B2 Ecological Issues

Introduction

The aim of this section of the EIS is to describe the potential environmental impacts arising from the current manner in which the rock lobster fishery operates. A risk analysis, considering all components of the ecosystem and large-scale ecological processes, is used to identify those aspects of the existing operation of the fishery (described in Chapter B1) that could impact the environment. Those aspects of the current fishery that are assessed as having a high likelihood of compromising the ecological sustainability of the environment and/or the fishery will be identified and should be significantly modified or changed through the Fishery Management Strategy (FMS), whereas aspects assessed as posing little or negligible risk may receive little, if any, modification in the FMS (Chapter D).

In Chapter E the proposed management strategy will be assessed to determine whether its management measures can effectively reduce the risk to the environment and ensure that the fishery continues to operate in an ecologically sustainable manner. The recommendations arising from this assessment should where possible be incorporated into the management strategy for the fishery to improve the ecological performance of the fishery.

B2.1 Outline of the Risk Analysis Process

B2.1.1 Introduction

A broad range of risk analysis, risk assessment and risk management information and literature was reviewed. This information and literature covered generic environmental risk analysis principles (Standards Australia/Standards New Zealand 2000), a risk analysis and reporting framework for ecologically sustainable development in fisheries (Fletcher et al. 2002), the risk analysis terminology provided by the Food and Agriculture Organisation of the United Nations (FAO) in their online glossary of fisheries terms and definitions (http://www.fao.org/fi/glossary), and relevant publications in the aquatic sciences dealing with quantitative and qualitative risk analyses and assessments (Francis, 1992; Francis and Shotton, 1997; Lane and Stephenson, 1998).

A description of this risk analysis framework and the definitions of the terms used are provided below.

B2.1.2 Risk Analysis Framework and Terminology

Risk analysis is an iterative process that has three main steps: risk assessment, risk management and risk communication (see Figure B2.1). The risk analysis process is intended to provide insights about sources of risk and their potential impacts, which then enables managers to take mitigative action against undesirable outcomes.

Risk is the probability or likelihood of an undesirable event happening. This broad definition of risk reflects common usage in fisheries science (Francis and Shotton 1997; FAO, http://www.fao.org/fi/glossary). This definition requires that an *a priori* definition of consequence be given for the undesirable event that is being analysed. In this way, the definition of risk combines the consequence and likelihood of an undesirable event happening.

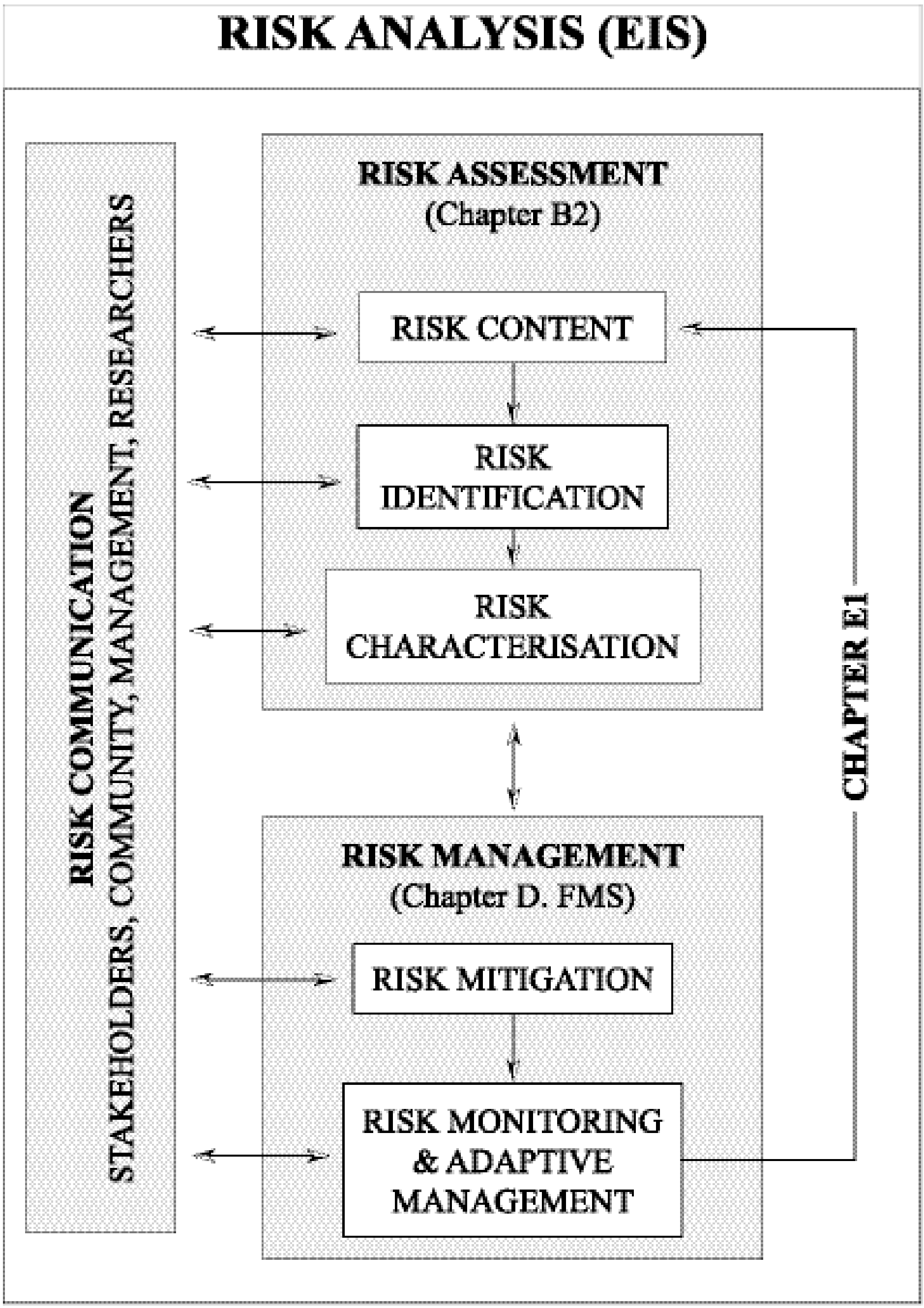

Figure B2.1 Framework of the risk analysis used for the Lobster Fishery.

Consequence is the outcome of an event expressed either quantitatively or qualitatively. In qualitative risk analysis an *a priori* definition of the consequence of an event can be used to provide the context or scope of the risk analysis.

Likelihood is a qualitative description or estimate of probability. This means that likelihood is a qualitative measure or estimate of risk.

Risk assessment is the first main step in the risk analysis process. Risk assessment contains three parts: risk context, risk identification, and risk characterisation (see Figure B2.1).

Risk context must be the first part of any risk analysis. The scope or context of the risk analysis can be defined clearly by specifying three main elements: (1) the risk that is to be analysed (eg. in a qualitative risk analysis the risk should be defined explicitly by: (a) describing the undesirable event that is to be avoided; and (b) stating the consequence of the undesirable event); (2) the relevant temporal extent of the risk analysis (eg. this may be the life of a management plan); and (3) the spatial extent of the risk analysis (eg. this could include the entire known distribution of a target species or be restricted to a single jurisdiction).

Risk identification is the second part of risk assessment. The aim of risk identification is to generate a comprehensive list of sources of risk. This can be done using a variety of methods that include: literature reviews, examination of historical records, expert panels, brainstorming, and consultation meetings to discover stakeholder opinions and perceptions. The results of this risk identification step are often presented as lists, tables or as component trees (see Fletcher *et al*. 2002).

Risk characterisation is the third part of risk assessment. The aim of risk characterisation is to estimate the probability or likelihood that the various sources of risk (identified in the previous step) will indirectly or directly cause the undesirable event that has been defined. Risk characterisation is an iterative process that involves: (a) the integration of qualitative and/or quantitative information, including the associated uncertainties, about the sources of risk; (b) the separation of the sources of risk into categories according to their estimated probability or likelihood of causing the previously specified undesirable event; (c) the acceptance of negligible risks with a justification supporting the conclusion reached (these negligible risks are now eliminated from the subsequent risk analysis); and (d) the rejection of the remaining sources of risk that have been estimated to be above the threshold of negligible risk, followed by an iterative re-analysis of relevant factors at a finer scale of resolution within each major source of risk.

In a qualitative risk analysis it is acceptable to use rankable categories such as lower, intermediate and higher to describe risk. There is no restriction to the number of categories that can be used but it is implied that each category has an equal weighting of risk (eg. the use of three categories – lower, intermediate, higher – implies each category accounts for one third of the total risk). The re-analysis of major risk sources then involves a detailed investigation of all lower level factors that may influence the probability or likelihood of that source of risk causing the undesired event. This approach is useful when risk characterisation is done iteratively by stepping down through a series of hierarchical levels. For example, risk characterisation can be done initially at the broad ecosystem level to examine large-scale ecological processes and biodiversity issues, and then at a finer resolution for individual taxa (or other ecological component) impacted by the fishery.

Risk management is the second step in the risk analysis process. Risk management contains two main components: (a) risk mitigation; and (b) risk monitoring (see Figure B2.1).

Risk mitigation is the first part of risk management. The aim of risk mitigation is to minimise the risk of the undesirable event that has been defined in the risk context. This is done by evaluation and implementation of regulatory and/or non-regulatory (eg. code of practice) management responses. The draft FMS document provides a detailed overview of the proposed management initiatives that have been designed to mitigate the risk of the undesirable event that was specified in the risk context section of the risk analysis. It is assumed that management initiatives outlined in the draft FMS will be effective for mitigating risk. Consequently, the risk analysis done on the proposed FMS for the Lobster Fishery should be regarded as a “best outcome” because the effectiveness of the management initiatives are unproven.

Risk monitoring and adaptive management is the second part of risk management. The aim of risk monitoring and adaptive management is to collect information to determine whether the management initiatives that were implemented previously were effective in minimising the risk of the undesirable event. Quite simply, risk monitoring is useful for: (a) validating management actions when they have been effective; and (b) highlighting areas that need further management response when previous initiatives have been shown to be ineffective. Risk monitoring and adaptive management should be regarded as a practical appraisal of management initiatives and an opportunity to modify management plans in a timely manner.

Risk communication is an important step in the risk analysis process because it provides the basis for information flow among stakeholders, fisheries managers, scientists and consultative committees. Risk communication should occur continuously during the risk analysis process in order to achieve a better outcome (see Figure B2.1).

The information on commercial catches of eastern rock lobster is substantial and has allowed the development of length-structured mathematical models for this species. However the paucity of biological information for a number of byproduct and bycatch species that are taken in the Lobster Fishery, as well as the general ecosystem and habitats for the target species, makes it difficult to analyse the risk of fishing-related impacts on these species. Two potential solutions exist for overcoming these knowledge gaps and completing a risk analysis for the fishery. The first solution is to apply the precautionary principle whenever biological information for a species is unknown. The application of this "precautionary-at-all-times" approach would mean that all species for which biological knowledge gaps exist would be assessed as having a higher level of risk. The outcome of a "precautionary-at-all-times" approach would inevitably lead to the unworkable situation where most byproduct and bycatch species in the fishery are assessed as having a higher level of risk. Consequently, limited management resources would then be allocated disproportionately to mitigating risk levels that have been increased artificially for these minor species. A second solution is to consider the available biological information at a coarser taxonomic resolution (generic or family level). This "best available knowledge" approach is particularly useful when examining general biological traits or characteristics such as reproductive modes and strategies in fishes. In this way, biological inferences can be made for most species for which biological knowledge gaps exist by using the best available information. The outcome of this approach would enable a better ranking of most bycatch and byproduct species according to their broad levels of risk.

B2.1.3 Development of qualitative risk matrix for target, byproduct and bycatch species

The scientific literature, fishery status reports and the expert opinion of fisheries managers and scientists were used to obtain information on the biology, ecology and exploitation status for the target, byproduct and bycatch species. This information was then used to construct a qualitative risk matrix that integrated the main factors contributing to the risk that a species could be fished unsustainably. The vertical-axis indicates the level of fishery impact exerted on a species and the horizontal-axis indicates the level of resilience of a species.

The fishery impact axis represents the overall fishing-related impact that is exerted on a species. Ideally, it would be possible to determine separate fishery impact profiles for different fisheries or sectors that harvest the same species. Detailed and accurate information for each fishery or sector would ideally be available to describe catch levels and trends for species, catch per unit effort trends for species, discard rates and mortalities for different species, the relative share of the catch among different fisheries or sectors, a sound knowledge of the biology and ecology of the main species harvested in the fishery including information on the size/age structure of harvested populations, and measures or indices of additional fishing-related mortality attributable to ghost fishing and gear escapement. However, large information gaps exist making it impossible to accurately partition the impacts of separate fisheries that harvest the same species in NSW. The use of an “exploitation status” for a species or taxon provides a practical solution to this problem. The exploitation status for any given species or taxon is an integrated measure of fishery impact across all fisheries and sectors that harvest a taxon. The exploitation status is derived from formal stock assessments for data-rich species and from the consensus of expert opinion for data-poor species. It is important to note that a taxon’s position on the fishery impact axis can be directly influenced by management action.

Resilience has a formal definition in scientific publications (e.g. Underwood, 1989) which is a measure of the response a population or assemblage of species has to a disturbance of known magnitude. In the context of this risk assessment, the term resilience will be defined as the capacity of a natural fish stock or population to recover from the effects of fishing. The resilience rating of each target, byproduct and bycatch taxon was derived qualitatively from an assessment of relevant biological characteristics. It is important to recognise that a taxon’s position on the resilience axis cannot be changed by management actions because biological characteristics are determined on an evolutionary timescale.

The two axes, fishery impact and resilience, formed a five by five matrix (25 squares) which was divided into five equally sized (5 squares) levels of risk (Figure B2.2). The utility of this qualitative risk matrix approach was to provide relative rankings for different taxa, thereby prioritising taxa according to their need for management action.

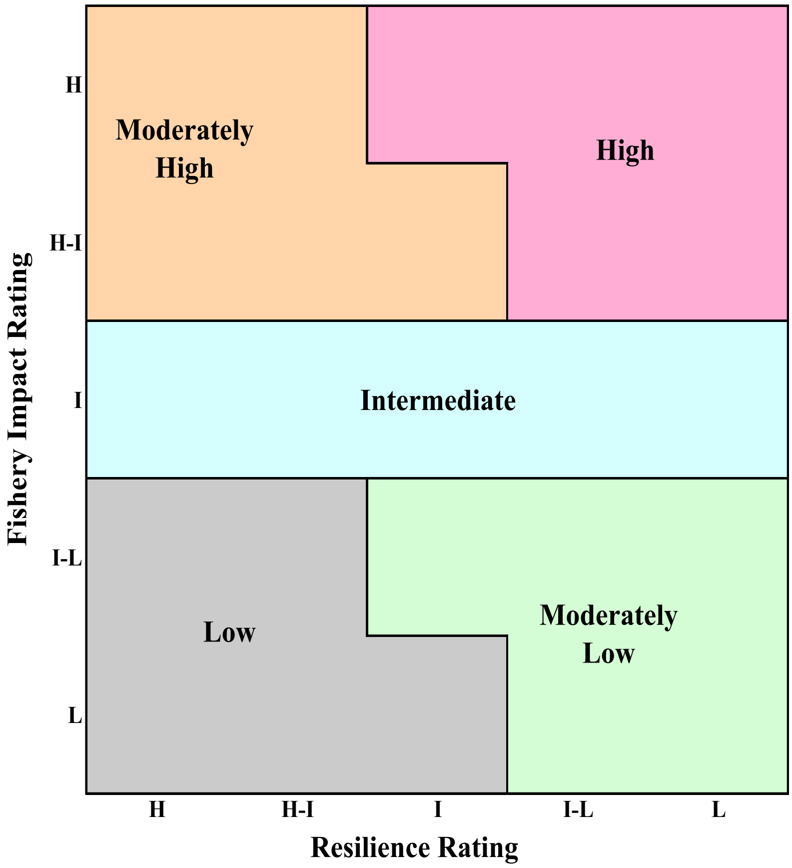

Figure B2.2 Qualitative risk matrix used to determine levels of risk for primary, byproduct and bycatch species taken by the Lobster Fishery.

(H – High, H-I – High to intermediate, I – intermediate, I-L – intermediate to low, L – low.)

The top right hand corner and the bottom left hand corner of the risk matrix represent the highest and lowest risk levels respectively. High levels of risk correspond to species with lower resilience and largest level of fishery impact, whilst low levels of risk correspond to species with higher resilience and smallest level of fishery impact. Management measures should give first priority to species with highest levels of risk, which require direct and immediate action to decrease the level of the fishery impact exerted on them, thereby reducing their risk of becoming ecologically unsustainable. The top left hand corner and the bottom right hand corner of the matrix represent moderately high and moderately low levels of risk respectively. Moderately high levels of risk corresponded to species that have larger levels of fishery impact and are highly resilient. The focus of management action for species at this level should be to decrease their fishery impact but because their resilience is higher than those species at highest risk they would be second in priority rank. Moderately low levels of risk correspond to species that have smaller levels of fishery impact but lower resilience. The lower resilience of these species means that potentially any increase in the fishery impact could put these species at a higher level of risk. Therefore, management measures should be focused as a minimum on ensuring the fishery impact does not increase on these species. Intermediate levels of risk correspond to species with an intermediate level of fishery impact regardless of their resilience levels. Management measures for these species should focus on reducing their fishery impact starting with those species with lowest levels of resilience.

B2.1.3.1 Assigned risk levels

The qualitative risk matrix provides a mechanism for combining the two factors that contribute most to the risk of unsustainable fishing-related impacts, resilience and fishery impact. The qualitative risk matrix also provides a way for prioritising species for management action. The matrix has been divided into five areas of equal size, each of which represents a different risk level (see Figure B2.2). The fishery impact axis of the matrix is the most important for setting management priorities because the fishery impact rating is the only measure that can be directly changed by management actions. The resilience rating is used to provide rankings within each risk level and also within each row of the fishery impact axis.

B2.1.3.2 Resilience - biological characteristics

Three broad biological categories were used to determine the resilience rating for each taxon, these being: (a) reproductive strategy; (b) distribution and abundance; and (c) growth and longevity. Decision rules (or criteria) were determined for each biological category that distinguished between risk-prone and risk-averse character traits (Table B2.1).

Each of the three biological categories was given a risk-prone score. Live bearing elasmobranchs (ovoviviparous and viviparous) were assigned a double risk-prone score in the reproductive strategy category. The remaining two biological categories each contributed a maximum of a single risk-prone score to the overall resilience rating. A summation of the risk-prone scores determined the overall resilience rating for each primary, byproduct and bycatch species. Those species with highest risk-prone scores (maximum 4) were least resilient and those with lowest risk-prone scores (minimum 0) were most resilient (Table B2.2)

Table B2.1 Biological categories and decision rules for assigning risk-prone or risk-averse classifications.

Biological category	Description and reasons for use	Decision rules for risk classification
Reproductive strategy	An indicator of the capacity to maintain viable population sizes and to replenish populations after depletion. This category incorporates correlated biological characteristics such as fecundity, egg type (demersal or pelagic), egg size, and larval type.	**Averse** - Taxa with pelagic eggs and larvae that are not sequential hermaphrodites (e.g. snapper, mulloway). **Prone** - Taxa with demersal eggs (e.g. gobies, leatherjackets, spanner crabs, cephalopods); mouthbrooders (e.g. cardinal fish, catfish); oviparous elasmobranchs (e.g. Port Jackson sharks); taxa with pelagic eggs that are sequential hermaphrodites (e.g. some large groupers - *Epinephelus* spp., some wrasse species). **Prone x 2** (double weighting) - viviparous and ovoviviparous elasmobranchs (e.g. whaler sharks, wobbegong sharks, grey nurse shark).
Distribution and abundance	An indicator of rarity expressed in terms of: (a) prevalence (restricted geographical range and/or (b) intensity (local populations are small and non-dominant and overall the entire population size is small).	**Averse** - Taxa having widespread distributions/broad habitat specificity and relatively large populations (e.g. kingfish, bream). **Prone** - Taxa having restricted distributions/narrow habitat specificity and/or relatively small populations (e.g. grey nurse shark, gemfish).
Growth and longevity	An indicator of productivity, population turnover and hence capacity to recover from depletion. This category incorporates correlated biological characteristics such as, size and age at maturity.	**Averse** - Taxa having fast growth rates and are relatively short-lived (e.g. dolphin fish, many squid species). **Prone** - Taxa having slow growth rates and/or relatively long-lived (10+ years for fish, 5+ years for invertebrates). Examples include jackass morwong, snapper, spanner crab.

Table B2.2 Decision rules for assigning a resilience rating.

Resilience rating	Risk-prone score
High	0
High-Intermediate	1
Intermediate	2
Intermediate-Low	3
Low	4

The resilience rating used in this risk assessment was constructed so that it would be generally applicable across all taxa of commercially harvested crustaceans, cephalopods, finfish and elasmobranchs. The resilience scores, decision rules and overall resilience ratings were intended to provide a simple structure that could be used to rank taxa according to their biological capacity to recover from fishery-related impacts. It was recognised that the general utility of this simple scheme relied on its ability to: (a) separate taxa across the entire resilience axis; and (b) provide relative rankings that were logical and consistent with current ecological interpretations regarding the relative resilience of different taxonomic groups. For example, the resilience of most elasmobranch populations is considered to be much lower than the resilience of most teleosts.

B2.1.3.3 Fishery impact – operations of the fishery

The fishery impact rating is intended to represent a qualitative measure of total fishing impact on a taxon. Unlike biological characteristics, which remain largely unchanged by management intervention, the fishery impact rating can be directly influenced by management changes to the fishery. The exploitation status assigned to primary, byproduct and bycatch species has been used as a proxy for fishery impact rating (Table B2.3). Any taxon that was assigned an 'Unknown' or 'Uncertain' exploitation status was treated as an equivalent to a growth overfished taxon. This precautionary approach is justified for target, byproduct and bycatch species because the viability of the Lobster Fishery is dependent on the long-term sustainability of these taxa.

Table B2.3 Decision rules for assigning a fishery impact rating.

Fishery impact rating	Exploitation status
High	Recruitment overfished
High-Intermediate	Growth overfished, Unknown, or Uncertain
Intermediate	Fully fished
Intermediate-Low	Moderately fished
Low	Under-fished

B2.2 Risk Analysis of Current Operation of the Lobster Fishery – Broad Ecosystem

In this section the risk analysis framework described in Section B2.1 is applied to the Lobster Fishery. This is done in a series of iterative steps which include: (a) defining the context for the risk analysis; (b) identifying and assessing the sources of risk at the broad scale level of the whole ecosystem; (c) providing justification for eliminating sources of negligible risk from subsequent analyses; (d) re-analysing all remaining sources of risk at a finer scale by examining individual ecosystem components (e.g. target, byproduct and bycatch species, habitats) and their constituent elements (e.g. individual taxa and habitat types).

B2.2.1 Context for the Risk Analysis

The guidelines for the Environmental Impact Assessment of the Lobster Fishery issued by the NSW Department of Infrastructure, Planning and Natural Resources (DIPNR) in February 2003 state that the environmental assessment should test the sustainability of authorised fishing activities. This means that the risks being assessed can be defined as: (a) the likelihood that the current activities of the Lobster Fishery will lead to the widespread degradation of major ecological processes, biodiversity and habitats; and (b) the likelihood that the current activities of the Lobster Fishery will lead to ecologically unsustainable impacts on populations and communities of target, byproduct and bycatch species, bait sources, and protected and threatened species. These broad definitions of risk are used to define the parameters of the risk analysis and to explicitly describe the consequence that is being adopted at each step of the risk assessment. That is, the consequences for which we wish to mitigate risk are: (a) widespread degradation of major ecological processes, biodiversity and habitats; and (b) ecologically unsustainable levels of populations and communities of target, byproduct and bycatch species, bait sources, and protected and threatened species.

B2.2.2 Broad Scale Analysis

B2.2.2.1 Risk identification

To identify areas of risk the Lobster Fishery was divided into its individual activities (e.g. harvesting levels for retained species, discarding of non-retained species, physical impact of setting and retrieving traps, etc. see Table B2.4). The link between these activities and the broad components of the ecosystem was examined and levels of risk assigned (Table B2.5). It is important to note that the activities of the fishery can affect the environment both directly and indirectly and the risks of all of these effects need to be considered in the analysis.

Table B2.4 Description of activities of the Lobster Fishery that impact on the environment

Activity	**Description**
Potting	Deployment and retrieval of lobster pots
Harvesting	Removal from pots and retaining lobsters and byproduct species
Discarding	Returning undersized or oversized lobsters, berried lobsters, or undersized or unwanted bycatch
Rope entanglements	Entanglement of cetaceans, pinnipeds and turtles in trap ropes and/or floats
Loss of fishing gear	Loss of traps leads to ghost fishing - lost traps continue to capture lobsters or fish
Travel to/from grounds	Boat movements to fishing grounds and return
Boat maintenance & emissions	Tasks involving fuel, oil or other engine and hull related activities that could result in spillages or leakages into the sea or air.

B2.2.2.2 Risk characterisation

Table B2.5 Levels of risk to components of the environment by the activities of the Lobster Fishery.

Ecosystem component	Potting	Harvesting	Discarding			Rope Entangle-ments	Loss of fishing gear	Travel to / from grounds	Boat maintenance & emissions
			of target species	of byproduct species	of bycatch species				
Target species	L	I	L	L	L		L	-	-
Byproduct species	L	L-H	L	L	L		L	-	-
Other species	L	L	L	L	L		-	-	-
Threatened species	L		L	L	L	L	-	-	-
Protected areas							-		
Other habitats	L	L	-	-	-		L		-
Biodiversity	L	L	L	-	-	L	L		-
Diseases	L		-	-	-				
Water quality	L		-	-	-				L
Noise									-
Air									-
Light									-
Energy/greenhouse									-

H=high risk, I=intermediate risk, L=low risk, blank= not applicable, - = negligible risk.

The activity of potting (deploying baited traps and retrieving them) has low risk on all components of the ecosystem.

Harvesting was assessed to present an intermediate risk to the target species, risks ranging from Low to High for the byproduct species, and a low risk to other species and habitats.

Discarding poses no risk to aquatic habitats because any material brought up in the pot has already been potentially impacted by the potting activity itself. There is a negligible impact on diseases and water quality from discarding.

Rope entanglements pose a low risk to threatened species and biodiversity because of the extremely infrequent interactions between the fishing gear and the survival of species and habitats. This is dealt with in more detail at the finer scale risk analysis.

Loss of fishing gear was assessed to have a low risk for target and byproduct species, a negligible risk for threatened species and protected areas and a low risk to other habitats and biodiversity.

Travel to and from fishing grounds poses a negligible risk to target, byproduct and bycatch species as there is very little overlap between this activity and these species. There is negligible risk to ecological processes and aquatic habitats from travel to and from fishing grounds as any interference from the boat would only be for a short period of time.

Boat maintenance and emissions are a negligible risk to target, byproduct and bycatch species, including threatened and protected species. There is little overlap between these components and activities, and consequently any effects will be small in comparison to the effects of other activities of the fishery.

The areas of the environment with no or negligible risk (Table B2.5) have not been considered further in the finer scale risk analysis. The remaining components of the ecosystem which have a risk level that is greater than negligible will be examined below in detail to determine the extent and types of risks posed by the Lobster Fishery.

B2.3 The Target Species

B2.3.1 Biology and ecology of the target species

The eastern rock lobster *Jasus verreauxi*, a decapod crustacean of the family Palinuridae, is the primary target species of this fishery. Catches of eastern rock lobster represent more than 99% (by weight) of all rock lobster species in the commercial catch. Less than 1% of the catch comprises southern rock lobster *Jasus edwardsii* (taken in the south of the state) and species of painted rock lobster *Panulirus longipes* and *Panulirus ornatus* (taken in the north of the state). The fishery does not report byproduct other than southern and painted rock lobster species, however catches are monitored through an ongoing observer survey (G. Liggins, NSW Department of Primary Industries pers. comm.).

Eastern rock lobsters inhabit the waters off the east coast of Australia from Tweed Heads southwards around the Tasmanian coast and as far west as the Victoria-South Australia border (Montgomery and Chen, 1996). Because of the low abundance of eastern rock lobster in other states, the NSW Lobster Fishery is the only commercial fishery in Australia that targets this species. The species is also found and commercially fished in the northern waters of New Zealand, however it appears to be genetically discrete from the Australian stock (Brasher *et al*., 1992).

The distribution of eastern rock lobster across habitats and along the coast is related to size and age. Sexually mature eastern rock lobsters are concentrated on the north coast of NSW. The smallest size at which 50% of females bear eggs during the egg-bearing season (i.e. size at onset of breeding) is 167mm CL (Montgomery, 1992). Spawning occurs in waters north of Port Stephens from September to January (Spring through to Summer) in depths of less than 50 m, during which time females carry eggs on the tiny hairs of their pleopods (appendages adapted for swimming). A female eastern rock lobster may carry 400 thousand to 2 million eggs under her abdomen (Kensler, 1967), and the larger the female the more eggs she can carry. Eggs are released in early to mid summer.

There are several planktonic larval stages in the rock lobster’s lifecycle. After hatching, phyllosoma larvae spend approximately a year in ocean waters off the coast before moulting into a puerulus stage. Pueruli swim across the continental shelf to settle in rocky-reef sub-tidal habitat along the NSW coast. Only a very small proportion of larvae survive this first year. Most are eaten by predators or are not brought close enough to the coast for settlement on inshore reefs. After moulting through several puerulus stages, juvenile lobsters spend several years on these shallow rocky reefs. From the puerulus to early juvenile stages, lobsters are thought to be asocial, and occur principally within forests of macroalgae or within beds of seagrass in waters from the intertidal zone to depths of 30m. It is believed that lobsters then aggregate and move en masse offshore (at a size of about 120 mm carapace length (CL)) and migrate from the south to the north coast of NSW. Adult rock lobsters generally live in aggregations from depths of around 10m to those of the continental slope (Montgomery, 1990, 1995). From the older juvenile stage onwards, lobsters aggregate by day and roam alone at night.

The size of lobsters caught in waters on the edge of the continental shelf off the central and southern coasts of NSW is generally 120-150mm CL. Large (and sexually mature) lobsters are found at their greatest abundance on the north coast of NSW. Results from a research tagging program have also demonstrated such longshore northward migrations.

Eastern rock lobster is the largest species of rock lobster known (Phillips *et al*., 1980). They are known to live for over ten years, attain a maximum length of 1 m (total length) and a weight in excess of 8 kg. Eastern rock lobster takes about 3 to 5 years from hatching to reach the minimum legal harvest size, and an additional 4 to 5 years for females to reach the average size at maturity of 167mm. For animals of approximately legal size, two to three moults take place annually, with carapace increments of about 6-7mm for each moult. Eastern rock lobsters are omnivorous. They eat bottom living organisms such as molluscs and crustaceans among rocks and seagrass, and scavenge on dead organic matter. Octopus and various shark species are their major predators, although small juvenile lobsters may be eaten by finfish.

B2.3.2 Current status of the stock

The most recent assessment of the eastern rock lobster resource was completed in May 2004 (Liggins, 2004). It was mainly based on data collected from the fishery up to the end of the 2002-03 quota year with reference to research data collected during the 2003-2004 season. Annual resource assessments completed in recent years (Montgomery *et al.,* 1998; Liggins *et al.,* 1999, 2000, 2001, 2002, 2003; Liggins, 2004) have principally focused on estimating changes in abundance and biomass of the stock over the history of the fishery with particular emphasis on estimating change since 1994-95. Time series of catch and catch per unit effort (CPUE) data and size-distributions of lobsters in the commercial catch during 1999-00 to 2001-02 were used to fit biomass dynamic and length-structured models of the lobster population and fishery. These models do not explicitly incorporate the spatial structure that exists in the distribution of different sizes/ages/stages of maturity of lobsters across latitudes and depths. Nor do they explicitly account for differences in the distribution of fishing effort and fishing power across these spatial scales. Consequently, annual assessments also emphasize several recently established data-series that describe changes in catch, effort and CPUE for various components of the population of lobsters at finer spatial scales. Fishery-dependent catch, effort and CPUE were reported voluntarily by a sub-set of fishers between 1994-95 and 1996-97 and have been reported by all fishers since 1997-98. A time-series of the relative abundance of pueruli recruiting to inshore reefs has been available since 1995-96. An index of abundance and time-series of size-distributions of the mature stock have been available since 1998-99.

Based on the historical time-series of catch and effort and estimates of biomass from biomass-dynamics and length-structured models, the pattern in annual estimates of abundance of lobsters is one of long-term decline from the late 1880's through to 1991-92 (Figures B2.3 & B2.4). This long-term decline was interrupted by short-term increases during the periods 1917-18 to 1920-21 and 1940-41 to 1947-48, periods associated with the two world wars. The decline in biomass accelerated during the 1980's with biomass reaching its lowest point in the early 1990's. Between 1992 and 1994, in response to concerns about the status of eastern rock lobster stock, NSW Fisheries implemented several important management initiatives (restricting entry to the fishery, implementing a total allowable catch and quota management system, introduction of a management tag to restrict black-marketing of lobster, implementation of a maximum legal size of 200 mm CL).

Since the late 1980s and early 1990s, CPUE has increased but has fluctuated with a significant decrease in 2000-01, and a strong increase in 2002-03 (Figure B2.3). Whilst the long-term historical trends in biomass estimated using the biomass-dynamics and two alternative scenarios of the length-structured model are broadly similar, the trajectories of depletion diverge during the past 20 years (Figure B2.4). Similarly, estimated depletions of spawning biomass from the 2 alternative scenarios of the length-structured model diverge during the past 20 years (Figure B2.4). The "base-case" scenario

("LSM-Base") of the length-structured model is calibrated using both historical CPUE data and recent size-distribution data. In contrast, the scenario "LSM-Wt5" is calibrated by placing greater emphasis on the size-distribution data. The difference in estimated biomasses and depletions of biomass that result from these 2 alternative versions of the length-structured model reflect a "tension" or incompatibility between the CPUE and size-distribution data with which the model is calibrated. Whilst the "base-case" attempts to balance the fit of the model to these 2 sources of data, the more pessimistic scenario (LS-Wt5) was also used in the assessment to illustrate the possibility that depletions of lobster biomass may be much greater than indicated by the base-case.

Using the base-case scenario of the length-structured model, the median estimate of total biomass at the commencement of 2003-04 was 38% (90% C.I.: 27-47%) of the pre-exploitation level and had increased by a median 39% (90% C.I.: 21-76%) since 1994-95. The median estimate of spawning biomass at the commencement of 2003-04 was 29% (90% C.I.: 18-38%) of the pre-exploitation level and had increased by a median 64% (90% C.I.: 40-129%) since 1994-95 (Table B2.6).

Analyses of the sensitivity of model estimates to alternative weightings being placed on the CPUE and size-distribution data (with which the model is calibrated) revealed another source of uncertainty in model-based estimates of biomass. The greater depletions of biomass and the reduced improvement in biomass since 1994-95 that were estimated using scenario "LS-Wt5" indicate clearly that conclusions about current status of the stock are dependent on what assumptions are made about the reliability of alternative types of data used to calibrate the model. Of particular concern is the different conclusion that would be made about the status of the spawning stock depending on which scenario is closest to the "truth" (Table B2.6).

Fishers have provided, via the logbook, data describing the numbers of berried females and lobsters greater than the maximum size that they have caught (and returned to the water) since 1994-95. Indices of abundance based on this data suggest increases in abundance of spawners and lobsters >200mmCL between 1994-95 and 1999-00 with lesser abundance since that time (Liggins, 2004). The fishery-independent survey of the abundance of spawning stock indicates decreased abundance of berried females and lobsters >200mmCL since 2000-01 (Liggins, 2004). These observations are of major concern – particularly against the background of uncertainty about the level of depletion of spawning stock (relative to pre-exploitation level). In response to these observations and concerns expressed in recent assessments (Liggins *et al.,* 2003; Liggins, 2004), the TAC committee has reduced the TACC from 135t in 2003-04 to 102t for 2004-05 and recommended that further protection be provided to the spawning stock as soon as possible (TAC committee, 2004).

One of the factors affecting the recent apparent decrease in spawning stock involves increased targeting of the spawning stock during the past 3-4 years. It appears that 3-4 relatively poor years of puerulus supply to the north coast (1996-97 – 1999-00 on the far north coast and 1996-97 – 1998-99 on the mid north coast, see Liggins, 2004) subsequently resulted in 3-4 years of relatively poor abundance of small legal-size lobsters (104mmCL +) in the component of the north coast fishery close to the rocks in depths <10m during the period 2000-01 to 2002-03 (Figure B2.5). During the same period, catches and catch rates of medium-sized (130-160mmCL) migrating lobsters on the mid- and outer- continental shelf of the north coast were also poor relative to the previous few years (Figure B2.5). As a consequence of the relatively poor abundances of small lobsters in depths <10m and medium-sized lobsters on the mid- and outer-shelf (100-200m), fishers had no alternative but to increasingly target the grounds (typically 10-30m depth) on which larger lobsters (including spawning stock) are present. Decreased catches and catch rates have been taken by fishers on these grounds (10-

30m depth) since 2000-01 (Figure B2.5) and changes in the size-distribution of catches from these grounds observed during this same period are consistent with a "fish-down" of the stock that was present on these grounds in 1999-00. Catch rates and size-distributions obtained from the fishery-independent survey of spawning stock during this period are consistent with this explanation (Figure B2.5).

On a positive note for the future, the 3-4 years of relatively poor abundance of pueruli on the north coast between 1996-97 and 1999-00 were followed by 4-5 years of increased abundances (since 1999-00 on the mid-north coast and 2000-01 on the far north coast, Liggins, 2004). As would be predicted on the basis of puerulus abundance, catches and catch rates of small lobsters improved dramatically in 2002-03 on the mid-north coast (Figure B2.4) and in 2004-05 on the far north coast (G. Liggins, Pers. comm.). Improved catches and catch rates of medium-sized lobsters on the mid and outer shelf of the mid-north coast of NSW during 2002-03 (Figure B2.5) and 2003-04 (G. Liggins, Pers. comm.) are also a positive sign.

While the stock assessment uses best scientific practice in mathematical modelling of the stock and the estimates are based on the best available data from the commercial fishery and fishery-independent surveys of spawning stock and puerulus settlement, there is an important information gap in the form of a current and rigorously based estimate of the recreational catch of rock lobsters. The current estimate of 26 t for the recreational harvest (i.e. 25% of the total recreational and commercial harvest) is based on a small survey done in 1997 (Andrew *et al.* 1997). The estimate of effort and catch for the component of the recreational harvest taken by divers was based on a sufficiently large sample of fishers, but the sample contained insufficient fishers who had harvested rock lobsters using pots to provide a reliable estimate for that component. An associated problem is that there is probably a relatively large inter-annual variation in recreational harvest of rock lobsters. No such data exists for NSW, but for other states, large inter-annual variability has been found. If this is also the case for NSW, regular rigorously-based estimates of the recreational catch would be required to clarify this circumstance.

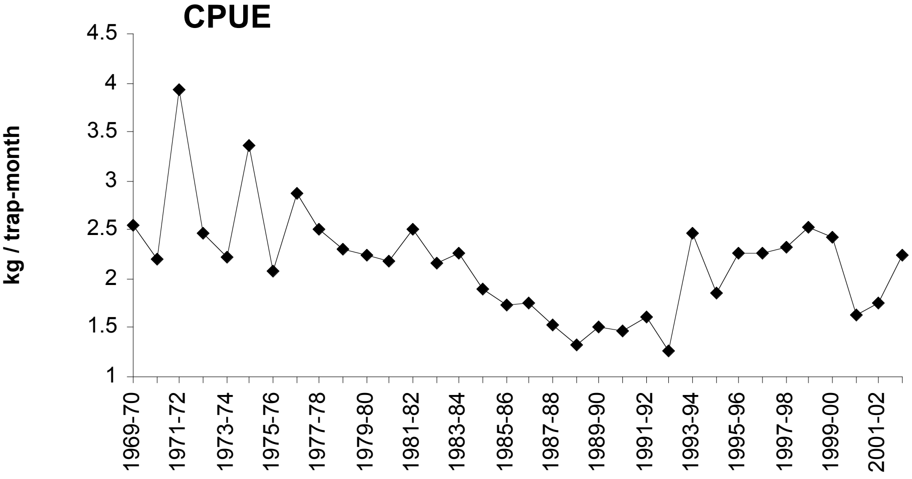

Figure B2.3. Catch per unit effort from the commercial fishery, 1969-70 to 2002-03 (Source: Liggins, 2004).

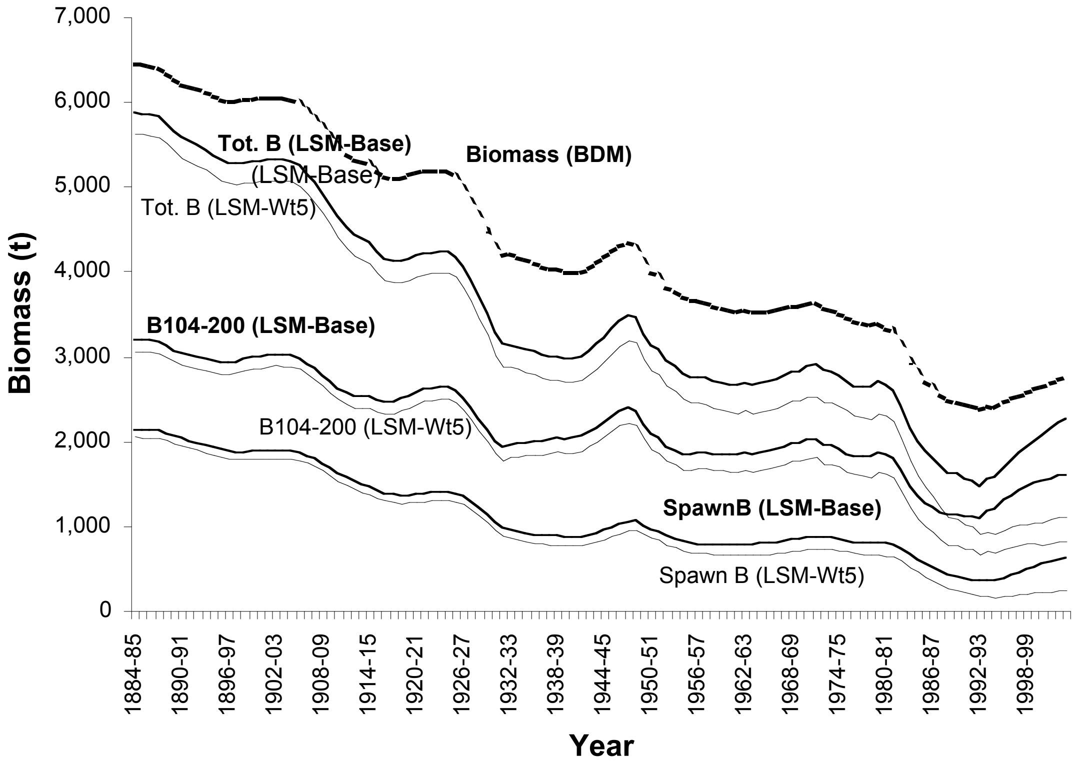

Figure B2.4 Median estimates of biomass of eastern rock lobsters, 1884-85 to 2003-04, from a biomass-dynamics model and 2 alternative scenarios of a length-structured model of the lobster population and fishery.

Total biomass ("Tot. B"), biomass of lobsters within the legal range of sizes 104 – 200 mm CL ("B104-200") and the biomass of spawning females ("Spawn B") is shown separately for 2 scenarios of the length-structured model. Scenario "LSM-Base" was calibrated using both historical CPUE data and recent size-distribution data. Scenario "LSM-Wt5" was calibrated placing much greater emphasis on recent size-distribution data. (Source: Liggins, 2004)

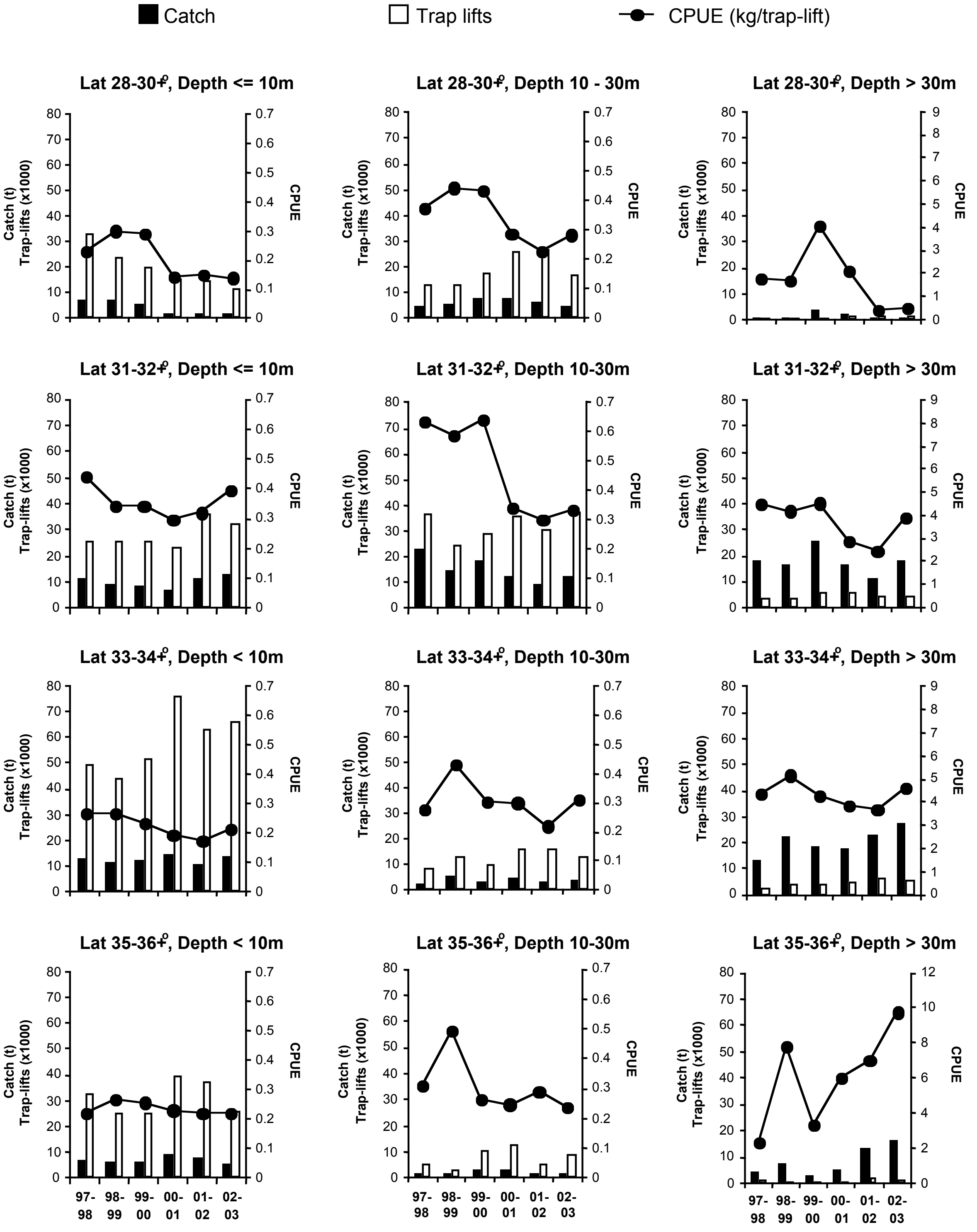

Figure B2.5. Spatial (4 regions, 3 depth ranges) and temporal (1997-98 to 2002-03) patterns in catch (t), effort (trap-lifts) and CPUE (kg/trap-lift) for the commercial catch of lobsters

(Source: Liggins, 2004).

Table B2.6 Median estimates of depletion of total biomass and spawning biomass for 2 alternative scenarios of the length-structured model.

The "LS-Base" scenario was calibrated using both historical CPUE data and recent size-distribution data. The "LS-Wt5" scenario was calibrated placing much greater emphasis on the recent size-distribution data. Median estimates of depletion are tabled with bracketed 90% confidence intervals (Source: Liggins, 2004).

	LS-Base	**LS-Wt5**
Depletion of total biomass **(2003-04 as % of 1884-85)**	38% (27 to 47%)	20% (15 to 28%)
Change in total biomass since 1994-95	+39% (+21 to +76%)	+23% (-8 to +82%)
Depletion of spawning biomass **(2003-04 as % of 1884-85)**	29% (18 to 38%)	11% (8 to 18%)
Change in spawning biomass since 1994-95	+64% (+40 to +129%)	+45% (0 - +152%)

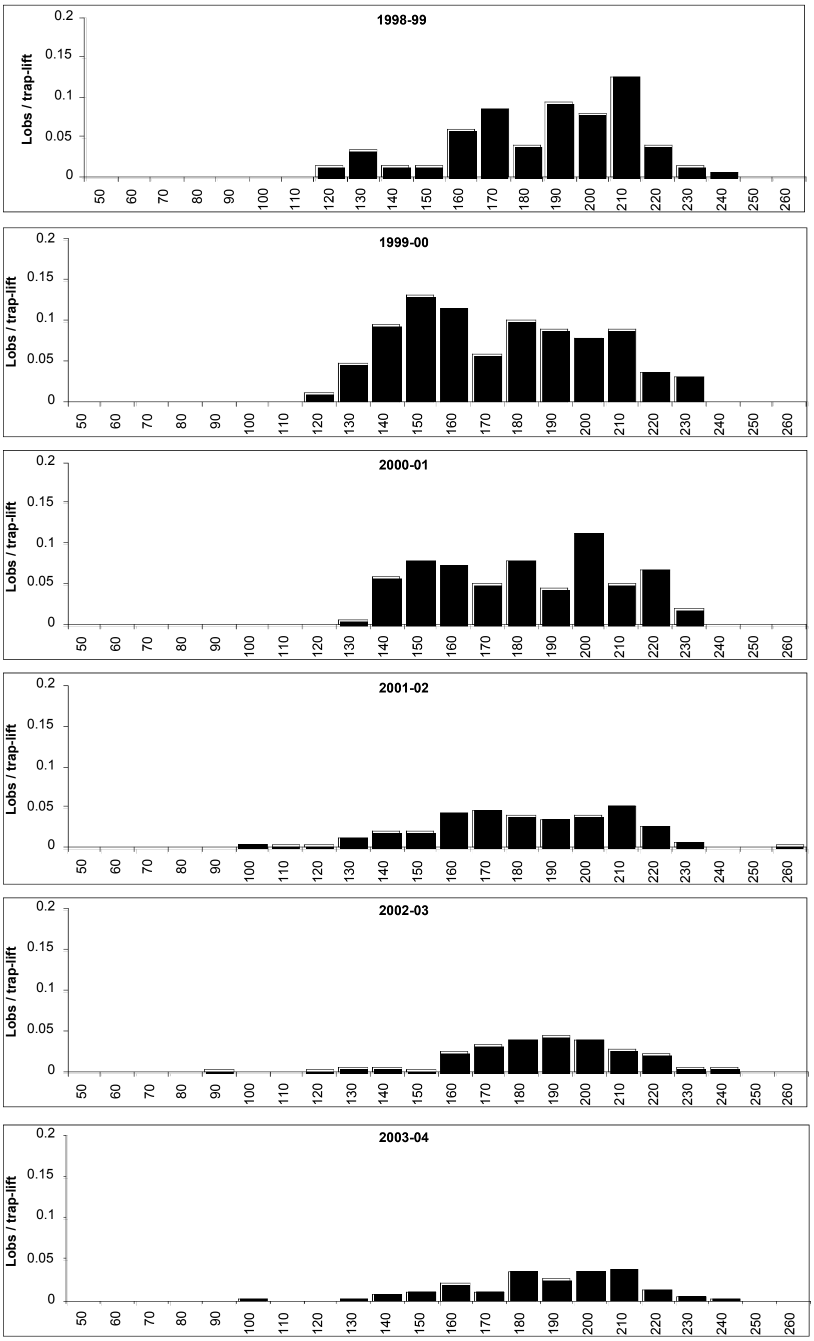

Figure B2.6. Annual catch/trap-lift of lobsters, fishery-independent survey of spawning stock ,by length (10 mm CL intervals),1998-99 to 2003-04

(Source: Liggins, 2004).

B2.3.3 External factors

Ocean currents have a very significant role in the larval phases of the life history of rock lobsters. In Australia, extensive research in this area has been carried out for the western rock lobster fishery by CSIRO biologists and oceanographers, WA Fisheries Department scientists and University researchers over the past 30 years (see e.g. Pearce and Phillips (1988), Caputi *et al*. (1996), Griffin *et al.* (2001)). The larval stages have been studied more intensively than in any other rock lobster fishery worldwide. In WA, nonadvective effects of the current (e.g. on temperature and primary production) have been shown to be primarily responsible for the high variation in natural settlement of the puerulus stage of Western rock lobster (Pearce and Phillips 1988, Caputi *et al.* 1996, Caputi *et al.* 2001).

Booth (1986) described the broad relationship between oceanographic features and the larval distribution of eastern rock lobster in New Zealand. Because the NSW fishery is relatively small (NSW representing only 1% of commercial rock lobster landings in Australia), there has been no specific research on the relationship between oceanographic conditions and the dispersal of eastern rock lobster in NSW waters. There is substantial information on the East Australian current (EAC) (Hamon 1961; Hamon and Tranter 1971; Hamon and Cresswell 1973; Godfrey et al. 1980; Nilsson and Cresswell 1981; Cresswell 1983; Cresswell *et al*. 1983; Anon 1975, 1998; Macauley 2001), although detailed knowledge of the EAC is only about 25% of that for the Leeuwin Current in WA (I. Suthers, University of NSW, pers. comm.). The EAC originates in the Coral Sea and generates eddies up to 200 km across, which can be more than one km deep. It frequently moves onto the continental shelf and close inshore, and at places where it moves away from the coast, the EAC causes nutrient-rich upwellings. This is known to occur at Cape Byron, Smoky Cape and Sugarloaf Point. Strong Southerly winds can slow down or reverse the current within 10 nautical miles of shore.

Caputi *et al*. (2001) concluded that environmental conditions were the primary influence upon fluctuations in puerulus settlement of the western rock lobster. Recently Griffin *et al*. (2004) published results of a study of the role of larval advection in maintaining populations of three rock lobster species, western rock lobster (*Panulirus cygnus)*, southern rock lobster (*Jasus edwardsii)* and tropical rock lobster (*Panulirus ornatus).* They conclude that the three species are similar in some respects regarding the advection mechanism, but are very different in others. For *J. edwardsii*, there did not appear to be a specific mechanism for retaining the larvae, but rather an absence of strong dispersive mechanisms. While it is very likely that in the waters off NSW the EAC has a major role in the dispersal of phyllosoma larvae and the subsequent return of puerulus to settle on coastal reefs, determining the causal mechanisms is bound to be very complex, and beyond the scope of research budgets which are appropriate to the value of the NSW Lobster Fishery.

It is likely that significant increases in sea temperature resulting from global warming will have some influence on the Eastern rock lobster population. There could be an impact on the survival of larvae at increased water temperatures, changes in the distribution, growth and survival of adults, changes in fecundity, etc. At this time, there are no scientific studies on the possible impacts of global warming on rock lobster populations.

B2.3.4 Diseases and mitigation measures

There have been no cases of significant debilitating disease reported in this fishery. In the absence of any reported disease problems, it is unlikely that research on possible diseases of *J. verreauxi* will be considered in the foreseeable future. The only examples of diseases in rock lobsters in Australia have been reported for Southern rock lobsters (*J. edwardsii*) kept in holding facilities in South Australia (Reuter *et. al*, 1999). It was concluded in that study that many species of *Vibrio* (rod-like bacteria) act as secondary opportunists, causing disease when the animal is under stress or when there is already damage to the shell, allowing bacteria to invade the underlying tissue. For *Jasus verreauxi* in New Zealand, Diggles (1999) and Booth and Kittaka (1994) reported that there was very little disease in wild populations, but disease agents were apparent during the initial stages of confinement and ongrowing of lobsters. In a study of mariculture of Southern rock lobster in New Zealand, Rayns (1991) found shell disease in about 13% of the lobsters in the study.

It was concluded from the risk assessment that there is a low risk of disease significantly impacting the stock of Eastern rock lobster in NSW.

B2.3.5 Overall risks from the operation of the fishery on the target species

The resilience rating for eastern rock lobster, as assessed by the procedures outlined in Section B2.2, is shown in Table B2.7.

Table B2.7 Components for resilience rating of eastern rock lobster

Reproductive strategy	Distribution and abundance	Growth rate and longevity	Risk prone score	Resilience rating
Averse	Averse	Prone	1	I - H

The fisheries impact factor was rated as Intermediate (I), as the fishery is regarded as being fully fished.

The resilience rating and fisheries impact rating when plotted on the qualitative risk matrix (Figure B2.2) produced an **overall risk of intermediate (I) for the target species.**

B2.3.5.1 Spawning and sub-adult lobsters

While the need to retain a consistent approach to EISs over all commercial fisheries meant that formal risk assessment was confined to the impact of the fishery on the rock lobster stock as a whole, the stock assessment process for the Lobster Fishery provided important information on the spawning and sub-adult components of the stock.

The risk assessment indicated that there was an intermediate risk to the eastern rock lobster stock under the current management arrangements. In the most recent assessment of the fishery (Liggins, 2004), size frequency distributions indicated a marked decline over the 5 year period to 2001/02 for spawning-sized lobsters, particularly on the north coast. The Total Allowable Catch (TAC) Committee for the NSW Lobster Fishery noted in its 2003/04 determination for the fishery that the spawning stock surveys provided substantial evidence for a large decline in the spawning stock over the previous three years. The TAC Committee recommended in its 2003 report that management actions be initiated to reduce the current threat to the spawning stock. The threat to the spawning stock would give rise to recruitment problems in the fishery unless the decline in the spawning stock was arrested. The current size limits for rock lobster are a minimum carapace length (CL) of 104mm and a maximum CL of 200mm. The size at first breeding has been estimated at 167mm (Booth, 1984b; Montgomery, 1992), meaning that (on average) rock lobsters are fished for approximately 4.5 years before first breeding. This appears to be unique in spiny lobster fisheries worldwide, most of which have a minimum legal size greater than or approximately equal to size at first breeding.

In New Zealand this species had a minimum legal size equivalent to 102mm CL from the start of the fishery in 1961 until 1969, when it was increased to the current level, which is equivalent to 155mm CL for females, 163mm CL for males (Booth 1979). There is a pre-spawning migration to a very limited area in which mature lobsters are caught at the northern tip of the North Island. In the NSW fishery, there is a similar pre-spawning migration to the north coast, which results in a very high proportion of the spawning stock for the Australian stock of eastern rock lobster being concentrated mainly in depths of 10 to 30m in an area north from Sugarloaf Point. It has been pointed out (Booth 1986, Chubb 1994) that in the circumstances of a single major breeding population and distinct migratory pathway, this species is particularly vulnerable to recruitment overfishing. The additional risk in the NSW fishery is that lobsters are subject to legal capture for a very long period between recruitment to the fishery and first breeding. As catch-per-unit-effort (CPUE) declines, there is a risk that fishers will seek new areas to exploit, and thus lead to serial depletion of the spawning stock. There is only very broad information on rock lobster habitat for the NSW coast, and only limited information on the movement of various size classes of lobster.

The assessed intermediate ratings for resilience and fishery impact resulted in an **assessed intermediate risk to the target species.**

B2.3.5.2 Recruitment overfishing

The primary effect of recruitment overfishing is ultimately the collapse of the fish stock. Recruitment becomes so low that it cannot replenish the exploitable stock and eventually results in insufficient landings. There have been several cases of collapses of fish populations that were in part caused by recruitment overfishing. These include northern cod off Newfoundland and Labrador (Hutchings and Myers, 1994), anchovetta of Peru (Patterson *et al.*, 1992) and haddock in Georges Bank (Fordham, 1996). In Australia, gemfish of the South East Fishery is close to (or past the point of) collapse from recruitment overfishing (Rowling, 1994). Clearly, a collapse of a target species is catastrophic for both fishers and the well-being of the ecosystem. There is a much greater danger of a stock collapsing from recruitment overfishing than growth overfishing. While there is no imminent risk of recruitment failure in the NSW Lobster Fishery, there is a significant risk if measures are not implemented to rebuild and closely monitor the spawning stock.

B2.4 Byproduct and bycatch

B2.4.1 Bycatch of target species

Rock lobsters caught in traps consist of legal-sized lobsters, lobsters below the legal minimum size or above the legal maximum size and berried females of legal size. Table B2.8 shows for each of the geographical zones of the fishery, the estimated number of rock lobsters of legal size retained, compared to the number of lobsters discarded annually because they were below the minimum size, beyond the maximum legal size or berried.

Table B2.8 Estimated number of lobsters discarded annually by fishing region, 1999-00 to 2001-02

(Source: G. Liggins, *pers. comm.*)

	<104mmCL DISCARDED	104-200mmCL & Not Berried KEPT	104-200mmCL & Berried DISCARDED	>200mmCL & Berried DISCARDED	>200mmCL & NOT Berried DISCARDED	Total
Far north	346	6,455	292	247	314	7,654
Mid north	91,037	47,819	106	141	252	139,355
Sydney south	55,816	53,220	14	4	28	109,082
Far south	9,199	30,674	1	0	6	39,880
Total	156,398	138,168	413	392	600	295,971
% catch of all classes	52.84	46.68	0.14	0.13	0.2	

The depth distributions are summarised as follows: For undersized lobsters 99% of the catch of undersize lobsters was from depths less than 30m; for berried females 84% of the catch was from depths less than 30m; for oversize lobsters, 10% of the catch was from depths less than 10m, 72% was from depths of 10-30m and 18% was from depths greater than 30m.

The discarding of undersized lobsters may adversely affect their survival and growth. Capture in traps and subsequent discarding can have direct effects through physical damage to the lobsters through contact with the traps, injury or stress through handling, injury or stress through exposure before return to the water as well as increased predation before a discarded lobster returns to its home ground. While the provision of escape gaps would reduce the proportion of undersized lobsters, it would not eliminate the catch of undersized lobsters. Brown and Caputi (1986), in studies of discarded undersized western rock lobster, indicate that with one escape gap of 54mm width, approximately one undersize lobster was retained for each legal-sized lobster, and this 1:1 ratio could be reduced to 0.45:1 with two 55mm escape gaps. The combined effects of damage, displacement and exposure of more than 15 minutes were estimated to produce an additional mortality of 11%. While these trials were on a different species in a different location, the risk factors of exposure, damage and displacement still apply for the NSW Lobster Fishery, and useful data on time of exposure, physical damage and displacement could be collected with relatively small extra effort from future observer studies.

It is possible that the handling of berried and oversized lobsters could have some effect on fecundity. While this is a possible impact, there is no evidence of a significant problem in this regard, and is not considered to be a research priority for NSW Lobster Fishery. While this aspect of discarding of the target species does not fit the risk assessment methodology used in environmental impact assessments for this and other NSW commercial fisheries, an informal risk assessment assigned a low level of risk to the discarding of rock lobsters.