Cardno Ecology Lab

Shaping the Future

Marine and Freshwater Studies

Marine Fish Stocking in NSW

Environmental Impact Statement

Vol I

Prepared for Department of Primary Industries

November 2011

Cardno (NSW/ACT) Pty Ltd
Trading as Cardno Ecology Lab

ABN 95 001 145 035
4 Green Street
Brookvale
New South Wales 2100
Australia
Telephone: 02 9907 4440
Facsimile: 02 9907 4446
International: +61 2 9907 4440
ecologylab@cardno.com.au
www.cardno.com.au

Marine Fish Stocking Vol I: Online version

Public Consultation Document

Cardno (NSW/ACT) Pty Ltd

ISBN 978 1 74256 221 6

Online Version

Copyright © State of New South Wales

Cover Image: Courtesy of DPI.

Document Control

Report Number	Status	Date	Authors	
EL0809106A	Final	7 November 2011	Craig Blount Kate Reeds Peggy O'Donnell Marcus Lincoln Smith	CB KR POD MLS

"© State of New South Wales through Department of Primary Industries 2011. This publication is copyright. You may download, display, print and reproduce this material provided that the wording is reproduced exactly, the source is acknowledged and the copyright, update address and disclaimer notice is retained."

Disclaimer: This public consultation document is for discussion and comment only and does not commit the New South Wales Government through Industry & Investment NSW or Cardno (NSW/ACT) to the views expressed or to any future action. While the publication has been prepared with care, the New South Wales Government does not accept liability for any decisions taken on the basis of this document.

DECLARATION

For the purpose of section 115K (4) of the *Environmental Planning and Assessment Act 1979*, Cardno Ecology Lab is responsible for the preparation of this Environmental Impact Statement (EIS) for Marine Fish Stocking. Cardno Ecology Lab worked with stakeholders and staff from Department of Primary Industries (NSW) with expertise and qualifications in fisheries management and environmental science to prepare the EIS. Where expertise was not available within Cardno Ecology Lab or DPI, external experts were consulted.

The EIS has been prepared by Cardno Ecology Lab Pty Ltd, on behalf of DPI.

The address for DPI is:

c/o NSW Department of Primary Industries (Fisheries)

Cronulla Fisheries Centre

PO Box 21, CRONULLA NSW 2230.

The location of the proposed activity is described in Chapter B Section 4. A description of the proposed activity and proposed controls is provided in Chapter E. An assessment of the environmental impact of the proposed activity as described in the Draft Fishery Management Strategy is presented in the EIS in Chapter G. 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.

VOLUMES

I

Chapter A	Executive Summary
Chapter B	Description of the Proposal
Chapter C	Review of Existing Information
Chapter D	Identification of Risks

II

Chapter E	The Draft FMS
Chapter F	Alternatives Considered
Chapter G	Assessment of Impacts of Implementing the Draft FMS
Chapter H	Justification
Chapter I	References

III

Appendix 1	Director Generals Requirements
Appendix 2	State Threatened Species Significance Assessments
Appendix 3	Commonwealth Threatened Species Significance Assessments
Appendix 4	Consultation
Appendix 5	Social Case Studies
Appendix 6	SERM Outputs
Specialist Report A	Aboriginal Issues Assessment
Specialist Report B	Economic Feasibility Assessment

CONTENTS AT A GLANCE

Volume I

Table of Contents

Volume I

Volume II

Volume III

List of Tables

Volume I

Volume II

List of Figures

Volume I

Volume II

ABBREVIATIONS

ACoRF	NSW Advisory Council on Recreational Fishing
ACEN	Aboriginal Culture and Environment Network
AHIMS	Aboriginal Heritage Information Management System
AIDP	Aquaculture Industry Development Plan
ALC	Alazarine Complex One
ANSA	Australian National Sportfishing Association
BIRC	Bribie Island Research Centre
BCR	Benefit Cost Ratio
BOD	Biological Oxygen Demand
CAMBA	China-Australia Migratory Bird Agreement
CBA	Cost Benefit Analysis
CMA	Catchment Management Authority
CPUE	Catch per Unit Effort
CWT	Coded Wire Tags
DAFF	Department of Agriculture, Fisheries and Forestry
DO	Dissolved Oxygen
DoP	Department of Planning and Infrastructure (NSW)
DGRs	Director General's Requirements
DNA	Deoxyribonucleic acid
DECCW	Department of Environment, Climate Change and Water (now Office of Environment and Heritage).
DEWHA	Department of the Environment, Water, Heritage and the Arts (Commonwealth).
DPI	Department of Primary Industries (NSW) (formerly Industry and Investment NSW)
DSEWPaC	Department of Sustainability, Environment, Water, Population and Communities (formerly DEWHA).
EAC	East Australian Current
EHN	Epizootic Haematopoietic Necrosis
EIS	Environmental Impact Statement
EPA	Environment Protection Authority (State).
EP&A Act	*Environmental Planning and Assessment Act 1979*
EPBC Act	*Environmental Protection and Biodiversity Conservation Act 1999*
ESD	Ecologically Sustainable Development
EUS	Epizootic Ulcerative Syndrome
FAD	Fish Aggregating Device
FM Act	*Fisheries Management Act 1994*
FMS	Fishery Management Strategy

FRDC	Fisheries Research and Development Corporation
GAV	Gill-Associated Virus
GIS	Geographic Information System
GNS	Grey Nurse Shark
GPIM	Generalised Predatory Impact Model
HMP	Health Management Plan
HPV	Hepatopancreatic-Parvo Virus
HRCMA	Hunter-Central Rivers Catchment Management Authority
HQAS	Hatchery Quality Assurance Scheme
HQAP	Hatchery Quality Assurance Program
ICOLLs	Intermittently closed and open lakes and lagoons
IHHNV	Infectious Hypodermal and Hematopoietic Virus
I&I NSW	Industry and Investment NSW (now Department of Primary Industries)
IPN	Infectious Pancreatic Necrosis
IUCN	International Union for the Conservation of Nature
JAMBA	Japan-Australia Migratory Bird Agreement
KTP	Key Threatening Process.
KOF	Knock-out Factor
LAeq (15 min)	Ambient noise level for a given period (e.g. 15 min).
LALC	Local Aboriginal Land Council.
LBSAS	Land-Based Sustainable Aquaculture Strategy.
LEP	Local Environment Plan
LPMA	Land and Property Management Authority (formerly the Department of Lands)
MAC	Management Advisory Committee (Commercial)
MBV	Monodon Baculovirus
MCA	Multi-Criteria Analysis
MCMS	Mid Crop Mortality Syndrome
MHWM	Mean High Water Mark
MoV	Mourilyan Virus
MPA	Marine Protected Area
MtDNA	Mitochondrial DNA
NCC	Nature Conservation Council of NSW
NFR	Nitrogen Fixation Rate
NLWR Audit	National Land and Water Resources Audit 2001
NPA	National Parks Association.
NPV	Net Present Value
NPW Act	*National Parks and Wildlife Act 1974*

NPWS	National Parks and Wildlife Service
NP&WR	National Parks and Wildlife Regulation 2002
NSW ALC	New South Wales Aboriginal Land Council
NRCMA	Northern Rivers Catchment Management Authority
NRIFS	National Recreational and Indigenous Fishing Survey
NTSCORP	Native Title Services Corporation Limited
NTDPI	Northern Territory Department of Primary Industries
OEH	Office of Environment and Heritage (formerly Department of Environment, Climate Change and Water)
OTC	Oxytetracycline (a marking agent)
PBV	*Plebejus* Baculovirus
PCR testing	Polymerase Chain Reaction – used to amplify specific regions of DNA that are known to vary among individuals.
PHV	Pilchard Herpes Virus
PIT	Passive Integrated Transponders
POAG	Peak Oyster Advisory Group
POEO Act	Protection of Environment Operations Act 1997
PV	Present Value
QDPI&F	Queensland Department of Primary Industries and Fisheries
QLD DPI	Queensland Department of Primary Industries
QSS	Queensland Sea Scallops
RAS	Recirculating Aquaculture System
RFH	Recreational Fishing Haven
RFSTEC	Recreational Fishing Saltwater Trust Expenditure Committee
ROKAMBA	Republic of Korea-Australia Migratory Bird Agreement
SEE	Statement of Environmental Effects
SEINS	Self Enforcing Infringement Notice System
SEPP	State Environmental Planning Policy
SERM	CSIRO Simple Estuarine Response Model
SIAC	Seafood Industry Advisory Council
SIP	Stocked Impoundment Permit
SRG	Stocking Review Guidelines
SMCMA	Sydney Metropolitan Catchment Management Authority
SMV	Spawner Mortality Virus
SRCMA	Southern Rivers Catchment Management Authority
SVC	Spring Viraemia of Carp Virus
TAP	Threat Abatement Plan

TPWD	Texas Parks and Wildlife Department
TSC Act	*Threatened Species Conservation Act 1995*
TSV	Taura Syndrome Virus
VIE	Visible Implant Elastomer
VNN	Viral Nervous Necrosis
WARFC	Western Australian Recreational Sport Fishing Council
WHA	World Heritage Area
WQO	Water Quality and River Flow Interim Environmental Objectives
WSSV	White Spot Syndrome Virus
YHV	Yellow Head Virus

UNITS

d^{-1}	Growth rate of fish (days)
F_{st}	Measure of genetic structure between populations.
ppt	Parts per thousand
ha	Hectares
m	Metres
kg	Kilograms
N_e	Genetic effective population size
km	Kilometres
t	Tonnes

GLOSSARY

Allele	Multiple forms of a gene are termed alleles when they occur at the same loci (location) on the chromosome, but produce different effects on development.
Allozyme	Variant forms of an enzyme that are coded by different alleles at the same locus.
Approved Species	Species assessed under the marine stocking EIS.
Aquaculture	The commercial farming of fish, molluscs, crustaceans and aquatic plants in natural or controlled marine or freshwater environments.
Benthic	Living on or in the seabed.
Benthos	The collection of organisms attached to or resting on the bottom sediments (i.e. epifauna) and those which burrow into the sediments (i.e. infauna).
Biodiversity	The variability among living organisms from all sources, including terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part.
Bottleneck	Significant reductions in population size, which can result in the loss of genetic diversity.
Brackish	Water that has greater salinity than fresh water, but lower salinity than seawater (Salinity 0.5 – 30 ppt).
Broodstock	Broodstock are a group of sexually mature individuals of a species that are kept separate for breeding purposes.
Carrying Capacity	The maximum equilibrium population size in a given area or habitat.
Catchability	The ease with which a fish may be caught
Census Population Size	The number of individuals alive in a population at a given time.
Competition	An interaction between organisms or species, in which the fitness of one is lowered by the presence of another. Limited supply of at least one resource (such as food, water, and territory) used by both is required.
Conservation Stocking	Stocking to assist in the recovery of a native species that is threatened or protected.
Critical Habitat	An area or areas of habitat declared under relevant threatened species legislation to be critical to the survival of a threatened species as declared under the TSC Act, FM Act or EPBC Act.
Cultural Stocking	Stocking for religious or ceremonial purposes.
Drain to dry	Refers to estuaries (particularly Intermittently closed and open lakes and lagoons) which completely dry up or experience severely reduced flows when the estuary entrance is open.
Density Dependence	Refers to negative effects whereby population growth is curtailed by crowding, predators and competition.
Designated Fishing Activity	Fishing activity as described in Schedule 1A of the FM Act.
Ecological Community	Populations of 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 in the future, can be increased' Australia's National Strategy for Ecologically Sustainable Development 1992.

Ecosystem	All the organisms in a community, together with the associated physical environmental factors (living and non-living) with which they interact.
Ectoparasite	Any parasite which lives on the exterior of animals.
Electrophoresis	A technique used for the separation of deoxyribonucleic acid (DNA), ribonucleic acid (RNA), or protein molecules using an electric field applied to a gel matrix. Used to determine the genetic similarity and kinship between populations or individuals.
Endoparasite	Any parasite that lives in the internal organs of an animal.
Epifauna	Animals that live on or are attached to the surface of, the seabed or subtidal habitat (including artificial structure).
Epizooic	The outbreak of a disease that affects a large proportion of the population.
Endemic (disease)	A disease is said to be 'endemic' to NSW when it is maintained in a steady state within a NSW population without external inputs.
Estuarine	Habitat lying at the interface between freshwater and marine environments; usually the mouths of streams and rivers.
Estuarine Waters	Waters ordinarily subject to tidal influence (other than ocean waters) as defined under the Fisheries Management (General) Regulation 2002.
Exotic (disease)	Of foreign origin or character and/or has been introduced to NSW from other States or abroad but has not yet reached a steady state in the population in question.
Fingerling	Juvenile fish of approximately 7 – 10 cm in length.
Fishing Effort	A function of the number of participating fishers, number of fishing events (e.g. fishing trips) and time (days/hours) spent fishing.
Freshwater	Water in a river or creek that is not subject to tidal influence, not including any coastal lake that is intermittently open to tidal influence.
Fry	Juvenile fish of 2 – 3 cm length.
Fungi	A taxonomic kingdom, includes microorganisms such as yeasts and molds.
Gametic Wastage	Mating occurs between native and stocked individuals, but hybrid offspring are not produced, which represents a significant waste of native reproductive activity that would have otherwise led to the next generation of wild fish.
Genetic Effective Population Size	The average number of individuals in a population that contribute genes to succeeding generations by breeding. This number is generally rather lower than the observed 'census population' size.
Genetic Diversity	The variety of genes (alleles) in a population and it is reflected in differences among individuals. It refers to the alleles that are present in the organism at a particular location (locus) in the DNA of cells, summed across all organisms in the population.
Genetic Drift	Divergence of isolated populations through random assortment of alleles per generation.
Genetic Fitness	the ability of an individual to pass its genes to the next generation.
Genetic Integrity	Natural genetic state.
Genetic Structure	The distribution of genetic variability among different populations or sub-populations of a species.
Habitat	Any area occupied, or periodically or occasionally occupied, by fish or marine

	vegetation (or both), and includes any biotic or abiotic component.
Harvest Stocking	Harvest stocking is a DPI program of stocking NSW estuaries with native fish recognised as recruitment limited, to enhance both the stock and recreational fishing opportunities'.
Haplotype	A set of closely linked genetic markers present on one chromosome which tend to be inherited together (not easily separable by recombination).
Heterozygous	An organism is heterozygous for a particular gene when two different alleles occupy the gene's position (locus) on the homologous chromosomes.
Homogeneous	Uniform in structure or composition throughout.
Homozygous	A cell is homozygous for a particular gene when identical alleles of the gene are present on both homologous chromosomes.
Hybridisation	Cross breeding two different species of organism.
Inbreeding	Refers to reproduction as a result of the mating of two animals which are genetically related to each other. If the relationship is a close one or it is practiced repeatedly, this generally leads to decreased genetic fitness or 'inbreeding depression'.
Inbreeding Depression	Decreased genetic fitness of a population resulting from inbreeding..
Incidental Catch	Species caught that are not the primary target of a fishing operation.
Infauna	Aquatic animals living within the sediment.
Intertidal	The portion of shoreline between low and high tide marks, that is intermittently submerged.
Introgression	The transfer of genes from captive-bred stocked fish into the native population as a result of interbreeding translocation exotic pathogens bacteria fungi parasites.
Invasive Marine Pests	Organisms (usually transported by humans) which successfully establish themselves and then overcome otherwise intact, pre-existing native ecosystems.
Larvae	Pre-adult form that may have distinct morphological, behavioural and habitat associations from the adult form.
Loci	The specific location of a gene or DNA sequence on a chromosome.
Macrofauna	Organisms associated with sediment and retained in a sieve of 1.0 mm.
Marine Extension	Marine extensions are offshore areas associated with National Parks or Nature reserves.
Marine Protected Area (MPA)	An area of sea especially dedicated to the protection and maintenance of biological diversity and associated natural and cultural resources and is managed through legal means.
Microsatellites	Tandemly repeated DNA sequences used as genetic markers that are expected to be selectively neutral.
Mitochondrial DNA (mtDNA)	The DNA located in organelles called mitochondria, structures within eukaryotic cells that convert the energy from food into a form that cells can use.
Ocean Waters	Waters east of the natural coast line of NSW. The natural coast line is defined by a line drawn along the high water mark of the sea.
Ontogenic	The origin and development of an individual organism from embryo to adult.
Panmixia	Random mating within a breeding population.

Pathogen	An infectious agent that causes disease to its host.
Parasites	An organism that lives on or inside another organism to the detriment of the host organism.
Phenotype	Any observable characteristic or trait of an organism.
Polymorphism	Occurs when two or more clearly different phenotypes exist in the same population of a species — in other words, the occurrence of more than one *form* or *morph*.
Population	Any collection of potentially interbreeding organisms in a given area.
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.
Predation	A biological interaction where a predator (an organism that is hunting) feeds on its prey, (the organism that is attacked).
Productivity	When applied to fish stock, the term productivity gives an indication of the birth, growth and death rates of a stock.
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.
Ramsar wetland	A wetland designated under Article 2 of the Ramsar Convention or declared under the EPBC Act for its representative, rare or unique habitat, or its importance in conserving biological diversity.
Recruitment	Entry of Individuals into a particular life history stage. Recruitment of juveniles into the breeding population occurs at sexual maturity (for example).
Recruitment Limitation	Conditions under which the addition of recruits (e.g. through stock enhancement) will increase the abundance of recruited stock.
Risk	The chance of undesirable events expressed as a function of the likelihood and consequence of those events.
Ryman-Laikre Effect	When the genetic effective population is low because the population is a mixture of native and captive bred individuals.
State Plan	The State Plan as developed by the NSW government which prioritises commitments to increased customer satisfaction with government services.
Stock Enhancement	The release of cultured juveniles into wild population(s) to augment the natural supply of juveniles and optimize harvests by overcoming recruitment limitation
Stocking Event	A stocking event includes single or multiple releases of a single species in a single estuary and includes the time it takes for all post-larvae or juveniles to reach a legally harvestable size. The length of the stocking event will vary among species and the number of releases. For example, post-larval prawns released as a single batch will reach a harvestable size within 1-2 years. Mulloway, on the other hand, may need to be released in up to five batches over a period of up to 5 years because of hatchery constraints. As juvenile mulloway would take about 3 years to reach a harvestable size, the stocking event could take up to 8 years.
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 as 'protected' under the FM Act.
Translocation	The movement of organisms (and transport media) beyond their natural range and/or to areas within their natural range that have genetic stocks and/or

	populations that are distinct from those at the source area.
Trophic	Relating to feeding by animals, in particular the relationships (food webs) between predators, prey and primary producers.
Wilderness Area	Lands (including subterranean lands) declared to be a wilderness area under the *Wilderness Act 1987* or the *National Parks and Wildlife Act 1974*.
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.
Zoonotic	A disease which can be transmitted (or shared) between animals and humans.

DIRECTOR GENERALS REQUIREMENTS

1. General Requirements

Standard requirements for the preparation of an EIS as outlined in the Environmental Planning and Assessment Regulation 2000 (EP&A Regulation) are summarised below with the relevant Section of the EIS indicated as relevant.

Director General's Requirements	Chapter/Section
1. A summary of the environmental impact statement.	A.
2. A statement of the objectives of the development or activity.	B.2.
3. An analysis of any feasible alternatives to the carrying out of the development or activity, having regard to its objectives, including the consequences of not carrying out the development or activity.	F.
4. An analysis of the development or activity, including: (a) a full description of the development or activity;	B.
(b) a general description of the environment likely to be affected by the development or activity, together with a detailed description of those aspects of the environment that are likely to be significantly affected;	C.
(c) the likely impact on the environment of the development or activity	G.
(d) a full description of the measures proposed to mitigate any adverse effects of the development or activity on the environment;	G.
(e) a list of any approvals that must be obtained under any other Act or law before the development or activity may lawfully be carried out.	A.2.
5. a compilation, (in a single section of the environmental impact statement) of the measures proposed to mitigate any adverse effects of the activity.	G (Table G.38).
6. The reasons justifying the carrying out of the development or activity in the manner proposed, having regard to biophysical, economic and social considerations, including the following principles of ecologically sustainable development:	H.
(a) The precautionary principle, namely, 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 environmental degradation. In the application of the precautionary principle, public and private decisions should be guided by: (i) careful evaluation to avoid, wherever possible, serious or irreversible damage to the environment, and ii) an assessment of the risk weighted consequences of various options,	H.6.1.
b) inter-generational equity, namely, that the present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations,	H.6.2.
c) conservation of biological diversity and ecological integrity, namely, that conservation of biological diversity and ecological integrity should be a fundamental consideration,	H.6.3.
d) improved valuation pricing and incentive mechanisms, namely, that environmental factors should be included in the valuation of assets and services, such as: i) polluter pays, that is, those who generate pollution and waste should bear the cost of containment, avoidance or abatement, ii) the users of goods and services should pay prices based on the full life cycle of	H.6.4.

Director General's Requirements	Chapter/Section
costs of providing goods and services, including the use of natural resources and assets and the ultimate disposal of any waste, iii) environmental goals, having been established, should be pursued in the most cost effective way, by establishing incentive structures, including market mechanisms, that enable those best placed to maximise benefits or minimise costs to develop their own solutions and responses to environmental problems.	
The matters to be included in item (4)(c) might include such of the following as are relevant to the development or activity:	
(a) the likelihood of soil contamination arising from the development or activity;	N/A –the activity would not impact on soil contamination.
(b) the impact of the development or activity on flora and fauna;	G.2.1.
(c) the likelihood of air, noise or water pollution arising from the development or activity;	D.6.
(d) the impact of the development or activity on the health of people in the neighbourhood of the development or activity;	N/A – the activity would not impact on neighbourhood health.
(e) any hazards arising from the development or activity;	D.3.
(f) the impact of the development or activity on traffic in the neighbourhood of the development or activity;	D.5.2.2.7. (Paragraph 3).
(g) the effect of the development or activity on local climate;	N/A – the activity would not impact on local climate.
(h) the social and economic impact of the development or activity;	G.2.2 and G.3. Specialist Report A. Specialist Report B.
(i) the visual impact of the development or activity on the scenic quality of land in the neighbourhood of the development or activity;	D.6.1.2.2.
(j) the effect of the development or activity on soil erosion and the silting up of rivers or lakes;	D.4.2.2.5. (Paragraph 3).

2. Specific Requirements

Pursuant to Clause 231 of the Environmental Protection and Assessment Regulation 2000 (EP&A Regulation), the Director General requires the EIS to conform to specific issues identified by the Department of Planning and other relevant agencies which include:

- Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC);
- Department of Environment Climate Change and Water (DECCW);
- Industry and Investment New South Wales (I&I NSW); and
- Land and Property Management Authority (LPMA).

These issues and the relevant Section of the EIS are provided in the following Tables:

Director General's Requirements– Department of Planning	Chapter/Section
Description of the Proposal:	
The EIS must include a full description of the proposal identifying: details of the activities undertaken including the species to be stocked;	B.3.
sources of broodstock;	B.6.2.
stocking methods and locations; and	B.6.3, B.4 and B.5.
quantity of fish to be stocked.	B.6.5.
This should be supported by maps/plans clearly showing the various stocking locations. Natural environmental features should also be included.	B.5.
Operational details including the ownership and responsibility for the ongoing operation and management of the fish stocking program.	B.6.6.
Justification for the Proposal:	
The EIS must include a detailed justification for the need and location of the proposal including:	H.
consideration of alternatives including the "no stocking" option.	F.2.
justification of the preferred option considering social,	H.3.
environmental; and	H.2.
economic factors.	H.4.
Detail the surrounding water use capability to host the proposal, also demonstrating its suitability and sustainability over the long term; and current and future demand for fish stocking.	B.4 and C.7.
Planning Context	
The EIS must assess the proposal against relevant environmental planning instruments, strategic and local planning documents.	C.6.2. Stocking Review Guidelines (Chapter E, Appendix E.1 and E.2).
The EIS must also outline any licence/approvals applicable to the project.	A.2, C.6.1.
Flora and Fauna	
Assessment of the following potential impacts of the proposal during construction and operation: Potential impacts on critical habitats, threatened and protected species, populations or ecological communities and their habitats in the region, and measures to mitigate these impacts;	G.2.1.2 and G.2.1.3.
Potential significant impacts to natural populations of predators and prey, trophic interactions and marine biodiversity in general;	G.2.1.1.
Ensure that the genetics of the broodstock are compatible with the genetics of the stock in the receiving waters.	G.2.1.4.
Disease Risks and Their Management	
Identify any disease risks to fish and aquatic health from introducing hatchery fish into the marine environment.	D.4.5.
Provide details of proposed measures to be used in maintaining the genetic integrity of local	G.2.1.4.

Director General's Requirements– Department of Planning	Chapter/Section
wild stocks.	
Provide detailed disease and pest management protocols.	G.2.1.5.
Performance Monitoring	
Include procedures to monitor a) catch rates of stocked fish, b) migration of stocked fish, c) the location of specific stocking events and the number of fish stocked.	a) E.3.2 (Goal 2.3 (d). b) E.2.8 (Table E.7, Research Topic 2.1). c) E.3.2. (Goal 4, Objective 4.2 (a) and Chapter E, Appendix E.4.
Marine Protected Areas	
Assessment of how the proposed activity interacts with the management objectives of marine parks, aquatic reserves and marine areas of national parks and nature reserves.	G.2.1.3.
Release strategies for waters directly adjacent to marine protected areas.	G.2.1.3.
Cost Benefit Analysis	
Include an assessment that demonstrates that a) the species to be stocked, b) the size at stocking, c) the stocking rates and d) the timing and location of stocking produce benefits that are optimal or near optimal.	a) Specialist Report B. b) F.5.5.1. c) F.5.4. d) Specialist Report B, E.2.8 (Research Topic 3.2) and E.3.2 (Goal 2).
Indigenous Cultural Heritage	
Include the interests of Indigenous people in fish stocking, any important Aboriginal heritage sites/places impacted by the proposed activity and outline any existing protocols/measures that aim to minimise risk of harm to these sites.	G.2.2.1.
Crown Land	
Include likely direct or indirect impacts of Crown Land and assets such as breakwaters or boat ramps.	D.5.2.2.3.
Environmental Monitoring and Management	
The EIS must describe in detail what measures would be implemented to avoid, manage, mitigate and/or off-set the potential impacts of the activity, and describe how the environmental performance of the activity would be monitored and managed over time.	E, G and Table G.38.
Consultation	
During the preparation of the EIS, you must further consult with the Marine Parks Authority, Department of Environment and Climate Change, Department of Lands, Department of Primary Industries and the Commonwealth Department of Environment, Water, Heritage and the Arts and any other relevant local, State and Commonwealth government authorities, service providers and community groups. In particular, you should consult the surrounding landowners and occupiers that are likely to be impacted by the proposal. Details of the consultations carried out and issues raised must be included in the EIS.	D.2 and Appendix 4.

Director General Requirements - DECCW	Chapter/Section
A detailed description of the proposal should clearly describe: objectives of stocking being proposed;	B.2.
Scope of the proposal in consideration of different types of stocking i.e. restocking, sea ranching and stock enhancement.	C.1.
The proposal and environmental assessment need to be clear on how different types of stocking will be handled, including in marine protected areas.	E.2 and G.2.1.3.
Delineation and formal assessment of threats of the stocking proposal to marine biodiversity is required.	D.4.
Need and cost-effectiveness for the stock enhancement proposal, including:	
detailed comparison of the proposal with alternative means of 'enhancing stocks' including size limits, marine protected areas, closed seasons, reduction in commercial fishing and protection/repair of habitats;	F.3.1.1, F.3.1.2 and F.3.1.3.
how the proposed stocking will help released juveniles of the species in question to complete their life cycles, grow to adults and contribute to spawning stocks;	C.1.
details of changes required to fishery management practices to support the enhancement program;	E.1.2, E.1.3.
examination of positive and negative interactions between stocking and NSW marine protected areas (marine parks, aquatic reserves and marine areas of national parks and nature reserves). This should include examination of: interactions between stocking that is undertaken within waterways that also include marine protected areas (e.g. stocking In Botany Bay and interactions with Towra Point Aquatic Reserve within Botany Bay);	G.2.1.3.
how the stock enhancement program can add value to marine protected areas.	G.2.1.3.
Formal analysis to support the proposed list of areas where stocking can and cannot occur and associated rationale.	B.5.
Analysis of effects of the stocking proposal on genetic diversity and suitable arrangements to manage these effects.	C.4.1.4 and G.2.1.4.
Description of implementation processes for stocking activities, especially as relevant to marine protected areas, and including:	E.2.6.
approvals required;	A.2 and E.2.6.
community, stakeholder and agency consultation on individual proposed stocking activities;	E.2.6 and G.2.2.1.2, G.2.2.2.3.
disease and pest management protocols;	G.2.1.5, E.1.4.6.
release strategies for waters in the vicinity of marine protected areas;	G.2.1.3.
Particular consideration should be given to any implications of individual proposed stocking activities for local Aboriginal communities. Where relevant, targeted consultation should occur with Aboriginal groups.	G.2.2.1.
Document the maximum size of stocking activities for which the environmental	B.6.5.

Director General Requirements - DECCW	Chapter/Section
assessment, implementation processes and any approval of the proposal are valid. The stocking proposal is predicated on activities being small in size. Should the stocking activities prove larger in actuality (e.g. more frequent or more sites), then it is important to document the maximum size of stocking activities for which the environmental assessment, implementation processes and any approval of the proposal are valid.	
Proposed research, monitoring, reporting and adaptive management programs for stocking activities, including for effects on biodiversity (including genetic diversity), interactions with marine protected areas and effectiveness for fishery enhancement. This should also include processes to be implemented in the event that monitoring and reporting show adverse environmental impacts (for example, temporary or permanent cessation of stocking programs).	E.2.8, E.4.5 and G (Table G.38).

Director Generals Requirements – DPI	Chapter/Section
Project Objectives	
Outline the objectives of the program and include the following issues: (a) Conservation of biological diversity in an ecosystem and maintenance or re-establishments of ecologically viable stock levels. (b) Conservation of protected and threatened species, populations or communities and their habitats. (c) Management of stocking activity so as not to place other aquatic species at risk. (d) Meeting conservation, recreational and commercial fishing sector interests.	B.2. (General) E.3.2. (Specific Goals and Objectives).
Existing Commercial Fishery	
Any environmental, economic and social impacts of estuarine and marine stocking that may impact on the existing operation of the commercial fishing industry should be considered. Such issues/impacts include but are not limited to the following: resource allocation and access between and within fishery sectors; consultation with commercial fishery advisory bodies; and expectations of stakeholders with respect to 'ownership' of stock.	G.2.2.2, D.2., Appendix 5, B.6.6.
Stocked Species	
Describe the species stocked and sources of stock in terms of the following; Identify the catchments and locations within the catchments where fish are stocked: Outline the purpose of and/or demand for the stocking and identify:	B.3, B.5.1.2, H.3, B.6.2.
(a) The status of the species to be stocked in terms of whether they are currently (i) under-fished, fully fished, over-fished or uncertain; Where stocks are currently overfished, describe how the stocking might contribute to rebuilding stocks to viable levels within nominated timeframes.	C.8.
(ii) protected from commercial and/or recreational fishing	C.8.
(iii) threatened species, population or ecological community; or	C.9.

Director Generals Requirements – DPI	Chapter/Section
(iv) target species of particular recreational or commercial fisheries;	C.8 – Recreational and commercial Importance.
(b) the likelihood of the species becoming self-sustaining or would die-out following stocking - including the factors thought to be responsible. Identify key species, populations, ecological communities and their life cycles, habitats, movement or migration that may be directly or indirectly affected by the stocking activities; indicate the local and regional scarcity. In particular provide information on:	D.4.4.1. G.2.1.1.
(i) impacts of the stocked fish on the life-cycle or movement of protected or threatened species, populations and ecological communities and their habitats;	G.2.1.2, Appendix 2 and Appendix 3.
(ii) incidental capture rates and mortality that might result from fishing due to the presence of stocked fish; and	G.2.1.2.4.
(iii) any relevant measures identified in a relevant recovery plan.	G.2.1.2.4.
Identify areas of high aquatic biodiversity/conservation significance; if relevant identify the following, indicating their incidence in catchment where stocking is undertaken or where broodstock are obtained, such as: marine parks, reserves, national parks or closure areas protected under the Fisheries Management Act 1994, NPW Act 1974 or Marine Parks Act 1997;	G.2.1.3.
other areas such as Ramsar wetlands, Japan Australia Migratory Bird Agreement (JAMBA), China Australia Migratory Bird Agreement (CAMBA), World Heritage Areas or areas registered in the National Estate or State Heritage Register.	G.2.1.3, D.5.2, C.9.3 and C.9.1.2 (*Estuarine Birds*).
Describe the species known to occur naturally in the catchments or locations. Outline the arrangements for undertaking the stocking including:	C.7.4.
transport and temporary holding of stock;	B.6.3.
stocking methods;	B.6.3.
authorisation of stocking events;	B.6.4.
involvement of associations/contractors/land owners/others in stocking events;	B.6.6.
verification of stocking events; and	B.6.3.
any areas where fish stocking is to be restricted all or some of the time e.g. aquatic reserves and marine parks (protected zones).	E.2.3 and E.2.4.
For each species (and if relevant for each of those locations), outline:	
extent and magnitude of research-based stocking for each species i.e. how, where and when stockings have taken place and the results of any research;	C.8. – Stocking suitability
natural distribution and abundance of stocked species on a catchment and Statewide basis;	C.8. – Natural distribution and stock structure.
sources of broodstock;	B.6.2.

Director Generals Requirements – DPI	Chapter/Section
method, timing and frequency of stocking.	B.6.3.
Identify any current issues affecting or affected by the proposed stocking activities Any seasonal, life history and other major factors that could affect how stocking will operate;	C.8. – Life history.
identify and discuss the importance of any areas of aquatic habitats to the success of stocking activities;	C.8. – Habitat.
discuss the vulnerability of stock to impacts from stocking methods.	B.6.3.
Outline the management tools used to manage/minimise the impacts of the stocking including:	
restrictions on species which can be stocked;	E.2.2.
restrictions on who can undertake the activity;	B.6.4.
controls on levels, where and when the activity can occur including the protocols and/or research used to determine the level of stocking activity;	E.2, E.4, Chapter E (Appendix E.6).
techniques to detect and mitigate/eradicate disease in both stocked and wild fish;	E.2.7.1. and G.2.1.5.
Protocols to maintain genetic integrity of the stocked species and resident species.	G.2.1.4.
protocols to maintain genetic diversity, including production details of any stocks designed as non-breeding fish (e.g. triploids).	G.2.1.4.
Trophic Structure	
Consider the effects of stocking on trophic structure (food webs) and where possible provide an ecological systems model, in particular:	C.7.3 and G.2.1.1.3.
identify the species (fish, invertebrates etc.) that are likely to be affected directly or indirectly by marine stocking (including those caught as food for young fish) and identify which of, and why the stocked species is thought to be primarily responsible (where appropriate on a catchment basis);	C.7.3.
identify likely productivity/flows and assess the impacts of addition of predators, prey or competitors including replacement of existing taxa at a given trophic level or the creation of an additional trophic level/niche within different waterways;	D.4.1, G.2.1.1.2 and G.2.1.1.1.
discuss the carrying capacity of the catchments (or waterways or locations) used for stocking and the extent to which stocking is likely to affect the system's capacity;	C.4.1. Chapter E (Appendix E.6).
discuss the risks and uncertainties of the stocked fish disrupting trophic structure and the management measures to address these risks and the effectiveness of mitigation measures. Indicate the level of confidence that the management and mitigation measures would achieve the predicted outcomes and would effectively manage the impact and associated risks;	D.4.1.2.3 and G.2.1.1.3.
Genetic Issues	
Assess the implications of fish stocking on the genetics of stocked and wild populations	C.8. – Genetic Stock

Director Generals Requirements – DPI	Chapter/Section
including:	Structure
review the current understanding of genetic variability in species (which have been or are likely to be stocked) in terms of the variability in catchments or locations where stocking is or may occur and in species populations that are currently used for broodstock; Identify major gaps in relation genetic information;	D.4.4, G.2.1.4.
assess the implications of stocking species from one population, race or subspecies into receiving waters with wild fish of the same species, but from a different population, race or subspecies;	C.4.1.4.7, D.4.4 and G.2.1.4.
discuss the appropriateness of stocking protocols as they pertain to distinct populations, races or subspecies in terms of broodstock and different populations, races or subspecies of wild fish in the catchments/sub-catchments or locations were stocking is to be undertaken.	E.2.2.
Assess the implications of any cross breeding as a result of the stocking activities: assess the implications of cross breeding particularly on any protected, threatened or vulnerable species; and predict the likelihood and assess the significance that any species being considered for stocking has the ability to hybridize with other species occurring in the receiving waters.	C.4.1.4.7, D.4.4.2.1 and D.4.4.2.2.
Describe measures to ensure unacceptable adverse impacts do not occur to the genetic integrity of wild populations in the receiving environment.	G.2.1.4.
Translocation of Organisms	
Outline any potential impacts on the environment from the translocation of organisms (e.g. fouling organisms and other pests) in particular: list any species of flora and fauna likely to be translocated;	C.4.1.5.4, D.4.5.2.5 and D.4.5.2.6.
review the past performance of research-based stocking in terms of translocation incidents and any implications on aquaculture, other water users and the environment; outline any changes in practice as a result of such incidence;	C.4.1.5.
assess the risk associated with translocation from marine stocking; outline the likely implications of translocation on aquaculture, other water users and the environment;	D.4.5.
provide details of proposed mitigation methods including information from any available pest species threat abatement plan; and	C.4.1.5.5 and G.2.1.5.
Outline a contingency plan for any pest/fouling species likely to be translocated by the activity.	G.2.1.5.4.
Fish Health and Disease	
Assess the potential impacts on fish health and disease from the proposed activity, in particular: Review the past performance of research based stocking activities in terms of stress and disease incidents because of broodstock collection and stocking activities and any implications on the health of wild stocks.	C.4.1.5.
Assess the implications of fish stocking on the health status of stocked and wild populations including:	D.4.5.

Director Generals Requirements – DPI	Chapter/Section
review the current understanding of health status in species (which have been or are likely to be stocked) in terms of baseline health data in catchments or locations where stocking is or may occur and in species populations that are currently and/or proposed to be used for broodstock;	C.4.1.5.
identify major gaps in relation to health information for such wild populations;	C.4.1.5.
review the current understanding of health status in species (which have been or are likely to be stocked) in terms of diseases reported in production systems; identify major gaps in relation to health information for such cultured populations;	C.4.1.5.
outline risks to the health of wild fish populations from the release of stock;	D.4.5.
discuss the appropriateness of stocking protocols as they pertain to aquatic health and disease;	G.2.1.5
describe measures to ensure unacceptable adverse health and disease impacts do not occur in wild populations in the receiving environment including protocols and quality control measures to minimise the risk of spread of disease into the receiving environment.	G.2.1.5.
Other Impacts	
Evaluate the effects of fish stocking on the following physico-chemical aspects of the environment: Water quality, including: identify potential sources of pollutants/contaminants from the stocking programs (e.g. release of water with fry into receiving waters) that may affect water quality; outline the characteristics, magnitude and probable frequency of these events;	D.6.1.2.1.
review any water quality information associated with existing stocking practices; identify any incidents which may have occurred in the past and practices which may have changed as a result;	D.6.1.2.1.
consider the risk to water quality taking into consideration proposed practices, the general condition or characteristics of the catchments, sub-catchments or locations and the likely assimilation capacity of the receiving water under stocking programs;	D.6.1.2.1.
Noise, Light, Air quality, Energy Issues: Review past performance in relation to the above issues in relation to broodstock collection, stocking events and related activities;	D.6.
outline the likely sources of impacts in relation to the implementation of stocking under the FMS. Consider the likely significance of these impacts taking into consideration any nearby dwellings and sensitive land uses;	D.6.1.2.2 (Noise/Light). D.6.1.2.3.(Air Quality). D.6.1.2.4 (Energy).
outline measures to manage impacts to an acceptable level;	G.2.3.
outline measures to maximise energy efficiency.	G.2.3.3.
Hatchery Production	
Identify hatcheries currently producing stocks of marine fish and their current role;	C.11.3.
identify the species produced;	C.11.3.

Director Generals Requirements – DPI	Chapter/Section
provide information on the trends in the annual production;	C.11.3.
describe their capacity or necessary upgrades required to meet the requirements of the marine stocking program;	C.11.3. B.6.6.
identify health status and health issues associated with those hatcheries;	C.11.3.
Identify scope and status of the approvals, permits or licences for each of the hatcheries and their suitability to broad marine stocking programs.	C.11.3.
Identify any current issues affecting the performance of the hatcheries and their ability to meet the demands of broad marine stocking program.	C.11.3.
Quality assurance programs for the production and release of fish, including measures to: ensure that genetics of the broodstock are compatible with the genetics of the stock in the receiving waters taking into consideration any distinct populations, races or subspecies in the target catchment/ location;	C.11.4, E.2.7.1, E.2.7.2. G.2.4.1.
ensure the stock is disease free prior to release;	G.2.1.5.
ensure that translocation of non-target species does not inadvertently occur;	G.2.1.5.
ensure accidental releases do not occur.	G.2.1.5.
Monitoring and Responsive Management	
Identify performance indicators to monitor whether the objectives of the program are being achieved.	E.4.1.1.
Identify the “triggers for review” of the program based on the performance indicators	E.4.1.2.
Identify the action to be taken when the trigger points are met.	E.4.2.2.
Indicate how the monitoring program will be linked to performance indicators, triggers, management rules and the research program.	E.3 and E.4.2 (linked).
Indicate the relevance of information from the monitoring of existing research-based stocking.	C.8. (Summary tables – demonstrated stocking success).
Indicate whether marking or tagging of stocked individuals will be undertaken (e.g. tetracycline markers).	E.2.8. (Table 7, Research Topic 3.1).
Monitor to ensure that genetic attributes of wild populations are not unacceptably affected by the programs.	E.2.8. (Table 7, Research Topic 1.1, 1.3).
Monitor key biodiversity or environmental parameters likely to indicate if adverse impacts are occurring to aquatic ecology or habitats (e.g. to key indigenous fish, frog or insect species).	E.2.8. (Table 7, Research Topic 1.2).
Indicate how the extent of environmental impacts will be determined, and if they are found to be occurring whether they are at the frequency and magnitude predicted in the initial assessment.	E.4.4. E.4.5.
Identifying links from the monitoring program and research programs to provide information relevant for continuous improvement in fisheries management.	E.3. and E.1.4.7
Proposed Research Programs	

Director Generals Requirements – DPI	Chapter/Section
A research program must be developed as part of the Management Strategy. The strategies should outline information deficiencies and identify appropriate research to be undertaken to provide valid information for the sustainable management of marine stocking activities. The program must: identify areas where further information is needed including improving knowledge of the stocked species and their receiving environment;	E.2.8. (Table E.7).
specify short-term and long-term aims and objectives of the research;	E.2.8.2.
identify links with monitoring and continuous improvement/responsive management programs.	E.4.

Director General Requirements - LPMA	Chapter/Section
The EIS should address the following: (i) the need for stocking to occur in a targeted way, with priority given to particular sites;	B.4 and B.5 and H.1 and B.2.
(ii) the identification of what sites should be given priority, e.g. (a) localities with existing habitat of high quality; (b) localities with priority habitat restoration/recovery plans; (c) localities with a low susceptibility to catastrophic events, e.g. depletion of oxygen events; (d) sites within recreation fishing havens, where no commercial fishing occurs; (e) localities with guaranteed environmental flows.	B.5.
(iii) the persons able to carry out stocking activities, and appropriate authorisation for those persons , (where not I&I NSW);	B.6.4.
(iv) the likely impact of the stocking program on Crown land and assets, such as breakwaters, boat ramps, etc.	D.5.2.2.3.
(v) the likely impact of the stocking program on activities on adjacent Crown land, particularly where such activities have been authorised under the Crown Lands Act 1989 via tenure (e.g. lease or licence) and/or relate to a Plan of Management for that land;	D.5.2.2.3.
(vi) the need for any lease, licence, permit or other approval under the Crown Lands Act where Crown land is proposed to be used for the stocking program (e.g. for access or other purpose).	D.5.2.2.3 and A.2.

Chapter A

Executive Summary

Cardno (NSW/ACT) Pty Ltd
Trading as Cardno Ecology Lab

ABN 95 001 145 035
4 Green Street
Brookvale
New South Wales 2100
Australia
Telephone: 02 9907 4440
Facsimile: 02 9907 4446
International: +61 2 9907 4440
ecologylab@cardno.com.au

www.cardno.com.au

Environmental Impact Statement on Marine Fish Stocking in NSW

Executive Summary

Cardno (NSW/ACT) Pty Ltd

Copyright © State of New South Wales

Cover Image: Courtesy of DPI.

Document Control

Report Number	Status	Date	Authors	
EL0809106A	Draft Final	12 August 2011	Craig Blount Kate Reeds Peggy O'Donnell Marcus Lincoln Smith	CB KR POD MLS
EL0809106A	Final	4 November 2011	Craig Blount Kate Reeds Peggy O'Donnell Marcus Lincoln Smith	CB KR POD MLS

"© State of New South Wales through Department of Primary Industries (DPI) 2011. This publication is copyright. You may download, display, print and reproduce this material provided that the wording is reproduced exactly, the source is acknowledged and the copyright, update address and disclaimer notice is retained."

Disclaimer: This public consultation document is for discussion and comment only and does not commit the New South Wales Government through DPI or Cardno (NSW/ACT) to the views expressed or to any future action. While the publication has been prepared with care, the New South Wales Government does not accept liability for any decisions taken on the basis of this document.

Table of Contents

Volume 1

CHAPTER A EXECUTIVE SUMMARY

A.1 Introduction

A.1.1 Background and Aims

NSW Department of Primary Industries (DPI) aims to enhance recreational fishing opportunities in New South Wales (NSW) by implementing a marine fish stocking program along the NSW coastline. DPI and private groups have been stocking native fish and salmonids in freshwater rivers and impoundments for over fifty years to boost fish stocks and enhance recreational fishing opportunities for anglers, for Aboriginal cultural purposes and for religious and ceremonial purposes. In recent years, around six million fish have been stocked in freshwater systems in NSW each year. Despite the relative success of NSW freshwater stocking programs, the enhancement of marine fisheries in Australia is still in its infancy and at present, there are no ongoing marine fish stocking programs (Taylor *et al.* 2005b). Worldwide, there are major stock enhancement programs coupled with the extensive development of hatchery technologies and these boost a variety of commercial and recreational fisheries. For example, in Texas 20–30 million fingerlings are released per year by Parks and Wildlife to boost opportunities in the recreational fishery for red drum (*Sciaenops ocellatus*) (McEachron *et al*. 1995). In NSW, DPI has collaborated with the University of New South Wales (UNSW) to undertake research stockings of mulloway (*Argyrosomus japonicus*) in large estuaries and eastern king prawns (*Melicertus plebejus*) in recruitment limited ICOLLS (Intermittently Closed and Open Lakes and Lagoons), to investigate their suitability for fisheries enhancement. Since 2004, approximately 127,000 mulloway fingerlings and 9.5 million eastern king prawns have been stocked into various estuaries. These research stockings have provided information on the dynamics and productive capacity of the target ecosystems to help ensure that appropriate resources (food and habitat) are available to support stocked individuals.

Advances in aquaculture technology, improved knowledge of species life history, cost-effective tagging techniques and quantitative estimations of stocking densities (enabling the success of stocking programs to be evaluated) have contributed to the feasibility of marine fish stocking in NSW. There are, however, challenges and uncertainties associated with any new fish stocking program which must be addressed from biological, socio-economic, and management perspectives to ensure that the program is carried out in a responsible and sustainable manner.

The key objective of the proposed marine stocking program is to enhance recreational fish stocks and improve recreational fishing opportunities through 'harvest stocking' within NSW. 'Harvest stocking', is specifically defined as "a DPI program of stocking NSW estuaries with native fish recognised as recruitment limited, to enhance both the stock and recreational fishing opportunities''. Recruitment limitation occurs where the supply of new recruits (i.e. larvae or juveniles) is insufficient to fully utilise the resources available in a particular system. Recruitment limitation can be species-based, location-based, or both. Recruitment of a species may be limited when there is a small spawning biomass and/or the stock is overfished. Location-based recruitment limitation can occur where there is some type of location based environmental constraint, for example, where the waterway is intermittently closed off to the ocean by a sand berm, or where there are insufficient resources (food, habitat, refuge) for recruits to survive and reach maturity. Stocking would only take place where there is evidence of recruitment limitation in terms of the species being stocked or the condition of the estuary to be stocked according to the criteria outlined in the draft Fishery Management Strategy (Chapter E).

Further objectives of the marine stocking program are to:

- Implement an environmentally sustainable stocking program with monitoring and assessment regimes;
- Optimise the survival and growth of stocked fish, crabs and prawns with respect to release size, release season and habitat;
- Ensure responsible stocking practices in accordance with the Environmental Impact Statement (EIS) and draft Fishery Management Strategy (FMS) for marine stocking (Section A.2); and
- Promote community awareness of responsible stocking practises.

A.1.2 Need for the Project

Marine stocking satisfies a number of significant community needs and contributes to fulfilling the primary objective of the *Fisheries Management Act 1994* (FM Act) which is 'to conserve, develop and share the fishery resources of the State for the benefit of present and future generations'. Further objects under the Act to which the proposal also contributes include promoting 'ecologically sustainable development' (ESD), including the conservation of biological diversity' and promoting 'quality recreational fishing opportunities'.

Recreational fishing is an important leisure activity which provides significant social benefits (Henry and Lyle 2003). The National Recreational and Indigenous Fishing Survey undertaken in 2000/2001 (Henry and Lyle 2003), indicated that NSW has the greatest number of recreational fishers in the country (999,000) and a participation rate of 17.1 %. It is likely that projected population increases for NSW would place a greater demand on fisheries resources in future.

In addition to controls on fishing effort and habitat protection or restoration, aquaculture based marine stocking is another means by which fisheries can be enhanced. Stocking (in addition to traditional management strategies) may help enhance fish populations and allow the social and economic benefits of recreational fishing in the community to be enhanced in the short and longer term.

A.2 Development of the Environmental Impact Statement and Fisheries Management Strategy

Fish stocking is a designated fishing activity under Schedule 1A of the FM Act. Under NSW legislation, a 'designated fishing activity' requires assessment and approval under Part 5 of the *Environmental Planning and Assessment Act 1979* (EP&A Act). Under Section 115O of the EP&A Act, a designated fishing activity must be the subject of an EIS and cannot proceed without a determination made by the Fisheries Minister. Further, approval, under Section 115P of the EP&A Act, must be given by the Planning Minister prior to the determination being made by the Fisheries Minister as DPI are the proponents and cannot be the sole determining authority. Cardno Ecology Lab Pty Ltd has been commissioned by DPI to prepare the marine fish stocking EIS.

The EIS provides a thorough and transparent assessment of the risks associated with the proposed activity and a number of mitigation and management measures for addressing the risks. This summary introduces the environmental assessment process for the proposed activity and outlines the legislative context and the findings of the assessment.

A.2.1 The Draft Fisheries Management Strategy

In association with environmental assessments, Section 115J of the EP&A Act requires the development of a FMS for designated fishing activities. The draft FMS introduces a management regime to minimise the environmental risks that are identified in the EIS risk assessment. Together the EIS and draft FMS will provide an approved framework for the assessment, authorisation and management of fish stocking activities in NSW estuaries through the DPI marine stocking program. This will include other applications for a permit to release fish under Section 216 of the FM Act.

A.2.2 The Environmental Impact Statement

The structure of the EIS is based on Director General's Requirements (DGRs) issued by the Department of Planning and Infrastructure. The DGRs are guidelines which outline the content and issues which should be included and addressed within the EIS. Other relevant government agencies were consulted by the Department of Planning and Infrastructure and their requirements incorporated into the DGRs.

The broad aims of the EIS were as follows:

- To provide a background review of existing information on marine fish stocking, including profiles of the marine species identified for stocking and the general environment to be affected;
- To give a detailed description of the project;
- To carry out a detailed assessment of the key issues/risks, and outline the mitigation and management strategies that would be employed to address such issues;
- To provide a compilation of all the proposed environmental management and monitoring measures; and
- To justify the project on economic, social and environmental grounds, taking into consideration whether the project is consistent with the objectives of the EP&A Act.

Based on the DGRs, the structure of the EIS is as follows:

Volume I

Chapter A	Executive Summary	Summary of the proposed marine stocking activity, assessment of impacts, justification, conclusion and invitation for submissions.
Chapter B	Description of the Proposal	Detailed description of the locations and species permitted for marine stocking, the estimated stocking rates and management responsibilities.
Chapter C	Review of Existing Information	Review of existing information on marine stocking activity (state, national and international), species information and relevant background information to support the assessment of impacts.
Chapter D	Identification of Risks	Formal risk analysis to identify key risks/issues that need to be addressed within the draft FMS.

Volume II

Chapter E	The Draft FMS	The framework for the assessment, authorisation and management of the DPI marine stocking program.
Chapter F	Alternatives Considered	Consideration of alternative options for implementing and managing the marine stocking program, including the 'no stocking' option.
Chapter G	Assessment of Impacts of Implementing the Draft FMS	Risk assessment and assessment of impacts, including a description of existing conditions and methods to mitigate and manage potential risks in relation to: ▪ Ecology; ▪ Threatened and Protected Species; ▪ Areas of Conservation Significance; ▪ Population Genetics; ▪ Disease, Parasites and Health; ▪ Aboriginal and Non-Aboriginal Cultural Values; ▪ Social Issues; ▪ Economics; and ▪ Other Impacts.
Chapter H	Justification	Detailed justification of the proposal in terms of its long-term suitability and with regard to principles of ESD.
Chapter I	References	List of references.

Volume III

Appendix 1	DGRs	All DGRs as provided by relevant Government Agencies
Appendix 2	State Significance Assessment	Threatened species assessments for species protected under State legislation
Appendix 3	Significance Assessment Commonwealth	Threatened species assessments for species protected under Commonwealth legislation
Appendix 4	Consultation	List of individuals/organisations consulted and copies of original letters/emails received.
Appendix 5	Social Case Studies	Case studies of social impacts of marine fish stocking in representative regional and metropolitan estuaries.
Appendix 6	SERM Outputs	Simple Estuarine Response Model Outputs used in estimating appropriate stocking rates.
Specialist Report A	Aboriginal Issues Assessment	Report on the interaction of Aboriginal cultural heritage values in relation to marine fish stocking.
Specialist Report B	Economic Feasibility Study	Report on the Economic Feasibility of the stocking program in relation to feasibility of species selected and regions proposed for stocking.

A.2.3 Stakeholder Consultation

Relevant local, State and Commonwealth government authorities, service providers, community groups, conservation groups, Aboriginal, recreational and commercial fishing stakeholders were consulted as part of the EIS process. Detailed consultation with Aboriginal community stakeholders (including statutory and non-statutory groups) was carried out by Umwelt (Australia) Pty Ltd and provided the basis for the assessment of impacts on Aboriginal cultural values. Stakeholders were engaged through a series of workshops in regional and metropolitan areas near to areas likely to be stocked and also through written correspondence. Feedback was received on the species and estuaries proposed for marine stocking as well as other general aspects of the proposal, including environmental concerns. The NSW Advisory Council on Recreational Fishing (ACoRF) and the Recreational Fishing Saltwater Trust Expenditure Committee (RFSTEC) responded to a questionnaire on which factors were considered the most important in relation to selecting estuaries appropriate for marine stocking.

A.2.4 Risk Management Approach

The EIS used a formalised risk assessment process adapted from the Australian and New Zealand Standard guidelines for risk management (AS/NZS 4360:2004) and the Handbook for Environmental Risk Management – Principles and Process (HB 203:2006)(Standards Australia 2006) which are considered international benchmarks in standard risk management. The risk analysis methodology deals mainly with impacts on the environment, however, the methodology was also adapted to analyse social and cultural impacts. Potential risks from the proposed marine stocking program were identified through a combination of workshops, specialist advice, literature review, stakeholder consultation and from issues identified in the DGRs. The risk analysis identified the relative significance of risks both before and after the treatment of risks (i.e. through the implementation of the draft FMS). Economic risks were not considered within the risk analysis methodology; instead they are discussed in a feasibility study carried out by Cardno (NSW/ACT) Pty Ltd and detailed in Specialist report B.

A.3 Description of the Proposal

A.3.1 Marine Stocking Locations

There are approximately 158 estuaries occurring along the NSW coastline, however, not all are suitable for stocking for a number of different ecological, physico-chemical and social factors, or because fish stocking is inconsistent with existing waterway usage. In order to identify a list of suitable estuaries that would be considered for future stocking events, a multi-criteria analysis (MCA) was carried out. The key aim of the MCA process was to identify estuaries where stocking the nominated species could be expected to result in the enhancement of fishing opportunities. A total of 80 estuaries were identified as suitable for stocking although not all species are suitable for stocking in every estuary because of ecological and other constraints. These constraints are discussed within the EIS and outlined within the draft FMS.

A.3.2 Species Proposed for Marine Stocking

Species proposed for marine stocking are:

- Yellowfin bream (*Acanthopagrus australis*);
- Mulloway (*Argyrosomus japonicus*);
- Dusky flathead (*Platycephalus fuscus*);
- Sand whiting (*Sillago ciliata*);
- Eastern king prawn (*Melicertus plebejus*);
- Giant mud crab (*Scylla serrata*);
- Blue swimmer crab (*Portunus pelagicus*).

The above species were shortlisted from a large number of potential candidates. They are considered most suitable in terms of the overall project aims, in terms of their biology/ecology and are popular recreational species which can be produced in aquaculture facilities in suitable quantities.

A.3.3 Operation

A.3.3.1 Definition of a Stocking Event

A stocking event is defined as 'single or multiple releases of a species in a particular estuary and includes the time it takes for all released post-larvae or juveniles to reach a harvestable size'. The duration of stocking events would vary among species depending on the growth rates and life cycles of the individual species.

Stocking events would be distributed across the three 'stocking regions' (i.e. Northern, Central and Southern) as identified in the EIS. DPI would endeavour to stock into the highest ranking estuaries as defined by the MCA for the selected species in order to best achieve the programs objectives. It is not possible to calculate the exact number of fish to be released in any one season through the harvest stocking program due to the number of combinations of fish species and estuaries possible within the proposal. However, this number would be limited through production constraints and stocking in recruitment limited situations only and is further restricted to the conservative recommended stocking rates as determined through modelling carried out as part of the EIS.

A.3.3.2 Sources of Broodstock

Broodstock are a group of sexually mature individuals of a species that are kept for breeding purposes. The use of appropriate broodstock and suitable hatchery protocols are essential to ensure that the genetic diversity of naturally occurring populations is maintained.

For five of the species in the proposal (dusky flathead, mulloway, sand whiting, yellowfin bream and giant mud crabs), it is unclear whether separate stocks occur in some estuaries or whether stocks range over wider areas or are panmictic across the NSW coast. Until more information on species genetic stock structure is available and under the precautionary principle, broodstock for the program would be sourced from the estuaries into which juveniles would be stocked. For the other two species (eastern king prawns and blue swimmer crabs), more information is available that allows conclusions to be made about their stock structure. Based on what is known about their stock structure, two separate genetic regions have been established for both the eastern king prawn and blue swimmer crab. Broodstock may be collected from anywhere within these genetic regions for stocking estuaries within that same region. These constraints and the specific boundaries of the genetic regions are outlined within the draft FMS (Chapter E, Appendix E.4.1).

Only hatcheries accredited under the Hatchery Quality Assurance System (HQAS) or other recognised accreditation program, which will be developed to include marine species, may produce stock for marine fish stocking.

A.3.3.3 Authorisation of Marine Stocking Events

Every stocking event that involves the release of fish into public waters of NSW requires authorisation under a stocking permit (Section 216 of the FM Act). Marine stocking programs conducted by DPI as well as individual fish releases would be permitted in estuarine waters subject to assessment under the marine fish stocking FMS. In the past, government agencies, non-affiliated fishing clubs, cultural groups and other organisations have all utilised the fish stocking permit system and are likely to also utilise the opportunity to stock the selected marine species. Aboriginal communities throughout NSW also place strong and continued cultural significance to each of the native species used in stocking programs. Individual or nominated members of an organisation can apply for a permit to release fish into public waters of NSW to support recreational, conservation or cultural purposes (Section 216 of the FM Act).

A.3.3.4 Ownership and Responsibility of the Ongoing Program

DPI would be the main agency carrying out marine fish stocking activity and would be responsible for managing all fish releases in NSW public waters. DPI would also be responsible for managing HQAS accredited aquaculture facilities where fish stocks would be produced for release in accordance with the marine fish stocking FMS. DPI would also be responsible for administering and approving other applications to stock under Section 216 of the FM Act (permit to release fish). Fish to be stocked would be sourced from suitably accredited hatcheries. It is not intended that any new hatchery facilities would require development at the initial stage of the project.

A.4 Assessment of Impacts

The following Section briefly describes the risks of the proposed activity as they pertain to biophysical, social and other (physico-chemical) components, the management responses proposed in the draft FMS to mitigate those risks, the residual risk and the expected outcome. The results of the assessment are also summarised in Table A.1. The potential impacts of the proposed activity were assessed under the following main areas:

1. Biophysical Impacts
   - Ecology;
   - Threatened Species, Populations and Ecological Communities;
   - Areas of Conservation Significance;
   - Population Genetics;
   - Disease, Parasites and Pests.
2. Social Issues
   - Aboriginal Social Issues;
   - Non – Aboriginal Social Issues.
3. Other (Physico – Chemical) Impacts
   - Water Quality;
   - Noise and Light;
   - Air Quality;
   - Energy.

An economic feasibility study was also carried out as part of the EIS which investigated the economic factors involved in marine fish stocking and recommends species and regions that are likely to result in the most favourable economic returns.

A.4.1 Biophysical Impacts

A.4.1.1 Ecology

Risk

Many studies have indicated that hatchery-released juveniles of a variety of fish and invertebrate species are able to survive in the wild and increase overall abundance of species, however, there is uncertainty about whether the increased abundances of stocked species displace wild conspecifics or other species with similar food or habitat requirements. When stocked individuals are put in a waterway the frequency of density-dependant interactions, such as predation and competition for food or habitat could increase. Without proper controls, 'overstocking' is possible whereby intra- and inter-specific competition are increased to levels that can lead to starvation, food limitation, stunting or cannibalism among wild conspecifics or competitors. Such effects could flow on to species further up and down the food chain having impacts at other trophic levels. In addition, if stocking were to substantially increase fishing effort, this could have negative effect by increasing pressure on wild stocks. The majority of impacts would be most relevant to species/populations that occur in stocked estuaries, although some potential impacts could be wider reaching. Almost all estuarine species would potentially be affected because of ontogenic changes in the dietary and habitat requirements of stocked fish or crustaceans and because stocked species may be the prey of higher consumers.

Stocking also has potential to affect estuarine habitats, directly (eastern king prawns may graze on seagrass and the epiphytic algae that live on them), or indirectly by increasing activities associated with fishing that can cause habitat disturbance (e.g. trampling of seagrass beds, particularly when prawning). An increase in fishing activity could also increase littering, the loss or discard of fishing gear and disturbance to riparian and intertidal habitats that may be important for estuarine birds.

Management Strategy

The draft FMS contains a number of policies and measures that contribute to the protection of wild conspecifics and aim to preserve estuarine trophic dynamics. The most direct and influential of these are listed below:

Management Strategy	Research and Monitoring
Appropriate stocking rates for each approved species and estuary would be determined. Fishing catch and effort would be monitored. Stocking would be timed in relation to natural life cycles and species recruitment patterns. Species would be stocked only in estuaries occurring within their natural geographic range. It would be ensured that stocking releases take place at suitable access points or by boat. Research and monitoring for potential impacts on wild conspecifics would be carried out. DPI would carry out routine inspections to ensure compliance with existing fishing rules and regulations.	The genetic distribution of native species and sub-populations would be investigated. Reliable data regarding food chain interactions between stocked fish and the aquatic environment would be established. This would be used to refine stocking rates. Research would be carried out to investigate the distance stock travel from the point of release. Research would be carried out to investigate how harvest stocking techniques may be optimised.

Predicted Outcome

These measures are likely to adequately address the risks identified to wild populations and trophic dynamics within the receiving estuaries. A key strategy to mitigating potential impacts on wild conspecifics is to determine the food resources of the receiving estuary and to ensure that overstocking does not occur. As part of the EIS, modelling, based on growth and population parameters of the species in question and habitat specific parameters of the receiving estuaries, was used as a tool to assist in estimating appropriate stocking rates so that stocking does not disrupt the ecological balance of estuaries. The modelling has been applied to all the estuaries that will be considered for stocking to estimate the appropriate numbers of fish or crustaceans that can be stocked. The current modelling is, however, a first step and further empirical data would be obtained throughout the stocking program to test and improve the accuracy and effectiveness of the model and to further develop the standard formula for use in the future. The recommended stocking thresholds are therefore considered to be a starting point that would be refined through the research and monitoring proposed in the draft FMS.

It is considered unlikely that marine stocking would result in a regional or Statewide increase in fishing effort that could lead to overfishing of wild stocks. It is possible that there may be an increase in fishing effort at the local (estuary) scale (due to a redistribution of effort), however, based on the available literature, this is likely to be small.

In order to address this uncertainty, the level of fishing effort and changes in effort associated with stocking would be monitored in representative regional areas.

The above measures are also likely to mitigate the potential for impacts to adjacent coastal waters beyond the boundaries of the stocked estuaries. Based on the risk assessment and mitigation as identified within the draft FMS, the overall risk to wild populations, trophic dynamics, estuarine habitat and adjacent coastal areas posed by marine stocking is considered to be mostly low with no significant impacts expected.

A.4.1.2 Threatened and Protected Species

Risk

Potential impacts to threatened and protected species, populations and ecological communities include the exacerbation of key threatening processes (KTPs), trophic impacts (as discussed in Section A.4.1.1), incidental capture, disturbance and habitat damage. All of the identified impacts could potentially be caused by trophic impacts or by an increase and/or localised concentration of fishing and boating activity associated directly with marine stocking. The majority of impacts would be most relevant to species/populations that occur or move into stocked estuaries, although some potential impacts could be wider reaching. Species considered most at risk to stocking and associated activities included fish (e.g. grey nurse sharks (*Carcharias taurus*) and black cod (*Epinephelus daemelii*) among others), marine mammals (particularly large slow moving cetaceans prone to boat strike), marine turtles and shorebirds. A number of these species are also migratory. The endangered populations of the little penguin population at Manly (*Eudyptula minor*), strapweed (*Posidonia australis*) in Port Hacking, Botany Bay, Port Jackson, Pittwater, Brisbane Water and Lake Macquarie and a number of Endangered Ecological Communities were also identified to be potentially at some risk from trophic impacts or habitat disturbance/damage from marine stocking and related activities.

Management Strategy

The draft FMS contains a number of policies and measures that contribute to the protection of threatened species, the most direct and influential of these are listed below:

Management Strategy	Research and Monitoring
A schedule of estuaries permanently closed to stocking, including those which contain Ramsar wetlands and sanctuary zones within Marine Parks has been established. Stocking would not take place in these estuaries. A schedule of waters with restriction to stocking (including all other areas of Marine Parks, Aquatic Reserves, marine components of National Parks and Nature Reserves and Critical Habitat) has been established. Stocking would not take place in these areas. Stocking would be appropriately managed in areas where the activity may adversely affect a threatened species. Each proposed stocking event would be reviewed in accordance with environmental assessment guidelines (called 'stocking review guidelines'). An education strategy to improve community understanding and public perception of the activity would be developed. This would include general education on responsible fishing. Releases would take place from suitable access points or by boat to minimise habitat disturbance. All management strategies listed in the previous Section	The impacts of representative stocking activities on the biodiversity of native populations within stocking areas, having specific regard to areas of conservation significance and marine protected areas (MPAs) would be investigated. The distance stock travel from the point of release would be investigated. This would provide data to support reviews of stocking events where threatened species or ecological communities may be affected. Sightings and incidences involving threatened and protected species within stocked estuaries would be monitored and recorded. Monitoring and research would be carried out to determine potential trophic impacts through food chain interactions. Fishing catch and effort would be monitored. Interactions between stocked fish, threatened species and areas of conservation significance would be investigated. Reliable data regarding food chain interactions between stocked fish and the aquatic environment would be established. This would be used to refine stocking rates.

Management Strategy	Research and Monitoring
(A4.1.1) would also be employed to address the broader ecological risks.	

Predicted Outcome

These measures are likely to adequately address the risks identified to threatened species. By not stocking into waters which are designated as areas of conservation significance including critical habitats, impacts to threatened and protected species would be minimised. Stocking would not take place within the Taren Point within Botany Bay where there is an endangered ecological community of shorebirds, which could potentially be disturbed by fishermen accessing the shore. Releases would generally take place from suitable access points or by boat to prevent disturbance to riparian habitat.

Measures to address potential impacts on ecological components of the environment (Section A4.1.1) would also mitigate risks to threatened species. The numbers of individuals stocked in any one estuary would not disrupt the ecological balance of estuaries. Given the conservative estimates for maximum numbers fish that could be stocked within any one estuary, impacts on threatened and protected species would be unlikely. The stocking rates would, however, be refined through the research and monitoring proposed in the draft FMS.

The draft FMS recognises the implications of the uncertainly associated with the potential for localised increases to fishing effort by proposing close monitoring for potential changes to fishing effort and incidents to threatened species so that unsatisfactory linkages between the two can be recognised where they have occurred and the program modified accordingly.

Based on the risk assessment and the mitigation implemented by the draft FMS the overall risks to threatened and protected species are low to moderate, although moderate risk levels may be reduced further through the outcomes of the proposed monitoring.

As such, it is concluded that the proposed harvest stocking program is not considered to have a significant impact on any threatened species, population or endangered ecological community (including those which are matters of National Environmental Significance), therefore a Species Impact Statement or a referral under the EPBC Act is not considered to be required.

A.4.1.3 Areas of Conservation Significance

Risk

Areas of conservation significance that are entirely or partly associated with estuarine habitats or are linked to estuarine habitats may have the potential to be affected by marine fish stocking activity. These areas could include Ramsar wetlands, Marine Protected Areas (Marine Parks and Aquatic Reserves), Critical Habitat, World Heritage Areas, Wilderness Areas, National Parks and Nature Reserves with an aquatic component. Stocking is not proposed to occur in Ramsar wetlands and Marine Parks so these types of areas of conservation significance could only be indirectly affected by marine fish stocking. Other types of areas of conservation significance may be directly or indirectly impacted through a number of biophysical processes, this could include, the introduction of parasites and diseases (Section A4.1.5), ecological impacts on wild populations and trophic interactions, leading to ecosystem imbalances and indirect impacts on habitat through increased fishing activity (Section A4.1.1). Considering that areas of conservation significance are often representative of unique or pristine habitat, or may include habitat critical to the survival of a threatened or protected species, impacts to these areas could potentially cause serious long-term ecological damage.

Management Strategy

The draft FMS contains a number of policies and measures that contribute to the protection of areas of conservation significance, the most direct and influential of these are listed below:

Management Strategy	Research and Monitoring
A schedule of estuaries permanently closed to stocking, including those which contain Ramsar wetlands, World heritage areas, Wilderness areas and sanctuary zones within Marine Parks have been established. Stocking would not take place in these estuaries. A schedule of waters with restrictions to stocking (including all other areas of Marine Parks, Aquatic Reserves, marine components of National Parks and Nature Reserves and Critical Habitat) has been established. Stocking would not take place in these areas.	The impacts of representative stocking activities on the biodiversity of native populations within stocking areas, having specific regard to areas of conservation significance and MPAs would be investigated. The distance stock travel from the point of release would be investigated. This would provide data to support reviews of stocking events where threatened species or ecological communities may be affected. Interactions between stocked fish, threatened species and areas of conservation significance would be investigated.

Predicted Outcome

These measures are likely to adequately address the risks identified to areas of conservation significance. As estuaries occurring within Ramsar wetlands, World heritage areas, Wilderness areas and/or Marine Parks would not be stocked under the current description of the activity, no significant impacts to these areas would be expected. As a further precautionary measure, and to address impacts to aquatic reserves which do occur in some estuaries proposed for stocking (e.g. Botany Bay, Port Hacking and Port Jackson), research would be undertaken to monitor the movements of stocked fish to determine the potential for interactions with all types of areas of conservation significance. Research and monitoring would also help determine the level of interaction between stocked fish, threatened species and areas of conservation significance.

Provided this is done, in combination with other mitigative and management strategies to mitigate ecological risks (as outlined in Section A4.1.1), the overall risk to areas of conservation significance posed by marine fish stocking is expected to be low.

It is concluded that the proposed harvest stocking program is not considered to have a significant impact on any wetland of international importance (listed under the Ramsar convention), therefore a referral under the EPBC Act is not considered to be required.

A.4.1.4 Assessment under the Environment Protection and Conservation Act

The EIS has assessed the proposal in regard to world heritage properties, national heritage places, wetlands listed under the Ramsar convention, listed threatened and protected communities, migratory species and Commonwealth marine areas. The result of the assessment was that no significant impact to matters of national environmental significance was likely to occur as a result of the proposal. In light of these assessment results no referral for assessment under the EPBC act was considered necessary.

A.4.1.5 Population Genetics

Risk

The review of existing information regarding the potential impacts of marine stocking on the genetic integrity of wild populations of native fish indicated that marine stocking in the absence of genetic controls and management poses significant risks. These risks can be compounded when there is a lack of information about the genetic diversity of the populations from which broodstock are collected and into which progeny are released.

The genetic effects of marine stocking may be broadly divided into those that are a direct consequence of interbreeding between stocked fish and native fish (i.e. direct effects) and those that occur in the absence of interbreeding (i.e. indirect effects). Interbreeding can lead to offspring that are less well adapted for survival in the natural habitat (this is known as introgression) and has been demonstrated in salmon populations across the northern hemisphere. Another potential direct effect is from inbreeding alone i.e. when the genetic diversity of the stocked population is reduced due to hatchery bred juveniles being derived from a relatively small number of broodstock and outnumbering the native fish. This may lead to a reduction in the fitness of individuals in the enhanced population and ultimately a decline in population size (known as the Ryman-Laikre effect). Potential indirect genetic effects include wastage of gametes, overfishing of mixed stock fisheries and naturalisation leading to fragmentation.

Without controls on stocking, it is likely that yellowfin bream would be stocked into estuaries where wild populations of black bream occur. Hybridisation of these species is known to occur in NSW and may increase if yellowfin bream are stocked into estuaries where black bream occur, leading to further loss of pure black bream.

Management Strategy

The draft FMS contains a number of policies and measures to mitigate risks of genetic effects on wild populations, the most direct and influential of these are listed below:

Management Strategy	Research and Monitoring
Quality assurance standards and an accreditation system for hatcheries supplying fish stocking would be developed and implemented by modification of the existing HQAS for freshwater species. Approved 'broodstock collection genetic regions' for each species permitted for stocking have been designated. Broodstock would only be collected from these regions. Species specific stocking guidelines directly relevant to species ranges in NSW would be implemented. The use of appropriate technology in genetic resource management would be promoted. Genetic resource management guidelines for marine fish stocking in NSW (including best practice in broodstock collection and management) would be implemented.	The genetic distribution of native species used in the activity would be researched and mapped to refine future broodstock collection requirements. The genetic effective population size of the target species population in each estuary where marine stocking occurs would be determined. Current literature would be reviewed and research carried out to determine the most appropriate genetic protocols under NSW conditions with regard to native species breeding programs and broodstock management arrangements. The most appropriate genetic markers that can be applied to potential broodstock to test their ancestry would be determined.

Predicted Outcome

These measures are likely to adequately address the risks identified to population genetics, particularly the direct genetic effects. Modification of the existing freshwater HQAS as relevant to marine species would address these risks by outlining measures to preserve the genetic integrity of the hatchery bred stock and thus the genetic diversity of wild populations. In its current form, much of the HQAS is already generalised and applicable to marine stocking, although designation of appropriate regions for the collection of broodstock specific to the marine species would need to be applied.

Based on the literature review, it is unclear whether separate stocks occur in some estuaries or whether stocks range over wider areas or are panmictic across the NSW coast for five of the selected species (dusky flathead, mulloway, sand whiting, yellowfin bream and giant mud crabs). As described in Section A.3.3.2, using the precautionary approach, broodstock for the program would therefore be sourced from the estuaries into which juveniles would be stocked for these species until more detailed information on stock structure is available. For the other two species (eastern king prawns and blue swimmer crabs), more information is available that allows conclusions to be made about their stock structure. For these species broodstock may be collected from anywhere within prescribed genetic regions for stocking estuaries within those same regions (Chapter E, Appendix E.3).

Hatcheries accredited under the modified HQAS would require systems to individually identify broodstock to be used in marine stocking programs and would need sufficient ponds or tanks to separate broodstock from different estuaries.

Yellowfin bream would only be stocked into estuaries outside of the known distribution of black bream, including a 50 km buffer zone to ensure the risk of hybridisation and wastage of gametes is mitigated for.

Research and monitoring plans are proposed in the draft FMS for reducing the potential for direct genetic effects by determining baseline genetic effective population sizes of wild fish populations in estuaries to be stocked. In addition, the genetic population structure of mulloway, giant mud crab, dusky flathead, yellowfin bream and sand whiting would be verified in order to minimise the constraints on broodstock collection and use. With the adoption of further genetic resource protocols into the existing HQAS and additional research, the overall risks to the genetic integrity of wild populations would be low to moderate and no significant environmental impact would be expected.

A.4.1.6 Disease, Parasites and Pests

Risk

Intensive rearing of juveniles in hatcheries can potentially create a favourable climate for the amplification of pathogens, which increases the potential for disease transmission to wild stocks. Certain viruses, bacteria, fungi, parasites and other organisms that may not be pathogenic under normal environmental conditions can become problematic in intensive rearing situations. Risks associated with disease and parasites and their potential impacts in relation to marine stocking activities, include the potential for infection of hatchery reared fish/crustaceans with diseases/parasites causing contamination of the aquaculture facility, adjacent waterway and translocation of crustacean or fish diseases/parasites into wild populations via hatcheries. Risks of translocation and/or infection with diseases/parasites exotic to NSW were generally considered to pose a greater risk than those considered to be endemic to NSW. Endemic diseases and parasites are likely to occur at background levels within the natural environment and hence native species are likely to have some resistance to increased infections. Without proper control there is also a risk that hatchery bred fish may be less susceptible to diseases and parasites and if released into the wild have potential to cause undesirable modification of wild genotypes through interbreeding. In the absence of stringent hatchery protocols and management, it is possible that the quality and health of the hatchery bred fish may be compromised within the hatchery or during transport leading to high post-release mortality. Only native species would be stocked within their natural geographic range under the proposed marine stocking program, however, there are still risks associated with the accidental release of non-target species, fouling and pest organisms. The accidental introduction of certain non-native or pest organisms may have serious detrimental impacts on the environment and other native species and therefore requires stringent management.

Management Strategy

The draft FMS contains a number of policies and measures that contribute to the management of diseases/parasites and pests of stocked and wild populations, the most direct and influential of these are listed below:

Management Strategy	Research and Monitoring
Adequate health and conditioning would be ensured by using stock reared in hatcheries that comply with the NSW HQAS. It would be ensured that any fish, eggs or larvae procured from interstate hatcheries for NSW fish stocking meet HQAS standards. Broodstock would be screened to be clinically healthy and treated for external parasites as part of HQAS quarantine procedures any diseases identified would assist with the knowledge of the disease status of the broodstock source area and further species specific risk assessments would be carried out if required. A Code of Practice that defines and promotes best practice in transport medium management, ethical treatment and care of stock, stocking verification procedures and the assessment of disease and fish health would be developed and implemented. The activity would be managed in accordance with State and national policies governing the translocation of live aquatic organisms.	Diseases which pose a translocation risk in NSW waters would be identified. Diseases which pose a genetic resistance risk in hatcheries would be identified.

Predicted Outcome

These measures are likely to adequately address the disease risks identified that could affect hatchery reared and wild populations. The key to disease prevention and management is the implementation of certification processes (i.e. the HQAS), which includes quarantine procedures, surveillance and monitoring within hatchery facilities and disease zoning policies.

HQAS would also be developed to involve a system whereby the DPI Biosecurity Branch (and any other relevant authorities) would immediately be notified of any disease thought not to occur in Australia or in NSW. Infection of broodstock in hatcheries would be minimised through screening of broodstock and seedstock and by minimising stressful environments especially during the culture period. In addition, knowledge of the pest and disease status of the source area (through HQAS broodstock quarantine procedures) prior to stocking would provide early indications of potential parasite and disease problems that may occur as a consequence of collecting broodstock. A code of practice developed to define and promote best practice in stocking techniques (including procedures for disease and health assessment) would ensure that stock remain in the good condition during transport and release and have good post-release survival.

These measures, in addition to existing quarantine arrangements in national and State-based translocation policies for cultured organisms would minimise disease risks to low-moderate and no significant environmental impact would be expected.

A.4.2 Social Issues

A.4.2.1 Aboriginal Social Issues

Risk

Activity associated with marine stocking (including accessing stocked waterways) has potential to impact on sites, places and objects of Aboriginal heritage value, many of which may occur along estuarine shorelines. The proposal to stock marine fish also raises issues in relation to Aboriginal social values because of the strong cultural and socio-economic association with estuarine fishery resources. The consultation process highlighted the strong views that Aboriginal stakeholders have in regard to maintaining a healthy and productive estuarine system. There is a high risk that insufficient information and involvement of Aboriginal stakeholders in the management, planning and implementation of stocking activities could result in uncertainty about the long-term impact of marine stocking on wild stocks and estuary health and concerns about lack of equity in access to the resource. There is also a perceived risk that stocking into estuaries where commercial fishing is permitted would result in less opportunity for Aboriginal cultural fishers to access the newly enhanced resource, which would also provide a source of food.

Management Strategy

The draft FMS contains a number of policies and measures that address potential risks to Aboriginal cultural heritage values that may arise from the proposed activity, the most direct and influential of these are listed below:

Management Strategy	Research and Monitoring
DPI would not conduct stocking inside estuarine Aboriginal Places without the approval of the relevant local Aboriginal stakeholder groups and the Office of Environment and Heritage (OEH). Stocking would not be conducted in areas where the local Aboriginal community expresses a specific cultural concern about the detrimental impact of fish stocking on the spiritual or other cultural values of an Aboriginal Place. DPI would consult with representatives of the local Aboriginal community groups at new estuaries that may be stocked in any given year. DPI would provide opportunities for Aboriginal stakeholders and the local community to be involved in	The level of socio-economic benefit for marine stocking would be monitored using surveys undertaken on an episodic basis. Research would be carried out to optimise harvest stocking releases.

Management Strategy	Research and Monitoring
planning, implementation and monitoring of marine stocking events. DPI would maintain sound records of the effects of marine stocking and ensure local communities and stakeholders are informed of relevant outcomes of stocking activities. DPI would continue to run long-term habitat restoration and protection programs that would complement marine fish stocking. Stockings would initially be small-scale and monitored to ensure success in line with appropriate management objectives.	

Predicted Outcome

These measures are likely to adequately address the risks identified to Aboriginal cultural heritage and the cultural values of Aboriginal stakeholders. The draft FMS represents a significant commitment to improving the involvement of Aboriginal communities in the activity of marine stocking and is consistent with the Indigenous Fisheries Strategy. The draft FMS provides mechanisms to engage communities in the activity of marine 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.

A protocol to consult with representatives of the local Aboriginal community groups would be developed that would be applied to each new estuary prior to any stocking activity. This would help identify any Places, sites or objects of Aboriginal cultural significance or relevant issues so that stocking activity can be managed appropriately. In order to ensure equity of access to stocked fisheries resources between Aboriginal cultural fishers, recreational fishers and commercial fishers, both estuaries which are Recreational Fishing Havens (RFHs) and estuaries open to commercial fishing would be considered for stocking.

A.4.2.2 Non- Aboriginal Social Issues

Risk

The activity of marine fish stocking as proposed could take place in any of 80 estuaries along the NSW coastline. As such, there is potential for conflict with non-Aboriginal heritage and social values. Other non- Aboriginal heritage sites may be listed under the Statewide Local Environmental Plan (LEP) template. Without reviewing each individual LEP prior to stocking there is a risk that recreational fishers or groups carrying out the releases could impact on items or sites of non-Aboriginal cultural significance through accessing the waterways. Increased recreational fishing may also be inconsistent with LEP zoning for particular areas.

Three community consultation workshops were held in Ballina, Sydney and Merimbula to get feedback from local stakeholders across the stocking regions. These meetings provided a basis for identifying further social issues that may require consideration in the implementation of the marine stocking program. One of the main issues was the potential for conflict between commercial fishers, aquaculture businesses and recreational fishers if stocked species interfered with commercial harvest or species being produced in sea cages or oyster leases. Without adequate consultation and the support of the local community where marine stocking is being implemented, it is also possible that the activity will be perceived as having detrimental environmental or social impact, thus failing to meet the objectives of the proposed activity.

Management Strategy

The draft FMS contains a number of policies and measures that address potential risks to non-Aboriginal cultural social issues that may arise from the proposed activity, the most direct and influential of these are listed below:

Management Strategy	Research and Monitoring
Relevant LEPs would be reviewed prior to stocking for listings of heritage places or objects under the Marine Stocking Review Guidelines. There would be a balance between the number of RFHs and non RFHs that are stocked. Stocking in parts of estuaries where oyster leases occur would be avoided. Mechanisms would be in place to report concerns and conflict in regard to stocking activity through an administrative framework. DPI would undertake further consultation with oyster farmers and industry representatives and monitor for any impacts. Further community consultation and education during the stocking process would be carried out to promote awareness and support.	The distance stock travel from the point of release would be investigated. The level of socio-economic benefit for fish stocking would be monitored using surveys undertaken on an episodic basis. This would include monitoring of fishing catch and effort. Research would be carried out to optimise harvest stocking releases.

Predicted Outcome

These measures are likely to adequately address the risks identified to non-Aboriginal cultural heritage values or social issues. Review of LEPs as part of the Stocking Review Guidelines would identify listed heritage places or objects that could be impinged upon prior to stocking occurring, therefore potential impacts on these places or objects would be prevented through consultation with the relevant authorities and adjustment of stocking activities as appropriate.

Reports of incidences of resource conflict would be included into a central database for review and further investigation where appropriate. In order to ensure access to stocked fisheries resources between recreational, Aboriginal cultural and commercial fishers, both estuaries which are RFHs and estuaries open to commercial fishing would be stocked. The draft FMS would also provide for opportunities for ceremonial/religious stockings. Provided these measures are implemented as described the majority of risks would be low, although the potential for stocked species (particularly giant mud crabs) to affect oyster leases would remain at moderate. Consultation with representatives of the oyster industry and lease holders in stocked estuaries would help clarify issues of concern and how these risks might be minimised. Research would also be carried out to determine the distance that stock may travel from the point of release which would help address uncertainty about how stocking might affect aquaculture in other parts of an estuary. Fishing catch and effort would also be monitored. This would contribute to measuring the socio-economic benefits of stocking as well as identifying any potential issues such as increased traffic, parking issues or crowding of boat ramps. Procedures for monitoring catch and effort would be established following the development of the stocking plan.

A.4.3 Other Impacts

Risk

There are a range of physico-chemical parameters that could potentially be influenced through activities such as recreational boating in association with stocking activity. A localised increase in boating activity could, for example result in a reduction in water quality (particularly in small, poorly flushed water bodies) and noise/light pollution. There is also potential for increased production within existing aquaculture facilities to result in unsustainable use of energy and reduction in water quality. The risk of marine stocking and aquaculture affecting these parameters is, however, relatively low because of the stringent controls, policies and legislation that currently regulate environmental pollution.

Management Strategy

The draft FMS contains a number of policies and measures that may be introduced to further improve the efficiency and environmental impact of marine stocking activity on physico-chemical environmental aspects, the most direct and influential of these are listed below:

Management Strategy	Research and Monitoring
It would be ensured that juvenile fish/crustaceans for stocking are reared in hatcheries that comply with the NSW HQAS. Marine fish stocking would be managed in accordance with principles of ESD. DPI would ensure there are mechanisms in place to report concerns over water quality, light or noise pollution (potentially related to marine stocking) for further investigation where necessary.	Water quality (within hatcheries) would be monitored as part of the HQAS. The level of socio-economic benefit from fish stocking would be monitored using surveys undertaken on an episodic basis.

Predicted Outcome

No significant environmental impact on water quality, noise/light pollution, air quality and energy consumption would be expected from the implementation of the marine stocking program. The efficiency and sustainability of hatchery operations may also improve by ensuring that hatcheries used for marine stocking are accredited under the HQAS and promote best-practice methods where possible.

A.4.4 Summary of Risks and Issues

A summary of the risks/issues identified through the EIS process, the mitigation/management measures proposed through the draft FMS to address those issues and the residual risks following mitigation/management are summarised below:

Environmental Aspect	Risk Description	Risk Level (Before Treatment)	Fisheries Management Strategy (FMS)	Treatment Type	Risk Level (After Treatment)
Ecology					
Conspecifics	Decrease in abundance of wild conspecifics e.g. from overstocking and/or increased fishing effort	High	Maximum stocking rates would not be exceeded Routine compliance inspections Research and monitoring	Reduce likelihood and consequence	Low
	Alteration of size-structure in populations	High	Maximum stocking rates would not be exceeded Routine compliance inspections Research and monitoring Stocking to be timed with natural recruitment patterns	Reduce likelihood and consequence	Low
	Alteration of the natural species distribution	Moderate	Species would be stocked into habitats and estuaries in which they occur naturally and within their natural range	Reduce consequence	Low

Environmental Aspect	Risk Description	Risk Level (Before Treatment)	Fisheries Management Strategy (FMS)	Treatment Type	Risk Level (After Treatment)
Ecology					
Competitors	Alteration of the distribution, abundance or structure of populations e.g. through inter-specific competition and/overstocking/increased fishing effort	High	Maximum stocking rates would not be exceeded Routine compliance inspections Research and monitoring	Reduce likelihood and consequence	Low
Other trophic levels	Alteration of the distribution, abundance or structure of populations	High	Maximum stocking rates would not be exceeded Routine compliance inspections Research and monitoring	Reduce likelihood and consequence	Low
Habitat	Direct effects (e.g. overgrazing of seagrass by stocked crustaceans)	High	Maximum stocking rates would not be exceeded Consistency with habitat protection programs Research and monitoring	Reduce likelihood and consequence	Low
Habitat	Indirect effects (e.g. trampling, littering, habitat disturbance)	High	Ensure releases take place at suitable access points or by boat Consistency with habitat protection programs Research and monitoring	Reduce consequence	Moderate
Adjacent coastal waters	Potential ecological impacts beyond the estuary e.g. trophic effects and competitive interactions	Low	No mitigation required Maximum stocking rates would not be exceeded Research and monitoring	Reduce likelihood	Low

Environmental Aspect	Risk Description	Risk Level (Before Treatment)	Fisheries Management Strategy (FMS)	Treatment Type	Risk Level (After Treatment)
Threatened and Protected Species, Populations and Communities					
Key Threatening Processes (KTPs)	Hook and line fishing in areas important for the survival of threatened fish species (FM Act)	High	Stocking would not take place into declared critical habitat of a threatened species of fish Monitor incidence of hooking mortality and fishing effort and manage as appropriate Education on responsible fishing	Reduce likelihood	Moderate
	Injury and fatality to vertebrate marine life caused by ingestion of, or entanglement in, harmful marine debris (EPBC Act)	High	Monitoring incidence of injury/fatality and fishing effort and manage as appropriate Education on responsible fishing	Reduce likelihood	Moderate
	Entanglement or ingestion of anthropogenic debris in marine and estuarine environments (TSC Act)	High	Monitor incidence of injury/fatality and fishing effort and manage as appropriate Education on responsible fishing	Reduce likelihood	Moderate
Trophic impacts	Competition and predation	High	Maximum stocking rates would not be exceeded Research and Monitoring	Reduce likelihood and consequence	Low
Increase/concentration of boating activity	Acoustic disturbance (marine mammals)	Moderate	No mitigation required Promote compliance with existing restrictions on approach distance to baleen whales Monitoring fishing catch/effort	Reduce likelihood	Low
	Boat strike (marine mammals)	Low	No mitigation required. Monitoring fishing catch/effort Promote compliance with existing restrictions on approach distance to baleen whales	Reduce likelihood	Low

Environmental Aspect	Risk Description	Risk Level (Before Treatment)	Fisheries Management Strategy (FMS)	Treatment Type	Risk Level (After Treatment)
Threatened and Protected Species, Populations and Ecological Communities					
Incidental capture of threatened / protected species	Injury/mortality	High	Education on threatened species identification and best practise in the release of incidentally caught fish Monitor incidence of hooking mortality and fishing effort and manage as appropriate Use of existing DPI mechanisms to report incidence of incidental capture or sightings of threatened and protected species Stocking would not occur in areas of conservation significance	Reduce likelihood	Moderate
Habitat	Trampling/ habitat disturbance	High	Stocking would not take place into Areas of Conservation significance Stocking would not take place at Taren Point Releases would take place from suitable access points or by boat Research and Monitoring	Reduce consequence	Moderate

Environmental Aspect	Risk Description	Risk Level (Before Treatment)	Fisheries Management Strategy (FMS)	Treatment Type	Risk Level (After Treatment)
Areas of Conservation Significance					
Areas of conservation significance	Potential impacts on Ramsars wetlands (indirect). Note that estuaries occurring within a Ramsar would not be stocked	Low	No mitigation required Maximum stocking rates would not be exceeded Research and monitoring	Reduce likelihood	Low
	Potential impacts on the conservation value of Marine Parks. Note that estuaries occurring within a Ramsar would not be stocked	Low	No mitigation required Maximum stocking rates would not be exceeded Research and monitoring	Reduce likelihood	Low
	Potential impacts on the conservation value of Aquatic Reserves	High	Estuaries that have Aquatic Reserves would not be excluded from stocking, but stocking would not take place within Aquatic Reserves	Reduce likelihood and consequence	Low
	Potential impacts on the conservation value of National Parks with marine extensions and Nature Reserves	Low	No mitigation required Stocking would not take place in marine extensions of National Parks or Nature Reserves	Reduce likelihood	Low
	Potential impacts on the conservation value of Critical Habitats	Low	No mitigation required Stocking would not take place in declared Critical Habitats	Reduce likelihood	Low

Environmental Aspect	Risk Description	Risk Level (Before Treatment)	Fisheries Management Strategy (FMS)	Treatment Type	Risk Level (After Treatment)
Population Genetics – Yellowfin Bream					
Direct effects	Ryman-Laikre effect	High	HQAS developed to include marine species Fish would only be stocked by HQAS accredited hatcheries Broodstock would be collected from the estuary where stocking is to occur Research & monitoring	Reduce likelihood	Moderate
	Introgression	High	HQAS developed to include marine species Fish would only be stocked by HQAS accredited hatcheries Broodstock would be collected from the estuary where stocking is to occur until more detailed information on stock structure is available Research & monitoring	Reduce likelihood	Moderate
Indirect effects	Wastage of gametes	Extreme	A buffer zone would be established between the southern-most yellowfin bream stocking location and the northern-most black bream estuarine population to control the possible flow of stocked yellowfin bream southwards into black bream habitat HQAS measures to preserve genetic integrity	Avoid risk	Low
	Naturalisation leading to fragmentation	Low	No mitigation required	Accept risk level	Low
	Overfishing of mixed stock fisheries leading to a reduction in genetic diversity	Moderate	Routine compliance inspections Appropriate monitoring of catch rates and fishing effort	Reduce likelihood and consequence	Low

Environmental Aspect	Risk Description	Risk Level (Before Treatment)	Fisheries Management Strategy (FMS)	Treatment Type	Risk Level (After Treatment)
Population Genetics – Mulloway					
Direct effects	Ryman-Laikre effect	High	HQAS developed to include marine species Fish would only be stocked by HQAS accredited hatcheries Broodstock would be collected from the estuary where stocking is to occur Research & monitoring	Reduce likelihood	Moderate
	Introgression	High	HQAS developed to include marine species Fish would only be stocked by HQAS accredited hatcheries Broodstock would be collected from the estuary where stocking is to occur until more detailed information on stock structure is available Research & monitoring	Reduce likelihood	Moderate
Indirect effects	Wastage of gametes	Low	No mitigation required (HQAS measures would help preserve genetic integrity)	Accept risk level	Low
	Naturalisation leading to fragmentation	Low	No mitigation required	Accept risk level	Low
	Overfishing of mixed stock fisheries leading to a reduction in genetic diversity	Moderate	Routine compliance inspections Appropriate monitoring of catch rates and fishing effort	Reduce likelihood and consequence	Low

Environmental Aspect	Risk Description	Risk Level (Before Treatment)	Fisheries Management Strategy (FMS)	Treatment Type	Risk Level (After Treatment)
Population Genetics – Dusky Flathead					
Direct effects	Ryman-Laikre effect	High	HQAS developed to include marine species Fish would only be stocked by HQAS accredited hatcheries Broodstock would be collected from the estuary where stocking is to occur Research & monitoring	Reduce likelihood	Moderate
	Introgression	High	HQAS developed to include marine species Fish would only be stocked by HQAS accredited hatcheries Broodstock would be collected from the estuary where stocking is to occur until more detailed information on stock structure is available Research & monitoring	Reduce likelihood	Moderate
Indirect effects	Wastage of gametes	Low	No mitigation required (HQAS measures would help preserve genetic integrity)	Accept risk level	Low
	Naturalisation leading to fragmentation	Low	No mitigation required	Accept risk level	Low
	Overfishing of mixed stock fisheries leading to a reduction in genetic diversity	Moderate	Routine compliance inspections Appropriate monitoring of catch rates and fishing effort	Reduce likelihood and consequence	Low

Environmental Aspect	Risk Description	Risk Level (Before Treatment)	Fisheries Management Strategy (FMS)	Treatment Type	Risk Level (After Treatment)
Population Genetics – Sand Whiting					
Direct effects	Ryman-Laikre effect	High	HQAS developed to include marine species Fish would only be stocked by HQAS accredited hatcheries Broodstock would be collected from the estuary where stocking is to occur Research & monitoring	Reduce likelihood	Moderate
	Introgression	High	HQAS developed to include marine species Fish would only be stocked by HQAS accredited hatcheries Broodstock would be collected from the estuary where stocking is to occur until more detailed information on stock structure is available Research & monitoring	Reduce likelihood	Moderate
Indirect effects	Wastage of gametes	Low	No mitigation required (HQAS measures would help preserve genetic integrity)	Accept risk level	Low
	Naturalisation leading to fragmentation	Low	No mitigation required	Accept risk level	Low
	Overfishing of mixed stock fisheries leading to a reduction in genetic diversity	Moderate	Routine compliance inspections Appropriate monitoring of catch rates and fishing effort	Reduce likelihood and consequence	Low

Environmental Aspect	Risk Description	Risk Level (Before Treatment)	Fisheries Management Strategy (FMS)	Treatment Type	Risk Level (After Treatment)
Population Genetics – Eastern King Prawn					
Direct effects	Ryman-Laikre effect	Moderate	HQAS developed to include marine species Fish would only be stocked by HQAS accredited hatcheries Broodstock would be sourced from the genetic regions specified in the draft FMS	Accept risk level	Moderate
	Introgression	Moderate	HQAS developed to include marine species Fish would only be stocked by HQAS accredited hatcheries Broodstock would be sourced from the genetic regions specified in the draft FMS	Accept risk level	Moderate
Indirect effects	Wastage of gametes	Low	No mitigation required (HQAS measures would help preserve genetic integrity)	Accept risk level	Low
	Naturalisation leading to fragmentation	Low	No mitigation required	Accept risk level	Low
	Overfishing of mixed stock fisheries leading to a reduction in genetic diversity	Moderate	Routine compliance inspections Appropriate monitoring of catch rates and fishing effort	Reduce likelihood and consequence	Low

Environmental Aspect	Risk Description	Risk Level (Before Treatment)	Fisheries Management Strategy (FMS)	Treatment Type	Risk Level (After Treatment)
Population Genetics – Giant Mud Crab					
Direct effects	Ryman-Laikre effect	High	HQAS developed to include marine species Fish would only be stocked by HQAS accredited hatcheries Broodstock would be collected from the estuary where stocking is to occur Research & monitoring	Reduce likelihood	Moderate
	Introgression	High	HQAS developed to include marine species Fish would only be stocked by HQAS accredited hatcheries Broodstock would be collected from the estuary where stocking is to occur until more detailed information on stock structure is available Research & monitoring	Reduce likelihood	Moderate
Indirect effects	Wastage of gametes	Low	No mitigation required (HQAS measures would help preserve genetic integrity)	Accept risk level	Low
	Naturalisation leading to fragmentation	Moderate	Fish would be stocked at appropriate densities to prevent overstocking or swamping Variation of stockings in space and time	Reduce likelihood and consequence	Low
	Overfishing of mixed stock fisheries leading to a reduction in genetic diversity	Moderate	Routine compliance inspections Appropriate monitoring of catch rates and fishing effort	Reduce likelihood and consequence	Low

Environmental Aspect	Risk Description	Risk Level (Before Treatment)	Fisheries Management Strategy (FMS)	Treatment Type	Risk Level (After Treatment)
Population Genetics – Blue Swimmer Crab					
Direct effects	Ryman-Laikre effect	High	HQAS developed to include marine species Fish would only be stocked by HQAS accredited hatcheries Broodstock would be sourced from the genetic regions specified in the draft FMS Research & monitoring	Reduce likelihood	Moderate
	Introgression	High	HQAS developed to include marine species Fish would only be stocked by HQAS accredited hatcheries Broodstock would be sourced from the genetic regions specified in the draft FMS Research & monitoring	Reduce likelihood	Moderate
Indirect effects	Wastage of gametes	Low	No mitigation required (HQAS measures would help preserve genetic integrity)	Accept risk level	Low
	Naturalisation leading to fragmentation	Moderate	Fish would be stocked at appropriate densities to prevent overstocking or swamping Variation of stockings in space and time	Reduce likelihood and consequence	Low
	Overfishing of mixed stock fisheries leading to a reduction in genetic diversity	Moderate	Routine compliance inspections Appropriate monitoring of catch rates and fishing effort	Reduce likelihood and consequence	Low

Environmental Aspect	Risk Description	Risk Level (Before Treatment)	Fisheries Management Strategy (FMS)	Treatment Type	Risk Level (After Treatment)
Disease, Parasites and Pests					
Fish/Crustaceans	Infection of hatchery-reared fish with exotic disease/parasite causing contamination of farm and adjacent waterways	High	Fish/crustaceans would only be reared and stocked by HQAS accredited hatcheries. Health authorities would be notified immediately of any potential disease risk	Reduce likelihood	Moderate
	Infection of hatchery-reared fish with endemic disease/parasite causing contamination of farm and adjacent waterways	Moderate	Fish/crustaceans would only be reared and stocked by HQAS accredited hatcheries. Obtain further knowledge of disease risks in stocking zones Health authorities would be notified immediately of any potential disease risk	Reduce likelihood	Low
	Translocation of exotic fish disease/parasite from hatcheries into wild populations	High	Fish/crustaceans would only be reared and stocked by HQAS accredited hatcheries	Reduce likelihood	Moderate
	Translocation of endemic fish disease/parasite from hatcheries into wild populations	Moderate	Fish/crustaceans would only be reared and stocked by HQAS accredited hatcheries Obtain further knowledge of disease risks in stocking zones	Reduce likelihood	Low
	Translocation of non-target species	High	Fish/crustaceans would only be reared and stocked by HQAS accredited hatcheries Fish would not be stocked outside their natural range Contingency plans would be in place	Reduce likelihood and consequence	Low
	Translocation of other pest organisms	Moderate	Fish/crustaceans would only be reared and stocked by HQAS accredited hatcheries Contingency planning	Reduce likelihood and consequence	Low

Environmental Aspect	Risk Description	Risk Level (Before Treatment)	Fisheries Management Strategy (FMS)	Treatment Type	Risk Level (After Treatment)
Fish/Crustaceans	Release of stock selected for reduced disease/parasite susceptibility causing undesirable modification of wild genotypes	High	Fish would only be reared and stocked by HQAS accredited hatcheries	Reduce likelihood	Moderate

Environmental Aspect	Risk Description	Risk Level (Before Treatment)	Fisheries Management Strategy (FMS)	Treatment Type	Risk Level (After Treatment)
Hatchery, Transport and Release Procedures					
	Hatchery/farm culture system failure causing poor on-farm stock health and culminating in stock which have difficulty withstanding stresses associated with harvest, transport and/or handling procedures	Moderate	Fish/crustaceans would only be reared and stocked by HQAS accredited hatcheries	Reduce likelihood and consequence	Low
	Transport system failure causing poor stock health prior to release	Moderate	Conduct practically achievable (visual) health assessments immediately prior to release and retain fish (do not release) if significant health issues are apparent Develop a code of practice for the safe transport and release of stock	Reduce likelihood and consequence	Low
	Release system failure causing poor stock health and/or mortalities at the release site	Moderate	Post-stocking surveillance Recover and dispose of dead/contaminated fish appropriately Develop a code of practice for appropriate release of stock	Reduce likelihood and consequence	Low

Environmental Aspect	Risk Description	Risk Level (Before Treatment)	Fisheries Management Strategy (FMS)	Treatment Type	Risk Level (After Treatment)
Aboriginal Social Issues					
Aboriginal cultural heritage	Impingement on areas of Aboriginal cultural importance (sites and Places)	Moderate	Further consultation with Aboriginal community groups at each new estuary that would be stocked in any given year Stocking would not occur inside estuarine Aboriginal Places or in areas where the local Aboriginal community expresses a concern about the spiritual or cultural values of a place	Reduce Likelihood	Moderate
Aboriginal social issues	Lack of involvement of Aboriginal stakeholders in fishery management and stocking activities	Low	No mitigation required Consultation with local Aboriginal stakeholders prior to stocking of any new sites. The FMS aims to provide opportunity for Aboriginal communities to participate in stocking activities where feasible and ensure local communities and stakeholders are informed of outcomes of stocking	Reduce likelihood	Low
	Fish stocking not seen as adequate or good value or a sustainable approach to looking after sea country	Moderate	Ongoing long-term habitat restoration and protection programs would complement marine fish stocking Stockings would initially be small-scale Monitoring of stocking success	Accept risk level	Moderate
	Competition from other fishing sectors reduces Aboriginal access to stocked fish for a healthy diet	Moderate	Ensure a balance between the number of RFHs and non RFHs Research and monitoring Maintain records of the effects of fish stocking ensure stakeholders are informed of relevant outcomes. Monitoring and research	Reduce likelihood	Low

Environmental Aspect	Risk Description	Risk Level (Before Treatment)	Fisheries Management Strategy (FMS)	Treatment Type	Risk Level (After Treatment)
Non-Aboriginal Social Issues					
Non-Aboriginal cultural heritage	Fish stocking not consistent with objectives of Statewide template LEP zone for waterways or other Statewide requirements for the coastal zone	Moderate	Consultation with relevant State agencies and local government would ensure that the proposal is consistent with planning requirements for sensitive coastal waterways	Avoid risk	Low
	Impacts to Crown Land and assets (e.g. boating facilities, wharves, banks and bed etc)	Low	No mitigation required	Accept risk level	Low
Resource sharing	Resource sharing (e.g. conflict among fishing sectors)	Low	No mitigation required Ensure provision of mechanisms to report concerns and conflict through an administrative framework Ensure that there is a balance between the number of RFHs and non RFHs	Accept risk level	Low
Other waterway users	Conflict between fishing groups and other waterway users	Low	No mitigation required	Accept risk level	Low
Aquaculture industry	Impacts on oyster leases	High	Stocking would be avoided in parts of estuaries where oyster leases are present Further consultation with oyster farmers and industry representatives Monitoring and research to determine the distance moved by stocked fish	Reduce likelihood	Moderate
	Impacts on other aquaculture	Low	No mitigation required	Accept risk level	Low

Environmental Aspect	Risk Description	Risk Level (Before Treatment)	Fisheries Management Strategy (FMS)	Treatment Type	Risk Level (After Treatment)
Non-Aboriginal Social Issues					
Community support, interaction and fishing effort	Perceived negative environmental impact of fish stocking	Moderate	Further community consultation and education during the stocking process to ensure awareness and support	Reduce likelihood	Low
	Lack of community support	Low	No mitigation required Further community consultation and education during the stocking process to ensure awareness and support	Accept risk level	Low
	Increase/concentration of fishing participation/effort	Moderate	No mitigation required	Accept risk level	Moderate

Environmental Aspect	Risk Description	Risk Level (Before Treatment)	Fisheries Management Strategy (FMS)	Treatment Type	Risk Level (After Treatment)
Physico-Chemical					
Water quality	Direct reduction in water quality from increased boating (large, well flushed, open estuary)	Low	No mitigation required Promote existing best practice boating guidelines	Accept risk	Low
	Direct reduction in water quality from increased boating (small, poorly flushed, semi-enclosed water body)	Moderate	Promote existing best practice boating guidelines and ensure mechanisms are in place to report water quality concerns. Action to be taken as and when required	Accept risk	Moderate
	Indirect reduction in water quality from aquaculture operations	Low	No mitigation required Ensure that juvenile fish/crustaceans for stocking are reared in hatcheries that comply with the HQAS. Any unauthorised release of untreated water into natural waterways would be reported	Accept risk	Low
Noise	Noise disturbance from increased recreational fishing/stocking activity	Low	No mitigation required	Accept risk	Low
Light	Light pollution from increased recreational fishing/stocking activity	Low	No mitigation required	Accept risk	Low
Air quality	Impact on air quality (e.g. from car/ boat emissions/hatchery facilities)	Low	No mitigation required (Note: HQAS includes provisions to maintain air quality)	Accept risk	Low
Energy	Hatchery production fails to be energy efficient	Low	No mitigation required	Accept risk	Low

A.5 Alternatives Considered

During the EIS process, numerous alternatives were considered for addressing the risks identified through implementation of the marine stocking program under the draft FMS as proposed. These ranged from consideration of alternative broad-scale approaches (such as habitat restoration and changes to fisheries regulations), to a review of more practical alternatives, such as stocking different species, estuaries and sizes of juveniles and the 'no stocking' alternative. Other management responses that could be implemented through the draft FMS were also discussed and considered. Although many feasible alternatives are available for the management of marine stocking in NSW, the cautious and pro-active suite of management actions put in place by the draft FMS are considered to cater for contingencies in a manner far more effectively than the alternatives. This is achieved with the well-being of those involved in the activity in mind, both socially and economically, while potential impacts on the natural environment are also adequately managed.

A.6 Justification and Conclusion

Various components of the environment were found to be at risk due to a range of elements of the proposed marine stocking activity. The draft FMS proposes a suite of management responses that the risk assessment concludes would effectively address the potential environmental impacts. These measures are considered to reduce the risks identified in the assessment of impacts to a level that is considered to be environmentally acceptable. Where some uncertainty remains, the draft FMS also outlines a prioritised list of research and management responses which would be carried out in conjunction with the marine stocking program to provide additional information on the potential risk or would result in mitigating the risk.

Recreational fishing is considered to be an important form of sport and relaxation which provides opportunity to enjoy the outdoors and provides significant social benefits in urban and regional locations (consistent with the aims of the NSW State Plan 2021). For Aboriginal people, fishing is an integral part of cultural lifestyle, as it is important for ceremonial occasions, provides a source of food and is connected to the traditional responsibilities of coastal management and kinship (Henry and Lyle 2003). Commercial fishing is also an important primary industry in NSW estuaries. The marine stocking program proposed under the draft FMS would not only benefit recreational fishers but also Aboriginal and commercial fishers. The species proposed for marine stocking are important to each of these fishing groups and to ensure access to stocked fisheries, estuaries which are RFHs and estuaries open to commercial fishing would be stocked.

Economic benefits from marine stocking are likely to be through direct expenditure on fishing related items and indirectly through tourism and employment. Stocking events would be distributed across three 'stocking regions' (i.e. northern, central and southern), to allow both metropolitan and regional coastal areas of the State to benefit. Employment opportunities within DPI would not be created through the marine stocking program, however, HQAS accredited hatchery operators, which would be registered to breed the stocked species, may directly benefit from financial contracts and may employ additional staff to handle additional work. All seven species proposed are considered economically viable for marine stocking, although some more than others because of the time it takes to reach a harvestable size and their relative market value. Similarly, stocking is considered to be economically viable for all the regions included in the economic assessment, although the economic returns are likely to be greater for certain areas.

In conclusion, it is becoming evident that the role of stocking in fishery systems is becoming greater with traditional measures and stocking being integrated into fisheries management frameworks. The marine stocking activities, under the strict management regime of the draft FMS, reflect the widely accepted best practice approach to responsible marine stocking and is justified in terms of protecting the natural environment, enhancing stocks and protecting the interests of stakeholders in estuarine fisheries and the community. Appropriately managed marine stock enhancement is likely to improve the quality of estuarine fishing in NSW and contribute to the overall experience and enjoyment of recreational fishers.

A.7 Submissions

Public exhibition of the EIS provides an opportunity for community stakeholders to review the proposed marine stocking program and to have input into its future management. The EIS is now on exhibition for public comment for a minimum period of 30 days. This is an opportunity for the community and stakeholders to provide feedback which would be considered in the approval process.

Submissions can be provided individually or on behalf of a group, which may help to pool ideas and information. Group submissions should indicate the names of participants or if the group is larger than 10 people, the number of people the submission represents needs to be indicated. When submitting comments on the EIS, it is helpful to provide reasons and relevant data to support any conclusions. When submitting comments on the EIS:

- point of view should be clearly stated and listed;
- a summary of the submission can be helpful;
- refer each point to the appropriate Section of the EIS;
- discussions should be separate for each Section addressed;
- any relevant factual information may be attached with the source of the information indicated; and
- information provided should be accurate.

Submissions should be lodged in writing by the closing date by any of the following methods:

Online: fishstocking.eis@industry.nsw.gov.au

By Post: EIS Submission

Fish Stocking

3/556 Macauley Street

Albury NSW 2640

By Fax: (02) 6021 0113 (marked attention “Fish Stocking EIS Submission”)

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

Copies of the EIS and supporting documents can be viewed and downloaded at the Department of Planning and Infrastructure website www.planning.nsw.gov.au. Questions regarding submissions should also be directed to DPI:

Telephone: (02) 6042 4202

Fax: (02) 6021 0113

Email: fishstocking.eis@industry.nsw.gov.au

Further information can also be obtained at the DPI website:

www.fisheries.nsw.gov.au

Chapter B

Description of the Proposal

Chapter B Contents

List of Tables

List of Figures

CHAPTER B DESCRIPTION OF THE PROPOSAL

B.1 Introduction

It is recognised internationally that besides control of fishing effort and habitat protection or restoration, aquaculture-based enhancement is a third principal means by which fisheries can be sustained and improved (Bell *et al*. 2008, Munro and Bell 1997; Welcomme and Bartley 1998, Blaxter 2000, Bell *et al*. 2005). This is reflective of the synergy between capture fisheries and aquaculture and recognises the opportunity to apply hatchery technology to restore and augment some coastal fisheries through the release of cultured juveniles. Similar interventions have long been used in the management of freshwater fisheries (Bell *et al*. 2008, Cowx, 1994). New South Wales Department of Primary Industries (DPI) and private groups have used this synergy with aquaculture in the management of freshwater fisheries for over fifty years through the stocking of native fish and salmonids in freshwater rivers and impoundments to boost fish stocks and enhance recreational fishing opportunities for anglers, for Aboriginal cultural purposes and for religious and ceremonial purposes. In recent years, around six million fish have been stocked in freshwater systems of NSW every year.

Fish stocking is a declared designated fishing activity under Schedule 1A of the *Fisheries Management Act 1994* (FM Act) and as such requires preparation of an Environmental Impact Statement (EIS) and associated Fisheries Management Strategy (FMS) consistent with the requirements of the *Environmental Planning and Assessment Act 1979* (EP&A Act). A similar EIS and FMS were approved in 2005 for freshwater fish stocking. Despite the relative success of NSW freshwater stocking programs, the enhancement of marine fisheries in Australia is still in its infancy and at present there are no ongoing marine fish stocking programs (Taylor *et al*. 2005b). Worldwide however, there are major fish stock enhancement programs coupled with the extensive development of hatchery technologies to produce a variety of fish species within appropriate genetic and environmental parameters. Examples of large-scale stocking programs are given in Chapter C.

Between 2003 and 2008, DPI in collaboration with the University of New South Wales (UNSW) undertook research stockings of mulloway (*Argyrosomus japonicus*) in large estuaries and eastern king prawns (*Melicertus plebejus*) in Intermittently Closed/Open Lakes and Lagoons (ICOLLs). The lakes were closed to the sea at the time of stocking. Since 2004, approximately 127,000 mulloway fingerlings have been stocked into Botany Bay and three north coast estuaries and 9.5 million eastern king prawns into Wallagoot and Back Lakes to research the optimal stocking levels and habitat requirements for these species. These research stockings have proven to be successful (Taylor *et al.* 2005b) by combining a responsible approach with a sound knowledge of the dynamics and productive capacity of the target ecosystem to help ensure that appropriate species are stocked and sustained by the environment (Taylor *et al.* 2005a, 2005b, 2006a, 2006b).

DPI recognises that in order to be effective, the proposed marine fish stocking program will need to contribute to the ecological, economic, social, and institutional management objectives of the target fisheries (Bell *et al.* 2008). DPI proposes to implement a marine fish stocking program, in estuaries throughout New South Wales, for selected marine species. The program would involve the release of cultured juveniles into wild population(s) in recruitment limited situations to augment the natural supply of juveniles.

As part of the EIS for the proposal, a draft FMS has been developed specifically for marine fish stocking to outline a management approach for marine fish stocking practices, which until now has not existed. The draft FMS is a framework for the ongoing assessment of fish stocking activities and would incorporate recruitment limitation as a key assessment criterion. DPI would be the main organisation carrying out fish stocking events, however, other authorised agents such as fishing clubs, religious groups, Aboriginal community groups and other organisations would be permitted to release approved marine fish under section 216 of the FM Act, permit to release fish (refer to Chapter B, Section 6.4 and Chapter C, Section 6.1).

The Director General's Requirements (DGRs) for the preparation of the Marine Fish Stocking Environmental Impact Statement (EIS) require a full description of the proposal identifying:

- Details of the activities undertaken including the species to be stocked, sources of broodstock, stocking methods and locations, and quantity of fish to be stocked. These should be supported by maps / plans clearly showing the various stocking locations. Natural environmental features should also be included; and
- Operational details including the ownership and responsibility for the ongoing operation and management of the marine fish stocking program.

This section of the EIS provides a full description of the proposed activity of marine fish stocking.

B.2 Objectives of Marine Fish Stocking

The key objective of the proposed marine stocking program is to enhance fish stocks and improve recreational fishing opportunities through 'harvest stocking' within NSW. 'Harvest Stocking', is specifically defined as 'a DPI program of stocking NSW estuaries with native fish recognised as recruitment limited, to enhance both the stock and recreational fishing opportunities'.

Recruitment limitation can be species-based, location-based, or both. For example, recruitment of a species may be limited by fishing pressure, or a result of a small spawning biomass, and/or where the species exhibit characteristics of an overfished stock. Location-based recruitment limitation can occur where there is some type of location based environmental constraint, for example, where the waterway is intermittently closed off to the ocean by a sand berm, and/or where there are insufficient resources (food, habitat, refuge) for larval phases to survive and reach maturity.

Stocking of a limited suite of species will only take place where there is evidence of one of the aforementioned forms of recruitment limitation, and according to the criteria outlined in the draft FMS (Chapter E).

Harvest Stocking as defined above is a specific program implemented by DPI, marine stocking is however broader than the harvest stocking program and encompasses stocking for cultural and conservation purposes as well. This EIS has also assessed this broader scope of stocking where relevant.

Further objectives of the marine fish stocking program are to:

- Implement an environmentally sustainable stocking program with monitoring and assessment regimes;
- Optimise the survival and growth of stocked fish, crabs and prawns with respect to release size, release season and habitat;
- Ensure responsible stocking practices in accordance with the EIS and FMS for marine stocking; and
- Promote community awareness of responsible stocking practices.

B.3 Species to be Stocked

There are a number of factors that require consideration in prioritising and selecting suitable species of finfish and/or invertebrates for stock enhancement. Lorenzen *et al*. (2010) recommend that selection should be based on a process that scores species on enhancement potential, based on criteria such as stock assessments and fishery management needs; preliminary enhancement modelling results; extent of habitat and recruitment limitations; likely impact on resident biota; aquaculture capability, or potential, for mass production of juveniles; cost-benefit considerations; life-history and dispersal patterns. In the development of this proposal, DPI has followed a similar process of establishing factors for selecting species. The following factors were considered by DPI, in consultation with the Advisory Council on Recreational Fishing (ACoRF) and the Recreational Fishing Saltwater Trust Expenditure Committee (RFSTEC), in the species selection process:

- Whether there is a licensed hatchery(s) in NSW for the production of the species;
- Whether the species is commercially available from hatcheries;
- Whether there is rearing technology available for the species;
- Cost per fingerling;
- Whether the species is an estuarine resident as opposed to highly migratory, oceanic or non-estuarine residents (that cannot be effectively stocked into estuaries due to high rates of dispersal or dilution that prevents effective harvest). Species that are estuarine residents are therefore the most suitable candidates;
- Growth rate (this is important as benefits from stocking will be realised within a shorter timeframe e.g. two to four years for fast growing species); and
- Whether the species is considered to be recreationally important in NSW.

A shortlist of 25 candidate species was ranked in terms of their suitability to marine fish stocking in relation to the selection factors. Of the ten species that met the selection factors, black bream (*Acanthopagrus butcheri)*, trumpeter whiting (*Sillago maculata)* and school prawn (*Metapenaeus macleayi*) were later disregarded for the following feasibility reasons.

School prawns are very similar to eastern king prawns in many ways. They live in similar habitats, have similar growth rates and are regularly caught coincidentally by prawners. Although school prawns are targeted specifically in some North coast estuaries by recreational anglers the majority of recreational prawn catch (97 %) is eastern king prawns (Henry and Lyle 2003). Given that there would be little advantage to stocking both species and stocking trials for eastern king prawns in ICOLLs have been shown to be successful through pilot research stockings (Section C.8.5.5), school prawns have not been considered any further at this stage.

Due to their similarity, only one whiting species was assessed in the EIS. Sand whiting were considered more preferable than trumpeter whiting (*Sillago maculata*) because they grow to a much larger size.

Black bream also met most of the general selection criteria for consideration for marine fish stocking. However, recent research has shown that there are few pure-bred black bream in NSW with the majority being hybrids that have resulted from cross-breeding with yellowfin bream (Section C.8.1). An abundance of hybrids would make it difficult to source pure strain broodstock, hence black bream have not been considered further (see Chapter F, Section 5.1).

This type of selection process is widely accepted as best practice in prioritising species for stock enhancement (Leber 1994, Blankenship and Leber 1995 and Lorenzen *et al.* 2010).

The seven species proposed for the marine stocking program are:

- Yellowfin bream (*Acanthopagrus australis*);
- Mulloway (*Argyrosomus japonicus*);
- Dusky flathead (*Platycephalus fuscus*);
- Sand whiting (*Sillago ciliata*);
- Eastern king prawn (*Melicertus plebejus*);
- Giant mud crab (*Scylla serrata*); and
- Blue swimmer crab (*Portunus pelagicus*).

While the above species are considered to be the most appropriate candidates for harvest stocking at the time of EIS preparation, it is important to note that there is potential for other species to be stocked in future depending on advances in aquaculture technology, future research, changes in demand, fishery objectives and temporal trends in fish population dynamics. Stocking of alternative species is discussed in Chapter F, Section 5.1.

For each of the seven candidates, detailed descriptions of the natural distribution and genetic stock structure, habitat, life history, recreational importance and aquaculture technology available are given in Chapter C, Section 8. The suitability of each species is explored further and additional factors such as evidence for recruitment limitation (such as overfishing) are also discussed. The natural geographic range and known genetic stock structure is important in considering ecological and genetic constraints in the identification of risks (Chapter D) and assessment of impacts (Chapter G). The economic feasibility of stocking these species is also assessed in Specialist Report B.

B.4 Marine Fish Stocking Locations

DPI records and coastal habitat mapping (Jones and West 2005) indicate that there are approximately 158 estuaries occurring along the New South Wales coastline, however, not all are suitable for stocking due to a number of different ecological, physico-chemical and social factors. Given the large number of estuaries, a multi-criteria analysis (MCA) was carried out to identify a list of estuaries that could be considered suitable for harvest stocking in recruitment limited situations (Section B.5). According to the assessment criteria used in the MCA, a total of 80 estuaries were identified as suitable locations for harvest stocking in general but not all species are suitable for stocking in every estuary, for example because the estuary is located outside the natural geographic range of that species. Tables B.5 to B.7 rank each estuary in terms of its suitability for each species and also indicate estuaries where certain species cannot be stocked. Estuaries that will not be permitted for stocking under any circumstances (and the reasons) are also listed in Tables B.5 to B.7.

B.5 Multi-Criteria Analysis

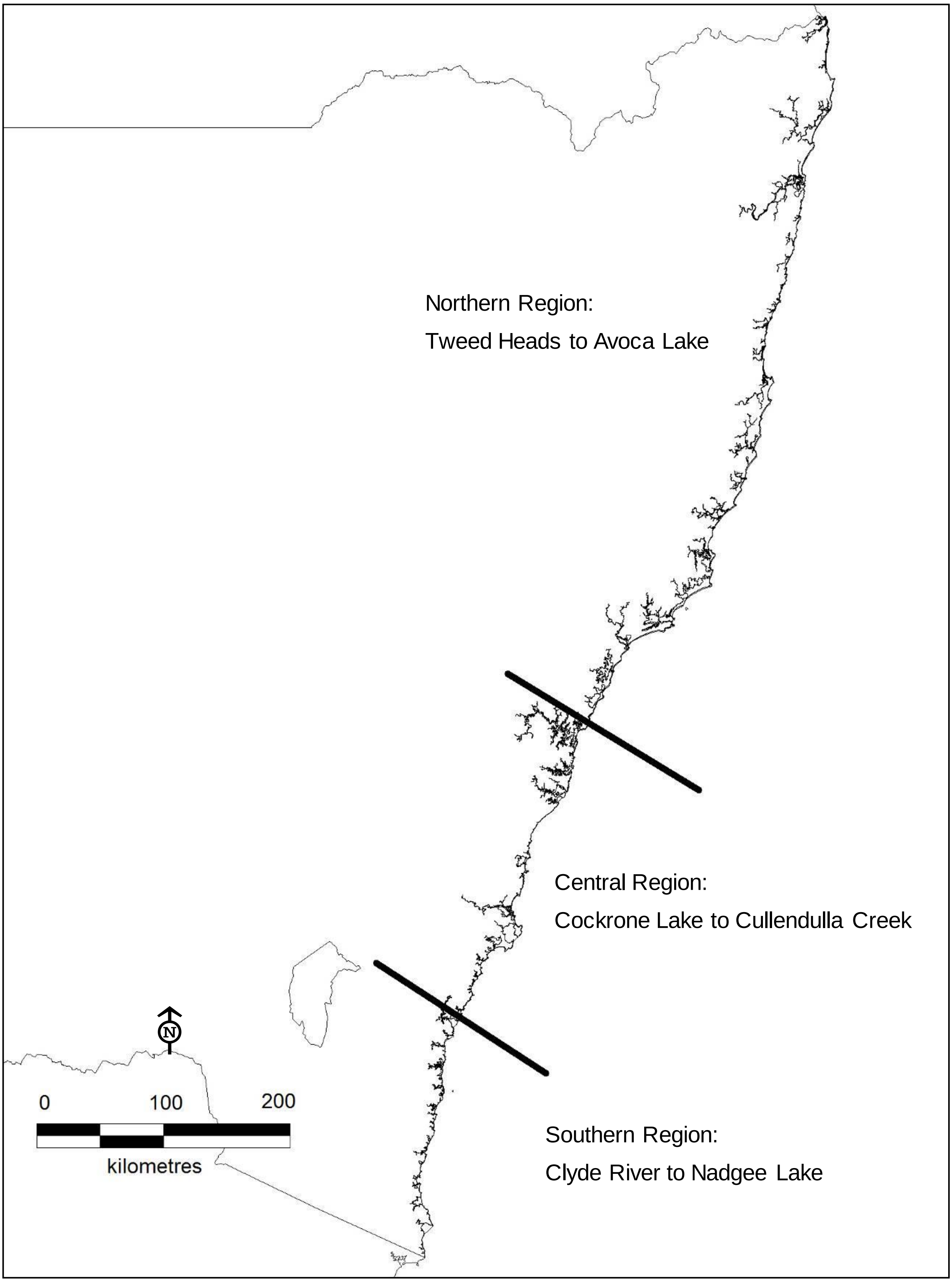
In order for fish stocking activities to achieve the aims of the proposal, locations for fish stocking must be appropriate and provide optimal conditions. To maximise outcomes of fish stocking activities, suitable locations for marine fish stocking were evaluated as part of the EIS using a MCA. The MCA is a rapid assessment method that ranks estuaries, for each species, according to their suitability as stocking locations based on weighted factors that included ecological, physico-chemical, and social factors. The process also eliminates some estuaries as potential stocking locations. The key aim of the MCA process was to identify estuaries where stocking the selected species could be expected to result in the enhancement of recreational fishing opportunities. While social and economic factors need to be considered for achieving this aim, ecological factors were given higher weightings in the MCA because it was considered that maximising the survival of stoked fish or crustaceans was of prime importance. Without suitable harvest of stocked fish or crustaceans, social and economic benefits would not be generated. It is important to note that although marine fish stocking could potentially occur in any of the estuaries selected using the MCA, it is not a requirement of the proposal to stock in all of these estuaries.

The list of species selected for stocking is given in Section B.3. The MCA was done separately for three regions that contained approximately the same number of estuaries for ease of assessment. These were:

- Northern Region: Tweed River to Avoca Lake (55 estuaries);
- Central Region: Cockrone Lake to Cullendulla Creek (54 estuaries); and
- Southern Region: Clyde River to Nadgee Lake (49 estuaries).

The locations of the boundaries between these regions are shown in Figure B.1.

Figure B.1: Stocking Regions



B.5.1 Estuary Selection Methodology

An initial list of 158 estuaries for consideration as stocking locations was generated using DPI records and coastal habitat mapping (Jones and West 2005). The 158 estuaries included all estuarine classifications within New South Wales, including the estuarine reaches of larger and smaller rivers and creeks, coastal embayments, estuarine lagoons with openings, varying from permanently closed to permanently open and also coastal lakes (for detailed descriptions of estuarine classification, see Chapter C, Section 7.2).

The MCA involved three stages:

- Stage 1 – this stage involved removing estuaries that would never be stocked due to physical characteristics of estuaries that would severely compromise the survival of stocked fish or crustaceans or government policies. Stage 1 generated a final list of estuaries;
- Stage 2 – the final list of estuaries were scored against factors generally affecting the suitability of marine fish stocking; and
- Stage 3 – the final list of estuaries were ranked according to their suitability for stocking particular species. This involved combining scores from Stage 2 with additional scores generated in Stage 3 pertaining to factors potentially affecting the stocking success of each of the seven candidate species.

The staged estuary selection process described below was undertaken separately for estuaries within the Northern, Central and Southern regions, as defined above.

Stage 1

Stage 1 of the of the MCA selection process aimed to eliminate estuaries that would be unsuitable for stocking due to obvious physical criteria or existing conservation status. Freshwater bodies were not included in the assessment of suitability as only saltwater species are to be stocked. Unsuitable estuaries included:

- Those whose small size would indicate that marine fish stocking was unlikely to be cost effective (i.e. it was considered unlikely that the effort required for stockings in these estuaries could be justified given that there would be very small harvests);
- Those waterways within the State's highest conservation areas; or
- Those with demonstrated history of draining to dry when open, representing a high risk of mortality to stocked fish or crustaceans.

These factors were considered sufficiently important to eliminate the estuary from further consideration for stocking, and are called "Knock-out Factors (KOFs)". To assess each estuary against the KOFs, spreadsheets were compiled for estuaries in the three regions. The location of each estuary was established using a Geographic Information System (GIS) database provided by the NSW Land and Property Information (LPI). Physical data was extracted from the National Land and Water Resources Audit (NLWR Audit 2001) and verified using the GIS database.

The conservation status and management jurisdiction for each estuary was compiled from internet sites of the relevant State and Commonwealth agencies, including DPI, the Office of Environment and Heritage (OEH) and Department of Sustainability, Environment, Water, Population & Communities (DSEWPaC). Those waterways within the State's highest value conservation areas, including Marine Protected Areas, Ramsar sites, Aquatic Reserves, World Heritage and Wilderness Areas were knocked out.

Historical data regarding the potential for an estuary to drain to dry was developed from available information from scientific journals, State of Environment reporting and Cardno's professional experience.

Table B.1 describes each of the six KOFs used within Stage 1 of the MCA, and lists the estuaries eliminated by each factor.

Table B.1: Explanations of factors used in Stage 1 of the Multi-Criteria Analysis and eliminated estuaries.

Factor	Description	Estuaries Eliminated
KOF 1	All estuaries with a waterway area less than or equal to 10 ha were excluded.	*Northern Region*: Broken Head Creek, Darkum Creek, Dalhousie Creek, Black Head Lagoon *Central Region*: Manly Lagoon, Towradgi Creek, Fairy Creek, Elliott Lake, Shellharbour Creek, Wrights Creek, Werri Lagoon, Wowly Gully, Flat Rock Creek, Nerrindilah Creek, Mollymook Creek, Kioloa Lagoon, Durras Creek, Maloneys Creek *Southern Region*: Bengello Creek, Middle Lake, Bournda Lagoon, Shadrachs Creek, Boydtown Creek, Fisheries Creek, Table Creek
KOF 2	All estuaries for which the entire estuary* is a MPA were excluded as MPAs are not included in the proposed activity. *Note estuaries which contain an MPA but for which the entire estuary is not an MPA were not eliminated.	*Northern Region:* Brunswick River, Belongil Creek, Tallow Creek, Sandon River, Wooli Wooli River, Station Creek, Corindi River, Arrawarra Creek, Woolgoolga Lake, Hearns Lake, Moonee Creek, Coffs Harbour Creek, Smiths Lake, Karuah River, Port Stephens *Central Region:* Carama Creek, Currambene Creek, Moona Moona Creek, Jervis Bay, Durras Lake *Southern Region:* Cullendulla Creek, Clyde River, Batemans Bay, Tomaga River, Candlagan Creek, Moruya River, Congo Creek, Meringo Creek, Kellys Lake, Coila Lake, Tuross Lake, Lake Brunderee, Lake Brou, Lake Dalmeny, Kianga Lake, Wagonga Inlet, Little Lake(near Narooma), Bullengella Lake, Nangudga Lake, Corunna Lake, Tilba Tilba Lake, Little Lake (Wallaga), Wallaga Lake
KOF 3	All estuaries for which the entire estuary is a Ramsar area were excluded.	*Northern Region:* Myall Lakes, Boolambayte Lake, Bombah Broadwater/Nerong Creek, Lower Myall River
KOF 4	All estuaries within or adjacent to the boundary of a World Heritage Area (WHA) or Wilderness Area were excluded.	*Southern Region:* Nadgee Lake, Nadgee River and Merrica River
KOF 5	All estuaries for which the entire estuary is designated as Commonwealth Waters were excluded.	No estuaries eliminated
KOF 6	All estuaries that 'drain to dry' when the mouth opens were excluded.	*Central Region:* Cockrone Lake, Dee Why Lagoon, Curl Curl Lagoon

Seventy eight estuaries were eliminated in Stage 1 of the MCA, and the remaining 80 estuaries progressed to the second stage of the selection process.

Stage 2

Stage 2 of the MCA involved scoring estuaries against ten factors considered important to the aims of the proposal. Factors were weighted by their relative importance to the aims of the proposal so that factors with greater weightings could potentially contribute more to the total score for an estuary than factors with less weighting. All scores were scaled to fall between 0 and 1, with scores approaching 1 representing the most positive or abundant condition possible within each Region. The outcome of Stage 2 was a score for each estuary that combined scores for the ten factors.

The factors considered, their weighting, the rational for their inclusion and the data sources used are listed in Table B.2 below.

Table B.2: Factors, weightings and scoring method used in Stage 2 of the Multi-Criteria Analysis.

Factor and Weighting	Description	Explanation/Scoring/Data Sources
ICOLL 1.1	An estuary with an **I**ntermittently **C**losed and **O**pen **L**ake or **L**agoon	Estuaries with intermittent openings to the ocean are more likely to have fish populations that are location-based recruitment limited. Fish stocking is more likely to be successful in such estuaries, given that appropriate habitats and food are sufficient to support existing and stocked fish. Scored as: 0 - Not an ICOLL 1 - An ICOLL Lagoon classification derived from Roper *et al.* (2010).
Water Quality 1.5	Summary of physical and chemical measures including nutrients, oxygen content, contaminants.	Water quality in estuaries proposed for stocking must be of sufficient standard to support existing and stocked fish. The existing water quality conditions, as summarised by an index, is indicative of potential of an estuary to provide appropriate water quality conditions for successful fish stocking. Scored as: 0 – Extensively modified 0.25 – Modified 0.5 – Largely unmodified 1 – Near pristine Water quality index derived from NLWR Audit (2001), updated/revised according to Roper *et al*. (2010).
Potential for movement of stocked species 1.7	Provides an indication of the potential for stocked species to leave the estuary after stocking.	To effectively result in increased opportunity for recreational fishing, stocked species should have a high probability of remaining within the estuary where they are stocked. This factor relates estuarine type with probability of retention of stocked species. Scored as: 0 – High potential: open estuary or embayment 0.25 – Large riverine system with significant tidal exchange and flood events 0.5 – Smaller riverine system with smaller tidal exchange and flood events 0.75 – ICOLL with regular openings, a regulated or small coastal

Factor and Weighting	Description	Explanation/Scoring/Data Sources
		creek 1 – Low potential: lake of ICOLL not open or infrequently open to ocean, infrequent flooding events Data derived from estuarine classification in NLWR Audit (2001) and to Roper *et al*. (2010).
Potential Usage 1.5	Gives an indication of the number of people in the area surrounding each estuary	To provide recreational fishing opportunities stocked estuaries should be located close enough to population centres to maximise likelihood of fishing events. This factor provides an indication of the population size within a 50 km radius of each estuary. This distance was considered a typical maximum distance fishers would travel to take advantage of a stocked estuary. Scores were scaled from: 0 – The smallest population within 50 km around an estuary, calculated separately for Northern, Central and Southern regions To 1 – The largest population within 50 km around an estuary, calculated separately for Northern, Central and Southern regions Population data by post code derived from Australian Census 2006, extracted using GIS database.
Fishing Activity and potential 1.6	Gives an indication of potential number of fishers who would benefit from fish stocking	Estuaries stocked should have potential to increase fishing opportunity for the greatest number of fishers possible. The number of fishing licenses issued within a 50 km radius of each estuary was considered to be indicative of the potential number of fishers who could take advantage of increased fishing opportunities in stocked estuaries. Scores were scaled from: 0 – The smallest number of fishing licenses within 50 km around an estuary, calculated separately for Northern, Central and Southern regions To 1 – The largest number of fishing licenses within 50 km around an estuary, calculated separately for Northern, Central and Southern regions Data for number of fishing licences by post code as of 2009 derived from DPI, extracted using GIS database.
Holiday Fishing potential 1.4	Gives an indication of the current appeal of an estuary with respect to fishing success.	Estuaries identified in holiday and travel publications as fishing "hot spots" are likely to be more suitable for fish stocking because fish stocking may increase fishing opportunities compared to estuaries not generally identified as successful fishing locations. Scored as: 0 - Not an identified "Fishing Hotspot" 1 - An identified "Fishing Hotspot" Data derived from Ross (1998) and consultation with ACoRF and RFSTEC.

Factor and Weighting	Description	Explanation/Scoring/Data Sources
Recreational Fishing Havens (RFHs) 1.6	Identifies estuaries or areas within estuaries dedicated to recreational fishing usage	Estuaries wholly or partly managed for recreational fishing are more likely to be suitable for fish stocking than estuaries not so managed because fish stocking activities would value add onto an existing usage, make use of existing facilities and have fewer potential usage conflicts. Scored as: 0 – No part of estuary is a RFH 0.5 – Some part of the estuary is a RFH 1 – Entire estuary is a RFH Data from DPI and consultation with ACoRF and RFSTEC.
Fishing Infrastructure and amenities 1.2	Identifies estuaries that have existing fishing infrastructure and amenities	Estuaries with existing fishing infrastructure such as boat ramps, wharves, jetties and amenities such as bait and tackle shops would be suitable for fish stocking as they can support additional recreational fishing opportunities offered by the proposal. Scores were scaled from: 0 – An estuary with no boat ramp, facilities or amenities to support recreational fishing, calculated separately for Northern, Central and Southern regions. To 1 – The estuary with the maximum number of boat ramps and facilities, standardised per km of estuary perimeter, calculated separately for Northern, Central and Southern regions. Data derived from boating facility database provided by NSW Maritime, using data on estuary perimeter from NLWR Audit (2001).
Indigenous Cultural Value 1.3	Identifies estuaries with items or areas of acknowledged aboriginal value related to fishing	Estuaries with acknowledged cultural values relating to catching and eating fish by aboriginal populations are likely to benefit more from the fish stocking proposal by value adding to existing estuary usage. The benefits of the proposal, increased opportunity for recreational fishing, are more likely to be shared by more people in estuaries with established aboriginal cultural values relating to fishing. Scored as: 0 – No acknowledged aboriginal cultural heritage related to fishing 1 – At least one item or area of aboriginal cultural value Data derived from community consultation with aboriginal stakeholders conducted by Umwelt as part of this EIS.
Non-indigenous Heritage 1.1	Identifies estuaries with items or areas of acknowledged non-aboriginal value related to fishing	Estuaries with identified items or areas of non-aboriginal culture related to water activities and fishing are more likely to be popular as fishing locations. The benefits of the proposal, increased opportunity for recreational fishing, is likely to be enhanced for such estuaries compared to estuaries without such values. Scored as: 0 – No acknowledged non-aboriginal cultural value related to fishing 1 - At least one item or area of non-aboriginal cultural value

Factor and Weighting	Description	Explanation/Scoring/Data Sources
		Data derived from DSEWPaC website (Heritage).

Stage 3

The score for each estuary calculated in Stage 2 was carried forward to Stage 3. In Stage 3, estuaries were scored according to their suitability for stocking each of the seven selected species. This refining of the selection process was required because the optimal stocking conditions vary for each species, depending for example on estuarine features such the amount of juvenile and adult habitat present. Four species-specific factors were developed and the relative importance of each factor was determined, taking into account the importance of each factor in the achieving the aims of the proposal. Factors considered in Stage 3 were given higher weightings than those in Stage 2 because of the importance of Stage 3 factors in maximising the yields of species. As in Stage 2, scores for individual factors were scaled separately for estuaries within each of the three Regions. All scores were scaled to fall between 0 and 1, with scores approaching 1 representing the most positive or abundant condition possible within each Region. A score for each species within each estuary was derived by mathematically combining the four factors, with each factor weighted by its relative importance. Scores for estuaries carried forward from Stage 2 were added to the species-specific scores calculated in Stage 3 to produce an overall score for each estuary for each of the seven species. These scores were ranked for estuaries in order of preference.

The factors developed for Stage 3, their weightings, the rational for their inclusion and scoring m ethod are listed in Table B.3 below.

Table B.3: Factors specific to each species considered in Stage 3 of the Multi -Criteria Analysis, weightings and scoring method.

Factor and Weighting	Description	Explanation/Scoring/Data Sources
Likelihood of occurrence 1.9	Potential for the species to occur naturally in an estuary	A selected stocked species has a greater likelihood of surviving and growing to a harvestable size if it occurs naturally in the estuary to be stocked. This factor elevates the scores of species in estuaries where they are already present and reduces scores for species in estuaries outside their current distribution. Scored as: 0 – Outside of known distributional range 0.25 – Not likely present, not recently 0.5 – Probably present at least sometime 1 – Known to be present Data on species distribution compiled from scientific journal articles/books on each species (e.g. Scandol *et al.* 2008).
Recruitment Index 1.9	Provides a measure of the potential of carrying capacity for a species in an estuary based on the relationship between the estuary catchment size and amount of habitat for juvenile fish	The potential for recruitment to an estuary is thought to be linked to the amount of freshwater flow through the estuary and the amount of habitat present that juvenile stocked species require to shelter, feed and grow. This index relates the potential for recruitment, measured as the ratio of the catchment area to the waterway area, to the amount of juvenile habitat present. Critical juvenile habitats for the selected species to be stocked were: Yellowfin bream – seagrass, mangrove Mulloway – deep holes (>5 m) Dusky flathead – seagrass, mangrove

Factor and Weighting	Description	Explanation/Scoring/Data Sources
		Sand whiting – unvegetated sediment, seagrass, mangrove Eastern king prawn - unvegetated sediment , seagrass Giant mud crab - seagrass, mangrove Blue swimmer crab – unvegetated sediment, seagrass Scores were scaled as: 0 – Smallest value for catchment area/waterway area/nominated juvenile habitat area within each Region To 1 – Largest value for catchment area/waterway area/nominated juvenile habitat area within each Region Data for catchment, waterway and habitat area from NLWR Audit (2001), updated in accordance with Roper *et al*. (2010) and checked against GIS database for estuarine macrophytes supplied by DPI. Bathymetry data from LPI and navigation charts were used to determine areas for deep hole habitat. Data for juvenile habitat requirements compiled from scientific journal articles/books on each species (e.g. Scandol *et al.* 2008).
Adult Habitat availability 1.8	Provides a measure of the likely survivorship of stocked species to harvestable size based on the availability of preferred adult habitat	To successfully grow to harvestable or adult size, stocked species require sufficient adult habitat to provide shelter and food. This factor provides an indication of the availability of primary and secondary adult habitat for each species within each estuary. Primary (1) and secondary (2) adult habitats for the selected species to be stocked were: Yellowfin bream -1: rocky reefs, 2: deep holes Mulloway – 1: deep holes, 2: rocky reef Dusky flathead – 1: unvegetated sediment, 2: mangrove Sand whiting – 1: unvegetated sediment, 2: seagrass Eastern king prawn – 1: unvegetated sediment, 2: seagrass Giant mud crab – 1: unvegetated sediment, 2: mangrove Blue swimmer crab – 1: unvegetated sediment, 2: seagrass Scored as: 0 – No primary or secondary habitat present 0.33 – Secondary habitat only present 0.66 – Primary but no secondary habitat present 1 – Both primary and secondary habitat present Primary and secondary adult habitat data compiled from scientific journal articles/books on each species (i.e. Scandol *et al.* 2008, See Chapter C. Section 8) .

Factor and Weighting	Description	Explanation/Scoring/Data Sources
Recreational Fishing Closures 1.7	Gives an indication of potential restrictions on recreational fishing due to fishing closures	Opportunities for recreational fishing will be greater in estuaries that have few or no closures or gear restrictions relevant to the species stocked. Partial or full time closures and or restrictions on gear used to catch the species selected for stocking would reduce fishing opportunities that arise as a result of the fish stocking proposal. Scored as: 0 – Closures exist for fishing methods relevant to species selected for stocking 0.5 – Partial closures exist for fishing methods relevant to species selected for stocking 1 – No closures for fishing methods relevant to species selected for stocking Data derived DPI data on fishing closures for NSW.

B.5.2 Results

The following tables (B.4 to B.14) summarise the overall outcome of the MCA estuary selection process.

Table B.4: Overall results of Multi-Criteria Analysis: Number of estuaries selected

Estuary Selection Results	Northern Region	Central Region	Southern Region	Totals
Number of Estuaries	55	54	49	158
Number Eliminated	23	23	32	78
Number Selected	32	31	17	**80**

The following tables summarise the rank for each species in each estuary or the basis for elimination of the species or estuary from potential stocking activities. For each species the ranks indicate the most to least suitable estuaries for stocking, but do not imply that that the species will be stocked in any or all of the highly ranked estuaries. No MCA ranks were calculated for giant mud crab in the Southern Region from the Bermagui River south to Nadgee Lake because these estuaries lie outside the natural distribution of the species.

Table B.5: Multi-Criteria Analysis results for the Northern Region.
Numbers within the table refer to the ranking of each estuary by species within each region.

MCA Results for Northern Region: Tweed River to Avoca Lake

Key to Eliminated Estuaries: Less than 10 ha (red); MPAs (pink); Ramsar Wetland (purple); Drains to Dry (black)

Estuary	Yellowfin Bream	Mulloway	Flathead	Sand Whiting	Eastern King Prawn	Giant Mud Crab	Blue Swimmer Crab
Tweed River	10	8	7	8	8	7	7
Cudgen Creek	24	24	30	31	31	30	30
Cudgera Creek	31	31	28	29	29	28	28
Mooball Creek	30	30	27	28	28	27	27
Brunswick River							
Belongil Creek							
Tallow Creek							
Broken Head Creek							
Richmond River	5	4	4	4	4	6	4
Evans River	18	16	18	18	18	18	18
Jerusalem Creek	29	29	31	27	27	31	31
Clarence River	6	9	13	13	13	11	13
Cakora Lagoon	32	32	29	30	30	29	29
Sandon River							
Wooli Wooli River							
Station Creek							
Corindi River							
Arrawarra Creek							
Darkum Creek							
Woolgoolga Lake							
Hearns Lake							

MCA Results for Northern Region: Tweed River to Avoca Lake

Key to Eliminated Estuaries:	Less than 10 ha	MPAs	Ramsar Wetland	Drains to Dry

Estuary	Yellowfin Bream	Mulloway	Flathead	Sand Whiting	Eastern King Prawn	Giant Mud Crab	Blue Swimmer Crab
Moonee Creek							
Coffs Harbour Creek							
Boambee Creek	26	27	21	23	23	21	21
Bonville Creek	19	18	19	19	19	19	19
Bellinger River	8	6	5	5	6	5	6
Dalhousie Creek							
Oyster Creek	27	26	22	24	24	22	25
Deep Creek	9	13	10	11	12	13	11
Nambucca River	4	5	8	9	9	10	8
Macleay River	15	12	15	15	15	15	14
South West Rocks Creek	16	17	9	10	11	4	10
Saltwater Creek	21	23	26	26	26	26	26
Korogoro Creek	14	19	17	17	17	17	17
Killick Creek	20	22	24	25	25	24	23
Hastings River	7	7	6	6	5	8	5
Lake Innes/Lake Cathie	25	25	25	22	22	25	24
Camden Haven River	11	10	12	12	10	9	9
Manning River	17	15	16	16	16	16	15
Khappinghat Creek	28	28	32	32	32	32	32
Black Head Lagoon							
Wallis Lake	3	3	3	3	3	3	3
Smiths Lake							
Myall Lakes							
Boolambayte Lake							
Bombah Broadwater/Nerong Creek							
Lower Myall River							
Karuah River							
Port Stephens							
Hunter River	13	11	14	14	14	12	16
Lake Macquarie	1	1	1	1	1	1	1
Tuggerah Lake	2	2	2	2	2	2	2
Wamberal Lagoon	23	21	23	21	21	23	20
Terrigal Lagoon	22	20	20	20	20	20	22
Avoca Lake	12	14	11	7	7	14	12

Table B.6: Multi-Criteria Analysis results for the Central Region.

Numbers within the table refer to the ranking of each estuary by species within each region.

MCA Results for Central Region: Cockrone Lake to Cullendulla Creek

Key to Eliminated Estuaries:	Less than 10 ha	MPAs	Ramsar Wetland	Drains to Dry
	(red)	(pink)	(purple)	(black)

Estuary Name	Yellowfin Bream	Mulloway	Flathead	Sand Whiting	Eastern King Prawn	Giant Mud Crab	Blue Swimmer Crab
Cockrone Lake							
Brisbane Water	3	3	5	5	5	4	4
Broken Bay	18	6	10	8	15	17	14
Hawkesbury River	6	5	6	6	7	5	5
Pittwater	13	9	9	11	10	8	9
Narrabeen Lagoon	4	4	7	7	6	11	12
Dee Why Lagoon							
Curl Curl Lagoon							
Manly Lagoon							
Middle Harbour Creek	7	8	4	4	4	3	3
Port Jackson	2	2	2	2	3	2	2
Lane Cove River	19	13	15	17	23	20	23
Parramatta River	17	12	14	16	21	12	13
Cooks River	23	19	22	22	28	28	29
Botany Bay	1	1	1	1	1	1	1
Georges River	5	7	8	9	8	7	7
Port Hacking	30	30	3	3	2	6	6
Towradgi Creek							
Fairy Creek							
Allans Creek	31	31	29	30	30	29	28
Lake Illawarra	12	16	13	15	13	21	20
Elliott Lake							
Shellharbour Creek							
Killalea Lagoon	26	26	27	27	26	27	27
Minnamurra River	20	21	21	21	19	19	19
Wrights Creek							
Werri Lagoon							
Crooked River	27	28	28	28	27	27	27
Shoalhaven River	14	20	20	19	17	15	17
Lake Wollumboola	29	27	31	31	31	30	30
Wowly Gully							
Carama Creek							
Currambene Creek							
Moona Moona Creek							
Jervis Bay							
Flat Rock Creek							
St Georges Basin	11	15	11	12	12	10	10

MCA Results for Central Region: Cockrone Lake to Cullendulla Creek

Key to Eliminated Estuaries:	Less than 10 ha		MPAs		Ramsar Wetland		Drains to Dry
	(red)		(pink)		(purple)		(black)

Estuary Name	Yellowfin Bream	Mulloway	Flathead	Sand Whiting	Eastern King Prawn	Giant Mud Crab	Blue Swimmer Crab
Swan Lake	21	22	23	23	20	22	21
Berrara Creek	24	24	25	25	24	24	24
Nerrindilah Creek							
Lake Conjola	9	10	17	14	14	14	11
Narrawallee Inlet	16	18	18	20	18	16	18
Mollymook Creek							
Ulladulla	28	29	30	29	29	31	31
Burrill Lake	8	11	12	10	9	9	8
Tabourie Lake	10	14	16	13	11	13	15
Termeil Lake	25	25	26	26	25	25	25
Meroo Lake	15	17	19	18	16	18	16
Willinga Lake	22	23	24	24	22	23	22
Kioloa Lagoon							
Durras Lake							
Durras Creek							
Maloneys Creek							
Cullendulla Creek							

Table B.7: Multi-Criteria Analysis results for the Southern Region.

Numbers within the table refer to the ranking of each estuary by species within each region.

Southern Region: Clyde River to Nadgee Lake

Key to Eliminated Estuaries: Less than 10 ha | MPAs | Wilderness Area | Ramsar Wetland | Stocking Not Permitted (Outside geographic range) | Drains to Dry

Estuary Name	Yellowfin Bream	Mulloway	Flathead	Sand Whiting	Eastern King Prawn	Giant Mud Crab	Blue Swimmer Crab
Clyde River							
Batemans Bay							
Tomaga River							
Candlagan Creek							
Bengello Creek							
Moruya River							
Congo Creek							
Meringo Creek							
Kellys Lake							
Coila Lake							
Tuross Lake							
Lake Brunderee							
Lake Brou							
Lake Dalmeny							
Kianga Lake							
Wagonga Inlet							
Little Lake(near Narooma)							
Bullengella Lake							
Nangudga Lake							
Corunna Lake							
Tilba Tilba Lake							
Little Lake (Wallaga)							
Wallaga Lake							
Bermagui River	13	14	11	14	14		13
Barragoot Lake	16	17	18	18	17		17
Cuttagee Lake	11	7	4	6	5		5
Murrah Lake	17	16	12	15	15		14
Bunga Lagoon	19	18	16	16	16		16
Wapengo Lake	8	8	10	8	9		9
Middle Lake							
Nelson Lake	5	5	3	5	6		6
Bega River	12	12	14	12	13		12
Wallagoot Lake	7	13	15	13	8		8

Southern Region: Clyde River to Nadgee Lake

Key to Eliminated Estuaries: Less than 10 ha | MPAs | Ramsar Wetland | Drains to Dry | Wilderness Area | Stocking Not Permitted (Outside geographic range)

Estuary Name	Yellowfin Bream	Mulloway	Flathead	Sand Whiting	Eastern King Prawn	Giant Mud Crab	Blue Swimmer Crab
Bournda Lagoon							
Back Lagoon	3	3	7	3	3		3
Merimbula Lake	1	1	1	1	1		1
Pambula Lake	4	4	2	4	4		4
Curalo Lagoon	2	2	5	2	2		2
Shadrachs Creek							
Twofold Bay	14	9	17	17	18		18
Nullica River	6	6	6	7	7		7
Boydtown Creek							
Fisheries Creek							
Towamba River	9	10	8	10	11		10
Wonboyn River	10	11	9	11	12		11
Merrica River							
Table Creek							
Nadgee River							
Nadgee Lake							

Table B.8: Results of estuary rankings for yellowfin bream in three regions.

Yellowfin Bream

A: Northern Region		B: Central Region		C: Southern Region	
Rank	**Estuary**	**Rank**	**Estuary**	**Rank**	**Estuary**
1	Lake Macquarie	1	Botany Bay	1	Merimbula Lake
2	Tuggerah Lake	2	Port Jackson	2	Curalo Lagoon
3	Wallis Lake	3	Middle Harbour Creek	3	Back Lagoon
4	Nambucca River	4	Brisbane Water	4	Pambula Lake
5	Richmond River	5	Hawkesbury River	5	Nelson Lake
6	Clarence River	6	Port Hacking	6	Nullica River
7	Hastings River	7	Georges River	7	Wallagoot Lake
8	Bellinger River	8	Burrill Lake	8	Wapengo Lake
9	Deep Creek	9	Pittwater	9	Towamba River
10	Tweed River	10	St Georges Basin	10	Wonboyn River
11	Camden Haven River	11	Lake Conjola	11	Cuttagee Lake
12	Avoca Lake	12	Narrabeen Lagoon	12	Bega River
13	Hunter River	13	Parramatta River	13	Bermagui River
14	Korogoro Creek	14	Broken Bay	14	Twofold Bay
15	Macleay River	15	Tabourie Lake	15	Barragoot Lake
16	South West Rocks Creek	16	Meroo Lake	16	Murrah Lake
17	Manning River	17	Shoalhaven River	17	Bunga Lagoon
18	Evans River	18	Narrawallee Inlet		
19	Bonville Creek	19	Minnamurra River		
20	Killick Creek	20	Lake Illawarra		
21	Saltwater Creek (Frederickton)	21	Swan Lake		
22	Terrigal Lagoon	22	Willinga Lake		
23	Wamberal Lagoon	23	Lane Cove River		
24	Cudgen Creek	24	Berrara Creek		
25	Lake Innes/Lake Cathie	25	Termeil Lake		
26	Boambee Creek	26	Killalea Lagoon		
27	Oyster Creek	27	Crooked River		
28	Khappinghat Creek	28	Allans Creek		
29	Jerusalem Creek	29	Cooks River		
30	Mooball Creek	30	Lake Wollumboola		
31	Cudgera Creek	31	Ulladulla		
32	Cakora Lagoon				

Table B.9: Results of estuary rankings for mulloway in three regions.

Mulloway

A: Northern Region		B: Central Region		C: Southern Region	
Rank	**Estuary**	**Rank**	**Estuary**	**Rank**	**Estuary**
1	Lake Macquarie	1	Botany Bay	1	Merimbula Lake
2	Tuggerah Lake	2	Port Jackson	2	Curalo Lagoon
3	Wallis Lake	3	Brisbane Water	3	Back Lagoon
4	Richmond River	4	Narrabeen Lagoon	4	Pambula Lake
5	Nambucca River	5	Hawkesbury River	5	Nelson Lake
6	Bellinger River	6	Broken Bay	6	Nullica River
7	Hastings River	7	Georges River	7	Cuttagee Lake
8	Tweed River	8	Middle Harbour Creek	8	Wapengo Lake
9	Clarence River	9	Pittwater	9	Twofold Bay
10	Camden Haven River	10	Lake Conjola	10	Towamba River
11	Hunter River	11	Burrill Lake	11	Wonboyn River
12	Macleay River	12	Parramatta River	12	Bega River
13	Deep Creek	13	Lane Cove River	13	Wallagoot Lake
14	Avoca Lake	14	Tabourie Lake	14	Bermagui River
15	Manning River	15	St Georges Basin	15	Murrah Lake
16	Evans River	16	Lake Illawarra	16	Barragoot Lake
17	South West Rocks Creek	17	Meroo Lake	17	Bunga Lagoon
18	Bonville Creek	18	Narrawallee Inlet		
19	Korogoro Creek	19	Cooks River		
20	Terrigal Lagoon	20	Shoalhaven River		
21	Wamberal Lagoon	21	Minnamurra River		
22	Killick Creek	22	Swan Lake		
23	Saltwater Creek (Frederickton)	23	Willinga Lake		
24	Cudgen Creek	24	Berrara Creek		
25	Lake Innes/Lake Cathie	25	Termeil Lake		
26	Oyster Creek	26	Killalea Lagoon		
27	Boambee Creek	27	Lake Wollumboola		
28	Khappinghat Creek	28	Crooked River		
29	Jerusalem Creek	29	Ulladulla		
30	Mooball Creek	30	Port Hacking		
31	Cudgera Creek	31	Allans Creek		
32	Cakora Lagoon				

Table B.10: Results of estuary rankings for dusky flathead in three regions.

Dusky Flathead					
A: Northern Region		**B: Central Region**		**C: Southern Region**	
Rank	**Estuary**	**Rank**	**Estuary**	**Rank**	**Estuary**
1	Lake Macquarie	1	Botany Bay	1	Merimbula Lake
2	Tuggerah Lake	2	Port Jackson	2	Pambula Lake
3	Wallis Lake	3	Port Hacking	3	Nelson Lake
4	Richmond River	4	Middle Harbour Creek	4	Cuttagee Lake
5	Bellinger River	5	Brisbane Water	5	Curalo Lagoon
6	Hastings River	6	Hawkesbury River	6	Nullica River
7	Tweed River	7	Narrabeen Lagoon	7	Back Lagoon
8	Nambucca River	8	Georges River	8	Towamba River
9	South West Rocks Creek	9	Pittwater	9	Wonboyn River
10	Deep Creek	10	Broken Bay	10	Wapengo Lake
11	Avoca Lake	11	St Georges Basin	11	Bermagui River
12	Camden Haven River	12	Burrill Lake	12	Murrah Lake
13	Clarence River	13	Lake Illawarra	13	Bega River
14	Hunter River	14	Parramatta River	14	Wallagoot Lake
15	Macleay River	15	Lane Cove River	15	Bunga Lagoon
16	Manning River	16	Tabourie Lake	16	Twofold Bay
17	Korogoro Creek	17	Lake Conjola	17	Barragoot Lake
18	Evans River	18	Narrawallee Inlet		
19	Bonville Creek	19	Meroo Lake		
20	Terrigal Lagoon	20	Shoalhaven River		
21	Boambee Creek	21	Minnamurra River		
22	Oyster Creek	22	Cooks River		
23	Wamberal Lagoon	23	Swan Lake		
24	Killick Creek	24	Willinga Lake		
25	Lake Innes/Lake Cathie	25	Berrara Creek		
26	Saltwater Creek (Frederickton)	26	Termeil Lake		
27	Mooball Creek	27	Killalea Lagoon		
28	Cudgera Creek	28	Crooked River		
29	Cakora Lagoon	29	Allans Creek		
30	Cudgen Creek	30	Ulladulla		
31	Jerusalem Creek	31	Lake Wollumboola		
32	Khappinghat Creek				

Table B.11: Results of estuary rankings for sand whiting in three regions.

Sand Whiting

A: Northern Region Rank	A: Northern Region Estuary	B: Central Region Rank	B: Central Region Estuary	C: Southern Region Rank	C: Southern Region Estuary
1	Lake Macquarie	1	Botany Bay	1	Merimbula Lake
2	Tuggerah Lake	2	Port Jackson	2	Curalo Lagoon
3	Wallis Lake	3	Port Hacking	3	Back Lagoon
4	Richmond River	4	Middle Harbour Creek	4	Pambula Lake
5	Bellinger River	5	Brisbane Water	5	Nelson Lake
6	Hastings River	6	Hawkesbury River	6	Cuttagee Lake
7	Avoca Lake	7	Narrabeen Lagoon	7	Nullica River
8	Tweed River	8	Broken Bay	8	Wapengo Lake
9	Nambucca River	9	Georges River	9	Towamba River
10	South West Rocks Creek	10	Burrill Lake	10	Wonboyn River
11	Deep Creek	11	Pittwater	11	Bega River
12	Camden Haven River	12	St Georges Basin	12	Wallagoot Lake
13	Clarence River	13	Tabourie Lake	13	Bermagui River
14	Hunter River	14	Lake Conjola	14	Murrah Lake
15	Macleay River	15	Lake Illawarra	15	Bunga Lagoon
16	Manning River	16	Parramatta River	16	Twofold Bay
17	Korogoro Creek	17	Lane Cove River	17	Barragoot Lake
18	Evans River	18	Meroo Lake		
19	Bonville Creek	19	Shoalhaven River		
20	Terrigal Lagoon	20	Narrawallee Inlet		
21	Wamberal Lagoon	21	Minnamurra River		
22	Lake Innes/Lake Cathie	22	Cooks River		
23	Boambee Creek	23	Swan Lake		
24	Oyster Creek	24	Willinga Lake		
25	Killick Creek	25	Berrara Creek		
26	Saltwater Creek (Frederickton)	26	Termeil Lake		
27	Jerusalem Creek	27	Killalea Lagoon		
28	Mooball Creek	28	Crooked River		
29	Cudgera Creek	29	Ulladulla		
30	Cakora Lagoon	30	Allans Creek		
31	Cudgen Creek	31	Lake Wollumboola		
32	Khappinghat Creek				

Table B.12: Results of estuary rankings for eastern king prawn in three regions.

Eastern King Prawn

A: Northern Region		B: Central Region		C: Southern Region	
Rank	Estuary	Rank	Estuary	Rank	Estuary
1	Lake Macquarie	1	Botany Bay	1	Merimbula Lake
2	Tuggerah Lake	2	Port Hacking	2	Curalo Lagoon
3	Wallis Lake	3	Port Jackson	3	Back Lagoon
4	Richmond River	4	Middle Harbour Creek	4	Pambula Lake
5	Hastings River	5	Brisbane Water	5	Cuttagee Lake
6	Bellinger River	6	Narrabeen Lagoon	6	Nelson Lake
7	Avoca Lake	7	Hawkesbury River	7	Nullica River
8	Tweed River	8	Georges River	8	Wallagoot Lake
9	Nambucca River	9	Burrill Lake	9	Wapengo Lake
10	Camden Haven River	10	Pittwater	10	Towamba River
11	South West Rocks Creek	11	Tabourie Lake	11	Wonboyn River
12	Deep Creek	12	St Georges Basin	12	Bega River
13	Clarence River	13	Lake Illawarra	13	Bermagui River
14	Hunter River	14	Lake Conjola	14	Murrah Lake
15	Macleay River	15	Broken Bay	15	Bunga Lagoon
16	Manning River	16	Meroo Lake	16	Barragoot Lake
17	Korogoro Creek	17	Shoalhaven River	17	Twofold Bay
18	Evans River	18	Narrawallee Inlet		
19	Bonville Creek	19	Minnamurra River		
20	Terrigal Lagoon	20	Swan Lake		
21	Wamberal Lagoon	21	Parramatta River		
22	Lake Innes/Lake Cathie	22	Willinga Lake		
23	Boambee Creek	23	Lane Cove River		
24	Oyster Creek	24	Berrara Creek		
25	Killick Creek	25	Termeil Lake		
26	Saltwater Creek (Frederickton)	26	Killalea Lagoon		
27	Jerusalem Creek	27	Crooked River		
28	Mooball Creek	28	Cooks River		
29	Cudgera Creek	29	Ulladulla		
30	Cakora Lagoon	30	Allans Creek		
31	Cudgen Creek	31	Lake Wollumboola		
32	Khappinghat Creek				

Table B.13: Results of estuary rankings for giant mud crab in three regions.

Giant Mud Crab

A: Northern Region		B: Central Region		C: Southern Region
Rank	**Estuary**	**Rank**	**Estuary**	
1	Lake Macquarie	1	Botany Bay	**Not to be stocked:** *Out of species' natural distribution range*
2	Tuggerah Lake	2	Port Jackson	
3	Wallis Lake	3	Middle Harbour Creek	
4	South West Rocks Creek	4	Brisbane Water	
5	Bellinger River	5	Hawkesbury River	
6	Richmond River	6	Port Hacking	
7	Tweed River	7	Georges River	
8	Hastings River	8	Pittwater	
9	Camden Haven River	9	Burrill Lake	
10	Nambucca River	10	St Georges Basin	
11	Clarence River	11	Narrabeen Lagoon	
12	Hunter River	12	Parramatta River	
13	Deep Creek	13	Tabourie Lake	
14	Avoca Lake	14	Lake Conjola	
15	Macleay River	15	Shoalhaven River	
16	Manning River	16	Narrawallee Inlet	
17	Korogoro Creek	17	Broken Bay	
18	Evans River	18	Meroo Lake	
19	Bonville Creek	19	Minnamurra River	
20	Terrigal Lagoon	20	Lane Cove River	
21	Boambee Creek	21	Lake Illawarra	
22	Oyster Creek	22	Swan Lake	
23	Wamberal Lagoon	23	Willinga Lake	
24	Killick Creek	24	Berrara Creek	
25	Lake Innes/Lake Cathie	25	Termeil Lake	
26	Saltwater Creek (Frederickton)	26	Killalea Lagoon	
27	Mooball Creek	27	Crooked River	
28	Cudgera Creek	28	Cooks River	
29	Cakora Lagoon	29	Allans Creek	
30	Cudgen Creek	30	Lake Wollumboola	
31	Jerusalem Creek	31	Ulladulla	
32	Khappinghat Creek			

Table B.14: Results of estuary rankings for blue swimmer crab in three regions.

Blue Swimmer Crab

A: Northern Region Rank	Estuary	B: Central Region Rank	Estuary	C: Southern Region Rank	Estuary
1	Lake Macquarie	1	Botany Bay	1	Merimbula Lake
2	Tuggerah Lake	2	Port Jackson	2	Curalo Lagoon
3	Wallis Lake	3	Middle Harbour Creek	3	Back Lagoon
4	Richmond River	4	Brisbane Water	4	Pambula Lake
5	Hastings River	5	Hawkesbury River	5	Cuttagee Lake
6	Bellinger River	6	Port Hacking	6	Nelson Lake
7	Tweed River	7	Georges River	7	Nullica River
8	Nambucca River	8	Burrill Lake	8	Wallagoot Lake
9	Camden Haven River	9	Pittwater	9	Wapengo Lake
10	South West Rocks Creek	10	St Georges Basin	10	Towamba River
11	Deep Creek	11	Lake Conjola	11	Wonboyn River
12	Avoca Lake	12	Narrabeen Lagoon	12	Bega River
13	Clarence River	13	Parramatta River	13	Bermagui River
14	Macleay River	14	Broken Bay	14	Murrah Lake
15	Manning River	15	Tabourie Lake	15	Bunga Lagoon
16	Hunter River	16	Meroo Lake	16	Barragoot Lake
17	Korogoro Creek	17	Shoalhaven River	17	Twofold Bay
18	Evans River	18	Narrawallee Inlet		
19	Bonville Creek	19	Minnamurra River		
20	Wamberal Lagoon	20	Lake Illawarra		
21	Boambee Creek	21	Swan Lake		
22	Terrigal Lagoon	22	Willinga Lake		
23	Killick Creek	23	Lane Cove River		
24	Lake Innes/Lake Cathie	24	Berrara Creek		
25	Oyster Creek	25	Termeil Lake		
26	Saltwater Creek (Frederickton)	26	Killalea Lagoon		
27	Mooball Creek	27	Crooked River		
28	Cudgera Creek	28	Allans Creek		
29	Cakora Lagoon	29	Cooks River		
30	Cudgen Creek	30	Lake Wollumboola		
31	Jerusalem Creek	31	Ulladulla		
32	Khappinghat Creek				

Figures B.2 to B.14 shows the locations of selected and eliminated estuaries (by factor).

Figure B.2: Tweed River to Richmond River

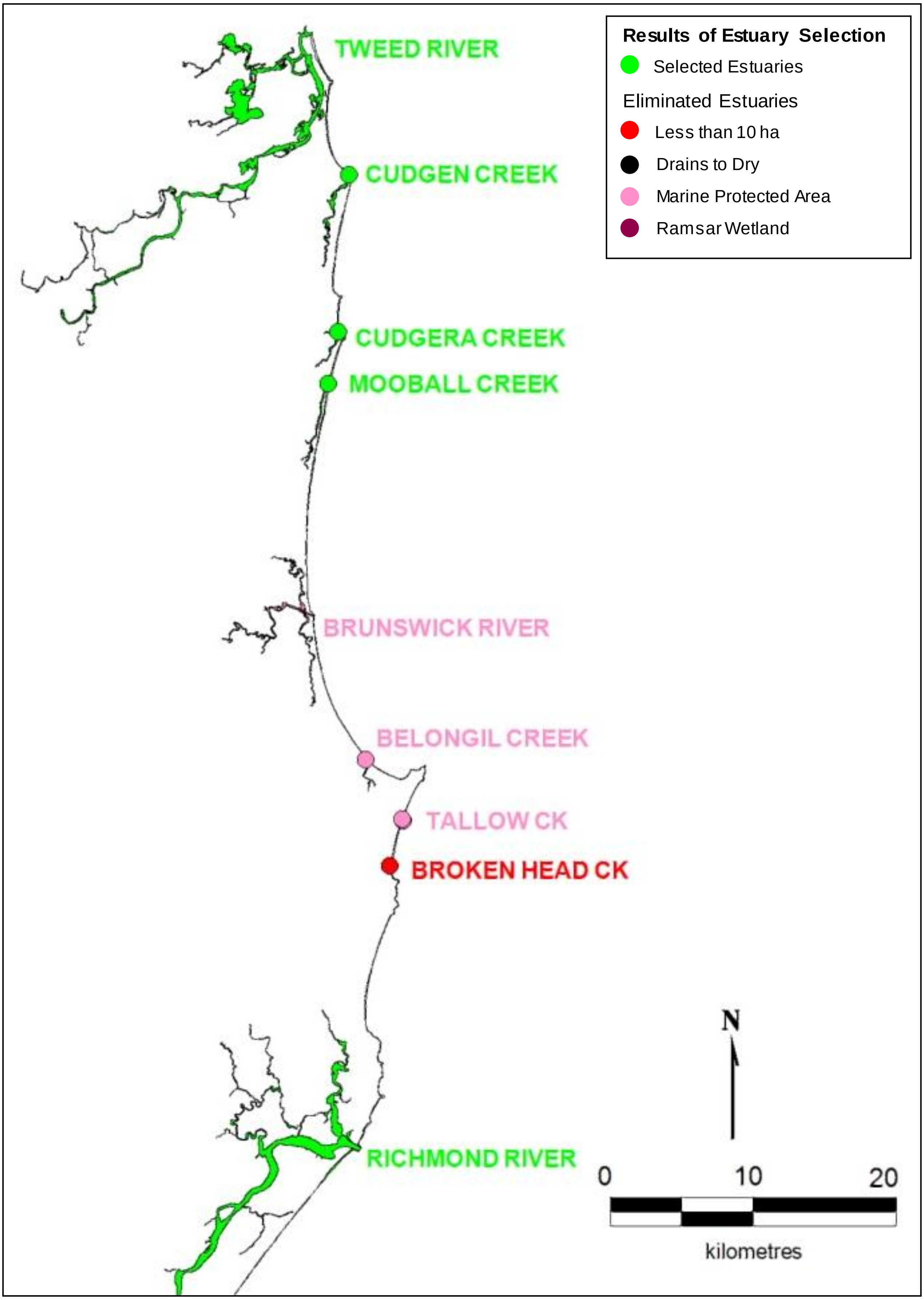


Figure B.3: Evans River to Sandon River

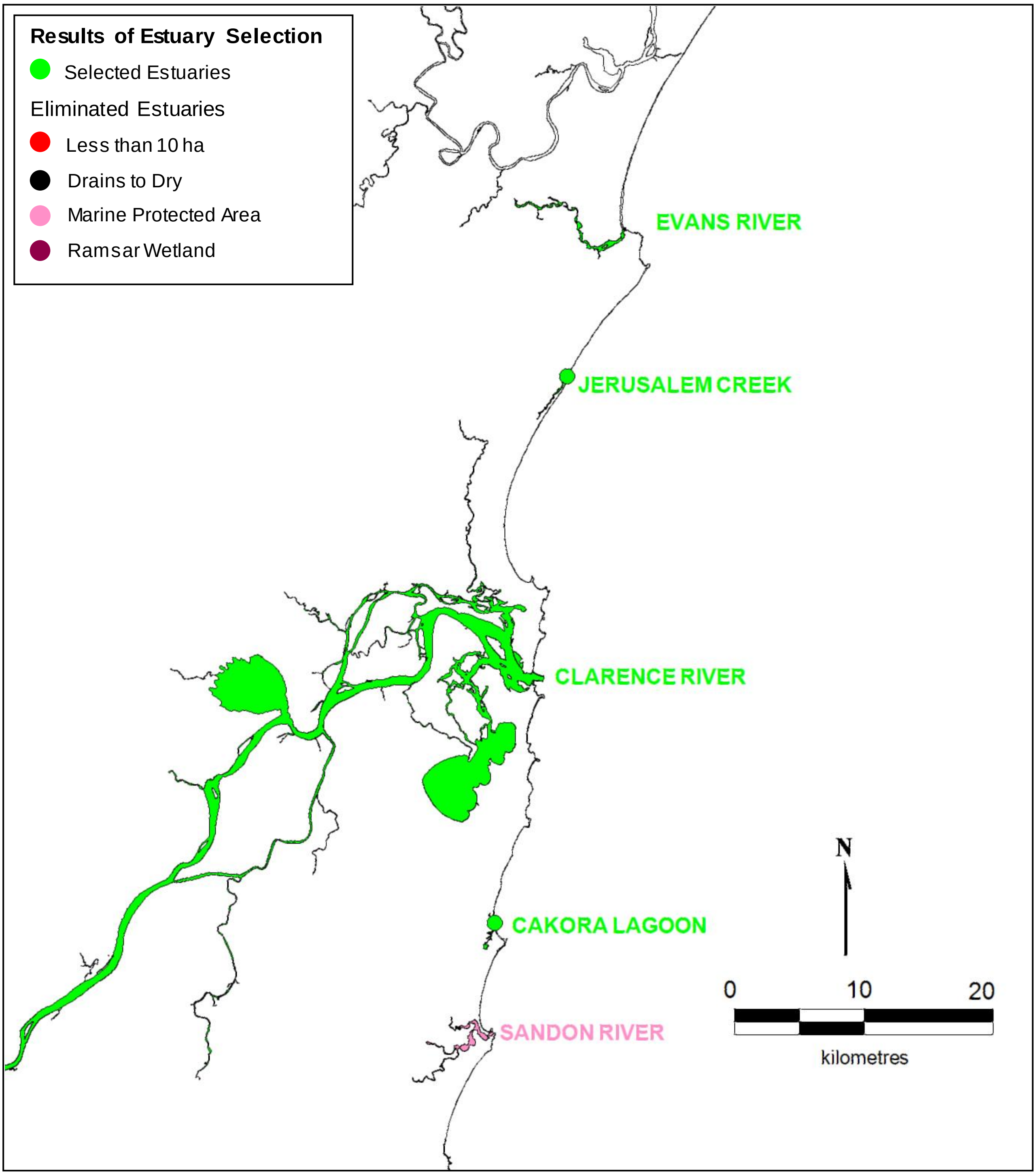


Figure B.4: Wooli Wooli River to Oyster Creek

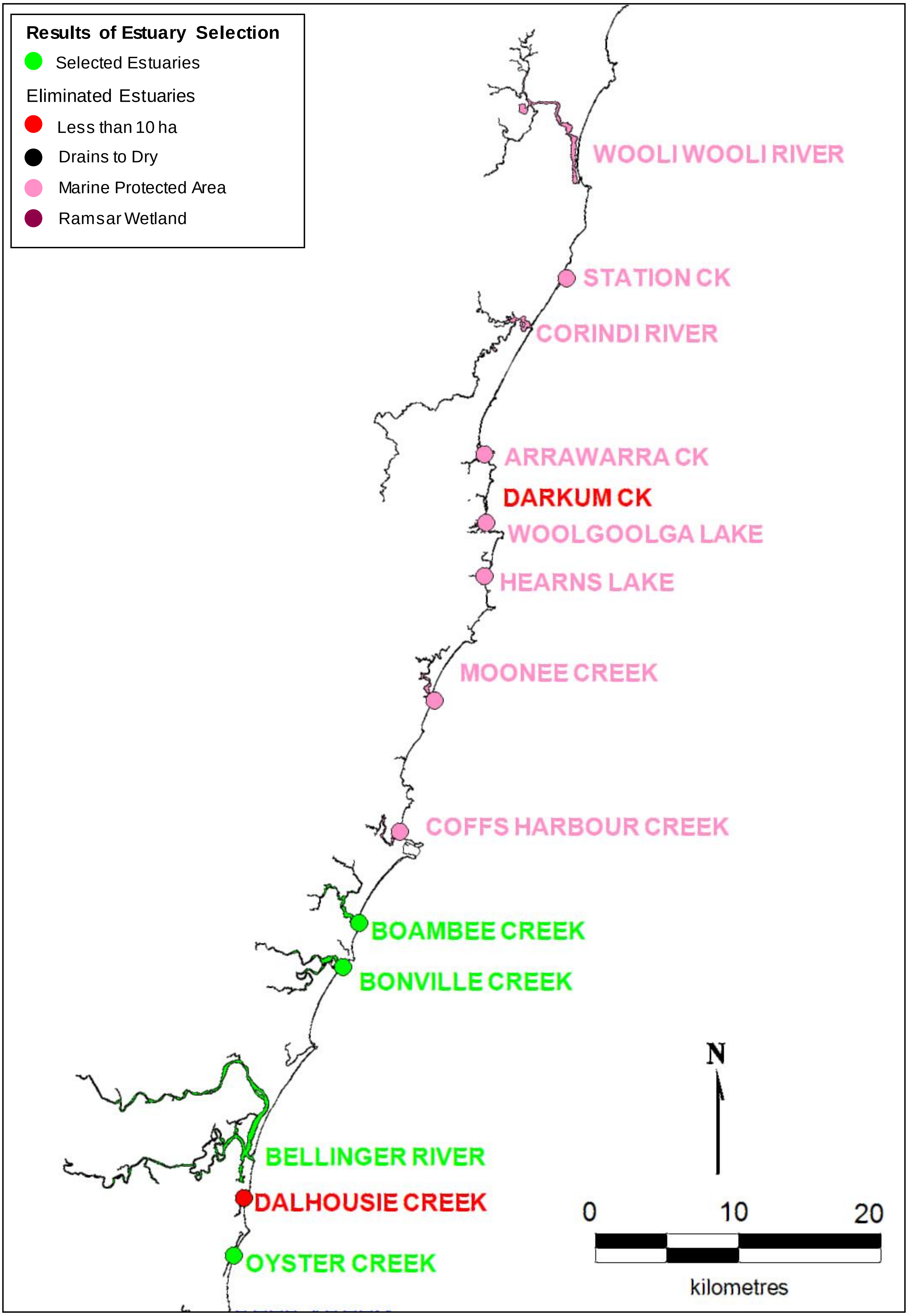


Figure B.5: Deep Creek to Killick Creek

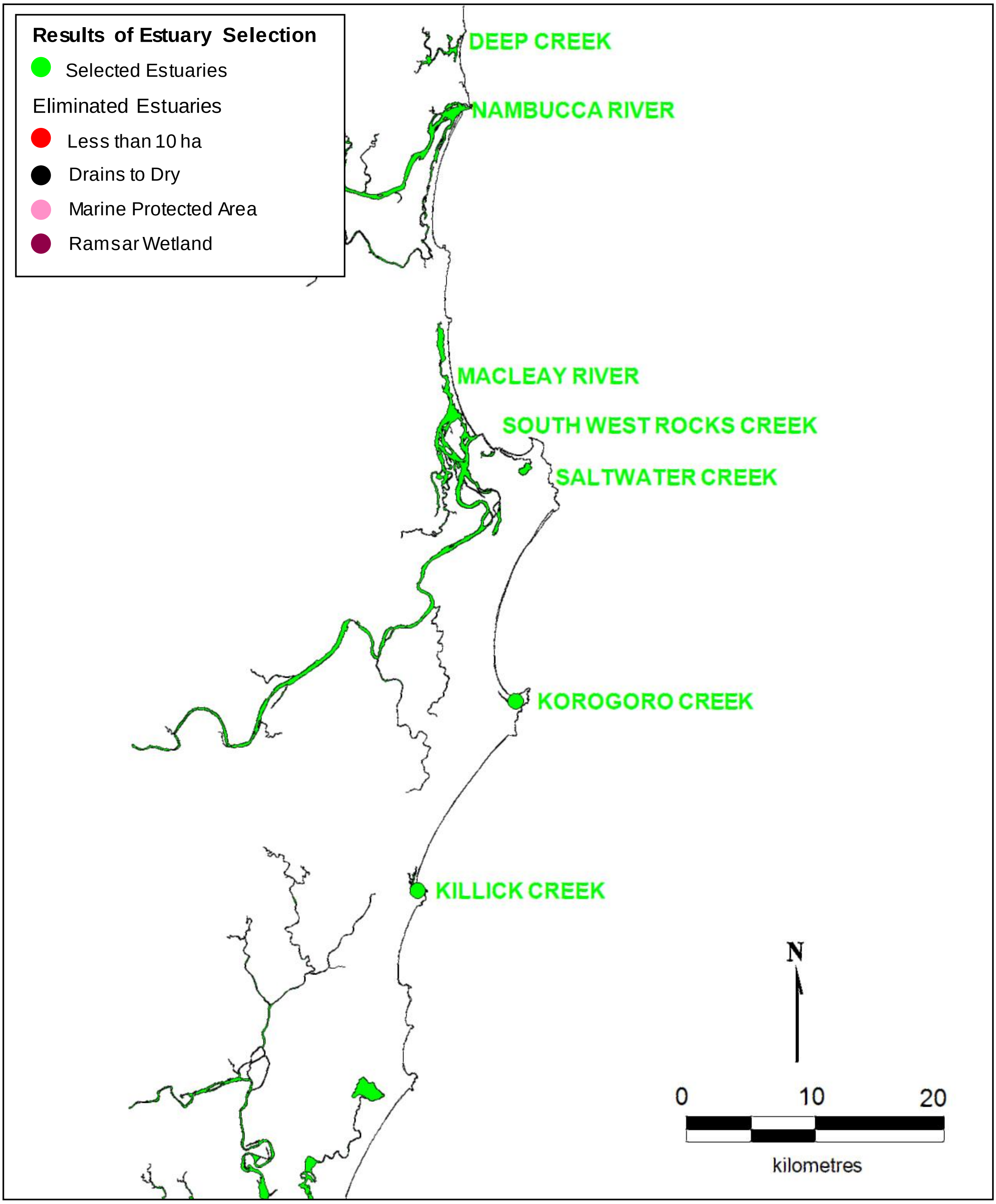


Figure B.6: Hasting River to Black Head Lagoon

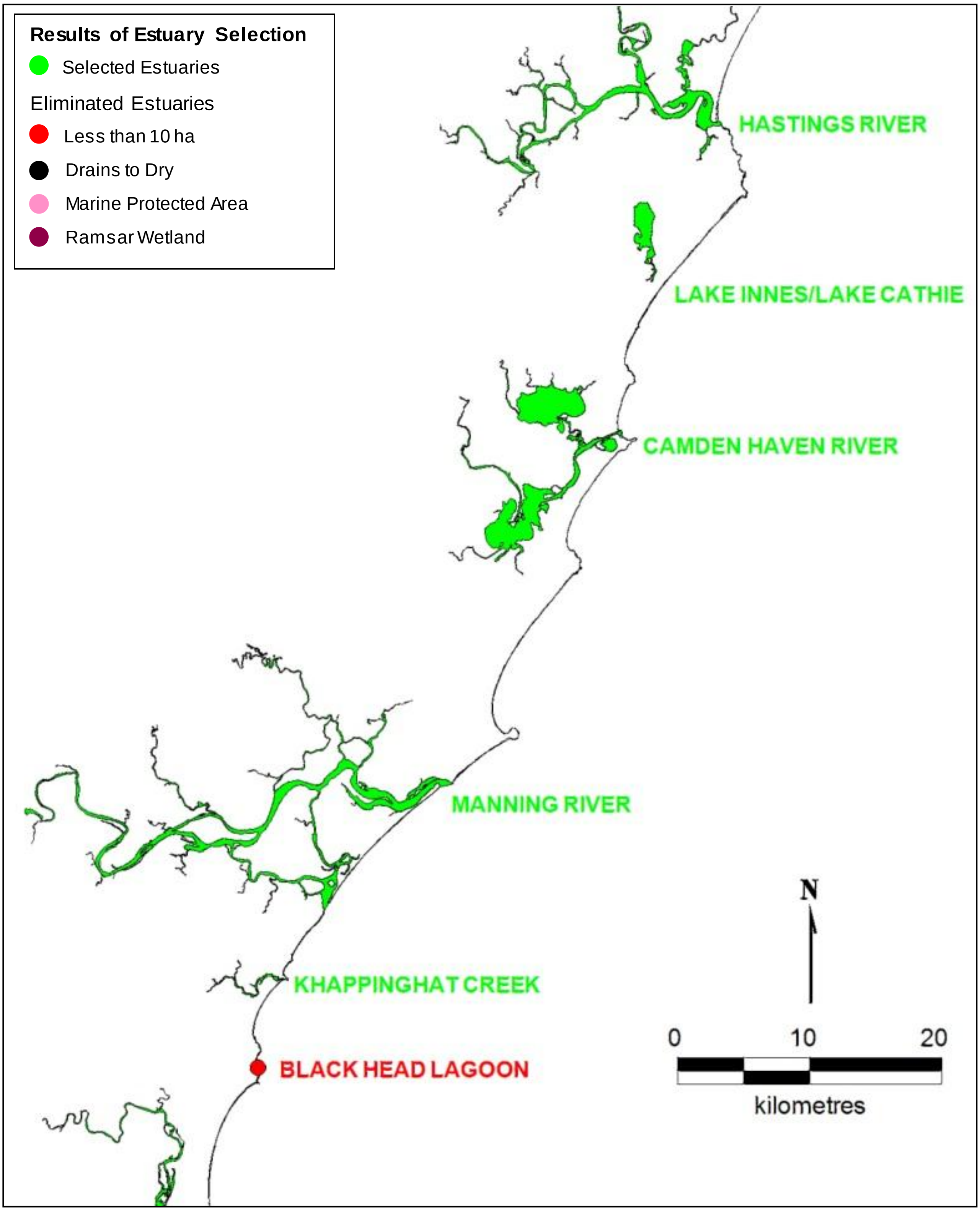


Figure B.7: Wallis Lake to Port Stephens

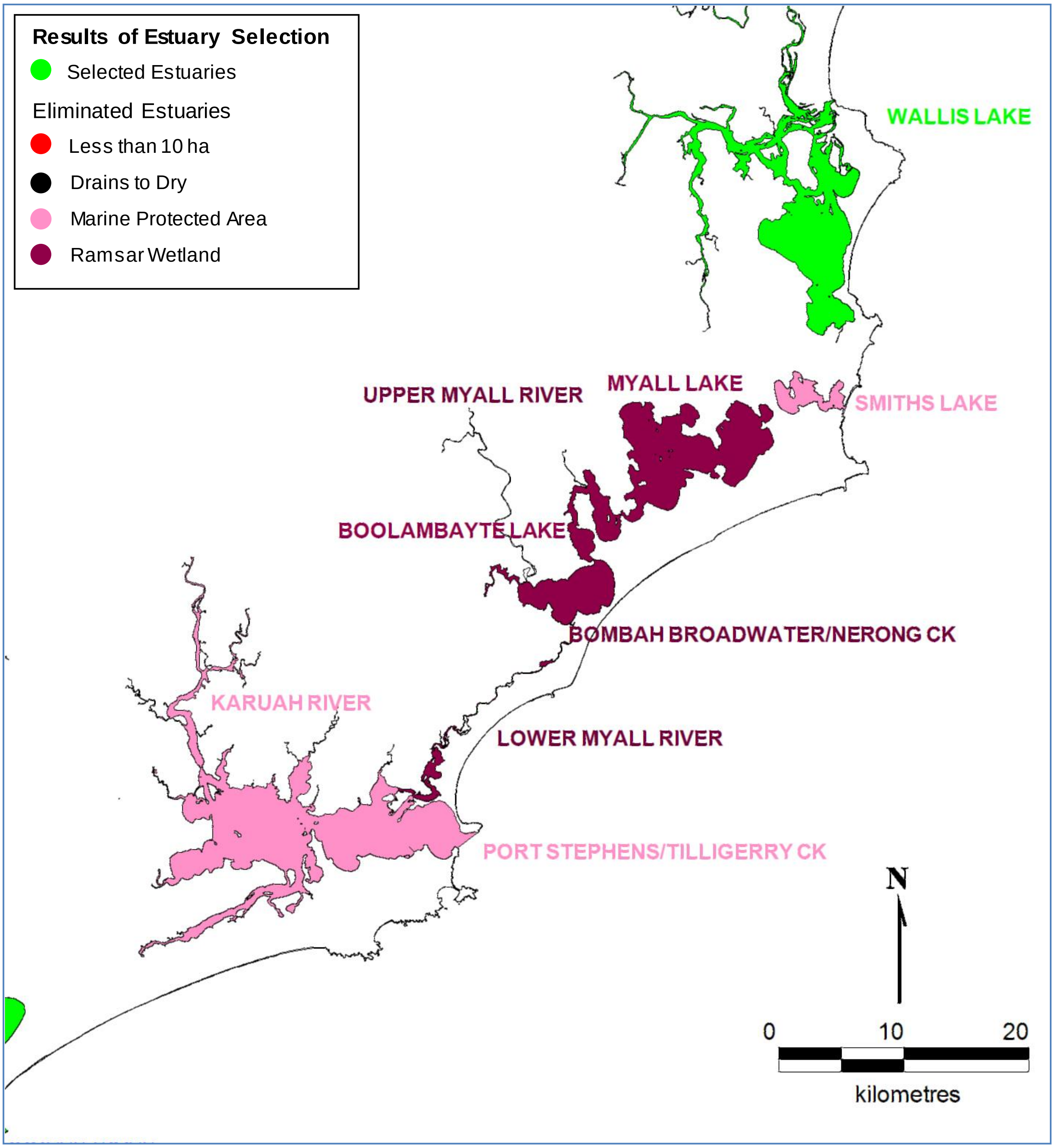


Figure B.8: Hunter River to Avoca Lake

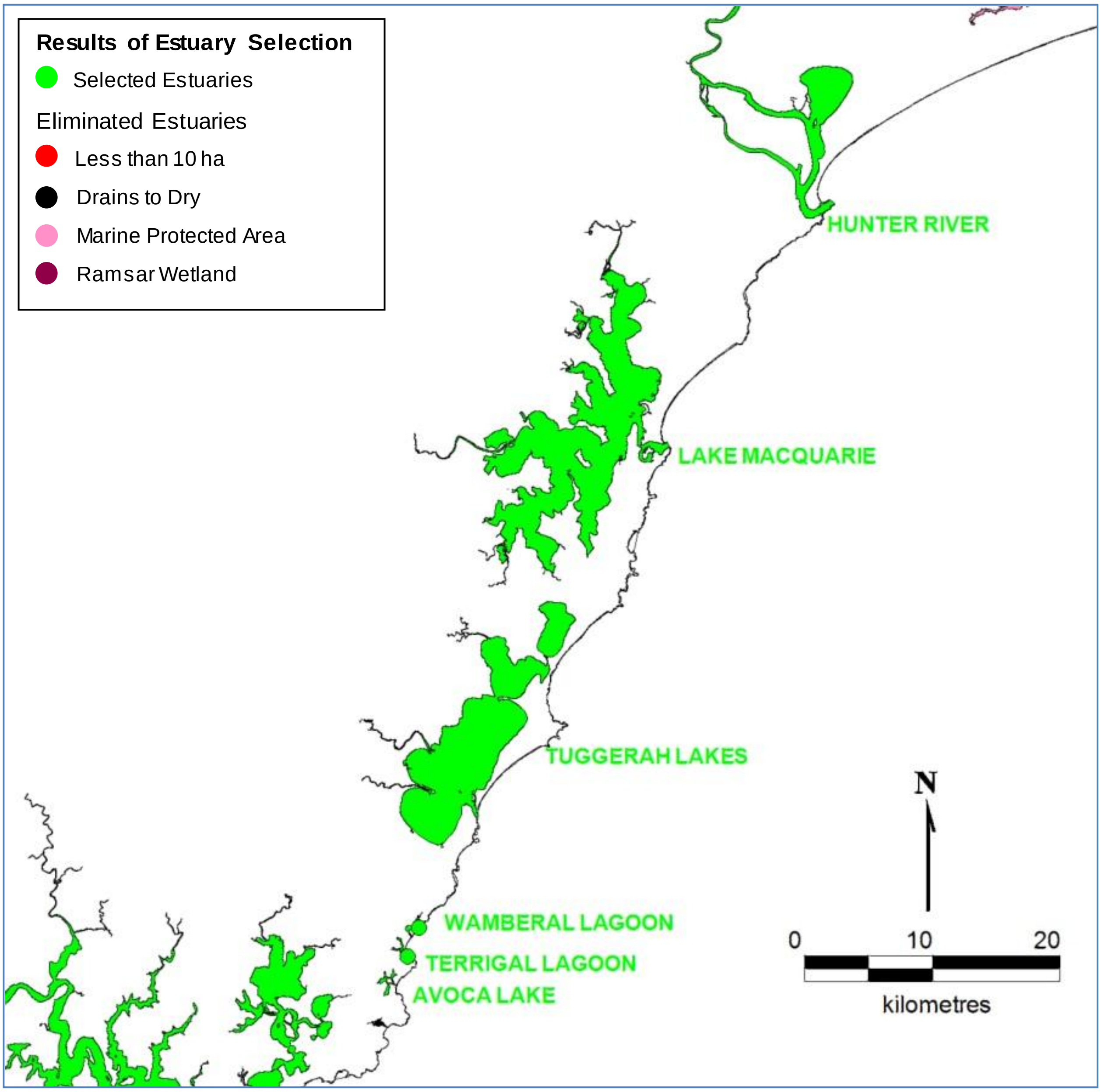


Figure B.9: Cockrone Lake to Port Hacking

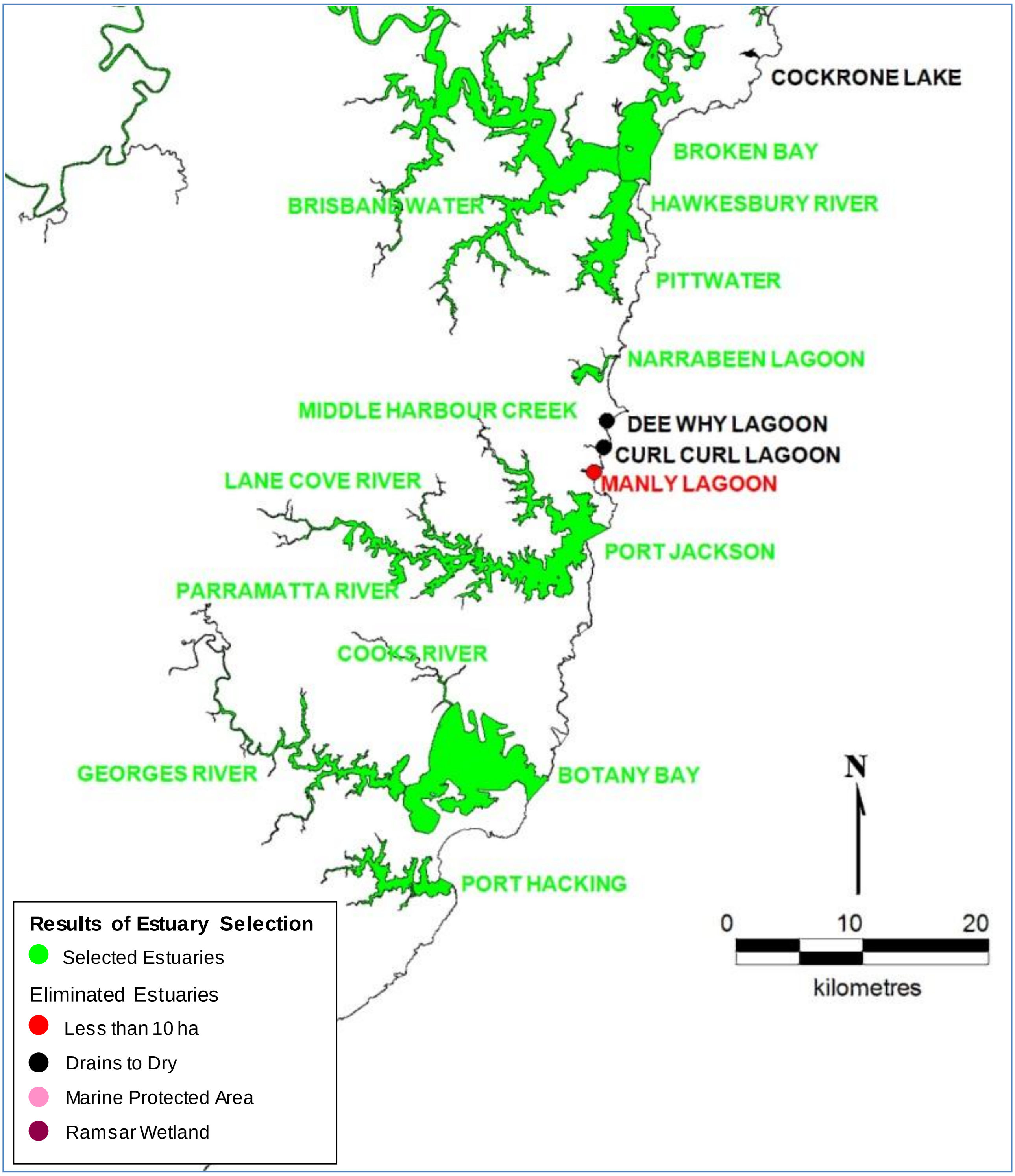


Figure B.10: Towradgi Creek to Flat Rock Creek

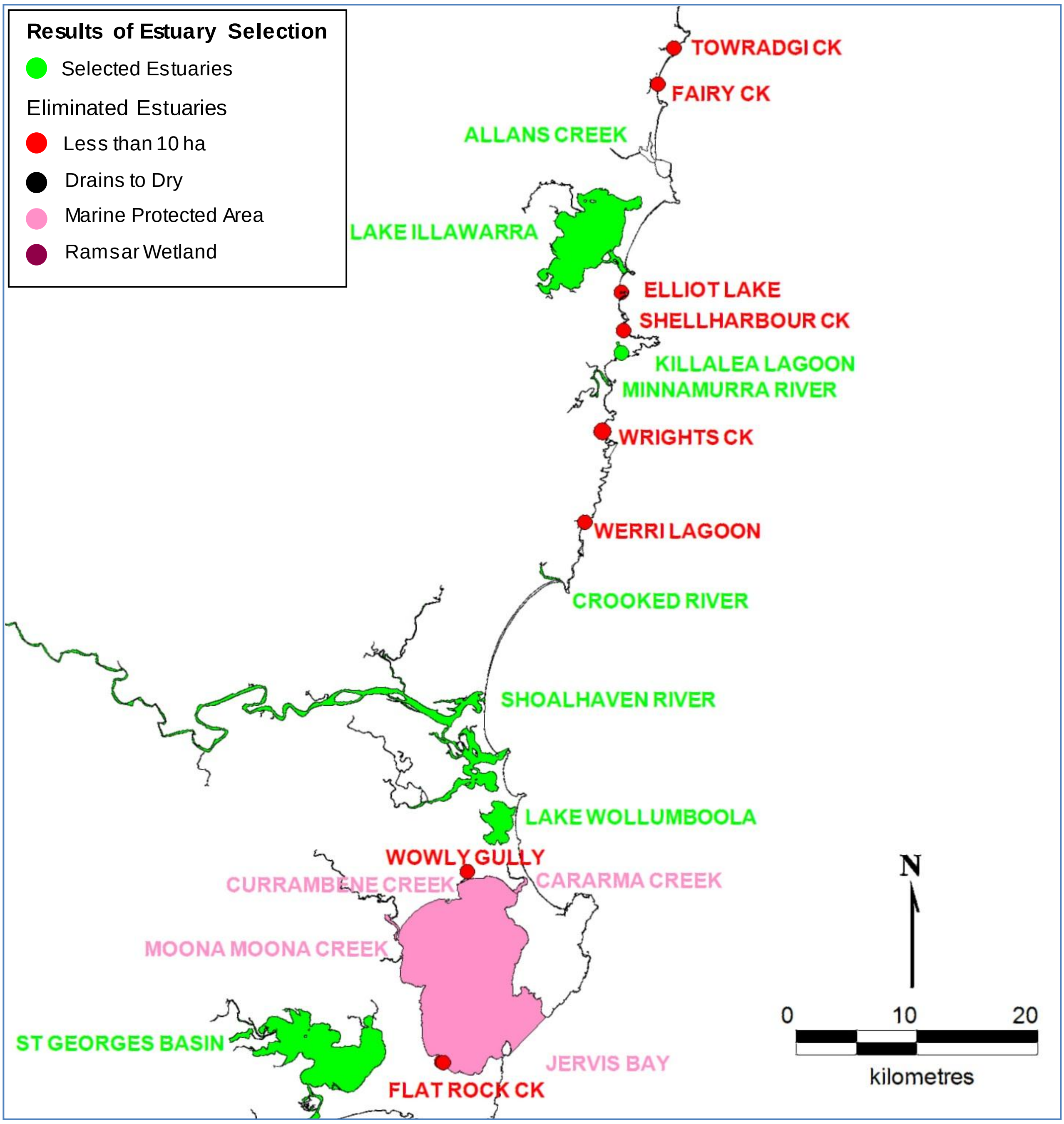


Figure B.11: St Georges Basin to Cullendulla Creek

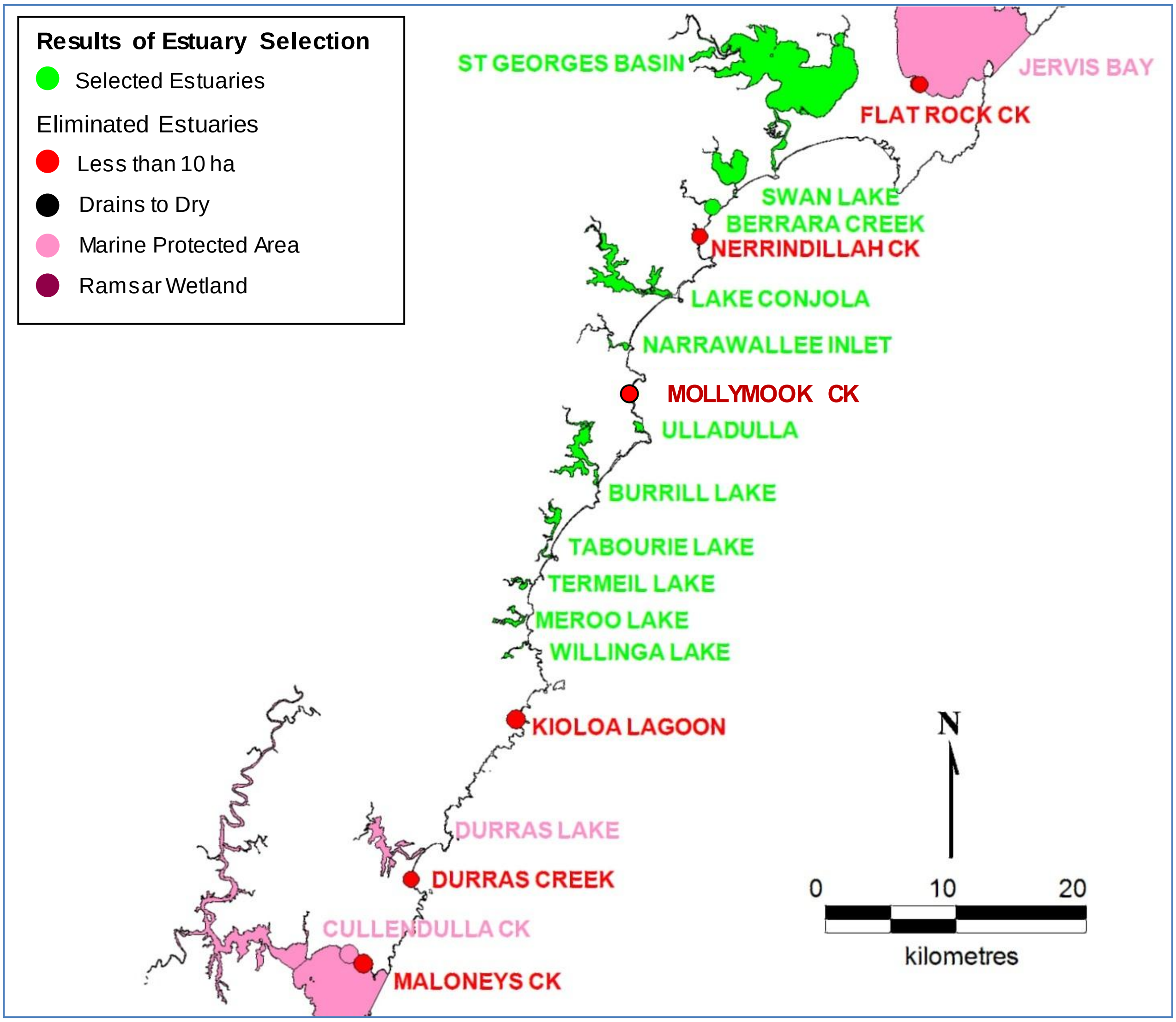


Figure B.12: Clyde River to Barragoot Lake

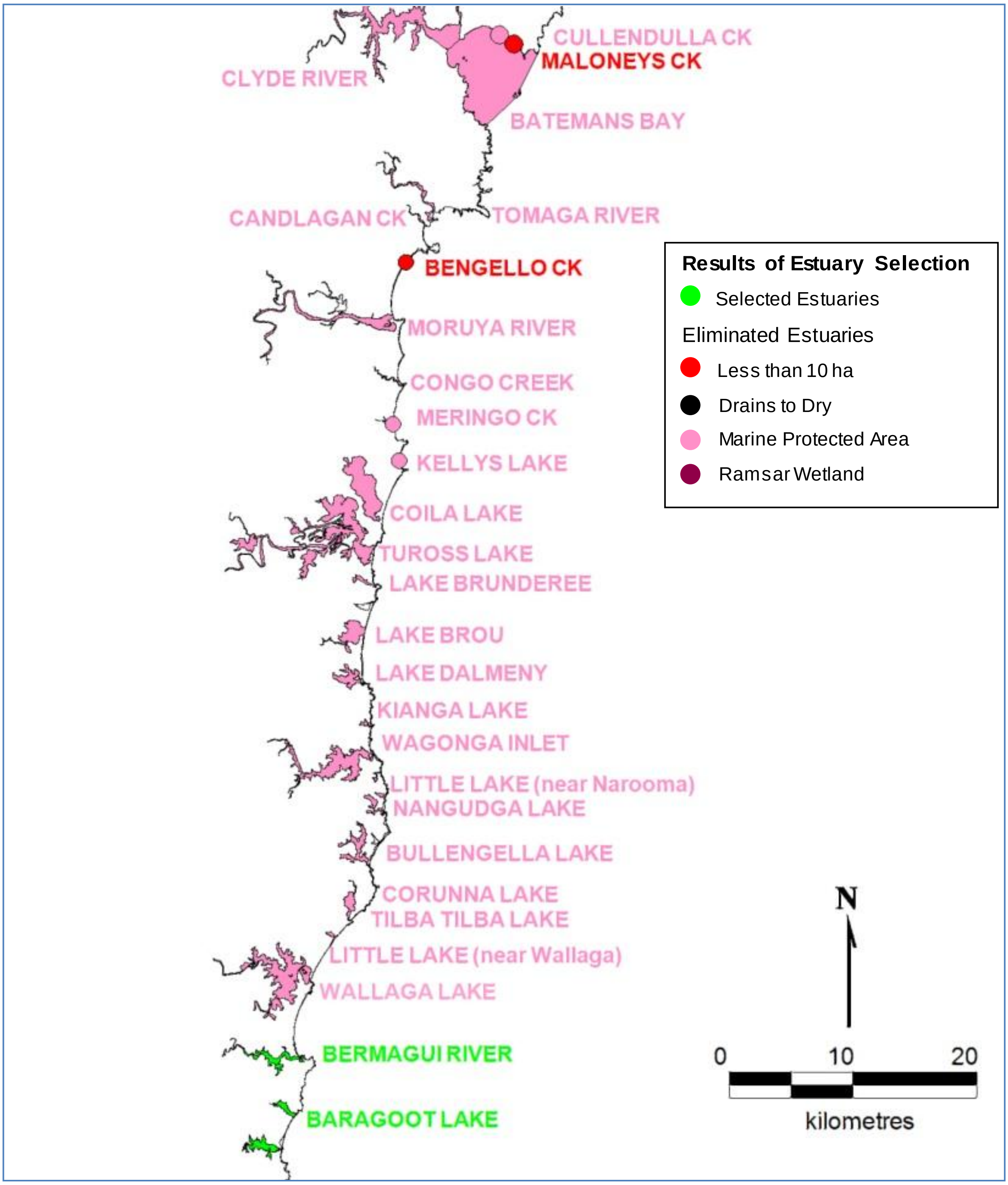


Figure B.13: Cuttagee Lake to Fisheries Creek

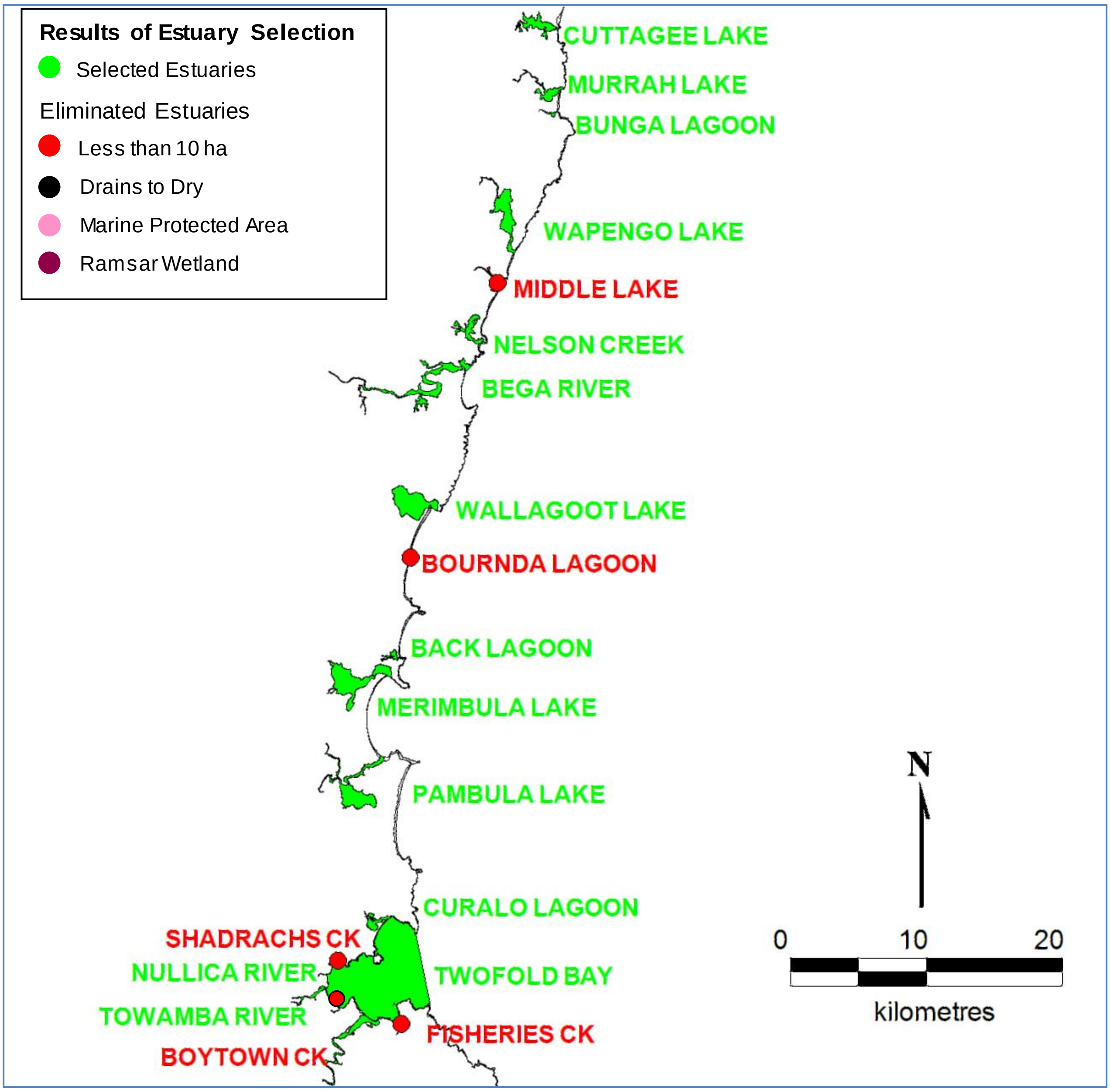
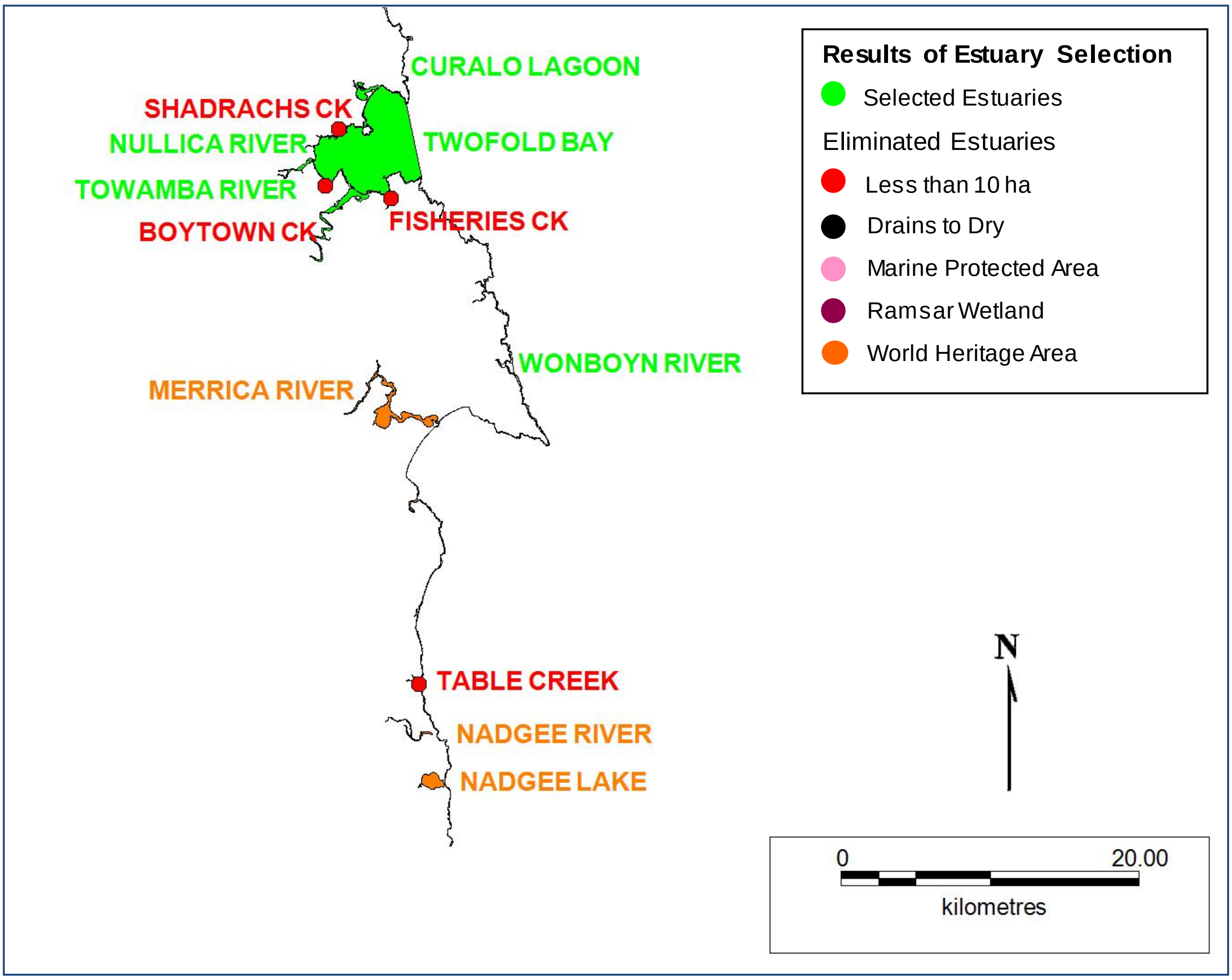


Figure B.14: Towamba River to Nadgee Lake



B.6 Operation

B.6.1 Definition of a Marine fish Stocking Event

A single marine fish stocking event is defined as;

'single or multiple releases of a species in a particular estuary and includes the time it takes for all released post-larvae or juveniles to reach a harvestable size'.

However, the age at which all released post-larvae or juveniles will reach a harvestable size will vary among the selected species; therefore the duration of a single stocking event has also been defined for each of the selected species. Table B.15 indicates the minimum harvestable size and average age at minimum harvestable size for each of the selected species which has been used to determine the duration of a single stocking event. To account for variability in the growth rate among individuals of any particular species, the duration of a stocking event is rounded up to the closest year. The exception to this is stocking events for eastern king prawns which are determined by the lifecycle of the species. Because eastern king prawns only spend one year of their post-larval life within an open estuary before entering the ocean and migrating northward to spawn (Rowling *et al.* 2010), the duration of eastern king prawn stocking events is limited to one year. The period would need to be extended in the event that an ICOLL closed after an initial stocking event or was closed at the time of stocking.

Table B.15: Definition of a 'stocking event' for each species proposed for stocking.
(*) indicates references for growth curve tables within Rowling *et al.* 2010. (TL)=Total Length, (CL)=Carapace Length. (m)=male, (f)=female.

Species	Minimum Harvestable Size (mm)	Ave. Age at Minimum Harvestable Size	Approximate Duration of Stocking 'Event' ^
Yellowfin bream	250 TL	3 yrs*	min 4 years
Mulloway	450 TL	2 yrs (Silberschneider & Gray 2005, 2008)*	min 3 years
Dusky flathead	360 TL	1.5 yrs (m) 1.0 yrs (f) (Gray & Barnes 2007)*	min 2 years
Sand whiting	270 TL	2 yrs, 5 months*	min 3 years
Eastern king prawn	N/A	N/A (but are known to reach adulthood and remain in estuaries for up to a year)*	min 1 year
Giant mud crab	85 CL	Approx. 5-6 months	min 1 year
Blue swimmer crab	60 CL	10 months (Johnson 2007)*	min 1 year

^ The period would need to be extended in the event that an ICOLL closed after an initial stocking event or was closed at the time of stocking.

Where production restrictions prevent hatcheries from producing the required number of post-larvae or juveniles for stocking in a single release then the stocking event would include the time taken to conduct all of the necessary releases (i.e. the time taken between the first release and the last release). Hence, multiple releases may extend the duration of a single stocking event by a number of years, particularly if broodstock can only be spawned in a certain season. The following example illustrates how the duration of a stocking event may be affected by the number of releases required to achieve the target number of fish to be stocked into an estuary.

Example of multiple releases contributing to a single stocking event

The modelling in the EIS indicates that 50,000 mulloway can be stocked into Estuary A in a single stocking event. The hatchery can only produce a maximum of 10,000 juveniles in any year, so for five consecutive years 10,000 mulloway are released into Estuary A, to reach the target number. As all the juveniles in the final 10,000 released will not reach harvestable size for three years the duration of the stocking event includes the time taken between the first release and the last release (~4 years) and the time it takes for all juveniles to reach a harvestable size (i.e. 3 years after the last release). Hence, the stocking event lasts for a total of seven years.

Stocking events will be distributed along the NSW coast through the three EIS identified 'stocking regions' (i.e. northern, central and southern). DPI will endeavour to stock into the highest ranking estuaries as defined by the MCA for the selected species in order to best achieve the programs objectives.

Records of all stocking events would be maintained and continually updated in a central stocking database. For each stocking event data would be recorded on the location, date, duration, species type, number of individuals, hatchery origin, marking, permit numbers etc. Further detail is provided in the draft FMS (Chapter E, Section 3.2, Goal 4.2).

B.6.2 Sources of Broodstock

Broodstock are a group of sexually mature individuals of a species that are kept separate for breeding purposes. The use of appropriate broodstock and suitable hatchery protocols are essential to ensure that the genetic diversity of naturally occurring populations is maintained.

The availability of appropriate broodstock will be a key factor in determining which of the selected species will initially be stocked and when, during the first few years of the program. Hatcheries supplying fish for the fish stocking program will need to have an appropriate H class aquaculture permit including licences for the selected species, accreditation under the Hatchery Quality Assurance Scheme (HQAS), which will be developed to include the selected marine species and also will be responsible for their own broodstock collection.

Many existing hatcheries are currently licensed to breed the species proposed in the marine harvest stocking program. Some of these hatcheries are already accredited for breeding freshwater species for stocking under the current HQAS and may also apply for accreditation under the scheme to produce stock for marine fish stocking. Other marine hatcheries may also apply for accreditation under the HQAS in order to be able to supply fish for marine fish stocking.

The EIS process identified genetic constraints relating to the locations where certain species can be stocked and or broodstock maybe collected. For five of the species in the proposal (dusky flathead, mulloway, sand whiting, yellowfin bream and giant mud crabs), it is unclear whether separate stocks occur in some estuaries or whether stocks range over wider areas or are panmictic across the New South Wales coast. Until more information on species genetic stock structure is available and under the precautionary principle, broodstock for the program would be sourced from the estuaries into which juveniles would be stocked. For the other two species (eastern king prawns and blue swimmer crabs), more information is available that allows conclusions to be made about their stock structure. Based on what is known about their stock structure, two separate genetic regions have been established for eastern king prawns and blue swimmer crabs. Broodstock may be collected from anywhere within these genetic regions for stocking estuaries within that same region.

These constraints and the specific boundaries of the genetic regions are outlined within the draft FMS (Chapter E, Appendix E.4.1).

B.6.3 Stocking Methods

Stocks of fish and crustaceans bred for the marine fish stocking program will be harvested and quarantined at HQAS accredited hatcheries. This quarantining allows for close inspection of the stock for signs of disease or contamination and reduces the chance of the transport water becoming polluted. Transport will be adapted to suit the type of species and size of juveniles being transported.

Stock would generally be released by the broadcast method. Fingerlings are separated from the main consignment in small lots (in plastic bags or buckets) and dispersed within a limited reach into areas of suitable habitat to increase dispersal and survival. GPS positions would be recorded at release points.

Releases may be carried out from shore where there is appropriate access, or by boat. Stocked fish would be acclimatised with the natural conditions, by gradually replacing water in the transportation tanks with water from the site. Prior to release, fish would be observed for any signs of stress to determine if there have been any adverse effects during transport. After any stocking activity, the hatchery would supply DPI with a stocking verification form to ensure the stocking was conducted as prescribed. Protocol outlined in the safe transport of fish and stocking code of practice (NSW DPI 2007) would be applicable for stocking of marine species.

B.6.4 Authorisation of Stocking Events

Every stocking event that involves the release of fish into public waters of NSW requires authorisation under a stocking permit (Section 216 of the FM Act). Stocking programs conducted by DPI as well as other organisations will be permitted in estuarine waters subject to assessment under the marine fish stocking FMS. Groups such as government agencies, non-affiliated fishing clubs, cultural groups and other organisations have all utilised the fish stocking permit system and are may utilise the opportunity to stock the selected marine species. Aboriginal communities throughout New South Wales also place strong and continued cultural significance to each of the native species used in stocking programs. Individual or nominated members of an organisation can apply for a permit to release fish into public waters of NSW to support recreational, conservation or cultural purposes (Section 216 of the FM Act).

B.6.5 Quantity of Fish to be Stocked

The maximum number of individuals that may be stocked in any single stocking event in a specific estuary would be determined by through the Generalised Predatory Impact Model (GPIM) (see Appendix E.5 of the draft FMS (Chapter E) for a detailed description). The GPIM was developed by Taylor and Suthers in 2008 and has been redeveloped through this EIS process to take into account a range of factors to assist in determining an appropriate number of species that can be sustainably stocked into a particular estuary.

DPI would endeavour to stock into the highest ranking estuaries as defined by the MCA for the selected species in order to best achieve the programs objectives. It is not possible to calculate the exact number of fish to be released in any one season through the harvest stocking program, primarily because the current extent of recruitment limitation is unknown, but also due to the number of combinations of fish species and estuaries possible within the proposal. However, this number would be limited through production constraints and stocking in recruitment limited situations only and is further restricted to the conservative recommended stocking rates as determined by the GPIM.

B.6.6 Ownership and Responsibility of the Ongoing Program

DPI will be the main agency carrying out marine fish stocking activity and will be responsible for managing all fish releases in New South Wales public waters. DPI will also be responsible for managing HQAS accredited aquaculture facilities where fish stocks will be produced for release in accordance with the marine fish stocking FMS. DPI will also be responsible for administering and approving other applications to stock under Section 216 of the FM Act (permit to release fish). Fish to be stocked will be sourced from suitably accredited hatcheries. It is not intended that any new hatchery facilities would require development at the initial stage of the project.

The department will also conduct research and monitoring as part of the ongoing management of the activity. Research will include the further development of breeding and husbandry techniques, development of marking agents and analysis of recaptured stock. Angler surveys would be conducted to determine recapture rates of stocked fish while creel surveys and angler knowledge surveys may also be used for other management arrangements.

Production of native fish to be stocked in approved waterways may occur at government hatcheries or may involve outsourcing or contract work from the commercial aquaculture industry through suitably accredited hatcheries. There are four hatcheries currently accredited under the freshwater HQAS that are also licenced to produce the species selected for harvest fish stocking. If these hatcheries were to produce fish for harvest stocking they would be required to meet similar standards, as defined in the proposed marine HQAS for the production of marine fingerlings. Other production work, management arrangements and policy development associated with the activity will be conducted by DPI.

B.6.7 Other Groups Involved in Stocking Events

In the past, government agencies, non-affiliated fishing clubs, cultural groups and other organisations have all utilised the fish stocking permit system and may utilise the opportunity to stock the selected marine species. The Aboriginal communities throughout NSW place strong and continued cultural significance on each of the selected species proposed in the marine stocking program. These communities have a close affiliation with the selected species as an important source of food, a cultural fishing activity and as a focal point for family gatherings and storytelling.

Chapter C

Review of Existing Information

Chapter C Contents

List of Tables

List of Figures

CHAPTER C REVIEW OF EXISTING INFORMATION

C.1 Introduction

This Chapter aims to provide a review of existing information relating to marine stocking and to outline the biophysical, social and economic uncertainties when stocking. This Chapter also contains supporting information for other parts of the Environmental Impact Statement (EIS).

The increasing human population is placing mounting pressure on coastal marine resources. An increasing demand for fish is apparent in increased commercial and recreational fishing (Booth and Cox 2003, Born *et al*. 2004, Bell *et al*. 2006, Leber 2004). Although worldwide production from capture fisheries increased from 63.4 million tonnes in 1974 to 96.5 million tonnes in 2004 (Bartley and Bell 2008), recent trends raise concerns about the capacity of wild harvests to sustain the future demand for fishing.

According to Bartley and Bell (2008) there is widespread agreement that rehabilitation of over-exploited and depleted stocks together with increased resilience of fully exploited stocks is needed for continued production from wild populations of fish. To achieve this goal, three main strategies have been identified and may be applied in fisheries management. These include traditional input and output controls on fisheries, habitat restoration and rehabilitation and more recently enhancement of fish stocks through the release of cultured juveniles.

Depending on the specific goals of fisheries managers, the release of cultured juveniles to augment wild stocks is internationally recognised as either 'restocking', 'sea ranching' or 'stock enhancement'. Bell *et al*. (2008) defines these techniques as follows:

- Restocking – The release of cultured juveniles into the wild population(s) to restore severely depleted spawning biomass to a level where it can once again provide regular, substantial yields. Bell *et al.* (2008) note that this may involve re-introducing a species that has become locally extinct (due to overfishing), or release of juveniles from conservation hatcheries to restore endangered or threatened species (i.e. analogous to 'conservation stocking' currently practiced under the NSW Freshwater Stocking Fishery Management Strategy).
- Sea Ranching – The release of cultured juveniles into unenclosed marine and estuarine environments for harvest at a larger size in 'put, grow and take' operations. In this case, the released animals are not expected to contribute to the spawning biomass, although this can occur when the size at harvest exceeds the size at first maturity, or if not all the released animals are harvested (Bell *et al.* 2008).
- Stock Enhancement –The release of cultured juveniles into wild population(s) to augment the natural supply of juveniles and optimize harvests by overcoming recruitment limitation. Bell *et al.* (2008) note that recruitment limitation is common for many coastal species with pelagic larvae in open ecosystems, even when spawning biomass is at the desired level.

For the purpose of this review, 'harvest stocking' as proposed by DPI is most closely linked to stock enhancement. The primary objective of the proposal is to enhance fish stocks and improve recreational fishing opportunities. The objective of harvest stocking is not designed as a restocking tool i.e. to restore fish populations with severely depleted spawning biomasses, but would be focused on estuaries where there is likely to be some level of recruitment limitation and/or species classified as overfished with associated recruitment limitations.

According to Taylor (2010) recruitment limitation is defined as 'where the supply of new recruits (i.e. larvae or juveniles) is insufficient to fully utilise the resources available in a particular system', acknowledging that there are other definitions in the scientific literature.

Recruitment limitation can be species based, location based, or both. Trends in the abundance of most commercial fish species are usually related to external forcing (i.e. density-independent), such as human exploitation, together with environmental variation via recruitment. Moreover, density-dependent mechanisms such as interactions within and between cohorts (cannibalism and competition) can generate population fluctuations (Bjørnstad *et al*. 1999; Fromentin *et al*. 2000, 2001; Stenseth *et al*. 1999, Cardinale and Svendang 2004). Populations often fluctuate in response to environmental variation (e.g. changes in climate, habitat, or the abundance of other species) and only through compensatory changes in demographic rates can populations counter such variability and persist over long periods of time (Murdoch 1994, Johnson 2006). Johnson (2006) identifies that the mechanisms driving demographic density dependence and evaluating their effects at the scale of large populations has been difficult, especially for species with complex life histories and that in the face of such variable replenishment mechanisms that contribute to density dependence in post-settlement growth, movement, and mortality are key to regulating variation in population size and, eventually, reproduction.

The NSW Resource Assessment System (RAS) describes some of the characteristics of an overfished stock as where fishing mortality rates are more than double natural mortality rates, estimates of biomass are less than 30 % of the estimated unfished stock or where there are trends in length/age compositions which indicate fishing mortality (for example).

It is well documented that recruitment and in turn total stock abundance may be driven by long-term environmental changes in marine systems (Steele, 1985; Fogarty *et al*. 1991; Walters and Parma, 1996, Cardinale and Svendang 2004). As such, location based recruitment limitation can occur where there is some type of location based environmental constraint, for example, where the waterway is intermittently closed off to the ocean by a sand berm, or where there is insufficient resources (food, habitat, refuge) for recruits to survive and reach maturity. Certain species also require freshwater flows as a cue for spawning and in situations where natural flow levels have been altered (e.g. from water abstraction or barriers), spawning behaviour may be suppressed and hence recruitment can be limited. A key to successful harvest stocking will be to identify estuaries where there is most likely to be some form of recruitment limitation. However, in general, great annual variation in abundance of juveniles settling from the plankton, continued rapid growth of new recruits and persistence of intermittent strong year classes are considered to be good indicators that carrying capacity of the habitat for juveniles is seldom reached (Munro and Bell 1997, Doherty 1999). Locations and/or species with these characteristics are therefore considered good candidates for harvest stocking.

Harvest stocking is currently seen as a possible option for enhancement of coastal fisheries and fisher catch due to significant advances and improvements in aquaculture and tagging techniques for a variety of fish and shellfish. Harvest stocking is designed to complement other ongoing fisheries management measures such as input and output controls and habitat protection and restoration (see also Chapter F, Section F.3).

Historically, the release of cultured stock into natural waters to provide better commercial or recreational fishing rose to prominence as a fisheries management tool in the mid 1800s with the development of fish hatchery systems in Europe and North America (Peets and Calow 1996). The development of fish spawning methodologies and live transport techniques for the eggs and larvae of several cold water species (trout and salmon in particular) facilitated the supply and movement of seed stock between different hatcheries and stocking locations. Stocking of marine finfish, however, was largely discontinued after 70 years for a number of reasons. First, research and development had concentrated primarily on the magnitude of hatchery production (Leber 2002), but had failed to develop appropriate methods for assessing and demonstrating benefit and/or adverse outcomes from stocking efforts. Second, little was known about the life histories and habitat requirements of stocked species and consequently stocking was not targeted to appropriate resource niches that would optimise survival and progression to the fishery. Third, hatchery-technologies only permitted releases of fish eggs and larvae, which consequently experienced the high mortalities associated with their early life history stages in unprotected or uncontrolled natural waters.

Although these factors led then to the demise of marine finfish stocking programs, release programs for anadromous species (i.e. marine species that move into freshwater to spawn) expanded, largely led by the apparent successes of several salmonid species (Hilborn 1992). Favourable publicity of the successes, strong support from government and industry for enhancement of sport and commercial fisheries and a desire to widely replicate these successes, has driven considerable research effort and continued expansions of these activities with anadromous species in many parts of the world.

Whilst releases of salmonid juveniles often had good survival and generally provided desirable fisheries outcomes, there are some notable exceptions where inappropriate stocking practices have led to undesirable outcomes, such as where wild production has been replaced rather than augmented. Such replacement reportedly occurred for a number of reasons, including declines in wild escapement amongst harvested hatchery stocks, competitive exclusion of wild fish by hatchery fish, and mismatches between predicted and actual natural carrying capacities (Cooney and Brodeur 1998).

Many of these mistakes can now potentially be avoided with well-designed stocking protocols and with pre-stocking surveys that assess the likely outcomes of release programs. For example, it has only been within the past 20 years or so that benign tagging techniques have been developed in conjunction with advances in aquaculture technologies for marine finfish and shellfish. This enables the production of juveniles to various sizes with adequate controls on their quality and with the application of recognisable identification marks that can distinguish them from their wild counterparts.

The need to track released fish (to monitor survival) with minimal influence on their behaviour has led to the development of a variety of tagging techniques (Tringali 2006). These include implanted coded wire tags (CWTs) (Ingram 1989, Russell and Hales 1992), visible implant elastomer (VIE) tags (Brennan *et al*. 2005, 2007), marking of otoliths with various chemicals such as oxytetracycline (OTC) (Taylor *et al*. 2005a), scale pattern analysis (Butcher *et al*. 2003), passive integrated transponders (PIT) tags and genetic markers or 'family printing' (Tringali 2006). Each of the techniques and tag types has advantages and disadvantages, and are more useful than others for particular needs. Some tags for example, can be repeatedly sampled without harm to the individual but are expensive (e.g. PIT tags). Others such as CWTs are comparatively less expensive, but require excision from the individuals to read the details of the tag. Genetic and chemical markers have limited constraints for the number, size, or species of release, and may be particularly applicable for batch-marking when there is no need to identify fish at an individual level.

In the northern hemisphere, theoretical and empirical knowledge now underpins hatchery production, release strategies and genetic management (Leber *et al*. 2004). According to Lorenzen (2008) 'understanding of population dynamics, ecological interactions, health management and socio-economics are less mature, but are developing rapidly'. Indeed, experimental release-recapture programs are greatly facilitating this improved understanding of our exploited ecosystems. Advances in aquaculture, together with a 'responsible approach' to developing, evaluating and managing marine stock enhancement programs (Blankenship and Leber 1995, Taylor *et al*. 2005b, Lorenzen *et al*. 2010, see also Section C.5), has provoked a renewed interest worldwide in the stocking of marine fish and shellfish for commercial and recreational fisheries. Restocking, stock enhancement and sea ranching are now considered to be promising options for several coastal fisheries (Bartley and Bell 2008).

C.2 Marine Stocking Worldwide

Between 1984 and 1997, 64 countries worldwide have reported some activity in marine stocking ranging from experimental research to large-scale industrial releases (Born *et al*. 2004). This includes 23 countries in Asia and Oceania, 19 European countries, 11 countries in Latin America, North America and nine countries in Africa. Approximately 180 different species have been released by these countries, of which 46 species are exclusively marine (Born *et al*. 2004). A brief overview of the scale of marine stocking done by some countries is given below.

Japan is considered to be the world leader in marine stocking with a history of releases involving over 80 species of marine fish, molluscs and crustaceans (Masuda and Tsukamoto 1998). In Japan, an estimated 90 % of the chum salmon (*Oncorhynchus keta*) fishery, 50 % of the kuruma prawn catch (*Penaeus japonicus*), up to 75 % of red sea bream (*Pagrus auratus*), 40 % of Japanese flounders (*Paralichthys olivaceus*) and almost all of the giant scallop (*Patinopecten yessoensis*) harvest, are of hatchery origin.

Techniques used by the Japanese to support hatchery releases include: habitat restoration, predator removal and behavioural conditioning. There is also a strong commitment to the program from coastal fishing communities (Science Consortium for Ocean Replenishment 2010). Several of the species are reared and released on an exceptionally large scale, such as annual releases of up to 14 billion short-necked clam (*Tapes philippinarum*), and 3 billion giant scallop (*Placopecten magellanicus*), which have supported a steady yearly increase in yield (Masuda and Tsukamoto 1998). The greatest finfish releases include red sea bream and Japanese flounder with 25 million and 8 million respectively released per year, with a 30 % recapture rate and an estimated cost-benefit ratio of 300 % for flounder releases (Masuda and Tsukamoto 1998). Other large-scale releases in Japan include 300 million kuruma prawns, 27 million speckled shrimp (*Metapenaeus monoceros*), 20 million swimming crabs (*Portunus trituberculatus*) and 11 million sea urchins (*Strongylocentrotus intermedius*) (Munro and Bell 1997). Smaller scale releases have taken place in Japan with crustacean species relevant to the present EIS, e.g. 1.5 million mud crab *Scylla* sp. juveniles in 1999 (Hamasaki 2002, cited by Davis 2004).

Bell *et al*. (2008) consider China to be one of the most progressive countries engaged in large-scale restocking and sea ranching programs which employ thousands of people in commercial organisations. Significant government funding has also been provided to supplement existing initiatives in large-scale stock enhancement and restocking programs. Iran is also a prominent country in stock enhancement where fisheries scientists raise and release approximately 12 million juveniles of indigenous sturgeon (*Huso huso*), supporting the majority of the national fishery and caviar industry. In addition, State run hatcheries release juvenile bream (*Abramis bjoerkna*), kutum (*Rutilus frisii*) and pike-perch (*Sander* sp.) all of which support fisheries harvested by licensed coastal cooperatives (Science Consortium for Ocean Replenishment 2010).

Marine stocking is extensively practiced in the USA and the history of stocking in this country has been well documented (Leber 2002, Lorenzen 2008, Leber 2004). The first US salmon hatchery was established in Maine in 1871 and soon after, shore-based marine finfish hatcheries were established for cod (*Gadus* sp.), haddock (*Melanogrammus aeglefinus*), pollock (*Pollachius* sp.), winter flounder (*Pseudopleuronectes americanus*) and lobster (*Homarus americanus*) in an attempt to replenish wild populations (Leber 2004). In contrast to salmonid enhancement, most non-salmonid marine stock enhancement is research orientated, with an emphasis on gaining a better understanding and greater control of stocking effectiveness. Pilot-scale releases have been undertaken in California with white sea bass (*Atractoscion nobilis*), California halibut (*Paralichthys californicus*) and rockfish (*Sebastes* spp.); in Florida with red drum (*Sciaenops ocellatus*), common snook (*Centropomus* spp.), sturgeon (*Acipenser* sp.), scallops (*Argopecten gibbus*), blue crab (*Calinectes sapidus*), red snapper (*Lutjanus* sp.); in Hawaii with striped mullet, pacific threadfin (*Polydactylus* sp.), red snapper; in New Hampshire with flounder (*Pseudopleuronectes americanus*); in South Carolina with red drum, cobia (*Rachycentron canadum*) and white sea bass; in North Carolina with lingcod (*Ophiodon elongates*), Pacific cod (*Gladus macrocephalus*), rockfish; and in Washington with salmon (Salmonidae). Several large research programs are also developing stock enhancement for depleted blue crab fisheries in Florida, Maryland, Mississippi and Virginia (Leber 2004, Science Consortium for Ocean Replenishment 2010).

Closer to home, stock enhancement is well established in New Zealand for the scallop (*Pecten novaezelandiae*) and for paua (*Haliotis iris*). Without intervention, the scallop fishery is typically variable due to yearly changes in natural populations caused by fluctuating mortality levels and recruitment of early life stages. Scallops are mainly stocked into the northern bays of the South Island as natural seed or wild caught spat which are re-laid. The enhanced scallop fishery is operated on a rotational basis, taking 3 years for the young scallops to reach a harvestable size. Enhancement has helped increase and stabilise production. In 1992, it was estimated that 40 –50 % of landings came from cultured stocks (Booth and Cox 2003). The success of the fishery has been attributed to the spat longlines that provide an artificial settlement substratum.

Outplanting of paua into the wild fishery has been done since 1984 in New Zealand. It has been estimated that 33 % of 15-20 mm outplanted juveniles survive to reach a harvestable size. The program aims to harvest 500,000 individuals per year by this process (J. Cooper, pers. comm.). Other species in New Zealand for which research stocking programs are underway, or are likely to occur, include dredge oysters (*Ostrea chilensis*), cockles (*Austrovenus stuchburyi*), pipis (*Paphies australis),* toheroa (*Paphies ventricose*) which is a type of surf clam, blue mussels (*Mytilus edulis*), green lipped mussels (*Perna canaliculus*), sea urchins (*Evechinus chloroticus*), rock lobster (*Jasus edwarsii*), certain seaweeds (Rhodophyta and Phaeophyta), snapper (*Pagrus auratus*) and chinook salmon (*Oncorhynchus tshawytscha*) (Booth and Cox 2003).

Marine stocking programs that are at the experimental stage or currently in progress are also taking place in many countries. Some of these are: in Norway and Denmark for cod and European lobster (*Hommarus gammarus*); in Spain for turbot (*Scopthalmus maximus*); in the UK for European lobster; in the Caribbean for queen conch (*Strombus gigas*); in the Philippines for giant clams (*Tridacna gigas*) and sea urchins (Echinodea); and in Indonesia and Vanuatu for topshells (Trochidae). Stock enhancement and restocking of sea cucumbers (*Holothuria scabra*) has also been investigated in New Caledonia over a four year period to determine optimal release strategies (Purcell and Simutoga 2008).

While the marine stocking programs discussed above have generally been developed to enhance commercial fisheries with potentially some additional benefit to recreational fisheries where they do occur, there are very few marine stocking programs dedicated to enhancing recreational fisheries. The red drum stock enhancement program run by Texas Parks and Wildlife Department (TPWD) is such an example. It is a long-term, large-scale stock enhancement program, which involves the release of 20–30 million red drum fingerlings (normally about 25 mm long) annually to supplement natural recruitment and boost recreational fishing opportunities (McEachron *et al*. 1995). Declines were observed in the fishery in the 1970's recognising this decline, TPWD (in partnership with The Gulf Coast Conservation Association and American Electric Power) opened a hatchery in 1982 and commercial fishing for the species was banned in 1990. Since implementing the stock enhancement program and together with bag and size limits and habitat management, red drum populations are currently considered to be stable. Population genetics and life-history research programs continue to be funded in conjunction with the stocking program.

C.3 Fish Stocking in Australia

Fish stocking has been undertaken in Australia for well over a century (NSW DPI 2003a), primarily to enhance recreational fisheries, although in some cases fish releases have been undertaken to restore severely depleted species. The majority of stocking has occurred in freshwater, beginning in Tasmania with the introduction of salmonids in 1864, followed by the introduction of brown trout (*Salmo trutta*) into New South Wales (NSW) waterways in 1888 (Kearney and Andrew 1995). Native freshwater species such as Murray cod (*Maccullochella peeli*), trout cod (*Maccullochella macquariensis*), golden perch (*Macquaria ambigua*) and silver perch (*Bidyanus bidyanus*) are now also stocked in Victoria (VIC) and NSW to enhance fisheries or assist in the conservation of the species (Rowland 1995). More recently, Australian bass (*Macquaria novemaculeata*) have been stocked into coastal rivers and lakes of south-eastern Australia (DPI 2003a, VIC DPI 2010, Kearney and Andrew 1995).

Despite the long history of freshwater stocking programs, marine stocking in Australia is still in its infancy and although aquaculture technology exists or is under investigation for a total of 23 species of estuarine finfish, at present there are no ongoing programs (Taylor *et al*. 2005b). Very early attempts to enhance coastal fisheries were first made in 1900 (Fisheries of NSW 1901) with the introduction of flounder (*Platichthys flesus*) from the UK, although these efforts proved unsuccessful. Since then, there have been various one-off releases or short-term programs in many States. Where reported, details of stockings that have taken place in Australia are discussed below.

C.3.1 Queensland

Freshwater Stocking

Several Australian native fish species have traditionally been stocked into freshwater dams and lakes in Queensland (QLD) to enhance recreational fisheries. These include silver perch, golden perch, Murray cod, Mary River cod (*Maccullochella peeli mariensis*), saratoga (*Scleropages* sp.), Australian bass and barramundi (*Lates calcarifer*). The first three of these have been widely translocated into drainages east of the Great Dividing Range. The latter two of these species are native to east coast drainages and since they spawn in brackish water they are now stocked over man-made barrages and weirs to maintain their historical distributions. The QLD Government supports ongoing research to optimise these activities (QLD DEEDI 2010a) and operates the Stocked Impoundment Permit (SIP) Scheme (QLD DEEDI 2010b) to help purchase fingerlings to regularly stock the 30 participating dams and impoundments in the State. Aquaculture technologies for most of these species were well developed many years ago, and their production is now routinely undertaken by commercial hatcheries.

Some marine species have also been successfully been stocked into freshwater impoundments in QLD including mangrove jack (*Lutjanus argentimaculatus*) and sea mullet (*Mugil cephalus*). Aquaculture techniques for mangrove jack have been studied over the last decade with recreational stocking as the prime objective and trial stockings into several dams in northern and central QLD are now beginning to show promising results (Mitchell 2009). Similarly, sea mullet are well known to grow to large sizes in freshwater environments and have been stocked on many occasions by private and government bodies for environmental purposes (e.g. vegetation and aquatic insect control). Since all weirs and impoundments overflow during periodic flood events, all of these species and stockings can be expected to have complemented estuarine stocks if they could physically survive the drops over dam walls and the subsequent salinities of tidal systems.

Barramundi

Barramundi have been widely released into impounded and non-impounded systems in QLD since 1986, to enhance recreational fisheries. Early releases into Lake Tinaroo and Lake Morris were studied closely by the then QLD Department of Primary Industries (QLD DPI) (MacKinnon and Cooper, 1987) and were determined to be economically viable, particularly when indirect economic factors are included in the cost-benefit equation (Rutledge *et al*. 1990). These freshwater impoundment releases were followed with several significant open system (river) releases in the 1990's, in eastern QLD (Cairns Inlet, Mary and Burrum Rivers: Doohan 1995) and in the Gulf of Carpentaria (Rimmer and Russell 1998). Although several reports from recreational and commercial fishers were very positive (e.g. Palmer 1995) proper evaluations were not possible.

Detailed assessments have, however, been undertaken in the Johnstone River in Northern QLD. Rimmer and Russell (1998) investigated the cost-benefit ratio of some 69,000 30-mm-long barramundi fingerlings that had been marked with CWTs. Analyses indicated that less than 1 % of stocked barramundi would need to be recaptured to cover the cost of the stocking program, but after ~3 years, 62 % of the stocked fish had been recaptured quite close to the release site (within 3 km). This demonstrated considerable positive economic outcomes. In later work summarised by Russell *et al*. (2004), the release of larger juveniles (300 mm long) provided better recapture rates and a much better benefit-cost ratio compared with smaller size classes tested (50 to 130 mm). This was despite the extra costs associated with growing fingerlings in nursery systems to larger sizes. Release sites with significant aquatic weed habitat were also suggested to improve survival through the provision of abundant prey and adequate cover for naive fingerlings.

To date, there have been no recorded disease introductions or amplifications in wild stocks, or other biosecurity-related issues that have arisen in QLD from any of this fishery enhancement work with barramundi (pers. com. D. J. Russell October 2009). Like other freshwater and marine fish, barramundi are at times known to harbour bacterial, viral and parasitic infections (QDPI&F 2005), so they can certainly be considered a potential disease vector. Given the lack of evidence for environmental contamination in the face of these quite significant and widespread hatchery-release programs, the biosecurity and disease-treatment activities of the producing hatcheries and translocation policies of Government (QDPI&F 2005) appear to have thus far adequately addressed the health of released fish. Alternatively, the lack of adverse events in this regard could also be seen as evidence for the general resistance and resilience of wild populations to the perturbations of endemic diseases.

Dusky flathead and sand whiting

Between 1995 and 1999, a collaborative pilot program was undertaken in the Maroochy River estuary in south-east QLD to investigate the effect of releasing large numbers of dusky flathead (*Platycephalus fuscus*) and sand whiting (*Sillago ciliata*) fingerlings. Approximately 335,000 sand whiting and 100,000 dusky flathead (40-50 mm long) were released over a three year period (Butcher *et al*. 2000) making it the largest marine stocking program so far undertaken in Australia (Taylor *et al*. 2005b). The best practice principles developed by Blankenship and Leber (1995) were applied (see Section C.5). Pre-stocking surveys attempted to assess baseline population levels, seasonal abundance and habitat preferences for both species in the estuary. Fingerling production methodologies were developed using locally caught broodstock and a standardised health assessment index. Scale pattern analysis was found most suitable for detection of recaptured specimens because it enabled reliable differentiation between wild and hatchery-reared fish (Butcher *et al*. 2003). Recruitment of stocked individuals to the recreational and commercial catches was clearly evident. Estimates of contributions to the recreational and commercial sectors were that stocked fish contributed 47 % and 28 % of catch, respectively for dusky flathead, and 44 % and 52 %, respectively for sand whiting (Butcher *et al*. 2000). Whilst the project achieved its aims (i.e. released fish survived and were recaptured), there was no evidence for increases in population sizes or overall landings for either species. Yearly population fluctuations both before and after the stocking events masked the overall effect on populations, results may also have been confounded by a large fish kill in the Maroochy estuary experienced during the project (Butcher 2000).

Saucer scallops

A marine stocking program for the saucer scallop (*Amusium balloti*) has been underway in Hervey Bay in southern QLD since 2005. The program is operated by a commercial consortium known as QLD Sea Scallops (QSS) and is underpinned by Fisheries Research and Development Corporation funding to develop business plans (QSS Pty Ltd 2005), Federal and Local Government business development grants (DEWHA 2006, Department of Infrastructure, Transport, Regional Development & Local Government 2009), and hatchery technology developments (Wang 2007), genetic studies (O'Brien *et al.* 2005), and marking techniques (Lucas *et al.* 2008) that have been conducted and developed by QLD DPI&F. As is the case for other scallop fisheries around the world, production in Hervey Bay can be highly variable from year to year and enhancement efforts are designed to maintain or enhance production despite years of poor natural recruitment. Stocks in QLD waters were found to be homologous and baseline diversity levels were identified to guide hatchery activities into the future (O'Brien *et al.* 2005). To date, several million spat (2-5 mm shell height) have been released onto sea bed leases. In recent commercial trials the shells were marked with OTC (Lucas *et al.* 2008).

C.3.2 Western Australia

In Western Australia (WA) there has been useful work towards stock enhancement for fish, molluscs and prawns. Barramundi have been released on a small-scale in Lake Kununurra (a freshwater impoundment) on two occasions. On the first occasion (1991), 124 fish were released with very few recaptured. In the second trial (2000/2001) approximately 600 juveniles were released. Twelve or more tagged fish were later recaptured below the Kununurra diversion dam (Borg 2004) which is estuarine.

Black bream and tarwhine

In 1983 and 1984, a low number (~700) of black bream (*Acanthopagrus butcheri*) were first stocked in WA after being translocated from North Landing (Bremer River in the south west of the State) to Lake Dumbleyung (inland from the Bremer River). Although successfully transferred, only two individuals were later captured in the Lake (two years later). Since then, about 200,000 black bream fingerlings have been stocked into inland-saline and fresh waters to assess survival and growth (Lenanton *et al*. 1999). Sarre *et al*. (2000) undertook a two year research project to investigate the success of these previous stockings. The study demonstrated that survival at lower salinities was poor, but survival and growth rates improved in more saline waters (Noriss *et al*. 2002). The study also found that most estuaries in southern WA did not contain suitable hydrographic habitats to support released individuals, however, where appropriate habitat and food were available, black bream could breed and establish self-sustaining populations.

In 1993, the WA Recreational Sport Fishing Council (WARFC) aimed to stock tarwhine (*Rhabdoglossus sarba*) and black bream into the Swan River, Perth. Tarwhine was the first to be cultured and released, although no attempt was made to evaluate the success of the introduction. Black bream enhancement was deemed to be of greater importance to recreational fisheries, and 767, ~150 mm externally-tagged black bream were released into the upper Swan River in 1995. Ninety-seven black bream (12.6 %) were recaptured during the study, which also indicated that released black bream could be more easily caught than wild individuals, and that hatchery releases could contribute to the fishery (Dibden *et al*. 2000).

Jenkins *et al*. (2006) extended this work into open systems in the Blackwood River Estuary (southern WA), which had shown significant declines in black bream abundance since the mid-1970's. A total of 220,000 alazarine complex one- (ALC) otolith-stained fingerlings (30-60 mm in length) were released at three sites in 2002 and 2003. This included 70,000 (60 mm) fingerlings in 2002 and 150,000 (30 mm) fingerlings in 2003. A further 1217 advanced juveniles (cultured for 18 months) and 102 broodstock were also released into the upper estuary in 2003 after the application of t-bar tags as part of the research program. Stocked bream were found to dominate the estuarine population thereafter, despite growing slower than the wild fish. Factors contributing to this slower growth remain unknown (Potter *et al*. 2008), but ALC-tagged fish continue to be recaptured in ongoing research in the Blackwood system to date and the activity has clearly demonstrated significant and long-term benefits to the region (pers. com. G. Jenkins October 2009).

Abalone

A preliminary assessment of stock enhancement of greenlip abalone (*Haliotis laevigata*) in WA was undertaken with the release of 6,000 (10-70 mm) juveniles near Augusta in 2004 (Hart *et al*. 2007). Overall, survival was 19 % for 1+ age abalone and 27 % for 2+ animals after 9 months. The objective of the project was to obtain quantitative data on the likelihood of enhancement and cost-benefit. It is understood that further trials are underway.

Prawns

Prawn stock enhancement has not yet been carried out on a large-scale in Australia, although the commercial potential of using the brown tiger prawn (*Penaeus esculentus*) for stock enhancement in Exmouth Gulf, WA, has been investigated. Efforts to evaluate the potential to enhance prawn fisheries in Northern Australia has been underway since the early 1990's (Loneragran *et al.* 2004). Initially, CSIRO conducted several workshops and feasibility studies based on some very detailed ecological work for several tiger prawn species in the Northern Prawn Fishery which had shown population declines from recruitment overfishing (Loneragen *et al*. 2001, 2006). A collaborative program involving CSIRO, the M.G. Kailis Group of Companies and the WA Department of Fisheries was set in motion. Bio-economic models were developed based on the release of significant numbers of brown tiger prawn juveniles. Release sites that provided appropriate habitats were identified and genetic markers suited to use in monitoring the success of the program were investigated. However, one of the biggest impediments to this work proceeding in the envisaged time frame was the production of the large numbers of prawn juveniles that would be required (e.g. 10-30 million). Unlike the prawn-farming industry of Australia, which stocks its ponds with one-month-old post larvae, this enhancement work sought to release much larger animals, so that new, more-advanced methods of juvenile production were necessary. Even though methods that can produce juveniles at high densities (e.g. 3000 m^{-3}) have now been developed, the bio-economic model that has weighed information from these projections suggests that the exercise may not be economically viable. The high cost of juvenile production and transporting them to release sites coupled with other operating costs, the current values of the harvested fishery product, and expected natural mortality events, have necessitated a revision of future plans in the program (Loneragran *et al.* 2004).

C.3.3 New South Wales

Freshwater Stocking

Stocking of freshwater fish is commonly used in NSW to replenish fish stocks in areas where there have been declines or to enhance recreational fishing opportunities at popular angling locations. Around 50 million fish have been stocked into waterways of south-eastern Australia since 1980 by angling clubs, community groups and government departments. The fish are produced at NSW Department of Primary Industries (DPI) Hatcheries at Narrandera Fisheries Centre, the Dutton Trout Hatchery at Ebor, the Gaden Trout Hatchery at Jindabyne, the Port Stephens Fisheries Centre as well as several commercial hatcheries and include Golden perch, Murray cod, silver perch, trout cod, Australian bass, rainbow trout, brown trout, brook trout and Atlantic salmon. Sites are stocked by staff from DPI and acclimatisation societies (for salmonids) based on extensive consultation with acclimatisation societies, fishing clubs and community groups and take into account the condition of the streams and impoundments (I&I NSW 2005e).

Marine Stocking

Targeted research programs investigating the feasibility of stocking some species of fish and invertebrates have occurred and there have been various, one-off marine stockings for various reasons.

DPI has managed small releases of fingerlings or adults of various species in some estuaries for cultural purposes and by Sydney Aquarium through the issue of permits issued under the *Fisheries Management Act 1994* (FM Act). The species released have included spotted wobbegong (*Orectolobus maculatus*), dusky whaler shark (*Carcharhinus obscurus*), green moray eel (*Gymnothorax prasinus*), white's seahorse (*Hippocampus whitei*), pipi (*Donax deltoides*), yellowfin bream (*Acanthopagrus australis*) and mulloway (*Argyrosomus japonicus*).

Targeted pilot enhancement programs have been done for mulloway, eastern king prawns (*Melicertus plebejus*) and abalone (*Haliotis rubra*). Stocking trials with abalone indicated low rates of long-term survival for hatchery-reared larvae but survival in out-planted juveniles (4–10 %) was better than expected for wild abalone at 3 of 12 release sites (Chick 2009). Reseeding and translocation of abalone has been used as a measure to help re-establish populations severely affected by outbreaks of perkinsus, although this was considered to be a remedial measure and not necessarily a long-term solution to the problem.

Significantly greater numbers of juveniles survived at multiple release locations than at control locations after >2 years. Further, the mean numbers of hatchery-reared juveniles had no detectable effect on the mean number of wild abalone over these time scales.

Since 1990, DPI has carried out research to determine the feasibility of stocking juvenile mulloway and have been able to demonstrate stocking potential for that species (Fielder *et al.* 1999). Fielder *et al*. (1999) aimed to evaluate techniques for the production of juvenile mulloway and to stock Intermittently Closed/Open Lakes and Lagoons (ICOLLs) in NSW which are considered to be recruitment limited because of the physical barrier created by the intermittent sand berms (Taylor *et al.* 2009). The best strategy to maximise survivorship and sustainable production of juvenile mulloway was to initially rear larvae in intensive tanks, followed by on-growing in fertilised ponds (Fielder *et al.* 1999). Three ICOLLS (Khappinghat Creek, Swan Lake and Smiths Lake) were each stocked with ~25,000 OTC marked juveniles (between 35 and 85 mm in size) reared at NSW Government hatcheries. The Georges River was also stocked in 2003 with 54,000 fingerlings. Post-stocking surveys did not yield any recaptures in Khappinghat Creek and Swan Lake, due in part to predation by sea birds, emigration and dense aquatic macrophyte beds which interfered with the sampling effort. Stocking of Smiths Lake proved successful where fish demonstrated rapid post-release growth, and large numbers of hatchery-reared fish were landed within 16 months of stocking (Taylor *et al.* 2009). About two years after stocking, commercial fishers reported mulloway up to 2.7 kg in mass (Fielder *et al*. 1999). The stocking had an evident effect on catches in Smiths Lake for several years after the stocking event with a 1500 % increase in mulloway landings, in spite of decreasing catch rates across the rest of the State (Taylor *et al*. 2005b).

Mulloway was also stocked in three north coast estuaries and the Georges River in 2003 and 2004. The Georges River yielded fishery independent recapture rates of up to 0.2 % (Taylor *et al.* 2009). For the 1997 and 2004 Smiths Lake releases and all Georges River releases, fish were found to grow and recruit into the fishery. The lack of recaptures from some of the coastal lakes, however, highlights the importance of choosing release habitat suitable for the species selected for stocking and highlights the need for pilot releases to optimise stocking strategies and assess fish stocking effects. A summary of releases and recaptures of mulloway cohorts released into NSW estuaries is provided in Table C.1.

Table C.1: Cohorts of mulloway (*Argyrosomus japonicus*) released in NSW estuaries (1996 – 2004). Source: Taylor *et al.* (2009).

Estuary	Release date	Mark	Release size mean ± SE (mm TL)	No. released	No. recaptured	Post-release mortality (%) (mean ± SE) after 7 days	Historic landings (mean ± SE) 1940/41–2004/05 (kg)*
Khappinghat Creek (coastal lake)	January 1996	OTC	40.3 ± 5.5	25 000	0	–	None
Swan Lake (coastal lake)	March 1997	OTC	51.3 ± 5.9	28 000	0	–	17.1 ± 6.8
Smiths Lake (coastal lake)	March 1997	OTC	76.7 ± 6.7	21 600	64	–	133.4 ± 23.2
	May 2003	OTC	79.6 ± 0.9	42 000	0	3.3 ± 3.3	
	February 2004	OTC	47.4 ± 0.4	18 000	5	4.5 ± 2.2	
Georges River (riverine estuary)	May 2003	OTC	82.5 ± 1.2	54 000	71	1.1 ± 1.1	2667.2 ± 277.1
	March 2004	ALC	77.2 ± 0.8	5 200	11	11.7 ± 4.4	

*Data from NSW Department of Industry and Investment Commercial Catch Statistics Database.

The University of New South Wales (UNSW) in collaboration with DPI, has also been undertaking research stockings of eastern king prawns to develop targeted stocking approaches for these species. Approximately six million eastern king prawn post larvae (12 – 13 mm in length) have been released into Wallagoot Lake and two million into Back Lake (both ICOLLS) during January and December 2007. Prawn populations in the two lakes have been monitored every two months since then. Results of monitoring and reports from prawners both indicate that the prawn stockings have been successful given the increases in catches. Since stocking began, individual prawns sizes also increased substantially from approximately 5 milligrams in weight to 54 grams 14 months post stocking - an increase in weight of up to 11,000 %. Growth rates have been better in Wallagoot, but abundance has been greater in Back Lake which has been intermittently open to the ocean allowing some degree of natural recruitment. The prawns in Back Lake are therefore likely to be a mixture of stocked and wild individuals, whereas Wallagoot Lake has not been open to the ocean for nine years so all those caught in the Lake would be stocked individuals. Prior to stocking, eastern king prawns had not been captured in Wallagoot Lake for over seven years (Taylor 2008).

These research stockings have provided information on the dynamics and productive capacity of the target ecosystems to help ensure that appropriate resources are available to support stocked individuals, especially in terms of food and habitat (Taylor *et al*. 2005a; 2006a, Taylor *et al.* 2009). Taylor and Suthers (2008) developed a quantitative Predatory Impact Model to estimate appropriate stocking densities of mulloway in the Georges River, Sydney. This quantitative technique is considered to be an important 'first step' in a responsible approach to stock enhancement, because it minimises the risk of overstocking which can displace wild conspecifics and competitors, and confound experimental results (Taylor and Suthers 2008). Published life history and population dynamics models, habitat information, diet data and key life history parameters for the species were used to calculate consumption, stocking density, and the predatory impact on the receiving environment. Approximately 1,760,000 m^2 of key nursery habitat was identified for mulloway within the Georges estuary. Within this habitat, 10 % of mysid shrimp production was assigned to support stocked fish, as mysids are one of the key prey species of juvenile mulloway. Based on these values it was calculated that 17,500 stocked mulloway (of 8 cm Total Length (TL)) could be supported by the receiving environment. In order to maximise the benefit of this approach Taylor and Suthers (2008) recommend that fish are directly stocked into key habitats as opposed to being released from few shore-based sites within the estuarine system.

The Predatory Impact Model has now been generalised, and will provide similar estimates for any finfish species and in any estuary, providing data requirements can be met. The model also produces estimates of survival and harvest, which can also be used to evaluate and optimise release scenarios prior to actual releases taking place.

C.3.4 Other Australian States

Although freshwater stocking programs occur in other Australian States (e.g. VIC, where between 700,000 and 1,000,000 fingerlings (including golden perch, Murray cod, salmonids and silver perch) are stocked each year, no large-scale marine fish or invertebrate stocking programs or pilot studies have been carried out to date. Policy for marine stocking is being developed, however, in most States.

C.4 Uncertainties in Marine Stocking

As outlined in Section C.2, technological advances in fish breeding mean that we are now able to produce and rear juveniles of many species in hatcheries. Furthermore, efficient and cost-effective tagging and monitoring methods, greater knowledge of species life histories and habitats and quantitative estimations of stocking densities enable the effectiveness (cost-benefit) of most stocking proposals to be evaluated. Notwithstanding this, there are challenges and uncertainties associated with any new stocking program.

C.4.1 Biophysical Uncertainties

C.4.1.1 Effects on Conspecifics

Many studies have indicated that hatchery-released juveniles of a variety of coastal finfish and invertebrate species are able to survive in the wild and increase natural abundance (e.g. Leber *et al*. 1995, Masuda and Tsukamoto 1998, McEachron *et al*. 1998, Booth and Cox 2003, Rimmer and Russell 1998, Dibden *et al*. 2000, Potter *et al.* 2008, Taylor *et al*. 2005a, 2006a). Less is known about whether increased abundances of stocked species displace existing wild stocks of conspecifics, competitors or prey species.

When the aim of stocking is to attain or approach the carrying capacity of the waterway there could be more frequent density-dependant interactions, such as predation and competition with wild fish (Munro and Bell 1997). It is possible that exceeding the carrying capacity of the receiving ecosystem from continued stocking could result in overstocking or ‘swamping’ thereby increasing intra- and inter-specific competition, which could lead to starvation, food limitation or cannibalism among stocked and wild individuals. Prior to stocking, the carrying capacity of the waterway needs to be known, and whether the addition of fish would exceed this. For example, in a large release (660,000) of juvenile cod (*Gadus morhua*) along the Norwegian coast there was no sign of enhancement to the population. Norwegian scientists reasoned that this was due to dietary overlap with wild cod, low condition, density-dependent growth and cannibalism and suggested that the environment was at its carrying capacity prior to the stocking (Blaxter 2000).

Studies of salmon fisheries in North America indicate that over-stocking has caused competition for food so that wild fish returning to spawn are smaller than average in size, are less fecund and produce smaller eggs and fry (reviewed by Cooney and Brodeur 1998). This has potential to influence the survival of progeny with serious consequences for both wild and hatchery populations. Indeed, Hilborn and Eggers (2000) found that mass hatchery production in the Prince William Sound pink salmon (*Oncorhynchus gorbuscha*) fishery replaced rather than augmented wild production so that wild production declined over time.

Finally, Leber (2002) proposed that stocking may increase fishing effort at both the location of release and where mixed conspecific stock fisheries occur, and this could lead to an increase in the fishing rates on the conspecific wild stock. Ackefors *et al*. (1991, in PIRSA 2007), illustrates how this has occurred for the salmon fishery in the Baltic Sea, where stocking of smolt led to a higher exploitation rate of wild stocks and possibly diminished the genetic pool in the wild. Hilborn and Eggers (2000) report similar findings for the Prince William Sound pink salmon fishery.

Apart from salmon, we have found no documented examples of wild stocks being displaced by hatchery-reared stocks. This is supported in a review by Blaxter (2000).An example of no impact was a study in Kaneohe Bay, Hawaii, where ~243,500 hatchery reared, 45 – 130 mm striped mullet (*Mugil cephalus*) were released directly into several nursery habitats; hatchery released and wild fish remained within the nursery habitats at release sites as juveniles (Leber *et al*. 1995).

The most likely scenario is that wild stocks have a competitive advantage over hatchery-reared stocks, both in terms of experience in the wild and overall fitness. For example, Potter *et al*. (2008) showed that wild stocks of black bream had better performance in terms of growth and reproductive development relative to hatchery fish. Leber *et al*. (2007) recommends that pilot-scale field experiments be designed to evaluate density-dependant effects such as growth and survival, and this be coupled with pre- and post- release monitoring of juvenile density (of wild and cultured individuals). This approach to the development of stock enhancement could also be refined at the pre-release stage, by using trophic models to match release density to resource availability (Taylor and Suthers 2008).

To minimise impacts to conspecifics, the challenge is to determine: carrying capacity; whether there is scope to augment wild populations and, the appropriate size of fingerlings so that stocked fish would not have a competitive advantage over wild fish or predate upon them. Synchronising the genetic make-up of stocked animals with target populations would also greatly reduce the risk of adverse impacts to wild stocks.

C.4.1.2 Effects on Competitors

Stocking creates potential for an increase in inter-specific competition between hatchery reared individuals and species that may have similar ecological requirements, if natural equilibria are disrupted. Such disruptions could conceivably lead to declines in abundance of competing species and prey species.

There is little experimental data to support an increase in inter-specific competition between hatchery reared individuals and other species in marine environments, although any form of competition between marine fishes is difficult to determine.

Whilst inter-specific competition is nevertheless a valid concern, there are examples in the literature that demonstrate how uncertainties can be minimised. As mentioned above, Taylor and Suthers (2008) developed their Predatory Impact Model to model the ecological implications of stocking mulloway. The Model estimates appropriate stocking density through the appraisal of the ecological characteristics of the target species and ecosystems. Using data about the abundance of prey items in the target estuary, stocking densities can be recommended that would minimise inter-specific competition. To further minimise impacts on competitors, Taylor and Suthers (2008) also recommend a targeted stocking approach whereby stocked fish are distributed among key habitat and at an appropriate density for each patch.

As with all ecosystem modelling, there are challenges in collecting the appropriate data required to produce realistic outputs and validation is also necessary.

C.4.1.3 Effects on Other Trophic Levels

Stock enhancement activities have potential to impact from the scale of species to the whole ecosystem (Molony *et al*. 2003). Molony *et al*. (2003) identifies potential ecosystem level impacts such as ecosystem shifts, local population extinctions and physical environmental damage. Ecosystem shifts are shifts in the distribution or biomasses of other species, which has potential for the loss of other ecosystem values. In extreme cases it is possible that the increased abundance of released fish results in the loss of wild species (e.g. Utter 1998, McDowell 2002). Lee *et al*. (2001), in Molony *et al*. (2003) also describes the potential for physical environmental damage as a result of stocking operations.

Molony *et al*. (2003) identified potential issues related to predator-prey interactions such as shifts in prey abundance and prey switching by wild predators as a result of increased abundances of hatchery reared fish. Increases in fish abundance and associated competition could have cascading effects down the food chain. Wild predators may focus on hatchery reared species rather than target species if hatchery reared individuals are less adapted to survival in the wild, and/or because of a concentrated abundance of naïve hatchery fish in a small area.

Unforseen changes may also occur. Recent findings indicate that increased predation pressure may cause ecosystem changes such as increased production at lower trophic levels (Christensen and Pauly 1998, Reznick and Ghalambor 2005).

Again, there are examples in the literature that demonstrate how to deal with these uncertainties, for example, assuming the appropriate data are available about the abundance of prey species, the Predatory Impact Model developed by Taylor and Suthers (2008) can assist in determining stocking levels for minimising trophic impacts.

C.4.1.4 Effects on Genetic Diversity and Fitness

C.4.1.4.1 Introduction

The objective of this review is to present and evaluate the latest theoretical and empirical studies on the effect of stocking on the genetic diversity, structure and fitness of naturally occurring populations of marine species such as fish and crustaceans. Stocking to 'rescue' endangered populations or species is not considered here. Stock enhancement programs have the potential to change the genetic diversity and structure of a population. In this case, a population is referred to in the same sense as a fisheries stock, which can be managed to allow sustainable harvest and conservation. Over evolutionary time various forces, for example genetic drift, natural selection, gene flow and mutation, shape genetic diversity and structure to allow species to survive in a particular set of environmental conditions. Artificial changes to genetic diversity and structure caused by stocking have the potential to affect population viability by disrupting local adaptation and reducing population fitness. These impacts are contrary to the objective of stocking (i.e. increased population size of recreational species) and should be mitigated. Without adequate genetic management of stocking programmes, many 1000's of generations may need to elapse before natural evolutionary forces restore genetic diversity to natural, pre-stocking levels.

C.4.1.4.2 What is Genetic Diversity?

Genetic diversity is the variety of genes (alleles) in a population and is expressed as differences among individuals (Frankham *et al.* 2002). It also refers to the alleles that are present at a particular location (locus) on the DNA summed across all individuals in the population. In diploid species (i.e. all species in this scoping study) individuals have two alleles at a particular locus. Some genetic loci (plural of locus) are identical among individuals, in which case they have the same alleles. Some loci have alternate alleles such that pairs of individuals from the population may differ at a particular locus. These loci are 'polymorphic'. If the alleles are identical, the individual is homozygous; if not, it's heterozygous. Proportions of heterozygosity (and its converse homozygosity) at the individual and locus level, as well as the number of different alleles (allelic diversity) per locus, are the main ways to describe the genetic diversity of a population.

C.4.1.4.3 What is Genetic Fitness?

Genetic fitness is the ability of an individual to pass its genes to the next generation. Fitness varies between individuals depending on the alleles they possess and the effect of the environment on the characteristics determined by the alleles (Hedrick 2000). Thus, individuals differ in how well they survive, find mates and reproduce. Natural selection for these traits occurs as a consequence of varying levels of fitness between individuals. Stocked individuals have alleles that are a product of the genetic management procedures of the hatchery (i.e. reflecting type and number of parents, relative family survival etc.) and may have lower fitness than native individuals under field conditions (e.g. Araki *et al.* 2007).

Genetic diversity is an essential pre-cursor for varying fitness levels between individuals and hence is essential for natural selection and adaptation to the local environment. In addition, differences in fitness can occur across different environments creating population genetic structure. Natural selection is the dominant of four evolutionary forces that determine the genetic diversity and structure of a population. Richard Lewontin claimed in 1974 that no one has succeeded in measuring with any accuracy the net fitness of genotypes for any locus in any environment in nature (Hedrick 2000) and this still applies today. Thus, as it is not possible to link any particular genetic locus with adaptation to the local environment, the default assumption is that maximum levels of genetic diversity should be conserved to allow the survival of populations in nature. In other words, it's the amount of diversity, not the occurrence or frequency of individual genes that is important to minimise the genetic effects of stocking.

C.4.1.4.4 How is Genetic Diversity and Structure Measured?

Genetic diversity is a measure of the number of alleles at polymorphic loci in a sample of individuals from a study location. The scientific study of genetic diversity and structure between and within populations is called 'population genetics'. Assessing the diversity of alleles at polymorphic loci can be achieved using protein (i.e. allozyme electrophoresis) or DNA technology. A suite of methods that directly target a variety of DNA loci are most commonly used. For our purposes, two types of DNA loci are important. The first are microsatellite loci, which are found throughout the nuclear genome, tend to by highly polymorphic and are biparentally inherited (i.e. according to classical Mendelian genetics). The second locus is mitochondrial DNA (mtDNA), which is found in cell cytoplasm (i.e. not the cell nucleus), is easily and quickly assayed for polymorphism and is a haploid maternally inherited genome. These loci are can be used to monitor genetic changes to populations (*e.g.* Lucentini *et al.* 2009), infer loss of genetic diversity (e.g. Gold *et al.* 2008) and tag stocked individuals (e.g. Saillant *et al.* 2009). They can also be used as markers for population structure (e.g. Ovenden *et al.* 2009) and detecting admixtures of populations (e.g .Laurent *et al.* 1998). The definition of populations is important to stocking programs. Best-practice for the production of captive-bred fish for stocking specifies the use of broodstock from the population that is the target of the stocking program. Population genetics is a useful way of identifying distinct populations although results can be open to alternate interpretations and criticism (Tringali *et al.* 2006, Ward 2006).

There are two components that are typically used to describe level of genetic diversity: within (i.e. intra-) and between (i.e. inter-) populations. The ratio of inter-population to overall genetic diversity is referred to as F_{ST} and is an important statistic used to determine if individuals are from one or several populations. F_{ST} approaches one when there is as much genetic diversity between populations as there is overall, indicating that individuals may represent different populations. But, if F_{ST} approaches zero, the inter-population genetic diversity is only a fraction of the overall diversity suggesting that there may be no population structure. Other statistical methods for determining population structure are also used (Hartl and Clark 1989) but all methods make underlying assumptions that should be tested as much as possible against existing biological information about the study species.

C.4.1.4.5 Knowledge Gaps in the Use of Population Genetics to Describe Genetic Diversity and Define Populations.

The genetic loci used in population genetics studies are presumed to be neutral with respect to selection. Therefore alleles at these loci respond predominantly to the evolutionary forces of genetic drift, gene flow and mutation. Allelic variation and heterozygosity in neutral loci are a consequence, not a driver, of evolution within a population or species. As alleles at these loci are not experiencing natural selection, they are not the genes responsible for the fitness of individuals in a population. The process of natural selection may be occurring in a population but may not be obvious from studying neutral loci. However, levels of allelic diversity and heterozygosity at neutral loci are reduced by small population size and can be used as an early warning signal for the occurrence of inbreeding (Frankham 2005).

Relative amounts of genetic diversity among population samples (i.e. F_{ST} approaches) are used to test for the presence of genetically separate populations. However, when using loci neutral with respect to natural selection, genetic structure could be present even when allelic diversity and heterozygosity are homogeneous (Utter 2003). Natural selection leading to local adaptation could occur on a local scale, but it would not be detectable using selectively neutral loci. The tools to assay for genetic variation in loci that affect traits such as temperature tolerance, disease resistance, spawning times or migration are only under development (Hauser and Carvalho 2008). Therefore it is important that populations proposed from genetic data are tested by studying variation in other characters that could separate populations, such as otolith chemistry (Newman *et al.* 2009) and parasite loads (Charters *et al.* 2010).

The conclusions reached in this EIS acknowledge these gaps. It is common that the pace at which resource management decisions have to be made exceeds the rate at which scientific advances are made, particularly for environments under threat (e.g. drought, agricultural run-off) or that contain large numbers of species (e.g. Murray Darling Basin, Great Barrier Reef).

C.4.1.4.6 The Effect of the Loss of Genetic Diversity

Genetic diversity is lost when the size of a naturally-occurring population is small or is declining (Frankham *et al.* 2002). The consequence of this loss is inbreeding. The rate of decay of genetic diversity and the increased inbreeding depend on the genetic effective population size, not the actual or census size (Frankham 2005). Genetic effective population size is almost always less, and sometimes substantially so, than the census population size. The concept of genetic effective population size is central to the following discussion of the genetic effects of stocking (Leberg 2005).

Census size is the number of individuals alive in a population at a given time, including all adults, juveniles and larvae. The difference between census and genetic effective population size is exemplified here. There is a marine population consisting of 1000 individuals. The population is outbred so individuals are unrelated to one another and there are an equal number of males and females in the population. All individuals participate in reproduction and on average each individual contributes one adult offspring to the next generation (i.e. population size is stable across generations). The next generation consists only of offspring (i.e. parents die after spawning) and the population is closed to migration. Under these circumstances, the genetic effective size of the next generation is equal to the census size of the parental generation. Alternatively, and more realistically, in the parental generation some animals do not participate in reproduction or if they do, their offspring die before becoming adults in the next generation. Consequently some animals (i.e. families) contribute many more offspring to the next generation than others. In this case, the genetic effective size of the next generation is less than the census size of the original generation. For populations of marine species, where fecundity and mortality is high and variable between families, the genetic effective population size can be three (Ovenden *et al.* 2007) to five (Hauser *et al.* 2002) orders of magnitude below census size. However, as marine populations are generally large, their genetic effective population size is often large enough to prevent inbreeding (Palstra and Ruzzante 2008).

Inbreeding occurs in populations when the genetic effective population size is low. In natural populations, genetic effective size, as a function of census size, can be low due to predictable (e.g. habitat loss, habitat fragmentation, over exploitation) and random (e.g. catastrophic) factors (Frankham 2005). Inbreeding has deleterious effects on reproduction and survival, including impacts on sperm production, mating ability, female fecundity, juvenile survival, age at sexual maturity and adult survival (Frankham 2005, Frankham *et al.* 2002). The effects of inbreeding have been extensively demonstrated in captivity (see examples below).

Inbreeding in naturally occurring populations can also occur when the genetic effective population size is low because the population is a mixture of native and captive bred individuals. This phenomenon is referred to as the Ryman-Laikre effect (Ryman and Laikre 1991). Inbreeding levels are often high in captive bred populations; the genetic effective size of the captive population is substantially lowered by the selective use of a small number of broodstock and adaptation to captivity often occurs across generations (Frankham 2008).

Examples of inbreeding in fish species

After salmonids and carp, *tilapia* spp. are the most important aquaculture species worldwide. To demonstrate the effects of inbreeding in captive populations of *Oreochromis niloticus*, Fessehaye *et al.* (2007) set up 35 families with classes of expected levels of inbreeding (*F*) corresponding to 0, 6.3, 9.4, 12.5 and 25 %. Levels of inbreeding significantly affected early fry survival and juvenile body weight. Juveniles were then tagged and grown for eight months in two earthen ponds. However, body weight at harvest was not correlated with levels of inbreeding.

Three-spined sticklebacks (*Gasterosteus aculeatus*) are a freshwater fish native to northern Europe, Asia and America. They are not commercial or recreational fishing targets, however they are important components of freshwater ecosystems and survive and breed well in captivity. Sticklebacks are a popular model species for studying evolution and behaviour. Using wild-caught broodstock, Frommen *et al.* (2006) showed that only one generation of brother-sister mating caused a significant decrease in fertilisation and hatching success of eggs. Fewer inbred individuals survived to reproductive age compared to outbred control offspring.

C.4.1.4.7 Framework to Describe the Genetic Effects of Stocking

Utter (2003) presented a framework to outline the genetic effects of stocking. His scheme divides genetic effects into those that are a direct consequence of interbreeding (i.e. direct effects) and those that occur in the absence of interbreeding between stocked and native fish (i.e. indirect effects)(Figure C.1).

1. Direct Effects

Direct genetic effects can occur when there is interbreeding between stocked and native fish. Interbreeding occurs when hatchery-reared fish become sexually mature and successfully reproduce with native fish. If hatchery reared fish are stocked at small sizes, there will be a delay in the occurrence of interbreeding until they become reproductively mature. The numbers of native fish available to mate with stocked fish limits the extent of interbreeding. Interbreeding is dependent on the stocked fish exhibiting mating behaviour at the appropriate time and place. It does not preclude reproduction within the native population and among stocked fish.

Introgression is the transfer of genes from stocked fish into the native population as a result of interbreeding. Subsequent generations of cross-bred offspring may be less well adapted for survival in the natural habitat (i.e. have lower genetic fitness). The deleterious effect of interbreeding is in direct contrast with the increase in desirable characteristics (i.e. heterosis) often shown by cross-bred offspring. The key difference is the requirement for the cross-bred offspring to survive in natural, compared to artificial environments. Due to their complex life-history and the extent of stocking activities, the effects of introgression in salmonid species have been well studied. As an example, cross-bred offspring between native and captive-bred salmonids generally do not exhibit the specific natal homing ability to return to freshwater from the marine habitat. Outbreeding depression and the breakdown of co-adapted gene complexes are special cases of introgression that can occur between genetically divergent individuals (Utter 2003).

Example of reduction in fitness due to introgression

Steelhead (ocean) trout are a strain of rainbow trout (*Oncorhynchus mykiss*) that feed in the oceans and return to freshwater each year to breed (i.e. anadromous). Unlike Pacific salmon (*Oncorhynchus* spp.) they make several spawning trips between the sea and freshwater (i.e. iteroparous). They are highly desirable as food and sports fish. In North America, steelhead and Pacific salmon populations are enhanced by the release of five billion captive-bred juvenile fish per year. While these juveniles are meant for harvest, captive-bred fish do reproduce in the wild and interbreed with native fish. Araki *et al.* (2007) studied the success of captive-bred fish when they reproduced in the wild compared to wild fish. They found that for each generation of captive rearing, the subsequent reproductive success in the wild was reduced by about 40 %. The observed effect was not attributed to inbreeding because reproductive success was measured in several families that originated from crosses between unrelated individuals (i.e. wild v captive-bred fish). Rather, the most plausible explanation was a loss in the genetic capability to survive in the wild as a result of genetic adaptation to survival in captivity. In other words, the captive-bred fish were genetically different to wild fish and offspring of cross-bred fish were less able to reproduce in the wild than offspring of wild parents. Thus, given continual contributions from captive bred fish, the overall fitness of the wild population would progressively decrease. This would mean that in the longer term, the population would become more and more reliant on enhancement to maintain adequate numbers.

Another significant direct effect is the Ryman-Laikre effect (Ryman and Laikre 1991), where potentially deleterious changes occur as a consequence of inbreeding alone (i.e. in the absence of any other effect). This can occur when the genetic effective size of the enhanced population is reduced when the released, captive bred fingerlings, derived from a relatively small number of broodstock, outnumber the native fish. A reduction in genetic effective population size will result in higher levels of inbreeding, a reduction in the fitness of individuals in the enhanced population and ultimately a decline in population sizes. In turn, this would increase the reliance on stocking to maintain an adequate population size for fishing purposes. In the long-term, there may be a considerable cumulative Ryman-Laikre effect and sourcing wild fish for broodstock would become progressively more difficult.

Example of the demonstration of a Ryman-Laikre effect

Red drum (*Scianenops ocellatus*) is a game fish found in the Atlantic Ocean on the west coast of the United States. Juvenile drum are found in coastal embayment's and marshes and reach maturity at three to six years. Three year olds weigh 2.7 to 3.6 kilograms or six to eight pounds. The TPWD began a stock enhancement program in the 1980s and now releases 20 to 30 million captive-bred fingerlings along the coast of Texas in the Gulf of Mexico. Gold *et al.* (2008) claim that it's the largest marine stock enhancement program. The program uses randomly sampled adults from the wild as broodstock and replaces 25 % of the males and females each year. Mating pairs are alternated each year and brood fish are used for no longer than four years. However it is not clear if broodstock are selected to not have a hatchery origin, or be descended from hatchery-bred fish. Gold *et al.* (2008) used genetic analysis of captive bred progeny to assess the likelihood of a Ryman-Laikre effect. Based on the number of brood fish used per tank to produce fingerlings for release (one to two sires and two to four dams), they predicted that the genetic effective size of the next generation would be 4.55 on average. This is slightly less than the three to six brood fish used per tank and assumes that all pairwise matings occurred and each mating produced the same proportion of offspring. Each broodstock tank produced on average 15 – 30,000 offspring. By genotyping about 100 of the offspring per tank, they determined that the actual genetic effective population size of offspring was 2.59 on average. The discrepancy was mostly due to non-participation in reproduction by some dams, but there was some discrepancy due to unequal family sizes. In 2003, spawning and release records at the TPWD hatchery indicate that the number of released populations (i.e. from a tank of broodstock) released per location into the Gulf of Mexico ranged from seven to 27. They calculated that the combined effective size of the release ranged from 28 to 46. Recalling that genetic effective population sizes of wild populations can be three to five orders of magnitude below census sizes, previous genetic analyses of the wild population had determined that the genetic effective size of red drum was approximately 270 per release site. Gold *et al.* (2008) concluded that the release of fingerlings in 2003 was reasonably likely to have caused a local Ryman-Laikre effect. The consequence would be that the overall genetic effective population size of red drum in the release location would be less than pre-enhancement and if interbreeding occurred, then levels of inbreeding would be elevated. Confirmation would depend upon the relative numbers of wild compared to captive-bred fish per release site. As the enhancement program has been operating for 20 years or more, there would be a considerable cumulative Ryman-Laikre effect. Sourcing wild fish for broodstock would progressively become more difficult.

2. Indirect Effects

Stocking can cause indirect genetic effects by facilitating a reduction in the population size of the native population, which leads to inbreeding and associated deleterious effects such as:

- Disease introduction from resistant carriers;
- Overfishing of mixed stock fisheries;
- Wastage of gametes; and
- Naturalisation leading to fragmentation.

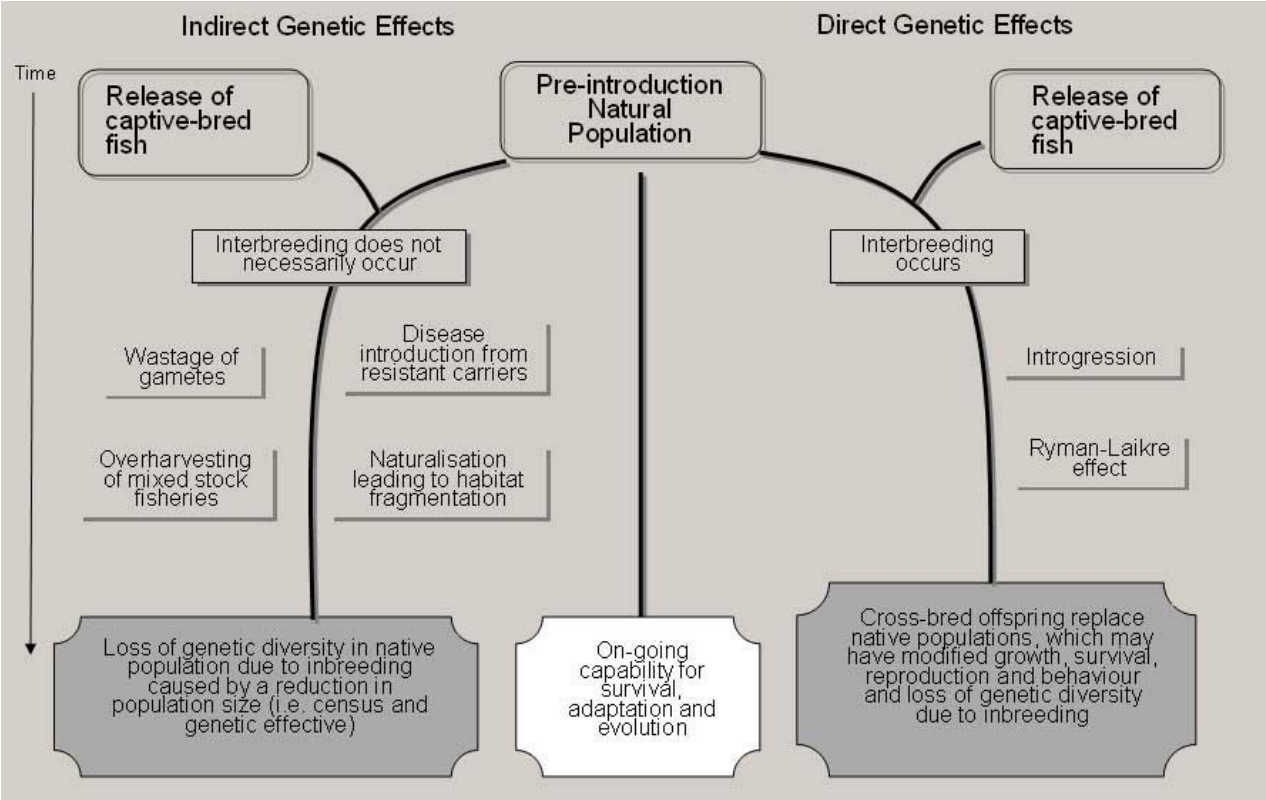
Disease introduction from resistant carriers can potentially occur when the stocked fish are resistant to a particular disease. The disease could be endemic to the natural population or introduced along with the hatchery reared fish. Stocked fish may then displace or out-compete native fish that are susceptible to the disease. This occurred when captive-bred Baltic Atlantic salmon (*Salmo salar*), which were resistant to the fluke *Gyrodactylus salaris*, escaped into wild Norwegian Atlantic salmon populations (Utter 2003). This issue overlaps with disease, parasites and health and is therefore addressed in Section C.4.1.5.

The native population can also be reduced in size by excessive harvest pressure i.e. increased fishing effort that may follow stocking activities, resulting in a loss of genetic diversity. In relation to marine stocking, this is considered more likely to have an effect on small populations within an estuary that are genetically distinct, rather than a single population which is panmictic along the entire coast.

Another example of an indirect genetic effect is gametic wastage. This is where mating occurs between native and stocked individuals, but hybrid offspring are not produced, which represents a significant waste of native reproductive activity that would have otherwise led to the next generation of wild fish (Utter 2003).

Finally, native populations can be fragmented (i.e. broken into smaller populations) if stocked fish establish viable populations in what was once contiguous habitat for the native population.

Figure C.1:Summary of indirect and direct effects of conspecific stocking on native populations (after Utter, 2003).



C.4.2 Diseases, Parasites and Pests

Marine stocking requires intensive aquaculture to rear individuals to a suitable size for stocking. Diseases and parasites can be problematic in aquaculture and land-based systems have been implicated as sources that have adversely affected wild populations. Molony *et al.* (2003) lists the introduction of diseases and parasites as a risk to natural ecosystems in stock enhancement activities, and refers to poor hatchery management and husbandry as the main causative factor. Conversely, concerns for disease and restocking in Japan, revolve more around the need for acquired resistance of released animals to the endemic diseases which can affect the success of enhancement efforts (Mushiake and Muroga 2004). In Australia, very close attention is paid to disease translocation protocols, because it is perceived that there are fewer diseases in natural environments, and of course the practice of restocking is much less widespread. Translocation is generally referred to as the 'movement of organisms from one area to another', in the context of this EIS it specifically refers to the movement of organisms (and their transport media) beyond their natural range and/or to areas within their natural range that have genetic stocks and/or populations that are distinct from the source area.

Intensive rearing of juveniles in hatcheries and nursery systems at high densities is considered to potentially create a favourable climate for the amplification of pathogens which increases the risks of disease transmission to wild stocks.

The main issues associated with disease and parasites in relation to marine stock enhancement activities are:

- Translocation of exotic diseases/parasites into wild populations from hatcheries;
- Disease or parasite enhancement from the reintroduction or amplification of disease/parasites into wild populations.
- Translocation of other pest organisms (such as plankton, invertebrates and algae) and non-target species into waterways.

Australia is in a unique position compared with many other countries in terms of its animal disease status. Its isolation from other major land masses in the world has afforded a high level of prevention and biosecurity controls against exotic diseases and parasites. Regular import risk analyses and reviews of quarantine arrangements in Australia aim to maintain this low prevalence status into the future (Biosecurity Australia 2010), and State-based translocation policies for cultured organisms (e.g. for QLD see QDPI&F 2006b) suggest that exotic outbreaks could be contained if identified quickly.

Notwithstanding these arrangements, the spread of pathogens is frequently associated with the translocation of aquatic (marine and freshwater) animals from hatcheries into the receiving environment, and certain viruses, bacteria, fungi, parasites and other organisms that may not be pathogenic under normal environmental conditions (for native/wild species) can become problematic in stock enhancement programs (Bartley *et al*. 2006). Furthermore, cultured species may be a vector for diseases or parasites that are harmful to other species, even if not to the carrier 'host' species. Langdon (1989) therefore states that it would be insufficient assurance to claim that an infectious agent in fish proposed for release appears harmless in that species.

Munro and Bell (1997) refer to a number of examples where disease introductions have occurred, including the spread of a virus among black lip pearl oysters (*Pinctada margaritifera*) in French Polynesia, an iridovirus-like disease in the UK and France from imported Portuguese oysters and the rapid spread of the pilchard herpesvirus (PHV) throughout Australia and New Zealand (Crockford 2007).

C.4.2.1.1 Diseases of Marine Fish

The economic importance of particular species has generally been a driving force behind research into diseases of marine and freshwater fishes. New viruses, other diseases and new hosts of well known pathogens are emerging with the development of advanced identification techniques and aquaculture expansions around the world. In Australia for example, our abilities to successfully address emergent disease issues for barramundi are greatly aided by the resources and experience that are developing around the growing aquaculture industry.

Few studies have focused specifically on the diseases of marine fish proposed for stocking in NSW. There is, however, a considerable literature and knowledge base available for fish diseases that have potential to affect different hosts around the world. These hosts would include the fish in this proposal. A description of the diseases most relevant to fish in the stocking proposal are described below.

Lymphocystis is a commonly occurring non-lethal condition caused by an iridovirus that is often associated with crowded conditions (Colorini 1998). It has been reported in over 125 species and is common in freshwater and saltwater aquarium fishes (Lawler 2005). It causes cell enlargement (or hypertrophy) often on the skin and fins. Whilst there is no effective therapy, a reduction of crowded conditions is palliative (Colorini 1998). The disease usually runs its course in 4 or more weeks (depending on species involved, water temperature, and other variables) and then the enlarged cells rupture or slough off and release the viral particles into the water. It is therefore transmitted in the water and is highly infectious. While infected, the fish may become slowed or weakened, or more visible in the water column, and thus be more prone to predation or attack. Mouth lesions may also cause difficulty in feeding. The low mortality rate that some attribute to lymphocystis is mostly due to secondary bacterial or fungal infections (Lawler 2005). Wild juvenile red sea bream that have been caught from the wild and held in captivity at high densities have been found to rapidly develop viral lymphocystis.

Viral encephalitis, also known as viral nervous necrosis (VNN) is a serious and fatal disease that has been described in over 40 species of fish species around the world (Azad *et al*. 2006). In Japan, VNN is the most important disease of fish (Mushiake and Muroga, 2004). Picorna-like viral particles have been shown to lead to vacuolization of the brain and retina and spongiosis of the nervous system, which rapidly disables the fish through loss of balance causing whirling movements prior to death (Colorini 1998). In barramundi and other species this syndrome has been shown to be due to viruses in the family Nodaviridae (Comps *et al*. 1994), Several native fish species have been shown to be susceptible to it (e.g. Australian bass: DAFF 2010). It has been shown to be transmissible in barramundi via vertical movements from broodstock to eggs and larvae (Azad *et al*. 2006). On a world-wide basis including tropical Australia, it has caused significant losses in aquaculture systems, but to date it is not known to have caused disease events in the wild. Avoidance measures through screening and biosecurity practices are now well publicised and practiced in Australia (DAFF 2010), and strict translocation policies are now applied to species that are known to carry this disease. Fingerlings for aquaculture and restocking generally require screening when they are 21 to 42 days old. This testing encompasses histological examinations of the central nervous systems and retinas, with various numbers of samples required by different States and regions.

It is likely that new viruses and new strains of known viruses will continue to become evident as globalisation and research in this area continues. Exotic viruses that are of concern in the movement of live finfish include Enteric Redmouth Disease (*Yersinia ruckeri* Hagerman strain), Enteric Septicaemia of Catfish (*Edwardsiella ictaluri*), Epizootic Haematopoietic Necrosis (EHN) virus, Infectious Pancreatic Necrosis (IPN) virus, Red Sea bream Iridoviral disease, Spring Viraemia of Carp virus (SVC)(QDPI&F 2005). Like the introduced redfin perch in eastern Australia which is considered a threat to small native freshwater species because they have the potential to spread EHN to native species, other introduced and native species have potential to spread viral diseases in natural waters. These considerations should be accounted for in risk analyses associated with the introduction or amplification of viral diseases. Bacterial diseases of fish include true pathogens which invade healthy tissues, and opportunistic pathogens which proliferate in compromised tissues. Epitheliocystis, vibriosis, pasteurellosis, and mycobacteriosis are common examples of bacterial infections that can occur in many marine fishes. Bacterial diseases of concern for barramundi in QLD include Bacterial Haemorrhagic Septicaemia (virulent strains of *Aeromonas* sp.), Vibriosis (virulent strains of *Vibrio* sp.), Integumentary Bacteriosis (virulent strains of *Aeromonas* sp. and *Vibrio* sp.), Streptococcosis (*Streptococcus iniae*), Bacterial Peritonitis (various bacterial species), Mycobacteriosis (*Mycobacterium* sp.) and Columnaris disease (*Flexibacter/Flavobacterium* sp.)(QDPI&F 2005). Austin and Gibb (1993) provide an extensive list (not provided here-in) of gram-negative and gram-positive bacteria that have been implicated as fish pathogens, and that are likely to be problematic in aquaculture into the future.

Ecto- and endo-parasitic infections in fish are also common in marine and freshwater environments, and many of these are also non-specific and can cause secondary bacterial infections. In freshwater environments there are serious examples of parasite introductions. Examples are where whole populations of salmon have been wiped out by the monogean parasite (*Gyrodactylus salaris*) that was reportedly released from hatcheries (Heggberget *et al*. 1993). Parasitic infections of teleost marine fish may be transferred (or shared) between animals and humans (known as 'zoonotic'). Larval anasakid nematodes (from the families Anisakidae and Raphidascaridae) which naturally parasitise fish, birds, cephalopods and marine mammals are an example of this. There is a generally poor understanding about the distribution of anasakid nematodes among Australian fish species (Doupé *et al*. 2003), although they have been prevalent in fisheries of the northern hemisphere in recent years. Larval morphotypes of *Anasakis* sp. have been found among 47 different species in QLD, four recreationally or commercially important species from WA and six tropical species from north-western Australia (Doupé *et al*. 2003).

Colorini (1998) provides information on the reported bacterial and parasitic infections of marine fish (summarised in Table C.2). Transmission is often by direct contact, or in the water, and all of the bacteria and some of the larger species (e.g. *Amyloodinium ocellatum*) are subject to aerosol transfer within hatchery environments (Roberts-

Thompson *et al.* 2006). Rohde (1990) reviewed the ecology and phylogeny of marine parasites and their effects on their hosts from an Australian perspective. Whilst examples from aquaculture were not included, parasites from several important groups were discussed including monogeneans, trematodes, cestodes, nematodes, copepods and protozoans.

Table C.2:Attributes of bacterial and parasitic diseases of marine fishes

Source: Colorini (1998).

Disease	Causative Organisms	Host specificity	Condition
Epitheliocystis	Chlamydial prokaryote	Host specific	Gill and epithelial cell hypertrophy
Vibriosis	*Vibrio* sp. within Vibrionaceae	Different strains can be host specific	Acute haemorrhagic septicaemia
Pasteurellosis	*Photobacterium damsela* within Vibrionaceae	Non-specific	Acute septicaemia and spleen damage
Mycobacteriosis	*Mycobacterium marinum*	Non-specific	Ulcers, exophthalmia, spleen and kidney damage
Amyloodiniosis	*Amyloodinium ocellatum* - Dinoflagellate	Non-specific	Epithelial damage
Cryptocaryonosis	*Cryptocaryon irritans* – Ciliated protozoan	Non-specific	Epithelial damage
Trichodinosis	*Trichodina* sp. – Ciliated protozoan	Non-specific	Epithelial damage
Brooklynellosis	*Brooklynella hostilis* – Ciliated protozoan	Non-specific	Epithelial damage
Myxosporean infection	*Myxidium leei* and several other species within Myxosporea	Non-specific	Visceral cavity, blood, muscle, or connective tissue damage
Coccidiosis	*Epieimeria ocellata* and *Goussia floridana*	Limited knowledge available	Limited knowledge available
Monogenean flukes	Various ubiquitous species including those in Microcotylidae and Dactylogyridae	Non-specific	Epithelial damage and anaemia
Branchiuran, copepod and isopod parasites	Various ubiquitous species including Argulids, Caligids and Gnathiids	Non-specific	Epithelial damage and anaemia

Fungal diseases are also of concern in fish translocation activities. For example, for barramundi one of these is Integumentary Mycosis caused by virulent species of *Saprolegnia* and *Achlya* (QDPI&F 2005). Others which are also known to infect this and a range of fish species include the Epizootic Ulcerative Syndrome (EUS) otherwise known as red spot disease. It is caused by the pathogenic fungus *Aphanomyces invadans*, is known to cause significant mortalities in wild juvenile fish, and is known to occur in rivers and estuaries in the Northern Territory (NT), QLD, WA and NSW (Humphrey and Pearce (2006). Khoo (2000) provides a useful review of the diagnosis, pathology, prevention and treatment of fungal diseases in fish.

In regard to the species proposed for marine stocking the information relating to diseases and parasites is limited. The exception to this is yellowfin bream for which detailed studies have been carried out. Several Monogenean parasites were found on its fins, gills and mouth parts (e.g. *Anoplodiscus australis*: Roubal and Whittington 1990; *Polylabroides multispinosus*: Diggles *et al*. 1993; *Allomurraytrema robustrum*: Roubal 1995), and the Acanthocephalan *Longicollum alemniscus* was documented by Roubal (1993) in the intestinal tract and rectum, along with the Myxosprean *Sphaerospora* sp. and the Digenean *Prosorhynchus* sp. in various internal tissues (Roubal 1994a). Diggles and Adlard (1995) also studied the taxonomic affinities of marine and freshwater white spot diseases of fish caused by the ciliates *Cryptocaryon irritans* and *Ichthyophthirius multifiliis*, respectively, using yellowfin bream captured from the Brisbane River in QLD as one of the marine sources of this pathogen.

Table C.3 lists the pathogens that have been documented to potentially affect the species of finfish proposed for marine stocking, where there is limited information on a particular species, studies carried out for similar species are referred to.

Table C.3: Pathogens potentially affecting species of marine finfish proposed for stocking (and closely related species).

Species	Disease/Parasite
Yellowfin bream (*Acanthopagrus australis*) List includes other closely related species of bream	**Bacteria**: *Streptococcus* - Agnew and Barnes (2007). **Protozoa**: *Cryptocaryon* - Diggles and Adlard (1995), Partridge and Jenkins (2002). **Monogenea**: 15 species described (Rohde 1990, Roubal 1981, Roubal 1986a) including *Polylabroides* - Byrnes (1985a), Diggles *et al.* (1993); *Lamellodiscus* - Byrnes (1986a); *Anoplodiscus*, *Udonella*, *Haliotrema*, *Allomurraytrema*, *Benedenia* – Byrnes (1986c), Roubal (1987, 1989a, 1995), Roubal and Whittington (1990). **Digenea**: 11 species described (Rohde 1990). **Myxosporea**: *Ortholinea* - Lom *et al.* (1992). **Branchiura**: 2 species described (Rohde 1990) including *Argulus* - Byrnes (1985b). **Copepoda**: 16 described (Rohde 1990, Roubal 1981) including *Ergasilus* - Byrnes (1986b), Roubal (1986c, 1987, 1989a); *Caligus* - Byrnes (1987), Roubal (1994b); *Colobomatus* - Byrnes and Cressey (1986); *Alella* - Roubal (1989b). **Cestoda**: 5 species described (Rohde 1990). **Nematoda**: 8 species described (Rohde 1990). **Acanthocephala**: 4 species described (Rohde 1990) including *Longicollum* (Roubal 1993). **Ichthyobdellidae**: *Austrobdella* - Roubal (1986b).
Mulloway (*Argyrosomus japonicus*)	**Monogenea**: *Sciaenacotyle* - Hayward *et al.* (2007). **Monopisthocotylea**: *Calceastoma* - Hayward *et al.* (2007). **Copepoda**: *Caligus* - Hayward *et al.* (2007).
Dusky flathead (*Platycephalus fuscus*) List includes other closely related species of flathead	**Cestoda**: Phyllobothriidae, *Nybelinia* - Hooper (1983). **Nematoda**: *Anisakis*, *Thynnascaris*, *Raphidascaris* and/or *Raphidascaroides*, *Echinocephalus*, *Philometra*, *Cucullanus*, *Spirocamallanus* - Hooper (1983). **Acanthocephala**: *Serrasentis*, *Gorgorhynchus*, *Rhadinorhynchus*, *Raorhynchus*, *Corynosoma* - Hooper (1983). **Isopoda**: *Nerocila*, *Codonophilus* - Hooper (1983). **Copepoda**: *Pterochondria* - Hooper (1983). **Trematoda**: *Digenea*: *Erilepturus*, *Lecithochirium*, *Aponurus*, *Didymozoon*, *Cryptogonimidae*, *Prosorhynchus* - Hooper (1983); *Neometadidymozoon* - Lester (1980).
Sand whiting (*Sillago ciliata*) List includes other closely related species of whiting.	**Fungi:** Aphanomyces - Catap and Munday (2002). **Protozoa:** Uronema - Gill and Callinan (1997). **Myxosporea:** Kudoa - Lom *et al*. (1992), Hallett *et al*. (1997), Moran *et al*. (1999). **Copepoda:** Parabrachiella - Piasecki *et al.* (2010). **Ichthyobdellidae:** Austrobdella - Badham (1916).

C.4.2.1.2 Diseases of Crustaceans

The culture of penaeid shrimp has been beset with disease the world over (Munro and Bell 1997). As in fishes, many of the diseases of prawns and shrimp are secondary to stressors which make the animals vulnerable to opportunistic pathogens (Colorini 1998). Similarly, there are many reports of diseases in crabs, and they also are often brought on by poor water quality and stress. Since many of these pathogens are important for both of these interest groups of crustaceans (Lavilla-Pitogo and de la Pena 2004), they are treated together in this summary.

There are many viruses known to infect crustacean species (Lightner 1999), and some of the most virulent forms can be transferred by a range of species. An example is Taura Syndrome Virus (TSV) which has been shown in Thailand to be transmissible from a range of aquatic carrier species including the giant mud crab, *Scylla serrata* (Kiatpathomchai *et al*. 2007). Three of these virulent crustacean viruses, namely TSV, White Spot Syndrome Virus (WSSV) and Yellow Head Virus (YHV), have caused serious losses in overseas prawn farming industries, but have not yet become established in Australia. The global importance of these three viruses is exemplified by their recent listing in protective European legislation (Stentiford *et al*. 2009). In addition, the importance of these viruses (and others) is demonstrated by their listing as notifiable diseases in NSW (Table C.5). WSSV has been reported from many species of shrimp and crabs (e.g. *S. serrata*, Chen *et al*. 2000). It is one of the most heavily studied viruses of shrimp, and thus serves as a useful model for discussion. Temperature is one water quality parameter that is known to mediate the replication and effect of WSSV infections (Guan 2003). It, like all other shrimp viruses, is known to be transferred through direct contact (e.g. ingestion of infected tissue), and in water (Schuur 2003), and recently Esparza-Leal *et al*. (2009) have shown that WSSV can also be attached to microalgae or zooplankton. Some of these (e.g. TSV) and others (Infectious Hypodermal and Hematopoietic Virus – IHHNV) have been shown to be transmissible in bird faeces, so they can be transferred by incidental species like seagulls over quite large distances (Vanpatten *et al*. 2004). The later of these, IHHNV, was first reported in Australia by Owens *et al.* (1992) in hybridised prawns in north QLD, when it was suggested to be endemic to the Indo-West Pacific region including Australia. It was recently (2008) reported in two northern Australian prawn farms (Radio Australia 2008), however this strain at this stage does not appear to cause mass mortalities like it does overseas (QDPI&F 2006a).

Other viruses that are endemic in Australian prawns include Gill-Associated Virus (GAV), Mourilyan Virus (MoV), Hepatopancreatic-Parvo Virus (HPV), Spawner Mortality Virus (SMV), Mid Crop Mortality Syndrome (MCMS) and Monodon Baculovirus (MBV) (QDPI&F 2006a). None of these have caused widespread mass mortalities in Australian prawn farms, but some (e.g. GAV) are substantially impacting on survival rates and productivity, and all can be minimised through screening of broodstock and seedstock (histology and PCR testing), and by minimising stressful environments during the culture period. Some of these may be specific to Australian conditions, since several have not been reported overseas (e.g. *Scylla baculovirus*, Lavilla-Pitogo and de la Pena 2004). Lester and Paynter (1989) have reported Plebejus Baculovirus (PBV) and other MBV-related viruses in the prawns *Penaeus plebejus, P. merguiensis* and *P. monodon.* It was found in the epithelium of digestive glands and was more prevalent in early larval and post larval stages. Gram-negative bacteria from the genera *Vibrio*, *Aeromonas*, *Pseudomonas*, and luminous bacteria, widely affect shrimp in culture activities (Colorini 1998). Vibriosis is caused by various *Vibrio* sp and is a very common infection in penaeid facilities. They are often opportunistic in nature and normally secondary to stress or other diseases which have previously caused a deterioration of the shrimp's condition (QDPI&F 2006a). Bacterial diseases can be particularly prevalent and problematic in crustacean larviculture activities. Principles of competitive exclusion and probiotics are commonly applied to overcome this problem in penaeid aquaculture (Palmer e*t al*. 2007), but hygienic practices including chemicals usage have been found to be indispensible for some species (Mushiake and Muroga 2004).

Giant mud crab larvae are also susceptible to various *Vibrio* species as well as filamentous bacteria. In other countries, antibiotics such as streptomycin, sodium nifurstyrenate and OTC are commonly used to reduce bacteria-related mortalities, either through prophylactic treatments of larval culture systems, or through the application of immersion baths of early larvae before introduction to larvicultures (Davis 2004). In Australia, the prophylactic use of antibiotics is illegal, and their use is only permitted under prescription from a registered veterinarian, so the supply of giant mud crab juveniles for restocking activities in Australia will likely be impacted by larval rearing success until alternate bacterial control measures can be found.

Various parasites and fungi are also important in crustacean aquaculture and particularly in larvicultures. Giant mud crab juveniles and adults in Australia can be infected with the dinoflagellate *Hematodinium* (Lavilla-Pitogo and de la Pena 2004), and this parasitic infection also known as milky disease has recently been reported to be acute in mud crab farms along the south-eastern coast of China (Li *et al.* 2008). Giant mud crab larvae are vulnerable to the ciliated protozoans *Zoothamnium* and *Vorticella*, and to the fungi *Haliphthoros*, *Lagedinium* and *Atkinsiella* (Davis

2004). In sand crabs (*Portunus pelagicus*) the parasitic barnacle *Sacculina granifera* has long been known to commonly occur on immature specimens in QLD (Weng 1987). In more recent studies (Shields 1992) found 15 parasites and symbionts in sand crabs, including the motile *Carcinonemertes mitsukurii*, the peritrich ciliate *Operculariella* sp. and a tetraphyllidean cestode. Juveniles were found to harbour fewer parasites and symbionts, mainly consisting of the lecanicephalid cestode *Polypocephalus moretonensis*, the microphallid trematode *Levinseniella* sp. and the barnacles *Octolasmis* sp. and *Chelonibia patula*. Most of the sedentary external parasites were affected by the moult cycle of the crab.

Shrimp are also known to be infected by gregariane protozoan parasites, and in Australia Peritrich protozoans in the genera *Cothurnia, Epistylis, Vorticella* and *Zoothamnium* are common (Lester and Paynter 1989). Lester and Paynter (1989) have also reported heavy infections of an Apostome ciliate similar to *Synophrya hypertrophica* in juvenile *P. plebejus* and *Metapenaeus macleayi* in ponds in NSW, and they also reported the occurrence of a *Lagenidium*-like fungus in the eggs, larvae and post-larvae of *P. plebejus.* On a worldwide basis, fungi in the genera *Lagenidium*, *Sirolpidium* and *Fusarium* are common in shrimp (Colorini 1998). Table C.4 lists the pathogens that have been documented to potentially affect the species of crustaceans proposed for marine stocking, where there is limited information on a particular species, studies carried out for similar species are referred to.

Table C.4: Pathogens potentially affecting species of marine crustaceans proposed for stocking (and closely related species).

Species	Disease/Parasite
Eastern King Prawn (*Melicertus plebejus*) List includes other closely related penaeids.	**Viruses**: Infectious Hypodermal and Hematopoietic Virus - Owens *et al.* (1992); Gill-Associated Virus, Mourilyan Virus, Hepatopancreatic-Parvo Virus, Spawner Mortality Virus, Mid Crop Mortality Syndrome, Monodon Baculovirus - QDPI&F (2006a), *Plebejus Baculovirus* - Lester and Paynter (1989), Taura Syndrome Virus, White Spot Syndrome Virus, Yellow Head Virus - Lightner (1999). **Bacteria**: *Vibrio*, *Aeromonas*, *Pseudomonas*, and luminous bacteria - Colorini (1998). **Protozoa**: *Cothurnia*, *Epistylis*, *Vorticella*, *Zoothamnium*, Apostome ciliates - Lester and Paynter (1989). **Fungi**: *Lagenidium* - Lester and Paynter (1989); *Sirolpidium*, *Fusarium* Colorini (1998).
Giant Mud Crab (*Scylla serrata*)	**Viruses**: Taura Syndrome Virus - Kiatpathomchai *et al.* (2007); White Spot Syndrome Virus - Chen *et al*. (2000); *Scylla baculovirus* - Lavilla-Pitogo and de la Pena (2004). **Bacteria**: *Vibrio*, filamentous bacteria – Davis (2004). **Dinoflagellate**: *Hematodinium* - Lavilla-Pitogo and de la Pena (2004), Li *et al.* (2008). **Protozoa**: *Zoothamnium*, *Vorticella* - Davis (2004). **Fungi**: *Haliphthoros*, *Lagedinium*, *Atkinsiella* - Davis (2004).
Blue Swimmer Crab (*Portunus pelagicus*)	**Rhizocephala**: *Sacculina* – Phillips and Cannon (1978), Bishop and Cannon (1979), Weng (1987); *Octolasmis*, *Chelonibia* - Shields (1992). **Nemertea**: *Carcinonemertes* - Shields (1992). **Peritrich ciliates**: *Operculariella* - Shields (1992). **Cestoda**: *Tetraphyllidea*, *Polypocephalus* - Shields (1992). **Trematoda**: *Levinseniell* - Shields (1992).

C.4.2.1.3 Declared Diseases

A list of 'declared diseases' is contained in Schedule 6B of the FM Act. DPI must be notified if a declared disease is suspected in any fish, captive or wild, in NSW. There are also offences for transmitting these diseases to live organisms, selling infected animals or vegetation or depositing infected animals or vegetation in any water (I&I NSW 2005). The list of declared diseases is given in Table C.5. Many of these diseases may not have been recorded for the seven species proposed for stocking, however, this is likely to be a result of a general lack of data regarding the host specificities and vulnerabilities. This suggests that a precautionary approach to disease management be taken and that these declared diseases be considered in pre-stocking screening (as described in Section C.4.1.5.1).

Table C.5: Diseases and parasites listed under Schedule 6B of the NSW *Fisheries Management Act 1994* as ‘declared diseases’.

Diseases Affecting Finfish
Epizootic haematopoietic necrosis - EHN virus
Epizootic haematopoietic necrosis - European catfish virus, European sheatfish virus
Infectious haematopoietic necrosis
Spring viraemia of carp
Viral haemorrhagic septicaemia
Channel catfish virus disease
Viral encephalopathy and retinopathy
Infectious pancreatic necrosis
Infectious salmon anaemia
Epizootic ulcerative syndrome (*Aphanomyces invadans*)
Bacterial kidney disease (*Renibacterium salmoninarum*)
Enteric septicaemia of catfish (*Edwardsiella ictaluri*)
Piscirickettsiosis (*Piscirickettsia salmonis*)
Gyrodactylosis (*Gyrodactylus salaris*)
Red sea bream iridoviral disease
Furunculosis (*Aeromonas salmonicida* subsp. *salmonicida*)
Aeromonas salmonicida - atypical strains
Whirling disease (*Myxobolus cerebralis*)
Enteric redmouth disease (*Yersinia ruckeri*—Hagerman strain)
Koi herpesvirus disease
Grouper iridoviral disease
Diseases Affecting Crustaceans
Taura syndrome
White spot disease
Yellowhead disease - yellowhead virus
Gill - associated virus
Infectious hypodermal and haematopoietic necrosis
Crayfish plague (*Aphanomyces astaci*)
White tail disease
Infectious myonecrosis
Milky haemolymph disease of spiny lobster (*Panulirus* spp.)

C.4.2.1.4 Translocation of Organisms

The term 'translocation' refers to any aquatic species being placed, either intentionally or accidentally into the aquatic environments in which they have never occurred naturally.

The movement of fish species beyond their natural range is potentially one of the most ecologically damaging of human activities (Koehn 2004).

The translocation of native species outside their natural range can have impacts upon populations of native fish, the general ecosystem into which translocations occur, as well as subsequent social and economic impacts over time (Morgan *et al*. 2004). Predator-prey interactions as well as direct and indirect competition for food, habitat and resources may be affected. The genetic integrity of natural populations through direct and indirect effects can also be potentially compromised.

It is well known that the introduction of certain non-native species has had detrimental impacts on the environment and native species. The European carp (*Cyprinus carpio*) in particular was introduced into river systems of the Murray-Darling basin as early as 1859, where the species has since proliferated and now dominates the fauna in many areas. Their feeding behaviour is believed to have detrimental impacts on aquatic ecosystems, and hence competitors, by increasing turbidity and nutrients and destroying aquatic plants. Redfin perch (*Perca fluviatilis*), was also introduced to Australian waterways in the 1860s for angling and is now a widespread competitor with native fish throughout NSW and VIC. Redfin perch has also been to known to act as a vector for the spread of the EHN virus.

In QLD, the banded grunter (*Amniataba percoides*), native to the northern part of the State was accidentally released into several parts of south-eastern QLD and northern NSW. Freshwater aquaculture escapes of silver perch (*Bidyanus bidyanus*) have also been recently recorded in WA (Cross 2000).

The banded grunter has serious effects on local shrimp populations and hence trophic dynamics. In NSW, the banded grunter has been declared as noxious (CRC Research 2004). In the late 1980s, archer fish (*Toxotes chatareus*), bony bream (*Namatalosa erebi*), the predatory mouth almighty (*Glossamia aprion*) and the banded grunter were unofficially released into Lake Eacham in the wet tropics of northern QLD, which was at the time, the only known habitat of the Lake Eacham rainbowfish (*Melanotaenia eachamensis*). These species were native to northern QLD but had not previously occurred in Lake Eacham. Surveys following the introduction of these species failed to record any rainbow fish but recorded the introduced species in abundance. The Lake Eacham rainbow fish has since been listed as 'endangered' on the Environmental Protection and Biodiversity Conservation (EPBC) threatened species list (CRC Research 2004).

There are also a number of successful fisheries in Australia which are based upon non-indigenous natives such as the translocated species of golden perch (*Macquaria ambigua*) in the Wimmera River, western VIC. Native fish such as barramundi (*Lates calcarifer*) have also been successfully farmed in freshwater aquaculture schemes outside their natural distribution providing substantial economic benefits.

In addition to diseases, parasites and non-target organisms, there is a number of marine pest organisms which could incidentally be translocated attached to equipment, nets and cages (for example), or in the water used to transport broodstock and fingerlings. There are, however, few (if any) reported incidences of marine pests being translocated as a result of stocking activities. This may be a result of data deficiency rather than lack of issue. Pest organisms and non-target pest species are also listed by DPI under Schedule 6B of the FM Act as 'declared diseases' (Table C.6).

Table C.6: Pest species listed under Schedule 6B of the NSW Fisheries Management Act 1994 as 'declared diseases'.

Pests Organisms
Finfish
Oreochromis mossambicus (Mozambique mouthbrooder)
Tilapia zillii (Redbelly tilapia)
Tilapia mariae (Black mangrove cichlid)
Neogobius melanostomus (Round goby)
Siganus rivulatus (Marbled spinefoot)
Crustaceans
Eriocheir spp. (Chinese mitten crab)
Charybdis japonica (Lady crab)
Hemigrapsus sanguineus (Asian shore crab)
Hemigrapsus takanoi (Pacific crab)
Hemigrapsus penicillatus (Pacific crab)
Carcinus maenas (European shore crab)
Balanus improvisus (Barnacle)
Molluscs
Mytilopsis sallei (Black-striped mussel)
Perna viridis (Asian green mussel)
Perna perna (Brown mussel)
Perna canaliculus (New Zealand green lipped mussel)
Musculista senhousia (Asian bag mussel, Asian date mussel)
Potamocorbula amurensis (Asian clam, brackish-water corbula)
Varicorbula gibba (European clam)
Mya arenaria (Soft shell clam)
Ensis directus (Jack-knife clam)
Rapana venosa (Rapa whelk)
Crepidula fornicata (American slipper limpet, slipper limpet)
Maoricolpus roseus (New Zealand screw shell)
Echinoderms
Asterias amurensis (Northern Pacific seastar)
Ascidians
Didemnum vexillum (Colonial sea squirt)
Polychaetes
Marenzelleria spp. (Red gilled mudworm)
Sabella spallanzanii (European fan worm)

Pests Organisms
Ctenophores
Mnemiopsis leidyi (Comb jelly, sea walnut)
Marine vegetation
Undaria pinnatifida (Japanese seaweed)
Grateloupia turuturu (Red macroalga)
Sargassum muticum (Asian seaweed)
Codium fragile spp. tomentosoides (Green macroalga)
Holoplankton
Pfiesteria piscicida (Toxic dinoflagellate)
Pseudo-nitzschia seriata (Pennate diatom)
Dinophysis norvegica (Toxic dinoflagellate)
Alexandrium monilatum (Toxic dinoflagellate)
Chaetoceros concavicornis (Centric diatom)
Chaetoceros convolutus (Centric diatom)

C.4.2.1.5 Techniques for Managing Disease, Parasites and Pests

While there is some published information on the health status of the species of fish and crustaceans proposed for marine stocking, information regarding the status of all NSW estuaries where stocking is proposed and/or broodstock may be collected from is limited as is the case for many species produced in aquaculture facilities. Several diagnostic technologies and screening efforts may therefore be employed in hatchery facilities to further mitigate potential disease and health issues.

Turner (1998) and Leber *et al*. (2007) recommend that the most effective solution to mitigate the translocation, enhancement and spread of disease and parasites is by obtaining health certification and using available diagnostic technologies to monitor the health of cultured stocks prior to release. Monitoring of stock prior to release is not however, considered to remove the issues altogether. Bartley *et al.* (2006) state that analysis of risks to animal health in stock enhancement programs should specifically involve the consideration of the source of animals to be released, the populations to be managed, hazard identification, risk assessment, risk management, quarantine, diagnostic and treatment procedures, mitigation measures, monitoring, reporting the disease status of hatchery and wild populations and the establishment of aquatic animal health standards.

There are several useful handbooks which are available and which can be recommended for the identification of diseases in fish and crustaceans. Internet searches are particularly useful in providing photographic and other information for use. The best of these information sources provide graphical and/or pictorial examples of many of the pathogens as identification aids, as well as information on life cycles which may need to be broken through detailed management regimes, and other useful biological and epidemiological background. Some of the most useful of these which have been uncovered in the present review process include Johnson (1978), Colorini (1998), QDPI&F (2006a) and Read *et al.* (2007). It is important to reiterate that laboratory diagnosis is the most effective tool in identification of pathogens and in providing a health certification for cultured fish prior to release;

Kautsky *et al.* (2000) reviewed the causes of pathogen spread in shrimp farming environments and suggested that high culture densities and the use of monocultures were the main problems. These coupled with a deterioration of water qualities and environmental organic loading leads to higher stress levels and a resulting predisposition to disease. Inappropriate facility positioning, and insufficient water supplies were other causes noted, along with less-than-optimal management regimes. Biosecurity controls such as ozone disinfection of supply waters (Schuur 2003), use of pathogen-free broodstock, and disinfection of gametes and embryos via various means (Brock and Bullis 2001, Mushiake and Muroga 2004) has been recommended in disease minimisation and prevention protocols.

The Hatchery Quality Assurance Scheme (HQAS) currently in place in NSW for fish fingerling production for freshwater stockings (NSW DPI 2008a) takes many of these considerations into account, including broodstock sources and culture methods, hatchery sites and infrastructures, water quality and fish health management, chemicals usage, records keeping, and protocols for transportation and despatch. Recent health management strategies for other species (e.g. silver perch, Rowland *et al*. 2007) can also assist in guiding these protocols in the Australian context of avoiding disease introductions to enhanced wild populations. Currently, however, the HQAS does not incorporate marine species or marine stocking in general and it would be modified should this proposal be approved.

The National Policy for the Translocation of Live Aquatic Organisms – Issues, Principles and Guidelines for Implementation (MCFFA 1999) provides a consistent national framework to assess the potential risks associated with all proposals for the translocation of live aquatic organisms. This risk assessment-based process is intended to deal with proposals for deliberate translocations where approval is sought from the relevant jurisdiction. This policy is not, however, directly relevant to the proposal for marine stocking in NSW as broodstock would be collected from within the population targeted for stocking.

The NSW translocation policy provides for continued fish stockings, but limits what species can be stocked and where stocking can occur in an attempt to minimise any adverse effects of these stockings. It is supported by the following legislation: Section 216(1) of the FM Act: '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' (SKM 2008).

C.4.3 Social Uncertainties

C.4.3.1 Aboriginal Social Issues

Aboriginal communities along the NSW coast have a strong and continuing cultural, economic and social association with estuarine fishery resources.

In regional coastal communities, for example, fishing continues to provide an important component of Aboriginal diet (for instance, see Schnierer and Faulkner 2002, Faulkner 2000, Cozens 2003, Egloff 1981, English 2002). Traditional cultural knowledge and practice are also related to features of estuarine waterways. Some of these aspects of Aboriginal cultural heritage value are reported in the literature, others are special knowledge held only within local communities where the cultural activities are practiced. Aboriginal people along the NSW coast are actively involved in the delivery of natural resource management programs that help to look after sea and land country. Some of these programs are part of the implementation of Catchment Action Plans. Other programs have been separately initiated by the Office of Environment and Heritage (OEH) in partnership with local Aboriginal communities. An example is the Land Alive program.

This assessment considers whether marine stocking can be managed in a way that contributes to the well being of Aboriginal communities along the coast, by supporting healthy functioning ecological systems and providing opportunities for Aboriginal people to be involved in looking after the cultural values of sea country. This specifically includes consideration of:

- Potential impacts on 'sites' and /or objects of Aboriginal cultural significance, such as middens, open campsites, archaeological deposits in rock shelters, rock art sites, sandstone engravings. Aboriginal objects are the physical evidence of past Aboriginal occupation of the land. Aboriginal sites are places where objects occur. Under Part 6 of the National Parks and Wildlife Act 1974 (NPW Act), it is an offence to knowingly move, damage, deface or destroy Aboriginal objects.
- Potential impacts on 'Places' of special significance to Aboriginal culture. Aboriginal Places do not need to contain Aboriginal objects, although some Places do. In general, Aboriginal Places are declared to protect traditional places associated with stories or legends. Some have also been declared to recognise post-contact sites such as Missions. When a place has been declared an Aboriginal Place, the entire place has the same level of protection under the NPW Act as any individual object.
- How marine stocking can benefit and involve Aboriginal communities in the stocking activities.
- How marine stocking can be implemented in a way that enhances the health of estuarine waterways e.g. through restoration, habitat protection and improved water quality.
- How fish stocking may help contribute to promoting a healthy diet in coastal Aboriginal communities.

Further information is given in the Aboriginal Issues Assessment (Specialist Report A).

C.4.3.1.1 Aboriginal Owners and Land Claims

Aboriginal Owners have been recognised under the *Aboriginal Land Rights Act1989* (see Section C.6.1) for some parts of the NSW coast, such as in the traditional country of the Yuin people on the far south coast (including Wallaga Lake in Gulaga National Park), the Bundjalung people on the north coast, Birpai people on the mid north coast and the Worimi people around Port Stephens.

On the south coast, Merrimans Local Aboriginal Land Council (LALC) and Wagonga LALC hold freehold title to the lands within Gulaga National Park, on behalf of the Aboriginal Owners. Gulaga National Park is leased to the Minister for the Environment for 30 years under the NPW Act. The land is part of the conservation estate of NSW, but is under the care, control and management of a Board of Management, with the majority of the Board being Aboriginal Owners. The lease over the National Park (December 2005) requires that it is managed in accordance with a Plan of Management, which reflects the cultural significance of the land to the Yuin people.

The Wagonga LALC also owns a parcel of land on the shore of Wagonga Inlet, between Black Bream Point and Paradise Point. It has plans for a cultural centre on this land. Other Land Councils also own land around the shores of estuaries, but not extending into the estuarine waters. In Port Stephens, some Worimi Aboriginal Owners are members of an advisory group which contributes to the management of the Port Stephens-Great Lakes Marine Park.

C.4.3.1.2 NSW Indigenous Fisheries Strategy and Implementation Plan

In 2002, DPI released the NSW Indigenous Fisheries Strategy and Implementation Plan. The strategy recognises that 'fishing has been an integral part of the cultural and economic life of coastal and inland Aboriginal communities since they have been in this land'. Most implementation activities occurred between 2002 and 2004.

Several of the initiatives of the strategy are noted below as they highlight the ongoing approach of DPI to involve Aboriginal people in all aspects of fishery management, including the proposed marine stocking program.

Key strategies include:

- Acknowledge and address Aboriginal issues in preparing every Fishery Management Strategy (FMS);
- Support and promote the employment of Aboriginal staff in DPI, within natural resource management generally and in the aquaculture and commercial fishing industries;
- Employ and retain Indigenous Fisheries Officers in regional locations, with an emphasis on having Aboriginal community involvement in fisheries management issues and promoting community commitment to regulations;
- Support a coordinated Indigenous approach to natural resource management;
- Negotiate with local communities on ways to achieve sustainable fisheries and where appropriate engage other agencies in joint strategies which contribute to sustainable resource management and
- The issues behind these strategies have been raised again by Aboriginal community stakeholders during consultation about the marine stocking proposal.

C.4.3.1.3 Cultural Fishing – NSW Fisheries Management Act

The FM Act was recently amended to extend its objects to formally recognise the spiritual, social and customary significance of the fisheries resource to Aboriginal persons. Further, amendments to the FM Act included: a definition of Aboriginal cultural fishing for the purposes of the FM Act; a specific provision for the authorisation of cultural fishing under a Section 37 permit; an exemption for fishers who are Aboriginal persons from paying a recreational fishing fee and the establishment of the Aboriginal Fishing Advisory Council (AFAC) to provide advice to the Minister on Aboriginal fishing issues.

C.4.3.2 Non Aboriginal Social Issues

C.4.3.2.1 Non-Aboriginal Heritage Sites

A potential challenge that may arise from marine stocking is when access to parts of estuarine shoreline is restricted by heritage land that prohibits or limits public access. Some of these heritage sites may be located along sections of the river or estuarine banks protecting sensitive areas or fragile constructions (i.e. old jetties). Conflict may arise if fishers have limited alternatives for water access and become non-compliant by using or trespassing on these sensitive sites without permission. It is important for these sites to be noted in areas targeted for marine stocking.

C.4.3.2.2 Managing Access to Fisheries Resources

One of the social uncertainties of marine stocking is the response of recreational and commercial fishers to the ‘newly enhanced resource’. Generally the users in the vicinity of the stocking areas are often the main beneficiaries (Bell *et al*. 2008). Particular challenges may arise with competition over shared assets and uncertainties over access and ownership of the newly enhanced resource between and within fishery sectors and conflict over what type of species should be stocked.

Between recreational fishers the types of conflicts that may emerge include conflict over catching methods (i.e. catch and keep vs. catch and release), a sense of ownership or possessive attitude towards the location or accepted use of the resource, attitude towards newcomers (holiday season influx) and intensity of fishing style (Arlinghaus 2005). These types of conflicts may increase or decline with marine stocking.

There is the risk that conflict may also arise between recreational and commercial fisheries. This is more likely to be the case where the same species are being targeted for fishing. The ‘tragedy of the commons’ can be applied to such situations where every fisher with unrestricted access to the common pool of resources tries to take as much fish as he or she can get to avoid someone else taking it (Arlinghaus 2005). This behaviour can occur within or between sectors and may change with marine stocking and increase fishing effort depending on willingness to comply with institutional regulations.

C.4.3.2.3 Other Waterway Users

Particular challenges and uncertainties arise when marine stocking is carried out in a common pool resource which is used by multiple users. The most likely challenges that may arise from marine stocking relate to user conflict.

Water sports constitute a popular Australian past time, and therefore can be considered as cultural heritage activities. The water and associated land based activities that may compete for space and disturb the marine stocking location or recreational fishers fishing include boating, water skiing, kayaking, surfing, swimming and jet skiing. Generally however recreational fishing is a static activity where fishers tend to locate themselves in one area per fishing visit, therefore having little impact on other shore or other water based activities.

Water users must follow the local regulations that exist in the waterway or open water such as speed limits and zones allocating different areas for different water-based activities such as sailing or water skiing therefore reducing the risk of potential incidents from occurring. Where regulations do not exist there is some potential for competition of the use of the space and a greater risk for incidents to occur i.e. recreational swimming from wharves or snorkelling from headlands. Alternatively user conflict may arise if marine stocking restricts these practices to locations frequented by recreational fishers to minimise disturbance of marine stocking locations.

C.4.3.2.4 Community Support, Participation and Fishing Effort

Research has shown that that the success of fish stocking is more likely when the community is committed to doing so prior to stocking, and is kept informed and involved in the processes (Garaway *et al*. 2006). The types of involvement include attending forums, public consultations, having an input into managing the ‘newly enhanced resource’ and key individuals taking on more involved positions. Local users often have considerable knowledge of the local resources and are often best placed to observe and aid in monitoring changes over time (Garaway *et al.* 2006). One of the key challenges in the commitment and success of the marine stocking program is encouraging the awareness, support and participation of the fishing community (both recreational and commercial). The geographical location, popularity of the potential marine stocking locations, and fishing affiliations will be a key factor in determining the level of interest and involvement in this process.

The National Recreational Fishing Survey (Henry and Lyle 2003) revealed that Australia has a high national recreational fishing participation rate of 19.5 %. In the 12 months prior to May 2000, an estimated 3.36 million Australians aged 5 years or older went recreational fishing at least once. Other results from the study revealed that an estimated 1.8 million households contained at least one recreational fisher, representing 24.4 % of households nationally, with an average of 1.9 fishers per fishing household nationally. In NSW, a high portion (17.1 %) of the general public participated in recreational fishing. NSW had the greatest number of recreational fishers compared to all other States; however participation rates were highest in the NT. The research findings also revealed that participation rates were twice as high in rural areas (30.1 %) and lowest in metropolitan areas such as Sydney (13.1 %). However by virtue of its population size, the highest numbers of recreational fishers came from large urban centres such as Sydney.

Existing information relating to fishing effort and stock enhancement is limited and there is some uncertainty as to whether marine stocking is likely to affect the level and distribution of fishing effort at a local and state-wide scale. Results of the few relevant studies and anecdotal evidence is summarised below.

DPI has conducted comprehensive recreational fishing surveys in Lake Macquarie and Tuross Lake prior to and after the establishment of Recreational Fishing Havens (RFH's). The establishment of RFH's provides a situation analogous to fish stocking, whereby an improvement to the quality of recreational fishing is expected. Surveys were first conducted in Lake Macquarie and Tuross Lake in 1999/2000 prior to their establishment as RFH's. Surveys were then repeated in 2003/04 using the same methodology to provide a direct comparison between years (Steffe *et al*. 2005a, b). In the Tuross Lake survey there was a significant (46 %) increase by weight in the annual harvest of fish, crabs and cephlapods in the post-RFH survey year which was co-incident with a significant increase in the number of boat trips of recreational fishers (25 %) (Steffe *et al*. 2005b). At Lake Macquarie, small increases in the post-RFH survey year in total weight were also recorded but these were not significant (Steffe *et al.* 2005b). There was a small overall increase in fishing effort (boat and shore, ~2.3 %) at Lake Macquarie in the post-RFH survey year, but this was not significant as the increase in boat trips was balanced by a significant increase in boat-based effort (12.8 %) and a significant decline in shore-based effort (22 %). Both surveys found significantly increased harvest (by weight) of some important recreational species in the post-RFH survey year but decreased harvest of others.

In terms of the harvest rate (number of fish per fisher hour), significant increases were detected in the post-RFH survey year for many of the key recreational species, particularly in Lake Macquarie (Steffe *et al*. 2005a). Results of the studies showed that fishing effort did not significantly increase in both places after the establishment of the RFH's, although it was recognised that the surveys were only a snapshot in time and are not evidence for a longer term trend.

Anecdotal evidence suggests that following trial stockings of eastern king prawns in Wallagoot Lake (southern NSW), there was a noticeable increase in associated recreational fishing activity (Taylor, M. T. Pers. Comm. 2010). This was thought to be evidence of a local redistribution of fishing effort rather than an overall increase in effort.

Currently the only reliable and accurate state-wide information on NSW recreational catch and effort is available from the National Recreational and Indigenous Fishing Survey, which was undertaken in 2000/01 (Henry and Lyle 2003). The main challenge throughout the world is how to obtain representative estimates of recreational catch and effort in a cost-effective way over large geographical scales. Another state-wide survey will commence in 2012 and provide for comparisons between surveys. However, in the absence of effort data, recreational fishing licence data is available which can provide indicators of effort.

At a regional scale, data on the number of recreational fishing licence holders (marine and freshwater) did not increase substantially between years 2001/02 and 2007/08 (465,420 and 488,086 respectively), which may suggest no overall increase in fishing effort. This is despite programs having been established during this time (i.e. freshwater stockings, estuarine artificial reefs, fish aggregating devices and RFH's) that aimed to improve recreational fishing opportunities. This lack of change to fishing effort suggests that an overall increase in fishing effort at a regional scale would be unlikely to occur as a result of marine stocking.

It is generally concluded that while marine stocking may result in a localised increase in fishing effort, this is unlikely to be substantial and would result from a redistribution of effort rather than an overall increase at a larger (e.g. State-wide) scale.

C.4.4 Economic Uncertainties

The National Recreational Fishing Survey (Henry and Lyle 2003) indicates that approximately 47 % of fishing effort is estuarine in nature within NSW, leading to an estuarine recreational fishing expenditure of $260.38 million (2003 dollars). The National Recreational Fishing Survey (Henry and Lyle 2003) did not contain detailed information as to where this expenditure was spent, where the associated fishing occurred, or what species (if any) were targeted during the associated fishing. This limits the usefulness of this State-wide data in valuing particular estuaries or species in terms of recreational value.

The values of commercial estuarine fisheries are given in Section C.10.3. The economic costs and benefits associated with fish stocking programs are described in Specialist Report B.

The majority of costs are either market based costs (e.g. wages) or commonly evaluated off-market costs (e.g. pollution and loss of vegetation). The majority of benefits relate to the value associated with changes to fishing effort (time and frequency) rather than the benefits associated with increased yields.

Theoretically, the need for, and benefits flowing from, a marine stocking program would be relatively simple to assess based upon the current fish population levels in relation to the maximum economic yield quantities and known quantities of stocked fish, effects on growth rates, and subsequent predicted increases in yield and changes in effort. However, this type of analysis is impractical in regard to most recreational fisheries as data of this type is typically unavailable. In addition, measuring both the existing value of recreational fishing and the impacts of marine stocking is considerably challenging as it is frequently the activity rather than the outcome of the activity (the catch) that is valued by fishers. Valuing the harvest caught by recreational fisheries, as done in commercial fisheries, would considerably underestimate the value attributed to the activity by those fishers who are likely to fish for reasons independent of numbers or species caught. The potential to utilise market values of individual fish and harvests as an attempt to value catch by fishers is also problematic as many fish caught are released. This received benefit is often ascribed to the “sport” aspect (the enjoyment received through the challenge and activity) rather than obtaining fish for food (under the food motivation the harvest price of fish may be an appropriate value estimate).

The framework and outcomes of the analysis used to evaluate the economic feasibility of this proposal for marine stocking are described in Specialist Report B and summarised in Chapter G, Section G.3.

C.5 Responsible Approach to Marine Stocking

A number of papers have been published advising on approaches to marine stock enhancement and management (e.g. Blankenship and Leber 1995, Munro and Bell 1997, Pruder *et al*. 1999, Blaylock *et al*. 2000, Molony *et al*. 2003, Hilborn 2003, Ulltang 2003, Taylor *et al*. 2005b, Bell *et al*. 2006, Lorenzen 2008, Bartley and Bell 2008, Bell *et al.* 2008, Russell 2008). The steps detailed in Blankenship and Leber (1995) in particular, has gained widespread acceptance as the ‘responsible approach’ to marine stock enhancement. Many aspects of fisheries science in general and fisheries enhancement have developed rapidly since the responsible approach was first formulated; hence, an update to this approach has been published by Lorenzen *et al*. (2010) in light of these developments. The updated approach emphasises the need for a broad and integrated view of the role of enhancements within fisheries management systems, the importance of stakeholder participation in the planning process, and the assessment of the potential contribution of enhancement and alternative measures to fisheries management goals early on in the development process.

The updated responsible approach as proposed in Lorenzen *et al*. (2010) proposes the following 15 elements arranged in three stages as follows:

<u>Stage 1: Initial appraisal and goal setting</u>

1. *Understand the role of enhancement within the fishery system.*
   - Clarify broad fishery goals so that areas of congruence or conflict with stocking can be identified and the ground prepared for a decision making process for development or reform.
2. *Engage stakeholders and develop rigorous and accountable decision making process.*
   - Lorenzen (2008) also states that a stakeholder participatory planning process should be carried out to determine whether stock enhancement has a cost-effective, socially and environmentally beneficial role in managing the fishery.
3. *Quantitatively assess contributions of enhancement to fisheries management goals*
   - The need for an integrated management approach is also highlighted as a key requirement for future stock enhancement programs. Lorenzen (2008) highlights that in order for marine stocking to be effective, releases need to contribute to the biological, economic, social and institutional management objectives of the fishery and that investment in restocking and stock enhancement should not be made unless they are likely to add value to other forms of management.
   - Evaluate strategies to use in conjunction with stock enhancement, for example, habitat enhancement through the construction of artificial habitats and/or restoration of existing habitat to increase the carrying capacity for cultured juveniles (Le Vay *et al.* 2008).
   - Identify harvest opportunity, stock rebuilding goals and genetic objectives.
   - Consider goals and objectives in context of the management plan for identified species.

4. *Prioritise and select target species and stocks for enhancement.*
   - An example of an appropriate procedure is outlined in Leber (1994), where a semi-quantitative decision making process was used to select species for stock enhancement research in Hawaii. This emphasizes the need for stakeholder consultation and participation and ranking of candidate species in relation to relevant selection criteria.
   - For stock enhancement to be most cost-effective, target species should (for example) be:
     - recruitment limited with evidence of species decline;
     - naturally occurring within the estuary to be stocked;
     - a less complex life-history is often better;
     - estuarine resident across the majority of its life history;
     - relatively fast growing to reach the minimum legal length for harvest;
     - a popular recreational species;
     - easily reared in aquaculture facilities;
     - proven as a suitable candidate through successful trial studies; and
     - not consist of an assemblage of genetically subdivided populations throughout the proposed range of stocking (to minimise the number of broodstock collections for culture).
   - For each species being considered, select suitable locations that are:
     - ecologically similar (to allow prediction of success across sites, to minimise the variety of ecosystem responses and to decrease the number of broodstock collections that will be needed for production of juveniles); and,
     - Within the natural range of the species.

5. *Assess economic and social benefits and costs of enhancement.*
   - Assess value in terms of costs and benefit.
   - Arnason (2008) notes that incentives that confer harvesting rights to those who invest in the production and release of juveniles are required to establish sustainable stock enhancement programs.

<u>Stage 2: Research and technology development including pilot studies</u>

6. *Define enhancement system designs suitable for the fishery and management objectives.*
   - Develop quantitative benchmarks against which success can be measured, such as an increase in landings or catch per unit effort (CPUE) of X %, an increase in spawner biomass of Z % by year "Y".
   - Benchmarks should relate to system type goals and genetic objectives.

7. *Develop appropriate aquaculture systems and rearing practices.*
   - Evaluate behavioural and physiological deficiencies that may be present in stocked fish.
   - Aim for a balance between culture efficiency and post-release fitness (i.e. wild-type characters). Evaluation of impacts of culture practices on survival in the wild should receive a high priority in technology development.

8. *Use genetic resource management to avoid deleterious genetic effects.*
   - De Innocentiis *et al.* (2008) recommend the use of sufficient, genetically correct broodstock to produce cultured juveniles with gene frequencies representative of wild populations.
   - Wild broodstock should be used to produce cultured juveniles with less risk of impacts to ecosystem dynamics.
   - Use an effective hatchery population size of >100, with 25 % turnover each year (Bartley *et al.*1995).

9. *Use disease and health management.*
   - Adopt responsible hatchery practice.
   - Ensure fish are free from viral, parasitic, bacterial and fungal infections.
   - Note that Bartley *et al.* (2006) have developed a 'risk analysis framework for aquatic animal health management in marine stock enhancement programmes'.

10. *Ensure that released hatchery fish can be identified.*
    - Develop efficient, benign methods for marking fish.

- This should incorporate the use of cost-effective tagging methods (Bartley and Bell 2008).

11. *Use an empirical process for defining optimal release strategies.*

- Determine whether the receiving environment is recruitment limited i.e. releases should not cause density dependant mortality among the cultured or wild animals or displacement of wild juveniles (Brennan *et al.* 2008, Seitz *et al.* 2008).
- Identify potential transport and release stress effects.
- Determine the suitability of the release habitat (and micro-habitat) as a nursery area i.e. release of cultured juveniles may be ineffective if there is insufficient nursery habitat to support them.
- Determine the optimal size of individuals at release, which is often a trade-off between post-release survival, naivety, and fingerling cost. This can affect economic efficiency (Obata *et al.* 2008).
- Determine the optimal season at release, which would usually lie in-mode with wild recruits. This is particularly important if the aim of the stock enhancement program is for the effective reproduction of the cultured individuals, whereby it should be ensured that juveniles are released at times and places that enable effective spawning (Hines *et al.* 2008, Zohar *et al.* 2008).
- The design of stock enhancement programs should aim to allow released juveniles to complete their life cycle, therefore contributing to spawning biomass (Zohar *et al.* 2008).

Stage 3: Operational implementation and adaptive management

12. *Devise effective governance arrangements.*

- Streamline arrangements for enhancement to integrate multiple organisations, rules and regulations.
- Ensure that measures are in place to protect released fingerlings, such as closed seasons, no trawling etc.

13. *Define a stock management plan with clear goals, measures of success and decision rules.*

- Evaluate stock enhancement in an ecological context and in relation to wider fisheries management and conservation goals.
- Select appropriate stocking locations.
- Undertake surveys of productivity followed by model-based estimation of appropriate stocking densities (i.e. the number of animals that can be supported), should be conducted in reference to enhancement targets.
- Apply decision rules for determining where and when stockings occur.

14. *Assess and manage ecological impacts.*

- Evaluate risks to wild stocks, competitors and ecosystems and set monitoring and management requirements accordingly.

15. *Use adaptive management.*

- Adopt a continuing assessment process that allows improvement over time.
- Allow integration of new ideas and strategies into the management process.

In examining a responsible approach to marine stock enhancement in an Australian fisheries context, Taylor *et al*. (2005b), identifies several areas where the success and effectiveness of stock enhancement can be maximised in accordance with the above principles. Taylor *et al*. (2005b) highlights the importance of recreational fisheries in Australia and that stocking of recreationally important species is shown to provide the greatest cost-benefit potential, with lower cost-benefit ratios, the stocking recreational species in urbanised ICOLLs protected from commercial fishing is feasible. Furthermore, Taylor *et al*. (2005b) consider the stocking of fast growing, estuarine species (such as mulloway and barramundi) into recreational fishing havens (RFH's) to be most effective and beneficial approach to marine stock enhancement, within a responsible management framework.

C.6 Statutory Framework and Guidelines

C.6.1 State Legislation

At present, there is no policy in NSW specifically governing the release of marine species into open waters in NSW (Taylor 2006b). Additional State Legislation of relevance to the proposal is outlined below:

Environmental Planning and Assessment Act 1979 (EP&A Act)

The objectives of this Act include:

- The proper management, development and conservation of natural and artificial resources, including agricultural land, natural areas, forests, minerals, water, cities, towns and villages for the purpose of promoting the social and economic welfare of the community and a better environment;
- The protection of the environment, including the protection and conservation of native animals and plants, including threatened species, populations and ecological communities, and their habitats; and
- Promoting ecologically sustainable development.

Fish stocking is a designated fishing activity under Schedule 1A of the FM Act (see below). Under NSW legislation, a 'designated fishing activity' requires assessment under Part 5 of the EP&A Act. Under Section 115O of the EP&A Act, a designated fishing activity must be the subject of an EIS and cannot proceed without a determination made by the Fisheries Minister. This is the basis for preparation of an EIS for this proposal. Further, approval, under Section 115P of the EP&A Act, must be given by the Planning Minister prior to the determination being made as DPI are the proponent and cannot be the sole determining authority.

Fisheries Management Act 1994 (FM Act)

DPI is responsible for administering the FM Act which seeks to conserve fish stocks; key fish habitats and; threatened species, populations and ecological communities of fish and marine vegetation. Consistently with those objectives is the aim to ensure social, cultural and economic benefits to commercial, recreational and Aboriginal fisheries as well as the wider community of NSW.

Fish stocking is a designated fishing activity under Schedule 1A of the FM Act. Section 216 of the FM Act states that releasing live fish into waters is prohibited except under the authority of a permit issued by the Minister or an aquaculture permit. This does not apply to the immediate return of fish to waters from which they were taken. 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, whereby the release of a fish, includes depositing them or permitting them to escape.

Species populations and communities identified as 'endangered' are listed in Schedule 4 of the FM Act. Species populations and communities identified as 'critically endangered' are listed in Schedule 4A of the FM Act and species populations and communities identified as 'vulnerable' are listed in Schedule 5 of the FM Act. The FM Act also lists Key Threatening Processes (KTPs) that may threaten the survival of those species, populations and ecological communities. KTPs relevant to the current proposal are:

- the introduction of fish to waters within a river catchment outside their natural range and
- introduction of non-indigenous fish and marine vegetation to the coastal waters of NSW.

Part 2, Division 2, Section 19 of the FM Act allows for the Regulation to declare specified species as protected fish; although not currently declining these fish must be protected so they do not become threatened in future. Provisions for the protection of aquatic habitats and aquatic reserves are included under Part 7 of the Act. In addition, Division 3 of the FM Act provides for the identification of habitat that is critical to the survival of an endangered species, population or ecological community.

It is relevant to note that the objects of the FM Act now extend to recognising the spiritual, social and customary significance of fisheries resource to Aboriginal persons whilst a definition of Aboriginal cultural fishing for the purposes of the FM Act is also provided for. Permits are authorised under Section 37 of the FM Act for cultural events where fishing activities are not consistent with current regulation. Other recent amendments include: an exemption for fishers who are Aboriginal persons from paying a recreational fishing fee and, the establishment of the NSW Aboriginal Fishing Advisory Council (AFAC). Membership includes up to ten Aboriginal people representing regions around the State; one other Aboriginal person; a representative from the NSW Aboriginal Land Council (ALC); a representative from the Native Title Services Corporation Limited; and a non-voting senior departmental officer.

Future management measures promoting the continuation of cultural fishing will be developed in close consultation with the AFAC. The AFAC will be the peak advisory group advising the Minister on issues affecting Aboriginal fishing interests and will play an important part in the future development of cultural fishing policy as well as exploring extensions on this looking at commercial opportunities for Aboriginal communities associated with fishing activities.

Nothing within the provisions of the FM Act or the regulations alters fishing rights awarded under Native Title determinations or recognised in Indigenous Land Use Agreements associated with claims.

Threatened Species Conservation Act 1995 (TSC Act)

In NSW, the TSC Act (administered through the NSW Office of the Environment) includes provisions to declare threatened species, populations, ecological communities and KTPs. Species populations and communities identified as 'endangered' are listed in Schedule 1 of the TSC Act. Species populations and communities identified as 'critically endangered' are listed in Schedule 1A of the TSC Act and species populations and communities identified as 'vulnerable' are listed in Schedule 2 of the TSC Act. The TSC Act also lists 'KTPs' that may threaten the survival of those species, populations and ecological communities. Entanglement in or ingestion of anthropogenic debris in marine and estuarine environments is the only KTP listed that is considered relevant to the proposal. This is because recreational fishing and boating could exacerbate this issue. Marine birds, mammals and reptiles are included in schedules of the TSC Act. In addition, the TSC Act provides for the identification of habitat that is critical to the survival of an endangered species, population or ecological community.

National Parks and Wildlife Act (NPW Act) and the National Parks and Wildlife Regulation (NPWR) 2002.

Under the National Parks and Wildlife Act (NPW Act), the Director-General of the National Parks and Wildlife Service (NPWS) is responsible for the care, control and management of all national parks, historic sites, nature reserves, reserves, Aboriginal areas and State game reserves. State conservation areas, karst conservation reserves and regional parks are also administered under the Act. The Director-General is also responsible under this legislation for the protection and care of native fauna and flora, and Aboriginal places and objects throughout NSW. The NPWR governs various activities under the NPW Act, including:

- the regulation of the use of national parks and other areas administered by the NPWS (Part 2)
- the preservation of public health in Kosciuszko National Park (Part 3)
- licences and certificates (Part 4)
- the protection of fauna (Part 5) including the protection of certain types of marine mammals (Division 3A);
- the exemption of Aboriginal people from the restrictions imposed by various sections of the Act on the hunting of certain animals and the gathering of certain plants (Part 6)
- boards of management and plans of management in relation to Aboriginal land (Part 7) and;
- advisory committees constituted under Section 24 of the NPW Act (Part 8).

The regulation replaces the former *National Parks and Wildlife* (Land Management) *Regulation 1995*, the *National Parks and Wildlife* (Administration) *Regulation 1995* and the *National Parks and Wildlife* (Fauna Protection) *Regulation 2001*.

Crown Lands Act 1989

Submerged land is generally classified as a type of Crown land. Submerged land includes most coastal estuaries, many large riverbeds, many wetlands and the State's territorial waters, which extend 3 nautical miles (5.5 km) out to sea. The proposal would therefore be located on Crown Land. The principles of Crown land management are that:

- environmental protection principles be observed in relation to the management and administration of Crown land;
- the natural resources of Crown land (including water, soil, flora, fauna and scenic quality) be conserved wherever possible;
- public use and enjoyment of appropriate Crown land be encouraged;
- where appropriate, multiple use of Crown land be encouraged;
- where appropriate, Crown land should be used and managed in such a way that both the land and its resources are sustained in perpetuity and;
- Crown land be occupied, used, sold, leased, licensed or otherwise dealt with in the best interests of the State consistent with the above principles.

Coastal Protection Act 1979

The objectives of this Act include:

- to protect, enhance, maintain and restore the environment of the coastal region, its associated ecosystems, ecological processes and biological diversity, and its water quality;

- to encourage, promote and secure the orderly and balanced utilisation and conservation of the coastal region and its natural and man-made resources, having regard to the principles of ecologically sustainable development and;
- to recognise and foster the significant social and economic benefits to the State that result from a sustainable coastal environment, including:
  - benefits to the environment and;
  - benefits to urban communities, fisheries, industry and recreation.

Aboriginal Land Rights Act 1983 (ALR Act)

The ALR Act provides a mechanism for compensating Aboriginal people of NSW for loss of their land. The preamble of the ALR Act states that land was traditionally owned and occupied by Aboriginal people and accepts that as a result of past Government decisions, the amount of land set aside for Aboriginal people had been reduced without compensation. To redress the loss of land Aboriginal Land Councils (LALCs) which are established under the act can claim vacant crown land, which if granted, is transferred as freehold title. Vacant Crown land can include land below the mean high water mark (See *Crown Lands Act 1989*).

A LALC has the following functions in relation to the acquisition of land and related matters:

- in accordance with the Act and the regulations, to acquire land and to use, manage, control, hold or dispose of, or otherwise deal with, land vested in or acquired by the Council;
- functions relating to the acquisition of land and any other functions conferred on it by or under Part 4A of the NPW Act;
- to submit proposals for the listing in Schedule 14 to the NPW Act of lands of cultural significance to Aboriginal persons that are reserved under the NPW Act;
- to negotiate the lease by the Council or by the Council and one or more other LALCs of lands to which Section 36A applies to the Minister administering the NPW Act;
- when exercising its functions with respect to land that is the subject of a lease, or proposed lease, under Part 4A of the NPW Act, to act in the best interests of the Aboriginal owners of the land concerned;
- to make written applications to the NSW ALC for the acquisition by the NSW ALC of land on behalf of, or to be vested in, the LALC; and
- To make claims to Crown lands.

A LALC has the following functions in relation to land use and management:

- to consider applications to prospect or mine for minerals on the Council's land and to make recommendations to the NSW ALC in respect of such applications; and
- to protect the interests of Aboriginal persons in its area in relation to the acquisition, management, use, control and disposal of its land.

A LALC has the following functions in relation to Aboriginal culture and heritage:

- to take action to protect the culture and heritage of Aboriginal persons in the Council's area, subject to any other law; and
- To promote awareness in the community of the culture and heritage of Aboriginal persons in the Council's area.

Protection of Environment Operations Act, 1997 (PoEO Act)

The PoEO Act is administered by the Environmental Protection Authority (EPA) within OEH and ultimately aims to protect, enhance and restore the quality of the environment in NSW, to reduce risk to human health and promote mechanisms that minimise environmental degradation through a strong set of provisions and offences. A licence is required from OEH if any of the activities associated with the proposal are determined to be a Scheduled Activity under Schedule 1 of the Act. At this stage, it is not expected that such a licence will be required.

Marine Parks Act 1997 (MP Act)

The MP Act provides for the declaration of marine parks; and for other purposes. It is administered jointly by the Minister for Primary Industries and the Minister for Climate Change and the Environment. The objects of the Act are as follows:

- to conserve marine biological diversity and marine habitats by declaring and providing for the management of a comprehensive system of marine parks,

- to maintain ecological processes in marine parks, where consistent with the preceding objects:
  - to provide for ecologically sustainable use of fish (including commercial and recreational fishing) and marine vegetation in marine parks; and
  - to provide opportunities for public appreciation, understanding and enjoyment of marine parks.

C.6.2 Environmental Planning Instruments

Environmental planning instruments, State Environmental Planning Policies (SEPPs) and local environmental plans (LEPs) are legal documents that regulate land use and development. The plan-making system in NSW is set out in the EP&A Act. The Act provides for members of the public to participate in planning decisions that will shape their community's future. Planning Instruments relevant to the proposal are outlined below.

SEPP No. 71 – Coastal Protection

The policy has been made under the EP&A Act to ensure that development in the NSW coastal zone is appropriate and suitably located, to ensure that there is a consistent and strategic approach to coastal planning and management and to ensure there is a clear development assessment framework for the coastal zone.

The aims of this Policy include:

- to protect and manage the natural, cultural, recreational and economic attributes of the NSW coast;
- to protect and preserve the marine environment of NSW and;
- manage the coastal zone in accordance with the principles of ecologically sustainable development.

Local Environment Plans (LEPs)

Consistency with LEPs requires consideration in relation to fish stocking because of the potential impacts on Heritage places or objects that are role in heritage management by identifying, assessing and managing heritage places and objects in important for the community and managed by the local council. There are over 20,000 individual local heritage items listed in LEPs and many more in the 183 local conservation areas located across the State. Local councils play an important their local area. All local councils are required to identify items of local heritage significance in a heritage schedule to the local environmental plan.

LEPs also include a zoning plan outlining the objectives, uses and planning provisions of each zone which may require consideration in marine stocking activity. Three types of zones are relevant to marine stocking activity although how and where zones are mapped vary among LEPs. Note that Councils may choose not to apply a waterway zone to smaller waterways (such as streams and intermittent creeks) and instead zone the waterway the same as the adjacent land. The waterway zones are generally intended for application to the waterway's channel and banks. Zones which may apply to marine stocking activity are described below:

W1 Natural Waterways

This zone is generally intended for waterways that are to be protected due to their ecological and scenic values. A limited number of low impact uses that do not have an adverse effect on the natural value of the waterway can be permitted in this zone. Objectives of the zone are:

- To protect the ecological and scenic values of natural waterways;
- To prevent development that would have an adverse effect on the natural values of waterways in this zone; and
- To provide for sustainable fishing industries and recreational fishing.

W2 Recreational Waterways

This zone is generally intended for waterways that are used primarily for recreational purposes such as boating, fishing and water skiing, but which may also have ecological, scenic or other values that require protection. Objectives of the zone are:

- To protect the ecological, scenic and recreation values of recreational waterways;
- To allow for water-based recreation and related uses; and
- To provide for sustainable fishing industries and recreational fishing.

W3 Working Waterways

This zone is generally intended for waterways which are primarily used for shipping, port, transport and other working uses. The zone recognises that there may also be recreational uses. Objectives of the working waterway zone are:

- To enable the efficient movement and operation of commercial shipping, water-based transport and maritime industries;
- To promote the equitable use of waterways, including appropriate recreational uses;
- To minimise impacts on ecological values arising from the active use of waterways; and
- To provide for sustainable fishing industries.

The natural, cultural, recreational and economic attributes and public access to and along NSW coastal foreshores is also provided for in the SEPP No 71 – Coastal Protection.

C.6.3 SEPP62. Sustainable Aquaculture Strategy

SEPP No. 62—Sustainable Aquaculture (SEPP 62) encourages sustainable aquaculture in NSW. The aims and objectives of this Policy are:

(a) to encourage sustainable aquaculture, including sustainable oyster aquaculture, in the State, namely, aquaculture development which uses, conserves and enhances the community's resources so that the total quality of life now and in the future can be preserved and enhanced;

(b) to make aquaculture development permissible in certain zones under the Standard Instrument, as identified in the *NSW Land Based Sustainable Aquaculture Strategy* (LBSAS);

(c) to set out the minimum site location and operational requirements for permissible aquaculture development (the minimum performance criteria);

(d) to establish a graduated environmental assessment regime for aquaculture development based on the applicable level of environmental risk associated with site and operational factors (including risks related to climate change, in particular, rising sea levels); and

(e) to apply the Policy to land-based aquaculture development and oyster aquaculture development in the State and to include facility for extension of the Policy to natural water-based aquaculture.

Sustainable Aquaculture Strategies have been developed for both the Land Based aquaculture industry and the NSW Oyster Industry. The Aquaculture Unit of DPI is responsible for working with the industries, the community and other agencies to ensure aquaculture develops in a sustainable manner - both environmentally and economically.

The NSW LBSAS (I&I NSW 2009a) is designed to provide information to investors, government agencies and the community and to ensure that aquaculture enterprises in NSW are established and operated in a sustainable manner. The NSW LBSAS is made up of two interlinked sections – a best management section and an integrated approvals section so that projects can be established and operated to meet sustainability objectives. The best management section provides the basis for the Aquaculture Industry Development Plan (AIDP) for land based aquaculture in NSW under the provisions of the FM Act. The AIDP identifies best management for business planning, species selection, site selection and design, planning and operation of the facility and includes the performance requirements for relevant environmental regulations.

Based on best practice in the AIDP a 'project profile analysis' has been established to provide an up-front preliminary assessment of the likely level of risk to the environment from aquaculture proposals. The project profile analysis provides the basis for streamlining approvals. Low risk proposals will require a statement of environmental effects to analyse potential environmental impact. Only those developments that are identified as high risk in the project profile analysis will require an EIS.

The NSW Oyster Industry Sustainable Aquaculture Strategy (OISAS):

- identifies those areas within NSW estuaries where oyster aquaculture is a suitable and priority outcome;
- secures resource access rights for present and future oyster farmers throughout NSW;
- documents and promotes environmental, social and economic best practice for NSW oyster farming and ensures that the principles of ecological sustainable development, community expectations and the needs of other user groups are integrated into the management and operation of the NSW oyster industry;
- formalises industry's commitment to environmental sustainable practices and a duty of care for the environment in which the industry is located;

- provides a framework for the operation and development of a viable and sustainable NSW oyster aquaculture industry with a clear approval regime and up-front certainty for existing industry participants, new industry entrants, the community and decision makers;
- identifies the key water quality parameters necessary for sustainable oyster aquaculture and establishes a mechanism to maintain and where possible improve the environmental conditions required for sustainable oyster production; and
- ensures that the water quality requirements for oyster growing are considered in the State's land and water management and strategic planning framework.

The sustainable aquaculture strategies recognise the importance of the role of DPI in extension and compliance. In addition to DPI Officers being available to provide current information from research programs and advice on best practice in aquaculture management, they will be in the front line in ensuring best practice is followed.

C.6.4 Commonwealth Legislation

The Department of Agriculture, Fisheries and Forestry (DAFF) do not currently have specific legislation relating to stock enhancement. Commonwealth legislation considered to be most relevant to the proposal is given below:

Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)

The EPBC Act is administered by the Commonwealth Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC) and aims to:

- provide for the protection of the environment, especially those aspects of the environment that are matters of national environmental significance (NES);
- promote ecologically sustainable development through the conservation and ecologically sustainable use of natural resources;
- promote the conservation of biodiversity; and
- provide for the protection and conservation of heritage.
- In the aquatic environment, the Act lists the following matters of NES:
- nationally threatened species, ecological communities, critical habitats and KTPs (including marine species);
- migratory species;
- Ramsar wetlands of national significance; and
- Commonwealth marine areas (this extends from 3 to 200 nautical miles from the coast).

Threatened fauna and flora are listed in any one of the following categories as defined in Section 179 of the EPBC Act as:

- Extinct;
- Extinct in the wild;
- Critically endangered;
- Endangered;
- Vulnerable; or
- Conservation dependent.

Species listed as 'extinct' or 'conservation dependent', are not considered matters of NES (protected matters).

Native Title Act 1993

Native Title is the name Australian law gives to the traditional ownership of land and waters that have always belonged to Aboriginal people according to their traditions, laws and customs. Native Title might continue to exist in areas such as beaches, oceans and other waters that are not privately owned.

Registered native title claimants gain a right to be notified of, and to comment on, certain acts which government proposes doing ('future acts') which may affect land within their claim area.

C.7 Estuaries in NSW

C.7.1 Introduction

Estuaries in NSW vary in their morphology, sizes and geological origins and these factors are largely responsible for determining the distribution and abundance of physical habitats and ecological assemblages. Estuaries represent a 'mixing zone' between completely sheltered freshwaters and the open ocean (Das *et al*. 2000). The forces driving this mixing include tides, wind, waves and river runoff (O' Loughlin *et al*. 1999), although the relative importance of each of these varies according to estuary type and the location within an estuary (Roy *et al*. 2001). Tidal currents are often dominant, depending on entrance condition and bathymetry. Gravitational circulation, caused by density differences between fresh and salt water may also be important in estuaries that are subject to large volumes of river runoff. Wind-driven circulation is most important in large shallow estuaries with small tidal ranges and low freshwater inflows (O' Loughlin *et al*. 1999), although sizeable wind waves (sufficient to cause longshore currents, sediment transport and/or foreshore erosion) may form wherever sufficient fetch is available. Ocean swell may also be factor near an estuary's entrance, particularly during rough sea conditions. Other factors, such as the degree and rate of sedimentation and water quality characterisation of an estuary, are also important influences on the presence and abundance of the major habitat components such as seagrasses, mangroves, saltmarsh and intertidal sand and mudflats.

C.7.2 Main Types of Estuaries

Based on geological criteria and the degree of marine influence, Roy *et al*. (2001) recognised five coastal water body types in eastern Australia: (1) embayment's (2) tide-dominated estuaries (3) wave-dominated estuaries (4) ICOLLs and (5) freshwater bodies. Key features and ecological characteristics of the estuary types are summarised in Table C.7 below.

Table C.7: Key features and ecological characteristics of estuaries.
Source: OzCoasts Database (2009).

1. Embayment's	Key Features	Habitats and Ecology
	▪ Typically marine, with extensive subtidal environments and narrow intertidal zone. ▪ Large entrance and efficient marine flushing. Deep water. ▪ River flow varies, floods are buffered and do not expel marine water due to large water area. ▪ Turbidity and extent of intertidal habitats is dependent on local tidal range. ▪ Sediments are generally not trapped. ▪ Typically floored by coarse sediment. ▪ Nutrient dynamics are generally similar to the coastal ocean. ▪ 'Immature' in terms of evolution: morphology may slowly change over time due to infilling.	Embayments represent transitional environments between true estuarine and marine environmental conditions (in terms of their salinity, water temperature, turbidity, and energy) and therefore contain an abundant and diverse biota. Depending upon energy conditions and climate (latitude), habitats such as saltmarshes, mangroves, intertidal flats, and sandy beach environments fringe the embayment. Swamp areas and freshwater wetlands tend to occur behind the bay prograding sandbars. Clear shallow waters support various seagrasses, rocky shores, and rocky reefs.
2. Tide-Dominated Estuaries	**Key Features**	**Habitats and Ecology**
	▪ A diverse range of marine, brackish, subtidal, intertidal and supratidal estuarine habitats are supported. Turbidity may preclude seagrasses in some areas. ▪ Large entrance promotes efficient marine flushing. ▪ River flow is typically high, however the effects of floods are buffered by large water area and large tidal exchange. ▪ Turbidity is naturally high due to strong turbulence induced by tides. ▪ Adjacent intertidal flats, mangroves, saltmarshes and saltflats tend to trap sediment and pollutants. Marine flushing results in loss of some material to the coastal ocean. ▪ Tidal movement over adjacent environments encourages the trapping and processing (e.g. denitrification) of nutrient loads. Some material is lost to the ocean by	Tide-dominated estuaries contain habitats such as channels, intertidal mudflats, mangroves, saltmarshes, saltflats, rocky shores and rocky reefs. These habitats typically support marine species, including transient visitors and permanent residents. Plant productivity tends to increase with increasing tidal range, due to greater rates of flushing and the consequent renewal of nutrients (Morrisey *et al.* 1995a). Littoral mangrove forests dominate many tide-dominated estuaries in NSW and plains vegetated with grasses, sedges and herbs, as well as freshwater wetlands and floodplain vegetation (such as *Melaleuca* spp.) lie above the influence of most tides (Woodroffe *et al*. 1989). Turbid water within the estuary largely limits the distribution of seagrasses although they may survive further seaward due to lower turbidity.

	marine flushing. ▪ 'Semi-mature' in terms of evolution: infilling by marine and terrigenous sediment will result in expansion of flanking environments, narrowing of channels, and seaward progradation.	
3. Wave-Dominated Estuaries	**Key Features**	**Habitats and Ecology**
	▪ A diverse range of both marine and brackish, subtidal, intertidal and supratidal estuarine habitats are supported. ▪ Narrow entrance restricts marine flushing, only a small proportion of the estuarine water volume is exchanged each tide. ▪ River flow is typically high and flooding may expel marine water and flush material from the estuary. ▪ Turbidity is naturally low except during extreme wind or fluvial runoff events. ▪ Central basin traps sediment and pollutants. ▪ Long residence time encourages trapping and processing (e.g. denitrification) of nitrogen loads. ▪ 'Semi-mature' in terms of evolution: morphology will rapidly change over time due to infilling, resulting in shallowing of the central basin, and expansion of the fluvial delta	Wave-dominated estuaries generally contain true estuarine species and transient visitors from full marine environments. This is because wave-dominated estuaries provide a diverse range of habitats, such as high-energy sandy beaches and channel sands, sheltered deep muddy basins, shallow water habitats, mangroves, saltmarshes, and intertidal flats (Roy *et al.* 2001). Depending upon entrance conditions and latitude, saltmarshes and mangroves can occur around the edges of the central basin and the high-energy conditions of the inlet produce a sandy substrate and relatively clear shallow waters that generally support various seagrasses (Hannan and Williams 1998). Central basin muds often support benthic micro - and macroalgae (Cahoon *et al*. 1999) and various invertebrates. Wave-dominated estuaries that have undergone slow infilling can contain large areas of rocky shore and reef habitats that support a variety of biota (Griffiths 2001b).
4. ICOLLS	**Key Features**	**Habitats and Ecology**
	▪ Intermittent entrance isolates the coastal waterway from the ocean for long periods. ▪ Habitats are limited by chemical conditions induced by poor exchange with the marine environment and highly variable salinity. ▪ River flow is intermittent to non-existent. Flooding is therefore uncommon, however , can cause large impacts such as entrance breaching and scouring of the central basin.	Despite intermittently experiencing significant variations in salinity, coastal lagoons and strandplain-associated coastal creeks are usually colonised by estuarine invertebrates and other 'euryhaline' aquatic organisms i.e. those that can tolerate a wide range of salinities. High mortality of marine species can occur during periods of closure that provides an opportunity for recruitment and development of estuarine and/or low salinity species. Coastal lagoons and associated coastal creeks are important habitats for a diverse assemblage of juvenile (and small-sized) fishes, some of which are economically important (Griffiths 2001b,

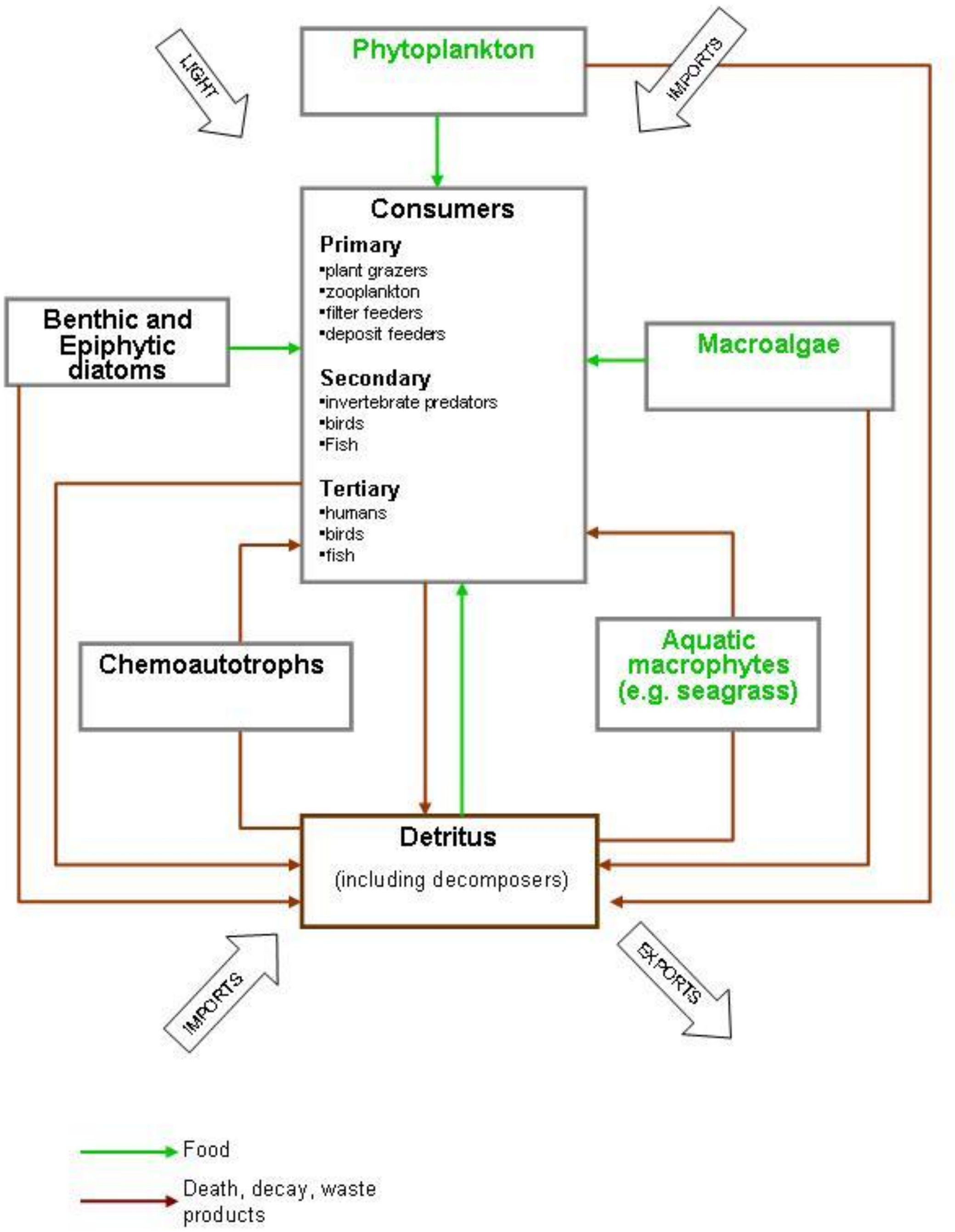
	▪ Turbidity is naturally low, however shallow basins are susceptible to wind-wave resuspension particularly where there is no seagrass. ▪ Central basin (where present) is an efficient 'trap' for sediment and pollutants. ▪ Long residence time encourages trapping and processing (e.g. denitrification) of nutrient loads, however the system may be susceptible to overloading due to small size. ▪ Evolution, in terms of infilling, is very slow due to the lack of significant sediment input.	Hannan and Williams 1998). The duration of water exchange between the ocean and the coastal lagoon is probably the most important factor influencing the recruitment of marine organisms (Potter and Hyndes 1994). Many coastal lagoons and associated coastal creeks support macroalgae, limited seagrass beds, saltmarshes, and floodplain species. Mangroves do not typically occur, due to the lack of connection with the open ocean (Roy *et al*. 2001).

C.7.3 Estuarine Food Webs and Interactions

In order to help determine the effects of stocking on estuarine systems, it is important to understand the existing structure of estuarine food webs and how altering a specific component of the food web (e.g. by stocking) has potential to affect other components of the system. A generalised estuarine food web is shown in Figure C.2.

Estuarine systems are generally highly productive, i.e. they generate a large amount of living plant and animal matter (biomass). Detritus is composed of non-living organic matter (i.e. the remains of dead organisms and aquatic plants) and in the form of products remaining after the bacterial decomposition of dead animals. Both detritus and nutrients can also be imported via freshwater and tidal flows. In this simplified example, primary consumers consist of zooplankton and invertebrates such as polychaete worms, crustaceans and molluscs that eat detritus and grazers that eat aquatic plants and algae. Secondary consumers include invertebrate predators e.g. prawns, crabs, birds and fish. Tertiary consumers generally include larger predatory fish and birds. Some consumers may be both herbivorous and predatory i.e. omnivores (NSW Department of Natural Resources 2010).

Figure C.2: Generalised estuarine food web.
(Source: NSW Department of Natural Resources (2010).



As juveniles, yellowfin bream, mulloway, dusky flathead, whiting and giant mud crabs would be described mainly as secondary consumers as they feed on a variety of invertebrates such as crabs, shrimp, molluscs and polychaete worms. Mulloway are mostly carnivorous with a substantial proportion of their juvenile diet consisting of mysid shrimp and as they become larger, small teleost fish. Larger dusky flathead feed on squid and octopus as well as shrimp crabs and small fish.

The diet of these species can, however, vary both seasonally with prey abundance and ontogenically. For example, polychaetes form a core component of the diet of sand whiting as juveniles and sub-adults with a shift toward molluscs as adults. Some species (i.e. mulloway and dusky flathead) may be both secondary and tertiary consumers, depending on their life stage.

Post-larval and juvenile eastern king prawns are opportunistic omnivores and are mostly primary consumers which feed on epiphytic algae, seagrass (Ochwada *et al.* 2009) and small zooplankton. Larger eastern king prawns are carnivorous feeding primarily on crustaceans, polychaetes and bivalves and can be considered secondary consumers. Blue swimmer crabs are opportunistic bottom-feeding carnivores and scavengers (Kangas 2000) which have been shown to consume a wide range of benthic invertebrates such as amphipod crustaceans, bivalve molluscs and polychaete worms and to a lesser extent, small fish, plant material, dead fish and squid (De Lestang *et al*. 2003a). They would primarily be considered secondary consumers.

Increasing the number of consumers within the system has potential to affect species at other trophic levels through predation and also to affect species at a similar trophic level and wild conspecifics through competition for similar resources (such as food/habitat). Many populations are however, only considered to be subject to such density-dependent interactions (i.e. predation and competition) when the populations become unusually high and/or they approach carrying capacity (Strong 1986).

C.7.4 Habitats and Assemblages

All the species proposed for marine stocking are estuary dependent at some, or all stages of their life cycle and many are explicitly dependent on a particular habitat type at certain life stages. This Section reviews the different types of estuarine habitats. Much of the information in this Section has been taken from the Estuary General Fishery EIS (NSW Fisheries 2001), kindly with permission from DPI.

C.7.4.1 Seagrass

Seagrasses are flowering plants that live and reproduce completely submerged in seawater (King 1981a, West 1989). They are rooted in the sediments, with the leaves appearing above the ground. They produce flowers and seeds, similar to terrestrial grasses (Keough and Jenkins 1995). Six species of true seagrass are found within NSW (West 1989). Strapweed (*Posidonia australis*) has straight broad leaves and grows from just below the water surface to a depth of 35 m, largely dependent upon water clarity (Keough and Jenkins 1995). Their leaves are often up to 60 cm long and 10-15 mm wide. Of eight known species of strapweed from around Australia, only *Posidonia australis* occurs in NSW. There are three species of narrow-leaved seagrasses, commonly called eelgrass, found in NSW. Their leaves are generally only a few millimetres wide and less than 30 cm long. These include *Zostera capricorni*, *Z. muelleri* and *Heterozostera tasmanica*. Eelgrass is found in very shallow water, often on mudflats that are exposed at low tide (Keough and Jenkins 1995). The other true seagrasses are referred to as paddleweeds and in NSW include the species *Halophila ovalis* and *H. decipiens*. They have small, oval-shaped leaves generally less than 5 cm long. Unlike the other seagrasses, these do not form extensive beds, but are generally found on their own in deeper water or mixed in with beds of the other seagrasses (Keough and Jenkins 1995). Although not a true seagrass, sea tassel (*Ruppia maritima*, *R. megacarpa* and *R. polycarpa*) is often considered as such and is included here. Unlike the true seagrasses, sea tassel does not live in seawater, preferring fresh to brackish conditions and is usually pollinated above the water surface (West 1989).

Seagrass is widely recognised as an important habitat for juvenile fish (e.g. SPCC 1981a, Pollard 1984, Bell and Pollard 1989, Connolly 1994), but it serves many more roles than the mere provision of food and habitat for species of economic value. They are also reported to: prevent erosion by restricting water movement and binding sediment (Fonseca *et al*. 1982, Scoffin 1970) form the basis of food webs through high productivity and providing detritus (Borowitzka and Lethebridge 1989, Hillman *et al.* 1989) provide surfaces for colonisation by epiphytes and periphyton (Harlin1975, Pollard and Moriarty 1991) and trap and recycle nutrients (Hemminga *et al.* 1991). Some studies have also reported the importance of detached seagrass supporting abundant fish communities adjacent to the beaches upon which it washes up on, forming accumulations known as wrack (Lenanton *et al.* 1982). In northern Australia, seagrasses form a major component of the diet of dugongs and turtles, but in more temperate environments such as NSW, few animals actually directly consume seagrass (Klumpp *et al*. 1989). Rather, as stated above, its importance to most megafauna is in the provision of food and habitat for the species upon which they feed.

The overall assemblages associated with seagrass beds have been defined into a number of ecological groups (Howard *et al*. 1989). Periphyton consists of microscopic organisms such as bacteria and single-celled plants, which cover the seagrass blades. Epiphytes are multi-celled plants, such as algae, that cover the leaves. Infauna are animals that live in the sediment and rhizomes, including worms, bivalve molluscs (e.g. pipis) and crustaceans (e.g. nippers or yabbies). Mobile epifauna are usually smaller, mobile animals associated with the surface of the sediment, among debris or on the blades, and include gastropod molluscs (e.g. snails) and crustaceans (e.g. crabs and amphipods). Sessile epifauna are animals attached permanently to stems or leaves. Epibenthic fauna are larger, often predatory, mobile animals that are associated loosely with the seagrass bed itself rather than individual leaves, and include crabs, prawns and fishes.

Seagrasses provide an important resource for many species of fish targeted by commercial and recreational fishers, including those species listed for marine stocking (see Section C.8). While fish rarely eat seagrass itself, they do eat attached epiphytes and eat the small invertebrates that live among the seagrass (Bell and Pollard 1989). Many species of fish of economic importance, including marine species, arrive in seagrass beds as small juveniles, including yellowfin bream, tarwhine, snapper (*Pagrus auratus*), luderick (*Girella tricuspidata*), blue groper (*Achoerodus viridis*), silver biddy (*Gerres subfasciatus*) and several leatherjackets (Monacanthidae). Other non-commercial species that are commonly associated with seagrasses include pipefishes (Syngnathidae), gobies (Gobiidae), scorpion fishes (Scorpaenidae) and toadfishes (Tetraodontidae) (Lincoln Smith and Jones 1995). Some species remain in the seagrasses their entire lives, whereas some species move to other habitats, including other species of seagrass, as they grow. Different species of seagrasses are known to support different assemblages of fish and invertebrates (SPCC 1981a; Middleton *et al.*1984) and other studies have also reported that the position of seagrass beds within an estuary is also important. Within the larger estuaries, beds closest to the mouth of the estuary supported a greater abundance and diversity of juveniles than those further upstream (Bell *et al.*1988, Hannan and Williams 1998, McNeill *et al.* 1992).

Almost all estuaries have some cover of seagrass, but four estuaries account for more than 50 % of the total area of seagrass in NSW: Wallis Lake 30 %; Clarence River 15 %; LakeMacquarie10 %; and Tuggerah Lakes 7 %. These and other barrier estuaries contain most of the larger seagrass beds, the exception is Jervis Bay (6 %), which is an open ocean embayment. Those estuaries thought to have little or no seagrass are predominantly very small, intermittently open estuaries. It is not only the distribution that is important, it is also the composition and quality of the seagrass beds. For example, in poorly flushed estuaries such as Tuggerah Lakes, some seagrass has been smothered by algae, whilst in Botany Bay, altered wave regimes have caused sea bed erosion and seagrass loss (West 1989; Keough and Jenkins 1995). In other estuaries, the species composition of seagrass beds has been altered. Eelgrass has replaced strapweed in parts of Botany Bay (Keough and Jenkins 1995), and paddleweed has replaced eelgrass in parts of Lake Macquarie (King 1986). As discussed above, such changes have implications for the types of assemblages that beds, and ultimately estuaries, can support. Seagrasses are protected in NSW and a permit is required from DPI to undertake works or activities that may harm them. Populations of *Posidonia australis* that occur in Port Hacking, Botany Bay, Port Jackson, Pittwater, Brisbane Waters and Lake Macquarie are listed as 'endangered' under Schedule 4 of the FM Act.

C.7.4.2 Mangroves

Mangroves are trees and shrubs that grow in soft sediments in the intertidal zone of estuaries, generally in sheltered areas where silt can accumulate. They usually form dense forests when conditions are optimal, but can exist as small, scattered trees on rocky shores in extremely sheltered areas (Chapman and Underwood 1995). Mangroves usually spread their roots out widely in the upper layers of sediment, as opposed to vertically, in order to maximise exposure to oxygen and to enhance stability in otherwise unstable substrata (Chapman and Underwood 1995). Many mangroves also have aerial roots called pneumatophores, which arise vertically out of the sediment and absorb oxygen and other gases. It is thought that sub-optimal growing conditions, particularly in polluted environments, results in an increase in the numbers of pneumatophores (Hutchings and Saenger 1987). In order to survive in saline environments, mangroves either secrete salt through glands in their leaves, exclude salt via a filtering system or accumulate it in old leaves (Chapman and Underwood 1995). Of over thirty species known in Australia, five have been recorded in NSW (West *et al*. 1985). These include the grey (*Avicennia marina*), river

(*Aegiceras corniculatum*), milky (*Excoecaria agallocha*), spider (*Rhizophora stylosa*) and large-leafed mangrove (*Bruguiera gymnorrhiza*).

Like seagrasses, mangroves have been widely recognised as important ecological communities, and some studies suggest they are the most productive (in terms of organic matter produced per hectare per year) of all estuarine habitats (Larkum 1981). They provide habitat for a variety of fish and invertebrates (e.g. SPCC 1981a & b, Pollard and Hannan 1994, Robertson and Alongi 1995), provide organic materials that form the basis of detrital food chains (West 1985, Robertson and Alongi 1995), provide feeding and roosting habitat for numerous species of birds (Chapman and Underwood 1995), stabilise sediments (West *et al*. 1985, Robertson and Alongi 1995), recycle nutrients (Robertson and Alongi 1995) and act as a filter system between the land and aquatic environment (NSW Fisheries 1999). Many commercially important marine and estuarine species live in mangrove channels as small juveniles including yellowfin bream, luderick, dusky flathead, silverbiddy, sea mullet, flat-tail mullet (*Liza argentea),* prawns (Penaeidae) and giant mud crab (*Scylla serrata*). They also feed and shelter in mangrove channels as adults, as do several non-commercial species (Bell *et al.* 1984). As mangroves are partially drained at low tide, there are few resident fishes of mangroves, rather they are visited during high tide by species from adjacent habitats (Hutchings and Recher 1974, Rooker and Dennis 1991). Residents are likely to include gobies, perchlets and toadfish as well as mud crabs. Mangroves are not as widespread as seagrasses because of their reliance upon more marine conditions. As such, they are rarely recorded from estuaries that are intermittently open to the sea, which comprise about 50 % of all estuaries. Further, three estuaries, Port Stephens (25 %), Hunter River (15 %) and Hawkesbury River (10 %) account for 50 % of the total area of mangroves recorded in NSW. These are all located in the central region of the State, are large in terms of surface area and are permanently open to the sea. Mangroves are protected in NSW and a permit of required from DPI to undertake works or activities that may harm them.

C.7.4.3 Saltmarsh

Saltmarsh refers to a collection of herbaceous plants and low shrubs that can tolerate highly saline soils and at least occasional inundation by seawater (King 1981b, Morrisey 1995b). Generally, they are found on the high shore between average high water of spring and neap tides and consequently often remain covered by water for long periods (Morrisey 1995). They develop on shorelines in estuaries with soft sediments and along sheltered parts of the coast, usually behind sandbars and in bays. As such, they are less common in the relatively steep-sided drowned river valleys and more common in barrier and coastal lagoons. Saltmarshes are relatively flat, with shallow pools separated by mounds that are usually vegetated. The plants that make up saltmarshes belong to a small number of families, most notably the grasses (Poaceae), saltbushes (Chenopodiaceae), rushes(Juncaceae) and sedges (Cyperaceae), and although more than 200 species have been recorded in Australia, most assemblages contain only a few species (Morrisey 1995b). Further, the species are generally divided into distinct zones across the marsh, or up the shore. In NSW, the lower shores are dominated by samphire (*Sarcocornia quinqueflora*), with saltwater couch (*Sporobolus virginicus*) on the slightly higher ground. Rushes (particularly *Juncus kraussii*) are also often prominent, especially near landward margins. Other common species include streaked arrow-grass (*Triglochin striata*), seablite (*Suaeda australis*) and *Samolus repens*.

There has been little work done in Australia on the value of saltmarsh as fish habitat, and extrapolations from studies in the Northern Hemisphere are not possible because they relate to fundamentally different marshes. Not only is the species composition different, but the plants are much taller than their analogues in NSW (Adam *et al*. 1988). Overall, saltmarshes are thought to play a similar water filtration role to that outlined for mangroves (Adam *et al*. 1985). They are also commonly regarded as highly productive (Zann 1996), although specific information on details such as energy pathways, and the export of detritus to adjacent habitats, is very limited and invariably from overseas studies in different types of saltmarsh to those in NSW (Morrisey 1995b, Adam *et al*. 1985).

Due to their perceived high productivity, it is probable that the major role of saltmarshes as far as fish and invertebrates are concerned is in the export of organic material to estuarine and marine environments. Numerous overseas studies have reported the importance of saltmarsh creeks as juvenile fish habitat, but as stated previously these marshes are very different to those in NSW, which do not have major contiguous creeks flowing through them (Adam *et al*. 1985).

Williams *et al*. (1995) studied saltmarsh fish communities as part of a major study of habitat rehabilitation in the lower Hunter River. The most common commercial species were flat-tail mullet and yellowfin bream. Individuals of these two species were mainly juveniles, but also included some adults. The non-commercial species included gobies (Gobiidae), perchlets (Ambassidae) and sprats (*Hyperlophus vittatus*). Morton *et al*. (1987) sampled fish in a tidal inlet to a saltmarsh in southern Moreton Bay, QLD. Nineteen species of fish were recorded, 11 of which were of economic importance. Banded toadfish were the most common species (~ 27 %), followed by flat-tail mullet (~ 25 %) and yellowfin bream (~ 16 %).

Saltmarshes also provide important habitat for birds, crabs, molluscs and insects (Morrisey 1995). Saltmarshes are used by a large variety of migratory and resident birds for feeding, roosting and/or breeding, including egrets, sandpipers, curlews, whimbrels, plovers, dotterels and banded stilts (Morrisey 1995b, Zann 1995, 1996). They also provide habitat for some terrestrial species, such as chats and parrots, and several birds of prey, such as brahminy kites, whistling kites and harriers.

Saltmarsh is widely distributed and occurs within estuaries along the entire NSW coastline. In 1985, the total area occupied by saltmarsh within NSW was approximately 57 km^2 (West *et al*. 1985) and, as with the other estuarine habitats, only a few estuaries account for more than 50 % of the total cover. Port Stephens has the largest area of saltmarsh, 7.7 km^2, and when added to Karuah River (an arm of Port Stephens) with 4.8 km^2, they account for 25 %. Lake Innes/Cathie (12 %), Hunter River (10 %) and Wallis Lake (8 %) also have extensive areas of saltmarsh. Like seagrass and, to an even greater degree, anthropogenic processes have affected many areas of saltmarsh. Those near urban centres are degraded because of weed infestations, dumping, stormwater runoff and damage from off road vehicles (Adam *et al*. 1988, Zann 1995, 1996). Significant losses have occurred as a result of reclamation and drainage and it is suggested that along the Central Coast, more than half of the original saltmarsh area may have been lost (Adam *et al*. 1988, Zann 1995, 1996). In some cases, local destruction or modification of saltmarsh will have occurred where foreshore works, such as floodgates, culverts and levee banks, impede tidal exchange (Williams and Watford 1996). Coastal saltmarsh is listed as an endangered ecological community under Schedule 1 of the TSC Act.

C.7.4.4 Unvegetated Soft Substrata

Unvegetated soft substrata, including shallow mudflats, sandflats and deeper areas/holes, are the most common habitat in estuaries, yet are largely ignored because of their lack of physical structure. Their type and distribution have not been recorded in previous estuarine inventories, rather mapping vegetated areas (West *et al*. 1985, Bell and Edwards 1980) has implied their extent. Such mapping, however, does not discriminate between sandy and muddy areas, which support different assemblages of invertebrates and therefore probably different fishes and birds.

Intertidal soft sediment shores can comprise both sandflats and mudflats, the major difference being the relative proportions of sand, silt, clay and organic matter in the sediment. Sandflats are generally found near the mouths of estuaries, where there are stronger currents and wave action, and sand. Mudflats are located further upstream in more sheltered environments, where silt and clay that has been carried downstream from the upper catchment settles out in response to a reduction in flow and mixing with more saline waters. Mudflats remain saturated during low tide due to their smaller particle size and chemical properties prohibiting the creation of large spaces between particles (Inglis 1995). This also causes minimal flushing with oceanic water, and combined with the decomposition of organic matter, causes all but the top few centimetres of sediment to become deoxygenated (Inglis 1995). As most animals cannot survive anoxic conditions, mudflats are comprised of a distinct set of fauna, which is discussed in detail below.

Most of the studies of assemblages of fish associated with unvegetated sediments have been done in comparison to vegetated habitats such as seagrass (e.g. Gray *et al.* 1998, Connolly 1994, Ferrell and Bell 1991, SPCC 1981a). Such studies generally found that seagrasses supported more diverse and abundant assemblages, but that bare sand was also important for some species, particularly sand whiting, sand mullet (*Myxus elongatus*), silver biddy, snapper, flatheads (Platycephalidae) and flounders (Pleuronectidae), prawns and crabs (SPCC 1981a, Gray *et al*. 1990, Ferrell and Sumpton 1997). Deeper areas may also be important refuge habitat for some species such as mulloway (Taylor *et al*. 2006b). Bare substrata are also important habitat for many species of baitfish, particularly sprats and sardines (Clupeidae), hardyheads (Atherinidae) and anchovies (Engraulidae) (Lincoln Smith and Jones 1995). SPCC (1981a) recorded 102 species from soft bare substrata within Botany Bay and, in relation to other habitats types within the bay, concluded that many species of marine and estuarine fishes inhabit soft bare substrata during at least part of their lifecycle. Whilst not generally recognised as nursery habitat to the same extent as are vegetative habitats such as seagrass, bare substrata, particularly that adjacent to seagrasses, provides further habitat complexity within an estuary and important habitat for the adults of many species.

In addition to fishes, soft substrata are inhabited by a large variety (often hundreds of species) of invertebrates including polychaete worms, crustaceans and molluscs collectively termed benthos (Rainer 1982, Jones *et al.* 1986, Morrisey *et al*. 1992a & b, CSIRO 1994). Depth, salinity, sediment size characteristics and the degree of sediment movement are among the physical factors that determine benthic community composition (Jones and Candy 1981, CSIRO 1994, Zann 1996). Irrespective of specific assemblage composition, benthos can be broadly classified according to their method of feeding (Morrisey 1995a). Suspension-feeders trap suspended organic material, microbes and small animals from the water above the sediment. Deposit-feeders obtain food by swallowing the sediment itself. Browsers move over the surface of the sediment consuming organic matter. Predators often live in tubes or burrows waiting for their prey to pass by, or roam the surface of the sediment in search of prey (e.g. crabs and prawns). Scavengers are the final group and consist largely of gastropod molluscs feeding on decaying animal matter. Any or all benthos can be subsequently eaten by many species of fish (SPCC 1981b). Sand whiting and silver biddy feed on polychaete worms and small crustaceans, whilst yellowfin bream eat worms, molluscs and larger crustaceans.

Bare substrata are no less prone to modification than other habitats. Human impacts are particularly evident in those estuaries supporting major port facilities and/or having extensive industrial/residential development in their catchments; e.g. Newcastle Harbour, Port Jackson and Port Kembla. Large areas within these estuaries have been made deeper and muddier as a result of dredging (e.g. Jones and Candy 1981, Birch *et al*. 1997), and contaminated by nutrients, heavy metals and toxic chemicals (Shotter *et al.* 1995, Birch 1996, Birch *et al.* 1996, 1997). With respect to benthic invertebrates, these impacts are likely to have resulted in reduced diversity (e.g. Jones and Candy 1981) and shifts in community composition (Jones 1997).

As stated previously, bare substrata have not been included in estuarine inventories done in the past in NSW (e.g. Bucher and Saenger 1991, West *et al* 1985, Bell and Edwards 1980). The distribution of the major intertidal shores, however, has been inferred by a mapping program by the EPA (formerly the SPCC). The EPA mapped the distribution of coastal resources that could be affected by oil spills, and used records of occurrence of wading and threatened birds from the NPWS database and waterway maps to map their occurrence within estuaries. Most such areas are found in the lower parts of estuaries where sandflats are utilised and in the upper parts where mudflats dominate.

C.7.4.5 Rocky Shores and Reefs

The other key habitat within estuaries is that of intertidal rocky shores and subtidal rocky reefs, although they are far less common than the other habitats. Rocky shores include both natural reef and man-made habitats such as breakwaters (SPCC 1981a, Pollard 1989). Natural rocky shores are most common in the drowned river valleys such as Port Jackson, Hawkesbury River and Port Hacking (Morrisey 1995a), and artificial rocky shores are common at the mouths of many barrier estuaries, such as Clarence River and Wallis Lake. The areas of rocky shorelines and reefs have not been mapped in previous inventories.

There are no studies of overall distribution or physical or biological composition within NSW estuaries. It is likely that many estuarine reefs, being subject to freshwater influence, are relatively species-poor, providing interim habitat for larger juvenile fish moving between nursery habitats (such as seagrass and mangroves) and habitats used by adults (SPCC 1981b).

Many species of fish and invertebrates depend on rocky reef habitat for some or all of their life (e.g. SPCC 1981b). Species of economic importance include rock blackfish (*Girella elevata*), red morwong (*Cheilodactylus fuscus*), luderick, bream, octopus (*Octopus* spp.), eastern rock lobster (*Jasus verreauxi*) and abalone. Also, many of the protected aquatic species in NSW depend on rocky reef habitat for part, if not most of their life cycle, including grey nurse shark (*Carcharias taurus*), blue devil fish (*Paraplesiops bleekeri*), elegant wrasse (*Anampses elegans*), black and estuarine cod (Serranidae), blue groper, Australian bass and estuary perch (*Macquaria colonorum*) (NSW Fisheries 1999).

Diverse assemblages of brown, red and green macroalgae, along with sponges, ascidians and other sessile invertebrates enhance habitat complexity of rocky shores and reefs and provide many opportunities for specialisation (e.g. Jones and Andrew 1990, Lincoln Smith and Jones 1995). The large macroalgae (such as kelp) that partially cover most rocky reefs enhance overall species diversity by providing patches of shaded habitat favoured by distinct assemblages of organisms (Kennelly 1995). Also, rocky reefs along most of the NSW coast, including those within estuaries, are utilised on a seasonal basis by juveniles of tropical species. These juveniles are swept southward by the East Australian Current each summer and autumn (Kailola *et al.* 1993, Kuiter 1993), but do not usually survive the winter or, if they do, they fail to establish breeding populations (Lincoln Smith and Jones 1995). Rocky reef provides refuge and feeding opportunities for a variety of fish and mobile invertebrates (e.g. SPCC 1981b, Jones and Andrew 1990, Lincoln Smith *et al.* 1992, Lincoln Smith and Jones 1995). Small fish and invertebrates can escape predators by hiding in cracks and crevices and larger fish such as yellowfin bream, sergeant baker (*Aulopus purpurissatus*), wirrah (*Acanthistius ocellatus)* and red rock cod (*Scorpaena cardinalis*), along with octopus and cuttlefish (Sepiidae) appear to use rocky reef as cover from which they can ambush passing prey. Demersal fish such as yellowfin bream often occur on reefs. Pelagic fish including kingfish (*Seriola lalandi*), tailor (*Pomatomus saltatrix*) and Australian salmon (*Arripis trutta*) are also attracted to rocky reef areas by aggregations of small baitfish such as yellowtail (*Trachurus novaezelandiae*). Some fish, such as luderick, herring cale (*Odax cyanomelas*), surgeon fishes (Acanthuridae) and drummers along with abalone and sea urchins (Echinodea) eat drift and/or attached algae associated with rocky reefs (e.g. Jones and Andrew 1990).

C.8 Biology, Ecology and Selection Criteria of Species Selected for Marine Stocking

C.8.1 Yellowfin Bream (*Acanthopagrus australis*)

C.8.1.1 Natural Distribution and Stock Structure

The yellowfin bream, *Acanthopagrus australis* (family: Sparidae) is endemic to Australia and occur from Townsville in Queensland to the Gippsland Lakes in Victoria (Rowling *et al*. 2010). In NSW the species is primarily found in estuaries but may also inhabit waters adjacent to ocean beaches, rocky headlands and inshore reefs. Yellowfin bream can withstand a wide range of salinities and can also occur at the freshwater reaches of coastal rivers (Rowling *et al*. 2010). The genetic stock structure of yellowfin bream is uncertain, although Rowland (1984) reported that in some landlocked coastal lakes and under unusual environmental conditions there are instances where black bream (*A. butcheri*) and yellowfin bream hybridize. In a comprehensive genetic study, Roberts *et al.* (2009) provided evidence for the widespread occurrence of hybridisation between black and yellowfin bream. They sampled 565 adult yellowfin and black bream from 25 estuaries in WA, South Australia (SA), VIC, Tasmania, NSW and southern QLD. Samples were taken in areas where the species co-occurred (VIC to Forster, NSW) and where the species were found in isolation (black bream, WA and SA; yellowfin bream, northern NSW to southern QLD). Of 565 adults sampled, 15 % (83 fish) were hybrids and 70 % of these were found in southern NSW estuaries (e.g. Meroo, Coila and Cuttagee Lakes). The majority of hybrids were found in the area where the two species co-occurred (i.e. in sympatry). Eight microsatellite loci revealed that the hybrids were a complex mixture of F1 generation, later generation hybrids and backcrosses, inferring that the hybrids were fertile and capable of interbreeding freely. A combination of microsatellite and mtDNA evidence suggested that hybrid backcrosses most often, but not exclusively, involved black bream which is an obligate estuarine species. Microsatellite alleles could be used to distinguish between pure-bred yellowfin and black bream. Morphological compared to genetic identification of specimens suggested that it would be impossible to separate pure-bred black bream from hybrids. The morphological similarity of *A. australis* (yellowfin bream) to hybrids was not tested. Yellowfin bream had a higher expected heterozygosity (0.815) than black bream (0.610) and nearly twice as many alleles per locus. Hybridisation with the yellowfin bream may be facilitating gene flow among demographically isolated black bream populations and genetic ‘swamping’ of black bream populations by yellowfin bream genes may be occurring. The mechanisms facilitating hybridisation and the role of anthropogenic influences in hybridisation remain unclear. Roberts (2010) is referred to as evidence for panmixia (random mating within a breeding population) for yellowfin bream throughout its range.

C.8.1.2 Habitat

Yellowfin bream are demersal and adults associate with a variety of substrata including sand, mud, rocky sections of river bed, rocky reef, mangroves, seagrass beds, as well as artificial structures such as oyster leases, pier and bridge pylons and breakwalls. In a comprehensive study of the ecology of fish in Botany Bay where sampling was done in seagrass, mangroves, shallow mud, shallow sand, deep mud, deep sand and hard substratum, small juveniles were found almost exclusively in mangrove and seagrass habitats (SPCC 1981b). This corresponds with the findings of other studies (Munro 1945, Dredge 1976 in SPCC 1981b).

C.8.1.3 Life History

Reproduction (Spawning)

Spawning occurs mainly during winter (Pollock 1982) although there can be considerable variation in spawning season between estuaries and between years. In southern and central NSW, spawning can take place as early as late autumn (SPCC 1981b). Spawning takes place in the vicinity of river entrances; over river bars or in the surf zone. Bream form into shoals of several hundred fish, and during spawning season (winter) the larger fish tend to group in schools of similar sized fish. Eggs are planktonic and hatch after 2.5 days. There are no estimates of fecundity for yellowfin bream although the number of eggs produced are thought to be similar to that of black bream (which can produce between one and three million eggs per season). After one month as planktonic larva, the post-larvae enter estuaries on the flood tide (Pollock *et al*. 1983) and settle out of the plankton when they are approximately 13 mm TL.

Recruitment

Post-larvae and juveniles are thought to recruit to sheltered nursery habitats during winter (Griffiths 2001a, Gillanders and Kingsford 2003) although small juveniles may appear in late Autumn (SPCC 1981b). Much of the preferred habitat of yellowfin bream (such as seagrass) is concentrated within intermittently open estuaries. Consequently, if an estuary is not open to the ocean during the period of spawning and recruitment, age 0+ recruits will be absent from the estuary until the following spawning season and these available habitats may not be effectively utilised. As a result of these life history patterns, recruitment to intermittently open estuaries, and later recruitment to the fishery, can be highly variable or non-existent in some estuaries (Griffiths 2001a).

Growth

Yellowfin bream grow at ~0.04 mm d^{-1} and 0.67 mm d^{-1} during winter and summer respectively (Griffiths 2001a), however growth is highly related water temperature and this will likely vary with latitude. In Tuggerah Lakes, yellowfin bream juveniles reach approximately 130 mm Fork Length (FL) at an age of one year and 230 mm FL by three years of age (Henry 1983), however age 1yr + fish can be as small as 80 mm in some estuaries (Griffiths 2002). Yellowfin bream reach maturity at ~220 mm FL (Rowling *et al.* 2010), at ~3 years for males and ~4 years for females, and are thought to grow to a maximum length and weight of 550 mm FL and 3.7 kg (Rowling *et al.* 2010). Yellowfin bream reach the minimum legal length of 250 mm TL, at approximately 3 years of age.

Feeding

Yellowfin bream consume a diverse range of prey species dominated by molluscs, bivalves and fish, although decapod crustaceans and polychaete worms are also important. Differential estimates between instantaneous (gut content) and integrated (isotopic composition) estimates of dietary contribution (Hadwen *et al*. 2007), suggests that the contribution of these organisms to the diet varies both seasonally and ontogenetically.

Migration

Adult yellowfin bream undertake spawning migrations to the surf zone. All mature male fish undertake the spawning migration, but the proportion of spawning females decreases as they age. Tagging studies confirmed that some fish can migrate considerable distances (up to 90 km), which indicates that inter-estuarine exchange between population is likely (Pollock 1981).

C.8.1.4 Recreational and Commercial Importance

The yellowfin bream fishery extends from Bundaberg in QLD to Bermagui on the south coast of NSW, with the majority of the catch is taken in estuarine waters. Bream are targeted in many estuaries and form a significant component of the catch in the Clarence River, Port Stephens, Lake Macquarie, Tuggerah Lakes and Hawkesbury. Yellowfin bream is classified as fully fished and the commercial fishery is relatively stable in regard to length composition and catch rate data, indicating no declines in older fish (Rowling *et al.* 2010).

Commercial landings of yellowfin bream for the year 2006/07, including from the Ocean Trap and Line, Ocean Hauling and Estuary General Fisheries combined was approximately 360 t (Rowling *et al.* 2010) with the majority of the NSW catch from the Estuary General Fishery. In recent times, catches of bream in this fishery have been steady at about 300 t (Rowling *et al.* 2010).

Bream are a very popular recreational species and the annual catch of bream in NSW total between 820 t – 1070 t (Henry and Lyle 2003). The recreational catch is therefore substantially greater than the commercial catch. There is a combined recreational bag limit of 20 for all bream and tarwhine. A size limit of 25 cm also applies.

C.8.1.5 Existing Aquaculture Technology

Yellowfin bream can be reared by commercial hatcheries in NSW. At the 30 June 2011, there were six aquaculture farms in NSW with permits to culture this species. Yellowfin bream have been bred in NSW aquaculture facilities since 1999/2000 (DPI 2011d), with hatcheries breeding the species as well as other aquaculture facilities growing the species out for the restaurant trade.

C.8.1.6 Stocking Suitability

Yellowfin bream are a popular angling species although they are slower growing than the other selected species. Although no pilot stockings have been conducted in NSW to date with yellowfin bream, in WA black bream (which can hybridise with yellowfin bream) have been involved in several large scale and successful stocking programs. In the early releases of black bream, Noriss (2002) found that most estuaries in southern WA did not contain suitable habitats to support released individuals, however, where appropriate habitat and food were available, stocked black bream could breed and establish self-sustaining populations. The stockings in WA have indicated that released black bream could be more easily caught than wild individuals, and that hatchery releases could contribute to the fishery (Dibden *et al.* 2000). ALC-tagged fish continue to be recaptured in ongoing research in the Blackwood system and the activity has clearly demonstrated significant and long-term benefits to the region (pers. com. G. Jenkins October 2009). The stocking success with this closely related species suggests the potential stocking suitability of yellowfin bream in NSW. The species has been successfully produced in NSW hatcheries since 1999/2000 (DPI 2011d). The potential for hybridisation with black bream is an issue that requires consideration and is discussed in Chapter D, Sections D.4.4.2.1 and D.4.4.2.2 and Chapter G, Section G.2.1.4.1.

Summary of factors affecting selection of yellowfin bream for marine stocking.

Factor	Status
Exploitation Status	Fully Fished
Summary of fishery	Yellowfin bream has a long history of stability of both the length composition (since the 1950s) and commercial catch rate data. The species is the basis of very significant recreational and commercial fisheries in NSW (Rowling *et al.* 2010).
Geographic range	Endemic to Australia and found throughout NSW estuaries and adjacent coastal waters.
Genetic stock structure	Roberts (2010) suggests evidence for panmixia throughout its range, however, further investigation is considered necessary for the purpose of the proposal.
Estuarine residency	Shows some estuarine residency but may leave estuaries to live offshore. Connectivity between estuarine and coastal habitats, and potential natal homing and straying need to be resolved to establish the extent of estuarine residency.
Suitable life history traits	Considered to be relatively slow growing although reaches maturity at a relatively small length (similar to black bream), and has the opportunity to reproduce before recruiting to the fishery.
Demand	Forms the basis of a substantial recreational fishery in NSW, estimated at somewhere between 820 and 1070t (Henry and Lyle 2003).
Available aquaculture technology	There is a history of production of this species in NSW hatcheries and grow out facilities, although no hatcheries in NSW are currently producing this species.
Demonstrated stocking success	No release trials have been conducted to determine stocking success, however a small number of yellowfin bream (<40) have been released in NSW in the past. Stockings of the closely related black bream in WA have proven successful, indicating yellowfin bream as a good potential candidate for NSW stocking programs.

C.8.2 Mulloway (*Argyrosomus japonicus*)

C.8.2.1 Natural Distribution and Stock Structure

Mulloway, *Argyrosomus japonicus* (family: Sciaenidae), occurs in subtropical to temperate regions of the Atlantic, Indian and Pacific Oceans surrounding Australia, Africa, India, Pakistan, China, Korea and Japan. In Australia, mulloway are distributed along the eastern, southern and western coasts from the Burnett River in QLD to the North West Cape in WA (Rowling *et al* 2010, Kailola *et al*. 1993).

A detailed study of the genetic population structure of mulloway was carried out using mtDNA and fifteen microsatellite loci (Archangi *et al.* 2009). The study presents clear evidence of widespread gene flow within Australia, but there are areas of doubt about the fine-scale genetic structure of the species in NSW. Samples were taken from 12 locations along the NSW coastline, from one location in SA and one location in WA. Mulloway from South Africa were used to provide contrast to the Australian data. Nine mtDNA haplotypes were found among the Australian samples based on 424 base pairs of the ATPase gene region. Statistical tests of mtDNA haplotype homogeneity among the 12 NSW locations were compromised by low numbers of samples; for example, four locations were represented by one sample and other locations were represented by five samples or less. There was no significant genetic (mtDNA) difference between habitats (i.e. estuarine or marine) or latitude (i.e. south, central and north coast) of the NSW collection sites. This may be due to the observed haplotype frequencies reported among NSW locations. For example, haplotype #1 is the most common haplotype in the Georges River (i.e. 67 %), while haplotype #2 is the most common in the Shoalhaven River (i.e. 67 %). Neither of these haplotypes was found in the Hunter River, where there were three alternative haplotypes (i.e. #3, #8 and #9). Small sample sizes may also have influenced the analysis of NSW population structure using microsatellite loci. Ninety fish were analysed from Eastern Australia and compared to 30 fish from SA and 40 fish from WA. At this large spatial scale (i.e. across Australia), microsatellite allele frequencies were not partitioned, although the overall F_{ST} (a measure of genetic structure between populations) was not presented. Overall F_{ST} was not presented for the NSW locations that had adequate sample sizes. The pairwise F_{ST}'s that were presented for NSW locations are preliminary evidence for a low level of genetic stock structure, which appears to correspond with minimal stock structure Australia-wide. The low statistical power and preliminary evidence of mtDNA haplotype variation between NSW rivers in the study by Archangi (2008) needs to be clarified so that a definitive statement on mulloway stock structure can be made.

The results of Archangi (2008) contrast to those of Black and Dixon (1992), where they provided preliminary evidence from allozyme loci that the WA population was genetically distinct to southern and eastern Australia. However, their study was also compromised by low sample sizes.

Mulloway were the subject of pilot stock enhancement studies on the mid-north coast of NSW (Taylor and Suthers 2008).

C.8.2.2 Habitat

Mulloway inhabit estuaries and coastal marine waters. Their distribution within estuaries is linked to salinity, turbidity, freshwater influxes and depth, which may vary amongst regions (Silberschneider and Gray 2008). Juveniles (including early post-settlement stages) recruit to deeper waters in estuaries, where they remain until reaching 50 cm (TL). Fish larger than 500 mm also use deep holes in estuaries, but expand their range to shallower waters for foraging (Taylor *et al*. 2006b). Larger individuals are distributed across deep holes, breakwalls, pylons, and rocky reefs in estuarine and nearshore coastal areas, as well as the surf zone.

C.8.2.3 Life History

Reproduction (Spawning)

Silberschneider and Gray (2008) suggest spawning is most likely to take place within nearshore coastal waters or in the lower reaches of estuaries. The timing of spawning is likely to be linked to hydrographic conditions, and lagged relationships between CPUE and large freshwater inflows into estuaries provide evidence for a relationship between seasonal freshwater pulses and spawning or recruitment events (Ferguson *et al.* 2008). Eggs are pelagic and have been collected in estuarine and coastal waters off south-eastern Australia between January and April (Smith 2003). Larvae settle out of the plankton onto deep bare substrates within estuaries (Neira *et al.* 1998).

Recruitment

Juveniles <150 mm (TL) predominantly recruit to the upper regions of estuaries where salinities are relatively low (Gray and McDonall 1993). This is known to occur in April and June (SPCC 1981b). Turbid conditions and estuaries with high freshwater flows are preferable in juveniles, and as described above, freshwater flows may promote recruitment of larvae and juveniles to estuaries (Ferguson *et al.* 2008) by providing hydrographic stimuli by which pelagic larvae can locate estuaries. In NSW juveniles appear to be more prevalent in deeper riverine type estuaries compared to shallow barrier type estuaries (Silberschneider and Gray 2008).

Growth

Studies in South Africa (Griffiths and Hecht 1995) and Australia (Silberschneider and Gray 2005) have found that mulloway grows to 350 mm (TL) in 1 year and up to 900 mm (TL) in 5 years. In eastern Australia, mulloway grow as fast as 1 mm d^{-1} and can recruit to the fishery within 18 months (Taylor *et al*. 2009). Sexual maturity is attained at >550 mm (TL) in males or >680 mm (TL) in females. In WA sexual maturity is not attained until 5-6 years age and >800 mm (TL) (Silberschneider and Gray 2008). The maximum reported length and age for mulloway is 1810 mm (TL) and 42 years respectively for a fish caught in South African waters. Anecdotal reports suggest that in Australia the largest mulloway captured was a male of 1680 mm (TL), aged 23 years (M. Taylor, pers. comm). Based on growth curves (Silberschneider and Gray 2005), mulloway reach the NSW minimum legal length of 450 mm (TL), at approximately 2 years of age.

Feeding

Mulloway are benthic carnivores, but may also feed throughout the water column (Kailola *et al*. 1993). Taylor *et al.* (2006a) describes spatial and ontogenetic variation in the diet of mulloway, with the main sources of food, crustaceans (mainly mysid shrimp) and small teleost fish. Fish <200 mm TL feed primarily on shrimp, before shifting to prawns (200-450 mm TL), and then to fish (>450 mm TL). Generally, the species can adapt to new environments as the proportion of prey in the diet generally shifts according to the proportion of prey in the environment (Taylor *et al.* 2006a).

Migration

Silberschneider and Gray (2008) provide a synopsis of tagging studies investigating the movement patterns in mulloway. Data show that while some fish (predominantly juveniles) remain relatively sedentary, others move significant distances (up to 400 km) along the coastline and between estuaries. However, given that high percentages of tagged individuals were recaptured within the estuaries from which they were released, there is considered to be a high degree of estuarine residency. This was confirmed by monitoring the movements of acoustically tagged individuals, which provide a remarkable degree (80 %) of estuary and site fidelity (Taylor *et al*. 2006b).

C.8.2.4 Recreational and Commercial Importance

Mulloway are highly prized by recreational anglers and important in commercial fisheries due to their large size and good eating. Commercial landings in NSW increased sharply to a peak of 380 t in 1973/74, but have steadily declined to 60 t in 2005/6 (Silberschneider and Gray 2008). The majority of commercial catches are taken from estuaries rather than ocean waters. The recreational harvest of mulloway in NSW is estimated to lie between 100 t and 500 t per annum, based on the results of the National Recreational Fishing Survey (Henry and Lyle 2003) and onsite surveys undertaken by DPI (Rowling *et al.* 2010).

Stock assessment analyses indicate that mulloway in NSW are overfished. Research results suggest that the spawning stock of mulloway in south-eastern Australia has been greatly depleted and that remedial management action is required to protect the species (Silberschneider *et al.* 2008).

The minimum legal length for capture of mulloway in NSW is 450 mm (TL) and there is a recreational bag limit of five individuals with only two greater than 700 mm (TL). As this is much smaller than the size of sexual maturity for females this is likely to contribute to overfishing and that the stock is significantly growth overfished as the optimum length at first capture is in the range 80-100 cm (Rowling *et al.* 2010). A size limit of 700 mm would increase yield and egg production, allowing spawning to occur at least once (Rowling *et al.* 2010).

A species recovery program is currently being developed for the species (Rowling *et al.* 2010). The decrease in catch has been attributed to habitat degradation, overfishing, and incidental capture (bycatch) in estuarine and coastal prawn trawlers (Taylor *et al*. 2005a, Silberschneider *et al.* 2008).

C.8.2.5 Existing Aquaculture Technology

DPI has been assessing the potential for the hatchery production of mulloway since 1990 (Fielder *et al.* 1999). Mulloway larvae were reared for the first time in 1993 using intensive hatchery techniques, however, this technique is labour intensive and expensive, and it is difficult to produce numbers sufficient for large-scale stock enhancement. An alternative ‘extensive’ larval rearing method using large ponds was subsequently developed, which requires a relatively low input of labour from skilled pond managers and relies on propagation of natural zooplankton following addition of fertilisers to the ponds. In NSW, there are a total of 10 aquaculture farms with permits to produce mulloway, which is one of the main marine species that is bred for intensive aquaculture purposes at three of these aquaculture farms (NSW DPI 2009a).

The potential for mulloway aquaculture is supported by the extensive research and development of other Sciaenidae internationally, such as red drum (*Sciaenops ocellatus*) in the USA. Red drum is very similar to mulloway in its life history and breeding requirements and the larval rearing requirements are similar in the two species.

C.8.2.6 Stocking Suitability

Mulloway has been identified as a plausible candidate for stocking in Australia (Taylor *et al*. 2006). Trial studies in NSW (Fielder *et al.* 1999) and large-scale stock enhancement programs for similar species in the US (McEachron *et al.* 1995) have also been undertaken. The species is also classified as overfished in NSW (Rowling *et al*. 2010) and is popular with recreational fishers (Henry and Lyle 2003). Mulloway is also a good candidate for aquaculture due to high fecundity, fast growth and tolerance of a wide range of salinity and temperature (Fielder and Heasman 2011).

Mulloway release trials have yielded variable results in NSW estuaries (Taylor *et al*. 2009). Fish stocked in certain regions experience high growth and good retention within the estuary and release trials have identified the best conditions and habitats under which releases should occur. Quantitative evaluation of mulloway releases are confounded due to the difficulty in catching juveniles of the species, the effort required for robust fishery independent sampling (Gray *et al*. 2005) and the requirements for quantitative analysis of catch data obtained from recreational fisheries (Pollock *et al*. 1994). Data collection is ongoing and preliminary (unpublished) genetic analysis indicates that pilot releases of mulloway prior to 2007 may have contributed 2-12 % of the recreational catch in the Georges River Sydney. The final outcomes of this study will be available after monitoring concludes in early 2012.

Summary of factors affecting the selection of mulloway for marine stocking.

Factor	Status
Exploitation Status	Overfished
Summary of fishery	The age composition of the fishery in NSW is strongly indicative of an overfished stock and the spawning potential ratio is below the recommended threshold (Rowling *et al* 2010).
Geographic range	In Australia, mulloway are distributed along the eastern, southern and western seaboards from the Burnett River in Queensland to the North West Cape in Western Australia (Rowling *et al* 2010).
Genetic stock structure	The pairwise F_{ST}'s that were presented for NSW locations are preliminary evidence for a low level of genetic stock structure, which appears to correspond with minimal stock structure Australia-wide. The low statistical power and preliminary evidence of

Factor	Status
	mtDNA haplotype variation between NSW rivers in the study by Archangi (2008) needs to be clarified so that a definitive statement on mulloway stock structure can be made.
Estuarine residency	Show strong estuarine residency as juveniles but some individuals move offshore or to other estuaries.
Suitable life history traits	The species is fast growing. Mulloway is an estuarine resident until maturity and is thus likely to reside in the estuary prior to and after recruitment to the fishery.
Demand	A heavily targeted recreational sportfish, as well as a substantial commercial target in estuaries and coastal areas. The annual recreational harvest of mulloway in NSW is likely to lie between 100 and 500 t (Henry and Lyle 2003).
Available aquaculture technology	Mulloway fingerlings have been successfully reared in aquaculture facilities in NSW and Queensland and have potential for production on a relatively large-scale. It appears the species has not been cultured elsewhere within its range in Africa and the north western Pacific.
Demonstrated stocking success	Fielder *et al.* (1999) and Taylor *et al*. (unpublished data), have shown that stocking of mulloway can be successful in NSW estuaries and a similar species from the family scienidae (Red drum) has been successfully stocked on a large scale in the United States.

C.8.3 **Dusky Flathead (*Platycephalus fuscus*)**

C.8.3.1 Natural Distribution and Stock Structure

The dusky flathead, *Platycephalus fuscus* (family: Platycephalidae) is endemic to Australia occurring from Cairns in Queensland to South Australia (Rowling *et al*. 2010) and inhabits estuaries and nearshore coastal waters. It is one of 41 flathead species in Australia. There are 14 species in the genus *Platycephalus* and 11 are endemic (Keenan 1991). Currently, the genetic stock structure of the species is unknown. Although some spawning is reported to occur offshore, a significant amount of spawning occurs within estuaries suggesting that some component of the population may be endemic to separate estuaries. In the absence of more detailed information on life history stages, such as their habitat requirements and potential for dispersal (e. g. swimming capacity) and tagging studies that may reveal the degree of adult movement among estuaries, it would be premature to conclude a single stock on the coast of NSW.

C.8.3.2 Habitat

Dusky flathead can remain within an estuary throughout their life cycle but can also be found in sandy bays and inlets to a depth of 30 m (in southern NSW). The species is demersal and adults are often associated with soft substratum, including muds, sand and seagrass beds (Rowling *et al.* 2010). In a comprehensive study of the ecology of fish in Botany Bay where sampling was done in seagrass, mangroves, shallow mud, shallow sand, deep mud, deep sand and hard substratum, small juveniles were found principally in mangrove, nearby shallow mud and seagrass habitats (SPCC 1981b). Dredge (1976 in SPCC 1981b) also found juveniles in mangrove fringed areas of estuaries. As juveniles were rarely recorded in the Botany Bay study in other soft sediment habitats beside the shallow mud near mangroves, it is assumed that soft sediment generally is not a key habitat for small juveniles of this species.

C.8.3.3 Life History

Reproduction (Spawning)

Dusky flathead are reported to spawn between October and March in southern QLD/northern NSW (Gray *et al*. 2002). *S*pawning is generally thought to occur in the lower reaches of estuaries and in coastal waters near river mouths. Eggs and larvae are dispersed along the coast by tidal and current movements and are present in the coastal waters of central NSW during September and May (Gray and Miskiewicz 2000). Larvae enter estuaries and settle into juvenile habitats, which substantially overlap with adult habitats.

Recruitment

Small juveniles <120 mm, first appear in coastal bays one to two months after spawning (i.e. in April) but are present all winter (SPCC 1981b).

Growth

Barnes and Gray (2008) sampled dusky flathead from various locations throughout NSW between 2001 and 2006 to investigate aspects of the species biology to assist in fisheries management. The length of maturity for 50 % of the population (L_{50}) was estimated to be 320 mm for males and 570 mm for females. The corresponding age at which 50 % of the population is reproductively mature (A_{50}) was 1.2 years for males and 4.6 years for females. The largest observed female was 980 mm TL (7.5 kg) and the oldest was estimated to be 16 years old. The largest male was 615 mm (TL) and 11 years of age. Females were also found to grow faster than the males. The minimum legal length is 360 mm and there is a recreational bag limit of 10 individuals with one fish exceeding 700 mm. Based on growth curves (Gray and Barnes 2007) dusky flathead reach the minimum legal length of 360 mm (TL), at approximately 1 year of age for females and 1.5 years for males.

Feeding

The dusky flathead is a cryptic ambush predator that generally lies partially buried in the substratum and waits for passing prey such as caridean shrimp, crabs, small fish, polychaetes, squid and octopus (Platell *et al*. 2006, Hadwen *et al.* 2007).

C.8.3.4 Recreational and Commercial Importance

Dusky flathead are NSW most heavily targeted recreational species (Henry and Lyle 2003), and are highly prized throughout their geographic range in Australia. Commercial catch of the dusky flathead in NSW is mainly taken by the Estuary General Fishery (Rowling *et al.* 2010). Reported commercial landings for the year 2007/08 were approximately 187 t and 123t in 2008/09. The recreational catch greatly exceeds the commercial catch, with up to 886 t harvested by anglers, in 2000/2001 (Henry and Lyle 2003).

Due to concerns over the long-term stability of dusky flathead populations, the minimum legal length was increased from 330 mm to 360 mm in 2001. Barnes and Gray (2008) consider that further information concerning the biology of the species is required prior to any further catch restrictions. The stock status is currently considered to be fully fished and commercial catch rates have remained relatively steady over the past 10 years.

C.8.3.5 Existing Aquaculture Technology

Dusky flathead fingerlings can be reared *en masse* (approximately 250,000) using extensive aquaculture technique. They have been successfully cultured at the Bribie Island Aquaculture Research Centre, (QLD) with a 95 % success rate (Burke 2000) and in NSW by commercial hatcheries.

At 30 June 2011, there were 4 aquaculture farms in NSW with permits to culture this species.

C.8.3.6 Stocking Suitability

As this species has been successfully cultured in Australia on a large scale and is a popular recreational species it is potentially a good candidate for stock enhancement. A stock enhancement program using dusky flathead and sand whiting was carried out in the Maroochy Estuary (QLD) between 1995 and 1999 by QLD DPI&F. Approximately 335,000 sand whiting and 100,000 dusky flathead (40 - 50 mm long) were released over a three year period (Butcher *et al*. 2000) making it the largest marine stocking program so far undertaken in Australia (Taylor *et al.* 2005b, Butcher *et al*. 2003). Butcher *et al.* (2000) reported that flathead fingerlings survived well after release and that hatchery reared flathead comprised approximately 47 % and 28 % of recreational and commercial catch samples respectively, post-stocking. Whether the stocking events actually contributed to the total population of flathead, was not, however, able to be determined.

Summary of factors affecting selection of dusky flathead for marine stocking.

Factor	Status
Exploitation Status	Fully Fished
Summary of fishery	Commercial catch landings and catch rates are steady in NSW, but the species is primarily harvested by recreational fishers (Rowling *et al*. 2010).
Geographic range	Is endemic to Australia and occurs from Cairns in Queensland to South Australia (Rowling *et al*. 2010).
Genetic stock structure	It is uncertain whether the species forms a single east coast population.
Estuarine residency	Likely to be an estuarine resident, although some spawning adults may move offshore. Research currently being undertaken by UNSW and DPI is aimed at identifying the extent of inter-estuarine and along shore migrations.
Suitable life history traits	Fast-growing to a harvestable size.
Demand	Very popular estuarine recreational species in NSW. The annual recreational harvest of dusky flathead in NSW is likely to lie between 570 t and 830t (Henry and Lyle 2003).
Available aquaculture technology	Successfully cultured on a large scale in QLD (Butcher *et al*. 2000). There are licensed facilities in NSW to breed this species.
Demonstrated stocking success	Stocking in the Maroochy Estuary, QLD shows positive results (Butcher *et al*. 2000).

C.8.4 **Sand Whiting (*Sillago ciliata*)**

C.8.4.1 Natural Distribution and Stock Structure

The geographic range of sand whiting, *Sillago ciliata* (family: Sillaginidae) occurs along the entire eastern coastline of Australia, from Cape York in Queensland to Victoria and eastern Tasmania (Rowling *et al*. 2010). The species also occurs in the waters of Lord Howe Island, New Caledonia, Woodlark Islands and Papua New Guinea (McKay 1992).

There have been no genetic analyses of the population structure of this species, however, Dixon *et al.* (1987) analysed the population structure of a species (*S. flindersi*, was *S. bassensis flindersi*) that also occurs on the coast of NSW. Samples of *S. flindersi* were collected from 17 locations in NSW. Sampling was repeated over time at six of these locations. Sample sizes varied, but the majority consisted of around 100 fish per location, with some less (around ten fish) and some more (up to 200 fish). Allele frequency variation was determined at seven polymorphic allozyme loci using starch gel electrophoresis. Loci had between three and six alleles. There was no evidence for clinal variation in genetic variation along the coastline, but there was evidence of a genetic discontinuity between populations to the north of Coffs Harbour compared to populations to the south of Forster following pairwise genetic comparisons between all collection locations. In some pairwise comparisons, geographic distance compared to genetic difference was not concordant and this was attributed to patchy recruitment of larvae. Population-level processes that may operate to restrict gene flow in an offshore species such as *S. flindersi* would presumably be substantial enough to also restrict gene flow in the onshore species *S. ciliata*.

C.8.4.2 Habitat

Sand whiting are an inshore and nearshore fish species and are found off coastal islands and on coastal beaches and sandbars, in coastal lakes, estuaries, tidal rivers and open bays. Sand whiting enter estuaries and move far upstream to the tidal limits of rivers and creeks where juveniles and adolescent fish may be abundant (McKay 1992). The species is most abundant in southern QLD and northern NSW, where they can be found in shallow water with sandy substrata, especially adjacent to surf beaches and sand flats within sheltered estuaries. Burchmore *et al.* (1988) found that juveniles sampled within Botany Bay were most abundant within shallow beds of patchy seagrass (*Zostera* sp.) which provide important nursery and feeding habitat for the species whereas adults were more abundant in shallow sandy habitats (Burchmore *et al.* 1988). In contrast, on the far north coast, Gray *et al*. (1998) found small sand whiting predominantly over bare sand. In another study of the ecology of fish in Botany Bay where sampling was done in seagrass, mangroves, shallow mud, shallow sand, deep mud, deep sand and hard substratum, small juveniles were found principally in seagrass, mangrove and sandy habitats (SPCC 1981b). Dredge (1976 in SPCC 1981b) also found smaller juveniles in shallow, partially vegetated areas of estuaries.

C.8.4.3 Life History

Reproduction (Spawning)

*S*pawning is generally thought to occur in the lower reaches of estuaries and in coastal waters near river mouths, during summer. Initiation of spawning is likely to be temperature related as the spawning events takes place earlier in warmer waters (e.g. QLD). The presence of two size classes of eggs within ovaries of sand whiting suggests the species spawns twice a year. This is consistent with results of a study by Smith and Sinerchia (2004) who found two recruitment and spawning pulses of sand whiting in Botany Bay.

Recruitment

Smith and Sinerchia (2004) investigated recruitment patterns of sand whiting in Botany Bay (NSW) using trends in length frequency distributions of juveniles. Timing of recruitment events were found to closely reflect the timing of spawning events whereas recruitment in other species inhabiting the bay were more closely related to lunar or tidal cycles. Small juveniles in Botany Bay are most abundant from April to October (SPCC 1981b).

Growth

Sand whiting grow relatively quickly, taking around 2 years to reach 250 mm (FL) after which growth slows (Rowling *et al.* 2010). Burchmore *et al*. (1988) found that maturity of sand whiting sampled in Botany Bay is reached at approximately 240 mm in both males and females. Maximum length is considered to be approximately 500 mm (Rowling *et al.* 2010). Sand whiting reach the minimum legal length of 270 mm (TL), at approximately 2 years and five months of age.

Feeding

Juvenile sand whiting feed mainly on macrofaunal decapods and polychaetes (Kruck *et al*. 2009). Whilst polychaete worms remain the core dietary component of larger and sub-adult individuals, predation switches from decapod crustaceans to bivalves and molluscs (Hadwen *et al.* 2007).

C.8.4.4 Recreational and Commercial Importance

Sand whiting are a primary target of the Estuary General Fishery, with landings between 100 – 160 t year. Smaller numbers of sand whiting (between 5 t and 50 t) are also landed by the Ocean Trawl and Ocean Hauling Fishery (for which they are a target species). In NSW, sand whiting are a popular recreational species with the annual recreational harvest estimated to be between 230 – 460 t (Henry and Lyle 2003), which is substantially more than commercial landings. Catch landings have remained relatively stable over the past 10 years (Rowling *et al.* 2010) and the species is considered to be fully fished in NSW.

C.8.4.5 Existing Aquaculture Technology

Sand whiting have been successfully reared and commercially bred in aquaculture facilities in NSW and QLD. In QLD, the Department of Primary Industries and Fisheries (QLD DPI&F) started work towards fingerling production for the Maroochy estuary fish-stocking program in 1994. Sand whiting was one of the target species as it appeared to have several desirable traits for aquaculture production. QLD DPI&F found that large numbers of eggs (300,000 to 600,000) could be produced and larvae were resilient and survived well (Butcher *et al*. 2000). Approximately two million fingerlings have been successfully reared in outdoor ponds with almost no incidence of disease which is often a problem in intensive aquaculture (Burke 2000). In NSW there are five aquaculture farms currently holding permits to culture this species (NSW DPI 2009b).

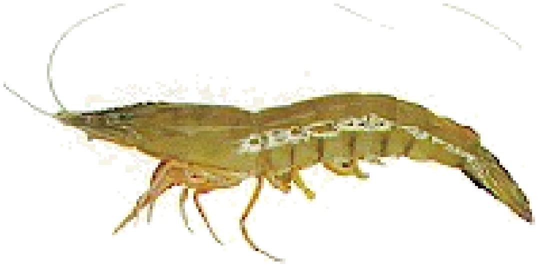
C.8.4.6 Stocking Suitability

Given that sand whiting are a popular recreational species, are restricted to estuarine and coastal near-shore environments and have potential for culture in large numbers, they are considered to be a good candidate for stock enhancement. Approximately 335,000 sand whiting and 100,000 dusky flathead (40 - 50 mm long) were released over a three year period as part of the Maroochy Estuary stocking program (QLD) (Butcher *et al*. 2000) making it the largest marine stocking program so far undertaken in Australia (Taylor *et al.* 2005b, Butcher *et al*. 2003). Butcher (2000) reported that sand whiting fingerlings survived and that hatchery reared whiting comprised approximately 44 % and 52 % of recreational and commercial catch respectively, post-stocking. Scale-circuli analyses were developed to assess the origin of recaptured fish as Oxytetracycline (OTC) marking trials were unsuccessful (Butcher *et al* 2000b). As for the dusky flathead, it was not determined whether the stocking events contributed to the total sand whiting population, the results may have been confounded by a large fish kill in the Maroochy estuary experienced during the project (Butcher *et al*. 2000b).

Summary of factors affecting selection of sand whiting for marine stocking.

Factor	Status
Exploitation Status	Fully fished
Summary of fishery	Sand whiting are targeted by recreational anglers and commercial fishers throughout their range. Commercial landings and catch rates are stable. The size composition of the commercial catch has been relatively stable since the 1960s.
Geographic range	Occurs along the entire eastern coastline of Australia, from Cape York in Queensland to Victoria and eastern Tasmania (Rowling *et al* 2010). The species also occurs in the waters of Lord Howe Island, New Caledonia, Woodlark Islands and Papua New Guinea (McKay 1992).
Genetic stock structure	Some offshore spawning indicates it is possible that only a single stock exists in NSW however, it is uncertain. Data from another species within the same genus suggests population sub-structure within NSW.
Estuarine residency	Likely to be an estuarine resident, with spawning migrations to coastal waters and lower reaches of estuaries.
Suitable life history traits	Fast-growing to a harvestable size.
Demand	Popular estuarine recreational species in NSW. The annual recreational harvest of sand whiting is likely to lie between 230 t and 460t (Henry and Lyle 2003).
Available aquaculture technology	Successfully cultured in NSW and on a large scale in QLD (Butcher *et al*. 2000).
Demonstrated stocking success	Stocking in the Maroochy Estuary, QLD shows positive results (Butcher *et al*. 2000).

C.8.5 Eastern King Prawn (*Melicertus plebejus*)



C.8.5.1 Natural Distribution and Stock Structure

The eastern king prawn, *Melicertus plebejus* (family: Penaeidae) is endemic to the waters off eastern Australia having been recorded from Mackay in Queensland southwards to north-east Tasmania in depths from 1m to 200m (Rowling *et al*. 2010, Montgomery *et al*. 2007). They can also be found off Lord Howe Island and are considered to be the most widely distributed of prawn species found along the east coast. Tagging studies carried out by Montgomery (1990) indicated movement of adults and juveniles towards northern NSW and southern QLD, where spawning is thought to occur. The size-structure of the commercial catch supports the hypothesis that prawns do not complete their migration until they reach northern areas (Montgomery *et al*. 2007). Whereas a large proportion of females in northern oceanic waters are capable of spawning, only a small proportion of females on the mid-north coast of NSW are capable of spawning and even less, if any, capable of spawning on the far south coast of NSW. Mulley and Latter (1981) concluded that eastern king prawns constitute a single genetically distinct stock across their geographic range. Prawns were sampled from eleven locations along the eastern seaboard from Mooloolaba (southern QLD) to Lakes Entrance (VIC) and allele frequencies were estimated at two polymorphic allozyme loci (*Mpi* and *Est-3*) in approximately 100 individuals per location. Allele frequencies were not significantly different across locations (Mulley and Latter 1981), however, the use of two allozyme loci is considered inadequate to conclude that there is no population structure. Current best practice studies involve the investigation of many allozyme loci.

Rothlisburg *et al.* (2005) proposed the hypothesis that nearshore spawners would contribute greatly to local estuarine recruitment because of tidally sensitive behaviour in the larvae that allows them to be trapped nearshore and hence be more easily swept into estuaries. Rothlisburg *et al*. (2005) suggests this behaviour is more likely to occur in shallow water where prawns can sense a pressure change associated with tidal height. Based on this assumption, prawns that spawn nearshore on the NSW coast would contribute more to recruits in local estuaries than prawns that spawn further away and offshore. This could potentially lead to separate stocks of prawns existing in some northern estuaries if prawns leaving an estuary were to spawn nearby. Given that juvenile prawns moving out of an estuary are immature and generally migrate away from their source estuary before they reach maturity it is more likely that nearshore spawners are not from the local estuary but rather were on migration to south-east QLD.

C.8.5.2 Habitat

Eastern king prawns can occur at depths up to 200 m. Post-larval to juvenile king prawns inhabit bare and vegetated substrates within estuaries, protected coastal embayments and ICOLLs, with a preference for vegetated substrates (Ochwada *et al*. 2009). Sub-adults are present in those waterways, however, usually move to offshore waters. The closure of ICOLLs prevents access to offshore waters, making it common for sub-adult prawns to become trapped within coastal lagoons.

C.8.5.3 Life History

Reproduction (Spawning)

Spawning occurs offshore and there is evidence to suggest that this happens throughout the year (Courtney 1997). Montgomery *et al*. (2007) found that females capable of spawning were found along the east coast, however reproductive potential was greatest north of Ballina and was greatest in autumn. Females can produce up to 200,000 eggs which are planktonic and hatch into nauplius larvae within two to three weeks. The nauplius larvae then develop into post-larvae through a series of moults (Rowling *et al.* 2010). Post larval to adolescent eastern king prawns inhabit bare and vegetated substrata in areas of marine influence within estuaries and probably within shallow embayments in ocean waters. They emigrate from estuaries over spring and summer and then move northwards over long distances prior to spawning (Rowling *et al*. 2010) Sexual maturity is reached within several months of leaving the estuary.

Recruitment

Spawning and recruitment can occur throughout the year, but post-larvae are in greatest abundance in estuaries between February and October (Coles and Greenwood 1983). Montgomery (1990) hypothesised that eastern king prawn larvae are transported from northern NSW and QLD, southwards and carried into these estuaries via the East Australia Current (EAC). This is supported by the fact that tagging studies have shown movement of juveniles and sexually mature individuals to be in a northerly direction. Once mature, adult prawns do not generally return to the estuaries. Further studies are considered necessary to fully understand and quantify the oceanic sources of larvae that contribute to recruitment in estuaries and estuarine sources of juveniles that contribute to adults in spawning stock areas offshore (Montgomery *et al*. 2007).

Growth

In NSW, eastern king prawns live for a maximum of three years reaching a carapace length of approximately 45 mm Carapace Length (CL) in males and 60 mm CL in females. The shortest length at which 50 % of female eastern king prawns carry eggs is 42 mm CL (Rowling *et al.* 2010).

Feeding

Post-larval and juvenile eastern king prawns are opportunistic omnivores, which feed on epiphytic algae and small zooplankton. Larger eastern king prawns are carnivorous, and feed primarily on crustaceans, polychaete and bivalves (Suthers 1984). The prawns are predated upon by most carnivorous marine species and also birds (Rowling *et al.* 2010). Observations during pilot stockings also suggest that juvenile eastern king prawns may graze on seagrasses (*Zostera* spp.) (Taylor, Pers. Comm. 2009, Ochwada, Pers. Comm. 2010).

Migration

The species is characterised by its movement over long distances (Ruello 1975). Tagging and recapture studies of eastern king prawns have been carried out by Glaister *et al.* (1987) and Montgomery (1990) along the east coast of Australia. Montgomery (1990) tagged a total of 26,504 prawns of which, 684 individuals were recaptured and provided data that could be used to investigate distances moved. Seventy nine percent of individuals were recovered within 10 km of the initial point of release. The longest distance recorded was 1193 km. In both studies, all prawns captured away from their point of release recorded a northerly movement.

C.8.5.4 Recreational and Commercial Importance

The eastern king prawn is a valuable target species that is harvested by commercial fisheries operating in NSW, VIC and QLD. Almost all commercial landings in NSW are adult prawns taken by the Ocean Trawl Fishery, for which eastern king prawn is a primary species. They are also caught as juveniles in NSW waters by the Estuary General Fishery, Estuary Prawn Trawl Fishery and the recreational fishery. The annual recreational harvest is estimated to be less than 110 t per annum (based on Henry and Lyle 2003) and is thought to account for approximately 83 % of the total recreational prawn harvest in NSW. Scoop nets, scissor nets and hand haul nets are the three types of gear used by recreational fishers. Recreational fishing for prawns occurs in estuaries often coincides with the run of prawns to the sea.

Commercial fisheries landings have steadily declined over the past nine years from over 1000 t in 2000/01 to approximately 773t in 2007/08 and 567t in 2008/09 This is attributed to reduced fishing effort and cyclical trends in prawn abundance (Rowling *et al.* 2010). There is a combined recreational bag limit of 10 litres for all prawns.

The species is currently considered to be growth overfished as determined by yield-per-recruit modelling (Rowling *et al.* 2010). Catch rates are, however, considered stable in both NSW and QLD and modelling of stock dynamics indicate that the stock does not appear to be at high-risk in the near future and that significant changes in the future catch are not expected to have a large impact on catch rates (Ives and Scandol 2007). These projections, however, depend on the assumption that there is continued and robust recruitment from QLD.

C.8.5.5 Existing Aquaculture Technology

A number of large-scale stock enhancement programs are being carried out internationally for penaeid species mainly in Japan and China (Loneragen *et al.* 2006). This has concentrated mainly on the enhancement of kuruma prawns (*Penaeus japonicus)* and *Penaeus chinensis.* Prawn stock enhancement has not yet been carried out on a large-scale in Australia, although the potential for brown tiger prawn (*Penaeus esculentus*) commercial stock enhancement in Exmouth Gulf, WA, has been investigated. So far, the culture of the brown tiger prawn and the eastern king prawn in hatcheries, has been achieved. Whilst eastern king prawn post larvae can be reared with relative ease using intensive methods, on-growth of this species to later stages is not commercially viable due to the requirement for a high protein diet (which is traditionally expensive). However the lack of viability of the species for grow out is not relevant to the stocking program as the prawns would be released as postlarvae and growing penaeid species to this stage in commercial hatcheries has been successful.

At the 30 June 2011, there were six aquaculture farms in NSW with permits to culture this species.

C.8.5.6 Stocking Suitability

Species from the penaeid family are generally considered to be resilient in their life history strategy as they are fast growing, with high fecundity and early maturity (Loneragen *et al*. 2006), making them good candidate species for stock enhancement. At present, further investigations are required to refine the optimal size, habitat, time, and density to provide reliable cost-benefit information for producing hatchery reared juveniles for stock enhancement. Releases of eastern king prawns into closed ICOLLs in southern NSW have shown survival of the stocked individuals given the visual observation of numerous prawns within the water column during sampling trips and recaptures of large juveniles by recreational fishermen. Following the releases in Wallagoot Lake, the low recovery rates in individual tows were possibly caused by limited gear efficiency used in the studies sampling (Ochwada-Doyle *et al*. 2011). Releases of eastern king prawns are ideally conducted over macrophyte habitat which give the prawns an opportunity to acclimatise to feeding and predation within a sheltered environment, which contributes to post release survival (Ochwada *et al.* 2009). Also, where an estuary is completely closed to the sea, stocked prawns persist for up to 2 years, experience fast growth rates and recruitment to the fishery within 3 months, contributing to substantial recreational harvest.

Summary of factors affecting selection of eastern king prawn for marine stocking.

Factor	Status
Exploitation Status	Growth overfished.
Summary of fishery	Status continues to be growth overfished as determined by yield-per-recruit modelling, but this is under review (Rowling *et al* 2010). Population modelling indicated that the NSW stock was very resilient under the assumption of stable levels of recruitment from Queensland (Ives and Scandol 2007).
Geographic range	Endemic to the waters off eastern Australia having been recorded from Mackay in Queensland southwards to north-east Tasmania in depths from 1m to 200m (Rowling et al 2010, Montgomery *et al*. 2007)
Genetic stock structure	The life history of the eastern king prawn and one allozyme study suggests a single east coast population, however, this data is considered insufficient to draw a final conclusion on genetic structure.
Estuarine residency	The species stays in estuaries for a large part of its juvenile stage (for approximately 1 year), or if the estuary is closed to the sea the prawns may remain within the estuary for their entire life.
Suitable life history traits	Fast-growing to a harvestable size.
Demand	Very popular estuarine recreational species. The annual recreational harvest of eastern king prawns is likely to be less than 110t (Henry and Lyle 2003).
Available aquaculture technology	Post-larvae can be successfully produced in hatcheries (Loneragen *et al.* 2006).
Demonstrated stocking success	Preliminary results from research on pilot prawn enhancement projects have indicated that released prawns recruit to the fishery within 3 months, and may experience around 4 % survival. Two consecutive releases of 0.9 – 1 million prawns in Wallagoot Lake on the south coast of NSW in January and December 2007, contributed an estimated 10 tonnes of prawns to the recreational fishery, with catch rates of prawns by anglers of 3 kg h^{-1} and up to 10 kg $night^{-1}$.

C.8.6 Giant Mud Crab (*Scylla serrata*)

C.8.6.1 Natural Distribution and Stock Structure

The geographic distribution of the giant mud crab, *Scylla serrata* (family: Portunidae) includes the Indo-West Pacific region and around the Indian Ocean to east Africa (Rowling *et al* 2010). In Australia, the species is found in tropical-temperate waters from the Bega River in southern NSW north to the Gulf of Carpentaria and around to Broome in WA (Rowling *et al*. 2010).

Gopurenko and Hughes (2002) analysed patterns of genetic homogeneity among populations on the eastern and northern coasts of Australia. There was no significant difference in mtDNA (cytochrome oxidase subunit I) haplotype frequencies among four populations that were sampled on the east coast of QLD (Hinchinbrook Island, Mackay, Rockhampton and Moreton Bay). These populations were significantly different from a population at Cape Grenville (north-east Cape York, QLD) and from six populations stretching from the Gulf of Carpentaria along the northern coast of Australia to Exmouth (WA). Genetic homogeneity among the four QLD populations may be maintained by larval dispersal as a consequence of the release of eggs into offshore currents in the Coral Sea. Two locations that were approximately 400 km apart (by sea; Cape Grenville and Weipa) were genetically distinct despite being connected by the shallow continental shelf waters (i.e. less than 200 m in depth), albeit adjacent to different water bodies (i.e. Gulf of Carpentaria and Coral Sea). The mechanisms that prevent dispersal between the Gulf and the Coral Sea must be strong, as a later paper by Gopurenko *et al.* (2003) proposed that a one-off dispersal event from the north to the south coast of WA (over thousands of kms) led to the establishment of a southern population. The implication of these two studies for the assessment of *S. serrata* as a species for stocking is two-fold. Firstly, it appears that new, abundant populations in temperate regions can be established; indicating that stocking on the NSW coastline could lead to a new fisheries resource. Secondly, the genetic break around Cape York despite continuous shallow habitat raises the possibility of similar breaks in areas that have not been studied to date (i.e. the south-eastern Australian coast), possibly associated with eddies in the East Australian Current or transition zones between tropical and temperate waters.

C.8.6.2 Habitat

As juveniles, giant mud crabs are usually found in sheltered soft sediment habitats such as estuaries and tidal flats and are closely associated with mangroves and seagrass beds. Adult giant mud crabs may live intertidally in burrows, but mostly they remain buried in muddy subtidal substrata (Kailola *et al*. 1993, Williams 2002).

C.8.6.3 Life History

Reproduction (Spawning)

The giant mud crab moves offshore to spawn to depths up to 60 m. This is thought to provide a mechanism for the dispersal of larvae and enable the megalopa stage larvae (the first stage resembling the adult form) to recruit to habitats distant from the parents (Hill 1994). This offshore movement occurs during September and October, and females are then thought to return to the nearshore coast after spawning. Female giant mud crabs carry between two and five million eggs (Rowling *et al.* 2010).

Recruitment

Scandol *et al*. (2008) notes that NSW is at the most southern extent of the species range and therefore the fishery may partly depend on larval recruitment from the north. Due to the pelagic offshore larval phase, recruitment to key nursery habitats within estuaries is most likely dependent on oceanographic conditions that are ideal for onshore transport. This, and the spawning period would suggest that recruitment in NSW is most likely to be in summer months.

Growth

Among the four species of mud crabs (*Scylla* spp.) that occur in the Indo-Pacific region, the giant mud crab (*Scylla serrata*) has the highest growth rate reaching a marketable size of 500 g or more and carapace width between 260 mm and 450 mm in approximately five to six months. After a succession of moults, the species reaches maturity between 18 – 24 months and can live up to 4 years. In all male and most females, the moult that marks the transition from a juvenile into an adult is the final moult. A small proportion of females are capable of reproducing for a second time (Rowling *et al.* 2010). The minimum legal size for giant mud crabs to be harvested (male or female) is 85 mm CL.

Feeding

Giant mud crabs forage at night for molluscs, crustaceans and polychaete worms (Rowling *et al.* 2010). A substantial component of the diet of large adult crabs are smaller grasped crabs, comprising 21 % of total consumption (Hill 1976).

Migration

Tagging experiments carried out in Moreton Bay, QLD found two main types of movements in giant mud crabs; offshore spawning migrations in females and small-scale free ranging movements. A total of 6233 crabs were tagged and 1180 recaptured (18.9 %). Crabs in a narrow creek with mangrove covered banks showed little movement, whereas in areas with large intertidal flats (bare of mangroves), crabs underwent more movement.

Limited movement between populations inhabiting an estuary and adjacent bay was observed, due to separation by an area of unsuitable habitat (Hyland *et al*. 1984), although some exchange between populations in a mangrove creek and a neighbouring bay was evident.

C.8.6.4 Recreational and Commercial Importance

The giant mud crab is one of four species of mud crab that are commercially important throughout the Indo-Pacific region. In Australia, the giant mud crab is commercially and recreationally important, although the main commercial fishery for mud crabs is in QLD. In NSW, the giant mud crab is harvested primarily by the Estuary General Fishery in quantities ranging between 100 t – 120 t per annum, and its exploitation status is undefined. The commercial fishery is seasonal with the greatest harvest occurring during summer, peaking in February and March (Rowling *et al.* 2010). In some areas, recreational catches reportedly outweigh commercial with baited traps or crab pots being the most frequently used gear type (Lee 1992). On the whole, however, the annual recreational harvest of giant mud crab in NSW is estimated to lie between 30 t and 60t, less than half the commercial catch. This estimate is based upon the results of the offsite National Recreational and Indigenous Fishing Survey (Henry and Lyle, 2003) and onsite surveys undertaken by NSW DPI (Rowling *et al.* 2010). Female giant mud crabs are protected in QLD, NT and WA. In NSW, female giant mud crabs carrying eggs are protected.

C.8.6.5 Existing Aquaculture Technology

To date, the culture of giant mud crabs in Asia has been hindered by the lack of hatchery technology for the production of seed, and has been entirely dependent on the collection of natural seed (Lebata *et al*. 2009). This has prevented the development of the grow-out industry and meant that all life stages of the species, from first recruits to mature individuals are targeted in unregulated local fisheries. More recently, the results of several initiatives suggest that commercial hatcheries will be operational in the near future and the technology to produce juveniles from the hatchery may lessen the pressure on wild stocks by decreasing the demand on juveniles for use in aquaculture (Lebata *et al*. 2009).

In Australia, only the NT Department of Primary Industries (NTDPI) hatchery has produced giant mud crabs with a survival rate greater than 10 % on a consistent basis. Recently, the Bribie Island Research Centre (BIRC) in partnership with NT researchers and support from the Fisheries Research and Development Council (FRDC) has developed commercial methods for hatchery and nursery production of mud crabs, leading to increased availability of mud crab juveniles for on-farm grow out trials.

At the 30 June 2011, there were three aquaculture farms in NSW with permits to culture this species.

C.8.6.6 Stocking Suitability

A recent evaluation of the hatchery based stock enhancement of mud crabs (*Scylla serrata* and *Scylla olivacea*) in mangroves of the Philippines has shown positive results. Lebata *et al*. (2009) conducted a study between April 2002 and November 2005 which looked at the effectiveness of releasing wild-caught and hatchery reared mud crabs in areas where there had been a decline in fishery yields. There was previous evidence of recruitment limitation in the mangrove system being studied and the high recapture rate of release animals resulted in increases in the mean fishery yield (46 %), and CPUE in terms of both number (51 %) and biomass (42 %) resulting from the translocated and hatchery-reared crabs released into the mangrove system (Lebata *et al*. 2009). Survival of the wild-caught individuals was found to be greater compared to hatchery reared individuals. The study did not formally investigate cost-effectiveness, although it was noted that production and release costs were covered by the yield of the recaptures. Lebata *et al*. (2009) note that unit production costs are likely to decrease with increasing scale and efficiency and that equally, appropriate species, size class and conditioning regimes can be expected to improve recapture efficiency. They also concluded that release strategies should include conditioning hatchery-reared juveniles in earthen (*sic*) ponds for at least 1 month and growing them to a minimum size of at least 50 mm carapace width before release. That was shown to result in survival and growth at least equivalent to, or better than, that of wild crabs in the same system (Lebata *et al*. 2009).

The high growth rates and limited movement of crabs within mangrove systems mean that fisheries yields can be enhanced within a few months in recruitment limited populations (Le Vay *et al.* 2008) making stock enhancement an attractive option. Recruitment success and subsequent stock abundance in giant mud crabs, however, may also be dependent on habitat availability. Depending on local conditions, a balanced approach between habitat restoration and stock enhancement may be required as the most effective fisheries management approach (Le Vay *et al*. 2008, Hamasaki and Kitada 2008).

Summary of factors affecting selection of giant mud crab for marine stocking.

Factor	Status
Exploitation Status	Undefined.
Summary of fishery	Significant commercial and recreational fisheries occur in NSW which is at the southernmost extent of the species' range.
Geographic range	The geographic distribution includes the Indo-West Pacific region and around the Indian Ocean to east Africa (Rowling *et al* 2010). In Australia, the species is found in tropical-temperate waters from the Bega River in southern NSW north to the Gulf of Carpentaria and around to Broome in WA (Rowling *et al*. 2010).
Genetic stock structure	There is evidence for genetic structuring among estuaries around northern Australia (Gopurenko and Hughes 2002), however, connectivity and structure between NSW estuaries is unknown.
Estuarine residency	Strong estuarine residency until moving offshore to spawn.
Suitable life history traits	Fast-growth to a harvestable size.
Demand	Very popular estuarine recreational species. The annual recreational harvest of giant mud crabs is likely to lie between 30 t and 60t (Henry and Lyle 2003).
Available aquaculture technology	Technology is available in Australia for hatchery production at the Bribie Island Research Centre. At the 30 June 2011, there were 3 aquaculture farms in NSW with permits to culture this species.
Demonstrated stocking success	Successful releases have led to increased yields of a magnitude that covers the costs of release in the Philippines (Lebata *et al*. 2009).

C.8.7 Blue Swimmer Crab (*Portunus pelagicus*)

C.8.7.1 Natural Distribution and Stock Structure

The blue swimmer crab *Portunus pelagicus* (family: Portunidae) is distributed throughout coastal waters of the tropical regions of the western Indian and the eastern Pacific Oceans (Kailola *et al*. 1993). Inhabits coastal waters in all Australian states except Tasmania, spanning tropical, subtropical and temperate waters (Rowling *et al*. 2010, Kumar *et al*. 2003).

There have been two Australia-wide genetic stock structure studies on blue swimmer crabs. In both studies, crabs were taken for genetic analyses from the coastline of SA, WA, the NT, QLD and NSW. Bryars and Adams (1999) assayed allelic variation in seven allozyme loci (total of 29 alleles), while Chaplin *et al.* (2001) focussed on six microsatellite loci across a larger number of alleles (n = 139). In the allozyme study, sample sizes for two locations on the QLD coast (n = 11, 5) and one location on the NSW coast (n = 4) were inadequate (i.e. less than 50) to be included in a robust analysis of population structure. In the microsatellite study, sample sizes for the QLD and NSW locations were adequate to provide a test of genetic subdivision between samples from Darwin and SA. The Australian east coast sampling locations (i.e. three QLD locations; Mackay, Hervey Bay and Moreton Bay, and two NSW locations; Wallis Lake and Port Stephens) were significantly different from Darwin samples (FST = 0.04 to 0.07) and from SA samples (FST = 0.07 to 0.18). Chaplin *et al.* (2001) regarded the five sampling locations from the Australian east coast as a single genetically homogeneous stock. They proposed that genetic homogeneity over geographic distances (i.e. greater than 1500 km), which exceed the per generation dispersal capacity (i.e. larvae, approximately 300 km over 21 days of larval life in currents of 7 to 10 km per day; juveniles and adults, less than 100 km), was maintained by a combination of chance long-distance dispersal and significant genetic mixing on smaller spatial scales. They noted that genetic continuity along a linear coastline could be interrupted by processes that exceeded average dispersal distances and that migration could significantly enhance the recovery of depleted populations. Blue swimmer crabs occurring north of Port Stephens are therefore regarded as a single stock, however, as no samples were taken south of Port Stephens further data is considered necessary to confirm a single east coast population.

C.8.7.2 Habitat

In NSW, blue swimmer crabs are mainly found within estuaries and inshore coastal waters (Rowling *et al.* 2010). Within estuaries, they are thought to prefer sandy or muddy habitat but may also be found in algal and seagrass habitats, from the intertidal zone to a depth of 50 m (Poore 2004, Kangas 2000). Difference in habitat preference is evident between male and female crabs. Females have been found to be more abundant in shallow areas particularly on sand banks, whereas males have shown preferences for deeper gutters and the lower slopes of sandbanks (Kangas 2000). Juvenile crabs inhabit shallow seagrass meadows, sand and mud banks in and around estuaries (Williams 2002).

C.8.7.3 Life History

Reproduction (Spawning)

In temperate regions, spawning usually occurs in summer months although the exact timing can vary among locations and years according to annual temperature variations (Xiao and Kumar 2004). This is unlike tropical or subtropical blue swimmer crabs which can spawn continually throughout the year. Adults may spawn in oceanic waters, inshore coastal waters or in the entrance channels of estuaries (Kangas 2000). Investigations carried out in WA suggest that assemblages of crabs that inhabit marine embayment's often do not leave the area to spawn but may spawn in the high salinity regions within the embayment.

The eggs and larvae of blue swimmer crabs are planktonic with the larval phase consisting of five stages. During the larval phase, crabs may drift as far as 80 km and spend up to six weeks offshore before returning to settle in shallow inshore waters (Williams 1982). De Lestang *et al*. (2003a) found that larger crabs can produce two or three egg batches compared with only one in smaller individuals and that the number of eggs produced may vary between 78,000 in small crabs (carapace width of 80 mm) up to 1,000,000 in large crabs (carapace width of 180 mm).

Recruitment

Recruitment of juveniles into estuarine waters occurs in the spring and summer and is thought to be facilitated by the prevailing oceanographic conditions. In WA, small crabs recruit into estuaries in late summer and the following spring (De Lestang *et al*. 2000).

Growth

According to Scandol *et al*. (2008), blue swimmer crabs can grow to carapace lengths greater than 950 mm and have a life span up to three years. The estimated carapace length at which 50 % of a population reaches maturity (L_{50}) is 46 mm for females and 44 mm for males. Studies carried out in WA (De Lestang *et al*. 2003b) also indicated that growth rates in males and females were similar. For recreational fishing, the minimum legal carapace length is 60 mm and there is a recreational bag limit of 20 crabs. Based on growth curves (Johnson 2007), blue swimmer crabs reach the minimum legal length of 60 mm carapace length at approximately 10 months of age.

Feeding

Blue swimmer crabs are opportunistic bottom-feeding carnivores and scavengers (Kangas 2000). They have been shown to consume a wide range of benthic invertebrates such as amphipod crustaceans, bivalve molluscs and polychaete worms and to a lesser extent, small fish, plant material, dead fish and squid (De Lestang *et al*. 2003a). The type of prey consumed has also been found to differ according to body size (De Lestang *et al*. 2003a, Edgar 1990). De Lestang *et al*. (2003a) reported the dietary composition of smaller individuals to consist mainly of benthic and epibenthic crustaceans (such as amphipods and tanaids) with a shift towards polychaete worms, small decapods and fish in larger crabs.

Migration

Blue swimmer crabs move into the open ocean from estuaries for spawning and also in response to freshwater flows that result in lowered salinities. The species is considered to be a strong swimmer and has been recorded to travel as far as 20 km in one day (Sumpton and Smith 1991). Movements on this scale are, however, considered rare and tagging experiments have found that the majority of individuals are recaptured within 2 km of their release sites and a small percentage recaptured within 10 km of their release sites.

C.8.7.4 Recreational and Commercial Importance

The blue swimmer crab is an important fisheries species throughout the Indo-West Pacific and within Australia including NSW. As an example, the total worldwide landings in 1998 were 109,000 t which represents approximately 10 % of all brachyuran crabs landed in that year (De Lestang *et al*. 2003b). It is also an important target species in the recreational fishing sector. Commercial landings in NSW have been relatively stable over the past 10 years with reported landings (of the blue swimmer crab and common sand crab combined) ranging between 150 t and 210 t per annum (Rowling *et al.* 2010). The species is mostly caught as a key secondary species in the Estuary General Fishery and to a lesser extent in the Ocean Trawl Fishery. The annual recreational harvest is thought to be comparable to or greater than the commercial harvest, and has been estimated at between 150 t and 310 t (Henry and Lyle 2003).

The stock status of the blue swimmer crab is categorised as fully fished. There is some concern over fishing pressure within the Wallis Lake estuary and for offshore populations of female crabs (Rowling *et al.* 2010).

C.8.7.5 Available Aquaculture Technology

The blue swimmer crab is an emerging aquaculture species in the Indo-Pacific and has successfully been cultured and released for stock enhancement purposes in Japan since 2000. Between 1,857 and 3,195 juvenile crabs (of carapace lengths between 8 mm and 10 mm) were released each year between 2000 and 2004 (Hamasaki and Kitada 2008).

C.8.7.6 Stocking Suitability

The blue swimmer crab is considered to be relatively fast growing, reaches maturity early and has high fecundity. Given that this species has successfully been cultured in Japan there is potential for it to be considered as a candidate for stock-enhancement, however, additional breeding technology is required in NSW.

Summary of factors affecting selection of blue swimmer crab for marine stocking.

Factor	Status
Exploitation Status	Fully fished.
Summary of fishery	An important recreational and commercial species. Five estuaries account for 95 % of the commercial catch, with Wallis lake being the most important. Recreational landings are likely to be greater than the commercial catch, but no recent estimates are available (Rowling *et al* 2010).
Geographic range	Inhabits coastal waters in all Australian states except Tasmania, spanning tropical, subtropical and temperate waters (Rowling *et al*. 2010, Kumar *et al*. 2003).
Genetic stock structure	It is accepted that a single genetic stock exists north of Port Stephens and considered likely that there is a single east coast genetic stock, however, further studies (south of Port Stephens) are considered necessary to confirm this.
Estuarine residency	Strong estuarine residency but some individuals may move offshore to spawn.
Suitable life history traits	Fast-growing to a harvestable size.
Demand	Popular recreational and commercial species. The annual recreational harvest of blue swimmer crab in NSW is likely to lie between 150 t and 310 t (Henry and Lyle 2003).
Available aquaculture technology	Technology is available from Japan (Hamasaki and Kitada 2008).
Demonstrated stocking success	There are no published examples of previous releases of blue swimmer crabs in Australia; however, there have been releases in Japan (Hamasaki and Kitada 2008).

C.9 Species and Areas of Conservation Significance

C.9.1 Threatened Species

For the purposes of this assessment, 'threatened species' refers to any estuarine or coastal species, populations or ecological communities and their habitats as defined and listed under Schedules 4, 4A or 5 of the FM Act, Schedules 1 or 2 of the TSC Act, or Subdivisions C or D of the 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.

The NSW government 'BioNet' database (BioNet 2009), the OEH threatened species database (NSW DECCW 2010b) and the DSEWPaC threatened species database were searched for threatened species, populations and ecological communities listed under relevant Schedules of the TSC Act, FM Act and EPBC Act that could potentially occur within or around NSW estuaries. The search was carried out in September 2009 and included marine or estuarine fish, mammals, reptiles, algae/vegetation, invertebrates and estuarine birds. All searches were carried out to cover the whole of NSW including the marine zone. This allowed a broad-scale assessment of all threatened and protected species that could potentially occur in NSW. The results of the NSW database searches are given in Table C.8. Oceanic seabirds such as petrels, albatrosses, prions and shearwaters were not included and only birds that are associated with estuarine habitats are included in Table C.8.

Each of the species, populations and ecological communities listed in the NSW searches were then ranked as high, moderate, low or none in terms of their relevance to the proposal based on their likelihood of occurring in NSW estuaries and their dependence on estuaries. The species, populations and communities were ranked as follows:

- High = species/population/community is likely to occur in NSW estuaries (species is entirely dependent on estuarine habitat at some stage of its life cycle).
- Moderate = species/population/community could occasionally occur in estuaries (species is not entirely dependent on estuarine habitat).
- Low = is unlikely to occur in estuaries (species is not dependent on estuarine habitat).
- None = would generally not occur in estuaries (species is not dependent on estuarine habitat).

The known geographic distribution of these species within NSW is also indicated (Table C.8).

C.9.1.1 Assessment under State Legislation

A total of 14 species of fish were protected under State legislation including one species that is presumed extinct (the green sawfish, *Pristis zijsron*), one critically endangered species (grey nurse shark, *Carcharias taurus*), one endangered species (Southern bluefin tuna, *Thunnus maccoyii*), two species listed as 'vulnerable' and nine species that are 'protected'. Thirty one species of cetacean were listed as protected, three species listed as vulnerable and one species listed as endangered. The 'endangered' dugong (*Dugong dugon*) was the only species of sirenian listed in NSW. Seven species of pinnipeds (seals and sealions) were listed comprising five 'protected' and two 'vulnerable' species. Five species of marine reptiles, including four species of sea turtle (one endangered, two vulnerable and one protected) and one protected seasnake were also listed. All the estuarine birds listed in Table C.8 are considered likely to occur in and/or depend on estuarine habitat at some or all of their life cycle. These include diving birds such as cormorants, little penguins and pelicans, wading birds such as ibises, spoonbills, storks, curlews, godwits, snipes, sandpipers, plovers and oystercatchers. A number of gulls, gannets, terns and jaegers were also listed among others. Under State legislation, 106 of the total species of birds were listed as 'protected', 13 species listed as 'vulnerable' and six listed as 'endangered'. The Manly population of the little penguin (*Eudyptula minor*) is also listed as 'endangered' and is the only mainland breeding colony of little penguins. The recently listed endangered populations of *Posidonia australis* (seagrass) in Port Hacking, Botany Bay, Port Jackson, Pittwater, Brisbane Waters and Lake Macquarie has also been included.

Species that were of high, moderate or low significance were assessed under the NSW State 'Assessment of Significance' according to Threatened Species Assessment Guidelines (NSW DPI 2008b). This is required under section 5A of the EP&A Act which aims to improve the standard of consideration afforded to threatened species, populations and ecological communities and their habitats and ensure a transparent planning and assessment process (NSW DPI 2008b). The Assessment of Significance is the first step in considering 'potential' impacts at a local level, therefore any species which could be affected, even those considered unlikely to occur in estuaries, but that could 'potentially' occur there have been considered in the assessment.

Assessments of Significance were done for all species listed in table C.8, listed as having high relevance to the proposal. Note that estuarine birds were grouped into feeding guilds (i.e. waders, divers, raptors) as the potential impacts identified were similar. The full assessments of significance are given in Appendix 2. The State Assessment of Significance only applies to species, populations and communities that are listed on Schedules 1, 1a and 2 of the TSC Act and Schedules 4, 4A and 5 of the FM Act, therefore species that are listed as 'protected' were not included in the Assessment of Significance.

C.9.1.2 Assessment under Commonwealth Legislation

A total of four species of fish were listed under Commonwealth legislation, although the orange roughy (*Hoplostethus atlanticus*) and the whale shark (*Rhincodon typus*) would not occur in estuaries and are not considered any further in the assessment. Thirty seven species of cetacean were protected under Commonwealth legislation including two that are 'endangered' and two are 'vulnerable'. The remaining 33 species were listed as either 'migratory', as 'cetaceans' or both. The dugong is listed as migratory under Commonwealth legislation. Of the seven pinnipeds protected under the EPBC Act, one was 'vulnerable and the others were 'listed'. Six species of marine reptile including marine turtles and seasnakes were protected under the EPBC Act of which two are 'listed', two are 'vulnerable' and two are 'endangered'. All marine turtles are also listed as migratory. Seventy two species of estuarine birds were protected under the EPBC Act including 26 that were 'listed', 33 that were 'migratory', and 13 that were both 'listed' and 'migratory'. Note that all species of migratory birds listed under Annexes of bilateral migratory bird agreements i.e. JAMBA (Japan-Australia Migratory Bird Agreement), CAMBA (China-Australia

Migratory Bird Agreement) and ROKAMBA (Republic of Korea-Australia Migratory Bird Agreement) are protected as matters of NES under the EPBC Act.

Species that were identified as being of high, moderate or low significance to the proposal were assessed under the EPBC Act according to EPBC Act Policy Statement 1.1 'Significant Impact Guidelines' for Matters of National Environmental Significance (NES)(DEWHA 2006). Any species that were identified in the search that would not occur in estuarine habitats were not considered any further in the assessment. Apart from humpback whales and southern right whales which may use the larger estuaries for resting during migration, all of the other listed baleen whales and large toothed whales have generally not been recorded in estuaries. A few Brydes whales and a sperm whale have been recorded entering the Manning River but it was considered that these individuals were accidentally washed into the estuary while feeding near the mouth (Priddel and Wheeler 1997). Most of these whales died from lack of food and an inability to return to the ocean and one was given assistance to 'escape'. Only species and populations or communities that are listed in Section 179 as 'critically endangered', 'endangered' or 'vulnerable' are considered to be matters of NES and therefore only these species have been assessed using the Significant Impact Guidelines (Appendix 3).

Several of the species listed under the EPBC Act have already been assessed under the State Assessment of Significance (which is very similar to the Commonwealth assessment), further assessment is not required. In January 2007, the Commonwealth and NSW governments signed a Bilateral Agreement which allows the assessment regimes under the EP&A Act (Parts 3A, 4 and 5) to be automatically accredited under the EPBC Act. The agreement also accredits the assessment processes under Part 6 of the TSC Act and Part 7A of the FM Act. This means that separate assessment processes are not required for some species.

In addition, many of the species that were listed as 'endangered' or 'vulnerable' under the EPBC Act, and were assessed under these schedules, did not require further assessment if they were also listed as 'migratory'.

All EPBC listed species that were assessed (either under the State or Commonwealth Assessment) are listed in table C.8. As for the State assessment, estuarine birds were grouped and assessed according to feeding guild. Results of the assessment of significance are given in Appendix 3. Potential impacts of the proposed marine stocking program on all estuarine species (including threatened and non-threatened species) are discussed in Chapter D, Section D.4.2.

Table C.8: Threatened species known or likely to occur in NSW estuaries.

Species known or predicted to occur in NSW estuaries that are listed under the FM Act, the TSC Act, NPW Act and the EPBC Act. PE = presumed extinct, CE = critically endangered, E = endangered, V = vulnerable, CD= Conservation Dependant, M = migratory, L = listed, Cet = cetacean and P = protected. Source: NSW 'BioNet' database (2009), DECC Threatened Species database and the EPBC Database environmental reporting tool (accessed September 2009) and Ganassin and Gibbs (2005a). High = species/population/community is likely to occur in NSW estuaries (species is entirely dependent on estuarine habitat at some stage of its life cycle). Moderate = species/population/community could occasionally occur in estuaries (species is not entirely dependent on estuarine habitat). Low = is unlikely to occur in estuaries (species is not dependent on estuarine habitat). None = would generally not occur in estuaries (species is not dependent on estuarine habitat).

Scheduled Species/Population/ Ecological Community	Common Name	TSC/FM Act Status	EPBC Act Status	Geographic Distribution	Relevance to Proposal (High, Moderate, Low, None)
1. Fish					
All syngnathiformes (Seahorses, seadragons, pipefish, pipehorses and seamoths)		P		All NSW coast	Mod
Anampses elegans	*Elegant wrasse*	P		All NSW coast	Mod
Carcharias taurus	*Grey nurse shark*	CE		All NSW coast	Mod
Carcharodon carcharias	*Great white shark*	V	V, M	All NSW coast	Mod
Chaetodontoplus ballinae	*Ballina angelfish*	P		Northern NSW	Low
Epinephelus coioides	*Estuary cod*	P		Northern to Central NSW	High
Epinephelus daemelii	*Black cod*	V		All NSW coast	Mod
Epinephelus lanceolatus	*Giant Queensland groper*	P		All NSW coast	Mod
Girella cyanea	*Bluefish*	P		All NSW coast	Low
Odontaspis ferox	*Herbsts nurse shark*	P		All NSW coast	None
Paraplesiops bleekeri	*Bleekers devil fish*	P		All NSW coast	Mod
Pristis zijsron	*Green sawfish*	PE	V	NSW-north of Jervis Bay	High
Protroctes maraena	*Australian grayling*	P		Southern NSW	Mod
Rhincodon typus	*Whale shark*		M, V	All NSW coast	None
Thunnus maccoyii	*Southern bluefin tuna*	E		All NSW coast	Low
Galeorhinus galeus	*School shark*		CD	All NSW coast	Mod
Hoplostethus atlanticus	*Orange roughy*		CD	Central NSW south	None
2. Cetaceans					
Balaenoptera acutorostrata	Dwarf minke whale	P	Cet	All NSW coast	None
Balaenoptera bonaerensis	Antarctic minke whale	P	Cet, M	All NSW coast	None
Balaenoptera edeni	Bryde's whale	P	Cet, M	All NSW coast	None
Balaenoptera musculus	Blue whale	E	Cet, E, M	All NSW coast	None
Balaenoptera physalus	Fin whale	P	Cet, V, M	All NSW coast	None
Caperea marginata	Pygmy right whale	P	Cet, M	All NSW coast	None
Delphinus delphis	Common dolphin	P	Cet	All NSW coast	Mod
Eubalaena australis	Southern right whale	V	Cet, E, M	All NSW coast	Mod
Feresa attenuata	Pygmy killer whale	P	Cet	northern NSW	Low

Scheduled Species/Population/ Ecological Community	Common Name	TSC/FM Act Status	EPBC Act Status	Geographic Distribution	Relevance to Proposal (High, Moderate, Low, None)
Globicephala macrorhyncus	Short-finned pilot whale	P	Cet	All NSW coast	Low
Globicephala melas	Long-finned pilot whale	P	Cet	All NSW coast	Low
Grampus griseus	Risso's dolphin	P	Cet	All NSW coast	Mod
Hyperodon planifrons	Southern bottlenose whale	P	Cet	All NSW coast	None
Kogia breviceps	Pygmy sperm whale	P	Cet	All NSW coast	None
Kogia simus	Dwarf sperm whale	P	Cet	All NSW coast	None
Lagenodelphis hosei	Frasers dolphin	P	Cet	Northern tip of NSW	Low
Lagenorrhycus obscurus	Dusky dolphin	P	Cet, M	All NSW coast	Mod
Lissodelphis peronii	Southern right whale dolphin	P	Cet	All NSW coast except far north	Low
Megaptera novaeangliae	Humpback whale	V	Cet, V, M	All NSW coast	Mod
Mesoplodon bowdoini	Andrews beaked whale	P	Cet	All NSW coast	None
Mesoplodon ginkodens	Ginko-toothed beaked whale	P	Cet	All NSW coast	None
Mesoplodon grayi	Gray's beaked whale	P	Cet	All NSW coast	None
Mesoplodon layardii	Strap-toothed beaked whale	P	Cet	All NSW coast	None
Mesoplodon mirus	True's beaked whale		Cet	All NSW coast except far north	None
Mesoplodon densirostris	Blainville's beaked whale	P	Cet	All NSW coast	None
Orcinus orca	Killer whale	P	Cet, M	All NSW coast	Low
Peponocephala electra	Melon-headed whale	P	Cet	All NSW except far south	None
Physeter macrocephalus	Sperm whale	V	Cet, M	All NSW coast	None
Pseudorca crassidens	False killer whale	P	Cet	All NSW coast	Low
Sousa chinensis	Indo-pacific hump-backed dolphin	P	Cet, M	Northern tip of NSW only	High
Stenella attenuata	Spotted dolphin	P	Cet	Central to northern NSW	Low
Stenella coeruleoalba	Striped dolphin	P	Cet	Central to northern NSW	Low
Stenella longirostris	Long snouted spinner dolphin	P	Cet, M	Central to northern NSW	Low
Steno bredanensis	Rough toothed dolphin	P	Cet	All NSW except far south	Low
Tursiops aduncus	Indo Pacific Bottlenose dolphin	P	Cet, M	All NSW coast	Mod
Tursiops truncatus	Bottlenose dolphin	P	Cet	All NSW coast	Mod

Scheduled Species/Population/ Ecological Community	Common Name	TSC/FM Act Status	EPBC Act Status	Geographic Distribution	Relevance to Proposal (High, Moderate, Low, None)
Ziphius cavirostris	Cuvier's beaked whale		Cet	All NSW coast	None
3. Sirenians					
Dugong dugon	Dugong	E	L, M	Northern NSW but recorded as far south as Twofold Bay	High
4. Pinnipeds					
Arctocephalus forsteri	New Zealand fur-seal	V	L	All NSW except far north	Mod
Arctocephalus pusillus doriferus	Australian fur-seal	V	L	All NSW except far north	Mod
Arctocephalus tropicalis	Sub Antarctic fur-seal	P	V	Southern NSW	Mod
Hydrurga leptonyx	Leopard seal	P	L	Southern NSW	Mod
Lobodon carcinophagus	Crab eater seal	P	L	Southern NSW	Low
Mirounga leonina	Southern elephant seal	P	L	Southern NSW	Low
Neophoca cinerea	Australian sea lion	P	L	Southern NSW	Mod
5. Marine Reptiles					
Marine Turtles					
Caretta caretta	Loggerhead turtle	E	E,M	Northern NSW	High
Chelonia mydas	Green Turtle	V	V,M	Northern to central NSW	High
Dermochelys coriacea	Leatherback turtle	V	E, M	All NSW coast	Mod
Eretmochelys imbricata	Hawksbill turtle	P	V, M	Northern NSW	Mod
Seasnakes					
Hydrophis elegans	Elegant seasnake		L	Northern tip of NSW	Low
Pelamis platurus	Yellow-bellied seasnake	P	L	All NSW except far south	Low
6. Birds					
Actitis hypoleucos	Common sandpiper	P	L, M	Whole coast except the far south coast	High
Anas acuta	Northern pintail	P		All NSW coast	High
Anas castenea	Chestnut teal	P	L	All NSW coast	High
Anas gracilis	Grey teal	P	L	All NSW coast	High
Anas superciliosa	Pacific black duck	P	L	All NSW coast	High
Anhinga melanogaster	Darter	P		All NSW coast	High
Anous minutus	Black noddy	P		All NSW coast	High
Anous stolidus	Common noddy	P		All NSW coast	High
Aquila audax	Wedge-tailed eagle	P		All NSW coast	High
Ardea alba	Egret	P	L	All NSW coast	High

Scheduled Species/Population/ Ecological Community	Common Name	TSC/FM Act Status	EPBC Act Status	Geographic Distribution	Relevance to Proposal (High, Moderate, Low, None)
Ardea intermedia	Intermediate egret	P		All NSW coast	High
Arenaria interpres	Ruddy turnstone	P	L	Whole coast except the far south coast	High
Biziura lobata	Musk duck	P	L	All NSW coast	High
Butorides striatus	Striated heron	P		All NSW coast	High
Calidris acuminata	Sharp-tailed sandpiper	P	M	All NSW coast	High
Calidris alba	Sanderling	V	M	Whole coast except the far south coast	High
Calidris bairdii	Bairds sandpiper	P	M	All NSW coast	High
Calidris canutus	Red knot	P	M	All NSW coast	High
Calidris ferruginea	Curlew sandpiper	P	M	All NSW coast	High
Calidris fuscicollis	White-rumped sandpiper	P		All NSW coast	High
Calidris mauri	Western sandpiper	P		All NSW coast	High
Calidris melanotos	Pectoral sandpiper	P	M	Whole coast except the far south coast	High
Calidris minuta	Little stint	P	M	All NSW coast	High
Calidris ruficollis	Red-necked stint	P	M	Whole coast except the far south coast	High
Calidris subminuta	Long-toed stint	P	M	All NSW coast	High
Calidris tenuirostris	Great knot	V	L, M	occurs as far south as Narooma	High
Charadrius bicinctus	Double-banded plover	P*	M	All NSW coast	High
Charadrius leschenaultii	Greater sand plover	V	M	Whole coast except the far south coast	High
Charadrius mongolus	Lesser sand plover	V	M	All NSW coast	High
Charadrius ruficapillus	Red capped plover	P		All NSW coast	High
Chlidonias hybridus	Whiskered tern	P		All NSW coast	High
Chlidonias leucopterus	White-winged black tern	P		All NSW coast	High
Chlidonias niger	Black tern	P	M	All NSW coast	High
Circus approximans	Swamp harrier	P		All NSW coast	High
Cladorhynchus leucocephalus	Banded stilt	P		All NSW coast	High
Cygnus atratus	Black swan	P	L	All NSW coast	High
Egretta garzetta	Little egret	P	L	All NSW coast	High
Egretta novaehollandiae	White-faced heron	P		All NSW coast	High
Egretta sacra	Eastern reef egret	P	L	All NSW coast	High
Ephippiorhyncus asiaticus	Black-necked stork	E	L	Northern NSW	High
Erythrotriorchis radiatus	Red Goshawk	E		Northern NSW	High

Scheduled Species/Population/ Ecological Community	Common Name	TSC/FM Act Status	EPBC Act Status	Geographic Distribution	Relevance to Proposal (High, Moderate, Low, None)
Esacus neglectus	Beach stone curlew	E		Northern NSW	High
Eudyptula minor	Little penguin	E	L	Central to southern parts of NSW	High
Falco peregrinus	Peregrine falcon	P	L	All NSW coast	High
Fregata ariel	Lesser frigatebird	P	L, M	Northern NSW	High
Fregata minor	Great frigatebird	P	M	All NSW coast	High
Gallirallus philippensis	Buff-banded rail	P	L	All NSW coast	High
Haematopus fuliginosus	Sooty oystercatcher	V		All NSW coast	High
Haematopus longirostris	Pied oystercatcher	V		All NSW coast	High
Haliaeetus leucogaster	White-bellied sea-eagle	P	L, M	All NSW coast	High
Haliastur indus	Brahiminy kite	P	L	Northern NSW	High
Haliastur sphenurus	Whistling kite	P	L	All NSW coast	High
Hamirostra melanosternon	Black-breasted buzzard	V		All NSW coast	High
Heteroscelus brevipes	Grey-tailed tattler	P	L, M	Whole coast except the far south coast	High
Heteroscelus incanus	Wandering tattler	P	M	All NSW coast	High
Himantopus himantopus	Black-winged stilt	P		All NSW coast	High
Ixobrychus flavicollis	Black bittern	V		Rarely occurs south of Sydney	High
Larus dominicanus	Kelp gull	P		All NSW except far north coast	High
Larus novaehollandiae	Silver gull	P	L	All NSW coast	High
Larus pacificus	Pacific gull	P		from Sydney to south coast	High
Larus pipixcan	Franklin's gull	P		All NSW coast	High
Lewinia pectoralis	Lewins rail	P		All NSW coast	High
Limicola falcinellus	Broad-billed sandpiper	V	M	All NSW coast except far north and far south coast	High
Limnodromous semipalmatus	Asian dowitcher	P	M	All NSW coast	High
Limosa haemastica	Hudsonian godwit	P		All NSW coast	High
Limosa lapponica	Bar-tailed godwit	P	L, M	Whole coast except the far south coast	High
Limosa limosa	Black-tailed godwit	V	L, M	From Queensland border to Bermagui	High
Malacorhyncus membranaceus	Pink-eared duck	P		All NSW coast	High
Milvus migrans	Black kite	P		All NSW coast	High
Morus capensis	Cape gannet	P		All NSW coast	High

Scheduled Species/Population/ Ecological Community	Common Name	TSC/FM Act Status	EPBC Act Status	Geographic Distribution	Relevance to Proposal (High, Moderate, Low, None)
Morus serrator	Australasian gannet	P	L	All NSW coast	High
Numenius madagasgariensis	Eastern curlew	P	L	Whole coast except the far south coast	High
Numenius minutus	Little curlew	P	L, M	All NSW coast except far north and far south coast	High
Numenius phaeopus	Whimberal	P	L, M	All NSW coast	High
Nycticorax caledonicus	Nankeen night heron	P	L	All NSW coast	High
Pandion haliaetus	Osprey	V	L, M	Northern NSW south to Wonboyn Lake	High
Pelecanus conspicilliatus	Australian pelican	P*	L	All NSW coast	High
Phalacrocorax fusecesans	Black-faced cormorant	P		All NSW coast	High
Phalacrocorax melanoleucos	Little pied cormorant	P		All NSW coast	High
Phalacrocorax sulcirostris	Little black cormorant	P		All NSW coast	High
Phalacrocorax varius	Pied cormorant	P		All NSW coast	High
Phalaropus lobatus	Red-necked phalarope	P	M	All NSW coast	High
Phalaropus tricolor	Wilsons phalarope	P		All NSW coast	High
Philomachus pugnax	Ruff	P	M	All NSW coast	High
Platea regia	Royal spoonbill	P	L	All NSW coast	High
Platelea flavipes	Yellow-billed spoonbill	P		All NSW coast	High
Plegadis falcinellus	Glossy ibis	P	M	All NSW coast	High
Pluvialis apricaria	Eurasian golden plover	P		All NSW coast	High
Pluvialis dominica	American golden plover	P	M	All NSW coast	High
Pluvialis fulva	Pacific golden plover	P	M	All NSW coast	High
Pluvialis squatarola	Grey plover	P	M	All NSW coast	High
Podiceps cristatus	Great crested grebe	P		All NSW coast	High
Poliocephalus poliocephalus	Hoary-headed grebe	P		All NSW coast	High
Porzana fluminea	Australian spotted crake	P	L	All NSW coast	High
Porzana tabuensis	Spotless crake	P	L	Whole coast except the far south coast	High
Rallus pectorallis	Lewin's rail	P	M	Whole coast except the far south coast	High
Recurvirostra novaehollandiae	Red-necked avocet	P		All NSW coast	High
Stercorarius parasiticus	Arctic jeager	P	M	All NSW coast	High
Stercorarius pomarinus	Pomarine jaeger	P	M	All NSW coast	High

Scheduled Species/Population/ Ecological Community	Common Name	TSC/FM Act Status	EPBC Act Status	Geographic Distribution	Relevance to Proposal (High, Moderate, Low, None)
Sterna albifrons	Little tern	E	M	All NSW coast	High
Sterna bengaiensis	Lesser crested tern	P	M	All NSW coast	High
Sterna bergii	Crested tern	P	L	All NSW coast	High
Sterna caspia	Caspian tern	P		All NSW coast	High
Sterna hirundo	Common tern	P	M	All NSW coast	High
Sterna nereis	Fairy tern	P		All NSW coast	High
Sterna nilotica	Gull-billed tern	P		Whole coast except the far south coast	High
Sterna paradisaea	Arctic tern	P		All NSW coast	High
Sterna striata	White-fronted tern	P		All NSW coast	High
Sterna sumatrana	Black-naped tern	P	M	All NSW coast	High
Tadorna radjah	Radjah shelduck	P		All NSW coast	High
Tadorna tadornoides	Australian shelduck	P	L	Central to southern parts of NSW	High
Thinornis rubricollis	Hooded plover	E		from Sydney to south coast	High
Threskiornis mollucca	Australian white ibis	P	L	All NSW coast	High
Threskiornis spinicollis	Straw-necked ibis	P		All NSW coast	High
Todiramphus chloris	Collared kingfisher	V		All NSW coast	High
Todiramphus macleayii	Forest kingfisher	P		All NSW coast	High
Todiramphus santus	Sacred kingfisher	P		All NSW coast	High
Tringa glareola	Wood sandpiper	P	M	All NSW coast	High
Tringa nebularia	Common greenshank	P	L, M	All NSW coast	High
Tringa stagnatilis	Marsh sandpiper	P	L, M	All NSW coast	High
Tringa totanus	Common redshank	P	M	All NSW coast	High
Tryngites subruficollis	Buff-breasted sandpiper	P	M	All NSW coast	High
Vanellus miles	Masked lapwing	P		All NSW coast	High
Xenus cinereus	Terek sandpiper	V	L, M	Northern Rivers south to Lake Wollumboola.	High
Zosterops luteus	Yellow white eye	P		All NSW coast	High
7. Endangered Populations					
Eudyptula minor	Little penguin population	E		Little Manly, Sydney	High
Posidonia australis	Strapweed	E		Port Hacking, Botany Bay, Port Jackson, Pittwater, Brisbane Waters and Lake Macquarie	High
Carcharias taurus	Grey nurse shark		CE	East Coast	Mod

Scheduled Species/Population/ Ecological Community	Common Name	TSC/FM Act Status	EPBC Act Status	Geographic Distribution	Relevance to Proposal (High, Moderate, Low, None)
8. Ecological Communities					
Coastal saltmarsh (NSW North Coast, Sydney Basin and South East Corner Bioregions)		E		See description	High
Swamp oak floodplain forest (NSW North Coast, Sydney Basin and South East Corner bioregions)		E		See description	High
Swamp Sclerophyll Forest on Coastal Floodplains (NSW North Coast, Sydney Basin and South East Corner Bioregions)		E		See description	Mod
River-flat Eucalypt Forest on Coastal Floodplains (NSW North Coast, Sydney Basin and South East Corner Bioregions)		E		See description	Mod
Subtropical Coastal Floodplain Forest (NSW North Coast Bioregion)		E		See description	Mod
Freshwater Wetlands on Coastal Floodplains (NSW North Coast, Sydney Basin and South East Corner Bioregions)		E		See description	High
The Shorebird community occurring on the relict tidal delta sands at Taren Point		E		Taren Point, Botany Bay	High
Littoral Rainforest and Coastal Vine Thickets of Eastern Australia			CE	All NSW coast	Mod
Eastern Suburbs Banksia Scrub of the Sydney Region			E	Sydney Region	Mod

C.9.2 Key Threatening Processes (KTPs)

KTPs are threatening processes that, in the opinion of the Fisheries Scientific Committee, adversely affect threatened species populations or ecological communities, or could cause species, populations or ecological communities that are not threatened to become threatened. KTPs listed under State legislation that are relevant to the marine stocking proposal include:

- Entanglement in or ingestion of anthropogenic debris in marine and estuarine environments;
- Hook and line fishing in areas important for the survival of threatened fish species; and
- Introduction of non-indigenous fish and marine vegetation to the coastal waters of NSW.

As the marine stocking program proposed by DPI intends only to stock native species the latter KTP (the introduction of non-indigenous fish and marine vegetation to the coastal waters of NSW is not considered further).

The only KTP listed under Commonwealth legislation that is relevant to the proposal is

- Injury and fatality to vertebrate marine life caused by ingestion of, or entanglement in, harmful marine debris.

The potential for the proposed marine stocking program to facilitate any of the above KTPs is discussed in Chapter G.

Relevant KTPs are discussed in more detail below:

Entanglement or ingestion of anthropogenic debris in marine and estuarine environments (TSC Act)

The NSW Scientific Committee has declared entanglement in or ingestion of anthropogenic debris in marine and estuarine environments to be a KTP in NSW. Marine debris is mostly comprised of fishing gear, packaging materials, convenience items and raw plastics. The major sources of marine debris are from ship waste, recreational activities, aquaculture industry and both urban and rural discharges into rivers, estuaries and coastal areas (NSW DECCW 2010c). Marine debris, particularly plastics, can become entangled around or be ingested by marine animals. This can lead to a number of lethal or detrimental impacts for example:

- strangulation;
- increased drag;
- potential poisoning by polychlorinated biphenyls (PCBs);
- blockage and/or perforation of an individual's digestive system;
- wounds caused by line or net and subsequent infection; and
- gastric impaction by plastic bodies.

Even sub-lethal effects of entanglement or ingestion of marine debris may reduce an individual's fitness and ability to successfully reproduce, catch prey and avoid predation. Records kept by the NSW National Parks and Wildlife Service (NPWS) and Taronga Zoo databases show that entanglement in monofilament line, presence of hooks in the mouth and/or gut, net/line wounds and gastric impaction of plastic bodies are the main reasons for injury or mortality in marine wildlife (NSW DECCW 2010c).

A number of threatened marine species including marine turtles, seals, cetaceans and a number of marine birds have been found entangled in marine debris or to have ingested marine debris.

Hook and line fishing in areas important for the survival of threatened fish species (FM Act)

Hook and line fishing refers to the use of a combination of lines and hooks for catching fish, including lines composed of microfilament, wire and cord, with attached lures, hooks and jigs. Hand – lines, set lines, rod and reel fishing, trolling, lure fishing and fly fishing are all included in the activities identified as a KTP. This definition includes catch and release, not just the 'taking' of fish (FSC 2003). Areas that are used for feeding and breeding are considered important for the survival of a threatened species and with the exception of grey nurse shark, such areas are poorly defined, if at all, for the majority of threatened species considered in these assessments. Following identification, some of these areas may be declared as critical habitat, such as 10 of the grey nurse shark aggregation sites along the NSW coast. The grey nurse shark and black cod are considered particularly vulnerable to this KTP (See Chapter G, Section G.2.1.2). Even when accidentally captured, hooks caught in fishes mouths can result in damage that can impact on feeding behaviour and success. The effects of fish hooks can be more serious over a longer time if retained in the mouth, throat and stomach of fishes and sharks, and ultimately can lead to death (FSC 2003). It is recognised that listing all hook and line fishing throughout NSW waters as a KTP would be unpractical and unwarranted. However, where known aggregation sites, spawning areas, important juvenile habitats and feeding areas are concerned, activities that could kill or adversely affect threatened fish species should be considered a threatening process and managed accordingly. A Threat Abatement Plan is yet to be developed for this KTP.

Injury and fatality to vertebrate marine life caused by ingestion of, or entanglement in, harmful marine debris (*EPBC Act)*

This KTP is similar to the KTP listed under the TSC Act, but applies to vertebrate marine life protected under Commonwealth legislation. DSEWPaC has developed a draft Threat Abatement Plan to address the impacts of this KTP (DEWHA 2008).

C.9.3 Areas of Conservation Significance

C.9.3.1 Ramsar Areas

Ramsar sites are areas that have been designated under Article 2 of the Ramsar Convention or declared by the Minister for the environment to be a declared Ramsar wetland under the EPBC Act. Sites containing representative, rare or unique wetlands or wetlands that are important for conserving biological diversity may be declared as a Ramsar site. Once designated, these sites are added to the Convention's List of Wetlands of International Importance and become known as Ramsar sites. Ramsar wetlands can include swamps, marshes, billabongs, lakes, salt marshes, mudflats, mangroves, coral reefs, fens, peat bogs and may be natural or artificial. Water within these areas can be static or flowing; fresh, brackish or saline and can include inland rivers and coastal or marine water to a depth of six metres at low tide (NSW DECCW 2010d). Australia currently has 65 wetlands of international importance listed under the Ramsar Convention, of which, 11 occur in NSW. Ramsar wetlands relevant to the proposal (from north to south) include:

- The Hunter Estuary

The Hunter Estuary Wetlands Ramsar site comprises Kooragang Nature Reserve and Shortland Wetlands. The two areas are about 2.5 km apart and are connected by a wildlife corridor consisting of Ironbark Creek, the Hunter River and Ash Island. Kooragang Nature Reserve is known as one of the most important bird study areas in NSW. The area is extremely important as both a feeding and roosting site for migratory shorebirds. Shortland Wetlands is a small but unique complex of wetland types which is surrounded by urban development along three boundaries (NSW DECCW 2010d).

- Myall Lakes

The Myall Lakes wetlands is approximately 44,612 hectares in area, situated approximately 75 km north of Newcastle between the villages of Hawks Nest and Tea Gardens on the central coast of NSW. Myall Lakes National Park comprises three main lakes (the Bombah Broadwater, Boolambayte and Myall Lakes), together with the lesser areas of Nerong Creek, Two Mile Lake, sections of the Upper and Lower Myall River, Boolambayte Creek, Fame Cove inlet and Broughton Island approximately 2 km offshore from the mainland. The other main features of the Park are the coastal dune system and the forested areas of the Koolonock and Myers Ranges. The Park incorporates a number of distinct wetlands associated with the waterways and dune systems. Little Broughton Island and Corrie Island Nature Reserves are also included within the Ramsar site (NSW DECCW 2010d).

- Towra Point

The Towra Point wetland is approximately 386.5 hectares in area and located 16 km south of the Sydney CBD. Towra Point adjoins the Kurnell Peninsula forming the southern and eastern boundaries of Botany Bay. The site contains approximately half the mangrove communities remaining in the Sydney region and provides habitat for a number of important migratory, wading and wetland birds.

Because of their statutory designation, any part of an estuary occurring within the Ramsar sites identified above would not be considered for marine stocking activities.

C.9.3.2 Marine Protected Areas

Marine Protected Areas (MPAs) include Marine Parks, Aquatic Reserves, National Parks and Nature Reserves. Marine Parks are areas of marine waters and lands permanently set aside to protect the biological diversity of marine plants and animals and to provide protection for unique and representative areas. The NSW system of MPAs encompasses six multiple use marine parks, 12 aquatic reserves and national parks and reserves of which some have marine components (DPI 2011c).

The six Marine Parks in NSW are (from north to south), Cape Byron, Solitary Islands, Port Stephens-Great Lakes, Lord Howe Island, Jervis Bay and Batemans Bay. Apart from the Lord Howe Island Marine Park, all encompass a number of estuaries, lakes and inlets which could potentially be stocked. Under the Marine Parks Zoning Regulation (2009) Marine Parks are zoned for multiple-uses as follows:

- Sanctuary zones – provide the highest level of protection for biological diversity, habitat, ecological processes, natural and cultural features. Recreational, educational activities (or otherwise) that do not involve harming any animal or plant or causing any damage to or interference with natural or cultural features or any habitat are permitted within sanctuary zones. Recreational fishing is not permitted in sanctuary zones and therefore stocking would not take place within or in close proximity to these areas. Consent may be given in exceptional circumstances for scientific research, traditional or public health and safety activities that would not usually be permitted in a sanctuary zone.
- Habitat protection zones - provide a high level of protection for biological diversity, habitat, ecological processes, natural and cultural features. Recreational and commercial fishing, scientific research, educational activities and other activities are permitted provided they are ecologically sustainable and do not have a significant impact on any fish populations or on any other animals, plants or habitats. Lists of specific species that may be caught within a habitat zone are listed within the respective Marine Park zoning plans.
- General use zones - provide protection for biological diversity, habitat, ecological processes, natural and cultural features. Recreational and commercial fishing, scientific research, educational activities and other activities are permitted provided they are ecologically sustainable.

- Special purpose zones – provide for the specific management of aquaculture, fish-feeding and boating facilities such as marinas, slipways and breakwaters, commercial and residential facilities. Sites or items that warrant special management such as shipwrecks may also be provided for.

Under the MP Act these zones are subject to review and amendment processes.

Aquatic Reserves have been established under the FM Act to protect biodiversity and provide representative samples of marine life and habitats. Aquatic Reserves are generally small compared with marine parks, but play a significant role by protecting important habitat, nursery areas and vulnerable and threatened species and also have research and educational roles (NSW MPA 2010b).

Of the 12 Aquatic Reserves that occur in NSW, Barrenjoey Head, Cape Banks, North Harbour, Ship Rock and Towra Point Aquatic Reserves occur within an estuary or on the border of an estuarine system.

Under the NPW Act areas of land can be declared National Parks or Nature Reserves. National Parks are areas of land protected for their unspoiled landscapes, outstanding or representative ecosystems, native plant and animal species and places of natural or cultural significance (NSW DECCW 2011a). Nature Reserves are areas of predominantly untouched land in a natural condition and are considered to have high conservation value. Their primary purpose is to protect and conserve outstanding, unique or representative ecosystems, native plant and animal species or natural phenomena (NSW DECCW 2010e). Nature Reserves are generally terrestrial, but may have associated marine components. Nature Reserves differ from Aquatic Reserves and Marine Parks in that there is no zoning or regulation for multiple uses. Although these areas can protect animals, vegetation and substrata, they do not directly protect fish or aquatic invertebrates from fishing unless through specific arrangements are made with DPI e.g. through designated fishing closures (Breen *et al*. 2005).

C.9.3.3 World Heritage Areas (WHAs)

WHAs are outstanding examples of the world's natural or cultural heritage. The World Heritage Committee oversees listing these areas on behalf of the United Nations Educational, Scientific and Cultural Organisation (UNESCO). The Australian Government has to ensure that Australia's world heritage properties are managed to protect their natural and cultural values.

The assessment of estuaries' suitability to marine stocking (Multi-Criteria Analysis) indicated there were no WHAs that could potentially be affected by the proposal (i.e. there are no WHAs in NSW estuaries below the high water mark). Hence, WHAs are not considered further in this EIS.

C.9.3.4 Wilderness Areas

Wilderness areas represent the largest, most pristine areas in the state's reserve system. The *Wilderness Act 1987* affords declared wilderness the most secure level of protection, requiring it to be managed in a way that will maintain its wilderness values and pristine condition by limiting activities likely to damage flora, fauna and cultural heritage (NSW DECCW 2011b).

The assessment of estuaries' suitability to marine stocking (Multi-Criteria Analysis) indicated there were three Wilderness Areas that could potentially be affected by the proposal, i.e. there were three Wilderness Areas with proposed estuaries within or adjacent to their boundaries, the Bundjalung, Limeburners Creek and Nadgee Wilderness Areas.

C.10 Recreational, Aboriginal and Commercial Fishing

C.10.1 Recreational Fishing

Recreational fishing is a popular pastime and occurs in most NSW estuaries. The exceptions are estuaries which may have spatial and temporal closures to fishing or where the whole estuary has been declared a Marine Park Sanctuary Zone. Short-term fishing bans have also been established in some northern estuaries, on occasion, after mass fish kills from floods or poor water quality.

In many estuaries, recreational fishers use the same areas as commercial fishers and catch similar species. Hence, there is some potential for competition between the two groups. Recreational fishing havens (RFH's) were created in 2002 to improve recreational fishing opportunities (Section C.10.1.3). Notwithstanding this, the recreational sector is dependent on the commercial sector for bait (e.g. prawns, beachworms and some fish species that are harvested in the Estuary General Fishery or Estuary Prawn Trawl Fishery) and a large number of recreational fishers and the community consume commercially harvested seafood.

Recreational fishers use a range of fishing platforms involving boats (private, hire and charter) and the shore (rocks and man-made structures). Many types of fishing gear are used in estuaries. These include: line fishing methods (lines, lures, jigs, fly etc.) for fish; fishing with pots or traps (for crabs); fishing with nets (for prawns); and hand collecting methods (pumps, rakes, spades and hand collecting) for bait.

C.10.1.1 Catch and Effort

Recreational fishing surveys have been done in NSW since the late 1950's. Approximately 30 recreational fishing surveys have now been done, encompassing a range of biological, economic and social issues. Unfortunately, most surveys are limited in their temporal (once-off) or spatial (single lake or estuary) scale which has reduced their value in assessment of resources and their management on a State-wide basis. Short term surveys have provided information for localised management issues, but there is an ongoing need for additional large-scale, longer term, monitoring programs into the management of recreational fisheries, such as those in place for commercial fisheries.

The National Recreational and Indigenous Fishing Survey (hereafter called the National Survey) provided information relating to recreational fishing patterns and levels of harvest at a State-wide scale (Henry and Lyle 2003). DPI have summarised the information from that report as it relates to NSW in a report entitled Survey of Recreational Fishing in NSW (NSW Fisheries 2003b). Much of the information presented below has been taken from that report.

The National Survey estimated that there were approximately one million recreational fishers in NSW and that the proportion of the population that participated in recreational fishing was 17.1 %. Interstate participation is also important with 7.3 % of fishing events in NSW done by interstate visitors. The participation rate in NSW country regions was estimated to be twice as high as the rate observed in the main metropolitan area. The highest rate of participation occurred on the NSW south coast (30.1 %) while Sydney recorded the lowest (13.1 %). However, Sydney had the largest number of recreational fishers (482,739 fishers) by virtue of its population size. Almost half the State's recreational fishers lived in Sydney. The Hunter (131,348 fishers), Mid-North Coast (74,441 fishers) and Illawarra (73,686 fishers) were also important recreational fishing communities.

Recreational fishing activity was greatest in estuarine waters (47 % of total events). Line fishing methods (lines, lures, jigs, fly, and setlines) accounted for 90 % of activity. Bait gathering with pumps, rakes, spades and hand collecting accounted for 4 % of effort. Pots and traps accounted for 4 % of effort. Recreational diving with spears or for hand collecting (1 %) accounted for the smallest level of effort. 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 done from private fishing boats as opposed to 4 % from charter vessels and 4 % from hire boats. The range of fishing activity varied from one day fishing per person per year to 169 days fishing per person per year. The average was 6.9 days fishing per person per year. At the lower end of the effort scale, i.e. fishers who fished for 1-5 days per year, a large number of fishers (50 % of fishers) were responsible for a relatively small amount of the fishing effort (less than 20 % of the total effort). At the top of the scale, 10 % of fishers were responsible for nearly 30 % of the fishing effort.

In all waters of NSW, recreational fishers harvested approximately 13 million finfish (e.g. bream, whiting, flathead), 1.3 million baitfish (e.g. pilchards, yellowtail), 500,000 crabs and lobsters, 16 million prawns and yabbies, 1.2 million shellfish (e.g. abalone, pipi, oysters), 160,000 squid and cuttlefish and 300,000 miscellaneous fish molluscs and crustaceans. Flathead, bream, whiting, tailor and luderick were among the most prominent species in the NSW catch. Other estuarine species such as prawns and crabs were obviously important to recreational fishers (i.e. they were nominated as their target and had a large harvest). Prawns were harvested in greater numbers than any other recreational species while yabbies and blue swimmer crabs were harvested in larger numbers than most fish species. All of these species with the exception of tailor are listed as either primary or key secondary species for the commercial Estuary General Fishery.

Comparisons between the recreational and commercial catches in NSW indicated that both sectors harvested about 200 species of fish. For popular recreational species, the recreational catch is about 33 % of the total catch (Table C.9). As the major portion of the recreational catch was taken from estuarine waters it is likely that recreational catch is a much greater proportion of total catch in estuaries. Indeed, the six species taken in greater numbers by recreational fishers are generally common estuarine species. These were flathead (unspecified), bream (unspecified), mulloway, yellowtail kingfish, nippers (yabbies) and catfish (unspecified).

Table C.9: Recreational fishing catch compared with commercial fishing catch for commonly caught recreational species in 2000/1.

Grey shading indicates species proposed for marine stocking. Source: NSW Fisheries (2003b).

	Sector	
Species	**Recreational (kg)**	**Commercial (kg)**
Whiting (Sillaginidae)	394,081	1,181,793
Flathead (Platycephalidae)	886,824	496,335
Bream (Acanthopagrus spp.)	728,752	365,383
Garfish (Hemiramphidae)	22,672	97,875
Tailor (*Pomatomus saltatrix*)	252,736	190,675
Australian salmon (*Arripis trutta*)	221,977	790,143
Snapper (*Pagrus auratus*)	116,967	273,159
Trevally (Carangidae)	87,530	273,884
Leatherjackets (Monacanthidae)	107,966	117,034
Wrasse/tuskfish/gropers (Labridae)	52,373	69,810
Luderick (*Girella tricuspidata*)	280,130	503,600
Mackerels (Scombridae)	128,627	443,567
Cod (various)	8,133	35,835
Catfish (Siluriformes)	94,222	28,965
Mulloway (*Argyrosomus hololepidotus*)	273,703	63,796
Morwong (Cheilodactylidae)	139,929	429,606
Tuna/bonitos (Scombridae)	844,480	1,000,500
Sharks/rays (Chondrichthys)	60,186	441,090
Yellowtail kingfish (*Seriola lalandii*)	180,003	137,349
Prawns (Penaeidae)	104,833	2,346,976
Blue swimmer crab (*Portunus pelagicus*)	154,831	165,461
Squid/cuttlefish (Sepiidae)	65,717	824,183
Mud crab (*Scylla serrata*)	30,000	135,144
Lobsters (Palinuridae)	7,398	120,000
Abalone (*Haliotis rubra*)	10,570	304,000
Nippers (Thalassinidea)	15,167	0
Total	**5,269,807**	**10,836,163**

Average recreational catch rates in NSW for the seven species listed for the proposed marine stocking activity can be estimated from the National Survey. These estimates, however, are coarse and do not discriminate estuarine catch and effort from that in oceanic waters. Avid recreational fishers who target particular species are likely to have much higher catch rates for their target species. These estimates, along with catch rates for particular species, where they have been estimated in other studies are presented in Table C.10.

Table C.10: Catch rate (kg per angler hour) for species relevant to the marine stocking program.

		Catch per angler hour			
Species		**Henry and Lyle (2003)**	**Steffe *et al*. (2005a)**	**Steffe *et al.* (2005b)**	**Reid and Montgomery (2005)**
Unspecified whiting	Sillaginidae	0.078	-	-	-
Sand whiting	*Sillago ciliata*	-	0.000 - 0.150	0.000 - 0.090	-
Unspecified flathead	Platycephalidae	0.096	-	-	-
Dusky flathead	*Platycephalus fuscus*	-	0.000 - 0.160	0.000 - 0.310	-
Unspecified bream	Sparidae	0.090	-	-	-
Yellowfin bream	*Ancanthopagrus australis*	-	0.000 - 0.440	0.010 - 0.140	-
Mulloway	*Argyrosomus japonicus*	0.006	-	-	-
Unspecified prawns	Penaeidae	0.481	-	-	0.05 - 1.05
Blue swimmer crab	*Portunus pelagicus*	0.018	0.000 - 1.600	-	-
Giant mud crab	*Scylla serrata*	0.002	-	-	-

C.10.1.2 Expenditure

The National Survey provided information on the economic activity associated with recreational fishing in NSW, i.e. the expenditure of fishers during the course of fishing. This is not an estimate of the 'value' of recreational fishing to the community - that needs to be explored by different techniques. However, economic activity, in this case direct expenditure, is useful information to help understand the importance of fishing to regional economies.

Recreational fishers in NSW spent more than $550 million on fishing related items during the survey year. Expenditure varied from 100 % in the case of fishing gear to 1-2 % in the case of other items. Boat and trailer ($276 million) was the largest individual expense. These items accounted for approximately 50 % of the expenditure of NSW fishers. Vehicle and other travel costs related to fishing ($118 million), accommodation on fishing related trips ($54 million) and fishing gear ($46 million) followed in importance. More than $26 million was spent on the charter/ hire of boats and $12 million on bait/ burley/ice. This expenditure pattern may reflect the fishing opportunities and characteristics of NSW recreational fisheries. Anglers in NSW are willing to travel to fish and use boats. The estimated expenditure by NSW recreational fishers equates to an average expenditure of about $550 per angler per year.

C.10.1.3 Recreational Fishing Havens

In 2002, 30 locations along the NSW coast were set aside for recreational fishing following a buyout of commercial fishing entitlements (Table C.11). Some of the North Coast estuaries are partial RFH's where commercial fishing still occurs in some areas. The purpose of these RFH is to improve opportunities for recreational fishing in key areas of significance to recreational fishers. The process was facilitated through buyouts of commercial fishing entitlements, surrendered in exchange for ex-gratia payments (I&I NSW 2005a).

Table C.11: The 30 Recreational Fishing Havens (RFH's) in NSW.

Note that RFH's include all bays, tributaries, creeks, canals and artificial lakes within that area. 'Closed' refers to closure to commercial fishing (source: I&I NSW 2005a).

Estuary	Notes
Tweed River	Closed downstream from Boyd's Bay Bridge and from south of Rocky Point east to Fingal Road. Wommin Lake, Wommin Lagoon and six canal estates beyond that area is also closed (ie. Seagulls Canal, Tweed West Canals, Blue Water Canals, Crystal Waters Canal, Endless Summer Canal Estate, Oxley Cove).
Richmond River	Closed downstream from a line drawn east across the Richmond River from the south eastern corner of portion 21 which is the river end of Emigrant Point Lane beside the flood gate. Crab trapping and eel trapping continues to be permitted in the river and Emigrant creek upstream from the Burns Point ferry. Commercial sea mullet hauling is allowed within the Recreational Fishing Haven – adjacent to Shaws Bay below the Missingham Bridge – from 1 April to 31 July.
Clarence River	The following areas are closed: 1) Middle Wall - a 2 kilometre stretch at the Clarence River mouth near Yamba (hauling during the mullet travelling season - April to August - is still permitted in this area). 2) Romiaka Bridge - waters adjacent to the Romiaka Channel Road Bridge, just outside Yamba. 3) Oyster Channel Bridge - waters adjacent to Oyster Channel Road Bridge, near Yamba. 4) Entrance of Saltwater Inlet - a 300 metre stretch of River on the eastern side of North Arm, between Arris Island and Saltwater Inlet, near Iluka.
Bellinger River (including Kalang River)	Completely closed.
Deep Creek	Completely closed.
Hastings River	Completely closed.
Camden Haven River	Closed downstream from Dunbogan Bridge and North Haven Bridge (including Gogleys lagoon).
Manning River	Closed downstream from Ghinni Ghinni and Berady Creek (including Scotts Creek).
Lake Macquarie	Completely closed.
Botany Bay	Closed with the exception of abalone gathering and rock lobster trapping. Note - Abalone gathering is currently prohibited - see the closure notice.
St Georges Basin	Completely closed.
Lake Conjola	Completely closed.
Narrawallee Inlet	Completely closed.
Burrill Lake	Completely closed.
Lake Tabourie	Completely closed.
Meroo Lake	Completely closed.
Tomaga River	Completely closed.
Tuross Lake (including Tuross River and Borang Lake)	Completely closed.
Lake Brunderee	Completely closed.
Dalmeny Lake (also known as Mummaga Lake)	Completely closed.

Estuary	Notes
Little Lake (also known as Little Tilba Lake and Hoyers Lake)	Completely closed.
Bermagui River	Completely closed.
Nelson Lake (Nelson Lagoon)	Completely closed.
Bega River	Completely closed.
Back Lake (Back Lagoon)	Completely closed.
Pambula River	Completely closed.
Yowaka River	Completely closed.
Nullica River	Completely closed.
Towamba River (also known as Kiah River)	Completely closed.
Wonboyn Lake, River and Wonboyn Beach (to 500 metres from mean high water level)	Completely closed.

C.10.2 Aboriginal Fishing

This Section provides information about the various aspects of Aboriginal connection to estuary fisheries and how that connection is relevant to and affected by the proposal for marine stocking.

C.10.2.1 Aboriginal Cultural Traditions and Estuary Fisheries

The relationship of Aboriginal people to fishery resources in estuaries and other waterways was summarised by Cr Bev Manton (Chairperson of the NSW ALC) in her speech to the Port Stephens – Great Lakes Marine Park Advisory Council in July 2009:

"Aboriginal people have a spiritual, social and customary association with fisheries resources. Aboriginal people have continued their tradition of fishing consistent with our cultural beliefs. It is crucial to Aboriginal culture that this connection be maintained for the present and the future generations. Our fishing rights have provided us with a staple and healthy diet for thousands of years. Seafood kept us healthy and fit for generations but now we cannot fish in our traditional areas, or teach our kids, the next generation of our cultural fishing ways because we cannot fish in there. It has been a long standing concern of our people that cultural fishing has not been adequately recognised by NSW legislation. I hope to have this rectified during my last two years as Chairperson of NSWALC".

C.10.2.2 Aboriginal Estuarine Totems and Traditional Stories

The traditional social structure of Aboriginal communities includes familial or totemic relationships to natural features, plants and animals. When a person or family has a fish species as their totem, they have a deep interest in its full life-cycle and the habitats in which it lives. For example, there are strong cultural links with black bream (or blackfish) which is both a food and a bush medicine for Aboriginal people. Blackfish is seen to eat a weed that needs nutrients supplied from the catchment; it also needs clean sand and logs in the water to lay its eggs; when these are available and the blackfish grows strong, it supports the needs of Aboriginal people. In turn, Aboriginal people have a responsibility to look after the habitats that the blackfish needs (Pers. Comm. Ben Cruise, Eden LALC).

There are also stories about the relationship between Aboriginal people and dolphins along the NSW coast. For example, Faulkner 2000 refers to a documented tradition of dolphins assisting Aboriginal people to fish on the beaches in the Yaegl territory at Yamba. Faulkner refers to a similar relationship in the Moreton Bay region, at Bribie Island and North Stradbroke Island in QLD. Mick Leon (pers. comm. 2003) from the mid north coast, noted that dolphins are considered as 'brothers' on that part of the coast. The Gumbaingirr people on the mid north coast (English 2002) also tell of people calling to the dolphins from the headland at Corindi. Yuin people also rely on communication from plants for important ecological information about totem species.

It is clear that marine/aquatic species are totems or kin for coastal Aboriginal people, including dolphins, ducks, sea eagles and possibly bream; these traditional relationships continue today and for those with traditional knowledge, the concept of kinship with animal and plant species underpins Aboriginal community approaches to the management of land and sea country. However, there appears to be limited documentary information about kinship with particular fish species. Previous research projects such as those conducted under the OEH (then NPWS) Biodiversity Program refer to people relying on even quite small coastal lakes and creeks (such as Corindi Lake for the Gumbaingirr people) for a range of resources, such as oysters, prawns, crabs, turtles, fish and birds, and also wood worm. Fishing activities are highly valued by Aboriginal people. There is much less historical information about the species of fish that were targeted or whether any of these species were identified as having kinship relationships with local Aboriginal people.

The key principle of kinship to animal species is to look after them and their habitat. In this context, marine stocking using species that are generally valued by Aboriginal people may be seen as positive. The value of fish stocking to Aboriginal people is considered to increase if Aboriginal people had an active role in the stocking activities or in monitoring how stocked fish interact with wild fish stocks.

C.10.2.3 The Archaeology of Aboriginal Estuarine Fisheries

Aboriginal archaeological sites along the NSW coast and estuarine shorelines provide evidence of the continuity of fishing over 6000 years or more. In excess of 1500 midden sites have been recorded along the NSW coast. Midden sites are identified by the presence of shell from edible species, but also often include remains of fish species. Also along the coast are open campsites, artefact scatters and rock shelter deposits, which do not contain shell, but may contain bones of fish, birds or other animals.

The largest middens in NSW are located in the Macleay Valley (Clybucca and Stuarts Point), and similar large sites are known along the Richmond and Clarence Rivers. Mounded middens are also known from Pambula, Wallaga Lake, Wagonga Inlet and Sussex Inlet (near Wreck Bay) on the south coast. The Clybucca middens are up to four metres high, and several kilometres in length; they are estimated to contain between 150,000 and 200,000 cubic metres of material.

Despite the large volume of material in estuarine midden sites, McBryde (1982) estimated that the shell fish remains could only account for less than 1 % of the total diet of Aboriginal people over the 2000 years that the middens accumulated. For these observations to be consistent with the ethnographic observations of Aboriginal fishing and the account of Aboriginal people themselves of the significance of fishing activity for community well being, then much of the fish and shellfish must have been consumed elsewhere. For instance, there are many accounts (such as Threlkeld, in Gunson 1974) of Aboriginal people cooking and eating fish in their canoes.

There is a tendency towards an increasing variety of fish species and sizes in the upper layers of midden sites. Several authors suggest that this is due to the introduction of new fishing techniques (particularly line fishing) over time. Dates for fish hooks are all less than 1000 years. On the south coast, there is also an apparent change towards consumption of hairy mussel and edible mussel over the last 1000 years.

Common fish species in archaeological sites include snapper, southern bream, black bream, blue groper, red rock cod, leather jacket, dusky flathead, wrasse (Labridae), luderick, morwong (Cheilodactylidae), wirrah, tailor, sand whiting, mullet (Mugilidae) and Australian salmon (Poiner 1980).

There are frequent references in the literature highlighting the use of specific fishing techniques to target fish in particular habitats, of particular species and size. Methods include fish traps or weirs (made of rock and plant material), hook and line, four pronged spears from land or canoe, butterfly style nets and combinations of these.

C.10.2.4 Ethnographic Records

There are many nineteenth century ethnographic references to Aboriginal people fishing in north and south coast estuaries, at estuary mouths and around headlands. Although these descriptions would have been affected by the cultural values of the European sailors and settlers who made them, they do provide a clear indication of the ways in which coastal Aboriginal people accessed fishery resources and of the dependence of coastal Aboriginal people on fish and shellfish as key sources of nutrition. This does not mean that coastal Aboriginal people only ate fish and shellfish, or that they relied on fish and shellfish as staples for the whole year – many of their other subsistence activities involving hunting and gathering in bushland would have been much less obvious to European observers. The frequent references to Aboriginal people very quickly spearing or netting sufficient fish to feed substantial groups of people, does however, suggest that fish were abundant in estuaries. Aboriginal fishers note that they always target what is seasonally available, increasing the impression of abundance (mullet, tailor, salmon etc.).

Another important observation from the ethnographic and historical records and in comments from contemporary Aboriginal fishers is that Aboriginal people have targeted diverse species in estuarine waterways – from wood worms to eels to whales and a wide range of shellfish and water birds. They appreciated and drew on the complexity of estuarine ecology. These historical records are consistent with the attitudes expressed by people consulted about the proposed marine stocking, that looking after fish stocks should mean more than just adding fingerlings of fin fish. In their view, looking after estuary health and fish stocks requires attention to all types of estuary habitat, and to a range of invertebrate species, not just fish.

C.10.2.5 Estuarine Fishing and the Wellbeing of Contemporary Aboriginal Communities

The traditions of fishing continue through the modern generations of coastal Aboriginal families, particularly those living in regional coastal areas. However, English (2002) also notes that traditions that were strong in the 1950s, 1960s and 1970s have declined over the last 30 years, partly because of reduced access to private land, pollution of waterways, land clearing and changes to social welfare access, natural resources legislation, availability of vehicle transport and changing work conditions for Aboriginal people. An example is the decline in reliance on fish resources from Corindi Lake, which became more polluted in the 1970s as the local town grew rapidly. In the 1970s the Gumbaingirr people still relied on Corindi Lake for fish, oysters, prawns, crabs, turtles, fish and birds. In the early and mid twentieth century, many of the Aboriginal camps and missions were in relatively isolated places, with limited road access. The traditional cultural knowledge of people living in these coastal and estuarine places was essential for subsistence and to medicine and also 'cemented' attachment to country. In recent decades, Aboriginal people have not needed to hunt, fish and collect resources to the same extent as previously, but some traditions have been maintained – as much to continue connections to country and respect for Elders as for economic necessity (English 2002).

English (2002) suggests that the loss of access to land based resources since the 1960s and 70s may have been more dramatic than loss of sea resources. Many of the terrestrial places mapped by Gumbaingirr people in the study had not been used for many years. Modern wild resource use along the coast has therefore become more focused on sea resources such as fish and shellfish (and coastal plants). On the south coast, Smyth (1997) reported that 90 % of adult Aboriginal people in the community fished regularly, making fish a core component of the community's diet. Aboriginal commercial fishers on the NSW south coast are reported to work seasonally both in vegetable picking and in beach or estuary hauling (Chapman 1996). Chapman refers to 'circular fishing', whereby Aboriginal people employ a circular method of fishing for whatever is in season at the time. This is illustrative of the approach that Aboriginal fishers have taken to fishing and is consistent with other ethnographic and historical descriptions.

C.10.2.6 Indigenous Fisheries Surveys

DPI conducted a survey of recreational fishing activity (Henry and Lyle 2003), in which data about Aboriginal fishing practices was analysed separately from the general population. Fishing households were first contacted by telephone (i.e. a phone survey) and encouraged to participate in a diary program where monthly information was collected about fish catches, fishing effort and fishing expenditure. Basic information collected about each household included household structure and demographic character (including ethnicity). Of 10,300 households who were sampled by phone survey in NSW (containing 19,600 people over 5 years of age), 1.4 % identified as Aboriginal people. Of 1836 households who participated in the diary program, 1.3 % of households, with 1.7 % of people were Aboriginal (63 people, including both coastal and inland fishers). This is a very small sample, given the Aboriginal population of NSW and the importance of fishing to Aboriginal communities. The 63 Aboriginal fishers who participated in the survey reported going fishing on 266 separate occasions over a ten month period. They reported a very diverse catch and also reported a relatively high release rate.

The reported catch statistics for estuarine/marine species are shown in Table C.12. Species corresponding to those proposed for stocking are highlighted. The three species most commonly reported as being caught by Aboriginal people in this survey (bream, flathead and whiting) are all species proposed to be stocked into estuaries.

Table C.12: Records of the National Recreational Fishing Survey, Aboriginal Households.
Source: Henry and Lyle (2003). Species proposed for marine stocking are highlighted.

Species Common Name	Kept	Released	Total
Bream (*Acanthopagrus* spp.)	32	66	98
Cod – red rock/red scorpion/coral perch (various)		2	2
Flathead (*Platycephalus* spp.)	43	79	122
Flounder/sole/flatfish(Pleuronectiformes)		6	6
Garfish(Hemiramphidae)	30		30
Gurnard (Triglidae)	3		3
Leatherjacket (Monacanthidae)	6		6
Lobster (Panuliridae)	12	11	23
Morwong, blue (*Nemadactylus douglasi*)	0		0
Mullet, unspecified (Mugilidae)	4	7	11
Mulloway//kingfish (*Argyrosomus japonicus/ Seriola lalandi*)	3		3
Salmon, Australian east/west/kahawai (*Arripis trutta*)		1	1
Shark, unspecified (Carcharhinidae)	1		1
Snapper, pink/southern/squire (*Pagrus auratus*)	2	13	15
Tailor/chopper/jumbo (*Pomatomus saltatrix*)	9	7	15
Whiting, unspecified (Sillaginidae)	10	39	49
Yabbies/nippers/bass yabbies (Thalassinidea)	40		40
Fish – other		12	12

Although this was a recreational fishing survey, it should be noted that most Aboriginal fishers who participated would not have considered that they were fishing for recreational purposes. Rather, Aboriginal people consistently report that they are fishing for cultural purposes or for subsistence, or as part of how they look after country and country looks after them. Very often, those who are fishing do so to support an extended family or other kin. The fishing effort by Aboriginal fishers over the period of the survey is greater than the average across the State, hinting at both the subsistence value of catches and the broader community consumption of catches made by Aboriginal people. A more detailed survey and consultation with Aboriginal people in coastal communities was conducted by Schnierer and Faulkner (2002). This research involved 150 questionnaires and multiple interviews with individuals, families and communities. During this consultation, many different fish and invertebrate (shellfish, crabs, prawns, lobsters, squid and cobra worm) species were nominated by Aboriginal communities. Invertebrate species identified as being targeted by Aboriginal fishers are listed in Table C.13. Species that are also proposed as part of the marine stocking program are highlighted. Responses to this survey and consultation reinforce the views expressed in other forums about the importance of fish and shellfish catches as a significant part of the diet of Aboriginal communities along the coast. The responses also highlighted the importance of sharing catches with extended family.

Table C.13: Invertebrates targeted by Aboriginal fishing communities in NSW.
Source: Schnierer and Faulkner (2002). Species proposed for marine stocking are highlighted.

Common Name	Scientific Name	Marine (M) or Estuarine (E)
Abalone	*Haliotis ruber*	M
Beach worm	*various*	M
Bearded mussel	*Trichomya hirsuta*	M
Bimbula cockles	*Various*	E
Blue swimmer crab	*Portunus pelagicus*	M, E
Cobra	*Teredo navilis*	E
Eastern king prawn	*Penaeus plebejus*	E
Edible mussel	*Mytilus planulatus*	M, E
Greasy back prawn	*Metapenaeus bennettae*	E
Lobster	*Various*	M, (E)
Giant mud crab	*Scylla serrata*	E
Mud oyster	*Ostrea angasi*	E
Octopus	*Various*	M, E
Pacific oyster	*Crassostrea gigas*	M, E
Periwinkle	*Various*	M, E
Pipi	*Donax deltoides*	M
School prawn	*Metapenaeus macleayi*	E
Sea urchin	*Various*	M, (E)
Shrimp	*Macrobrachium sp*	E
Squid	Various	M, E
Sydney cockle	*Anadara trapezia*	E
Sydney rock oyster	*Saccostrea commercialis*	M, E
Tapestry cockle	*Tapes watlingi*	E

C.10.3 Commercial Fishing

Commercial fishers operate throughout NSW State waters including estuaries, beaches, bays and ocean. The industry and its fishers, wholesalers, processors and retailers generate many millions of dollars of economic activity each year. Of this, the wild harvest component is worth more than $90 million dollars at first point of sale (I&I NSW 2010i). More than 4000 people work either directly or indirectly in the industry, including approximately 1000 commercial fishers. The NSW fishing industry is primarily made up of small family businesses that rely on high levels of local knowledge and skills learnt over many generations.

The main commercial fisheries in NSW operate within estuaries are the Estuary General Fishery and the Estuary Prawn Trawl Fishery. To a much lesser extent, the Ocean Hauling fishery may operate in Jervis Bay and Port Hacking and some commercial lobster fishermen may work within estuaries, although this would be rare.

C.10.3.1 Estuary General Fishery

The Estuary General Fishery is a share management fishery and is divided geographically into seven regions from the Far North Coast to the Far South Coast of NSW. It is a multi-species multi-method fishery that may operate in 76 estuaries in NSW (Table C.14). It is the most diverse commercial fishery in NSW and comprises approximately 600 fishing businesses authorised to utilise 17 types of fishing gear. This fishery is a significant contributor to regional and State economies providing high quality seafood and bait to the community (I&I NSW 2010a). In 2008/9, the total catch was 3,128 t and this was worth $18,945,000 based on Sydney Fish Market monthly average price (I&I NSW 2010b).

Table C.14: Regions of the Estuary General Fishery and estuaries open to commercial fishing.

A reference to an estuary includes a reference to all creeks, rivers, lakes, lagoons and tributaries flowing into or from that estuary (Source: Fisheries Management (Estuary General Share Management Plan) Regulation 2006).

Region	Description of Region	Estuary
1 - Upper North Coast	That part of the State lying generally between the border between the States of QLD and NSW and the parallel 29°15' south latitude	Tweed River, Cudgen Lake, Cudgera Creek, Mooball Creek, Brunswick River, Richmond River, Evans River and Jerusalem Creek
2 - Clarence	That part of the State lying generally between the parallel 29°15' south latitude and the parallel 29°45' south latitude	Clarence River and Sandon River
3 - North Coast	That part of the State lying generally between the parallel 29°45' south latitude and the parallel 31°44' south latitude	Wooli Wooli River, Station Creek, Corindi River, Arrawarra Creek, Darkum Creek, Woolgoolga Lake, Hearns Lake, Moonee Creek, Coffs Harbour Creek, Boambee Creek, Bonville Creek, Dalhousie Creek, Oyster Creek, Nambucca River, Macleay River, South West Rocks Creek, Saltwater Creek, Korogoro Creek, Killick Creek, Lake Cathie (Lake Innes) and Camden Haven River
4 - Central	That part of the State lying generally between the parallel 31°44' south latitude and the parallel 33°25' south latitude	Manning River, Khappinghat Creek, Wallis Lake, Smiths Lake, Myall Lakes (Myall River), Port Stephens (Karuah River), Hunter River and Tuggerah Lakes
5 - Metropolitan	That part of the State lying generally between the parallel 33°25' south latitude and the parallel 34°20' south latitude	Hawkesbury River and Port Hacking
6 - Upper South Coast	That part of the State lying generally between the parallel 34°20' south latitude and the parallel 35°25' south latitude	Towradgi Creek, Lake Illawarra, Minnamurra River, Spring Creek, Werri Lagoon, Crooked River, Shoalhaven River, Lake Wollumboola, Jervis Bay, Swan Lake, Berrara Creek and Nerrindillah Creek
7 - Lower South Coast	That part of the State lying generally between the parallel 35°25' south latitude and the border between the States of NSW and VIC	Termeil Lake, Willinga Lake, Durras Lake, Clyde River (Batemans Bay), Moruya River, Congo Creek, Coila Lake, Lake Brou, Wagonga Inlet, Corunna Lake, Tilba Tilba Lake, Wallaga Lake, Barragoot Lake, Cuttagee Lake, Murrah Lake, Bunga Lagoon, Wapengo Lake, Middle Lake (Bega), Wallagoot Lake, Bournda Lagoon, Merimbula Lake, Pambula Lake and Curalo Lake

The most frequently used fishing methods in the Estuary General Fishery are meshing and hauling nets. Other methods include:

- prawn nets (set pocket, running, seine, hand-hauled, push or scissors, dip or scoop);

- fish traps;
- eel traps;
- handlining;
- mud crab traps (including lift or hoop nets); and
- hand picking.

The hand gathering of pipis and beachworms from ocean beaches is also part of this fishery.

On average, the 10 species that make up over 80 % of landings by weight are sea mullet 40 %, luderick 8 %, yellowfin bream 8 %, school prawn (*Metapenaeus macleayi*) 5 %, blue swimmer crab 4 %, dusky flathead 4 %, sand whiting 3 %, pipi 3 %, giant mud crab 3 % and silver biddy 2 %. Five of these are included in the proposal for marine stocking.

Although the fishery operates in many estuaries, some are more important to commercial fishers (in terms of productivity) than others (Table C.15). It is also noteworthy that although most of the seven species proposed for stocking are harvested in each of the estuaries that the fishery operates in, some species dominate the catch in some estuaries while other species dominate in others.

Table C.15: Estuary General and Estuary Prawn Trawl Commercial fishing catch (kg) by estuary in 2008/09 for the species relevant to the current proposal.

Source DPI ComCatch 20-10-2010 (extract). For confidentiality, where < 6 fishers operated in an estuary, catches were included in the 'other' category.

Estuary	Sand Whiting	Dusky Flathead	Bream (Yellowfin & Black)	Mulloway	Eastern King Prawns	Blue Swimmer Crab	Giant Mud Crab
Richmond River	378	574	986	648			3,620
Tweed River	4,026	2,905	819	505			6,374
Clarence River	12,331	9,855	38,793	1,983	47	3	10,503
Lake Wooloweyah	1,619	2,201	6,798	158			2,237
Camden Haven River	2,411	9,394	4,356	251		572	8,560
Lake Innes/Lake Cathie	1,818	7,330	1,043	75		215	1,941
Macleay River	1,641	1,387	1,642	3,134		219	3,807
Nambucca River	2,019	1,124	5,442	825		21	3,332
Hunter River	3,010	3,740	6,377	2,852	269	646	91
Manning River	1,449	3,913	2,178	329	287	2	302
Myall Lakes/Port Stephens	7,818	12,531	19,530	1,375	58	15,844	6,527
Smiths Lake	2,963	3,768	4,087	34		1,565	362
Tuggerah Lakes	12,607	22,397	38,037	967	13,988	5,020	672
Wallis Lake	22,723	27,455	19,750	135	10,960	57,255	13,005
Hawkesbury River	2,447	2,261	8,605	3,649	3,038	2,501	256
Lake Illawarra	8,383	1,821	11,207	402	10,010	12,036	310
Lake Wollumboola	24	6	402				
Shoalhaven River	10,774	2,460	2,907	2,901		34	26
Coila Lake	151		2,119				
Corunna Lake	55	219	4,652		71	11	
Cuttagee Lake		57	573		365	59	
Moruya River	1,218	633	810	57			

Estuary	Sand Whiting	Dusky Flathead	Bream (Yellowfin & Black)	Mulloway	Eastern King Prawns	Blue Swimmer Crab	Giant Mud Crab
Wallaga Lake	74	1,312	11,715	57		13	
Other Estuary	854	2,819	5,572	252	21	96	990
Total	**100,792**	**120,160**	**198,396**	**20,587**	**39,114**	**96,111**	**62,914**

C.10.3.2 Estuary Prawn Trawl Fishery

The Estuary Prawn Trawl Fishery is a share management fishery. Fishers use otter trawl nets to target school prawns and eastern king prawns in three estuaries in NSW (the Clarence, Hawkesbury and Hunter Rivers). Eastern king prawns are included in the proposal for marine stocking. Overall, school prawns comprise a major part of the total fishery catch, with the proportion of non-target species contributing to the catch varying between estuaries (I&I NSW 2010c).

With the exception of the Hawkesbury River, the fishery operates for defined seasons (generally October to May) and within each estuary is confined to specific times and areas. The majority of prawn catches are landed during the 'dark' of the moon (between the last and first quarter), on either run out or 'slack' tides (I&I NSW 2010c).

In 2008/9, the total catch was 620 t and this was worth $3,730,000 based on Sydney Fish Market monthly average price by species (I&I NSW 2010c). This was 4 % of the total commercial catch from NSW and 5 % of the value of the total catch.

C.10.3.3 Other Fisheries

Three other fisheries, although not able to operate directly in most estuaries, are dependent on fish and crustaceans moving out of estuaries at some point in their life cycle. These are the Ocean Hauling Fishery, Ocean Trawl Fishery and Ocean Trap and Line Fishery. Many of the species caught in the estuarine fisheries are also caught in these ocean fisheries (Table C.16).

Table C.16: Top 50 species caught in NSW estuaries.

Includes Estuary General and Estuary Prawn Trawl and three that mainly operate in oceanic waters (Ocean hauling, Ocean Trap and Line and Ocean Hauling) for years 2008/2009, by weight (tonnes). Highlighted rows are species proposed for the marine stocking program. Source: DPI ComCatch 20-10-2010 (extract).

	Fishery						
Species	**Estuary General**	**Estuary Prawn Trawl**	**Ocean Hauling**	**Ocean Trawl (Fish)**	**Ocean Trawl (Prawn)**	**Ocean Trap and Line**	**Total**
Pilchard	4	6	2,222	2	0	5	2,240
Mullet, Sea	1,192		574			0	1,766
Australian salmon	16	0	1,508	0		8	1,531
Prawn, School	290	569			140		999
Whiting, School		0		335	597		932
Prawn, Eastern King	36	3			528		567
Leatherjacket, Unspecified	6	1		79	7	364	457
Mackerel, Blue	0	0	388	2	0	40	431
Yellowtail	5	3	224	27	26	22	306
Luderick	281		21			0	302
Snapper	1			4	0	239	244
Bream, Black and Yellowfin	198	0	15	1	0	16	230
Flathead, Tiger				208	1		208
Bonito	0		0	0	0	183	184
Flathead, Sand	6		0	114	44	2	166
Sandy sprat (whitebait)	11	0	140				150
Kingfish, Yellowtail	1			0	0	132	133
Mullet, Sand	121		11				132
Flathead, Dusky	120	0	0	1	2	0	123
Silver biddy	103	9	1	6	3		122
Lobster, Eastern Rock							0
Whiting, Sand	101		7	0	4	0	113
Abalone, Blacklip							0
Crab, Blue Swimmer	94	2		0	3	0	100
Trevally, Silver	11		0	65	0	22	99
Octopus	3	1		4	83	5	96
Sea Urchin and Turban Shell							0
Eel, Longfin River	70	0	0			0	70
Mullet, Fantail	63		5				68
Spanner crab						68	68
Shark, Fiddler	0	0		53	8	3	64
Crab, Mud	63	0			0		63
Cuttlefish	2	0	0	24	34	1	60

Species	Fishery						
	Estuary General	Estuary Prawn Trawl	Ocean Hauling	Ocean Trawl (Fish)	Ocean Trawl (Prawn)	Ocean Trap and Line	Total
Tailor	16		7	1	0	25	49
Shark, Gummy	0			8	3	34	45
Sweep	0		2		0	40	42
Whiting, Trumpeter	34	7	0	0			41
Morwong, Rubberlip	0			7		33	39
Bug, Balmain				2	37		39
Mulloway	21	0	10	0	0	5	36
Dory, John				33	1	0	33
Squid	1	16	0	3	12	0	33
Garfish, Sea	6		27				33
Pipi	32						32
Calamari, Southern	0		0	28	2	0	31
Shark, Angel				28	3	0	31
Redfish				25	1	2	28
Carp	0						0
Tarwhine	16		4	6	1	1	27
Blue-eye						27	27
Other Species	206	4	21	183	133	306	852
Gross reported Tonnes	3,128	620	5,187	1,252	1,673	1,583	13,443
Est. Value of Landings$ '000	**$18,945**	**$3,730**	**$15,096**	**$5,827**	**$15,170**	**$10,171**	**68,939**

Ocean Hauling Fishery

The Ocean Hauling Fishery divided into 7 regions along the NSW coast and targets approximately 20 finfish species using commercial hauling and purse seine nets from sea beaches and in ocean waters within 3 nautical miles of the NSW coast.

The catch is mainly made up of pilchards (*Sardinops sagax*) 34 %, sea mullet 30 %, Australian salmon 17 %, blue mackerel (*Scomber australasicus*) 8 %, yellowtail scad 5 % and yellowfin bream 2 % of the total catch (I&I NSW 2010d).

In 2008/9, the total catch was 5,187 t and this was worth $15,096,000 (DPI ComCatch 20-10-2010 (extract)). This was 38 % of the total commercial catch from NSW and 19 % of the value of the total catch.

Ocean Trawl Fishery

There are two sectors to the NSW Ocean Trawl Fishery: the prawn trawl sector and the fish trawl sector. Both sectors use similar gear, the otter trawl net, and many of the fishers endorsed for fish trawling are also endorsed for prawn trawling.

The major species taken in the Ocean Trawl Fishery include school whiting (comprising of stout whiting and red spot whiting), eastern king, school and royal red prawns (*Haliporoides sibogae*), tiger flathead (*Neoplatycephalus richardsoni*), silver trevally (*Pseudocaranx dentex*), various species of sharks and rays (Chondrichthys), squid, octopus and bugs (*Ibacus* spp.) (I&I NSW 2010e). In 2008/9, the total catch was 2,925 t and this was worth

$20,997,000 (DPI ComCatch 20-10-2010 (extract)). This was 21 % of the total commercial catch from NSW and 26 % of the value of the total catch.

Ocean Trap and Line Fishery

The Ocean Trap and Line fishery is a multi-method, multi species fishery targeting demersal and pelagic fish along the entire NSW coast, in continental shelf and slope waters. Snapper, yellowtail kingfish, leatherjackets, bonito (*Sarda* spp.) and silver trevally form the bulk of the commercial catch. Other key species include rubberlip (grey) morwong, blue-eye trevalla (*Hyperoglyphe antarctica*), sharks, bar cod and yellowfin bream. Spanner crabs (*Ranina ranina)* are also harvested from Tweed Heads to Korogoro Point, near Hat Head on the mid-north coast of NSW. Tuna and tuna-like species are primarily managed by the Commonwealth Government outside three nautical miles.

The fishery uses a variety of methods, most commonly involving traps or lines with hooks. The methods used in the fishery (and the key species taken by each method) include: demersal fish trap (snapper, silver trevally, morwong and leatherjackets), setlines/trotlines (snapper and sharks), driftlines (mackerel and tuna (Scombridae), yellowtail kingfish, and sharks), hand-held line (mulloway, yellowtail kingfish and bonito), dropline (blue-eye trevalla and hapuku (*Polyprion oxygeneios*)), trolling/leadlining (yellowtail kingfish, mackerel and tuna) and spanner crab nets, known as a 'dilly'. The spanner crab is a highly regarded seafood product caught on the north coast of NSW. In 2008/9, the total catch was 1,583 t and this was worth $10,171,000 (DPI ComCatch 20-10-2010 (extract)). This was 11 % of the total commercial catch from NSW and 13 % of the value of the total catch.

C.11 Aquaculture

C.11.1 Oyster Farming

The Sydney rock oyster (*Saccostrea glomerata*) is the main focus of oyster production in the State. With a current annual production of over 106 million oysters worth over $35 million, oyster farming has been the most valuable aquaculture industry in NSW for over 100 years (I&I NSW 2010g).

Oyster farming now employs many different techniques, all of which take place on selected sites held under about 3200 aquaculture leases, with a total current area of about 4300 hectares, which are administered by DPI. Commercial production in the State occurs in 41 estuaries between Eden in the south to the Tweed River in the north. Wallis Lake and the Hawkesbury River are the main producing areas.

The first 75 years of the NSW oyster industry saw production grow to approximately 60 million oysters per year. It laid the foundation for unprecedented growth to approximately 175 million oysters per year during the latter 25 years of its history. Production peaked in 1977 and has dropped back to about 101 million oysters per year since 1990. Total production in 2007/8 was 6,350,078 dozen worth $36,064,843.

Three distinct cultivation methods have evolved in NSW over the years; rock culture (now seldom practiced), stick culture and various tray type cultures.

Stick culture has been the mainstay of the industry since the 1930's and commences with oyster larvae settling on tarred (and sometimes additionally cemented) hardwood sticks 1.8 m long and 25 mm square, which are placed in areas of estuaries where spatfall (settling of spat) is most reliable, typically near river mouths. The sticks are then moved to low spatfall areas to reduce 'overcatch' (further spatfall on growing oysters) and are grown to maturity on horizontal racks in the inter-tidal zone. The process takes from 3 to 4 years with great care required in the first two years to protect the oysters from excessive heat and predators (bream, octopus and stingray). At maturity, the oysters are removed from the sticks and graded into various sizes prior to marketing. While this method has proven to be the most efficient for the industry relying on natural catch, it may be less significant should commercial oyster hatcheries establish and produce single seed oysters.

Another method is tray culture. Oyster trays are usually one metre wide and from 1.8 - 2.7 metres in length, of timber and wire or plastic construction. They have many advantages as a cultivation method over earlier methods and in some cases even stick culture. Trays are more portable, easier to manage and allow precise stocking densities to encourage oysters to grow in a more uniform and marketable shape. Oyster farmers have devised techniques to further exploit these advantages culminating in the 'single seed technology'.

The third method is known as single seed culture. Increasingly, oyster farmers are removing oyster spat from the catching surface (usually sticks or PVC slats) very soon after settlement when the oysters are still only 3-8 mm in diameter. Spat are then either placed on specially constructed trays or in recently developed plastic mesh cylinders or baskets. These systems provide excellent protection from predators and the early removal of the stick prevents oysters becoming misshapen or clumped together. Faster growth rates have also been reported. Whilst single seed techniques require substantial capital investment, faster growing, better shaped oysters generally allow more precise grading and the oysters generally receive a higher market price. Research into the commercial production of "triploid" oysters, which grow faster and hold market condition longer, is aimed at further enhancing the viability of single seed culture.

Apart from the production of the unique Sydney rock oyster, fledgling industries farming other species are becoming established in several NSW estuaries. Pacific oysters (*Crassostrea gigas*), which are the most commonly farmed oysters in the world, are now grown in Port Stephens. Production is increasing each year with strong demand bringing high prices. 'Flat' or 'dredge' oysters (*Ostrea angasi*) cultivation is developing in some south coast estuaries. While production is limited by available growing areas, initial returns are good and there is potential for expansion in the cultivation of these native oysters and possible future export opportunities to the large European flat oyster market.

Water pollution is one problem that oysters are subject to however; environmental stress can manifest itself in many forms, all of which may affect oysters. Oyster farms can also affect the environment, but when properly managed, oystering is a low impact and sustainable industry relying, however, on a well managed catchment. Oyster leased infrastructure provide important habitat for fish populations, especially their juvenile stages, as well as important foraging areas for protected bird species such as the pied and sooty oyster catchers. Oysters in trays are also preyed upon by stingrays and giant mud crabs. Due to the attraction of oyster lease areas to many species of fish, oyster leases and their surrounds also provide significant opportunities for recreational and in some cases commercial fishers.

C.11.2 Other Marine Aquaculture

The non-oyster marine based aquaculture activities in NSW are developed around both oceanic and estuarine aquaculture based industries culturing finfish, crustaceans and molluscs. Submerged Crown land leases for oceanic based aquaculture activities have been issued in Twofold Bay, Botany Bay and off Port Stephens.

Commercial mussel farming has been conducted in Twofold Bay since the mid 1970s. The waters of Twofold Bay are fed by the convergence of the tropical Eastern Australian Current (EAC) meeting with the temperate waters of the Tasman Sea which provides an excellent environment for mussel aquaculture. Mussel farming is restricted to the colder waters of Australia. The average sea surface temperature of about 19 °C in the waters of Twofold Bay has resulted in some of the fastest growth rates for blue mussel (*Mytilus edulis*) in Australia. The mussel farming leases occupy about 50 hectares in Twofold Bay and are located off Oman Point and Torarago Point. Mussels are cultivated using both raft and longline culture methods. Culture ropes are hung under the rafts to collect naturally occurring mussel spat which settle naturally on the ropes. The ropes once the mussel spat has settled are then moved onto the main lines of longlines for growout.

Port Stephens and Botany Bay are the State's only sea cage aquaculture farms which utilise sea cage technology to culture species such as snapper, mulloway and kingfish. The lack of availability of shore based facilities to support offshore sea cage culture in NSW has limited the development of this aquaculture sector in NSW.

The non-oyster estuarine aquaculture in NSW is based on land based aquaculture facilities which access estuarine waters for the production of predominantly marine finfish and prawns. The NSW Government, industry and other relevant stakeholders have cooperatively development the NSW LBSAS which aims to ensure the environmental sustainability of the NSW land based aquaculture industry. The NSW LBSAS (Section C.6.3) and the HQAS (Section C.11.3), sets out the best practice for the development of this industry.

The prawn sector is the mainstay of the non-oyster estuarine aquaculture industry with there being 12 aquaculture permit holders authorised to culture prawns in earthen pond based farms with a total area of about 124 hectares. In 2007/08 the prawn sector produced 201,850 kg of prawns with a production value of $2.7. It should be noted that due to competition from cheaper imported prawns, the production of prawns in NSW has decreased in recent years. This has resulted in some of the affected farmers restructuring their businesses to produce marine finfish species. Marine finfish species such as yellowfin bream, mulloway, whiting, and snapper are also cultured in earthen based ponds and to a lesser extent in recirculated aquaculture systems. In 2007/08 this sector produced about 9,500 kgs of product with a production value of $73,000. This sector is expected to expand dramatically in the coming years.

C.11.3 Hatcheries

As of 30 June 2011, there were 62 private hatcheries approved to produce up to 300 species of marine and freshwater fish and invertebrates within NSW. Ten of which are approved to produce mulloway, four for dusky flathead, five for sand whiting, six for yellowfin bream, six for eastern king prawn, and three for giant mud crab.

The hatcheries which currently produce this range of estuarine finfish and crustaceans are often associated with land based aquaculture facilities. Broodstock (mature prawns or fish) used for breeding purposes in these hatcheries are usually captured from the wild. The resources of commercial fishermen in estuarine waters is often utilised for broodstock collection. Progeny from these broodstock are used to stock the aquaculture farms.

The DPI Port Stephens Fisheries Institute (PSFI) is the sole NSW government saltwater hatchery that is currently licenced as a multispecies marine fish hatchery. The PSFI was established in the early 1970's as an aquaculture research facility. It was donated to the NSW Government by a mining company called VAM Limited and was originally called the Brackish Water Fish Culture Research Station. This was later changed to Port Stephens Research Centre to reflect the broader range of fisheries research being conducted here. With the transfer of a number of administrative and policy duties to Port Stephens in 1999, the site was renamed the Port Stephens Fisheries Centre and then given institute status in 2009 to become the Port Stephens Fisheries Institute (DPI 2011).

The PSFI plays an integral part in the development of technologies for the marine fish hatchery industry in NSW. Key facilities used for this development and research at the PSFI include a mollusc hatchery, a quarantine mollusc hatchery, marine fish broodstock centre, marine fish hatchery, marine fish nursery facilities and grow-out tanks and ponds. Facilities for commercial and pilot-scale research are available as well as replicated, small-scale facilities for applied research. Research directions are developed in consultation with representatives from industry through the Aquaculture Research Advisory Committee.

Key program areas currently at the PSFI include:

Oysters

- Research into sustaining NSW's oyster industry in a profitable and environmentally sustainable way;
- Developing and improving hatchery and nursery techniques for Sydney rock, Pacific, pearl and flat oysters, as well as other molluscs (e.g. pipis);
- Genetically improving Sydney rock oysters (e.g. for disease resistance, faster growth and improved condition); and
- Researching the impacts of human activities and climate change on oysters.

Marine Fish

- Improving methods for hatchery production of mulloway, Australian bass, yellowtail kingfish and southern bluefin tuna;
- Producing Australian bass and mulloway for stock enhancement; and
- Investigating potential of inland saline water for aquaculture.

Algal Production

- Production of live algae for PSFI and industry; and
- Mass culture 7-12 algal species.

Nutrition, Diet Development

- Developing and improving diets for fish and prawns;
- Currently focused on mulloway and yellowtail kingfish growout diets;
- Replacing fishmeal with Australian agriculture ingredients; and
- Producing more cost-effective, environmentally friendly feeds.

The Aquaculture Research Unit helps coordinate aquaculture production research for the Seafood Cooperative Research Centre and manages hatchery networks for Australian shellfish and marine finfish hatcheries. The unit also has an international role in assisting with developing and managing the aquaculture projects funded by the Australian Council for International Agricultural Research (DPI 2011a).

Most aquaculture facilities like the PSFI usually have a number of species listed on their permit. This allows for flexibility in production systems and potentially better economic opportunities. There are several markets open to aquaculture facilities, with the main two markets being grow out for the restaurant trade and the aquarium or ornamental fish trade.

Past production has been relatively small, especially in comparison to the well-established freshwater hatchery production in NSW. There was a concerted effort to produce snapper for marine fish cages in Botany Bay and Port Stephens during the 1990's but mulloway has since replaced snapper as the fish of choice for aquaculture in recent years. The PSFI has previously operated as a stop-gap for fingerling supply if there is a shortfall in the private sector.

The DPI Aquaculture Production Report 2009-2010 indicates that the marine fish hatchery industry is a relatively new and small area of aquaculture development. Commercial hatchery production for mulloway in 2009-2010 resulted in only 35,000 fish being bred, which is significantly smaller than the well-established hatchery production for Murray cod or golden perch which were producing 1,218,385 and 1,835,160 respectively (DPI 2011b). Despite the size of the marine aquaculture industry in NSW, the value of the fish produced is still substantial in comparison to freshwater, with the combined value of black tiger prawn and mulloway production totalling $2.72 million in 2009-2010 in comparison with Murray cod and golden perch which was worth $64,500 (DPI 2011b). Despite the value of the industry, much of the growth within the industry has been depressed due to a lack of market access. The development of the marine fish stocking program may provide an enhanced market for marine hatcheries and allow further development of technologies specifically related to the proposed species.

There are four hatcheries that are accredited under the current freshwater HQAS (which will be extended to include the marine species). These hatcheries are licenced to breed estuarine species and may meet standards required for the production of marine fingerlings for the proposed harvest stocking program. Non-accredited hatcheries would need to be individually assessed for compliance with HQAS standards should they wish to stock fingerlings to waterways. Current freshwater HQAS facilities producing Australian bass maintain a Health Management Plan (HMP) under the HQAS. The HMP would require updating to ensure it covered the particular marine species the respective hatchery was wishing to produce for stocking. As a minimum, this would include the identification of diseases of concern for the respective marine species and clearance testing and demonstrate that they could adequately maintain respective broodstock and fingerlings/larvae.

The current non-HQAS hatcheries would need to undergo the HQAS approval process and would also need to apply for a species variation if they are not already authorised to culture the respective marine stocking species. Further information about the existing HQAS is provided in Section C.11.4.

New businesses would also be required to comply with the NSW Land Based Sustainable Aquaculture Strategy (LBSAS) to meet approval standards (I&I NSW 2009a). The NSW LBSAS includes identification of appropriate aquaculture sites and a simplified approvals process. It is gazetted under State Environmental Planning Policy (SEPP) – 62 Sustainable Aquaculture. NSW LBSAS also contains an Aquaculture Industry Development Plan (AIDP) which is gazetted under the FM Act. The AIDP specifies best practice guidelines based on ESD principals.

The LBSAS identifies physico-chemical parameters which could potentially be affected by marine fish stocking activity including water quality, noise, light, air quality and energy.

The Strategy's assessment regime assists aquaculture facilities to determine the development requirements such as the need for a Statement of Environmental Effects (SEE) or Environmental Impact Statement (EIS) which should predict the likely environmental impacts of the proposal (including construction and ongoing operation) and provide the basis for the project's on-going sustainable management. This information is important for the applicant in making business decisions and for the broader community to understand what is happening in their community and the approval bodies so they have adequate information to make a decision.

The preparation of a SEE or EIS should be preceded by effective consultation with relevant government agencies, councils and stakeholders. There should be early evaluation of alternatives, taking into consideration the factors in this guideline and in the relevant chapters in the NSW LBSAS. A high priority should be given to:

- considering environmental factors in site selection;
- evaluating alternative species, design, layout and management practices; and
- ascertaining the suitability of the proposal in the intended location.

The analysis and justification for the preferred site, species and technology should be consistent with ecological sustainability principles. The assessment process should focus on key environmental issues. Key matters for land based aquaculture facilities and related activities include:

- selection of an appropriate location and design layout to provide for sustainable management;
- water lifecycle management: source and availability of water and minimisation; management of wastewater; and
- minimisation of adverse impacts on flora and fauna, in particular the risks associated with the species to be farmed and management of predators (I&I NSW 2009a).

Hatcheries have indicated a willingness to produce marine species and commit capital to expanding facilities but to date demand has been limited. Should demand increase it is anticipated that NSW hatcheries would expand to meet demand.

C.11.4 Hatchery Quality Assurance Scheme (HQAS)

The HQAS (NSW DPI 2008a) accredits NSW fish hatcheries for the production of native freshwater fish fingerlings for recreational fishing enhancement stocking programs and aquaculture production. The current HQAS will be developed to include the seven proposed marine stocking species. The four parts of the HQAS manual are summarised below.

Part 1 Introduction

The HQAS serves as a manual to hatchery operators outlining the standards that must be adhered to. The HQAS manual was primarily developed to meet the requirements of the Freshwater Fish Stocking FMS. The HQAS implements the Hatchery Quality Assurance Program (HQAP) (Rowland and Tully 2004) for Murray cod, golden perch, silver perch and in addition, includes Australian bass. It does not refer to any marine species at this stage.

Part 2 Commitments

DPI is currently committed to updating the HQAS manual to meet the requirements of the Freshwater Fish Stocking FMS. If the Marine Stocking FMS is approved DPI would update the HQAS to accommodate marine fish species. The HQAS Scheme Manager (DPI Manager - Aquaculture) can accredit, suspend or audit hatcheries. Accredited hatcheries must operate in accordance with the HQAS manual.

Part 3 Standards

While some of the standards could possibly be applied to breeding and production of fingerlings for freshwater or marine stocking, others are specific to freshwater fish and that stocking program only.

The HQAS manual includes standards for:

- site selection;
- approvals;
- pond and tanks;
- hatchery infrastructure;
- water quality monitoring;
- chemicals;
- disease and health management;
- dispatch;
- records;
- broodstock genetic regions for particular species; and
- breeding.

Site Selection

The hatchery must have an adequate supply of good quality water.

Approvals

The hatchery must have a NSW Class H aquaculture permit or exemption under Section 144(4) of the FM Act.

Ponds and tanks

Ponds and tanks must meet standards for screens, drainage, harvest, effluent and aeration.

Hatchery infrastructure

Hatchery infrastructure must meet standards for filtration, capacity, drainage and chemicals.

Water Quality Monitoring

The hatchery must have the appropriate equipment for water quality monitoring and must undertake sufficient systematic water quality monitoring to maintain adequate water quality.

Chemicals

The hatchery must only have chemicals prescribed by a veterinarian or approved for use by the Australian Pesticides and Veterinary Medicines Authority (APVMA) and must have copies of APVMA minor use permits (MUPs) and/or veterinarian prescriptions held on site.

Disease and Health Management

The hatchery must have a written HMP detailing a planned response to fish health management issues. The HMP must contain a disease surveillance routine.

The hatchery must have a sterilisation procedure for hand nets, buckets and other equipment, a binocular or monocular microscope having a powered light source and sampling, dissection and specimen submission equipment.

All new broodstock entering the hatchery must be quarantined for three days.

Dispatch

The hatchery must complete a Hatchery Dispatch and Health Statement for each consignment, examine ten fish from each batch less than 24 hours prior to dispatch and must not dispatch a consignment having non-target species (including insects, snails, tadpoles and vegetation); moribund fish, fish with signs of disease (including fungal lesions, ulcers, parasites or abnormalities), malnourished fish or fish with abnormal discolouration and/or markings.

The hatchery must quarantine each consignment for a minimum of 24 hours post harvest. The hatchery may choose to quarantine for 48 hours or longer. Any transport tank used by the hatchery must have bottled oxygen, a regulator and a diffuser.

The hatchery must use a salt bath prior to dispatch and/or during transport; or, the hatchery must use a fresh water bath for the marine culture of Australian Bass.

Records

The hatchery must maintain the following records for four years:

- copies of hatchery dispatch and health statements;
- copies of compliance self declaration and compliance audit reports;
- broodstock records;
- disease surveillance records;
- water quality monitoring records;
- analytical test results or Veterinarian reports; and
- broodstock collection permits and records associated with broodstock collection permits.

Broodstock Genetic Regions

The HQAS implements the HQAP (Rowland and Tully 2004) for Murray cod, golden perch, silver perch and, in addition, includes Australian bass. For each species where the hatchery holds the broodstock for more than one breeding season, the hatchery must have a minimum of 10 pairs of broodstock for each broodstock genetic region.

Broodstock and Breeding

For non-threatened species, the HQAP indicated effective population size (N_e) (calculated from the number of broodstock used to produce fingerlings) should be at least 50 per generation. Further, the HQAP indicated that an N_e of 50 can be achieved by using at least 5 different pairs of broodstock each year to produce each batch of fingerlings for stocking in a location over a 5-year period. Because some fish don't spawn or spawn poor quality eggs, at least 8 pairs should be injected with hormones. One female must be mated with only one male, and females must be mated with a different male each year. Where natural spawning is used, broodstock must be rotated between ponds at least every 2 years to reduce the chance of same pair matings in consecutive years. Similar numbers of larvae from at least 5 pairs of fish must be stocked into each larval rearing pond. There should be no grading or selection of fingerlings after harvest. The broodstock must be replaced with fish from the wild after the generation period of 5 years.

In addition, the HQAS requires that hatcheries must have a satisfactory system to individually identify all broodstock and must have sufficient ponds or tanks to separate broodstock from different genetic regions. Different species from different broodstock genetic regions must be kept separate during concurrent production runs.

Part 4 Accreditation

Hatcheries must submit applications to get HQAS accreditation and prior to accreditation be audited to check compliance with the required standards. Breaches of standards following accreditation may lead to cancellation depending on the severity of the breach.

Chapter D

Identification of Risks

Chapter D Contents

List of Tables

List of Figures

CHAPTER D IDENTIFICATION OF RISKS

D.1 Introduction

This Chapter of the Environmental Impact Statement (EIS) identifies the potential risks and issues that require consideration in relation to the proposal in the absence of any mitigative or management action. All stages of the marine stocking process were considered in the risk identification process, from the collection of broodstock and hatchery rearing, to transport, release and long-term operation. Direct and indirect, long and short-term impacts and cumulative impacts are considered in relation to aspects of ecology, threatened species, populations and communities, areas of conservation significance, genetics, diseases, parasites and health, cultural and social values. Results of an economic feasibility study (Specialist Report B) are considered later in the assessment of impacts of implementing the draft Fisheries Management Strategy (FMS).

Potential risks relating to the proposed activity were identified through several methods. Firstly, existing information and literature was reviewed to outline our current understanding of fish stocking practices in Australia and internationally, to gain an understanding of the different components of the environment (biological, social, economic and physiochemical) which could potentially be affected (Chapter C). A literature review was also conducted to establish the biology and ecology of each species proposed for marine stocking and to identify species specific issues (Chapter C, Section C.8).

Community consultation was carried out to inform stakeholders in the different estuarine regions of New South Wales (NSW) about the proposal and to get feedback on issues of concern. Details of the responses from the community consultation meetings are contained in Appendix 4. Relevant government agencies were also consulted throughout the EIS process (Section D.2).

A formal risk analysis was then carried out that considered the Director General's Requirements ((DGRs), Appendix 1), the review of existing information (Chapter C), the outcomes of stakeholder consultation (Section D.2), the biology and ecology of the species proposed for stocking (Chapter C, Section C.8) and advice from specialist consultants. The results of the risk analysis are summarised in Section D.3.3 and explained in the following Sections: Biophysical Impacts (Section D.4); Social Impacts (Section D.5); and Other Physico-Chemical Impacts (Section D.6). Existing conditions and background information related to each area of assessment are cross-referenced to the relevant parts of Chapter C.

D.2 Consultation

D.2.1 Groups Consulted

In preparation of the EIS, the following statutory authorities and non-statutory groups were consulted:

Statutory Authorities and Organisations

- NSW Department of Planning and Infrastructure;
- NSW Department of Primary Industries (DPI);
- NSW Crown Lands Division (CLD), part of DPI;
- Office of Environment and Heritage (OEH);
- National Parks and Wildlife Service (NPWS), part of OEH;
- Marine Parks Authority, part of DPI;
- Commonwealth Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC);
- Northern Rivers Catchment Management Authority (NRCMA), part of DPI;
- Hunter-Central Rivers Catchment Management Authority (HRCMA), part of DPI;
- Sydney Metropolitan Catchment Management Authority (SMCMA), part of DPI;
- Southern Rivers Catchment Management Authority (SRCMA), part of DPI;
- NSW Advisory Council on Recreational Fishing (ACoRF);
- Commercial Fisheries Management Advisory Committees (MACs);
- Seafood Industry Advisory Council (SIAC).
- NSW Aboriginal Land Council (NSWALC);
- Local Aboriginal Land Councils (LALCs) along the NSW coast (x 40);
- NSW Registrar of Aboriginal Owners;
- Native Title Services Corporation Limited (NTSCORP Limited).

Non-Statutory Organisations

- Nature Conservation Council of NSW (NCC);
- Australian National Sportfishing Association (ANSA);
- Recreational Fishing Saltwater Trust Expenditure Committee (RFSTEC);
- Peak Oyster Advisory Group (POAG);

Consultation was carried out by letter, email and through a series of stakeholder consultation meetings. Marine stocking was also included as an agenda item as part of regular stakeholder meetings (e.g. ACoRF, RFSTEC and Aboriginal community meetings). Stakeholder presentations were conducted by the NSW Department of Primary Industries (DPI), Cardno Ecology Lab and Umwelt (Australia) Pty Ltd (who specifically undertook consultation with Aboriginal stakeholder groups). Further details of the consultation and responses are given in Appendix 4 and Specialist Report A (Aboriginal Issues Assessment).

DPI and Cardno Ecology Lab made presentations at Merimbula (27 Nov 2009), Sydney (2 Dec 2009) and Ballina (8 Dec 2009) to get feedback from local stakeholders in the three stocking regions. At these presentations, the following information was provided:

- The processes used to select the species and locations suitable for stocking;
- The proposed frequency of stockings in particular estuaries;
- Development of the draft FMS and the EIS.

The time and locations of these stakeholder presentations were advertised on the DPI website, in local newspapers and invitations were sent to all of the saltwater recreational fishing clubs registered with DPI (~900 clubs).

Similar presentations were given at Aboriginal community meetings at the following locations:

- Yamba – meeting with north coast LALCs at their regional forum (this group also included Aboriginal Owners);
- Nambucca – meeting with Nambucca LALC and elders;
- Coolongolook – Wang Wauk River – meeting with members of the HCRCMA, Aboriginal Culture and Environment Network (ACEN). This meeting included LALC members, elders, Aboriginal Owners and Aboriginal staff of the Catchment Management Authority (CMA);
- Raymond Terrace – meeting with Worimi Knowledge Holders, including Aboriginal Owners.

D.2.2 Outcomes of Consultation

Responses from the statutory and non-statutory groups consulted were received via mail, telephone, email and from the stakeholder consultation meetings. Not all groups contacted during the consultation responded, however, the proposal was generally well-received in terms of the species and estuaries to be stocked and the processes used in selecting these. There were, however, many questions and concerns about other aspects of the proposal. Details and copies of written responses are provided in Appendix 4. Outcomes of consultation with Aboriginal Stakeholder groups are provided in detail within Specialist Report A (Aboriginal Issues Assessment).

A summary of the key issues raised through the stakeholder consultation is summarised in the following Tables (D.1-D.3). Each of these key issues has been addressed through the EIS process and a cross reference to the relevant section addressing the risk is provided within the tables.

Table D.1: Summary of biophysical issues raised through stakeholder consultation.

Stakeholder Group/Forum(s)	Issue	Assessment/Response
▪ NCC. ▪ POAG. ▪ Consultation Meetings (Merimbula, Sydney and Ballina). ▪ Worimi Knowledge Holders Meeting. ▪ HCRCMA and ACEN community meeting. ▪ LALCs. ▪ Nambucca LALC.	<u>Long-Term –Sustainability and Habitat Management</u> Stocking would appear to be a 'band-aid' solution, i.e. a short-term solution to other impacts on estuarine environments and fish stocks. Stocking does not address the underlying causes of declining fish stocks. Habitat protection and restoration programs may be more beneficial as a long term strategy to maintain sustainable fishery resources. The FMS should provide for the integration of stocking with other complimentary methods to minimise pressure on fisheries resources such as input and output controls and habitat enhancement programs. Degraded habitats should not be stocked. Marine stocking should be combined with temporary fishing closures, to give wild stocks time to recover and to allow stocked fish to grow to a legal size.	Refer to Chapter F, Section F.3.1.2.
▪ NCC. ▪ HCRCMA and ACEN community meeting. ▪ LALCs. ▪ Worimi Knowledge Holders Meeting.	<u>Genetics</u> Implications for altering the genetic integrity of wild fish stocks were of concern. Concern was expressed about quality control in hatcheries and the potential for poor genetic stock.	Refer to Chapter G, Section G.2.1.4
▪ NCC.	<u>Disease Management</u> Implications for translocation of diseases and pest species were a concern.	Refer to Chapter G, Section G.2.1.5.
▪ LALCs. ▪ HCRCMA and ACEN community meeting.	<u>Areas of Conservation Significance</u> Areas of conservation significance such as Myall Lakes should not be stocked.	Refer to Chapter G, Section G.2.1.3.
▪ LALCs. ▪ Worimi Knowledge Holders Meeting.	<u>Monitoring</u> Concern was expressed about the survival of stocked fish in natural waterways and how this would be monitored. It was suggested that monitoring of marine fish stocking outcomes should be linked to other monitoring of estuary health to align marine stocking with the management framework for natural resources in NSW.	Refer to Chapter E, Section E.4.4.

Stakeholder Group/Forum(s)	Issue	Assessment/Response
▪ LALCs	Ecology Marine stocking should be introduced gradually, starting in healthy but robust estuary systems. Stocked fish, estuary health after stocking and catches should be monitored and the stocking strategy adapted if necessary.	Refer to Chapter G, Section G.2.1.1.
▪ Stakeholder Consultation Meetings (Sydney, Ballina).	Companion Stocking It was suggested that it would be logical to stock eastern king prawns simultaneously with predators (i.e. mulloway, yellowfin, dusky flathead and sand whiting) as the prawns would increase the source of food for these predators. Other methods of improving the productivity of estuaries were also proposed (e.g. increasing light and nutrients to increase the productivity of phytoplankton).	Refer to Chapter F, Section F.5.2.
▪ Stakeholder Consultation Meetings (Sydney).	Species Selection Why was John Dory not on the list as these species are very popular and occur in estuaries?	Refer to Chapter F, Section F.5.1.
▪ Stakeholder Consultation Meetings (Merimbula).	Species Distribution It was not understood why giant mud crabs are not to be stocked in the far south of the State as this species occurs there and is occasionally seen and caught by recreational fishers.	Refer to Chapter G, Section G.2.1.4.1.

Table D.2: Summary of social issues raised through stakeholder consultation.

Stakeholder Group/Forum(s)	Issue	Assessment/Response
▪ NSW Registrar of Aboriginal Owners. ▪ HCRCMA and ACEN community meeting. ▪ LALCs	<u>Further Consultation with Aboriginal Stakeholders</u> It was widely viewed that traditional owners and Aboriginal people should be consulted about any local marine stocking activities prior to stocking and given opportunities to contribute to sustainable management of the fishery resources.	Refer to Chapter G, Section G.2.2.1.
▪ LALCs. ▪ HCRCMA and ACEN community meeting. ▪ Worimi Knowledge Holders Meeting.	<u>Opportunity for Community Involvement</u> Regional Aboriginal communities would like opportunity to be involved in stocking events – both in planning and in monitoring. Regional Aboriginal communities should be involved in management, planning and monitoring of marine fish stocking and estuary health and actively communicating about sustainable management of estuarine resources.	Refer to Chapter G, Section G.2.2.1.2.
▪ LALCs. ▪ Nambucca LALC Meeting.	<u>Opportunity for Employment</u> Local Aboriginal people would like the opportunity for employment for example as field officers or rangers to assist in an enforcement and educational role. It was noted that this would be consistent with the Indigenous Fishery Strategy	Refer to Section D.5.1.2.2.
▪ Nambucca LALC Meeting. ▪ LALCs. ▪ POAG. ▪ Consultation Meetings (Ballina).	<u>Resource Sharing</u> There were concerns over resource allocation between commercial and recreational fishing groups and that commercial fishermen would catch the majority of fish stocked into estuaries. Representatives from Aboriginal groups stated their preference that marine stocking should only occur in estuaries that are Recreational Fishing Havens. POAG considered it unwise to cater only for recreational fishing groups.	Refer to Chapter G, Section G.2.2.2.2
▪ LALC	<u>Access to Stocked Fish</u> Concerns of Aboriginal community health could be addressed by improved collaboration between local Aboriginal groups, CMAs and DPI, to maintain and enhance all estuary habitats and stocks of all estuary species, not just selected fish and crustaceans.	Refer to Chapter G, Section G.2.2.1.4.
▪ POAG.	<u>Conflict with Commercial Fisheries</u> Concerns were raised over the potential for giant mud crabs to prey on farmed oysters kept in trays with wire lids. Further consultation was considered necessary before POAG would endorse fish stocking activities in estuaries.	Refer to Chapter G, Section G.2.2.2.3.

Stakeholder Group/Forum(s)	Issue	Assessment/Response
▪ Stakeholder Consultation Meetings (Sydney).	Ceremonial Stockings The Buddhist community in NSW questioned whether the proposal would include/exclude ceremonial fish stockings.	Refer to Chapter B, Section B.6.7.

Table D.3: Summary of economic issues raised through stakeholder consultation.

Stakeholder Group/Forum(s)	Issue	Assessment/Response
▪ Consultation Meetings (Merimbula, Sydney and Ballina).	Allocation of Funds It was questioned whether money allocated to a stocking program would be wiser spent on programs aiming to restore/improve/enhance fish habitat or detecting and mitigating causes of degradation to estuarine environments (i.e. has a cost-benefit analysis been done or is one proposed).	Refer to Chapter F, Section F.3.
▪ Stakeholder Consultation Meetings (Merimbula, Sydney and Ballina).	Funding Sources Benefits from stocking (i.e. potentially a greater availability of fish to be caught) would be shared among recreational and commercial fishers, yet the project would appear to be funded solely by the recreational sector (i.e. by money allocated from the Saltwater Recreational Fishing Trust).	Refer to Chapter F, Section F.5.8.
▪ Stakeholder Consultation Meetings (Sydney).	Long-Term Funding of the Project Concern was raised about the longevity of funding for the proposal.	Refer to Chapter F, Section F.5.8.

D.3 Risk Analysis

D.3.1 Introduction

Environmental risk arises from the relationship between humans and human activity in the environment (AS/NZS HB 203:2006). Risk is defined as the chance of something happening that will have an impact on objectives. It is measured in terms of consequences and their likelihood. 'Risk' in the environmental context should be thought of as the environmental consequences of a given severity and the likelihood of that particular consequence occurring (AS/NZS 4360: 2004).

A qualitative risk analysis was carried out to identify potential risks associated with marine stocking, to determine and evaluate the level of risk associated with this activity and to assist in identifying appropriate options to mitigate these risks. Steps of the general risk analysis process are given in Figure D.1. Potential risks were identified in relation to biological aspects (ecological processes, threatened species, areas of conservation significance, population genetics, diseases and pests), social values (Aboriginal and non- Aboriginal) and other physico-chemical aspects of the environment (water quality, air, noise and energy).

A specialist workshop at Cardno Ecology Lab was held in October 2009 to assist with identification of risks to ecological processes. The workshop was attended by:

- Peggy O'Donnell (Cardno Ecology Lab);
- Craig Blount (Cardno Ecology Lab);
- Kate Reeds (Cardno Ecology Lab);

- Sarah Boyd (DPI);
- Matt Taylor (UNSW);
- Faith Ochwada (UNSW).

An initial risk analysis (i.e. determining the potential consequences for ecological processes due to stocking and their likelihood of occurring) was carried out during the workshop and has been assessed further in an internal workshop between staff of Cardno Ecology Lab.

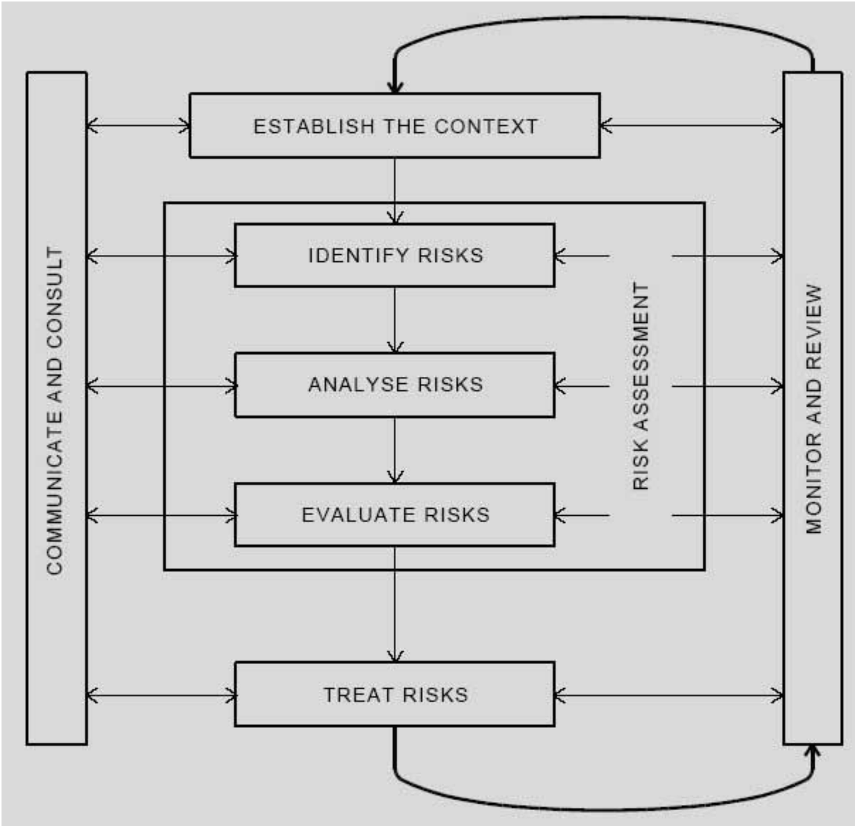
Risks and potential impacts associated with population genetics, fish health (disease and parasites) and social aspects of the proposal included input from experts in their field. This included input from Dr Jenny Ovenden who is a senior a fisheries geneticist from the Queensland Department of Primary Industries and Fisheries (QDPI&F), Paul Palmer, a senior biologist at the Bribie Island Research Centre (BIRC) and specialist consultants in socio-economic and cultural issues from Cardno Lawson Treloar and Umwelt respectively.

Consultation with statutory and non-statutory groups also assisted in identifying issues or potential impacts that were considered in both the risk assessment and assessment of impacts.

D.3.2 Methodology

Cardno Ecology Lab used a formalised risk assessment process based on the Australian and New Zealand Standard guidelines for risk management (AS/NZS 4360:2004) and the Handbook for Environmental Risk Management – Principles and Process (HB 203:2006) (Standards Australia 2006) which are considered international benchmarks in standard risk management. Steps of the general risk analysis process are given in Figure D.1 below.

Figure D.1: Steps in the general risk analysis process.
(Source AS/NZS 4360:2004).



The rationale for scoring likelihood and consequence of an incident occurring is given in Tables D.4 and D.5. Scores of likelihood and consequence are then combined into a matrix to provide a qualitative assessment of significance (Figure D.2). Based on this, each hazard/risk is identified as low, moderate, high or extreme. This does not mean that the project should not proceed (i.e. if the level of risk is high) or that an issue should be ignored if the level of risk is considered low, but rather that the issue may need greater or less effort in management and mitigation or that further research on the receiving environment is required. Once the potential risks of the marine stocking program were identified, the likelihood and consequences of these risks occurring without the draft FMS in place were evaluated. Key points that need to be recognised in relation to the general risk analysis:

- Potential risks were identified through a combination of workshops, specialist advice and stakeholder consultation (Section D.2).
- The risk analysis methodology has been adapted to analyse social/cultural impacts and impacts on areas of conservation significance, by using separate tables to define consequence (Table D.5).
- The categories for environmental consequence are based on duration and spatial scale of potential impacts. Those that are localised and limited to the duration of a stocking event i.e. 1 - 3 years are considered minor, whereas those that last longer and are more widespread have a greater consequence.
- Detailed discussion of the potential impacts of the proposal and the rationale for the levels of likelihood and consequence allocated in the risk analysis are discussed in Sections D.4 - D.6.
- The risk analysis identifies the relative significance of risks before treatment (i.e. implementation of the draft FMS). Risks are re-evaluated in Chapter G with the draft FMS in place.
- Although some risks are considered to be ‘low’, further action may be recommended (through routine procedures) as appropriate.
- Risk analysis is an ongoing process and is a tool to help identify the appropriate level of management or mitigation required. It is also limited in its subjectivity.
- Economic risks are not considered here in the risk analysis; instead they are discussed in a feasibility study in Specialist Report B and summarised in Chapter G, Section G.3.

Table D.4: Qualitative measures of likelihood.

Level	Descriptor	Description
A	Almost Certain	Is expected to occur as a result of the project under most circumstances.
B	Likely	Will probably occur as a result of the project in most circumstances.
C	Possible	Could occur and has occurred in similar circumstances.
D	Unlikely	Could occur as a result of the project but is not expected.
E	Rare	Could occur only in exceptional circumstances.

Table D.5: Qualitative measures of consequence.

Environment		
Level	**Descriptor**	**Description**
1	Catastrophic	Harm to estuaries throughout the State. Limited prospect of full recovery.
2	Major	Significant harm with widespread effect throughout the estuary- limited prospect of full recovery.
3	Moderate	Harm with possible effect throughout an estuary - recovery longer than three years.
4	Minor	Localised impact within estuary - recovery measurable within 1-3 years.
5	Insignificant	No impact on baseline environment within the estuary - no mitigative action required.
Social Issues/Cultural Heritage		
Level	**Descriptor**	**Description**
1	Catastrophic	Irreparable damage to highly valued structures/items/locations of cultural importance and/or infringement of social/cultural values.
2	Major	Significant damage to structures/items of cultural significance or infringement of social/cultural values.
3	Moderate	Moderate repairable damage to structures/items of cultural significance or infringement of social/cultural values.
4	Minor	Minor repairable damage to structures/items of cultural significance or infringement of social/cultural values.
5	Insignificant	No impact to structures/items of cultural significance or social/cultural values.
Areas of Conservation Significance		
Level	**Descriptor**	**Description**
1	Catastrophic	Significant harm with widespread effect throughout the conservation area - limited prospect of full recovery.
2	Major	Significant harm within the conservation area - recovery longer than three years.
3	Moderate	Harm with possible effect throughout the conservation area - recovery measurable within 1 – 3 years.
4	Minor	Localised impact within a conservation area - recovery measurable within 1 year.

5	Insignificant	No impact on baseline environment within the conservation area - no mitigative action required.

Figure D.2: Matrix defining four possible regions of risk levels.
(After AS/NZS 4360:2004).

Likelihood		Consequence				
		5	4	3	2	1
		Insignificant	Minor	Moderate	Major	Catastrophic
A	Almost Certain	A5	A4	A3	A2	A1
B	Likely	B5	B4	B3	B2	B1
C	Possible	C5	C4	C3	C2	C1
D	Unlikely	D5	D4	D3	D2	D1
E	Rare	E5	E4	E3	E2	E1

E	Extreme risk	Risk is unmanageable and cannot be justified under any circumstances. Measures to reduce risk to a lower level are required.
H	High risk	Risk is significant and requires significant cost-effective measures for risk reduction and/or management.
M	Moderate risk	Routine and cost-effective measures required to reduce and/or manage risk. Risk may be acceptable.
L	Low risk	Risk can be managed by routine procedures and/or no further measures to manage the risk are required.

D.3.3 Results

Results of the risk analysis are presented in the following Tables, D.6 – D.13. Note that economic issues are considered separately in the Economic Feasibility Assessment (Specialist Report B). Supporting information and a detailed description of the potential impacts as identified in the risk analysis are described in Sections D.4 - D.6.

D.3.3.1 Biophysical

Table D.6: Risk assessment - ecology.
L=Likelihood, C=Consequence.

Environmental Aspect	Risk Description (Event and Consequence)	Risk Level (Before Treatment)		
		L	C	Risk Level
Ecology				
Conspecifics	Decrease in abundance of wild conspecifics e.g. from overstocking and/or increased fishing effort	C	3	High
	Alteration of size-structure in populations	C	3	High
	Alteration of the natural species distribution	E	3	Moderate
Competitors	Alteration of the distribution, abundance or structure of populations e.g. through inter-specific competition, overstocking and/or increased fishing effort	B	3	High
Other trophic levels	Alteration of the distribution, abundance or structure of populations	B	3	High
Habitat	Direct effects (e.g. overgrazing of seagrass by stocked crustaceans)	C	3	High
	Indirect effects (e.g. trampling, littering, habitat disturbance)	C	3	High
Adjacent coastal waters	Potential ecological impacts beyond the estuary e.g. trophic effects and competitive interactions	D	4	Low

Refer to Section D.4.1.2. (Ecology) for discussion of results.

Table D.7: Risk assessment - threatened species, populations and ecological communities.
L=Likelihood, C=Consequence

Environmental Aspect	Risk Description (event and consequence)	Risk Level Before Treatment		
		L	C	Risk Level
Threatened and Protected Species, Populations and Ecological Communities				
Key Threatening Processes (KTPs)	Hook and line fishing in areas important for the survival of threatened fish species (FM Act)	C	3	High
	Injury and fatality to vertebrate marine life caused by ingestion of, or entanglement in, harmful marine debris (EPBC Act)	C	3	High
	Entanglement or ingestion of anthropogenic debris in marine and estuarine environments (TSC Act)	C	3	High
Trophic impacts	Alteration of distribution, abundance and structure of populations	C	3	High
Increase/concentration of boating activity	Acoustic disturbance (marine mammals and birds)	C	4	Moderate
	Boat strike (marine mammals and turtles)	D	4	Low
Incidental capture of threatened / protected species	Injury/mortality	C	3	High
Habitat	Trampling/ habitat disturbance	C	3	High

Refer to Section D.4.1.2. (Threatened Species) for discussion of results.

Table D.8: Risk assessment - areas of conservation significance.
L=Likelihood, C=Consequence.

Environmental Aspect	Risk Description (event and consequence)	Risk Level Before Treatment		
		L	C	Risk Level
Areas of conservation significance				
Marine Parks/Ramsar	Potential impacts on Ramsar wetlands (indirect)	D	4	Low
	Potential impacts on the conservation value of Marine Parks (indirect)	D	4	Low
Aquatic Reserves	Potential impacts on the conservation value of Aquatic Reserves (direct)	C	3	High
Critical Habitat, Nature Reserves, National Parks	Potential impacts on the conservation value of National Parks with marine extensions and Nature Reserves (indirect)	D	4	Low
	Potential impacts on the conservation value of Critical Habitats (indirect)	D	4	Low
World Heritage Areas	Impingement of sites designated as World Heritage Areas (WHAs)	E	5	Low
Wilderness Areas	Impingement on sites declared as Wilderness Areas	E	5	Low

Refer to Section D.4.3.2. (Areas of Conservation Significance) for discussion of results.

Table D.9: Risk assessment - population genetics.
L=Likelihood, C=Consequence.

a) Yellowfin Bream

Environmental Aspect	Risk Description (event and consequence)	Risk Level Before Treatment		
		L	C	Risk Level
Population Genetics (Yellowfin Bream)				
Direct effects	Ryman-Laikre effect	C	3	High
	Introgression	B	3	High
Indirect effects	Wastage of gametes	A	1	Extreme
	Naturalisation leading to fragmentation	E	4	Low
	Overfishing of mixed stock fisheries leading to a reduction in genetic diversity	D	3	Moderate

b) Mulloway

Environmental Aspect	Risk Description (event and consequence)	Risk Level Before Treatment		
		L	C	Risk Level
Population Genetics (Mulloway)				
Direct effects	Ryman-Laikre effect	C	3	High
	Introgression	B	3	High
Indirect effects	Wastage of gametes	E	4	Low
	Naturalisation leading to fragmentation	E	4	Low
	Overfishing of mixed stock fisheries leading to a reduction in genetic diversity	D	3	Moderate

Table D.9: Continued.

c) Dusky Flathead

Environmental Aspect	Risk Description (event and consequence)	Risk Level Before Treatment		
		L	C	Risk Level
Population Genetics (Dusky Flathead)				
Direct effects	Ryman-Laikre effect	C	3	High
	Introgression	B	3	High
Indirect effects	Wastage of gametes	E	4	Low
	Naturalisation leading to fragmentation	E	4	Low
	Overfishing of mixed stock fisheries leading to a reduction in genetic diversity	D	3	Moderate

d) Sand Whiting

Environmental Aspect	Risk Description (event and consequence)	Risk Level Before Treatment		
		L	C	Risk Level
Population Genetics (Sand Whiting)				
Direct effects	Ryman-Laikre effect	C	3	High
	Introgression	B	3	High
Indirect effects	Wastage of gametes	E	4	Low
	Naturalisation leading to fragmentation	E	4	Low
	Overfishing of mixed stock fisheries leading to a reduction in genetic diversity	D	3	Moderate

Table D.9: Continued

e) Eastern King Prawn

Environmental Aspect	Risk Description (event and consequence)	Risk Level Before Treatment		
		L	C	Risk Level
Population Genetics (Eastern King Prawn)				
Direct effects	Ryman-Laikre effect	E	3	Moderate
	Introgression	E	3	Moderate
Indirect effects	Wastage of gametes	E	4	Low
	Naturalisation leading to fragmentation	E	4	Low
	Overfishing of mixed stock fisheries leading to a reduction in genetic diversity	D	3	Moderate

f) Giant mud crab

Environmental Aspect	Risk Description (event and consequence)	Risk Level Before Treatment		
		L	C	Risk Level
Population Genetics (Giant Mud Crab)				
Direct effects	Ryman-Laikre effect	C	3	High
	Introgression	B	3	High
Indirect effects	Wastage of gametes	E	4	Low
	Naturalisation leading to fragmentation	D	3	Moderate
	Overfishing of mixed stock fisheries leading to a reduction in genetic diversity	D	3	Moderate

Table D.9: Continued.

g) Blue Swimmer Crab

Environmental Aspect	Risk Description (event and consequence)	Risk Level Before Treatment		
		L	C	Risk Level
Population Genetics (Blue Swimmer Crab)				
Direct effects	Ryman-Laikre effect	C	3	High
	Introgression	B	3	High
Indirect effects	Wastage of gametes	E	4	Low
	Naturalisation leading to fragmentation	D	3	Moderate
	Overfishing of mixed stock fisheries leading to a reduction in genetic diversity	D	3	Moderate

Refer to Section D.4.4.2. (Population Genetics) for discussion of results.

Table D.10: Risk assessment - disease parasites and pests.
L=Likelihood, C=Consequence.

Environmental Aspect	Risk Description (event and consequence)	Risk Level Before Treatment		
		L	C	Risk Level
Diseases & Parasites				
	Infection of hatchery-reared fish with exotic disease/parasite causing contamination of farm and adjacent waterways	C	3	High
	Infection of hatchery-reared fish with endemic disease/parasite causing contamination of farm and adjacent waterways	C	4	Moderate
	Translocation of exotic fish disease/parasite from hatcheries into wild populations	C	3	High
	Translocation of endemic fish disease/parasite from hatcheries into wild populations	C	4	Moderate
	Infection of hatchery-reared crustaceans with exotic disease/parasite causing contamination of farm and adjacent waterways	C	3	High
	Infection of hatchery-reared crustaceans with endemic disease/parasite causing contamination of farm and adjacent waterways	C	4	Moderate
	Translocation of exotic crustacean disease/parasite from hatcheries into wild populations	C	3	High
	Translocation of endemic crustacean disease/parasite from hatcheries into wild populations	C	4	Moderate
	Translocation of non-target species from one area to another resulting in unintentional stocking	D	3	Moderate
	Translocation of pest/fouling organisms (e.g. harmful plankton, invertebrates, algae) from hatcheries to waterways	D	3	Moderate
	Release of stock (fish and crustaceans) selected for reduced disease/parasite susceptibility causing undesirable modification of wild genotypes	C	3	High
Hatchery, Transport and Release Procedures				
	Hatchery/farm culture system failure causing poor on-farm stock health and culminating in stock which have difficulty withstanding stresses associated with harvest, transport and/or handling procedures	C	4	Moderate

Environmental Aspect	Risk Description (event and consequence)	Risk Level Before Treatment		
		L	C	Risk Level
	Transport system failure causing poor stock health prior to release	C	4	Moderate
	Release system failure causing poor stock health and/or mortalities at the release site	C	4	Moderate

Refer to Section D.4.5.2. (Disease, Parasites and Pests) for discussion of results.

D.3.3.2 Social Issues

Table D.11: Risk assessment - Aboriginal social issues

L=Likelihood, C=Consequence.

Environmental Aspect	Risk Description (event and consequence)	Risk Level Before Treatment		
		L	C	Risk Level
Aboriginal social issues				
Aboriginal cultural heritage	Impingement on areas of Aboriginal cultural importance (sites, Places and objects)	D	3	Moderate
Aboriginal social issues	Lack of involvement of Aboriginal stakeholders in fishery management and stocking activities	D	4	Low
	Marine stocking not seen as adequate, good value or a sustainable approach to looking after sea country	D	3	Moderate
	Competition from other fishing sectors reduces Aboriginal access to stocked fish for a healthy diet	C	4	Moderate

Refer to Section D.5.1.2 (Aboriginal Social Issues), for discussion of results.

Table D.12: Risk assessment - non- Aboriginal social issues.
L=Likelihood, C=Consequence.

Environmental Aspect	Risk Description (event and consequence)	Risk Severity Before Treatment		
		L	C	Risk Level
Non-Aboriginal social issues				
Non-Aboriginal cultural values	Marine stocking not consistent with objectives of State-wide template Local Environment Plan (LEP) zone for waterways or other State-wide requirements for the coastal zone	D	3	Moderate
	Impacts to Crown Land and assets (e.g. boating facilities, wharves, banks and bed etc.)	D	4	Low
	Resource sharing (e.g. risk of conflict among fishing sectors)	D	4	Low
Other waterway users	Conflict between fishing groups and other waterway users	D	4	Low
Aquaculture industry	Impacts on oyster leases	C	3	High
	Impacts on other aquaculture	D	5	Low
Community support, participation and fishing effort	Perceived negative environmental impact of marine stocking	C	4	Moderate
	Lack of community support	D	4	Low
	Increase/concentration of fishing participation/effort	C	4	Moderate

Refer to Section D.5.2.2 (Non-Aboriginal Social Issues) for discussion of results.

Other Impacts

Table D.13: Risk assessment - other impacts.
L=Likelihood, C=Consequence.

Environmental Aspect	Risk Description (event and consequence)	Risk Level Before Treatment		
		L	C	Risk Level
Physico-Chemical				
Water quality	Direct reduction in water quality from increased boating (large, well flushed, open estuary)	D	5	Low
	Direct reduction in water quality from increased boating (small, poorly flushed, semi-enclosed water body)	C	4	Moderate
	Indirect reduction in water quality from aquaculture operations	D	4	Low
Noise	Noise disturbance from increased recreational fishing/stocking activity	D	4	Low
Light	Light pollution from increased recreational fishing/stocking activity	D	4	Low
Air quality	Impact on air quality (e.g. from car/ boat emissions)	D	5	Low
Energy	Hatchery production fails to be energy efficient	D	5	Low

Refer to Section D.6.1.2. (Other Impacts) for discussion of results.

D.4 Biophysical Impacts

D.4.1 Ecology

D.4.1.1 Existing Conditions

Biophysical and key ecological features of different estuary types (i.e. embayment's, tide dominated, wave dominated and intermittent estuaries) are described in detail in Chapter C, Section C.7. In order to help determine the effects of stocking on estuary systems, it is necessary to understand the structure of estuarine food webs and the trophic position of the species selected for marine stocking within the food web (described in Chapter C, Section C.7.3). As juveniles, the species proposed for stocking (with the exception of the eastern king prawn) would generally be described as 'secondary consumers'. The diet of these species can, however, vary both seasonally with prey abundance and ontogenically and at some size, larger mulloway and dusky flathead would become tertiary consumers. This helps our understanding of how altering a specific component of the food web (e.g. by stocking) is likely to affect other components of the system. Post-larval and juvenile eastern king prawns are opportunistic omnivores and are mostly considered to be primary consumers which feed on epiphytic algae, seagrass (Ochwada *et al.* 2009) and small zooplankton.

Based on this information, the following Section considers the likely impacts of stocking on wild individuals of the same species (conspecifics), populations of stocked species as a whole, competitive interactions and habitat.

D.4.1.2 Results

D.4.1.2.1 Impacts on Conspecifics

Stocking has the potential to affect wild conspecifics through overstocking and swamping, by increasing fishing effort or by introducing stocked individuals that have a competitive advantage over the wild conspecifics. The evidence for these effects (found to occur in salmonids), is reviewed in Chapter C, Section C.4.1.1.

Overstocking is said to occur when the carrying capacity of the ecosystem is exceeded and habitat and food resources become limited, thereby increasing competitive interactions between stocked and wild individuals of the same species (i.e. intra-specific competition). Resource limitation can potentially lead to starvation (affecting mortality, reducing growth and fecundity), population fragmentation and even cannibalism between stocked and wild individuals. In rare instances, fish stocking has been known to replace rather than augment wild production so that wild populations declined over time (Hilborn and Eggers 2000). With the exception of salmon the documented evidence is that this is not the case for most species studied (Blaxter 2000).

It is also possible that stocked fish could have a competitive advantage over the wild population through conditioning within the hatchery or broodstock selection process. However, the most likely scenario is that wild stocks have a competitive advantage over hatchery-reared stocks, both in terms of experience in the wild and overall fitness, as was thought to be the case with the black bream stocked in Western Australia (Potter *et al*. 2008).

It has also been proposed that stocking may increase fishing effort at both the location of release and where both wild and hatchery stocks occur. This could lead to an increase in harvest on the conspecific wild stock and has occurred for the salmon fisheries overseas (Ackerfors *et al.* 1991, Hilborn and Eggers 2000). Note that the likelihood of an increase in fishing effort (at a local and regional scale) as a result of the proposed marine stocking program is discussed as a separate issue in Section D.5.2.2.7. Based on this assessment it is assumed that there may be a redistribution of fishing effort at a local scale (potentially leading to a concentration of fishing effort at stocked estuaries), but that an overall increase in fishing effort at a regional scale or State level would be unlikely.

Using the risk analysis model the likelihood of declines in abundance of conspecifics would be 'possible' (i.e. could occur and has occurred in similar circumstances). As the cohort of stocked fish would probably be present for at least one year, the consequences could be 'moderate' (i.e. harm with possible effect throughout an estuary, recovery longer than three years). Hence, the overall level of risk would be 'high' and measures are required to reduce or manage high risks.

Stocking could potentially alter the size-structure of estuarine populations of conspecifics if the cohort of stocked fish causes mortality of conspecifics of a particular size. Without proper control, the same issues associated with overstocking (as mentioned above) also apply to size-structure (i.e. the cohort of stocked fish could potentially outcompete or cannibalize wild fish of other sizes). Although there is evidence of adverse effects of competition between stocked and wild fish (Chapter C, Section C.4.1.2), little is known about the sizes of fish affected. It's probable that fish of a similar size to the stocked fish would be most vulnerable as these fish are likely to be competing for the same resources, whereas smaller or larger wild fish may be dependent on different types of food or habitat. Hence, conservatively, we consider that the likelihood of the size-structure of conspecifics being affected would be 'possible' if there was limited control of stocking events in NSW estuaries. As the cohort of stocked fish would probably be present for at least one year, the consequences could be 'moderate' (harm with possible effect throughout an estuary, recovery longer than three years). Hence, the overall level of risk would be 'high' and measures are required to reduce or manage high risks.

Without proper planning and species distribution information, there is also a risk that stocking could occur outside the natural geographical range of the species. This could potentially occur for giant mud crabs which are restricted to northern estuaries. To a lesser extent this could also occur for the other species if they were stocked into estuaries where they did not normally occur (e.g. because their preferred habitat was not available).

Stocking where species do not normally occur would constitute non-endemic introductions and would have serious implications for the dynamics of the receiving ecosystems. This would also constitute a key threatening process under the FM Act (Introduction of non-indigenous fish and marine vegetation to the coastal waters of NSW).

However, under the proposed harvest stocking program, species would only be stocked within their natural geographic range therefore the risks of this occurring would be 'rare '(i.e. could occur only in exceptional circumstances). As the cohort of stocked fish would probably be present for at least one year, the consequences could be 'moderate' (i.e. harm with possible effect throughout the estuary, recovery longer than three years). Hence, the overall level of risk would be 'moderate'.

D.4.1.2.2 Impacts on Competitors (Inter-Specific Competition)

Stocking has potential to increase competition among stocked species and other naturally occurring species that have similar ecological requirements, if natural equilibria are disrupted (i.e. causing inter-specific competition). Such disruptions could potentially lead to declines in abundance of naturally occurring species, particularly if overstocking occurs and there is an abundance of competitors (stocked and wild fish) but limited resources. As described in the previous Section, resource limitation can potentially lead to starvation (affecting mortality, reducing growth and fecundity), population fragmentation and even predation between stocked and wild individuals. This could have long-term consequences within an estuary as more than one species or component of the ecosystem could be affected.

It has also been proposed that stocking may increase fishing effort (at a local scale) at both the location of release and where both naturally occurring species (competitors) and stocked fish occur. This could lead to an increase in harvest of other species that compete with stocked fish. It is also possible that stocked fish could have a competitive advantage over wild populations through conditioning within the hatchery or broodstock selection, or if the stocked species was introduced into an estuary where it does not usually occur, although there is no evidence to support this so there is uncertainty in determining the risk level.

Given the level of uncertainty and the potential adverse effects, impacts on competitors would be considered 'likely' without control of stocking events. As the cohort of stocked fish would probably be present for at least one year or longer, the consequences could be 'moderate' (i.e. cause harm with possible effect throughout the estuary, recovery longer than three years). Hence, the overall level of risk would be 'high' and measures are required to reduce high risks to lower levels.

D.4.1.2.3 Impacts on Other Trophic Levels

Imbalances to density dependent interactions (i.e. competition and predation) in an estuarine ecosystem, as a result of stocking, has potential to effect the distribution, abundance and structure of populations of species at different trophic levels (Chapter C, Section C.4.1.3).

As juveniles, the seven species being assessed for stocking can be broadly described as secondary consumers, (with the exception of the eastern king prawn) which, at the post-larvae/juvenile stage, is considered a primary consumer. It is also noted that secondary consumers may switch prey according to seasonal abundance and or ontogenically.

Predation can be an important ecological process shaping abundances of marine organisms, that is, foraging activities of fish or invertebrates can remove large amounts of prey (Connell and Gillanders 2007, Underwood 1999). Increasing the number of consumers through stocking has potential to directly and indirectly affect populations of different species at other trophic levels through predation. For example, a substantial increase in the number of mulloway from stocking may result in increased predation of mysid shrimp (a major component of the diet of juvenile mulloway). Mysids fulfil a major role in estuarine and marine ecosystems. They are opportunistic omnivores with a large part of their diet consisting of copepods. They also facilitate the transfer of carbon from organic detrital material and phytoplankton to zooplankton and fish (Taylor 2008a). Therefore a decrease in numbers of mysids (from direct predation by mulloway) could have knock on effects at higher and lower trophic levels and also effect nutrient cycling. At lower trophic levels this might result in increased primary production (Christensen and Pauly 1998, Reznick and Ghalambor 2005).

When first released into an estuary, stocked juveniles will also be vulnerable to predation by large piscivorous and tertiary consumers such as birds, therefore having a positive effect on these consumers at higher trophic levels. An increase in tertiary consumers might have consequential and unpredictable effects on other components of the estuarine ecosystem. The introduction of prey items can also lead to prey switching e.g. predators switch from a naturally occurring target prey to stocked juveniles, which are less adapted to survival in the wild and/or because of a concentrated abundance of naïve hatchery fish in a small area as identified by Molony *et al*. (2003). This can potentially lead to an increase in the naturally occurring target prey causing cascading trophic effects.

It is noted that the creation of new niches or trophic levels as a result of marine stocking would not be expected as native species would be stocked only within their natural geographic range and into estuaries where habitats for those species naturally occur. Secondary consumers would therefore form a part of the natural estuarine dynamics.

In reality, trophic interactions are likely to be far more complex than potential impacts of predation alone and it is uncertain whether negative interactions as a result of marine stocking are likely to have any significant ecological impacts.

Based on the risk analysis model, and in the absence of species and estuary specific studies and controls on the number of stocked individuals, adverse impacts to other trophic levels in NSW estuaries would be 'likely'. As the cohort of stocked fish would probably be present for at least one year, and given the level of uncertainty, the consequences could be 'moderate' (harm with possible effect throughout an estuary, recovery longer than three years). Hence, the overall level of risk would be 'high' and measures are required to reduce this risk to lower levels.

D.4.1.2.4 Impacts on Estuarine Habitat

As described in Chapter C, Section C.7.4, there is a diverse range of habitats which occur in estuarine environments ranging from seagrass beds and unvegetated soft substratum (sand and mud) to subtidal rocky reefs and intertidal rocky shores. Estuarine waterways may also be fringed by riparian vegetation, including reeds, mangroves and saltmarshes and trees such as casuarinas, eucalypts and paperbarks, which are important roosting and nesting habitat for estuarine birds. Stocking has potential to affect estuarine habitats, directly e.g. through impacts of the stocked species or indirectly through fishing activities. Eastern king prawns (*Melicertus plebejus*), for example, may feed directly on seagrass and the epiphytic algae that live on them (Taylor Pers. Comm. 2009 and Ochwada Pers. Comm. 2010), thus overstocking of juvenile prawns directly into this habitat could potentially result in overgrazing and a reduction in the condition and abundance of seagrass habitat. Indirect effects may be caused by recreational fishers through habitat disturbance, trampling of vegetation and seagrass beds (particularly when prawning). An increase in fishing activity could also increase littering, lost or discarded fishing gear and disturbance to nests and roosting habitat of waterbirds. It is also possible that fish releases as part of the stocking program could contribute to indirect impacts by trampling and habitat disturbance if appropriate access points are not utilised.

The likelihood of adverse impacts to habitat are considered 'possible' with limited control of stocking events in NSW estuaries as there has been visual evidence of both direct (consumption of seagrass) and indirect effects (trampling) during prawn stocking trials (Taylor Pers. Comm. 2009). As the cohort of stocked fish would probably be present for at least one year or more, the consequences could be 'moderate' (i.e. cause harm with possible effect throughout an estuary, recovery longer than three years). Hence, the overall level of risk would be 'high' and measures are required to reduce high risks to lower levels.

D.4.1.2.5 Impacts on Adjacent Coastal Waters

The seven species selected in the proposal can be estuarine residents for the majority of their life cycles with most of the selected species likely to remain within the estuary as juveniles. All of the selected species, however, can occur outside estuaries or may move outside their resident estuary as adults to spawn, or may live in coastal inshore waters (Chapter C, Section C.8). This has implications for impacts beyond the estuary. For example, yellowfin bream may also inhabit ocean beaches, rocky headlands and inshore reefs and spawn in the surf zone, over river bars and river entrances during winter months (Pollock 1982). Spawning in mulloway, dusky flathead and sand whiting, is thought to take place near estuary mouths or nearshore coastal waters. Adult blue swimmer crabs may spawn in oceanic waters, inshore coastal waters or in the entrance channels of estuaries, whereas giant mud crabs move offshore (to depths up to 60 m) to spawn. Female giant mud crabs are then thought to return to the nearshore coast after spawning. Adult eastern king prawns are rarely present in estuaries, however, as juveniles move to offshore waters at certain times of the year. Many of the fish species may return to estuaries after spawning but it is uncertain whether they would return to the same estuary from which they were resident.

As a result of the varied spawning requirements of the selected species and for stocking to increase the abundance of these species there is potential for stocking to have effects in nearshore coastal waters beyond the limits of the stocked estuary. Potential impacts could include changes in competitive interactions from the increased abundance of a stocked species and consequentially to other components of the food web. There is also some potential for increased habitat disturbance outside the estuary or at estuary mouths, e.g. if recreational fishers target fish on a run out tide or during spawning events, although these impacts to habitat are likely to be insignificant. Potential ecological impacts beyond the stocked estuary could occur but are not expected and as such are ‘unlikely’ due to the small numbers of individuals (relative to those remaining in estuaries) that would disperse there. Where impacts occur, the consequences of these are likely to be ‘minor’ as they would be localised (outside the estuary), hence the overall risk is considered ‘low’.

D.4.2 Threatened Species

D.4.2.1 Existing Conditions

Detailed results of the database searches for threatened species are given in Chapter C, Section C.9.1. In total 14 species of fish, 31 species of cetaceans (whales and dolphins), one sirenian (the dugong), seven species of pinniped (seals and sea lions), five species of marine reptile (including turtles and sea snakes) and 125 species of estuarine bird were listed as threatened and/or protected within NSW estuaries. All syngnathiformes (seahorses, seadragons, pipefish, pipehorses and seamoths) were included as a group in addition to the 14 species of fish that were listed. The presence of threatened ecological populations and communities were also identified although only those known to be associated with estuarine habitats were considered.

D.4.2.2 Results

Threatened species potentially affected by the proposal are identified in Chapter C, Section C.9.1. Assessments against State or Commonwealth significant impact guidelines for individual or groups of species, populations and communities can be found in Appendix 2 and 3. Threatened species are potentially most affected by impacts of fish stocking if they reside or utilise estuarine waterways.

D.4.2.2.1 Key Threatening Processes (KTPs)

The following KTPs are relevant to the marine stocking proposal:

- *Hook and line fishing in areas important for the survival of threatened fish species* (FM Act);
- *Entanglement or ingestion of anthropogenic debris in marine and estuarine environments* (TSC Act); and
- *Injury and fatality to vertebrate marine life caused by ingestion of, or entanglement in, harmful marine debris* (EPBC Act);

A detailed description of each of these KTPs is provided in Chapter C, Section C.9.2.

Exacerbation of KTPs could occur if there were an increase in fishing effort within the stocked estuaries as a result of the proposal. It is illegal to catch threatened species in NSW but localised increases to fishing effort could lead to an increased risk of incidental hooking, netting or trapping which could lead to post-capture stress or mortality to some individuals. For example, black cod and estuary cod are also slow moving and relatively easy to catch by line, making them particularly vulnerable to hook and line fishing.

Anecdotal information suggests that these groups of animals are rarely caught in estuaries by nets or traps but since 2005, eight marine turtles have been reported drowned in crab traps. Nevertheless, the potential for increased fishing effort associated with stocking has potential to increase the level of discarded netting, line and traps from current levels. A localised increase in fishing effort within the stocked estuaries would potentially also increase the risk of lost fishing gear and harmful marine debris entering estuaries. Studies have found that threatened marine species (particularly marine turtles, pinnipeds, small cetaceans and seabirds) can ingest or become entangled in marine debris (often plastics) (NSW DECCW 2010c). This can lead to lethal or detrimental impacts such as strangulation, increased drag, poisoning, blockage and/or perforation of an individual's digestive system, wounds, consequent infection and gastric impaction. Sub-lethal effects of entanglement or ingestion of marine debris may reduce an individual's fitness and ability to successfully reproduce, catch prey and avoid predation (DECCW 2010c). Gear restrictions and modifications are not, however, within the scope of the FMS and are addressed through DPI who continually promotes the improvement and modification of gear to minimise impacts on threatened and protected species.

The likelihood of adverse impacts to threatened species are considered 'possible' as there has been evidence of hook and line fishing and ingestion or entanglement of marine debris by threatened species elsewhere. As there could be harm with a possible effect throughout an estuary (and recovery could be longer than three years), the consequences could be 'moderate'. Hence, the overall level of risk would be 'high' and measures are required to reduce high risks to lower levels.

D.4.2.2.2 Trophic Impacts

Increasing the number of consumers within a system has potential to affect species at other trophic levels through density-dependent interactions such as competition and predation.

Change in competitive interactions can potentially result in the alteration of distribution, abundance and structure of populations. Trophic impacts can also extend beyond the stocked estuaries if some of the stocked fish leave the estuaries, although these effects are likely to be negligible compared to the potential effects within the stocked estuaries.

As a precautionary approach the likelihood of adverse trophic impacts from stocking to threatened species are considered 'possible' if there was limited control of stocking events. As there could be harm with a possible effect throughout an estuary (and recovery could be longer than three years), the consequences would be 'moderate', hence, the overall level of risk would be 'high' and measures are required to reduce high risks to lower levels.

D.4.2.2.3 The Potential for Concentration/Increase in Recreational Boating Activity

The potential for increased fishing activity within stocked estuaries could also increase recreational boating activity in the stocked estuaries resulting in greater risk of:

- boat strike (marine mammals and turtles);
- acoustic disturbance (marine mammals and bird nesting or foraging habitat).

It is possible that there may be a localised increase in fishing effort where there is stocking activity, thus there would be potential for increased recreational fishing boating activity. Although an increase to commercial fishing boating activity could also occur it would be negligible when compared to the potential for an increases to recreational fishing boating activity as there are much fewer registered commercial fishing vessels (NSW Fisheries 2001). Cetaceans, turtles and sirenians (dugongs) are vulnerable to boat strike as they can be slow moving and found swimming just below the water line. Turtles and some marine mammals (i.e. dolphins) are relatively common in some NSW estuaries and anecdotal reports suggests that they are able to avoid harm from boats, although boat strike to loggerhead turtles has been identified as an issue for this species in Queensland. Some large cetaceans such as humpback and southern right whales would be most vulnerable during their annual migrations along the NSW coastline (May to November). During these periods these species are known to pass through or rest in coastal embayments and there is a small chance that they could be affected either directly (e.g. boat strike, acoustic disturbance) or indirectly, (e.g. by reduced water quality) if there is an increase in boating activity. Twofold Bay (southern NSW) is considered an important resting place for humpback whales including for cow-calf pairs on their southern migration (DEH 2005b) and southern right whales occasionally calve there (DEH 2005a). Assuming that stocking increased the level of boat-based fishing, the likelihood of boat strike would still be 'unlikely', as approach distances and interaction with marine mammals is regulated under the NSW *National Parks and Wildlife Regulation 2009*, administered by the OEH. The consequence would be considered 'minor' as the impact would be localised. The overall level of risk would therefore be 'low'.

Many studies have indicated that marine mammals show short-term behavioural reactions to anthropogenic acoustic disturbance such as boats (e.g. Richardson *et al*. 1995) and turtles and birds could also be disturbed. There is a risk that increased boating as an indirect result of marine fish stocking in estuaries could contribute cumulatively, to existing noise/vibration levels caused by boat engines. In the worst case, marine mammals and turtles are likely to show avoidance behaviour by diving or moving away, any brief interruption of normal behaviour is unlikely to have significant effects on the well-being of individuals. Based on the risk assessment it is therefore considered 'possible' that some estuarine marine fauna could be affected by acoustic disturbance, as there are examples of this occurring elsewhere, the consequences would be minor (i.e. localised impact within an estuary), thus the overall risk level is moderate.

Note that other general impacts associated with increased boating activity (e.g. reduced water quality, noise and light pollution) are discussed in Section D.6.

D.4.2.2.4 Incidental Capture

Incidental capture from increased fishing effort potentially associated with the proposal could affect threatened species of fish, marine turtles and seabirds foraging in stocked estuaries. Incidental capture can lead to post-capture stress and in some cases mortality (see KTPs, Section D.4.2.2.1). Even when returned to the water, hooks caught in fishes mouths can result in damage that can impact on feeding behaviour and success. Over a longer time, hooks retained in the mouth, throat and stomach of fishes, sharks and turtles can lead to early mortality (FSC 2003).

Some threatened fish (e.g. black cod), wading birds, diving birds and raptors and marine turtles reside in estuaries. Other threatened species may range into estuaries to feed on occasion. The threatened species identified through this EIS process as the most vulnerable to incidental capture by hook and line are black cod which are usually cryptic, relatively slow moving and readily take baits and marine turtles which may be netted or trapped. For these species, the likelihood of incidental capture causing injury or mortality would be 'possible' with 'moderate' consequence; hence the overall risk is 'high' and requires measures are to reduce high risks to lower levels.

D.4.2.2.5 Damage to Habitat

Increased fishing activity potentially associated with the proposal could lead to trampling and/or disturbance of threatened species habitat such as seagrass, mangroves and endangered ecological communities (e.g. coastal saltmarsh or shorebird nesting and feeding habitat). *Posidonia australis* (a type of seagrass commonly known as strapweed) that occurs in Port Hacking, Port Jackson, Botany Bay, Pittwater, Brisbane Water and Lake Macquarie is/are listed as an endangered populations under the FM Act. Marine fish stocking has been proposed for all estuaries that support endangered populations of *Posidonia australis.* Critical habitat for little penguins also occurs at Little Manly (Port Jackson).

Seagrass is valuable as nursery, feeding and shelter areas for many aquatic animals including threatened marine turtles and dugongs, which are dependent on seagrass habitat for food at some or all of their life stages. Trampling of seagrass could potentially occur if there was a significant increase or redistribution and concentration of fishing effort as a result of stocking and therefore have indirect impacts on the species that depend on it. The scale of any potential impact is, however, likely to be small and is not expected to cause fragmentation or damage to the extent that a population of any of the above species would be affected. Dugongs feed on seagrass but they are not resident to NSW and those that are occasionally recorded in NSW are considered to be vagrants. Some turtles feed on seagrass and these can be more common. Any trampling associated with prawning or angling is most likely to occur in very shallow areas of estuaries where dugongs and turtles would probably not venture often. There are a number of endangered ecological communities and other intertidal habitats important to threatened species that could also be potentially affected by habitat disturbance or trampling from increased fishing activity related to stocking (Appendix 2). Two endangered ecological communities are particularly relevant to the proposal as they occur across the intertidal zone of estuaries, these are *coastal saltmarsh in the NSW north coast, Sydney basin and south-east corner bioregions* and the *shorebird community at Taren Point, Botany Bay*. Many areas of intertidal or high shore habitat considered important to the survival of any threatened or protected species of shorebirds are, however, already protected within Ramsar wetlands which would not be stocked. Any ecological community that fringes an estuary has potential to be disturbed or trampled by fishermen accessing the waterways and possibly during stocking releases.

Other riparian habitats, such as nesting areas of endangered population of little penguins at Manly could be vulnerable to disturbance, although fishing activity from stocking would be unlikely to significantly contribute to the existing level of disturbance in the area which is urbanised and already popular for fishing, boating and swimming. There is a minor risk that fisherman accessing waterways from areas of unconsolidated banks or increased wash from recreational boats associated with recreational fishing activity could affect bank erosion. However, given that any increase in local fishing effort is likely to be small, the activity itself would be very unlikely to cause a noticeable cumulative impact such that there would be an impact on sedimentation or bank stability.

With limited control of stocking, the potential for these impacts to occur to an extent or frequency that would cause an adverse effect on a protected habitat is 'possible' with 'moderate' consequence, hence the overall risk is 'high' and requires measures to reduce high risks to lower levels.

D.4.3 Areas of Conservation Significance

D.4.3.1 Existing Conditions

Areas of conservation significance which have been considered in this assessment are those that are entirely or partly associated with estuarine habitats or are linked to estuarine habitats and therefore have potential to be affected by marine stocking activity. These include:

- Ramsar Areas;
- Marine Protected Areas (MPAs);
  - Marine Parks;
  - Aquatic Reserves;
- Critical Habitat with a marine extension;
- National Parks with a marine extension;
- Nature Reserves with a marine extension;
- World Heritage Areas with an estuarine component;
- Wilderness Areas with an estuarine component.

Information regarding these areas of conservation significance is provided in Chapter C, Section C.9.3.

D.4.3.2 Results

Stocking directly into MPAs or into waters connected to MPAs could have potential detrimental impacts to species and habitats through a number of processes discussed in other Sections of this assessment. This could include, for example, the introduction of parasites and diseases (Section D.4.5), ecological impacts on wild populations and trophic interactions, leading to ecosystem imbalances (Section D.4.1) and indirect impacts on habitat through increased recreational fishing activity (Section D.4.1.2.1). Considering that areas of conservation significance are often representative of unique or pristine habitat, or include habitat critical to the survival of a threatened or protected species, impacts could potentially cause serious long-term harm if not adequately managed. The scale of impact is also relevant to the extent of the conservation area (and not at the estuary scale); hence a separate scale of consequence was used for the basis of the risk assessment (Table D.5).

D.4.3.2.1 Marine Park/Ramsar Wetland

As an outcome of the Multi-Criteria Analysis (MCA) it was determined that stocking would not take place into Marine Parks or Ramsar wetlands. Information about these types of MPAs is provided in Sections C.9.3.1 and C.9.3.2. As these types of MPA are often open systems and (as described in Section D.4.1.2.5) stocked species may move outside their resident estuary, there is potential for stocking to interact with these areas. As for D.4.1.2.5 (Impacts on Adjacent Coastal Waters), all the potential ecological impacts discussed in the biophysical impact Section are likely to be significantly less ('unlikely') in waters outside the stocked estuaries due to the small numbers of individuals (relative to those remaining in estuaries) that could disperse there. Where impacts occur, the consequences of these are likely to be localised ('minor'), hence the overall risk is considered 'low'.

D.4.3.2.2 Aquatic Reserves

Aquatic Reserves located along the NSW coast generally occur outside of estuaries or on the periphery (see Chapter C, Section C.9.3.2). As outlined in Section D.4.1.2.5 (impacts on adjacent coastal waters), potential impacts to aquatic reserves could include changes in competitive interactions (from the increased abundance of a stocked species) and other components of the food web. There is also potential for increased habitat disturbance. Risks associated with stocking activity on Aquatic reserves located outside estuaries would, however, be considered unlikely and any impacts related to stocking would be undetectable.

The exceptions to this are Towra Point, Ship Rock and North Harbour Aquatic Reserves which are located within Botany Bay, Port Hacking and Port Jackson respectively. It is possible that without appropriate management, stocking could impact on these few Aquatic Reserves. The likelihood of stocking having an impact on Aquatic Reserves is considered to be 'possible' and the consequences potentially 'moderate' (i.e. could cause harm with a possible effect throughout the Aquatic Reserve). The overall risk of stocking into Aquatic Reserves is therefore 'high' i.e. the risk is significant and measures to reduce or manage the risk are required.

D.4.3.2.3 Critical Habitat, Nature Reserves, National Parks

Critical Habitat, Nature Reserves and National Parks with marine extensions do not occur within estuaries proposed for stocking and would therefore not be directly affected by the impacts associated with fish stocking (such as ecological impacts on wild populations, ecosystem imbalances and indirect habitat impacts). As such, the likelihood of a detectable indirect impact occurring would be 'unlikely' and if an impact was detected the consequences are considered to be 'minor'. The overall risk of stocking impacting on Critical Habitat and/or Nature Reserves and National Parks (marine components) is therefore considered to be 'low'.

D.4.3.2.4 Impingement on World Heritage Areas (WHAs)

No WHAs that extend below the Mean High Water Mark (MHWM) were identified to occur in any of the 80 estuaries proposed for marine stocking (as determined through the MCA process). As such, the 'likelihood' of a detrimental impact on such areas would be 'rare' and the consequence should an impact occur be 'insignificant', hence the overall risk level is 'low' and the issue is not considered further within the EIS.

D.4.3.2.5 Impingement on Wilderness Areas

The assessment of estuaries' suitability to marine stocking (Multi-Criteria Analysis) indicated there were three Wilderness Areas that could potentially be affected by the proposal (Bundjalung, Limeburners Creek and Nadgee Wilderness Areas). Estuaries that occur within or adjacent to these boundaries (Merrica River, Nadgee Lake and Nadgee River) were eliminated in stage one of the MCA and therefore would not be stocked. As such, the 'likelihood' of a detrimental impact on such areas would be 'unlikely' and the consequence should an impact occur be 'minor', hence the overall risk level is 'low' and the issue is not considered further within the EIS.

D.4.4 Population Genetics

D.4.4.1 Existing Conditions

Potential impacts on genetic diversity and structure are important considerations regarding the genetic effects of fish stocking. Background information on genetic diversity and structure and the use of population genetics to measure these effects is provided in Chapter C, Section C.4.1.4. The genetic effects of stocking can be broadly divided into those that are a direct consequence of interbreeding between stocked and native fish (i.e. direct effects) and those that occur in the absence of interbreeding (i.e. indirect effects). It is expected that a substantial proportion of stocked fish would be harvested once they reach a legal size. Individuals of some species are likely to reach a legally harvestable size before they reach maturity (e.g. mulloway, eastern king prawn and giant mud crab), therefore a proportion of these stocked individuals may not reproduce. Stocked individuals that reach maturity before they reach a legally harvestable size could potentially reproduce either among themselves or with wild conspecifics and could therefore contribute to the longer-term sustainability of the population. It is for that proportion of the population that there is a greater risk of direct genetic effects from interbreeding (i.e. introgression and the Ryman-Laikre effect). A framework to describe the genetic effects of stocking (Utter 2003) and examples are given in Chapter C, Section C.4.1.4.

D.4.4.2 Results

D.4.4.2.1 Direct Impacts

1. Introgression

Direct impacts of introgression are considered to be similar for all species proposed for stocking with the exception of the eastern king prawn (see below). There is no evidence to suggest that stocked individuals could interbreed with other species (including threatened or protected species) apart from the yellowfin bream which is known to hybridise with the black bream (*Acanthopagrus butcheri*), which is discussed further in Section D.4.4.2.2.

Using the risk assessment model the likelihood of introgression effecting species proposed for stocking would be 'likely' (i.e. would probably occur) if there was limited control of stocking events in NSW estuaries. If estuaries were stocked without appropriate broodstock and hatchery management protocols, the consequences could be 'moderate' (i.e. cause harm with a possible effect throughout an estuary and with recovery longer than three years). Hence, the overall level of risk would be 'high' and measures are required to reduce the risk. The likelihood of introgression affecting the eastern king prawn is 'rare' (i.e. could only occur in exceptional circumstances) because the majority of stocked prawns are likely to be caught as juveniles. The small number of stocked prawns that survive to mix and mate with the spawning population is likely to be very small relative to the number of wild individuals. Although the consequences would still be 'moderate' if interbreeding did occur, the overall risk level for eastern king prawn is 'moderate'.

2. Ryman-Laikre Effect

With limited control on stocking activity, the likelihood of causing Ryman-Laikre effects to wild populations would be 'possible' (i.e. could occur and has occurred in similar circumstances) for all species proposed for stocking with the exception of the eastern king prawn. The effects may be less severe for species that form large populations and disperse along the coast (e.g. blue swimmer crab) creating a greater effective genetic population size. For the eastern king prawn, Ryman-Laikre effects are likely to be 'rare' (i.e. could occur only in exceptional circumstances). This is because the life cycle of eastern king prawns includes breeding migration northwards, spawning in a presumably large population in northern waters, followed by larval advection southwards and movement of post-larvae into NSW estuaries. Stocking post-larvae into selected estuaries may enhance local recreational prawn fishing opportunities, but the possibility that stocked post-larvae successfully contribute to the breeding population is low, given life cycle and presumably large census size of the adult breeding population. Interbreeding of stocked and wild populations is therefore 'unlikely'.

The consequences of the Ryman-Laikre effect occurring would be 'moderate' (i.e. could cause harm with possible effect throughout an estuary, with recovery longer than three years) for all species if it was to occur. Hence, the overall risk level would be 'moderate' for the eastern king prawn and 'high' for yellowfin bream, mulloway, dusky flathead, sand whiting, giant mud crab and blue swimmer crab. Measures are therefore required to reduce these risks.

D.4.4.2.2 Indirect Impacts

1. Wastage of Gametes

Without controls on stocking it is likely that yellowfin bream would be stocked in estuaries where wild populations of black bream occur. Interbreeding of the two species would be 'likely' as hybridisation of these species is known to occur in NSW. This would constitute significant wastage of gametes to black bream populations that may not have interbred with yellowfin bream if stocking had not been done. The consequence of this occurring would be 'major' to populations of black bream as they may never recover. Based on the risk assessment model, this constitutes an 'extreme' risk.

For all other species, the likelihood of gametic wastage would be 'rare' (i.e. could only occur in exceptional circumstances) as there is no reason why stocked and wild fish would not interbreed and contribute to future populations. The consequences would be 'minor'. Hence the overall risk level would be 'low' and no further management is required.

2. Naturalisation leading to fragmentation.

The likelihood of naturalisation and subsequent fragmentation occurring are considered to be 'rare' for those species that can disperse along the coast in their adult stages (i.e. yellowfin bream, mulloway, dusky flathead, sand whiting, and eastern king prawns) and that are assumed to disperse within estuaries. Thus, native populations are more likely to become sympatric (i.e. co-occurring) with stocked fish and crustaceans rather than isolated by groups of them that had become naturalised. If stocking caused naturalisation and subsequent fragmentation the consequences would be 'minor' (localised impact but recovery measurable within 1 - 3 years) and hence the overall risk would be 'low' and no specific action is required to further reduce this risk for these species.

The risk of naturalisation and subsequent fragmentation occurring is greater for species that may not disperse at a later stage in their life cycle (i.e. giant mud crabs and blue swimmer crabs). Based on the risk assessment model, this would be 'unlikely' and the consequences would be 'moderate', hence the overall risk level would be 'moderate'.

3. Overfishing of mixed stock fisheries

Stocking has potential to increase fishing effort (at a local scale). This could potentially lead to the overfishing of populations. Should overfishing occur, the effective population sizes for some species might be reduced. Genetic effects of overfishing on yellowfin bream, mulloway, dusky flathead, sand whiting and giant mud crab are considered 'possible' as it is uncertain whether these species are panmictic, or exist as genetically distinct sub-populations within some estuaries. Montgomery *et al*. (2007) identifies the importance of eastern king prawn populations south of Port Stephens, as there is no information available about the relative contribution of recruits from different areas to the eastern king prawn spawning stock. Similar can be said for the blue swimmer crab populations along the NSW coast despite both species being part of large populations along the NSW coast. Any potential impacts of overfishing are likely to have a greater impact on small populations than a population that occurs throughout the NSW coast. However, existing fishing regulations on gear type and restrictions on bag and size limits and the ability to amend these regulations to address the risk of overfishing for the stocked species are considered adequate measures to minimise the possible impacts of overfishing from a potential increase in fishing effort associated with stocking. This considered, the likelihood of reduced genetic diversity from overfishing resulting from stocking would be 'unlikely' and the consequences of overfishing would potentially be 'moderate' for the above species. Hence the overall risk would be 'moderate'.

D.4.5 Disease, Parasites and Pests

D.4.5.1 Existing Conditions

Intensive rearing of juveniles in hatcheries and nursery systems at high densities can potentially create a favourable climate for the amplification of pathogens, which increases the potential for disease transmission to wild stocks. Certain viruses, bacteria, fungi, parasites and other organisms that may not be pathogenic under normal environmental conditions but can become problematic in stock enhancement programs (Bartley *et al*. 2006). This assessment takes into account the potential for disease to have direct (e.g. via release of infected stock) or indirect (e.g. via water discharge) impacts to natural NSW populations. It also considers the impacts of endemic and exotic disease which in the context of this assessment are defined as:

Exotic: Of foreign origin or character and/or has been introduced to NSW from other States or abroad but has not yet reached a steady state in the population in question.

Endemic: A disease is said to be 'endemic' to NSW when it is maintained in a steady state within a NSW population without external inputs.

Risks associated with disease and parasites and their potential impacts in relation to marine stock enhancement activities are discussed under the following Sections:

- Infection of hatchery reared fish/crustaceans with *exotic* disease/parasite causing contamination of farm and adjacent waterway;
- Infection of hatchery reared fish/crustaceans with *endemic* disease/parasite causing contamination of farm and adjacent waterway;
- Translocation of *exotic* crustacean or fish diseases/parasites into wild populations from hatcheries;
- Translocation of *endemic* crustacean or fish diseases/parasites into wild populations from hatcheries; and
- Release of stock selected for reduced disease/parasite susceptibility causing undesirable modification of wild genotypes.

This Section also assesses the potential for marine stocking activities to facilitate the translocation of marine pests/fouling organisms and non-target species and the likely impact on the environment.
This issue is discussed under the following Sections:

- Translocation of other pest organisms; and
- Translocation of non-target species.

Furthermore, the risks and potential impacts associated with fish/crustacean health during the hatchery operation, transport and release are assessed under the following headings:

- Hatchery/farm culture system failure causing poor on-farm stock health, culminating in stock which have difficulty withstanding stresses associated with harvest, transport and/or handling procedures;
- Transport system failure causing poor stock health prior to release; and
- Release system failure causing poor stock health and/or mortalities at the release site.

Note that the assessment relating to disease, parasites and pest issues is general and does not consider risks of individual pathogens for each individual species.

Background information in regard to diseases and parasites and the translocation of pests and non-target species associated with marine stocking are reviewed in Chapter C, Section C.4.1.5.

D.4.5.2 Results

D.4.5.2.1 Infection of Hatchery-Reared Fish and Crustaceans with Exotic Disease/Parasite Causing Contamination of Farm and Adjacent Waterways

Parasites and disease are an integral part of any natural system; however, the introduction of an exotic pathogen into natural water bodies can cause the subsequent infection of existing species and change the disease status of the natural waters. The introduction may also exacerbate existing diseases by increasing their incidence, virulence, potency or frequency and can reduce the competitiveness of the affected species.

Exotic viral diseases of fish, including various forms of viral nervous necrosis (VNN) have caused serious problems in hatcheries supporting sea-farming programs throughout the world. There are, however, a number of controls that have been established, such as pathogen free broodstock collection and egg disinfection activities, that effectively reduce the likelihood of the most problematic types of pathogens (i.e. viral infection) occurring. For cultured crustaceans, White Spot Syndrome Virus (WSSV) is likely to be the most important disease around the world. It has caused a five-fold reduction in shrimp production in China in the early 1990's (Lucien-Brun 1997) and has since spread to Japan, the rest of Asia, and to the southern parts of the U.S.A. It and some of the other similar viral diseases of crustaceans like Yellow Head Virus (YHV) and Taura Syndrome Virus (TSV) have not yet occurred in NSW (or anywhere in Australia), but represent a significant risk to Australian wild and cultured crustacean fisheries. These viruses are spread via birds, insects and many other aquatic organisms and so are difficult to contain. Examples in Taiwan and elsewhere have shown that the potential for contaminated farms to affect adjacent waterways can have major effects on the industry and is therefore a substantial threat should it become established in NSW waterways.

Without proper hatchery quality assurance, surveillance and controls, the likelihood of contamination of NSW waterways with exotic disease (even from adjacent Australian States) would be 'possible' as there are examples of contamination of farms by exotic pathogens the world over. There would also be potential for contaminated farms to affect adjacent waterways. Based on examples elsewhere, the consequences could be 'moderate', (i.e. harm with possible effect throughout an estuary, recovery longer than three years). Hence, the overall level of risk would be 'high' and measures are required to reduce these risks to lower levels.

D.4.5.2.2 Infection of Hatchery-Reared Fish and Crustaceans with Endemic Disease/Parasite Causing Contamination of Farm and Adjacent Waterways

Farm-based endemic disease can contaminate hatcheries, leading to the amplification and/or reintroduction of pathogens and parasites into NSW waterways.

An example of a cosmopolitan, opportunistic bacterial disease that may affect fish and crustaceans within NSW and has been recorded in other parts of Australia is Vibriosis, which has caused high losses in prawn and crab hatcheries. The disease is often associated with stress or occurs as a secondary infection due to high densities or poor water quality, Vibriosis is therefore less likely to cause problems in healthy waterways adjacent to hatchery operations unless very active infections are present in the farm where bacterial shedding heavily contaminates discharge waters.

Mortalities have been reported in aquaculture facilities producing certain species of marine fish including mulloway and yellowfin bream associated with organisms such as ciliated protozoan and monogenean trematodes. Heavily infested fish may lose appetite, flash or rub their bodies on tank surfaces, swim slowly, lose their flight response when attempts are made to catch them and show rapid or laboured gill movement. Heavy mortality can occur if diseases are left untreated and at other times when fish are stressed. Several viruses affecting prawns may also be specific to Australian (NSW) conditions, since several have not been reported overseas e.g. *Scylla baculovirus* (Lavilla-Pitogo and de la Pena 2004).

Hence, with limited control over hatcheries, the likelihood of adverse impacts would be 'possible' as there are examples from elsewhere (e.g. bacterial vibriosis in Japan) where endemic diseases have caused serious problems in several fish species in hatcheries and there would also be potential for contaminated farms affecting adjacent waterways. The consequences would be 'minor' (localised impact within estuary, recovery measurable within 1 – 3 years) as diseases are endemic and the receiving environment although problems elsewhere have been serious they have generally been controlled through standard hygienic practices and chemotherapy (Mushiake and Muroga 2004). Hence, the overall level of risk would be 'moderate'.

D.4.5.2.3 Translocation of Exotic Fish and Crustacean Disease/Parasite from Hatcheries into Wild Populations

Translocation (i.e. movement from one area to another), of exotic disease organisms may be devastating to wild populations within NSW (even from other States) because they are likely to have little or no resistance to new infection and passage. A common response of any natural population exposed to an introduced pathogen is mass mortalities (MCFFA 1999). Mass mortality of natural populations may lead to other trophic impacts, negative aesthetic impacts and have knock-on effects on the commercial and recreational fishing value of a waterway. An example of a serious disease that has been spread through fish introductions is whirling disease caused by the parasite *Myxobolus cerebralis*. It was introduced into the United States in the early 1950's and has since spread through salmonid populations causing significant devaluation of fisheries resources.

Parasites of salmonids have also been transferred into new bioregions and from hatchery-reared fish to wild populations (e.g. *Gyrodactylus salaris* into Norway: Johnsen and Jensen 1986). *G. salaris* is seen as a disease that spreads easily in cultured and wild stocks regardless of fish density (Murray 2009).

Another example is a viral epidemic that affected Western Australian pilchards between 1995 and 1999. Farmed tunas were fed on imported pilchards which caused a localised accumulation of the *herpesvirus* pathogen. Stocks were, however, found to recover quickly as juvenile schools did not become infected and the species of imported and wild fish were different, which was thought to reduce the transmission (Murray *et al*. 2001, Murray and Gaughan 2003). In this example, the fast recovery leads to a less severe impact.

As described in Chapter C, Section C.4.1.5.2, the three main exotic diseases of crustaceans that threaten NSW (and Australian) waterways are WSSV, YHV and TSV. The occurrence of these pathogens has caused devastating effects to shrimp farming enterprises in many parts of the world and similar damage could be expected in NSW and Australia should these pathogens become translocated into natural waterways. The consequences of these or similar viruses being translocated to NSW are potentially 'moderate', as they could cause widespread and long-term damage throughout an estuary if not properly mitigated. The likelihood of translocation is 'possible' as problems have occurred elsewhere. Hence the overall risk is 'high' and measures to reduce the risk are required.

D.4.5.2.4 Translocation of Endemic Fish and Crustacean Disease/Parasite from Hatcheries into Wild Populations

Translocation (i.e. movement from one area to another), of disease organisms endemic to NSW is considered to present less potential for adverse impacts than exotic introductions as they are likely to occur at background levels within the natural environment and native species are therefore likely to have some resistance to increased infections.

Hatchery production using asymptomatic carrier broodstock has, however, been known to amplify endemic disease beyond threshold levels causing significant disease expression in wild populations of molluscs. Several bacterial diseases are endemic to fish and crustaceans in different parts of the world (e.g. furunculosis in salmonids caused by *Aeromonas salmonicida*: Waples and Drake 2004), but are also thought to have been spread by fish introductions (e.g. furunculosis into the UK: Peeler *et al*. 2007) and by escapees from fish farms (e.g. furunculosis into Norway, Hastein and Lindstad 1991). Another example is bacterial kidney disease, which occurs widely in nature but has also been transmitted to wild populations from hatchery progeny (Mitchum *et al.* 1979).

Infectious Pancreatic Necrosis Virus (IPNV) is a common pathogen of Atlantic salmon which is increasing in prevalence and has now spread to most countries with salmonid production (Murray 2006), apart from Australia (DAFF 2009). Although it does not always cause high levels of mortality, it is highly contagious and considered one of the most damaging viral diseases of salmon in Europe (Murray 2006). In the UK it has been successfully controlled by movement restrictions and is approaching stability in its prevalence overseas. It is seen as a density-dependant disease which exists at subclinical levels in wild populations and is not expected to spread far in low density wild populations (Murray 2009). Compared with the damage that exotic diseases can have on the populations they invade (such as *G. salaris*), IPNV is thought to do little damage in the ecosystems where it is considered to be endemic (e.g. Russia, Finland and Sweden: DAFF 2009).

Hence, if there was limited control of hatcheries the likelihood of adverse impacts would be 'possible' as there are examples from elsewhere where endemic diseases have been translocated to wild populations. The consequences would be 'minor' (localised impact within an estuary, recovery within 1 - 3 years) as diseases are endemic to the State and it is likely that natural resistance would allow fish to recover without severe declines to populations. Hence, the overall level of risk would be 'moderate'.

D.4.5.2.5 Translocation of Non-Target Species

The accidental release or escape into the wild of non-target species could have several deleterious effects on the receiving ecosystem and existing wild populations. Where translocated fish are able to interbreed and reproduce there is potential to cause a genetic shift in the wild populations (discussed in Section D.4.4). Fish or crustaceans that are accidentally released into waterways may also establish non-native populations, if the individuals are able to survive long enough. This could have a range of adverse effects on natural communities including competition, predation, displacement and environmental modification, regardless of whether they are self-sustaining. Translocated organisms that do not naturally occur in the receiving waterway may compete with and displace naturally occurring species, causing potentially long-term effects on community structure. Where accidentally translocated species are not endemic to the region (or even country), the effects could be severe on the populations that they may prey upon, as there would have been no predator-prey co-evolution between the species (MCFFA 1999). Translocated organisms can potentially alter aquatic habitat through disturbance to aquatic vegetation, affect water quality and habitat of native species MCFFA (1999).

Given that accidental releases of non-target species has occurred in the past (albeit under a less stringent management regime), it is considered 'possible' that this would occur as a result of the proposed marine stocking program. If an accidental release did occur, the consequences would be 'moderate' as it could cause harm with possible effect throughout an estuary and with recovery longer than three years, hence the overall risk level is 'high' and measures to reduce this risk are necessary.

D.4.5.2.6 Translocation of Other Pest Organisms

With limited hatchery regulation, there is a risk that pest organisms (other than disease causing pathogens/parasites), such as algae, harmful plankton or pest invertebrates may be moved with the target species. There is also potential for organisms to be translocated from a hatchery to a waterway via the water used to contain the species for stocking during transport. The risks are considered to be greater when the stock comes from waters where pest organisms or algal blooms (for example) may be common and these organisms are not present in receiving waters. Translocation is, however, strictly regulated under National and State policy and also under the FM Act and permits are required for the release of any fish in NSW waterways. It is therefore considered 'unlikely' that this could occur as a result of the marine stocking program. The consequences of pest species being translocated would be 'moderate' as it could cause widespread and long-term damage throughout an estuary; hence the overall risk level is 'moderate'.

D.4.5.2.7 Release of Hatchery-Produced Fish and Crustaceans Selected for Reduced Disease/Parasite Susceptibility Causing Undesirable Modification of Wild Genotypes

The release of hatchery-produced fish or crustaceans with innate or acquired immunity to pathogens which may occur in the release area may be desirable (Mushiake and Muroga 2004), but there is potential for hatchery-based manipulations to directly or indirectly affect wild genotypes. For example, selection for juveniles that are resistant to, or apparently do not harbour the targeted diseases may reduce the number of broodstock that can be used and thus reduce the diversity of gene pools and/or inadvertently select for juveniles which have other attributes that are less desired. Once released these effects could filter through the wild populations through interbreeding. The approach of releasing resistant stock is most advanced in Japan where wild populations of fish and shrimp are infected with troublesome diseases that reduce the survival of seed produced from disease-free broodstock. To address this, the Japanese now use broodstock that are sourced from the areas to be stocked, thus making use of natural localised adaptations.

Hence, if the activity of marine stocking was not fully controlled so that hatchery-based manipulations to select disease resistant progeny were permitted, the likelihood of adverse genetic impacts to natural populations would be 'possible' as there are examples from elsewhere where this has occurred. The consequences of altering gene pools would be 'moderate' for populations that are contained within an estuary. Hence, the overall level of risk would be 'high' and measures to reduce the risk are required.

D.4.5.2.8 Hatchery Culture System Failure

There are many parts to fish hatcheries and culture systems that need to be managed for optimal results. In some cases failures are obvious, for example, when stocks die or fail to achieve desired growth rates or production levels. In some situations the stocks survive, but are not robust enough to cope with the stresses of harvest and transportation. Mechanical failures (e.g. electricity supplying power to aerators) can also result in ongoing health problems in progeny. With no control of hatchery protocols the likelihood of poor progeny health occurring in the marine stocking program is 'possible' as it has been known to occur elsewhere. The consequence to the estuarine environment are 'minor', however, as there would be local contamination only. The overall risk to the baseline environment of estuaries would be 'moderate'.

D.4.5.2.9 Transport System Failure Causing Poor Progeny Health Prior to Release

Difficulties in maintaining adequate water quality during the transportation of large numbers of fingerlings is common in aquaculture operations. Low dissolved oxygen (DO) and pH levels are the most common causes of problems, although excessive turbidity and ammonia toxicity in the transportation vessel can also occur. When dealing with new species, there may be some uncertainty and greater margins for error in terms of transport times and progeny handling procedures may be required. Poor health may only be evident once the stock has reached its release site leading to low survival rates and poor catch returns. This in turn, could lead to negative perceptions of stocking, thus preventing the benefits of ongoing successful activities.

With no control of hatchery protocols the likelihood of poor progeny health occurring is 'possible' as it has been known to occur elsewhere. The consequence to the estuarine environment are 'minor', however, as effects would be localised. The residual risk level is therefore 'moderate'.

D.4.5.2.10 Release System Failure Causing Poor Progeny Health and/or Mortalities at the Release Site

It is possible that mortalities can still occur soon after fingerlings are released. This again has potential to present a contamination risk, a subsequent negative perception of stocking activity and economic losses.

With no control of hatchery protocols the likelihood of release system failure is 'possible' as it has been known to occur elsewhere. The consequence would be 'minor' as there would be local contamination only. The overall risk level is therefore 'moderate'.

D.5 Social Impacts

D.5.1 Aboriginal Social Issues

D.5.1.1 Existing Conditions

The OEH defines Aboriginal cultural heritage as: "Places and items that are of significance to Aboriginal people because of their traditions, observances, customs, beliefs and history. It is evidence of the lives of Aboriginal people right up to the present. Aboriginal cultural heritage is dynamic and may comprise physical (tangible) and non-physical elements. As such it includes things made and used in earlier times, such as stone tools, art sites and ceremonial or burial grounds, as well as more recent evidence such as old mission buildings, massacre sites and cemeteries". From this definition, Aboriginal cultural heritage values are associated with:

- Aboriginal sites – the physical evidence of past Aboriginal use of the landscape.
- Aboriginal Places – locations that are associated with stories about the landscape or with personal or community totemic associations with the natural world. NSW OEH (2009) notes '*plants, animals and ecosystems are at the core of their attachment to the land and the sea.* Plants and animals are valued as part of *'country'* and may also act as totems.'
- Aboriginal cultural landscapes and cultural values of biodiversity. English (2002) highlights five key Aboriginal cultural values associated with biodiversity. These apply to all landscape types, not just estuaries:
    - Flora, fauna and landscape features are integral components of people's cultural construction of 'country' or significant lands. The health and well-being of ecological communities are fundamental parts of Aboriginal attachment to country.
    - Individual species can be identified as totems and in turn may be related to family and kinship.

    - Social benefits accrue from obtaining, processing and utilising wild foods and medicines including strengthening of group bonds and identity, passing on and using cultural knowledge, using and interacting with valued places, sharing and instilling respect for elders.
    - Medicinal and health benefits associated with wild resources that are seen as being important for treating health problems such as diabetes, high cholesterol, colds, flu and migraines.
    - Wild resources can provide economic benefits that supplement incomes and provide fresh foods. Peoples ecological knowledge can also be an important foundation for cultural or eco-tourism.
- Aboriginal cultural practices and traditional cultural knowledge.
- Ongoing Aboriginal community attachment to the sea and the land.

From the information presented Specialist Report A (Aboriginal Issues Assessment) and consultation meetings with Aboriginal stakeholder groups, a number of conclusions can be drawn about the values of estuarine wild fisheries to Aboriginal people in NSW and how marine stocking may affect these (summarised in Chapter C, Section C.4.2.1).

D.5.1.2 Results

D.5.1.2.1 Impact of Marine Stocking on Areas of Aboriginal Cultural Heritage

Areas of Aboriginal cultural heritage, refers to the following:

- Places listed on the National Heritage List for their Aboriginal cultural values;
- Aboriginal objects and sites protected under the NPW Act;
- Aboriginal Places (as gazetted under Section 84 of the NPW Act).

1. Places listed on the National Heritage List for their Aboriginal cultural values.

Several National Heritage Listed places in NSW include estuarine landscapes with references to Aboriginal cultural values. These references are restricted to midden sites along estuarine shorelines and to rock art sites which depict marine and estuarine species such as whales and sharks. A search of estuarine landscapes included in the National Heritage List was conducted by Umwelt Pty Ltd (Table 4.1 of Specialist Report A) and showed a number of estuarine sites which included places of Aboriginal importance, including Ku-ring-gai chase, Royal National Park, North Head and the Kurnell Peninsula. It was not, however, considered that the activity of marine stocking would have any impact on the Aboriginal values of these places and the issue has therefore not been considered further in this assessment.

2. Aboriginal objects and sites protected under the NPW Act.

Aboriginal objects are the physical evidence of past Aboriginal occupation of the land. Aboriginal sites are places where objects occur. Under Part 6 of the NPW Act, it is an offence to knowingly move, damage, deface or destroy Aboriginal objects.

The activity of stocking into estuarine waters involves delivering fingerlings from fish hatcheries and placing them into the estuary. Fish would be placed in the water directly from boats or from existing structures (jetties) around the shoreline of the estuary. Marine stocking activities would also use existing car parking areas and boat ramps to access estuarine waters for very short periods of time usually during low activity periods.

DPI is aware of the types of Aboriginal sites that may occur around estuaries and of the general distribution of these sites in the landscape. DPI has consulted with Aboriginal communities about how stocking into estuaries could interact with the Aboriginal cultural values of estuarine waterways and the presence of Aboriginal sites around estuarine shorelines.

DPI has not obtained a full site search from Aboriginal Heritage Information Management System (AHIMS) (the OEH Aboriginal sites data base) of all known Aboriginal sites on estuarine shorelines. This is not necessary from a due diligence perspective because marine stocking activities would use only existing structures to access the waterways. These existing structures are well established waterway access points and are also used by recreational anglers and others.

Some Aboriginal sites may occur in close proximity to existing recreational access structures. These existing structures are located on Crown land (reserves) or on community land managed by local government. Plans of Management prepared under the *Crown Lands Act 1989* and the *Local Government Act 1994* require that the Aboriginal cultural heritage values of reserves are taken into account and protected.

3. Aboriginal Places (as gazetted under Section 84 of the NPW Act).

Aboriginal Places do not need to contain Aboriginal objects, although some Places do. In general, Aboriginal Places are declared to protect traditional places associated with stories or legends. Some have also been declared to recognise post-contact sites such as missions. When a place has been declared an Aboriginal Place, the entire place has the same level of protection under the NPW Act as any individual object.

Aboriginal Places have been declared at several locations along the NSW coastline (e.g. Birubi Point in Port Stephens local government area, Goanna Headland at Evans Head on the north coast and Pulbah Island in Lake Macquarie local government area), but overall, few are associated with estuarine waterways.

English (2003) notes that no Aboriginal Places have been declared expressly to protect an area that has been or is used by Aboriginal people to obtain wild resources. However, English (2003) also points out that many Aboriginal Places declared for their spiritual values would also have been used for wild resource collection. He cites the Saltwater Aboriginal Place (an estuarine place near Foster) as a gazetted Place that has been used by local Aboriginal people for camping, fishing and teaching during the entire period of European settlement.

Separate to gazetted Aboriginal Places are a large number of localities which are associated with traditional Aboriginal stories, but have no formal statutory protection. For example, in the Lake Macquarie estuary, there are traditional stories associated with rock formations in the bed of Fennell Bay and with sea monsters which guarded the deeper waters between Pulbah Island and Wangi Point.

This assessment does not attempt to document the many local stories of traditional estuarine use or prohibition from along the NSW coast. This would be discussed with relevant local Aboriginal community groups when DPI identifies any new estuaries or parts of estuaries to be stocked.

Using the risk assessment model the likelihood of stocking impinging on areas of Aboriginal cultural importance would be 'unlikely' (i.e. could occur as a result of the project but is not expected), if there was limited control of stocking events in NSW estuaries. The consequences are considered to be 'moderate' (i.e. moderate repairable damage to structures/items of cultural significance or infringement of cultural values). Hence, the overall level of risk would be 'moderate'.

D.5.1.2.2 Aboriginal Stakeholder and Community Involvement

Aboriginal stakeholders have strong views about what contributes to a healthy and productive estuarine system and are uncertain that marine stocking will be cost-effective in delivering improved outcomes for estuaries and estuary fishers. Without the draft FMS in place, there is a high risk that insufficient information and involvement of aboriginal stakeholders in the management, planning and implementation of stocking activities could result in uncertainty for aboriginal communities about the impact on fish stocks and estuary health, concerns about lack of equity in access to the resource and a poor relationship between Aboriginal stakeholders and DPI. Opportunities for employment were also discussed at the Aboriginal stakeholder consultation meetings; however, it is not expected that management of the proposed activity will create any new employment associated with this project as it is currently described. Any community involvement would therefore be in a voluntary capacity.

Based on the risk assessment model, a lack of involvement of Aboriginal stakeholders would be 'unlikely' (i.e. could occur but is not expected) as Aboriginal groups have previously been involved in the freshwater stocking program and DPI recognise the importance of Aboriginal community involvement. The consequences are considered to be 'minor' (i.e. minor infringement of cultural values); hence, the overall level of risk would be 'low'.

D.5.1.2.3 Marine Stocking as a Valuable Part of Looking After Sea Country

Over the last five years, Aboriginal communities have engaged strongly with a range of catchment management initiatives, sponsored by CMAs. The coastal CMAs all employ Aboriginal community support and catchment officers and have an Aboriginal stakeholder reference group which provides feedback on proposed activities and opens links into the community. Programs of actions being implemented by these groups draw on local connections and commitment to look after land and sea country. Participants are proud of the achievements in habitat enhancement and see these programs as important steps towards culturally relevant and sustainable natural resource management. Outcomes of the community consultation process (Section D.2) indicated strong concerns as to whether the risks of stocking will outweigh the benefits. Aboriginal groups considered habitat protection and restoration programs together with controls on commercial and recreational fish harvesting to be the preferred strategies for the long-term sustainability of fisheries resources rather than adding hatchery reared broodstock. Without this commitment marine stocking may be seen as an inadequate means to protect the Aboriginal values of 'sea country' and may result in a lack of support from the Aboriginal community and stakeholders. DPI is committed to ensuring the 'long-term' sustainability of fisheries resources.

Based on the risk assessment, the likelihood of this occurring would be 'unlikely' and the consequences are considered to be moderate, hence, the overall level of risk would be 'moderate'.

D.5.1.2.4 Access to Stocked Fish

Access to fish is important to the Aboriginal community in coastal areas as it has social significance and is a healthy source of food. Results from the community consultation (Section D.2) indicate that fish stocking is generally considered to result in more fish to catch and eat in stocked waterways, but only if Aboriginal access to those waterways is properly maintained and commercial fishing is either reduced or excluded. There was a strong view expressed at Aboriginal community meetings that fish stocking activities in estuarine waterways should be managed to provide benefits to recreational and Aboriginal fishers, rather than to commercial fishers. If fingerlings were to be stocked into commercially fished estuaries, it was thought that many would be lost as by-catch before they grew to a legally harvestable size for recreational and Aboriginal fishers.

Based on the risk assessment model, it is considered possible that competition between Aboriginal and other fishers will result in a lack of Aboriginal access to stocked fish without management through the draft FMS. The consequence of this is considered minor (i.e. a minor infringement of cultural values would be expected); hence, the overall level of risk is 'moderate'.

D.5.2 Non- Aboriginal Social Issues

D.5.2.1 Existing Conditions

Stocking activity has potential to impact on Crown assets and/or non- Aboriginal cultural heritage, or zoning plans as outlined in LEPs. Relevant environmental planning instruments and principles of Crown land management (under the *Crown Lands Act 1989*) are outlined in Chapter C, Sections C.6.1 and C.6.2.

Social assessments of fish stocking are necessary to understand how human interaction with the process affects what biological outcomes are achieved. Information to identify non-Aboriginal recreational fishing habits, perceptions and potential impacts of marine stocking in NSW is reviewed in Chapter C, Section C.4.2.2. As it would be unfeasible to describe the social conditions for all 80 estuaries within the scope of the EIS, case studies were used on a representative portion of those estuaries in a regional and metropolitan context. The Bega Valley was used as a regional case study including the following estuaries:

- Merimbula Lake;
- Pambula Lake; and
- Curalo Lagoon.

Sydney was used as the metropolitan case study and included the following estuaries:

- Hawkesbury River;
- Botany Bay; and
- Port Hacking.

Results and conclusions drawn from the case studies are presented in Appendix 5 and were then considered in the risk and impact assessment process.

The key social issues identified to influence the marine stocking program include:

- Non- Aboriginal cultural values;
- Resource allocation;
- Community support interaction and regulation;
- Fishing participation and effort; and
- Conflict between fishing groups and other waterway users.

In addition, feedback from community consultation (Section D.2) has also identified potential conflict of interest with the aquaculture industry.

D.5.2.2 Results

A potential challenge that may arise from marine stocking is when access to the 'newly enhanced resource' is restricted by heritage land that prohibits or limits public access. Some of these heritage sites may be located along sections of the river or estuarine banks protecting sensitive areas or fragile constructions (i.e. old jetties). Conflict may arise if recreational and commercial fishers have limited alternatives for water access and become non-compliant by using or trespassing on these sensitive sites without permission. It is important for these sites to be noted in areas targeted for marine stocking. Stocking activities should be consistent with the existing LEPs and State-wide requirements for coastal protection i.e. the State Environmental Planning Policy No 71 – Coastal Protection.

D.5.2.2.1 Consistency with Objectives of the State-wide Template LEP Zone for Waterways or Other State-wide Requirements for the Coastal Zone

Without reviewing each individual LEP prior to stocking there is a risk that accessing stocked estuaries could impact on items or sites of non-Aboriginal cultural significance.

Review of the LEP template and waterway zoning plan indicates that marine stocking would be consistent with the objectives for natural, recreational and working waterways.

In the absence of appropriate control measures, the likelihood of stocking being inconsistent with relevant local and State-wide planning requirements would be 'unlikely' and the consequences 'moderate', hence the overall risk level is moderate.

D.5.2.2.2 Impacts to Crown Land and Assets

Submerged land is generally classified as a type of Crown land. Submerged land includes most coastal estuaries, many large riverbeds, many wetlands and the State's territorial waters, which extend 3 nautical miles (5.5 km) out to sea. Crown Land coastal waterways are reserved under the *Crown Lands Act 1989* as a series of Regional Crown Reserves. Crown assets include maritime infrastructure from Eden to Tweed Heads and includes boating facilities, public wharves, jetties etc. These structures play a fundamental role in public safety, access and use of land and water assets for community and business purposes and the protection and maintenance of coastal amenity and environmental enhancement. Recreational and commercial fishing and activity associated with stocking events (i.e. releases) would require the use of maritime infrastructure for land or boat-based activities. A measure of existing access and amenity (such as jetties, wharves, boat ramps and boat fuel outlets) was considered as part of the MCA analyses. Estuaries with suitable access were therefore favoured in the assessment to help minimise the risk of damage to beds and banks from uncontrolled access. Estuaries with higher suitability rankings through the MCA process as a result of the presence of better amenities would be prioritised for stocking.

Furthermore, the NSW Crown lands division was consulted as part of the EIS process. No matters of concern have been raised in respect to impact of the proposed program on Crown waterway area given that stock would be raised elsewhere and released directly into the waterway either directly from shore or by boat. The overall impacts on Crown Assets are considered to be minimal and the overall risk level would be low. No further mitigative or management action is therefore required.

D.5.2.2.3 Resource Sharing

Resource sharing can influence how and by whom the newly enhanced resource is used and therefore is able to affect the distribution of benefits and consequent impact (Garaway *et al*. 2006). Generally, the users in the vicinity of the fish stocking areas are often the main beneficiaries (Bell *et al*. 2008). Challenges may arise with competition over shared assets and uncertainties over access and ownership of the new resource between and within fishery sectors.

Among recreational fishers, the types of conflicts that may emerge include a sense of ownership or possessive attitude towards the location or accepted use of the resource and attitude towards newcomers (holiday season influx). These types of conflicts may increase or decline with marine stocking.

There is the risk that conflicts may also arise between recreational fishers and commercial fisheries. This is more likely to be the case where the same species are being targeted for fishing.

Case studies in the regional, (Bega Valley) and city (Sydney) (see Appendix 5), context show that both recreational and commercial fishing have been occurring together in these areas for some time. The success of Eden fishing port in capturing fish and the popularity of the location for resident and recreational fishers alike indicates that this relationship is workable and may improve and benefit both commercial and recreational fishers and the economy if marine fish stocking occurred. Some recreational fishers expressed opinion that there is excessive commercial fishing effort in the Hawkesbury River (Sydney), particularly Mooney Creek, Marramarra Creek and Berowra Creek, however there has been a significant reduction in commercial fishing businesses as a result of various buy out processes over the past decade. Similarly, there may be potential for conflict among commercial fishing groups targeting the same resource. The case studies also indicated that there are a substantial number of charter boat businesses that operate in estuaries in the Sydney metropolitan area and a few businesses in the Bega Valley region that operate out of Merimbula. These businesses are likely to benefit from a marine stocking program within their region. There have not been any incidents of conflict with charter businesses and commercial operators reported.

Using the risk assessment model, the likelihood of conflict relating to resource sharing (of stocked fish) would be 'unlikely' (i.e. could occur but is not expected). The consequences are considered to have only a 'minor' social impact, hence, the overall level of risk would be 'low'.

D.5.2.2.4 Conflict Between Fishing Groups and Other Waterway Users

Where marine stocking is undertaken in waterways used by multiple users (which is likely to be the case for many estuaries) there is potential for conflict of practices that are sharing the same space as the recreational or commercial fisher. Water sports including sailing, boating, water skiing, kayaking, swimming and jet skiing (for example), are popular Australian past times and may therefore compete for space and land based amenities. User conflict may arise if marine fish stocking restricts these practices or if recreational fishers are disturbed from noise or wash relating to water sport activity. In the Sydney case study, conflicts between noisy waterway users (such as jet skis) and recreational fishers are evident, particularly in Port Hacking. This is not the case in the regional Bega Valley case study, where recreational fishers share the waterways with other waterway activity such as sailing, kayaking, swimming and in some cases water skiing. In this case, there are numerous locations for recreational fishing alone; therefore competition over space and disturbance of fishing activities would not be expected to escalate. Stocking in areas close to large population centres is more likely to result in competition for space. It would be 'unlikely' that stocking would cause an increase in fishing activity to the extent that there would be conflict with other waterway users. The consequences are considered to have only a 'minor' social impact; hence, the overall risk level would be 'low'. Furthermore, existing regulations such as no wash zones and speed restrictions would help limit disturbance in the channels, lakes and estuaries. No further mitigation or management requirements area therefore considered necessary and the issue is not considered further in the assessment.

D.5.2.2.5 Aquaculture Industry

The aquaculture industry in NSW focuses mainly on the production of the Sydney rock oyster (*Saccostrea glomerata*) which is the most valuable aquaculture industry in NSW. Other species such as the Pacific oyster (*Crassostrea gigas*) and flat (or 'dredge') oyster (*Ostrea angasi*) are also cultivated in some parts of the State. Commercial production in NSW occurs in 41 estuaries between Eden in the south to the Tweed River in the north.

Non oyster, marine-based aquaculture activities in NSW are developed around both oceanic and estuarine aquaculture industries culturing finfish and mussels. Submerged Crown land leases for oceanic based aquaculture activities have been issued in Twofold Bay (mussels), Botany Bay and off Port Stephens (finfish). Background to the NSW aquaculture industry is provided in Chapter C, Section C.11.

Stocking is considered 'unlikely' to affect finfish aquaculture approvals within Botany Bay and offshore from Port Stephens. As a minimum it would be possible that stocked fingerlings and/or crustaceans would be small enough to enter sea pens and be consumed by the cultured fish (such as kingfish, snapper and mulloway), but would not affect natural trophic levels as the fish are contained in the sea pens for harvesting. Hence, the consequences would be 'insignificant'. Given the low risks to non-oyster aquaculture this issue is not considered further in the assessment.

Consultation with POAG suggests that giant mud crabs and potentially yellowfin bream can predate upon oysters cultured in trays within estuaries. Given that there are oyster leases present in many of the estuaries proposed for stocking there is some potential for a loss of cultured individuals through predation although the likelihood and extent of this potential impact is unknown.

Based on the risk assessment model, it is considered 'possible' that stocking has the potential to affect oyster farms in stocked estuaries. The consequences of this could have both social and economic implications if stocking did affect oyster farmers, but is considered 'moderate', hence the overall risk is 'high' and requires action to reduce the risk to a manageable level.

D.5.2.2.6 Community Support, Participation and Fishing Effort

Research has shown that the success of fish stocking is more likely when the community is committed to doing so prior to stocking and is kept informed and involved in the processes (Garaway *et al*. 2006). As the proposal will be funded using funds from the Recreational Fishing Trust and has been identified as a priority by the NSW Advisory Council on Recreational Fishing, a lack of community support would not be expected. Feedback from consultation workshops across the State have also been met with general support for the project. Based on the risk assessment model, the likelihood of conflict arising from lack of community support, and perceived negative impacts would therefore be 'unlikely' (i.e. could occur but is not expected). The consequences are considered to have a 'minor' social impact, hence, the overall level of risk would be 'low' and no further mitigative action is considered necessary.

The current and future demand on fish stocks is largely dependent on fishing participation trends. The National Recreational and Indigenous Fishing Survey (NRIFS), (Henry and Lyle 2003) was designed to provide a range of information about non-commercial fishing throughout Australia. The results of the study revealed that Australia has a high national recreational fishing participation rate of 19.5 %. In the 12 months prior to May 2000 an estimated 3.36 million Australians aged 5 years or older went recreational fishing at least once. Other results from the study revealed that an estimated 1.8 million households contained at least one recreational fisher, representing 24.4 % of households nationally, with an average of 1.9 fishers per fishing household nationally. In NSW, a high portion (17.1 %) of the general public participated in recreational fishing. NSW had the greatest number of recreational fishers compared to all other States; however participation rates were highest in the Northern Territory. The research findings also revealed that participation rates were twice as high in rural areas (30.1 %) and lowest in metropolitan areas such as Sydney (13.1 %). However by virtue of its population size, the highest numbers of recreational fishers came from large urban centres such as Sydney.

It is possible that marine stocking could result in a local increase in fishing effort. This could potentially result in greater pressure on wild fish stocks (including both conspecifics and those susceptible to similar fishing gear) and has implications for increased incidental capture of threatened and protected species, habitat degradation and population genetics. These risks in terms of ecological consequences are discussed in Section D.4.1.2. In terms of social impacts, more people participating in recreational fishing could result in increased traffic and congestion at boat ramps within or near to stocked estuaries and annoyance to local residents. If stocking occurred in an estuary where there is commercial fishing and/or aquaculture (such as oyster leases) they may be increased likelihood of conflict over the resource. This would be most likely to occur in smaller regional estuaries which may not have the amenities to cater for a high level of usage and would be less likely in metropolitan estuaries where the number of recreational fishers is likely to be high. Based on the review of existing information (Chapter C, Section C.4.3.2.4), the few relevant studies that have been undertaken indicate that while marine stocking may result in a localised increase in fishing effort, this is unlikely to be substantial and would be likely to result from a redistribution of local effort rather than an overall increase in effort at a larger (e.g. regional or State-wide) scale.

Based on the risk analysis framework, and given the level of uncertainty, the potential for an increase or concentration of fishing participation and/or effort is considered to be 'possible' although the potential for adverse social consequences would be 'minor' (i.e. minor repairable damage social/cultural values) and more likely to be beneficial from a socio-economic perspective. The overall level of risk is therefore 'moderate'.

D.6 Other Impacts

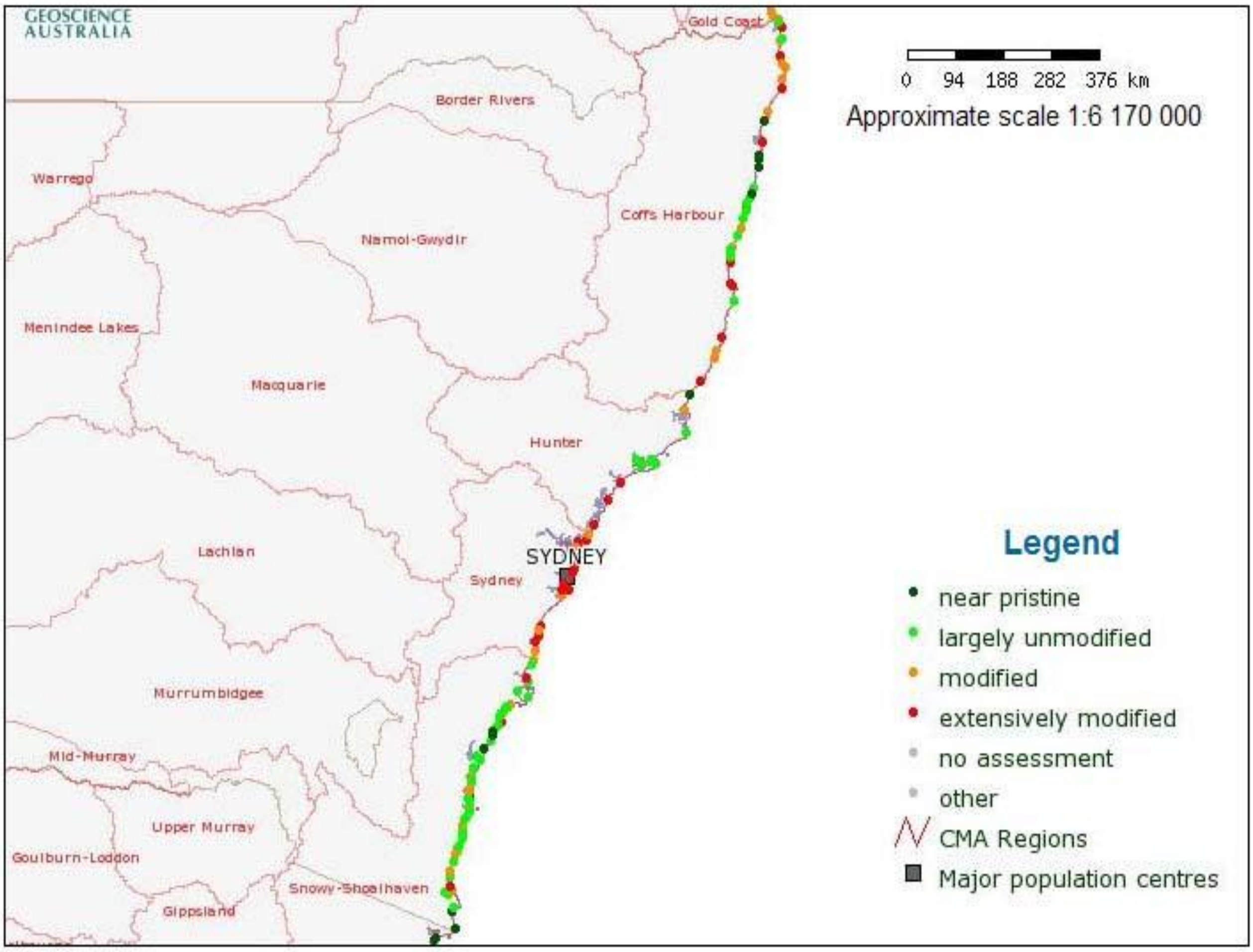
D.6.1.1 Existing Conditions

The risk assessment carried out in Section D.3 identifies physico-chemical parameters which could potentially be affected by marine fish stocking activity including:

- Water quality;
- Noise;
- Light;
- Air Quality; and
- Energy.

Figure D.3 and Table D.14 indicates the relative condition of estuaries along the NSW coastline. As it would be impractical to describe the existing conditions of all 80 estuaries in terms of their physico-chemical attributes in this Section of the document, 'estuary condition' (as defined in OzCoasts 2010) has been used as an indicator of level of pollution i.e. where estuaries are pristine or un-modified, water quality is likely to be relatively good, in comparison with extensively modified estuaries. Background levels of noise, light, air quality and energy consumption are also a direct function of population size and the level of estuary modification. It can therefore be assumed that where estuaries are extensively modified there are likely to be greater population sizes and higher levels of background pollution as opposed to rural areas away from major population centres. Furthermore, where there are lower background levels of pollutants (e.g. in rural areas) the potential impacts of new development or activities are likely to be more significant.

Figure D.3: Map showing the relative condition of estuaries in the NSW coastal region.
Source: OzCoasts reporting tools.



Further background information relating to physical estuary characteristics is given in Chapter C, Section C.7.

Table D.14: Relative condition of estuaries in the NSW coastal region.
Source: OzCoasts reporting tools.

Estuary Name	Estuary Condition	Estuary Name	Estuary Condition
Allans Creek	no data	Merimbula Lake	modified
Avoca Lake	modified	Meroo Lake	near pristine
Back Lagoon	modified	Middle Harbour Creek	no data
Baragoot Lake	largely unmodified	Minnamurra River	modified
Bega River	modified	Mooball Creek	modified
Bellinger River	modified	Murrah Lake	largely unmodified
Bermagui River	modified	Nambucca River	extensively modified
Berrara Creek	largely unmodified	Narrabeen Lagoon	extensively modified
Boambee Creek	modified	Narrawallee Inlet	largely unmodified
Bonville Creek	largely unmodified	Nelson Lake	largely unmodified
Botany Bay	extensively modified	Nullica River	largely unmodified
Brisbane Water	extensively modified	Oyster Creek	largely unmodified
Broken Bay	no data	Pambula Lake	largely unmodified
Bunga Lagoon	largely unmodified	Parramatta River	no data
Burrill Lake	largely unmodified	Pittwater	modified
Cakora Lagoon	no data	Port Hacking	modified
Camden Haven River	modified	Port Jackson	extensively modified
Clarence River	extensively modified	Richmond River	extensively modified
Cooks River	extensively modified	St Georges Basin	modified
Crooked River	largely unmodified	Saltwater Lagoon	modified
Cudgen Creek	no data	Shoalhaven River	extensively modified
Cudgera Creek	largely unmodified	South West Rocks Creek	extensively modified
Curalo Lagoon	extensively modified	Swan Lake	largely unmodified
Cuttagee Lake	largely unmodified	Tabourie Lake	modified
Deep Creek	largely unmodified	Termeil Lake	near pristine
Evans River	modified	Terrigal Lagoon	modified
Georges River	extensively modified	Towamba River	largely unmodified
Hastings River	extensively modified	Tuggerah Lake	extensively modified

Estuary Name	Estuary Condition	Estuary Name	Estuary Condition
Hawkesbury River	extensively modified	Tweed River	modified
Hunter River	extensively modified	Twofold Bay	modified
Jerusalem Creek	near pristine	Ulladulla	extensively modified
Khappinghat Creek	near pristine	Wallagoot Lake	largely unmodified
Killalea Lagoon	no data	Wallis Lake	modified
Killick Creek	largely unmodified	Wamberal Lagoon	extensively modified
Korogoro Creek	largely unmodified	Wapengo Lagoon	largely unmodified
Lake Conjola	modified	Willinga Lake	near pristine
Lake Illawarra	extensively modified	Wonboyn River	largely unmodified
Lake Macquarie	extensively modified		
Lake Innes/Lake Cathie	no data		
Lake Wollumboola	largely unmodified		
Lane Cove River	no data		
Macleay River	extensively modified		
Manning River	extensively modified		

D.6.1.2 Results

D.6.1.2.1 Water Quality

Marine stocking activities have potential to affect water quality through boating activity and through impacts from aquaculture facilities. Boating can impact on water quality through the release of hydrocarbon fuels and oil (either accidentally or through poor engine maintenance), release of sewage/grey water, breakdown of anti-fouling agents and littering. To what extent marine stocking would increase boating activity is uncertain and can only be determined with monitoring and review over the course of a stocking event. The extent of impact would depend on the size and estuary type, i.e. impacts on a large, well-flushed and open estuary would be less than for a small poorly, flushed, semi-enclosed water body, given the same amount of exposure to any pollutants released from boating activity. It would also depend on the condition and land use of the receiving estuarine catchment i.e. a potential reduction in water quality is more likely to be measurable within a pristine system than an estuary occurring within an industrial or urbanised catchment.

Under the *Protection of the Environment Operations Act 1997* (POEO Act) it is an offence to pollute any waters in NSW unless permitted under an environment protection licence issued by the Environment Protection Authority (EPA). NSW Maritime Authority officers can issue on-the-spot infringement notices of $750 to an individual or $1500 to a corporation where cases of pollution from vessels are detected. Waste from vessels should be stored on board and disposed of responsibly on shore. Results of the risk assessment (Table D.13) indicate that although it would be possible for increased boating activity (as a result of stocking) to impact on water quality, it would be ‘unlikely’ to affect baseline water quality conditions within a large, well-flushed open estuary and the consequences would be ‘insignificant’, hence, the overall risk level would be ‘low’. It would be ‘possible’ that localised impacts within a smaller, poorly flushed, semi-enclosed type water body could occur and would have an overall ‘moderate’ risk level.

Intensive aquaculture involves the addition of formulated feeds that result in elevated nutrient levels in the culture system and effluents. Feed (protein) input can alter water quality by increasing turbidity (algae and suspended solids), ammonia, nitrite and nitrates. These processes can, in turn, influence levels of DO, pH, alkalinity, carbon dioxide, hydrogen sulfides and other parameters. Pond aquaculture environments also assimilate wastes generated from stocks that require appropriate waste management. If released into natural waters, discharge from aquaculture facilities has the potential to increase nutrient levels which can affect benthic fauna, macroalgal growth and diversity, epiphyte abundance and phytoplankton, zooplankton and bacterial communities (Jegatheesan *et al*. 2007). Use of chemicals such as fertilizers, pesticides, antifoulants (for cages) and chemotherapeutants are all considered to constitute a risk to the environment (Erondu and Anyanwu 2005).

During the release process, fish fry (or juvenile crustaceans) would be transported between hatcheries and proposed stocking locations in large tanks of water (up to 1000 litres). Water in the transport tanks is then adjusted to assist in acclimatising the juvenile fish in their release.

The transport water that is released into the waterway with the fry is oxygenated in order to maintain fish health (approximately 8 mg/l) and of high quality. Given the relatively small fraction of transport water released with the fry and the infrequent (e.g. up to 5 times a year) nature of the proposed stocking events, it is considered highly unlikely that this would have any measurable impact on local water quality.

It is DPI policy that intensive freshwater aquaculture farms are not permitted to directly discharge water into natural waterbodies or wetlands, with exception for approved open (flow through) systems (NSW LBSAS 2009).

Aquaculture farms discharging water (fresh, estuarine, marine or saline ground waters) to natural waterways may require a licence issued by the OEH under the POEO Act. Discharge structures placed in, on or within 40 m of a water source are subject to controlled activity approval for their construction under the *Water Management Act 2000*. The management of the ecological processes within the reconditioning areas or tanks can significantly improve discharge water quality prior to its return to the culture unit, reuse system or the environment (if permitted).

Aquaculture farms that are permitted to discharge water to natural waterbodies must manage this water to ensure it complies with the conditions of the aquaculture permit, the development consent and any licence issued by the OEH under the (POEO Act). The OEH licence conditions including load and concentration limits and monitoring and reporting requirements are determined on a case by case basis. Conditions are developed with a view to maintaining the NSW Government Water Quality and River Flow Interim Environmental Objectives (WQOs) in the relevant catchment. OEH licences for aquaculture will usually be set for a number of parameters, including biological oxygen demand (BOD),nitrogen fixation rate (NFR), total phosphorous (TP), total nitrogen (TN), DO and pH. The licences may place limits on the daily discharge from the farm (e.g. 10,000kL/day). The licence will set out how the discharge volume is to be monitored and calculated. Monitoring of above parameters and an annual statement of compliance is required under the POEO Act. As such, there has been no known pollution incidences reported in relation to land based aquaculture in NSW or in other parts of Australia and the hazards from intensive aquaculture practices are mostly documented in relation to their impacts in developing countries where policies that might ensure safe aquaculture practices are either insufficient or not adequately enforced (Erondu and Anyanwu 2005).

Based on the risk assessment framework the existing controls and protocol are considered sufficient to minimise the risk of a reduction in water quality of natural waterways, hence the overall risk level would be 'low' and no further mitigation or management is required.

It is not envisaged that any additional aquaculture facilities would be required to augment the proposed marine stocking program as existing hatcheries would be used. Existing controls on water quality and discharge of waste water are sufficient to mitigate potential risks to water quality of natural waterways. If, in future, additional land based aquaculture facilities were required, then these facilities would be subject to the existing assessment and approvals process.

D.6.1.2.2 Noise and Light

The POEO Act and the Protection of the Environment Operations (Noise Control) Regulation 2000 are the primary legislative means of controlling noise on NSW waterways (NSW Maritime 2010). The principal factor under noise legislation is the concept of offensive noise. Offensive noise is defined in the POEO Act as noise:

(a) that, by reason of its level, nature, character or quality, or the time at which it is made, or any other circumstances: is harmful to (or is likely to be harmful to) a person who is outside the premises from which it is emitted, or interferes unreasonably with (or is likely to interfere unreasonably with) the comfort or repose of a person who is outside the premises from which it is emitted; or

(b) that is of a level, nature, character or quality prescribed by the Regulations or that is made at a time, or in other circumstances, prescribed by the Regulations.

For example, a vessel operating at 80 dB(A) in the middle of Botany Bay may not be emitting 'offensive noise' because it is not affecting another person. However, a vessel operating at 75 dB(A) - which is below the recommended limit - at 6am in the Hawkesbury River close to residential property may be emitting 'offensive noise' because it is disturbing other people's sleep. The test for offensive noise is one of a 'reasonable person'. In deciding whether the noise from a motor vessel is offensive, the factors that would be taken into account include:

- the character of the noise (e.g. pitch, whine, growl);
- the quality of the noise;
- the noise level;
- the effect of the noise on activities;
- the amount the noise exceeds the background noise level;
- the time of the noise event;
- the waterside land-use; and
- the number of people affected.

There is some potential for increased boating activity related to marine stocking (e.g. fishing and broodstock collection) that could cause offensive noise, particularly if an estuary not previously targeted for fishing becomes popular as a result of the activity. The level of disturbance would therefore depend on the location of the estuary (e.g. regional or metropolitan) and the ambient noise levels within that particular estuary. Based on the risk assessment framework, it is considered 'unlikely' that increased boating activity as a result of stocking could contribute to offensive noise, although the consequence of this occurring is considered to be 'minor', therefore the overall risk level is 'low' and does not require further mitigative action.

Species such as mulloway, yellowfin bream and eastern king prawn can be targeted by fishermen after dark or at night when they become more active. The use of boat lighting and flashlights on the water and car headlights at boat ramps can be a potential nuisance to residents living on or nearby waterways. An increase in night time fishing activity at stocked estuaries could potentially exacerbate 'light trespass' into residential properties which can reduce privacy and hinder sleep. However, given the relatively low intensity and duration of boat and flash light usage and the likely small-scale of night time fishing activity (as a direct result of stocking) light levels would be unlikely to exceed background conditions (particularly in urban areas). Based on the risk assessment, it is considered 'unlikely' that increased recreational fishing and/or stocking activity could contribute to light pollution and the consequences would be 'minor', hence the overall risk level is 'low'. No further mitigative or management action is therefore required and the issue is not considered further in the assessment.

D.6.1.2.3 Air Quality

Marine stocking and related activities have potential to impact upon air quality through emissions from boat engines and cars and also from use of recirculating aquaculture systems (RAS) in hatchery facilities.

It is firstly possible that recreational fishers might be willing to travel further in order to access stocked estuaries (either by car or boat) thus, increasing fuel consumption and emissions for fishing activities. An increase in overall fishing effort could also contribute to emissions if people increased their usage of cars and boats to fish. The likelihood of this occurring to the extent that ambient air quality could be affected, would, however, be extremely unlikely, especially in urbanised areas. It is also considered unlikely that there would be an overall increase in fishing effort, rather a redistribution of fishing effort with a potential increase at the local scale.

Another potential source of air pollution could come from aquaculture facilities. Where RASs are used, operators use ozone to inactivate a range of bacterial, viral, fungal and protozoan fish pathogens (I&I NSW 2005b). Ozone is extremely toxic and any exposure to humans constitutes a serious health hazard. DPI currently recommend that hatchery operators ensure that ozone reactors are leak-free and made of suitable ozone resistant materials and that Australian exposure standards for residual ozone are not exceeded. Given the existing level of hatchery compliance, the risk that marine fish stocking activity (including hatchery operations) could impact on ambient air quality are considered to be 'unlikely' with an 'insignificant' impact, hence the overall level of risk would be 'low'. Although the overall risk level is low and does not require further mitigative action, Chapter G, Section G.2.3.2 identifies how implementation of the HQAS would help in maintaining minimal impacts to ambient air quality.

D.6.1.2.4 Energy

The main source of energy consumption relating to marine stocking is the operation of hatcheries, although different production systems will have different labour, energy and physical components. As there is little available literature on the energy consumption of land-based marine fish hatcheries and also because there are no commercial scale marine fish hatcheries in NSW, the following examples have been used to provide an *indicative* assessment of power requirements and energy efficiency for six different types of land-based commercial hatchery systems used in the production of Atlantic Salmon (*Salmo salar*) smolts.

Colt *et al.* (2008) evaluated the following types of aquaculture operations:

- Flow through with gravity water supply (FT-G);
- Flow through with pumped water supply (FT-P);
- Flow through with pure oxygen (PO);
- Partial re-use system (PR);
- Partial re-use with heating (PR-T); and
- Re-use system (RU).

These technologies are well developed for commercial fish culture (Colt *et al.* 2008). Power and feed energy accounted for the majority of the required energy for all rearing options evaluated. The energy efficiency (energy output/energy input) of the six options ranged from 0.97 % for flow through with pumped supply to 3.49 % for the flow through with gravity supply (Table D.15). The rearing options with the three highest energy efficiencies were flow through with gravity supply (3.49 %), partial re-use (2.75 %) and re-use (2.64 %) (Table D.15). It should be noted that the energy efficiency takes into account all direct and indirect energy, transportation energy, greenhouse gas emissions and pollutant discharges. A study by Pitcher (1977) calculated energy efficiency of 11.6 % for rainbow trout reared in a flow through system, although this example did not take into account pumping energy, hauling of fish and feed, calcium carbonate and indirect energy feeds. When Colt *et al.* (2008) removed these components for FT-G, the energy efficiency increased from 3.49 % to 12.0 %.

The total electrical energy and fuel inputs included electrical inputs (from water supply pumps, internal hatchery uses and water treatment), natural gas and hydropower components. Typically the largest power components are influent pumping, heating and water treatment, although this varies depending on the type of system. On the basis of producing 1 kg of salmon smolt (Total Energy MJ kg^{-1}), the six options showed a wide range of performance from between 218 – 786 MJ kg^{-1} (Table D.15). The actual energy consumption that would be attributed to the marine stocking program is likely to be negligible given the relatively small-scale of the production compared with large commercial activities provided in this example. It may, however, take time to develop the most energy efficient rearing techniques for newly approved marine species. Provided that the hatcheries used to supply marine stocking are approved and accredited under the HQAS and implement existing principles of best practice in terms of sustainability according to the NSW LBSAS (2009), then the likelihood of poor energy efficiencies and excessive energy consumption within land-based hatchery facilities (for production of marine species) would be 'unlikely' and the consequences 'insignificant', hence the overall risk would be 'low'. Although further mitigative action is not considered necessary, Section G.3.3.2 identifies how minimal impacts to ambient air quality could be maintained through implementation of the LBSAS.

Table D.15: Examples of energy efficiency and energy consumption in hatcheries.

Examples are for six different types of land-based, commercial scale aquaculture facilities in the Pacific Northwest (US) in the production of Atlantic salmon smolts. After Colt *et al.* (2008).

Parameter	Units	Land-Based Hatchery System					
Energy Efficiency		FT-G	FT-P	PO	PR	PR-T	RU
$Energy_{out}$ / $Energy_{in}$	%	3.49%	0.97%	1.81%	2.75%	1.16%	2.64%
$Energy_{in}$ / $Energy_{out}$	MJ MJ^{-1}	29	103	55	36	86	38
Total Annual Electrical/Fuel Energy Inputs	TJ	23	131	62	36	109	38

Parameter	Units	Land-Based Hatchery System					
Total Energy Consumption	MJ kg^{-1}	218	786	420	276	657	288

It is also noted that under State Environmental Planning Polices (SEPP) No. 62 - Sustainable Aquaculture (Gazetted: 25.08.00) the sustainable expansion of the industry in NSW is encouraged.

D.7 Summary of Key Impacts.

Extreme Risk

Biophysical Impacts

- Population Genetics:
  - Wastage of gametes (yellowfin bream only).

High Risk

Biophysical Impacts

- Ecology:
  - Decrease in abundance of wild conspecifics e.g. from overstocking and/or increased fishing effort;
  - Alteration of size-structure in populations;
  - Alteration of the distribution, abundance or structure of populations e.g. through inter-specific competition and/overstocking/increased fishing effort (conspecifics);
  - Alteration of the distribution, abundance or structure of populations (other species);
  - Direct/Indirect effects on habitat (disturbance /trampling).
- Threatened Species:
  - Hook and line fishing in areas important for the survival of threatened fish species (FM Act);
  - Injury and fatality to vertebrate marine life caused by ingestion of, or entanglement in, harmful marine debris (EPBC Act);
  - Entanglement or ingestion of anthropogenic debris in marine and estuarine environments (TSC Act);
  - Alteration of distribution, abundance and structure of populations (trophic impacts);
  - Injury/mortality (from incidental capture);
  - Direct/Indirect effects on habitat (disturbance /trampling).
- Areas of Conservation Significance:
  - Potential impacts on the conservation value of Aquatic Reserves.
- Population Genetics:
  - Ryman-Laikre effect (yellowfin bream, mulloway, dusky flathead, sand whiting, giant mud crab, blue swimmer crab);
  - Introgression (yellowfin bream, mulloway, dusky flathead, sand whiting, giant mud crab, blue swimmer crab).
- Disease, Parasites and Pests:
  - Infection of hatchery-reared fish or crustaceans with exotic disease/parasite causing contamination of farm and adjacent waterways;
  - Translocation of exotic fish or crustacean disease/parasite from hatcheries into wild populations;
  - Translocation of non-target species;
  - Release of stock selected for reduced disease/parasite susceptibility causing undesirable modification of wild genotypes.

Social Impacts

- Non- Aboriginal Social Issues:
  - Impacts on oyster leases.

Moderate Risk

Biophysical Impacts

- Ecology:
  - Alteration of the natural species distribution.
- Threatened Species:
  - Increase/concentration of boating activity leading to acoustic disturbance (marine mammals);
- Population Genetics:
  - Ryman-Laikre effect (eastern king prawn);
  - Introgression (eastern king prawn);
  - Naturalisation leading to fragmentation (giant mud crab, blue swimmer crab);
  - Overfishing of mixed stock fisheries leading to a reduction in genetic diversity.
- Disease, Parasites and Pests:
  - Infection of hatchery-reared fish with endemic disease/parasite causing contamination of farm and adjacent waterways;

    - Translocation of endemic fish or crustacean disease/parasite from hatcheries into wild populations;
    - Hatchery/farm culture system failure causing poor on-farm stock health and culminating in stock which have difficulty withstanding stresses associated with harvest, transport and/or handling procedures;
    - Translocation of other pest organisms;
    - Transport system failure causing poor stock health prior to release;
    - Release system failure causing poor stock health and/or mortalities at the release site.

Social Impacts

- Aboriginal Social Issues:
    - Impingement on areas of Aboriginal cultural importance (sites, places and objects);
    - Competition from other fishing sectors reduces Aboriginal access to stocked fish for a healthy diet;
    - Marine stocking not seen as adequate or good value or a sustainable approach to looking after sea country.
- Non- Aboriginal Social Issues:
    - Marine stocking not consistent with objectives of State-wide template LEP zone for waterways or other State-wide requirements for the coastal zone;
    - Perceived negative environmental impact of marine stocking;
    - Increase/concentration of fishing participation/effort.

Other Impacts

- Water Quality:
    - Direct reduction in water quality from increased boating (small, poorly flushed, semi-enclosed water body).

Low Risk

Biophysical Impacts

- Ecology:
    - Potential ecological impacts beyond the estuary e.g. trophic effects and competitive interactions.
- Threatened Species:
    - Increase/concentration of boating activity leading to boat strike (marine mammals).
- Areas of Conservation Significance:
    - Potential impacts on Ramsar wetlands;
    - Potential impacts on the conservation value of Marine Parks;
    - Potential impacts on the conservation value of National Parks with marine extensions and Nature Reserves;
    - Impingement on WHAs;
    - Impingement on Wilderness areas
    - Potential impacts on the conservation value of Critical Habitats.
- Population Genetics:
    - Naturalisation leading to fragmentation (yellowfin bream, mulloway, dusky flathead, sand whiting, eastern king prawn);
    - Wastage of gametes (mulloway, dusky flathead, sand whiting, eastern king prawn, giant mud crab, blue swimmer crab).

Social Impacts

- Aboriginal Social Issues:
    - Lack of involvement of Aboriginal stakeholders in fishery management and stocking activities.
- Non- Aboriginal Social Issues:
    - Impacts to Crown Land and assets (e.g. boating facilities, wharves, banks and bed etc.);
    - Conflict between fishing groups and other waterway users;
    - Resource sharing (i.e. conflict among recreational and commercial fishing groups);
    - Lack of community support;
    - Impacts on other aquaculture (not including impacts on oyster leases which were assessed as high risk).

Other Impacts

- Water Quality :
    - Direct reduction in water quality from increased boating (large, well flushed, open estuary);

    - Indirect reduction in water quality from aquaculture operations.
- Noise and Light:
    - Noise disturbance from increased recreational fishing/stocking activity;
    - Light pollution from increased recreational fishing/stocking activity;
- Impact on air quality (e.g. from car/ boat emissions);
- Hatchery production fails to be energy efficient.