastern/western drainages	Yes Yes

Australian bass

Of the species currently stocked into State waters, only Australian bass (*Macquaria novemaculeata*) has been sufficiently studied. Jerry, (1997) demonstrated moderate but significant genetic structuring throughout the distribution of bass using allozyme electrophoresis (Fst=0.021). However, this level of population subdivision incorporated Glenbawn Dam, a stocked impoundment. When Glenbawn Dam was removed from the analysis, structuring was reduced (Fst=0.017), with Rogers' genetic distance indicating that this population now clades significantly differently from all ancestral populations. This level of population subdivision is broadly concordant with analyses of mtDNA control region (Øst=0.05) (Jerry and Baverstock, 1998). Structuring for both markers indicated isolation by distance along the coast, such that there is a marked difference between populations on the north and south coast, but that this difference is less obvious between neighbouring catchments.

Golden perch

Musyl and Keenan, (1992) surveyed golden perch (*Macquaria ambigua*) from the Murray River, Lake Keepit, Condamine River, Fitzroy Basin, Bulloo River and the Lake Eyre Basin. They concluded the Lake Eyre Basin population constituted a significant enough divergence (Nei's D=0.23) to be considered a different species. Significant structuring was evident between all four basins. Keenan *et al*., (1995) demonstrated significant structuring using allozyme markers with denoted populations in central Murray/ Darling, Paroo River, Ambathalla Creek, Lachlan River, lower Murray and two impoundments.

Eastern cod

Surveys of eastern cod (*Maccullochella ikei*) from the Clarence catchment have indicated some of the lowest recorded genetic diversity seen in endangered species. Despite this low level of both allelic diversity and heterozygosity, population structuring was observed. The Guy Fawkes and Sara Rivers demonstrated significant differences to all other sub-catchments. However this research is ongoing and only has data from two microsatellite loci so far, with several sub-catchments still to be sampled.

Data from hatchery progeny of eastern cod has indicated a significant reduction in both allelic diversity (decrease of 69% and 70% at loci EC1F & EC2B, respectively) and heterozygosity (decrease of 78%). It is clear that hatchery protocols within the hatchery are not sufficient to capture remnant genetic diversity of wild eastern cod or prevent the loss of heterozygosity. It has been estimated for fish species such as salmonids, that for every 10% reduction in heterozygosity there is a corresponding reduction in growth of 5 to 10%. A reduction in heterozygosity of 25% in rainbow trout (*Oncorhynchus mykiss*) as a result of inbreeding was shown to decrease fry survival by 19% and growth by 23% and increase phenotypic deformities by 38% (Kincaid, 1976a,b).

Trout cod

Trout cod were sampled from three populations including the Murray River downstream of Lake Mulwala, the Ovens and King Rivers and Sevens Creek. Genetic structuring was observed between the Ovens/King/Seven catchments sample and the Murray River (Fst=0.047) (Bearlin and Tikel, 2002).

Murray cod

Although Murray cod have been surveyed in some locations and for two markers there remains insufficient sample sizes to determine population subdivision (Bearlin and Tikel, 2002).

Eel-tailed catfish

Although not well surveyed, cryptic species have been recorded (Musyl and Keenan, 1996) and several others are being investigated at present (D. Jerry, pers. comm.). A study by Keenan *et al.*, (1995) found no evidence for population subdivision in riverine populations of catfish, though impounded waters were significantly different from one another indicating allele frequency changes in these waters. Further sampling is still required.

B2.5.2.1 Major knowledge gaps

There remain significant knowledge gaps for almost all the species currently stocked into NSW waters. Only the Australian bass has been comprehensively studied. There are major tributaries that have not been surveyed for most species. Eastern cod is very well surveyed with only Chandlers, Clouds, Coombadjha creeks, with major rivers including the Aberfoyle, Boyd, Rocky, and Cataract still to be sampled. Murray cod remains to be surveyed in most of its range. Golden perch remains unsurveyed for major parts of its natural distribution. Silver perch and eel-tailed catfish remain largely unsurveyed. There has been some work on the population subdivision of trout cod. The salmonids do not require any population structuring research as they are non-endemic and are therefore not likely to contain geographic genetic differences.

B2.5.3 Implications of stocking between populations

Populations that are isolated for long periods are likely to accumulate localised adaptive genetic variation. The level of localised adaptive variation will depend on the length of time since isolation, regional selective pressures and level of isolation between populations. There are several main problems with stocking the progeny of one population into a different population, including outbreeding depression and the reduction in population or evolutionary distinctiveness.

Population level crosses may show many of the same problems as species level hybridisation if the species are significantly divergent. Therefore the crossing of isolated populations may reduce the fitness of progeny or retard recruitment events, as offspring may be sterile or deformed.

Table B39. Species most at risk of population hybridisation

Species	Data	Risk
eastern cod	population subdivision demonstrated	high
Murray cod	likely to be population subdivision	high
trout cod	status unknown	low
Macquarie perch	likely to be distinct groups either side of Great Diving Range	low
golden perch	shown population subdivision across range and possible new species in Lake Eyre Basin	high
silver perch	likely to be population subdivision	high
eel-tailed catfish	likely to be population subdivision	high
Australian bass	population subdivision demonstrated	very high

B2.5.3.1 Outbreeding depression

Outbreeding depression is a decrease in fitness as a result of crossing isolated populations of the same species (Emlen, 1991). The two main causes of outbreeding depression are coadaptation and local adaptation (Templeton *et al*., 1986). Coadaptation is the result of a localised population that evolves a gene pool that is internally balanced with respect to reproductive fitness. Local adaptation is the adaptation of an isolated population to a set of regional environmental conditions (Templeton, 1997). Hybridisation among any of these localised populations can result in progeny that are not adapted to any or the wrong environmental conditions. The threat of local adaptation is likely to increase with geographic distance or isolation (Templeton, 1997). Outbreeding has been demonstrated to lead to the extinction of local populations due to translocation events (Templeton, 1997). To limit the potential threat of outbreeding, individuals should be sourced from the same geographic region. Stockings should be made only to the population from which the broodstock were sourced.

B2.5.3.2 Evolutionarily significant units and management units

As isolated populations diverge through the random assortment of alleles per generation (genetic drift) they take on their own evolutionary path. The Evolutionarily Significant Unit (ESU) concept was developed to provide a rational basis for prioritising taxa for conservation effort (e.g. captive breeding), given that resources are likely to be limited and the existing taxonomy may not adequately reflect underlying genetic diversity (Ryder, 1986; Waples, 1991; Moritz, 1994). The main aim of ESU is to ensure that evolutionary heritage is recognised and protected and evolutional potential inherent across the set of ESU is maintained. However, defining what constitutes a workable definition remains controversial. Ryder (1986) proposed a definition based on significant concordance between sets of data derived from different techniques, both ecological/biological and genetic. Waples (1991) suggests populations with reproductive separation containing unique adaptations. Moritz

(1994) proposed reciprocal monophyly at mitochondrial genes along with significant divergence at nuclear loci. All techniques offer certain levels of evolutionary protection and although still debated, most of the focus for defining ESU has moved towards capturing the evolutionary process using ecological/biological and molecular data (Crandall *et al*., 2000; Frazer and Bernatchez, 2001). This methodology is focussed at assessing individual populations and determining and maintaining the main natural processes separating populations.

To avoid the reduction of this evolutionary heritage and potential it is recommended that stockings only occur into the same ESU as the broodstock are sourced from. To further reduce the loss of evolutionary potential and the risk of outbreeding, stocking should be kept within the same geographic region, referred to as Management Units (MU) (Baverstock *et al*., 1993) or deme.

B2.5.4 Implications of hybridisation as a result of fish stocking

Cross breeding or hybridisation between species is likely for several of the species that are commonly stocked in NSW (Table B39). Hybridisation is believed to be more common in fishes (poikilotherms) than in other vertebrate groups such as mammals and birds (homoiotherms) (Lever, 1996). Several biological attributes of fish may explain this difference, including external fertilisation, weak ethological isolating mechanisms, unequal abundance of the parents, competition for limited spawning habitat, and susceptibility to secondary contact between recently evolved forms (Campton, 1987). Congeneric species of fishes are often infertile, and hybrid swarms representing genetic admixtures of the two parental species may be produced following the translocation of fishes.

Repeated backcrossing of hybrid descendants with a parental species can further result in the introgression of genes from one species into the gene pool of another. The process of introgressive hybridisation can cause the loss of entire species or unique populations (Campton, 1987). In other words, hybridisation between two species is likely to reduce the differences between the two species, and can in some circumstances lead to the local functional extinction of one or both species as parent species are no longer significantly different from one another.

Hybridisation is common in fish that are confined together in close geographic proximity, though it is rare in open healthy systems. Hybridisation often produces infertile or severely deformed offspring as the functional isolating mechanisms are affecting the embryonic development stage. Sterility and/or deformity can lead to a significant reduction in recruitment. In extreme circumstances, where recruitment is required to recovery the population from a catastrophic event, producing infertile hybrids my significantly reduce the ability of the species to recover and may lead to local extinction. Alternatively, if one of the F1 hybrid progeny is fertile and can backcross with either parental species, subsequent progeny will contain genetic material from both species.

B2.5.4.1 Extent of hybridisation in NSW waters

Eastern cod and Murray cod

There exists very little data describing hybridisation between stocked fish in NSW and their interactions and/or hybridisations with other native fishes. Concerns have been raised about the likelihood of hybridisation and introgression between congeners Murray cod and eastern cod. Murray cod have been translocated from western drainages into eastern catchments, primarily in tributaries of the Clarence River to reseed denuded local populations (as eastern cod was once thought to be Murray cod) and create new fisheries (A. Butler, pers. comm.). There is also a very real likelihood that eastern cod have been stocked into western catchments, most likely around Tenterfield. Despite the transfer of species from one catchment to the other and the close evolutionary relationship of both species, there remains no evidence for the presence of Murray cod in the Clarence catchment, or of the hybridisation or introgression of genetic material in 263 eastern cod and 52 Murray cod screened using microsatellite markers (Nock *et al*., 2003). These findings are supported by Rowland (1993), who reported matings between eastern cod and Murray cod produced no viable offspring within a controlled hatchery environment.

Trout cod and Murray cod

Hybridisation was confirmed between two wild, naturally sympatric Murray River populations of trout cod and Murray cod using protein electrophoresis (Douglas *et al*., 1995). There was no evidence of introgression between the two species. Hybrids have also been reported from a stocked impoundment, Cataract Dam within an eastern catchment, although fishing is not permitted in the dam (J. Diplock, NSW Fisheries, pers. comm.). Molecular studies are currently underway to establish the level of hybridisation in this population (C. Nock, Southern Cross University, pers. comm.).

Eastern and western populations/species of Macquarie perch

Interim results of studies of Macquarie perch indicate that there are significant genetic differences between eastern and western populations of Macquarie perch, which may be at the level of species (D. Gilligan, NSW Fisheries, pers. comm.). There is no evidence yet of hybridisation or introgression, though the risk remains high if species are translocated given the very close evolutionary heritage.

Australian bass and estuary perch

Australian bass and estuary perch have been shown to hybridise in natural populations (Jerry, 1998). Both species are closely related, share similar spawning habitats and form dense spawning schools which is likely to contribute to cross fertilisation between species. Given that both species remain distinct in most cases, and are sympatric, the likelihood of significant levels of hybridisation is very low.

Silver perch and spangled perch

The terapontids, silver perch and spangled perch, have the possibility of hybridisation and introgression. At this stage there is no evidence of either hybridisation or introgression, although this could be due to the limited genetic knowledge we have for both species. The risk remains fairly low despite cohabitation, as there is only limited riverine stocking of silver perch and spangled perch have not been stocked. Further work needs to be done to clarify the potential and extent of hybridisation.

Silver perch, Welch's grunter and Barcoo grunter

The aquaculture industry, in an attempt to produce a faster growing fish has made many crosses with silver perch and other terapontids including Welch's grunter and the Barcoo grunter. These species were reported to hybridise quickly, though it is not clear whether they produced viable offspring. Anecdotal reports suggest that the crosses of all three species have been sold to the aquaculture industry and widely disseminated throughout Queensland and NSW for broodstock and stocking, although the veracity of these claims is as yet unsubstantiated.

B2.5.4.2 Implications of hybridisation for threatened species

Eastern cod

Despite the lack of evidence for hybridisation between eastern cod and Murray cod, it remains a distinct possibility. Hybridisation between these species could breakdown distinct differences between both species. Constant interbreeding between species could render eastern cod locally extinct. Given that many hybrids are likely to be sterile, lack of yearly recruitment could significantly impact or retard the species' recovery.

Trout cod

Trout cod and Murray cod are sympatric and are therefore likely to have evolved distinct mechanisms that prevent hybridisation. The fact that they do hybridise in the wild suggests that this mechanism may not be strong and may indicate that both species were isolated during the speciation process and have only recently (in geological terms) come back into contact. The problem should be monitored, but even if further hybridisation were highlighted, a solution would be difficult to find.

Macquarie perch

The potential hybridisation between eastern and western populations of Macquarie perch on contact is relatively high, though the probability of meeting could be considered fairly low as the species is notoriously difficult to breed in captivity, therefore limiting stocking possibilities.

Oyleyan pygmy perch

Oxleyan pygmy perch appear quite easy to breed in captivity (J. Knight, NSW Fisheries, pers. comm.) and as such may be considered for stocking into areas they have disappeared from if there is suitable habitat or it can be rehabilitated. Given that the regions likely to be stocked have no other congeners it is very unlikely that there will be problems with hybridisation.

B2.5.5 Summarise the risk to genetic structure of resident populations

The review of existing information about genetic protocols of hatcheries and structuring of wild populations of native fish suggests that the current activity of fish stocking is posing a significant risk to the genetic integrity of wild populations of native fish. This risk is compounded by the lack of information about the genetic diversity of the populations from which broodstock are collected and progeny released. There is very little genetic information for the majority of the species that are currently used for stock enhancement and the genetic profiles of many populations may already be compromised. The limited monitoring that has been done for some species indicates that not only is there genetic structuring for most species throughout the State, but also that there are likely to be separate species determined following further work.

The limited available information indicates that inbreeding has been detected in wild populations of golden perch and silver perch that were supplemented from hatchery stock. Inbreeding can cause reduced fecundity and survival, and increases the number of deformities and the probability of extinction in wild populations. Within hatcheries and thus stocked fish, it is generally caused by the use of insufficient numbers and/or management of broodstock. Further, and of greater concern is that the genetic guidelines adopted to aid the endangered eastern cod have either been insufficient to maintain genetic diversity, or have not been adhered to. The remaining population has a naturally low genetic diversity, and this has been further compromised by the current breeding program.

In order to mitigate these risks, it will be necessary to implement strict guidelines for hatcheries that propose to produce fish for stocking. Those hatcheries must be distinct from other aquaculture facilities, and as part of that extreme measure, broodstock collection, management and recording procedures need to be introduced. Further, once the guidelines have been developed, any hatchery proposing to be involved in stocking should undergo some form of certification or accreditation proving that they can consistently produce fish in accordance with those guidelines. Accreditation also needs to be an ongoing process, not just an initial approval. This will require an element of compliance through *in situ* checks by NSW Fisheries, and the delivery of samples or broodstock information upon request.

B2.6 Translocation of organisms

B2.6.1 Potential impacts of translocation

The translocation of organisms outside their natural distributions is likely to cause significant alterations to the receiving populations. Likely problems of translocation include a variety of ecological impacts including, habitat alterations, trophic alterations (through predation and competition), spatial alterations, disease and genetic changes. Unfortunately, relatively few ecological studies have been conducted on the impact of translocated species within freshwater environments of Australia, although the effects are believed to be similar to or the same as for introduced species. The effects of deliberately translocating both native and salmonids will be discussed, along with organisms that may be inadvertently translocated during the stocking process.

B2.6.1.1 Habitat alterations

Alterations to the habitat composition by translocated fishes principally involve the displacement of aquatic vegetation and the degradation of water quality (Lever, 1996). The displacement of aquatic flora is often a result of the consumption of plant material by herbivorous species, by the uprooting of macrophytes through digging for food or nesting sites. Another important factor contributing to reductions in macrophyte abundance includes nutrient enrichment through animation of nutrient laden sediments when feeding which stimulates phytoplankton blooms, thereby increasing turbidity and decreasing light penetration and photosynthesis (Lever, 1996).

Macrophytes provide a variety of facilities in aquatic environments, including oxygen, nourishment, habitat, nesting sites and foraging areas. Aquatic plants are also critical in the cycling of nutrients and reducing turbidity (Anon, 1996). Therefore a reduction in macrophyte abundance may lead to increased turbidity, to the detriment of native species that have a low tolerance to turbid conditions. Increased turbidity may also smother invertebrate communities, for which many native species such as the eel-tailed catfish and Macquarie perch depend on for forage. Escalations in turbidity have also been linked to the disruption of reproductive processes in native fishes. Sediment may smother nests and eggs or may result in physiological stress of the individual leading to the resorption of eggs (Lever, 1996). Moreover, reductions in aquatic plants may lead to a loss of suitable breeding substrate that several important native fish families require. For example, members of the family's Nannopercidae (pygmy perches) (Kuiter *et al*., 1996), Chandidae (ambassids) (Allen, 1996b), Pseudomugilidae (blue-eyes) (Ivantsoff and Crowley, 1996), Retropinnidae (southern smelts) (McDowall, 1996c) and Melanotaeniidae (rainbowfishes) (Allen, 1996) all rely to some degree, on aquatic vegetation to lay their eggs onto. It may be that reductions in aquatic flora abundance have led to decreased recruitment in many native species. Taylor *et al* (1984) demonstrated a correlation between habitat degradation and a reduction in the numbers and diversity of native freshwater fish in North America.

The feeding behaviour of European carp has been shown to increase turbidity and reduce the density of shallow-rooted and soft leaved macrophytes in some lakes and billabongs (Morison and Hume, 1989). However, natural hydrological changes were found to be of greater significance than carp densities in determining turbidity and macrophyte abundance in lentic habitats (Fletcher *et al.,* 1985). European carp are a pest species in NSW and are not part of the current stocking program.

Of the species that are stocked in NSW waters, only the salmonids and native eel-tailed catfish are thought to physically modify their habitat. Salmonids modify streambed structure during the breeding season by digging redds, which are effectively depressions in the gravel in which to lay eggs. Eel-tailed catfish also create similar, but much larger structures, and inhabit them for an extended period. Although there have not been any direct studies into the impact of stocked species on habitats of NSW waters, it is considered possible that they make physical alterations to habitats that may affect endemic fauna or flora (Hilderbrand 1971; Huryn, 2002). As such, the species that are currently stocked in NSW waters are considered a low risk of physically modifying habitats, however, there is a great deal of uncertainty associated with that designation of risk. That uncertainty can only be removed by research into the effects of stocking on the receiving environment.

B2.6.1.2 Trophic alterations

Translocated fishes can alter trophic relationships in several distinct ways, all of which have the potential to affect native fishes. The first and most obvious impact is predation from introduced predatory fishes, which may profoundly affect the population dynamics of indigenous prey species (Taylor *et al* 1984). Murray cod are known to eat any fish small enough for it to consume.

The effect of predation from introduced salmonids on Australia's native freshwater fish fauna has been considerable (Lever, 1996). The most significant effects have been noted on the native galaxiids (Galaxiidae) (Anon, 1996). For example, it has been shown that when galaxiids and salmonids, predominantly trout, co-exist predation is high. In cases where galaxiids are abundant, they are likely to become the primary food source for adult trout. This is compounded in clear open lakes and streams where cover or refugia is limited. Under these circumstances galaxiids have been shown to dramatically decrease in abundance (Cadwallader, 1995).

The next most significant trophic alteration is dietary overlap and occurs when the feeding habits of introduced fish reduce the prey available to native predators. When resources are limited, dietary overlap can result in exploitation competition, leading to modifications in diet, growth, condition and breeding success among native species (Welcomme, 1988). Many of the terapontids will have a similar diet to Macquarie perch, and therefore could create problems in areas where they do not historically coexist.

The diets of adult galaxiids and juvenile trout have also been shown to overlap, especially in smaller streams that serve as trout spawning and nursery areas (Lever, 1996). In most cases galaxiids may be out-competed for food and space by the more aggressive salmonids. Exploitative competition may pose the greatest threat for those galaxiids, which are sedentary non-migratory riverine dwellers (Cadwallader, 1995). Australian galaxiid species that are believed to have become endangered as a result of interactions with salmonids include the Swan galaxias (*Galaxias fontanus*), barred galaxias (*Galaxias fuscus*), Clarence galaxias (*Galaxias johnstoni*), spotted galaxias or spotted mountain trout (*Galaxias truttaceus*) (Anon, 1996) and Pedder galaxias (*Galaxias pedderensis*) (Cadwallader, 1995).

The saddled galaxias (*Galaxias tanycephalus*) is now considered threatened as a result of competition or predation from brown trout (Wager and Jackson, 1993). NSW galaxiids impacted by salmonids and regarded as vulnerable include the mountain galaxias (*Galaxias olidus*), the broad-finned or climbing galaxias (*Galaxias brevipinnis*).

Additional native species that have been either directly of indirectly affected by introduced salmonids include the potentially threatened Yarra pygmy perch (*Edelia obscura*), Australian grayling (*Prototroctes maraena*), and the vulnerable variegated pygmy perch (*Nannoperca variegata*). Trout may have played a role in the decline of the endangered trout cod (*Maccullochella macquariensis*), Macquarie perch (*Macquaria australasica*) and the gadopsid river blackfish (*Gadopsis marmoratus*) (Anon, 1996).

Resource competition between gambusia and Australian native freshwater fish has been shown to have a significant impact. For example, Lloyd (1984) found that competition from gambusia in the Lower River Murray has led to the mutual exclusion of the pygmy perch (*Nannoperca australis*) from parts of its natural range. In Australia, gambusia have been implicated in the decline of species of *Ambassis*, *Chlamydogobius*, *Craterocephalus*, *Galaxias*, *Melanotaenia*, *Mogurnda*, *Pseudomugil*, *Retropinna* and *Scaturiginichthys* (Wager and Jackson, 1993). Gambusia also appear to have caused a severe decline of an endemic rainbow fish (*Rhadinocentris ornatus*) in a nearly pristine environment on North Stradbroke Island (Anon, 1996). Additionally, McKay (1978) noted that where gambusia were abundant in disturbed creeks, native fishes tend to be rare. The ecological impact of interference competition as a result of aggression and fin nipping by gambusia has been shown to be significant Knight *et al*., (unpublished). However, Lloyd (1987) found that gambusia would attack native fish twice their size and could inflict caudal fin damage (A. Moore personal observation). Gambusia have been witnessed to attack and kill and adult Australian bass in captivity.

Alternatively, translocated and introduced species may increase the amount of prey available to native predators. For example, in certain areas European carp are a common food source for Murray cod and golden perch (Wager and Jackson, 1993). It is also highly likely that smaller introduced species such as gambusia and the juvenile life stages of salmonids would become forage for larger endemic predatory fish.

B2.6.1.3 Spatial alterations

When translocated fishes are abnormally abundant, interactions between species may alter the distribution, density and existence of both species. For instance, interference competition arising from aggression and territoriality may cause the indigenous species to be displaced from favoured microhabitats such as feeding grounds, nesting sites and refugia (Taylor *et al.,* 1984; Lever, 1996). In extreme circumstances, harassment from introduced species may inhibit the reproductive responses of some native species. Lever (1996) suggests that harassment by European carp has resulted in retarded development and fecundity of native fishes.

B2.6.1.4 Disease

It has been suggested that the largest ecological impacts from translocated and introduced species are not the fish themselves but the parasites and diseases they carry. In contrast to other ecological effects, the translocation of parasites, pathogens and diseases can be made via exotic fish never intended for release into the wild. Many pathogens are considered to be host or group specific and as Australia's fish fauna is mostly endemic, such introductions do not represent a large risk

(Langdon, 1989). However, the movement of pathogens that are not host or group specific poses the greatest threat to native fishes (Ashburner, 1975).

The virus epizootic haematopoietic necrosis, thought to be introduced with redfin perch, has been found to infect such autochthonous species as silver perch (*Bidyanus bidyanus*), mountain galaxias (*Galaxias olidus*), Macquarie perch (*Macquaria australasica*), Murray cod (*Maccullochella peelii peelii*) and the introduced rainbow trout (*Oncorhynchus mykiss*) and gambusia (*Gambusia holbrooki*). Other pathogens that have been disseminated with alien species include (*Lernaea cyprinacea*), (*Chilodonella cyprini*), (*Chilodonella hexasticha*), (*Costia* spp.), (*Ichthyophthirius multifiliis*) and perhaps (*Trichodina* spp.) (Langdon, 1989).

Pathogens frequently pose a more serious threat to atypical hosts than typical hosts. The susceptibility of atypical hosts to non-endemic infectious diseases is partly a result of the lack of coadaptation of the host to the parasite. As the host did not evolve with the pathogen, a natural adaptive tolerance to the disease has not developed. Many of these introduced non-host-specific pathogens have caused large epizootics in a plethora of Australia's native freshwater fish fauna in the wild (Langdon, 1989). Additionally, many native fish hatcheries report epizootics of introduced pathogens as a major contributor to large-scale losses of both broodstock and fingerlings. For example, Rowland and Ingram (1991) found that silver perch (*B. bidyanus*), golden perch (*Macquaria ambigua*), Murray cod (*Maccullochella peelii peelii*) and trout cod (*M. macquariensis*) from Narrandera Fisheries Centre have all been infected with (*Ichthyophthiriasis multifilis*), often leading to high mortality. Native freshwater cod (*Maccullochella* spp.) are reported to be very susceptible to *Chilodonella* spp., leading to mortality (Rowland and Ingram 1991).

Despite the many pathogens found to infect native fish within Australian there remain many that are poorly researched and more than likely many that remain to be described. Additionally, there is almost nothing known about the population subdivision of most parasites and diseases. There is such poor data on Australian fish parasites that there is still many doubts about what is endemic and what is translocated or introduced. Additionally, there remains only a basic understanding of trigger mechanisms causing infection and epizootics. Research should be directed at filling these important knowledge gaps. A comprehensive survey of state waters for the presence of aquatic pathogens is highly recommended.

B2.6.1.5 Genetic effects

The restocking of denuded and depauperate fisheries has often led to the translocation of individuals outside their natural distribution. Additionally, genetically distinct stocks of the same species are often translocated between drainages (Keenan *et al*., 1995). Despite the extensive use of translocation as a conservation tool, there is evidence to suggest it can lead to genetic deterioration and loss of fitness through introduction of deleterious alleles, inbreeding, outbreeding, hybridisation and introgression (Hindar *et al*., 1991; Hansen and Loeschcke, 1994) (see B2.5).

B2.6.2 Flora and fauna likely to be translocated

Historically, species have been translocated out of their native ranges as a result of intentional liberations for stock enhancement (Tables B40 and B41) and unintentional releases with contaminated fish, escapees from aquaculture facilities, escapees from stocked farm dams and the release of unwanted aquarium pets (Tables B42 and B43). It is not readily possible to isolate the majority of those species that have been accidentally translocated due to fish stocking in NSW waters. Those native and exotic species that have been intentionally translocated will be described, as will the species and original mechanisms of introduction for potential translocations.

Table B40. Native species that have been intentionally translocated

Species	Location	Reason
Murray cod *Maccullochella peelii peelii*	Throughout NSW, many cryptic stocking & translocation events	Recreational fishing, aquaculture, farm dams
Eastern cod *Maccullochella ikei*	West of the divide, anecdotal reports	Recreational fishing
Trout cod *Maccullochella macquariensis*	Throughout NSW, likely cryptic stocking & translocation events	Recreational fishing
Golden perch *Macquaria ambigua*	Throughout NSW, likely cryptic stocking & translocation events	Recreational fishing, aquaculture, stocking farm dams
Silver perch *Bidyanus bidyanus*	Throughout NSW, likely cryptic stocking & translocation events	Recreational fishing, aquaculture, stocking farm dams
Australian bass *Macquaria novemaculeata*	Throughout NSW, likely cryptic stocking & translocation events	Recreational fishing, aquaculture, stocking farm dams
Eel-tailed catfish *Tandanus tandanus*	From the Macquarie River to the Hawkesbury, Wimmera (VIC), Murray rivers, throughout NSW, likely cryptic stocking & translocation events	Recreational fishing, aquaculture, stocking farm dams
Spangled perch *Leiopotherapon unicolor*	Darling River to southeast QLD, NSW, likely stocking & translocation events	Recreational fishing, aquaculture, stocking farm dams, bait
Bony bream *Nematolosa erebi*	From the Darling to the Hunter River	Recreational fishing, bait
Queensland lungfish *Neoceratodus forsteri*	Burnett River to southern QLD and Tweed River	Conservation

B2.6.2.1 Translocated native species

The translocation of favoured Australian native freshwater fish has been conducted since European colonisation. However, the extent to which translocations have occurred is unclear as few records exist and private individuals have conducted many of the translocations. Translocation of freshwater fish has only recently been regulated within Australia (Harris and Battaglene 1989).

Eel-tailed catfish (*Tandanus tandanus*) have been translocated from the Macquarie River in New South Wales to the Hawkesbury, Wimmera and Murray River systems (Harris and Battaglene, 1989). Murray cod (*Maccullochella peelii peelii*) have been widely distributed throughout New South Wales, as has the trout cod (*Maccullochella macquariensis*), Macquarie perch (*Macquaria australasica*), golden perch (*Macquaria ambigua*) and silver perch (*Bidyanus bidyanus*) (Harris and Battaglene, 1989). Both golden and silver perch are now stocked into eastern divide waters, such as Glenbawn Dam.

Spangled perch (*Leiopotherapon unicolor*) were introduced into southeastern Queensland from the Darling River, as were Australian bass (*Macquaria novemaculeata*) from the Hawkesbury River. Bony bream (*Nematolosa erebi*) were introduced into the Hunter River from the Darling River, but do not seem to have established. Australian bass have been stocked extensively throughout NSW coastal and inland waters in dam and rivers. The western carp gudgeon (*Hypseleotris klunzingeri*) was unintentionally introduced into the Wimmera Lakes in Victoria from the Murray River system (Harris, 1989). Additionally, the Queensland lungfish (*Neoceratodus forsteri*) were introduced to southern

Queensland rivers and the Tweed River in northern New South Wales from the Burnett River in Queensland for conservation (Harris and Battaglene, 1989).

B2.6.2.2 Translocated exotic species

In 1864 colonists shipped fertilised ova of brown trout to Tasmania where they were successfully introduced (Weatherley and Lake 1967). The Tasmanian stock was then disseminated to Victoria where it flourished in the highland waters. In 1888 brown trout ova from Geelong in Victoria were distributed throughout New South Wales (Roughley, 1951). In 1894, approximately 3,000 fertilised ova from the North American salmonid rainbow trout (*Oncorhynchus mykiss*) were transplanted from New Zealand to New South Wales (Lever, 1996).

The Atlantic salmon (*Salmo salar*) was introduced to the antipodes between 1864 and 1870 with little success (Davies and McDowall, 1996). No self-sustaining sea-run populations of Atlantic salmon have been recorded to date in Australia despite vigorous stocking into both Tasmania and Victoria. Atlantic salmon are established in Burrinjuck Dam, (1963-1964), and in Lake Jindabyne but are maintained in those storages by annual stocking (Lever, 1996).

As with the other salmonids brook char (*Salvelinus fontinalis*) are highly regarded for their sporting and edible qualities and were introduced into Tasmania in the early 1900s. Subsequently liberations were made into streams on the mountain tablelands of New South Wales in the 1970s, though supplementation is still required to perpetuate these populations (Davies, 1996).

European perch (*Perca fluviatilis*) were introduced into Australia as early as 1862 and are now widespread throughout the cooler waters on both sides of the Great Dividing Range. Perch are also abundant in central and southern New South Wales, Victoria, South Australia and Tasmania (McDowall, 1996). Populations are self-sustaining throughout their range, with the species thriving particularly well in large impoundments (Weatherley and Lake, 1967).

Table B41. Exotic species that have been intentionally released into NSW waters.

Species	Location	Reason
Rainbow trout *Oncorhynchus mykiss*	Throughout NSW, likely cryptic stocking & translocation events	Recreational fishing, aquaculture, stocking farm dams
Brown trout *Salmo trutta*	Throughout NSW, likely cryptic stocking & translocation events	Recreational fishing, aquaculture, stocking farm dams
Brook trout *Salvelinus fontinalis*	Throughout NSW, likely cryptic stocking & translocation events	Recreational fishing, aquaculture, stocking farm dams
Atlantic salmon *Salmo salar*	Lake Jindabyne, Burrinjuck Dam, likely cryptic stocking & translocation events	Recreational fishing, aquaculture
Redfin perch *Perca fluviatilis*	Throughout NSW, likely cryptic stocking & translocation events	Recreational fishing, aquaculture, stocking farm dams
European carp *Cyprinus carpio*	Throughout NSW, likely cryptic stocking & translocation events	Recreational fishing, aquaculture, stocking farm dams
Goldfish *Carassius auratus*	Throughout NSW, likely cryptic stocking & translocation events	Recreational fishing, aquaculture, stocking farm dams
Gambusia *Gambusia holbrooki*	Throughout NSW, likely cryptic stocking & translocation events	Biological control of mosquitos

B2.6.2.3 Biological control

Eastern gambusia (*Gambusia holbrooki*) or mosquitofish as it was later known, was thought to be the dominant larvavore in its native habitat of Central and South America. Gambusia were first used as a biological agent for the control of mosquitoes in 1905. They were introduced throughout the world in an attempt to eradicate mosquitoes as vectors for the spread of infectious disease. Civil health authorities introduced the initial stocks of gambusia into Australia in the 1920s, (Lloyd, 1989). Gambusia have now spread throughout most of Australia's inland and coastal drainages.

B2.6.2.4 Aquaculture species

Introduced and translocated species are a major contributor to NSW aquaculture production. Despite the aquaculture benefits of introduced species, it has been shown that large numbers of cultured fish are unintentionally released through escapes from aquaculture facilities. Accidental escapes from aquaculture facilities are most often associated with damage as a result of storms, collisions or general wear and tear (Hindar *et al*., 1991). Barlow and Rodgers (1989) suggest that escape proofing of ponds is virtually impossible, no matter what level of security is imposed. The issue of the unintentional liberation of cultured fish is a major problem wherever aquaculture exists. In countries that have very large fish culture industries such as Norway, escaped fish have been shown to constitute up to 80% of localised wild populations (Hindar *et al*., 1991).

The European carp (*Cyprinus carpio*) was introduced into Australia for aquaculture earlier this century (Roughley, 1951). Three distinct strains have been introduced, however only one has proven to be a highly adaptive coloniser. This variety of carp was subsequently termed the Boolara strain after the Boolara district in Victoria where it first became established (Shearer and Mulley, 1978). Carp were propagated and sold to primary producers to stock farm dams. This particular strategy of dissemination was particularly effective and led to the widespread colonisation of Victoria and New South Wales (Morison and Hume, 1989). The potential for carp to spread rapidly and cause environmental damage was first reported from North America in the 1950s, (Lever, 1996). Carp were later declared a noxious species in Victoria and an extensive eradication program was instigated to terminate all known carp populations in the State. Although severely reducing carp populations, the large-scale eradication of the species was unsuccessful (Morison and Hume, 1989). In 1964-1965 carp were reported in Lake Hawthorn in Victoria, where they have spread into and colonised the Murray-Darling River system (Shearer and Mulley, 1978). There are now many reports of carp from the east coast rivers on NSW.

B2.6.2.5 Ornamental species

Lever (1996) has divided exotic fish introduced for ornamental reasons into two categories. In the first category are temperate species such as Roach (*Rutilus rutilus*), tench (*Tinca tinca*), guppy (*Poecilia reticulata*), sailfin molly (*Poecilia latipinna*) and swordtails (*Xiphophorus helleri*). The second category consists of the innumerable small, tropical species, which have been introduced to Australian waters by aquarists. These include the black mangrove cichlid (*Tilapia mariae*), convict cichlid (*Cichlasoma nigrofasciatum*), and the Mozambique mouthbrooder (*Oreochromis mossambicus*).

However, the majority of tropical species have found colonising temperate waters very difficult, with only a few establishing breeding populations in artificially heated waters discharged from factories or power stations and in thermal springs (Wager and Jackson, 1993).

In the warmer climates of the tropics and sub-tropics, exotic tropical fish have been very successful colonisers. For example, the African cichlid, (*Oreochromis mossambicus*) (Peters), also known as tilapia and Mozambique mouthbrooder, has established breeding populations in a number of disjunct sites in Queensland and Western Australia (Arthington *et al*., 1984; Bluhdorn *et al*., 1989). No reports of self-reproducing populations of cichlids have been recorded in NSW.

Despite the instigation of management control to regulate the translocation of species, many translocations are made via cryptic individuals it would seem plausible that elimination of these practises may be difficult. Consequently, there is a need for the increased education of aquarists, aquaculturists, anglers, and the general public on the adverse effects and dangers associated with the dissemination of exotic and translocated species. Regular biannual workshops that include hatchery operators, stocking groups, acclimatisation societies, recreational fishers, aquarists, scientist and managers would be a very good way to disseminate information. This could be augmented with a regular newsletter containing the latest information on a range of stocking and translocation issues.

B2.6.3 Performance of stocking in terms of translocation incidents

Translocation of organisms outside their natural ranges can be categorised into two groups. Historically, intentional translocation of fish to new locations was to establish new recreational fisheries and aquaculture industries. Escapes from aquaculture facilities and farm dams were thought to be fairly common, although that risk is likely to be reduced following finalisation and implementation of the NSW Fisheries Aquaculture Compliance Strategy. Species such as silver perch and golden perch are now quite ubiquitous in coastal rivers of NSW (A. Moore, Southern Cross University, pers. obs.). However, it is unknown whether these populations are self-sustaining. It is not common practice today to translocate new species for the establishment of fisheries or aquaculture industries, but remains high for already established programs.

Unintentional translocations of organisms in the transport media used in fish stocking is likely to be very high and pose significant risks. As fish are harvested within the culture facility, it is likely that additional non-target species will be captured, transported and released into stocked waters.

Many hatcheries breed several fish species and distinct strains. It is relatively common for mixed batches of species and/or populations to be released in the stocking process. Barred grunter have been translocated into the Clarence River in northern NSW and Hinze Dam in southern QLD where they are considered a threat to the Hinze ecosystem and surrounding fisheries (M. Moore, pers. comm.). Several hatcheries also breed exotic species for the aquarium trade, and have the potential to unintentionally disseminate exotic species throughout the State while stocking other species. Liberations of unwanted aquarium fishes by hobbyists is another key area that contributes to the translocation of both native and exotic organisms.

Tables B42 to B46 present the native and exotic fauna and flora that have potential to be inadvertently translocated as a result of current hatchery practices and the subsequent use of fish for stocking NSW waters. They are not meant to be definitive, and are broadly based on those species that are currently reared in fish hatcheries in NSW. Many of the invertebrates listed in Table B45 are not reared in the hatchery, for example, but are likely to exist within the waterbodies used to rear fish.

Table B42. Species that could have been unintentionally translocated through the stocking process.

Species	Location	Mechanism
Barred grunter *Amniataba percoides*	Clarence River	Within consignment of stocked fish
Western carp gudgeon *Hypseleotris klunzingeri*	Wimmera Lakes VIC	Unknown
Roach *Rutilus rutilus*	Localised in NSW, likely cryptic stocking & translocation events	Unwanted aquarium pet releases
Tench *Tinca tinca*	Localised in NSW, likely cryptic stocking & translocation events	Unwanted aquarium pet releases
Guppy *Poecilia reticulata*	Throughout NSW, likely cryptic stocking & translocation events	Unwanted aquarium pet releases
Sailfin molly *Poecilia latipinna*	Localised in NSW, likely cryptic stocking & translocation events	Unwanted aquarium pet releases
Swordtails *Xiphophorus helleri*	Localised in NSW, likely cryptic stocking & translocation events	Unwanted aquarium pet releases

Table B43. Native fish species that have the potential to be inadvertently translocated during the stocking process.

Species	Mechanism	Probability
Barred grunter *Amniataba percoides*	Within consignment of stocked fish	High for some hatcheries
Firetail gudgeon *Hypseleotris galii*	Within consignment of stocked fish	High for eastern hatcheries
Midgely's Carp gudgeon *Hypseloetris sp. 4*	Within consignment of stocked fish	Moderate for western hatcheries
Lake's carp gudgeon *Hypseloetris sp. 5*	Within consignment of stocked fish	Moderate for western hatcheries
Western carp gudgeon *Hypseleotris klunzingeri*	Within consignment of stocked fish	High for some hatcheries
Empire gudgeons *Hypseleotris compressa*	Within consignment of stocked fish	High for eastern hatcheries
Southern purple-spotted gudgeon *Mogurnda adspersa*	Within consignment of stocked fish	Low for all hatcheries
Murray cod *Maccullochella peelii peelii*	Within consignment of stocked fish	High for some hatcheries
Eastern cod *Maccullochella ikei*	Within consignment of stocked fish	Low, only one hatchery
Trout cod *Maccullochella macquariensis*	Within consignment of stocked fish	Low, few hatcheries
Australian bass *Macquaria novemaculeata*	Within consignment of stocked fish	High for some hatcheries
Golden perch *Macquaria ambigua*	Within consignment of stocked fish	High for some hatcheries

Table B43 cont.

Species	Mechanism	Probability
Spangled perch *Leipotherapon unicolor*	Within consignment of stocked fish	High for some hatcheries
Olive perchlet *Ambasis agassizii*	Within consignment of stocked fish	Moderate for some hatcheries
Southern blue-eye *Pseudomugil signifer*	Within consignment of stocked fish	Moderate for most hatcheries
Crimson-spotted rainbowfish *Melanotaenia fluviatilis*	Within consignment of stocked fish	Low for all hatcheries
Flyspecked hardyhead *Craterocephalus stercusmuscarum fulvus*	Within consignment of stocked fish	Low for all hatcheries
Eel-tailed catfish *Tandanus tandanus*	Within consignment of stocked fish	High for some hatcheries
Australian smelt *Retropinna semoni*	Within consignment of stocked fish	Low for all hatcheries
Cox's gudgeon *Gobiomorphus coxii*	Within consignment of stocked fish	Moderate for eastern hatcheries
Striped gudgeon *Gobiomorphus australis*	Within consignment of stocked fish	Moderate for eastern hatcheries
Long-finned eel *Anguilla reinhardtii*	Within consignment of stocked fish	Moderate for eastern hatcheries
Short-finned eel *Anguilla australis*	Within consignment of stocked fish	Moderate for eastern hatcheries

Table B44. Exotic fish species that have the potential to be inadvertently translocated during the stocking process

Species	Mechanism	Probability
Gambusia *Gambusia holbrooki*	Within consignment of stocked fish	Very high for all hatcheries
Atlantic salmon *Salmo salar*	Within consignment of stocked fish	High for salmonid hatcheries
Brook trout *Salvelinus fontinalis*	Within consignment of stocked fish	High for salmonid hatcheries
Brown trout *Salmo trutta*	Within consignment of stocked fish	High for salmonid hatcheries
Rainbow trout *Oncorhynchus mykiss*	Within consignment of stocked fish	High for salmonid hatcheries
Redfin perch *Perca fluviatilis*	Within consignment of stocked fish	Moderate for some hatcheries
European carp *Cyprinus carpio*	Within consignment of stocked fish	High for some hatcheries
Goldfish *Carassius auratus*	Within consignment of stocked fish	High for some hatcheries
Aquarium species (too many to list, indeterminate species)	Within consignment of stocked fish	High for hatcheries that breed both natives and exotics

Table B45. Crustaceans and other invertebrates that have the potential to be inadvertently translocated during the stocking process.

Species	Mechanism	Probability
Yabby *Cherax destructor*	Within consignment of stocked fish	High for hatcheries that breed crayfish
Redclaw crayfish *Cherax quadricarinatus*	Within consignment of stocked fish	High for hatcheries that breed crayfish
Marron *Cherax tenuimanus*	Within consignment of stocked fish	High for hatcheries that breed crayfish
Murray river crayfish *Euastacus armatus*	Within consignment of stocked fish	Moderate for western hatcheries
Freshwater prawns *Macrobrachium* spp.	Within consignment of stocked fish	Very high for most hatcheries
Freshwater shrimps *Paratya* spp. & *Caridina* spp.	Within consignment of stocked fish	Very high for most hatcheries
Fairy shrimp *Branchinella* spp.	Within consignment of stocked fish	High for western hatcheries
Copepods Cyclopoids, Clalanoids & Harpacticoids	Within consignment of stocked fish	Very high for all hatcheries
Amphipods Corophiidae, Ceinidae, Eusiridae & Gammaridae	Within consignment of stocked fish	High for all hatcheries
Ostracods	Within consignment of stocked fish	Very high for all hatcheries
Water fleas (*Daphnia* spp.)	Within consignment of stocked fish	Very high for all hatcheries
Odonata	Within consignment of stocked fish	High for most hatcheries
Cnidarians, Hydrozoa	Within consignment of stocked fish	Low for most hatcheries
Plecoptera	Within consignment of stocked fish	High for most hatcheries
Ephemeroptera	Within consignment of stocked fish	High for some hatcheries
Hemiptera	Within consignment of stocked fish	High for most hatcheries

Table B46. Flora that have the potential to be inadvertently translocated during the stocking process

Species	Mechanism	Probability
Nodularia (*Nodularia* spp.)	Within consignment of stocked fish	High for some hatcheries
Azolla (*Azolla filiculoides* and *Azolla pinnata*	Within consignment of stocked fish	High for some hatcheries
Salvinia (exotic) *Salvinia molesta*	Within consignment of stocked fish	Low for most hatcheries
Volvox *Volvox* spp.	Within consignment of stocked fish	Very high for most hatcheries

B2.6.3.1 Implications of translocation for other water users

The spread of species outside their endemic range and the dissemination of exotic species are likely to have significant flow-on effects for all water users. Increases in the number of translocated species are likely to increase the chances of unwanted organisms entering aquaculture facilities. Predatory species entering aquaculture facilities have the potential to lead to significant mortality within culture facilities. The movement of new parasites and diseases to native populations poses the largest threat to aquaculture facilities. As aquaculture facilities maintain fish at high densities, the possibility for disease outbreak is very high, especially if fish have not previously been exposed to the pathogen. Translocation of species in wild environments is likely to change the species composition, increase resource competition within aquatic communities and degrade natural habitats. The degradation of natural habitats is likely to reduce biological diversity.

B2.6.4 Performance of stocking activities in terms of stress and disease

There is almost no information available that describes disease outbreaks or the spread of parasites as a result of stocking. There should be little doubt that disease organisms are released during the stocking process, but their effects of wild populations is unknown. Parasites and disease causing organisms are present at background levels in all natural aquatic ecosystems and usually only lead to epizootics when populations are significantly stressed. Stressors are likely to be degradations is environmental conditions necessary for the maintenance of life. Therefore the dissemination of small numbers of parasites is not likely to create significant problems in stocked populations. However, the release of new parasites or disease causing organisms have the potential to create health problems for wild fisheries and ecosystems. The immune response to new infectious organisms in likely to be much poorer than for previously exposed organisms.

The collection of broodstock has very low risks as far as the spread of parasites or disease organisms. The major problems associated with the sourcing of broodfish are likely to be the reduction of local recruitment, especially in populations that are denuded. To reduce stress, all broodfish should be collected well before hatchery production commences. For species such as Macquarie perch that do not ripen well in captivity, this may not be possible.

Fish maintained at densities common in hatchery facilities are likely to be prone to disease or parasitic infection. Larvae and juvenile fish are very prone to parasitic and disease infection, especially when held in the very high densities common in hatcheries. Regular checks for the organisms should reduce risk as will keeping broodstock densities low, maintaining adequate water quality and having facilities for the quarantining and treatment of infected individuals.

Common ectoparasites of Australian native fish include the protozoans *Chilodonella hexasticha*, *Ichthyophthirius multifiliis*, *Trichodina spp*., *Ichthyobodo necator*, *Tetrahymena sp.* and the parasitic copepod, *Lernaea sp.*. Adults, juveniles and eggs are all prone to outbreaks of the common aquatic fungi, *Saprolegnia spp.* and *Achlya spp.* (Rowland and Ingram, 1991). These pathogens are likely to affect all native fish stocked in NSW. Three viruses are known to infect fish in Australia include the barramundi virus, the virus causing the disease lymphocystis and EHNV (Rowland and Ingram, 1991). The iridovirus that causes the disease Epizootic Haematopoietic Necrosis (EHN) has been found to infect redfin perch, rainbow trout, Macquarie perch, silver perch and Murray cod.

The virus epizootic haematopoietic necrosis, thought to be introduced with redfin perch, has been found to infect such autochthonous species as silver perch (*Bidyanus bidyanus*), mountain galaxias (*Galaxias olidus*), Macquarie perch (*Macquaria australasica*), Murray cod (*Maccullochella peelii peelii*) and the introduced rainbow trout (*Oncorhynchus mykiss*) and gambusia (Gambusia holbrooki). Other pathogens that have been disseminated with alien species include (*Lernaea cyprinacea*), (*Chilodonella cyprini*), (*Chilodonella hexasticha*), (*Costia* spp.), (*Ichthyophthirius multifiliis*) and perhaps (*Trichodina* spp.) (Langdon, 1989).

Pathogens frequently pose a more serious threat to atypical hosts than typical hosts. The susceptibility of atypical hosts to non-endemic infectious diseases is partly a result of the lack of coadaptation of the host to the parasite. As the host did not evolve with the pathogen, a natural adaptive tolerance to the disease has not developed. Many of these introduced non-host-specific pathogens have caused large epizootics in a plethora of Australia's native freshwater fish fauna in the wild (Langdon, 1989). Additionally, many native fish hatcheries report epizootics of introduced pathogens as a major contributor to large-scale losses of both broodstock and fingerlings. For example, Rowland and Ingram (1991) found that silver perch (*Bidyanus bidyanus*), golden perch (*Macquaria ambigua*), Murray cod (*Maccullochella peelii peelii*) and trout cod (*Maccullochella macquariensis*) from the Inland Fisheries Research Station at Narrandera have all been infected with (*Ichthyophthiriasis multifiliis*), often leading to high mortality. Native freshwater cod (*Maccullochella spp*.) are reported to be very susceptible to *Chilodonella* spp., leading to mortality (Rowland and Ingram 1991).

To reduce the likelihood of cultivating and disseminating disease-causing organisms, hatcheries should undergo regular audits from a veterinarian. This should be part of a much larger audit of facilities that produce fish for stocking, and could be incorporated into a hatchery accreditation scheme.

B2.6.4.1 Impacts on populations of wild fish due to broodstock collection

The need to collect broodstock from the wild will depend on how well fish are managed within the hatchery. By manipulating breeding to better manage the contribution between generations it is possible to use and collect less broodstock (see section B2.5.1.3 on effective population size). Sound genetic protocols must be adhered to if this is to work effectively. The hatchery operator must understand what is required, and a laminated set of procedures to follow is a way to help increase compliance with these guidelines. However, many individuals will need to be sampled at least once to effectively sample representative genetic variation present in the wild population. However, this can be augmented with reciprocal transfers of broodstock between hatcheries that stock the same area to decrease the number collected from the wild.

When collection is warranted, which should be regularly to turn over broodstock, measures can be taken to reduce the impact on the wild population. Broodstock collection should be conducted using best practice principles and methods that are likely to cause the least amount of stress to the fish. The number of broodstock sourced from a particular area should take into consideration the health and numbers of adult fish present in the system. The removal of too many broodstock from already denuded areas may suppress recruitment enough to cause local populations to collapse.

The release of fish as part of a broodstock turnover program, which should be the cornerstone of good broodstock management, should be done in a manner to reduce stress. All fish should have sufficient time to recover from breeding before being returned to the wild.

The regular sharing and dissemination of information is essential to good management and could be organised as regular workshops between hatchery operators, stocking groups, recreational fishers, management organisations, conservation groups and scientists. The sharing of information could also be augmented with a regular newsletter to interested parties. A similar system has operated in QLD for some time and appears to be very beneficial (A. Moore, Spring Creek Environmental Consulting, pers. obs.).

B2.6.4.2 Health risks to populations of wild fish from fish stocking

The risk to the health of wild populations from the collection and release of broodstock is quite low and acceptable. The risk and probability associated with the release of diseases during the stocking process is quite high. The draft FMS needs to consider tighter controls on the release of disease-causing organisms. The draft FMS should include checks of fish for the presence of disease organisms by an authorised and trained person before being stocked. Tanks carrying water should be flushed away from waterways where possible to reduce the presence of these organisms. Regular audits by veterinarians should also be part of an accreditation program.

B2.6.5 Measures to mitigate the extent and effects of translocation

Hatcheries would need to screen inlet water to storage dams and between ponds and culture facilities. Different species or populations should be cultured in different ponds with any links between ponds well isolated and screened. Fish need to be checked prior to stocking by the hatchery, NSW Fisheries-approved inspectors and stocking groups at each step of the stocking process. These checks can look for the presence of unwanted species, deformities and the presence of ectoparasites and disease. Flushing of the tanker away from a waterway prior to stocking should reduce unwanted organisms entering the waters being stocked. As a minimum, there needs to be some form of hatchery accreditation system established, which should include:

- the screening of all water inlets and outlets within the hatchery and aquaculture facility
- regular audits all hatcheries for compliance with accreditation criteria
- isolating all species and strains within the hatchery
- conducting spot checks on all batches on fish before stocking to determine species composition (both fauna and flora)
- conducting spot checks on all batches on fish before stocking to determine parasite loads and the presence of disease, and
- flushing of the tanker away from a waterway prior to stocking to reduce unwanted organisms entering the waters being stocked.

B2.6.6 Contingency plan for translocated species

Whilst there are numerous strategies that can be implemented once a disease outbreak is detected, there are very few that are aimed at preventing the problem from occurring. The National Policy for the Translocation of Live Aquatic Organisms (1999) developed by the Commonwealth government recognised the need for a consistent assessment approach of proposals, but they are only guidelines to assist the State’s to develop their own translocation policies. The current translocation policy of NSW Fisheries was written in 1994, and thus does not include any of the assessment protocols recommended in the Commonwealth document. In preparing the draft FMS for fish stocking, NSW Fisheries should seek to incorporate the Commonwealth policy into any framework that is developed to review future stocking events.

Some of the key features that any framework or contingency plan for translocation of organisms should consider include how great a threat the new species is to the community, what is the probability that the species may already be present at the site, the probability of persistence of the species, are there any historical records of the species in question being translocated to the area previously and not surviving, what are the likely effects on the local ecological community, what is the most likely method of species dissemination, are there any methods that could be used to control or eradicate the species, what is the best method of containing the further spread of the species, what are the relevant agencies, both local, state and federal who need to be informed and participate in the response and who shall take the primary role in coordinating the response?

It should be noted that very few containment and eradication schemes have ever worked in aquatic systems as organisms can be cryptic, it is difficult to eradicate or contain every individual, often by the time a species is able to be seen it is in large numbers, aquatic organisms are often very fecund and offspring and fertilised eggs can travel larger distances undetected often through containment barriers. For these reasons it is important that the assessment of each stocking proposal include an extensive assessment of the potential for, and effects of, translocation. The framework needs to be complemented by an intensive hatchery accreditation process and compliance program. All of these measures would help to minimise the risks and effects of translocation.

B2.7 Summary of the environmental risk assessment

Despite the more detailed risk assessment on numerous components of the environment, the lack of reliable information about the impacts of stocking has done little to reduce the high level of uncertainty surrounding the activity. There are still many aspects that remain unclear, and in the absence of scientifically rigorous data, the assessment has been necessarily cautious, perhaps overly so in some areas. It is considered more prudent to adopt this stance and require the draft FMS to implement stringent management measures, rather than to assume that in the absence of data clearly indicating impacts due to stocking that there are no such impacts. It is also for this reason that in order to address the uncertainty, the risk assessment has made numerous references to the need for the draft FMS to propose and implement research. Until that research is done, the draft FMS will clearly need to impose a much stronger management regime on the activity of fish stocking than currently exists.

Consistent with the broad-scale risk identification stage, the fine-scale risk assessment suggests that all aspects of the current activity of fish stocking pose some threat to ecological sustainability. This is not overly surprising, however, as stocking has been conducted for over a hundred years and its original intent was solely to provide recreational angling opportunities through the introduction of salmonids into montane waters. The focus was on producing as many fish as possible and identifying those waters that were suitable for stocking. It is only in recent years that there has been a shift towards the broader impacts on the environment of stocking salmonids and the genetic implications of stocking native fish. With the advent of native fish stocking, hatcheries that were originally established for aquaculture purposes suddenly had an added source of income in that they were able to sell live fish for stocking purposes. Unfortunately, very few hatcheries changed their methods for producing fish for stocking as opposed to aquaculture, nor was there any regulatory requirement to do so.

Further, more recent concerns about the environment, in particular about the change in diversity and abundance of native species of fish and other aquatic fauna, has lead to the development of legislation and subsequent identification of threatened species. These have not historically been of concern during stocking programs, although they have been in more recent years, and it is clear from the risk assessment that many such species are still threatened by the activity of stocking despite some recent management initiatives.

More importantly, it is apparent that the species to be stocked is not the sole source of risk nor are threatened species the only component of the environment at risk due to stocking. All elements of the activity of stocking have been assessed as requiring some degree of management action to mitigate potential impacts. Even the most basic aspects of administration and data management need to be addressed in the development of the draft FMS. More complex and important elements, such as hatcheries and the associated genetic protocols, require direct and strong management responses in the draft FMS. The risk assessment for genetic integrity of wild populations recommends that this include some form of accreditation system for all hatcheries involved in the activity, so that there is a clear delineation between aquaculture hatcheries and those that can produce fish for stocking purposes.

The risk assessments for all components found that there was very little reliable information upon which to base the assessments. Overall, it is clear that the draft FMS needs to extend research beyond investigating the success of stocking (measured in terms of angler catch rates or spawning fish) from a limited number of impoundments. To conduct stocking in an ecologically sustainable manner, the draft FMS needs to develop and implement a research program, including a review of current research, so that the actual, not perceived, environmental impacts of stocking can be determined.

B3 Economic Issues

B3.1 Introduction

The management of freshwater fish stocking in New South Wales has not previously integrated economic and social information into the planning process in a formal manner. In undertaking the assessment of the economic impacts of fish stocking, it was readily apparent that there is a lack of information on basic economic characteristics of business operations and the secondary businesses dependant on fish stocking. For example, there have been no economic surveys of the viability of the fish hatchery sector supplying fish for stocking in public waterways.

There is some social information on recreational fishers, but little on the social composition of communities involved in fish stocking in NSW. The current study is the first attempt to gather and analyse economic and social information in order to appraise the fisheries management strategies proposed for freshwater fish stocking in NSW. In this section the economic issues arising as a result of fish stocking activities are addressed following a brief overview of freshwater fish stocking in NSW.

B3.1.1 Fish stocking activities

The activity of fish stocking occurs at three levels: the hatchery level (acquisition and maintenance of broodstock, and the production of fish); the stocking level (physical introduction of fish into inland waterways); and the end user level (this includes beneficiaries of the stocking activity). In undertaking an economic assessment of the existing situation, activity at all three levels must be taken into consideration.

At the hatchery level, both private and government-owned hatcheries are involved in the production of fingerlings for release into public waterways and private impoundments. Government-owned hatcheries are involved in the production of salmon and trout, while both government and privately owned hatcheries are involved in the production of golden perch, silver perch, Australian bass and Murray cod for release into inland waterways (rivers, streams, lakes, dams and impoundments).

There are approximately 150 aquaculture hatcheries in New South Wales. Of these hatcheries, around 20 (15 private and 5 government) are involved in stocking activities. Three of the government hatcheries produce approximately 7 million fish each year for stocking or 87.5 percent of the total number of fish produced for stocking. The other two government hatcheries undertake more of a research role, rather than being involved in the commercial production of stock and the physical process of stocking. Private hatcheries produce approximately 1 million fish each year or 12.5 percent of the total produced for stocking.

Fish stocking into public waterways in NSW is undertaken by the State government (NSW Fisheries), angling clubs, acclimatisation societies and some local councils in order to:

- increase the supply of fish available for recreational anglers, and
- re-establish or replenish threatened species.

Although no definitive study has been undertaken to determine the number of native fish in inland waterways that are a result of stocking, all salmonids in inland waterways are a result of stocking activities.

Fish stocking into private impoundments (mainly farm dams) is often undertaken for the purpose of providing stock to attract recreational fishers to the site to participate in "fish-outs", whereby a fee is paid by the fishermen to catch fish. This activity provides private hatcheries and landowners with a source of alternative income, and is likely to be an important way of attracting tourists to rural areas, although no surveys have been undertaken to investigate this market. Stocking fish in private impoundments is not the subject of this draft FMS and EIS.

Angling clubs and acclimatisation societies in NSW play an important role in the stocking of fish into public inland waterways. Members of these clubs and societies volunteer their services to help NSW Fisheries staff release stock into inland waterways. Acclimatisation societies primarily stock salmonids that are provided by the government hatcheries, and angling clubs concentrate their efforts on stocking native species.

An important component of the State government's initiative to enhance supplies of native fish in inland waterways is through the Dollar-for-Dollar native fish stocking program. Under this program, NSW Fisheries provides matching funds for purchases of fish from private hatcheries by stocking groups (namely angling clubs and societies). This funding ($200,000 per annum in total) comes from revenue collected from recreational fishing licences.

Since its inception in 1999, the native fish stocking program has released around 1.2 million golden perch, 580,000 Murray cod and 290,000 Australian bass into waterways across the State (NSW Fisheries, 2002). In addition, 960,000 silver perch fingerlings were released into inland waterways in 2000/01. Native fish are also stocked into impoundments by NSW Fisheries.

The Dollar-for-Dollar stocking program is only offered for stocking of inland native fish purchased from private hatcheries. No similar program exists for stocking of trout by private hatcheries. At present, 100% of public hatchery activities are funded through the government and the fish are given to stockists for distribution.

Increased recreational fishing opportunities, created as a result of stocking programs, brings about additional numbers of recreational fishers in a region (Watson, 2002). Expenditure by recreational fishers in the region in which the waterways are located also increases (Dominion, 2001). This brings important economic benefits to the regions in which the waterways are located (expenditure on hotels, food, tourism activities etc.).

B3.1.2 Information sources

This review of existing economic information is based on data provided by NSW Fisheries on stocking activities, production and employment in public and private hatcheries. The information is incomplete, and limits the depth of an economic and social analysis. In addition, whilst information was available on investment in public hatcheries, no information was collected on investment levels in private hatcheries.

Further investigation of available data revealed that there was a deficit of information on the more detailed aspects of employment and stocking in public and private hatcheries. In addition, information was not available on the social aspects of stocking activities, including the role of clubs and societies in the physical role of stocking, and the importance of tourist services such as fishing guides. Similarly public opinion of stocking has not been previously canvassed.

In order to gather more detailed information on the economic and social aspects of fish stocking activities in NSW, three short surveys were undertaken targeting key groups involved in, and benefiting from, fish stocking activities. They were:

1. private hatcheries
2. clubs and acclimatisation societies
3. fishing guides

Details of these surveys are given in Appendices B1.1 to B1.3 (Volume 3), respectively. Their results will be presented and discussed throughout sections B3 and B4.

A fourth survey was also conducted to ascertain the attitudes of the community towards stocking (Appendix B2.4). The community survey involved a random sample of 600 persons in city and country NSW asking their views about stocking practices and impacts. The survey was conducted by Roy Morgan Research Pty Ltd. It will be referred to in the text as the community survey.

Data on the contribution of recreational fishing to regional tourism was available through NSW Tourism. This information was supplemented by the results of a survey of the Snowy Mountains recreational trout fishery (Dominion, 2001).

In summary, this is the first economic and social analysis of fish stocking in NSW. It is undertaken against a history of little formal economic and social information. A major contribution of the analysis may be the introduction of an economic framework for evaluation of the economic aspects of fish stocking.

B3.2 Investment levels related to stocking

B3.2.1 Investment levels

Due to a paucity of data on investment levels in private hatcheries, questions about capital investment in buildings, ponds and equipment were asked as part of the survey of NSW hatcheries (Appendix B2.1). Only some of the hatcheries surveyed were willing to provide this information, and of those who did provide it, only a few were able to give a detailed breakdown of investment. In addition, many made an estimate of total investment, which in some cases also included land values. For this reason, the estimates of investment in private hatcheries (Tables B47 and B48) should be viewed with caution.

Of the 15 private firms surveyed (which represents all hatcheries involved in stocking), only 10 were willing to provide estimates of total market value. Furthermore, only 8 of these were willing to provide a separate breakdown of investment in buildings and land. As a result, the averages presented in Table B47 are only for those firms who provided information. An estimate has also been made of the percent of investment that is due to stocking based on an average over all surveyed hatcheries of 55% of fingerlings for stocking.

Table B47. Average capital investment in private hatcheries by region

Region	Number of hatcheries	Survey replies	Average land value	Average value of buildings	Average value of hatchery*	Average market value	Average market value less land	Investment due to stocking
East Coast	6	4	156,575	150,000	100,000	550,000	393,425	216,384
Darling East	4	2	62,500	35,000	70,000	225,000	162,500	89,375
Murray	5	2	122,500	51,250	160,000	1,997,500	1,936,250	1,064,938

* denotes that figures include the value of ponds and equipment.

Source: Dominion hatchery survey - Appendix B2.1

The averages presented in Table B48 have been extrapolated to provide an estimate of investment for the 15 hatcheries.

Table B48. Total capital investment in private stocking hatcheries by region

Region	Land	Buildings	Hatchery*	Total market value	Total market value less land	Investment due to stocking
East Coast	939,450	900,000	600,000	3,300,000	2,360,550	1,298,303
Darling East	250,000	140,000	280,000	900,000	650,000	357,500
Murray	612,500	256,250	800,000	9,987,500	9,681,250	5,324,688
Total	1,801,950	1,296,250	1,680,000	14,187,500	12,691,800	6,980,490

* denotes that figures include the value of ponds and equipment.

Source: Dominion hatchery survey

Information was available from NSW Fisheries on investment levels in public hatcheries. This information is reported in Table B49.

Table B49. Total capital investment in public hatcheries by region

Region	Number of hatcheries	Buildings	Hatchery*	Total market value less land
East Coast **	2	1,353,000	1,745,000	3,098,000
Montane	1	1,489,799	651,440	2,141,239
Murray	1	3,156,350	1,727,400	4,883,750
Darling East	1	1,797,150	899,700	2,696,850
Total	5	7,796,299	5,023,540	12,819,839

* denotes that figures include the value of ponds and equipment.

** Estimates for these sites only include apportioned hatchery use.

Source: NSWF

It is difficult to compare the results from public and private investment mainly because the public investment figures are replacement costs (i.e. don't account for depreciation), whereas the private investment figures are current market values (i.e. account for depreciation). However, for the purpose of analysing the results more fully depreciation can be added to the value for private investment.

B3.2.2 Overview of investment in fish stocking

The current capital market value of private hatcheries involved in stocking (not including land) is approximately $13M, of this around $7M is attributable to stocking. The historic cost of government hatchery assets (not including land) is approximately $13M. On a comparable historic cost basis, the statewide investment in public and private hatcheries involved in stocking is estimated at $33M (not including land)[1].

Land values for private hatcheries are estimated at $1.8M. Public hatchery investment in land is unknown. It is likely that the total investment value of public and private hatcheries in NSW (including land) is approximately $40M, with more than half invested in the Murray region

B3.3 Employment generated by fish stocking

As previously mentioned, fish stocking involves several different levels of activity, primarily the acquisition and maintenance of broodstock and production of fish, the physical introduction of fish into inland waterways, and the end use of the resource (including beneficiaries of the stocking activity). In addition there are research, management and monitoring activities taking place that support efficient use of the stocking resource.

At the end use level, recreational fishing contributes to the tourist industry in the region in which the fishing activity is taking place, and generates expenditure from recreational fishers in the local economy (i.e. purchases of fuel, bait, tackle etc.). It also creates employment opportunities in other industries, such as fish guiding (whereby companies/individuals coordinate fishing trips).

Important in quantifying the level of employment in the different industries involved in, and/or benefiting from, the activity of fish stocking is distinguishing between direct and indirect employment. Direct employment includes those persons employed in activities that directly contribute to the earning of revenue from fish stocking. In this case, it is private and public hatchery staff, and employees of NSW Fisheries who are involved both in the physical process of stocking as well as research, management and monitoring activities, who are directly employed as a result of fish stocking. Other industries, such as the fishing and tourism businesses, are all indirectly employed as a result of fish stocking. Fishing clubs and acclimatisation societies are neither directly nor indirectly employed, as there is no paid employment in these clubs/societies.

B3.3.1 Direct employment

B3.3.1.1 Private hatcheries

Employment in private hatcheries is reported in Table B50. This information was obtained from NSW Fisheries and was supplemented by information collected in the survey of private hatcheries (Appendix B2.1). Most privately owned hatcheries are owner-operated.

Table B50. Direct employment in private hatcheries (as at 31st December 2002)

Region	Total		Average per farm	
	Full time	Part time/Casual	Full time	Part time/Casual
East Coast	7	4	1.2	0.7
Murray	8	3	1.6	0.6
Darling East	1	9	0.3	2.3

[1] Public $13M + private $20M ($13M at current market value with an estimated $7M in depreciation)

B3.3.1.2 Public hatcheries

As mentioned previously, only three of the five government-owned hatcheries are involved in the production of stock for introduction into public waters, with the remaining two mainly performing research, management and monitoring roles. A large part of the management role associated with stocking activities is administrative in nature, namely the issuing of stocking permits and approval for applications for the Dollar-for-Dollar native fish stocking program.

In addition, there are several employees stationed at inland fisheries offices who are employed to undertake stocking roles, be it in the physical process of stocking, i.e. the delivery of stock to clubs and societies for release into inland waterways, or in the management and monitoring of stocking activities.

Those employees directly involved in hatchery production are also undertaking management and guiding roles. Some of them are also hatchery technicians who are involved in the general maintenance of hatchery equipment. The breakdown of government employment in public hatcheries by region and activity is presented in Table B51. Employment in research, monitoring and management activities is given in Tables B52 and B53.

Table B51. Direct employment in public hatcheries involved in the production of stock and the physical process of stocking (as at 31st August 2002).

Hatchery	Management	Assistant/ Foreman		Technician	Guiding
		Full time	Part time or casual		
Gaden	2	1			1
Dutton	2	1	1		1
Narranderra	1	3		1	1

Source: NSWF

Table B52. Direct employment in public hatcheries undertaking research, management and monitoring activities (as at 31st August 2002).

Hatchery	Total	
	Full time	Part time/Casual
Port Stephens	2	
Grafton	1	1

Source: NSWF

Table B53. Direct employment in inland fisheries offices undertaking stocking roles and research, management and monitoring activities (as at 31st August 2002).

Office	Full time
Tamworth	1
Albury	2

Source: NSWF

B3.3.1.3 Discussion

Employment in public hatcheries that are involved in the production of stock is all year round, even though the hatcheries are only in full operation for part of the year. In the low season employees in public hatcheries perform maintenance on the hatchery as well as taking annual leave. They also provide an education service to visiting tourist groups. In the private hatcheries, employment is generally seasonal, with only full time employees present all year round. These employees undertake maintenance on the hatchery in the low season. The length of a hatchery season depends on the size of the business, the type of species produced and the climate of the region in which the hatchery is located. For instance, in the smaller private hatcheries that are involved in stocking native Australian bass, the high season is in winter and spring.

B3.3.2 Indirect employment

Indirect employment in fish stocking activities includes those persons who provide services to cater for the needs of recreational fishers, for example, fishing guides, hotels, restaurants etc. Aside from those persons employed as fishing guides, employment numbers for those persons indirectly employed as a result of fish stocking activities are reported later in the study[2].

B3.3.2.1 Fishing guides

Many recreational fishers choose their own location to fish or use their own boats. An area which has grown as a result of fish stocking activities, and the subsequent increase in recreational fishing activity this has generated, is that of fishing guides, whereby fishers pay to be taken out on fishing trips. These trips can be day long, or over several days. According to available records, as of 31st December 2002 there were at least 22 people employed as freshwater fishing guides in NSW.

Almost all fishing guides are associated with the trout fishery. Indeed, the results of the survey of fishing guides for this study indicated that 100% of fishing was for trout. Most of these guides are operating in the Montane region, as this is where the two major trout fishing catchments are located (the Snowy Mountains region in the south and the New England region in the north). In addition, fishing guides most commonly operate in stocked waters. For example, in the Montane region, 90% of fishing trips were undertaken in stocked waters. The regions in which fishing guides undertook trips in 2002 is given in Table B54.

Table B54. Employment as fishing guides by region

Region	Employment
East Coast	2 *
Montane	7 *
Murray	1

*Includes one operator who guided across both regions

B3.3.3 Summary

There are a total of 32 people employed in private hatcheries that undertake stocking. Of these, around half are full time. In public hatcheries, there are around 14 people employed full time in activities associated with stocking, and 1 person part time. Indirect employment in stocking related activities includes 22 fishing guides who mainly operate trout related fishing trips in the Montane (Snowy and New England) region, as well as an undescribed number of others in the tourism industry. Information on freshwater and estuarine recreational fishing boats and recreational fishing suppliers

[2] Later in the study the flow-on indirect employment estimates from recreational fishing expenditure are presented. Part of the Snowy Mountain trout study included a survey of businesses supplying fishers. Many business owners were unable to say what proportion of their customers were anglers. The use of expenditure multipliers is proposed as being the most accurate data available.

(e.g. bait, tackle, gear etc.) does not currently exist. A specific recreational fishing survey is recommended.

B3.4 Proportional employment related to stocking

The production of fish, and fish stocking activities, may not take up 100% of the time for those persons with employment in private hatcheries. Most private hatcheries are owner-operated, with many owners often having full-time employment in other industries. For example, one of the survey respondents was employed in education and another was a tradesman. Income from stocking makes up only a very small proportion of total income for these individuals. By region, it is the Murray where there is the highest proportion of income generated from stocking related activities (Table B55).

Table B55. Proportion of income from stocking-related activities for private hatchery staff

Region	No. of people with jobs in other activities	Percentage of income from stocking-related activity
Darling East	2	3
East Coast	4	27
Murray	2	86

Those persons employed in public hatcheries by NSW Fisheries are spending 100% of their time on stocking related activities. For employees of NSW Fisheries engaged in research, management and monitoring activities directly related to fish stocking, employment in these activities does not account for 100% of their income. For instance, one employee involved in the issue of fish stocking permits only spends 10% of their time on this activity, with the rest of their time being spent on general research tasks in aquaculture. In Table B56 the proportion of income received by employees of NSW Fisheries engaged in research, management and monitoring activities, that is attributable to stocking activities, is given by hatchery.

Table B56. Proportion of income from stocking-related activities for employees of NSW Fisheries engaged in research, management and monitoring activities

Region	Hatchery/Fisheries Office	No. of people with jobs in other activities	Percentage of income from stocking
Darling East	Tamworth	1	70
East Coast	Port Stephens, Grafton	3	27
Murray	Albury	2	86

Source: NSWF

Those persons engaged as fishing guides do not spend 100% of their time engaged in this activity, nor do they receive 100% of their income from this activity. For example, on average, guides in the Montane region, the region where the greatest number of guides conducted fishing trips (7 of the 9 surveyed), spent 88 days a year running fishing trips. For NSW as a whole, this average was even lower, at around 70 days a year. The proportion of income represented by fish guiding activities varies widely between guides. For example, one guide operating in the Montane region obtained around 95% of his income from guiding, while another obtained only 15%. On average, for the Montane region, fishing guides obtained around 50% of their total income from guiding. There is no information about other sources of income of boat operators and fishing gear suppliers and the seasonality of their employment.

B3.5 Economic contribution to tourism related to stocking

Increased recreational fishing opportunities, created as a result of stocking programs, bring important economic benefits to regions in which waterways are located. These benefits are mainly in the form of increased expenditure. For example, recreational fishers and fishing tourists spend money in pursuit of their leisure needs on items such as fishing gear and accommodation. This expenditure is not only in the regions where fishing is being undertaken, but can be more widespread, for instance, expenditure on fuel in getting to a fishing location.

The economic benefits arising from stocking can be seen in several measures. The simplest measure is to use surveys to estimate expenditure by recreational fishers. Other methods include using input-output regional economic models to estimate the added value from recreational fishing activity in regional economies, and measuring value placed on access to the recreational fishing resource by fishers (fishers' willingness to pay and travel-cost methods). Access valuation methods give a truer measure of the value of the recreational resource as they measure "the value of access" above the amount expended by fishers (Edwards, 1992). The different methods that can be used to estimate economic benefits from stocking are summarised in box 1. In box 2 an overview of the economics behind estimating "the value of access" is presented.

Box 1: Expenditure, added value and access valuation

Several methods have been applied to valuing the economic benefits of stocking. To date all of these studies have been in the Snowy Mountains trout fishery. In addition, the Bureau of Tourism Resources have made estimates of regional expenditure by fishers who travelled to locations with "going fishing" nominated as an activity. These estimates are from the National Visitors Survey. In summary the main approaches to measuring the economic benefits from stocking have been:

a) through surveys of recreational fishers in the Snowy region - used to determine the level of angler expenditure (Dominion, 2001).

b) applying expenditure survey data to regional input-output tables to determine the contribution of fishing activities to the Snowy economy – added value and appropriate multipliers were estimated (CARE, 2002).

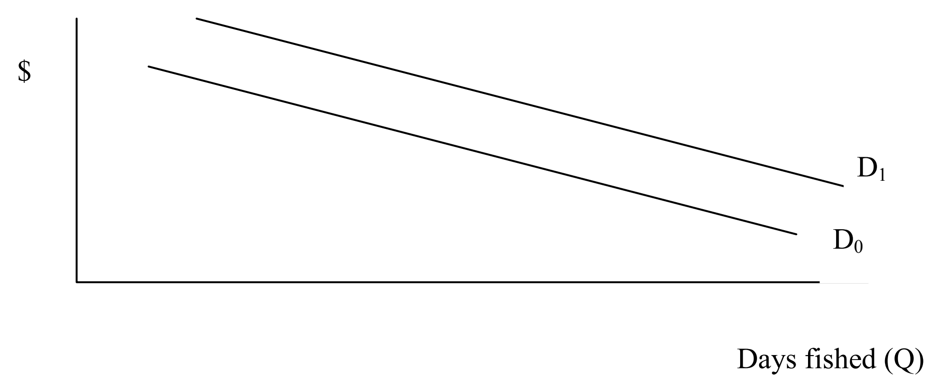
c) using the travel cost method to analyse angler expenditure survey data and determine the value of access placed on recreational fishing opportunities in the Snowy region (Watson, 2002). This is the most intangible of the valuation methods, deriving an estimate of economic value over and above money spent, from the travel decisions of anglers.

The above studies hold the only available empirical data on the economic benefits from stocking in NSW. They shall be referred to throughout this economic assessment and it is important that the reader is conversant with the difference between these different methodologies.. The assessment uses angler expenditure, but the added value data is useful in considering regional economic considerations. The travel cost method gives a "value of access" for fishers after all costs of the trip and access costs have been paid. This is regarded by economists as a truer value, but the robustness of statistical estimates may be poor.

Box 2: The value of access as a measure of the value of a recreational resource

Recreational fishing activity derived from stocking of waterways leads to expenditure and adding of value in local, regional and state economies. The value of access recreational fishers place on fishing activities is additional to this expenditure, and leads to further welfare gains in society.

A demand schedule for recreational fisher access to a fishing area is presented in the following diagram and explained below.



The graph indicates that for a fishing area, a relationship exists between the value of access to a fisher (vertical axis) and the number of days fished by all fishers (horizontal axis). In this model the area under the curve is a measure of the consumer surplus, or value of fishing access over and above fisher expenditure.

If the area is stocked, it is presumed that either the schedule (D0) moves vertically upwards (D1), or that stocking maintains the schedule around its initial position through time. If the curve moves upwards, the value of access (area under the curve D1) increases. This may happen due to stocking, good perceptions of fishing, or as a result of confidence in management of the fishery. The upward movement of demand in one fishing site may lead to a downward shift in demand at alternative fishing sites. This makes an evaluation of the contribution of stocking to economic growth across the state difficult to estimate.

B3.5.1 Expenditure estimates using survey data

The economic benefits arising from increased numbers of recreational fishers are in the form of increased expenditure on local goods and services, including on fishing related goods and services such as bait, tackle, fuel and fishing guides, and other goods and services such as hotels and food.

Expenditure on these goods and services in NSW, which can be directly attributed to recreational fishing activity, is estimated from two sources:

1. statewide estimates for angler expenditure and
2. recreational licence sales and expenditure of recreational fishers in the Snowy Mountains region.

In Table B57, the 1998 statewide estimates for angler expenditure (McIlgorm and Pepperell, 1999) are used to estimate the proportion attributable to freshwater fishing activity in NSW, including expenditure by interstate licence holders, and adjusted to the relative value in 2002. That earlier study suggests that freshwater fishing expenditure was approximately $210M in 2002. More recent estimates of freshwater fishing expenditure (Henry and Lyle, 2003), which have been determined over a longer timeframe and using different methods, suggest higher effort levels but lower expenditure than the previous survey, estimating freshwater fishing expenditure to be approximately $133M (Table B57). It is important to note, however, that neither study is able to provide an estimate of expenditure that is attributable to stocking, nor should the two values be compared as they were based on different methodologies.

Table B57. Estimates of expenditure by freshwater recreational fishers in NSW in 2002

Expenditure in NSW	Estimated angling expenditure in 1998* ($M)	Expenditure estimate adjusted to 2002 ($M)	Percentage attributable to freshwater fishing	Estimated freshwater angling expenditure in NSW in 2002 ($M)
Estimate (Conservative)*	809	882	20%	177
Estimate (Upper)*	1130	1232	20%	247
Snowy estimates**				206
Henry and Lyle (2003)	n/a	555	24%	133

Source: * denotes adapted from McIlgorm and Pepperell, 1999. ** denotes adapted from Dominion 2001.

Statewide expenditure estimates can also be derived from estimates of NSW recreational licence sales and expenditure of recreational fishers in the Snowy Mountains region. By applying the total number of recreational freshwater fishing licences purchased in NSW in 2000 to the average annual expenditure per fisher in the Snowy Mountains region ($2,132 per annum), an estimate of total annual expenditure estimate of $205.8M by freshwater recreational fishers was made (Dominion, 2001)[3].

Owing to the broader nature of those studies, the amount of expenditure attributable to stocking is unknown. However, an estimate can be derived by determining the amount of effort focussed on salmonids (100% due to stocking) and comparing this against the value of freshwater fishing expenditure. The Snowy study included a statewide survey of angler species preferences by days fished (Dominion, 2001). Salmonid fishing effort was 29% of days fished, inland natives 53.5%, coastal natives 10.9% and others 6.5%. On this basis, expenditure related to salmonids (and thus stocking) would be 29% of $206M, approximately $60M. Expenditure related to the stocking on inland and coastal native fish is unknown.

Using fishing effort and expenditure from the later study estimates expenditure to be approximately $55M (Henry and Lyle, 2003). This is based on 10% of effort and expenditure ($555M) being focussed in freshwater lakes and dams, where the majority of stocking has historically been done. This estimate would include both natives and introduced salmonids.

[3] In the Snowy survey 1340 anglers (1% sample of freshwater recreational fishing licence holders) were telephoned by Quadrant Research and asked to describe their angling preferences. A sub sample of these anglers were then asked in detail about their expenditure on trout fishing in the Snowy Mountains (Dominion, 2001). NSWF licence records indicated 7,717, 3-year licences, 78,829 annual and 50,828 1 month freshwater fishing licences issued in 1999-2000. This equates to 85,000 annual licence equivalents with an additional correction for non licence holders (youths and pensioners etc) (see Dominion, 2001). The current estimates assume all angler expenditure in NSW is similar to the Snowy study and this may be an overestimate. No alternative data are available.

B3.5.2 Tourism

Specific tourist data from the national visitors survey (NVS, 1999) can be used to estimate tourist expenditure related to fishing. More detailed information on those tourists who nominated "going fishing" as a preferred activity was also available[4].

Tourists who travel outside their immediate area for day or overnight trips contribute significantly to fishing activity in the regional areas to which they travel. The data collected by the NSW tourism visitor survey, reports the proportion of visitors (both day and overnight) to a region whom nominated recreational fishing as an activity.

In Tables B58 and B59 the number of overnight and day visitors to each region of NSW that recorded going fishing as an activity is reported. This number is reported as a percentage of total visitors to each region.

Table B58. Overnight visitors to NSW tourist regions whom nominated "going fishing" as an activity

Region	Tourist region visited	No. of overnight visits with fishing noted as an activity ('000)	Percentage of visits to each region with fishing noted as an activity	Estimate of expenditure ($M) (overnight visits at $100 per night[5])
East Coast	South Coast	666	26	66.6
East Coast	Illawarra	42	3	4.2
East Coast	Sydney	106	1	10.6
East Coast	Hunter	227	9	22.7
East Coast	Australia's Holiday Coast	466	14	46.6
East Coast	Northern Rivers	286	15	28.6
East Coast	Central Coast	176	12	17.6
Montane	**Snowy Mountains**	**90**	**14**	**9.0**
Montane	**Capital Country**	**25**	**4**	**2.5**
Montane	**Blue Mountains**	**14**	**2**	**1.4**
Murray	**Murray**	**80**	**6**	**8.0**
Murray	**Riverina**	**50**	**4**	**5.0**
Murray-Darling East	**Explorer Country**	**44**	**2**	**4.4**
Darling East	**Big Sky Country**	**43**	**3**	**4.3**
Darling West	**Living Outback**	**35**	**6**	**3.5**
Total		**2,350**		**235**

Notes: Regions and expenditure estimates have been added by the current study and those areas of interest to inland stocking have been bolded (Source: NVS, 1999).

Expenditure figures reported in Tables B58 and B59 may overestimate tourist expenditure as a result of fishing activities, as tourists may not be only spending money on fishing when they visit a region and may be undertaking a range of other tourist activities in the area.

In the NVS data, fishing may be one activity undertaken in a tourist visit. It may only be the primary determinant for a limit number of tourists in choosing a destination to visit. Many of the 14%

[4] The data for tourists indicating a preference for fishing are from a significantly different perspective than specific angler studies. The relationship between the NVS biannual surveys and specific studies of anglers requires further research. Thanks to NSW Tourism for data provision.

[5] The per night expenditure is an updated estimate based on the $87.70 per night in 1996-97 (LGA, 1998).

of visitors identifying fishing as an activity may still visit the Snowy Mountains in the absence of any fish stocking. Expenditure may be transferable among different leisure activities in the same region.

Overnight tourist expenditure for most freshwater fishing areas (excludes the freshwater reaches of the east coast) was $38.1M in 1998 (Table B58). Daily tourist expenditure for those freshwater fishing areas has been estimated at $9.4M (Table B59). Most of the expenditure in the East Coast is marine recreational fishing, and hence is not relevant to this study of freshwater recreational angling.

In summary, the available tourist data for non-coastal freshwater recreational fishing indicates that tourists on overnight and day trips with going fishing nominated as an activity spend as much as $47.5M per annum.

Table B59. Day visitors to NSW tourist regions whom nominated “going fishing” as an activity

Region	Tourist region visited	No. of daytrips with fishing noted as an activity (' 000)	Percentage of daytrips to each region with fishing noted as an activity	Estimate of expenditure ($M) (No. of day visits at $33.30 per day[6])
East coast	South Coast	155	7	5.16
East coast	Illawarra	105	2	3.5
East coast	Sydney	143	1	4.8
East Coast	Hunter	98	2	3.2
East Coast	Australia's Holiday Coast	228	7	7.6
East Coast	Northern Rivers	210	7	7.0
East Coast	Central Coast	129	3	4.3
Montane	**Snowy Mountains**	**4**	**2**	**0.13**
Montane	**Capital Country**	**43**	**3**	**1.43**
Montane	**Blue Mountains**	**47**	**2**	**1.56**
Murray	**Murray**	**92**	**9**	**3.06**
Murray	**Riverina**	**25**	**2**	**0.83**
Murray-Darling East	**Explorer Country**	**23**	**1**	**0.76**
Darling East	**Big Sky Country**	**36**	**2**	**1.12**
Darling West	**Living Outback**	**15**	**6**	**0.5**
Total		**1,353**		**45.1**

* Daytrips are those trips that do not involve an overnight stay. They involve travel for a round trip distance of at least 50km, and duration of at least 4 hours. Daytrips as part of overnight trips are excluded, as are routine trips such as commuting between work/school and home (Source: NVS, 1999).

B3.5.2.1 Regional expenditure and value added

In addition to direct expenditure by fishers in the regional economies in which they are basing their activities, is the expenditure by these fishers in other regions as a result of, for example, their travel to fishing locations (on top of this is the additional value fishers place on access to the fishing resource). CARE (2002) estimated this “added value” for the Snowy region.

Dominion (2001) estimated that direct regional expenditure by recreational fishers in the Snowy region was $46.5M. On top of this expenditure is expenditure in other regions by recreational fishers who are fishing in the Snowy region (fuel, car travel etc. across NSW). This was estimated at $22M, giving a total of $68.5M for statewide expenditure attributable to fishing in the Snowy region.

[6] The expenditure per day trip is an estimate based on expenditure estimates in McIlgorm and Pepperell, (1999).

Applying output-input models to the figure of $68.5M gives an additional added value of around $21M (i.e. a multiplier of 3.19 between total statewide recreational expenditure and added value) (CARE, 2002). Thus 30% of an unknown total of angler expenditure on stocked fish is added value in the economy.

B3.5.2.2 Access valuation and consumer surplus

Watson (2002) used the travel cost method to come up with an estimate of the value recreational fishers place on access to recreational fishing opportunities in the Snowy region. This value is a proxy for consumer surplus. Watson found that there was consumer surplus of between $5.9M and $10.7M associated with expenditure by recreational fishers of between $46.5M and $70.0M (these estimates vary according to the form of statistical model used). This gives a factor of 7.88 between recreational expenditure and consumer surplus.

Applying the factor to the estimates of statewide recreational fishing expenditure that have been used in this study, $206M (Dominion, 2001) and $133M (Henry and Lyle, 2003), gives an estimate of consumer surplus as a result of the value recreational fishers place on fishing opportunities of between $17M and $26M. This is in addition to the $6M paid by recreational licence holders for access to the recreational fishing resource.

B3.5.3 Fishing guides

As mentioned earlier, an important tourist industry that has grown as a result of fish stocking activities, and the subsequent increase in recreational fishing activity this has generated, is fishing guides, whereby fishers pay to be taken out on guided fishing trips.

Fishing guides are experienced fishers that charge clients for guidance and instruction in pursuit of fish. It is thus a mix of tourism and recreational fishing and includes the use of 4WD safaris and boat trips, and includes fishing in both lakes and dams/impoundments.

The survey of fishing guides for this study (Appendix B2.3) found that in 2001/02, there were a total of 22 fishing guides in NSW in the Professional Fishing Instructors and Guides Association (PFIGA). They spent 1,530 days guiding and generated an estimated $335,989 in revenue. Of the total number of people who used guides in 2001/02, 75 were tourists.

As an example of the characteristics of fishing guide businesses in NSW, the results from the survey of businesses undertaken as part of this report are summarised in Table B60. Given that the total number of guides in NSW is small, the information is presented at the aggregate level (i.e. whole of NSW) to protect the confidentiality of the surveyed operators.

Table B60. Characteristics of fishing guide businesses in NSW

Characteristic	Number
Average days guiding in 01/02	70 days
Average no. of customers	128 customers
Percentage that were tourists	75%
Guiding as a percentage of total income	39%
Average percentage of guiding in stocked waters	79%

Although on average only 79% of guiding activity was in stocked waters, 5 of the 8 respondents who answered this question guided 100% in stocked waters. Of the remaining 3 respondents, 1 person guided 85% in stocked waters, the other 50%, and the final respondent did not guide in stocked waters at all.

While expenditure on fishing guides is small, this activity is a significant indirect employer in rural areas, enhancing incomes and building culture and knowledge surrounding recreational fish capture.

It is expected that fishing guides will continue to bring important economic benefits to the regions in which recreational fishing in stocked waters is undertaken. These benefits are mainly through increased expenditure by fishers on guiding services.

B3.5.4 Multiplier effects of recreational fishing expenditure

An important consideration in estimating the economic contribution of recreational fishers to the region in which they are undertaking recreational fishing activities is the flow-on effects their expenditure generates in other areas of the economy. These flow-on, or multiplier effects, are in the form of output, income and employment and can be estimated using a simple input-output model.

Economic multipliers are a summary way of expressing all the responses (direct and indirect) to some economic change. In this case the effect of a change in expenditure by recreational fishers as a result of stocking activities. They can be measured at either the local/regional level, or at the state level. Multipliers are generally expressed as a ratio. There are two types of multipliers that are commonly used:

- Type I multipliers, which are estimates of the direct impacts and production-induced impacts of an activity, and
- Type II multipliers, which are estimates of the direct impacts, the production-induced impacts and the consumption-induced impacts of stocking.

Production-induced effects are the industry's (in this case fishing) purchases of goods and services from other industries (e.g. tackle shops). Consumption-induced effects arise from the spending of household income (fishers income) received as a payment for labour. In this study we report only the Type II multipliers, as we are interested in both production- and consumption-induced effects.

Multipliers can take a number of forms:

- output multipliers relate changes in industry outputs to changes in final demands. More specifically, they measure the sum of direct and indirect requirements from all sectors needed to deliver an additional unit of output of a particular industry to satisfy final demand
- employment multipliers measure the employment response to an increase in final demand, both directly in the industry concerned and indirectly in supplying industries, and
- income multipliers measure the amount of income that is generated by a change in final demand both in the industry directly and in other industries that service industry (IAC, 1989).

B3.5.4.1 Expenditure multipliers

As an illustration of the flow-on effects of recreational fishing in an economy, the expenditure of trout fishers in the Snowy Mountains estimated by CARE (2002) has been used. At the state level, it is estimated that direct expenditure by recreational fishers who are fishing in the Snowy region was $68.5M ($46.5M in the Snowy, plus fuel, car travel etc. across NSW). This is part of consumption expenditure and so represents the final consumption of a range of goods and services. These are modelled by estimating the level of expenditure on the products of the supplying industries. In the model the multipliers indicate how those purchases work back through the supply chain to generate the flow-on effects. For example, expenditure on fishing tackle would be a purchase from the retailer and from the manufacturer of the equipment. They in turn will purchase goods and services to run their retail outlet and to manufacture the tackle.

In allocating the total expenditure to the various supplying industries, allowances have to be made for goods that may be imported, for indirect taxes (e.g. the GST and excise taxes) and the various distributor margins. In this case the estimated expenditure of $68.5M includes $19.0M in indirect taxes and $3.1M of imported goods. The remaining $46.3M is purchases of goods and services.

Type II multipliers were calculated for the Snowy Mountains recreational trout fishery using an input-output model (CARE, 2002). Both regional and state multipliers were calculated. The state multiplier was about 1.92, indicating that $68.5M of expenditure by recreational fishers in NSW attributable to the Snowy Mountains trout fishery, generates $63.0M of flow on effects in the NSW economy (CARE, 2002).

Regional multipliers are generally lower than state multipliers, in the order of 1.5 (CARE, 2002). These multipliers are lower because regional economies are, in general, less diverse than State economies. In economic impact terms, it means that regional economies have less capacity to capture flow-on effects than the broader State economy. For example, a significant expenditure of fishers is in travel to the fishing site, usually by car. Their expenditure on fuel will mean that at the place of purchase, there will be a retail and distributor impact. As no NSW regions outside of Sydney have an oil refinery they cannot capture the flow-on of producing petrol. That flow-on is only captured at the State level.

There will be variation among types of recreational fishing. Some will attract serious anglers who have high quality tackle, travel a long way, stay in expensive accommodation, etc. They will have a much higher impact than say the casual estuary fisher who has much less expenditure. This factor of the type of fisher is likely to be the most important variable influencing the local economic impact of fishers. Further, the more they spend locally on services such as accommodation, meals, guides, etc. the higher the impact and the lower the loss through leakage to other sources of supply.

B3.5.4.2 Tourism multipliers

On the basis of the regional and state multipliers presented above we can make an estimate of the flow-on effects of tourist expenditure on a regional basis. Expenditure multipliers estimated for NSW are between 1.5 and 1.8 (depending on the region), 1.5 reflecting rural areas and 1.8 reflecting the Snowy Mountains region.

The estimated annual expenditure by non-coastal freshwater recreational fishing tourists on day and overnight trips of $47.5M (National Visitors Survey, BTR 2000) is expected to generate flow-on expenditure between $23.75M and $38M.

B3.5.4.3 Employment multipliers

Expenditure by recreational fishers on tourism and fishing related services generates employment in the local economies in which the expenditure is taking place. CARE (2002) estimates that for each $1M of expenditure in the Snowy region, there are 9.1 jobs created in the regional economy, and a further 7.5 jobs indirectly. This would imply that for the $47.5M of expenditure by non-coastal freshwater recreational fishing tourists on day and overnight trips there would be around 430 jobs created directly and 360 jobs indirectly.

Multipliers are higher when measured in value added and household income terms, and lower when measured in employment terms. The low employment Type II ratio (total employment to direct employment) reflects that there is a high direct employment because much of the expenditure is in low labour productivity of high level part-time employment (accommodation, restaurants and retail). The flow-on employment tends to be to industries where labour productivity is higher or where the incidence of part-time employment is lower.

B3.5.5 Discussion

The economic benefits associated with stocking practices and derived recreational fishing and tourism are seen to be:

- an unknown amount of statewide freshwater recreational fishing expenditure of between $133M and $206M is attributable to stocking and hence supports direct and indirect jobs
- tourism expenditure by recreational fishers of around $47.5M generating flow on expenditure of around $23.8M and $38M.
- added value in the NSW regional economies of up to 30% of recreational expenditure and a value of access of between $17M and $24M over and above recreational licence fees has been estimated statewide.

These measures are from best available data and estimates. Alternative non-monetary measures of angler satisfaction are not available and represent an area for future research that would benefit managers.

B3.6 Cost recovery mechanisms

B3.6.1 Fees, charges and revenue streams related to stocking

There are several fees and charges associated with recreational fish stocking programs leading to the generation of revenue. Hatchery and stocking permits are discussed below as well as revenue generated from collection of the recreational fishing licence fee.

B3.6.1.1 Hatchery permits

An application for a class H permit (to operate a hatchery) is established under Part 6 of the *Fisheries Management Act 1994*. The number of active permits is presented in Table B61, and the various types of permits and their associated fees are as follows:

- the prescribed fee for a class H permit is $535.00 as set out in clause 5 of the Fisheries Management (Aquaculture) Regulation 2002;

- if the applicant applies for other classes of permit at the same time, i.e. class C (extensive grow-out $321) or class D (intensive grow-out $535) or class F permit (fish out $321), then the highest fee applicable to any permit plus $100 is payable; and
- an annual contribution of $375 is in place for aquaculture permits by virtue of clause 7 of the Fisheries Management (Aquaculture) Regulation 2002.

There is no rental or lease-type fees applicable to these permits as the activity is carried out on freehold land as opposed to an oyster lease which attracts rental because it is on public water land.

Those hatcheries that currently produce fish for stocking (15 as of December 2002) are not considered as anything other than aquaculture facilities, i.e. under existing management arrangements there is no such thing as a fish stocking hatchery permit.

Table B61. Number of active fish hatchery permits in NSW

Number	Permit-Class	Permit-Status
6	Experimental	Current
406	Extensive (leases)	Current
3	Extensive (leases)	Suspended
41	Extensive Land Based	Current
33	Fish-out	Current
76	Hatchery	Current
2	Intensive (leases)	Current
203	Intensive Land Based	Current
3	Multiple Land Based	Current

B3.6.1.2 Stocking permits

On an annual basis, approximately 100 stocking permits are issued from Port Stephens Fisheries Centre (Miscellaneous Permit Administration Section) under section 216 of the Act. The majority of these permits are for the Dollar-for-Dollar program (i.e. more than 90%).

An estimated time to process each permit is 1 hour. The permits clerk rate (as deemed in a cost recovery exercise in 2000) is approximately $58.60 per hour or $7560 per annum (cost recovered).

The Recreational Fisheries Branch does the environmental assessment of the Dollar-for-Dollar permits through the Tamworth Office. This equates to one full time clerk (grade 7) at around 30% of his time (~$35,550 (cost recovery with above figures)).

There is no charge for issuing stocking permits.

B3.6.1.3 Recreational fishing licence fee

The Dollar-for-Dollar native fish stocking program is funded through the revenue generated by the collection of fees from the issue of recreational fishing licences. Of the revenue collected from recreational fishing licences, $200,000 was allocated to the Dollar-for-Dollar native fish stocking program for the purchase of fish. A further $300,000 was allocated to research activities associated with the stocking program.

B3.6.2 Administrative costs related to stocking

The administrative costs involved in the stocking program for 2001-02 were:

- issuing permits, $40, 863
- staff time utilised in managing and monitoring stocking activities, $133,334, and
- apportioned administrative elements of research activities.

B3.7 Summarise the risks to businesses involved in stocking

At present, many of the risks attributable to the impacts of stocking and stocking related activities and management are not borne by those benefiting from the stocking, for example, the potential introduction of pests and diseases into natural waterways, impacts on threatened species and changes to the genetic integrity of natural fish populations. These are all risks that can potentially compromise the integrity of the aquatic environment, which tends to be regarded as a public good. Many of the immediate benefits of stocking are received by fishers, fishing dependent businesses and hatcheries, such as through widespread fishing opportunities and lower operating standards and costs. However, these benefits may be eroded unless action is taken to reduce the risks attributable to stocking, by addressing threatened species, genetics, and pest and disease issues through management initiatives.

Commercial fish hatcheries are most directly impacted by changes in stocking policy. Other businesses, such as recreational fishing tourism, are less immediately impacted by changes in stocking policy.

B3.7.1 Hatcheries

There are a number of economic risks to private hatcheries. On the revenue side of the business, fish stocking policy has a major influence on private hatcheries reliant upon stocking for income. For instance, many hatcheries participate in stocking activities as a result of the Dollar-for-Dollar stocking program. If this program was to be significantly reduced or removed, it is likely these hatcheries may no longer be involved in stocking.

There are some major environmental risks for hatcheries. For example, a disease or pest incident may cause an interruption in demand for stocked fish, with cost implications in terms of foregone income and remedial actions. Similarly, new information indicating changes in the genetic integrity of local native fish populations or the presence of threatened species may lead to interruptions or cessation in the demand for stocked fish.

The current risk management strategies among hatcheries depend on general husbandry practices to protect the industry from such risks and require the government to deal with potential environmental problems at no cost to industry. Industry insufficiently recognises the environmental risks in their operating standards and are vulnerable to both impacts from such risks and to the increased costs of having adequate risk management procedures in place.

Other risks are related to potential constraints on production, such as the vulnerability of hatchery businesses involved in stocking to land and water production constraints. For example, insufficient water may limit the capacity of the business to meet potential stocking orders, although mechanisms exist for hatchery operators to purchase water and land within a competitive market.

Frequency of water problems may also affect hatcheries productive capacity and their ability to produce to order in future periods.

The financial position of some private hatcheries may be marginal or non-viable under the current circumstances. Reasons for continual operation of such hatcheries include:

- hatcheries participating in stocking activities as a result of the Dollar-for-Dollar stocking program (subsidised trade)
- being operated on a marginal basis from existing aquaculture enterprises, and
- the lack of viable alternative business opportunities.

There is a range of part time and full time hatchery businesses. There is little evidence that these businesses are currently economically profitable. Hence they are vulnerable to any increases in costs, for example through administrative charges for management or alterations to production techniques. Hatcheries may choose to pass these higher costs on to clubs and societies by charging them more for stock purchased under the Dollar-for-Dollar native fish stocking program.

This industry structure and the risks to be managed as mentioned above, limit the capacity for industry to adapt to changes in their business environment. It also makes the industry more vulnerable to changes in policy on stocking from which many of hatcheries derive a proportion of their income. As operating standards in the industry increase to protect against environmental risks, the viability of some hatcheries may be tested. However, the introduction of higher standards may lead to improvements in the efficiency of hatchery operations. As there are limited numbers of hatchery operators involved in stocking and they can readily be considered in any management changes. For example, phasing in new requirements should enable hatchery businesses to plan and adjust their operations. Some operators have the opportunity to focus on aquaculture. Alternative business opportunities, such as the aquarium trade and exports could be investigated, but will have risks and costs associated with them.

B3.7.2 Recreational fishing and tourism

Changes in stocking levels in a region may affect recreational anglers perceptions of the amount of fish able to be caught, and, in turn, affect the number of visits by tourists to the region. For example, a reduction in stocking levels may cause fishers to perceive that the quality of fishing is poor and may cause them not travel to a location, or to cease fishing altogether. Conversely, increasing stocking may also have the same result. This could be due to over-stocking a waterway leading to poor growth in the fish. This has implications for regional expenditure, especially if fishing is an important leisure activity, or tourist attraction.

Recreational fisher and tourist surveys indicate that businesses providing accommodation, and selling food, petrol and fishing tackle etc. in fishing regions, may be negatively impacted by changes in fishers' perceptions about the quality of fishing. However, the national visitors survey indicates that tourists visiting a region undertake a range of leisure activities, which may cushion businesses from the impacts of a decline in the quality of fishing. In the survey of anglers undertaken in the Snowy Mountains (Dominion, 2001), it was found that caravan park owners had equal revenue from snow and fishing tourism, though the snow season was only one quarter of the year.

Local fishing experts providing guiding services may also be impacted by changes in stocking policy and angler perceptions. Many fishing guides are part time businesses providing a service to recreational fishing enthusiasts and tourists. Fees from guiding enable guides to supplement other income while working in the great outdoors.

Reductions in stocking levels for a particular species may have similar effects. However, fishers may choose to target other species, in which case there will be a redistribution of fishing effort (as measured by the number of days fished), rather than an overall reduction in effort. For example, if more Australian bass is stocked in coastal waters, fishers who were previously targeting inland native fish may perceive that there are more fish available in coastal waters and may switch effort to targeting coastal native species. As a result the regional benefits of recreational fishing activity may become concentrated in coastal areas, at the expense of inland communities.

Other natural factors also affect the quantity of fish available to be caught, e.g. fluctuations in water levels and biological factors such as natural predation. Hence, it is difficult to quantify the effect of changes in stocking levels on the quantity of fish available to be caught. Even though fishers may perceive that there are less/more fish available to be caught, in reality this may not actually be the case. In addition, reductions in catch per unit effort may be hard to measure in relation to specific stocking events. The impacts of stocking on fish availability to anglers may also be cumulative indicating that the regularity of stocking may be important.

The social benefits of fish stocking are exposed to considerable uncertainty unless action is taken to reduce the risks attributable to stocking, by addressing threatened species, genetics, pest and disease issues in a pro-active and orderly way.

B4 Social Issues

Three approaches were taken to examine the social information on groups involved in stocking:

1. Australian Bureau of Statistics (ABS) data were used to examine the overall demographic profile of communities in NSW
2. existing information gathered by NSW Fisheries was used to estimate the total number of people engaged in stocking activities in NSW, and
3. surveys of groups involved in stocking activities were conducted in order to gather demographic information and community values associated with stocking.

B4.1 Introduction

The activity of stocking is undertaken by clubs and acclimatisation societies in conjunction with NSW Fisheries staff. In NSW there are a total of 600 freshwater fishing clubs (including acclimatisation societies). Of these, around 150 are involved in stocking. Groups involved in stocking get considerable social satisfaction out of the activity and for many the process of stocking is a community event. It is for these groups that the social benefits from stocking are the highest.

The majority of members of clubs and acclimatisation societies are recreational anglers who have a vested interest in stocking activity. Hence the value they place on this activity is high. However, for recreational anglers outside these groups, who are either members of angling clubs who do not participate in stocking, or who are independent from any club or society, the social capital associated with stocking is not as high. However, these independent anglers still obtain a certain degree of social satisfaction from the activity of stocking through the indirect benefits they obtain from better recreational angling opportunities.

Information was collected, via mail surveys, on the demographic profile of groups involved in stocking (Appendix B2). In addition, a telephone survey was commissioned to obtain information on community values associated with stocking (Appendix B2). Information was also collected on the demographic profile of persons employed in hatcheries and as fishing guides. No information was collected on the demographic profile of recreational fishers. Fishing suppliers and boat operators indirectly benefit from stocking activities and should be involved in future socio-economic studies.

B4.2 Demographic profile of those employed in the activity

The overall demographic profile of the population of NSW (as estimated on the night of the ABS census 2001), by statistical division, is given in Table B62.

B4.2.1 Direct employment

From the survey of fish hatcheries, we found that almost all of the people who are directly employed in private hatcheries that undertake fish stocking activities are male, and of these, most are aged between 34 and 46, with only one person outside this age bracket. Of the 10 hatcheries surveyed, only 8 respondents were willing to give their age.

In public hatcheries, those persons involved in stocking activities vary from 26 to 57 years of age, with an average age of 37. In general those involved in management roles are older, and hatchery assistants are generally quite young.

Those persons involved in research, management and monitoring activities (both the Inland Fisheries Officers and researchers and management staff at the Grafton and Port Stephens hatcheries) are aged between mid thirties and mid forties.

In general those persons employed in research activities at the Port Stephens hatchery are more qualified (university degrees etc.) than persons employed in trout hatcheries. This is because the technical expertise required to raise trout is generally lower than that required to raise Australian bass (the species that is being researched at Port Stephens).

Table B62. Demographic profile of NSW population by statistical division, 2001

Area	Average age	Average weekly income	% Male	% Female
Central West	36	327	50	50
Hunter	37	309	49	51
Illawarra	37	317	49	51
Mid North Coast	41	278	49	51
Murray	37	349	50	50
Murrumbidgee	34	359	50	50
North Western	35	326	50	50
Northern	36	314	50	50
Other	29	844	74	26
Richmond-Tweed	40	286	49	51
South Eastern	38	358	50	50
Sydney	34	444	49	51
Grand Total	**36**	**376**	**52**	**48**

Source: ABS Census data 2001

B4.2.2 Indirect employment

As already mentioned, indirect employment in stocking activities includes those persons employed in the fishing and tourism businesses that service the recreational fishing industry. For individuals operating fishing guide businesses (of which there are 22 in NSW), information was only available on the age distribution and gender for 8 of the 10 survey respondents. The survey respondents were male and were aged between 46 and 67, with an average age of 53. One person was out of this range, age 29.

B4.2.3 Voluntary activities

An important component of fish stocking activities is the role of members of angling clubs and acclimatisation societies in NSW who volunteer their services to help with the stocking of fish into inland waterways. A survey of these clubs and acclimatisation societies was undertaken as part of this study in order to gather more information on the demographics of volunteers (Appendix B2). The results of the survey for a profile of clubs by region are presented in Table B63.

Table B63. Profile of angling clubs and acclimatisation societies involved in stocking by region.

Region	Clubs & societies	Members	Volunteers	Fundraising days	Stocking days
East Coast	25	1,752	307	306.5	125
Darling East	24	3,120	422	271	89
Montane	55	2,108	578	633	115
Murray	36	2,592	446	79	59
Grand Total	**140**	**9,572**	**1,751**	**1,237**	**387**

Fishing activity undertaken by club anglers, and the percentage of fishing by these anglers that is in stocked waters is presented in Table B64. In addition, information is presented on the percentage of fishing in stocked waters by visiting anglers.

Table B64. Fishing activity by angling clubs and acclimatisation societies

Region	Anglers as a percentage of club members	Percentage of fishing in stocked waters	Percentage of visiting anglers using stocked waters
East Coast	92	73	51
Darling East	100	90	37
Montane	98	90	57
Murray	92	85	53
Grand Total	**95**	**84**	**48**

An important activity undertaken by angling clubs and acclimatisation societies is the holding of fishing competitions. Overall, around 69% of clubs involved in stocking held fishing competitions. The percentage of clubs, by region, who held these competitions, is presented in Figure B17. Information on any environmental groups that are involved in stocking is not available.

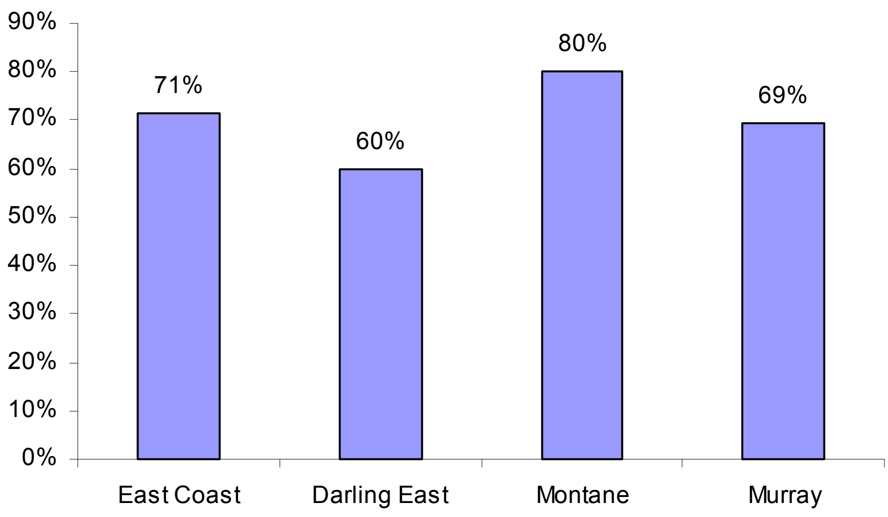


Figure B17. Percentage of clubs, by region, holding fishing competitions

Source: Fishing club and acclimatisation society surveys (Appendix B2)

The survey of 36 angling clubs and acclimatisation societies (out of a total population of 140 in NSW) revealed that most members were aged between 40 and 65 (Figure B18).

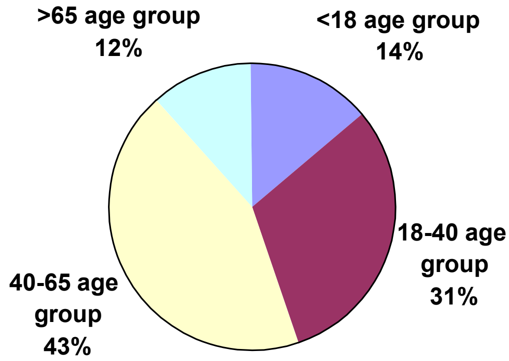


Figure B18. Age distribution for members of acclimatisation societies and fishing clubs in NSW.
Source: Fishing club and acclimatisation society survey (Appendix B2)

The age distribution of members of clubs and societies in NSW by stocking zone is presented in Table B65.

Table B65. Age distribution of members of angling clubs and acclimatisation societies by region

Region	Percentage under 18	Percentage aged 18-40	Percentage aged 40-65	Percentage over 65	Total
East Coast	17	38	45	16	63
Darling East	14	39	37	13	91
Montane	16	24	55	9	46
Murray	10	28	54	15	89
Grand Total	**14**	**31**	**44**	**12**	**100**

B4.3 Community values associated with stocking

In order to investigate community awareness, attitudes and values towards stocking of public impoundments with fish for the purpose of providing recreational fishing opportunities, a survey of the New South Wales population was commissioned. The survey was conducted via telephone by Roy Morgan Research Centre in January 2003. The details of the survey are given in Appendix B2.

The results of the survey are discussed below. Generally, the level of awareness among the community regarding stocking of fish in public impoundments was found to be high. Nearly two thirds of the population is aware that fish are stocked in such areas to provide recreational fishing opportunities. Awareness is greater than 75% among fishers, and among residents of regional New South Wales is about 75%.

B4.3.1 Threatened species

There were several ways in which possible effects of stocking were addressed in the community-based survey. The first statement put before respondents for level of agreement or disagreement was “Stocking of fish in public dams may harm threatened or endangered species of fish”. In the overall population, more persons agreed with this statement (42%) than disagreed (34%), although there was again considerable degree of uncertainty (24%). The range of responses to this statement was remarkably consistent among the different sub-groups, with, for example, fishers and non-fishers having similar responses to each other, and also to environmentally concerned groups. The strongest contrast appeared to be between Sydney and regional residents, where 41% of Sydney residents agreed that stocking might harm threatened or endangered species, compared with only 29% of regional residents.

In summary, there was a moderate concern among the population at large, and among sub-groups (including anglers) regarding possible harm to threatened or endangered species of fish from stocking. However, as with other aspects of possible environmental effects of stocking, about one quarter of the population was undecided either way.

The second statement was effectively the reverse of the first, determining any benefits to threatened or endangered species of fish from stocking. In this case, a slightly different result was obtained. Somewhat more persons agreed that stocking of fish may benefit threatened or endangered species (41%) compared with those who considered that it would not benefit such species (32%). Again, the range within sub-groups was relatively small, with freshwater fishers showing the highest level of agreement with the statement (49%), and non-fishers among the lowest level of agreement (38%). Sydney residents had the lowest agreement level (36%) while regional residents were among the highest level of agreement (46%) (not surprisingly, this result mirrored that of the previous statement).

The third statement related to stocking as a conservation strategy for threatened species. Nearly three quarters of the population (73%) agreed that such stocking is an important conservation strategy, and only 17% disagreed (a relatively small 10% were undecided). This level of general agreement with the statement was quite consistent, ranging from 80% of fishers agreeing to 66% of females. Interestingly, those moderately concerned and very concerned about the environment had a high level of agreement with the statement (71% and 75% respectively). This was also a statement about which Sydney and regional residents' responses closely coincided (72% and 74% agreement, respectively).

In summary, there was very strong agreement that stocking threatened or endangered species of fish in public dams was an important conservation strategy.

B4.3.2 Sport fish

Stocking of fish, either native or introduced, was seen by most participants as an effective way to improve fishing in impoundments, although there was a fairly high level of uncertainty about the impacts that it might have. Overall, it was viewed as a positive because it provided a healthy outdoor activity and provided a source of fish that might not otherwise be available.

B4.3.3 Commercial species

As commercial fishing is no longer practised in NSW freshwaters (beyond yabbies, eels and European carp), the issue of possible effects of stocking on commercial species, and community attitudes towards such effects, will not be considered further.

B4.4 Interaction of stocking with the community

At least 75% of the community at large perceive that fish stocking in public impoundments:

- provides recreational fishers with a healthy form of recreation
- attracts economic benefits to nearby towns
- benefits tourism, and

- is acceptable

The support for these benefits is even greater among fishers, compared with non-fishers, among regional residents compared with Sydney residents and among males compared with females.

There was also strong agreement (76% overall) with the use of public impoundments to stock edible fish (presumably since they would be caught by recreational fishers and eaten). This relates to part (iii) above, since there is no stocking of fish in public impoundments for commercial purposes.

B4.4.1 Recreational activities

Respondents to the community value survey were not asked their opinions of the effects of stocking of fish on other recreational activities since such questions would be difficult to frame and results difficult to analyse quantitatively. Shore based recreational fishing tends to be a relatively static activity with anglers generally staying in the one area during a fishing visit to an impoundment. This tends to have little impact on other activities such as bushwalking, picnicking etc. Recreational fishing boats must follow the local regulations that exist for different impoundments. Often these allocate different areas of an impoundment for different water-based activities such as water skiing, sailing, canoeing or fishing. Where regulations do not exist, some competition for space may occur between recreational fishers and other boat based users, but this issue did not emerge during the course of the study and is considered to be of minimal concern.

B4.4.2 Visual or amenity issues

The question of any direct visual impacts of stocking was deemed to be irrelevant in the context of this study since stocked fish are not visible and could not be considered to cause any obvious visual issues. The actual process of stocking involves some temporary vehicular movement and foreshore activity, but this is very short term (several days per year).

Regarding amenity issues, the survey showed that overall, 76% of the population agreed that stocking edible fish was a good use of public dams, compared with only 15% who disagreed (9% were undecided). The strongest agreement with this statement came from fishers, (87% agreement), especially freshwater fishers (90% agreement). Even a relatively high percentage of those who were very concerned about the environment (72%) agreed with this statement. The lowest agreement with the statement was among females (67% agreement) and Sydney residents (69% agreement). Regional residents contrasted with city dwellers in responding with 84% agreement. In summary, there was very strong agreement in the population at large that stocking edible fish was a good use of public dams.

B4.4.3 Concerns regarding the environmental impacts of stocking

There is general a low level of concern among the community with respect to effects of fish stocking on pollution or water quality among all groups, even among respondents who considered themselves to be very concerned about the environment. Over half of the population does not consider that fish stocking causes such problems, and among the regional population, this figure is 60%. As with all of the environmental aspects of fish stocking considered, a relatively high proportion of the population (23%) is undecided about this issue (quite possibly because they do not feel they know enough about the topic to give an informed opinion).

Three other areas of environmental aspects of fish stocking were examined (the second two outlined in some detail above, and further summarised here):

1. regarding whether or not fish stocking creates environmental problems for native fish and animals, a little more than one third of respondents agreed that stocking did cause problems, one third thought it did not, while the remaining one third were undecided. This large undecided section of the population again possibly indicates lack of information or knowledge of the subject

2. with respect to whether or not fish stocking might harm, or benefit threatened or endangered species of fish, again there was moderate concern among the population at large, and among sub groups (including anglers) regarding possible harm to threatened or endangered species of fish from stocking. Freshwater fishers, perhaps the most well informed group in relation to this issue, had the highest response that stocking benefits threatened or endangered species, with about half believing this to be the case. However, as with other aspects of possible environmental effects of stocking, a significant proportion of the population (about one quarter) was undecided either way, and

3. concerning the possible benefits of stocking threatened or endangered species of fish, nearly three quarters of the population agreed that this type of activity was an important conservation strategy. This general approval translated across all sub-groups considered, including those who were very concerned about the environment.

Other concerns such as introduction of diseases into the wild via hatchery stock, possibly affecting native fish species; or escape of hatchery stock into 'natural' waterways with possible adverse effects on ecosystems must be identified and assessed before conducting any survey to collect community opinion. In other words, community must be informed of any possible risks identified by conducting scientific experiments.

Overall, fish stocking is seen to be acceptable by an overwhelming majority of the community. There is strong majority agreement that fish stocking creates healthy recreational opportunities, is good for tourism and local economies and that stocking edible fish is a desirable use of public impoundments. On the other hand, there is considerable uncertainty about some possible environmental effects of fish stocking, with over a third of the general community considering that there could be some impacts on threatened or endangered species of fish, and nearly one third of the population undecided on the subject. On the other hand, the remaining one third does not believe there is an impact. One possible environmental impact of fish stocking, that of affecting water quality or causing pollution, was considered to be a problem by only one in five persons, but again, about one quarter of the population was undecided about this issue. Finally, stocking of threatened or endangered species in public dams was seen as an important conservation strategy by a large majority of the population.

B4.5 Health and safety issues

Information on occupational health and safety (OH&S) issues in stocking related activities was collected through the surveys of hatcheries, fishing guides and clubs and societies and in consultation with NSW Fisheries. The responses from the surveys are presented in Tables 20, 21 and 22. There are no available government OH&S data for comparison. In general, survey respondents reported more OH&S issues than employees of NSW Fisheries. Employees of NSW Fisheries are covered by a general OH&S policy under the NSW *Occupational Health and Safety Act 2000*. There is no specific OH&S policy for stocking related activities. The most common OH&S issue reported by employees of private hatcheries was that of driving, and water and electricity hazards (Table B66).

Table B66. Occupational Health and Safety issues reported by private hatcheries

Hazard	Respondents	No. of persons reporting issue *	Percentage
Driving	8	5	63%
Water	8	4	50%
Electricity	8	4	50%
Dangerous chemicals	8	3	38%
Falling/slipping	8	3	38%
Operating machinery	8	2	25%
Lifting	8	1	13%

* Only 8 of the 10 survey respondents identified that there were OH&S issues (Hatchery survey - Appendix B2)

For those persons engaged as fishing guides the most frequently reported OH&S issues were water safety and travel over rough country (Table B67). These issues were also those most commonly reported by fishing clubs and acclimatisation societies (Table B68). Another commonly reported issue for this group was that of strain injuries from lifting fish and water.

Table B67. Occupational Health and Safety issues reported by fishing guides

Hazard	Respondents	No. of persons reporting issue *	Percentage
Water safety	9	3	75%
Travel over rough country	9	3	75%
Snake bite	9	2	50%
Navigational hazards	9	1	25%
Farm hazards	9	1	25%
Exposure	9	1	25%
Bushfires	9	1	25%

* Of the 9 survey respondents, only 5 believed there were OH&S issues. Of these, 4 specified concerns.
Source: Fishing guide survey - Appendix B2

Table B68. Occupational Health and Safety issues reported by fishing clubs and societies

Category	Safety issue	No. of persons reporting issue *	Percentage
Dangers to People	Boating/Water related	5	42
	Strain injuries (from lifting water/fish)	4	33
	Driving to & from	4	33
	Snakes	3	25
	Exposure	2	17
	4 wheel driving	1	8
	slipping & falling	1	8
	"Normal accidents"	1	8
	Passing of pathogens from fish to humans	1	8
Dangers to fish health	Water pollution	1	8
	Passing of pathogens from humans to fish or vice versa	1	8
Dangers to environment	Dangers to environment (unspecified)	1	8

* Only 12 of 37 survey respondents made comments about OH&S issues.
Source: Fishing club and acclimatisation society survey - Appendix B2

B5 Aboriginal and Cultural Heritage Issues

The following summaries are based on the detailed report prepared by Umwelt (Australia) Pty Ltd and presented in full in Appendix B3.

B5.1 Interest of Aboriginal people in fish stocking

The archaeological and ethnographic evidence and the expressed views of the contemporary Aboriginal community all attest to the central cultural importance of fishing for traditionally caught species and fishery management to Aboriginal people. Fish and fishing have been an integral part of the cultural and economic life of coastal and inland Aboriginal communities since they have been in this land.

Aboriginal people have demonstrated a strong preference for fishing for traditional or native species (particularly golden perch/yellow belly, catfish and yabbies). Whilst these and other species clearly supplement family diets, the activity of fishing also has cultural values. It is a remaining direct link between the community and natural resources, it provides an opportunity for families to pass on stories about cultural values and it is an activity that can support larger extended family gatherings. Some native species also have a spiritual or 'moiety' value to specific nations.

Aboriginal community interest in fish stocking is centred around four areas of concern. First, Aboriginal people are keen to support actions that will protect and restore natural resources and the health of rivers in NSW. Second, the feedback from the limited survey sample also suggests that Aboriginal people may prefer stocking with native species above stocking with introduced species such as trout. Third, Aboriginal communities wanted to raise the awareness of cultural fishing practices and the ability to utilise traditional species, and fourth, that they needed to be able to access the waterways and thus those fish stocks. These latter points are also intrinsically linked to the first point in that cultural and natural resources are considered two sides of the same issue.

In discussion about the role of fish stocking, Aboriginal community groups have generally been supportive of the concept of fish stocking as part of a suite of actions to help restore the natural values of rivers. This support appears to be focused on natural values rather than the maintenance of recreational fisheries. The comments made in community discussions suggest that Aboriginal people do not consider themselves as recreational fishers, and do not consider fishing as "sport". None of the respondents to the survey for this project identified themselves as members of sporting recreational fishing clubs or acclimatisation societies. Aboriginal people consider themselves to be cultural fishers – thus stocking for recreational purposes is considered to be a lesser priority than stocking for the restoration of natural systems that have cultural associations.

Feedback from the limited survey sample also suggests that Aboriginal people may prefer stocking with native species above stocking with introduced species such as trout.

B5.2 Aboriginal heritage

NSW NPWS maintains a register of Aboriginal cultural heritage sites and places in NSW. There are also sites or places, some of high sensitivity, that are known to local Aboriginal communities but are not necessarily listed in the Register.

Aboriginal sites provided the archaeological context for Aboriginal relationships with the land and waters of NSW. However, sites occur in landscapes, and it is a site's association with the physical resources and cultural interpretations of the landscape that defines its significance.

The information presented in this assessment does not include a listing of every known Aboriginal site along a river or creek in NSW. This was considered to be inappropriate use of cultural information and would not add significantly to the assessment of potential impacts on heritage. The review of archaeological information clearly demonstrates that there are Aboriginal archaeological sites associated with the banks, alluvial terraces and valley footslopes in all catchments. Sites with fluvial associations dominate the archaeological record of inland NSW.

Aboriginal sites are diffusely distributed. Fish stocking activities are also diffusely distributed in the landscape and the actual stocking activity involves minimal disruption of the land surface. Notwithstanding the widespread distribution of archaeological cultural heritage evidence, the potential for fish stocking to directly impact on Aboriginal cultural heritage sites is considered to be low, and the risk is manageable with good communication.

B5.3 Historic, heritage or cultural significance

For the purposes of this report, historic heritage site or place is taken to mean places and sites that are identified in various registers and planning inventories. Whilst many places of historic interest or value, that are not listed in any existing register or inventory, may exist across NSW, it is beyond the scope of this report to document the local history of all possible fish stocking sites in NSW.

It is acknowledged that fish acclimatisation and the stocking of inland rivers is, itself, a historical cultural pursuit, having been practised for over a century. In this assessment, no consideration has been given to an estimation of the heritage values of fish stocking as a longstanding recreational and social/environmental historical activity. The focus of this assessment is on heritage values that are assessable pursuant to statute, and/or represented in material evidence, which is susceptible to impact from the practice of fish stocking.

The review of historic heritage has therefore defined those significant elements of the historic heritage resource that are, or appear to be, located in a position of proximity to projected fish stocking operations such that they might have some impact on a resource or vice versa. These features are located on riverbanks or within river channels.

Notwithstanding the presence of many items identified in heritage registers etc. in these locations, it is considered that the risks posed by fish stocking activities to historic heritage items are minimal.

The relevant sites/features that are recorded in national, State and local registers are all substantial structures, which are unlikely to be damaged in any way by fish stocking activities. Any potential interaction between stocking activities and heritage items can be readily managed by reference to appropriate heritage registers and other information at the local scale. The continuation of fish stocking does not suggest changes to the potential for impacts to occur.

Despite the minimal risk posed by fish stocking, the draft FMS should consider the potential for impact on historical heritage resources and values must be considered and the management of the activity prescribed to ensure that impacts on historic heritage are avoided.