Volume 2

Chapters E – J

This is the second of four volumes in the second draft of the Estuary General Fishery Environmental Impact Statement

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CHAPTER E. IMPACT ON THE FISH RESOURCES

The scientific name for the fish and invertebrates referred to by their common name in the following chapters can be found in Chapter C, section 6(e)(iii).

1. Retained Species

a) Species based biological assessment

i) Stock status

The current status of the 97% of species (by weight averaged over the three years 1997/98 to 1999/00) retained in the Estuary General Fishery is summarised in Table E1. Information was derived from NSW Fisheries (2001) and the NSW Fisheries Commercial Catch Database. The 29 species in Table E1 are considered throughout this chapter to be the principal retained species of the fishery.

Whilst some information is available for the more important harvested species, little is known about the status of most of the principal retained species. Six species (yellowfin bream, sea mullet, sand whiting, dusky flathead, yellowtail and silver trevally) have been assessed to an “assessment reliability” of 3 (Table E1), meaning that “The assessment is completed using both fishery dependent indices of abundance and ancillary information such as age structures or independent surveys but not yet in a formal model framework” (NSW Fisheries, 2001). Four species have an assessment reliability of 4 (Table E1), meaning that “The assessment is still under development or is only completed at an elementary level. Data underlying the assessment may be questionable (such as the use of only fishery dependent effort). Overly simple assumptions may have been used” (NSW Fisheries, 2001). The remaining 19 species have had “no assessment” (Table E1), meaning that “No formal assessment of the stock status has been completed” (NSW Fisheries, 2001).

It should be recognised that for many principal retained species taken in the Estuary General Fishery, current knowledge of stock status is poor or non-existent. Even for those species about which something is known, considerable caution will be needed when making conclusions, at least until stock assessments are better developed. Only with increased monitoring and research will the levels of confidence for most species improve over the life of the proposed FMS.

Table E1. Known information on the current stock status, including stock assessment reliabilities and levels of confidence in making predictions regarding stock status, for principal retained species taken in the Estuary General Fishery.

Species	Exploitation status +	Stock levels (exploitable) +	Stock levels (spawning) +	Five year catch trend in the Estuary General Fishery	Stock assessment reliability +	Confidence in making predictions regarding stock status
sea mullet**	fully fished	appears adequate	uncertain	decreasing	3	moderate
luderick**	moderately fished	probably adequate	probably adequate	decreasing	4	low-moderate
yellowfin bream**	fully fished	adequate	probably adequate	decreasing	3	moderate
dusky flathead	fully fished	possibly adequate	uncertain	increasing	3	moderate
sand mullet	unknown			increasing	no assessment	low
silverbiddy	unknown			decreasing	no assessment	low
sand whiting	moderately fished	adequate	probably adequate	decreasing	3	moderate
longfin river eels	under fished to fully fished depending on catchment	uncertain	possibly adequate	decreasing	4	low - moderate
flat tail mullet	uncertain			decreasing	no assessment	low
silver trevally*	fully / overfished	inadequate	probably adequate	decreasing	3	moderate
mulloway	unknown			fluctuating	no assessment	low
river garfish	unknown			increasing	no assessment	low
trumpeter whiting	unknown			stable	no assessment	low
shortfin river eels	unknown			fluctuating	no assessment	low
tailor	unknown			fluctuating	no assessment	low
estuary catfish	unknown			increasing	no assessment	low
tarwhine	unknown			fluctuating	no assessment	low
yellowtail*	fully fished	uncertain	uncertain	fluctuating	3	moderate
leatherjacket at least 3 species	unknown			decreasing	no assessment	low
old maid	unknown			increasing	no assessment	low
pipi	unknown			increasing	no assessment	low
school prawn	fully fished	inadequate	uncertain	increasing	4	low
blue swimmer crab	unknown			decreasing	no assessment	low
mud crab	unknown			increasing	no assessment	low
eastern king prawn	fully fished	inadequate	uncertain	increasing	4	low
greasyback prawn	unknown			fluctuating	no assessment	low
cockle at least 2 species	unknown			stable	no assessment	low
squid at least 4 species	unknown			decreasing	no assessment	low
beachworms	unknown			decreasing	no assessment	low

+The definition of terms is provided in Chapter C Table C12 and in NSW Fisheries (2001).
* Information largely derived from fisheries other than the Estuary General Fishery.
**Information largely derived from all commercial harvest fisheries.

Available stock assessment information for the principal retained species is provided in Appendix E1 and NSW Fisheries (2001) and summarised below for the major species.

Yellowfin bream (*Acanthopagrus australis*) are exploited by both commercial and recreational fishers, and are taken by wide range of methods and from a wide variety of estuarine and inshore habitats. Recreational catches may exceed commercial catches in some areas (West and Gordon, 1994) and preliminary data from the National Recreational and Indigenous Fishing Survey (Henry pers. comm.) confirm the significant recreational catch of this species. Approximately 400 to 600 tonnes of yellowfin bream have been harvested annually by commercial fishers, with catches being greatest in central NSW estuaries and coastal waters between Taree and Sydney. Since peaking in the mid 1980s to early 1990s, reported bream catches have steadily declined; although this has been accompanied by a corresponding decline in effort, along with changes in gear use. Most of the commercial catch is slightly above the minimum legal length, with the fish mostly being between three and eight years of age. The overall size composition of commercial landings has remained relatively stable since the early 1950s. The spawning stock level is assumed to be adequate, and it is likely that many bream spawn before being harvested in the fishery. Based on a preliminary assessment of the reported commercial catch, and of the available size and age data, the yellowfin bream stock is assumed to be fully fished (Gray *et al*., 2000; NSW Fisheries, 2001; Gray *et al*., b in review).

Dusky flathead (*Platycephalus fuscus*) are exploited by both commercial and recreational fishers, primarily in estuaries. Most of the commercial catch is taken in mesh nets, although a significant portion is also taken by hauling. Recreational catches may exceed commercial catches in some areas (West and Gordon, 1994) and preliminary data from the National Recreational and Indigenous Fishing Survey (Henry pers. comm.) confirm the significant recreational catch of this species. Approximately 150 to 200 tonnes of dusky flathead have been harvested annually by commercial fishers, with catches being greatest in some of the larger central NSW estuaries, as well as in the Clarence and Camden Haven Rivers. Reported commercial catches have been relatively stable over the last 40 years. Dusky flathead of between 33 and 50 cm have dominated, with the fish mostly being between two and four years of age. The overall size composition of commercial landings has remained relatively stable since the early 1950s. The spawning stock level is currently rated as uncertain. The minimum legal length has recently been increased to the size at which dusky flathead are believed to reach maturity (36 cm). Recent estimates of total mortality rates for dusky flathead are relatively high, although these estimates may be confounded by the highly selective nature of mesh nets. Based on a preliminary assessment of the reported commercial catch, and of the available size and age data, the dusky flathead stock is assumed to be fully fished (Gray *et al.,* 2000; NSW Fisheries, 2001; Gray *et al*., a in review).

Sand whiting (*Sillago ciliata*) are exploited by both commercial and recreational fishers, and are taken from estuaries and ocean beaches. Recreational catches may exceed commercial catches in some areas (West and Gordon, 1994) and preliminary data from the National Recreational and Indigenous Fishing Survey (Henry pers. comm.) confirm the significant recreational catch of this species. Commercial estuarine production has generally increased from less than 40 tonnes in the mid 1950s to around 130 – 180 tonnes in recent years, with the largest catches usually coming from the Clarence River, Wallis Lake, Port Stephens, Botany Bay and Tuggerah Lakes. Most of the catch taken in haul nets is slightly above the minimum legal length, with the fish mostly being between two and five years of age. Fish taken in mesh nets tend to be larger and are more likely to be older, with a far greater proportion of fish aged six to eight years. The spawning stock level is probably adequate, and it is likely that many sand whiting spawn before being harvested in the fishery. Based on a preliminary assessment of the reported commercial catch, and of the available size and age data, the sand whiting stock is assumed to be fully fished (Gray *et al.,* 2000; NSW Fisheries, 2001).

Luderick (*Girella tricuspidata*) are exploited by both commercial and recreational fishers, with the majority of the commercial catch being taken in estuaries. The commercial harvest of luderick from estuaries has remained relatively stable over the past 40 years, fluctuating around 400 tonnes. The central coast estuaries generally account for the largest catches. Most of the commercial catch is between 25 and 35 cm Fork Length (legal minimum approx. 23 cm FL), with fish sampled from commercial catches in the Clarence River found to be mostly between two and seven years of age. The spawning stock level is assumed to be adequate. Based on a preliminary assessment of the reported commercial catch, and of the available size and age data, the luderick stock is assumed to be moderately fished (Gray *et al.,* 2000; NSW Fisheries, 2001).

Sea mullet (*Mugil cephalus*) are exploited predominantly by commercial fishers, and are taken from both estuaries and ocean beaches. For much of the last 50 years, total commercial landings had fluctuated between 2000 and 3000 tonnes. However, from about 1985, catches increased sharply to a peak of more than 5500 tonnes in 1993/94 before declining to less than 2300 tonnes by 1999/00. The increase occurred in the ocean sector of the fishery, primarily in response to a developing export market for roe. Catch per unit effort appears to have declined in recent years in relation to estuary and ocean hauling, although it has remained stable for estuary mesh netting. Most of the commercial catch is above the minimum legal length, particularly in the case of that from ocean waters. The length structure of catches has been relatively stable since the 1940s; however, the average age of mullet in both ocean and estuarine samples has declined since age monitoring began in 1995. The spawning stock level is probably adequate, but is likely to have declined in recent years. Based on a preliminary assessment of the reported commercial catch, and of the available size and age data, the sea mullet stock is assumed to be fully fished (Virgona *et al.,* 1998; NSW Fisheries, 2001); however, it should be noted that recent landings in excess of 4000 tonnes may be unsustainable.

Longfinned river eels (*Anguilla reinhardtii*) are exploited by both commercial and recreational fishers, with most of the commercial catch being taken by specialised traps, which are used in both estuaries and freshwaters. Catches slowly increased through the 1970s and 80s then increased dramatically to more than 400 tonnes in 1992/93, primarily in response to new export markets and the opening up of freshwater impoundments. Catches have since fallen and have been around 200 tonnes in the last few years. The most productive areas have been the Clarence, Hawkesbury and Port Stephens catchments. Most of the eels taken are large juveniles or adults, although a limited harvest of so-called ‘glass eels’ (very small juveniles) is permitted for the supply of aquaculture. The spawning stock level is assumed to be adequate, although it can only be directly measured by estimating the number of eels migrating out of all the coastal catchments in NSW. Based on a preliminary assessment of the reported commercial catch, and of the available size and age data, the longfinned eel stocks of some catchments (particularly the Clarence, Hawkesbury and Port Stephens catchments) are believed to be fully exploited, whist those of many other NSW coastal catchments are assumed to be underfished (Pease, 2000).

The three main prawn species taken in NSW (school prawn, *Metapenaeus macleayi*; eastern king prawn, *Penaeus plebejus*; and greasyback prawn, *M. bennettae*) are taken from estuaries by both commercial and recreational fishers. Recreational catches make up about 5% of the total (Montgomery and Reid, 1995). Within the Estuary General and Estuary Prawn Trawl fisheries, school prawns dominate catches; there being only small percentages of the other species. Recreational catches (which are entirely estuarine) are, however, dominated by eastern king prawns, as are landings in the Ocean

Prawn Trawl Fishery. All three species are caught along the entire NSW coast, although both school and eastern king prawns are taken in greatest quantities in the north. Prawn catches characteristically fluctuate; however, there is some indication of overall declines in estuary general catches of both school and king prawns since 1985. School and eastern king prawns are taken over a wide size range, although most individuals are below the likely size of maturity. All eastern king prawns caught within estuaries are likely to be immature, with adults being taken exclusively in ocean waters. The spawning stock levels of the three main prawn species are uncertain, and no data on the distribution or abundance of such stocks for school or greasyback prawns are available. Spawning stocks of eastern king prawns appear to be concentrated in ocean waters off far northern NSW and southern QLD (Montgomery and Reid, 1995). Based on a preliminary assessment of the reported commercial catch and the available size data, prawn stocks are assumed to be fully fished (Montgomery, 2000; NSW Fisheries, 2001), particularly in the case of school and eastern king prawns. Results of modelling by Gordon *et al.,* (1995) suggest that both biological and economic benefits may be gained by allowing eastern king prawns in certain areas to move into ocean waters before being caught.

Yellowtail (*Trachurus novaezelandiae*) are caught by a variety of methods in several different fisheries, although about 80% are taken by purse seining in ocean waters. Recent landings have averaged approximately 370 tonnes, with most caught off the southern half of the state, particularly near Wollongong. While total landings (all commercial methods) have been increasing since the late 1980s, catches from the Estuary General Fishery have declined from approximately 80 tonnes to about 20 tonnes during this period. Most of the commercial catch consists of fish two or three years old, with ages ranging between one and 11 years. The spawning stock level is uncertain. Based on a preliminary assessment of the reported commercial catch and age data, the yellowtail stock is assumed to be fully fished (NSW Fisheries, 2001).

Silver trevally (*Pseudocaranx dentex*) are exploited by both commercial and recreational fishers, and are taken by wide range of methods and from a variety of estuarine and inshore habitats. The annual recreational catch has been estimated at approximately 250 tonnes, as compared with the 400 tonnes reportedly taken by the various commercial fisheries. Approximately 40 tonnes of silver trevally have been harvested annually by estuary general fishers in recent years. Since peaking in the late 1980s, overall reported trevally catches have declined from around 1500 tonnes to about 400 tonnes. The modal age of trevally in commercial catches has been estimated to have declined from 7-8 years in the late 1980s to only 3-4 years in recent years, and preliminary modelling suggests that silver trevally are often being caught at well below the optimum size (Rowling and Raines, 2000). The spawning stock level is rated as “probably adequate”, and recent recruitment levels appear to have been reasonably stable. Based on a preliminary assessment of commercial and recreational catches, and of the available size and age data, the silver trevally stock is assumed to be fully to overfished (Rowling and Raines, 2000; NSW Fisheries, 2001).

ii) Species risk assessment

Determining the likelihood of a species being over-exploited involves a risk assessment. There are many forms of risk assessment (Francis and Shotton, 1997) and they can be either quantitative or qualitative (Harding, 1998; Handmer, 1995). The purpose of risk assessment is to use various categories of information about a fishery to determine the likely effects of current and/or alternative management options (Francis and Shotton, 1997). Harding (1998) sets out five logical steps in risk management – risk context, identification, analysis, assessment and treatment. This section of the EIS concentrates of the last three steps, as the draft FMS and DUAP guidelines provide the context and identification of the risks. Analysis of the risks (e.g. overfishing) examines the levels of risk involved for a species or habitat i.e. high, medium and low. Assessment of risk determines whether a risk level is acceptable or unacceptable. The risk treatment examines what options are available to manage the different levels of risk.

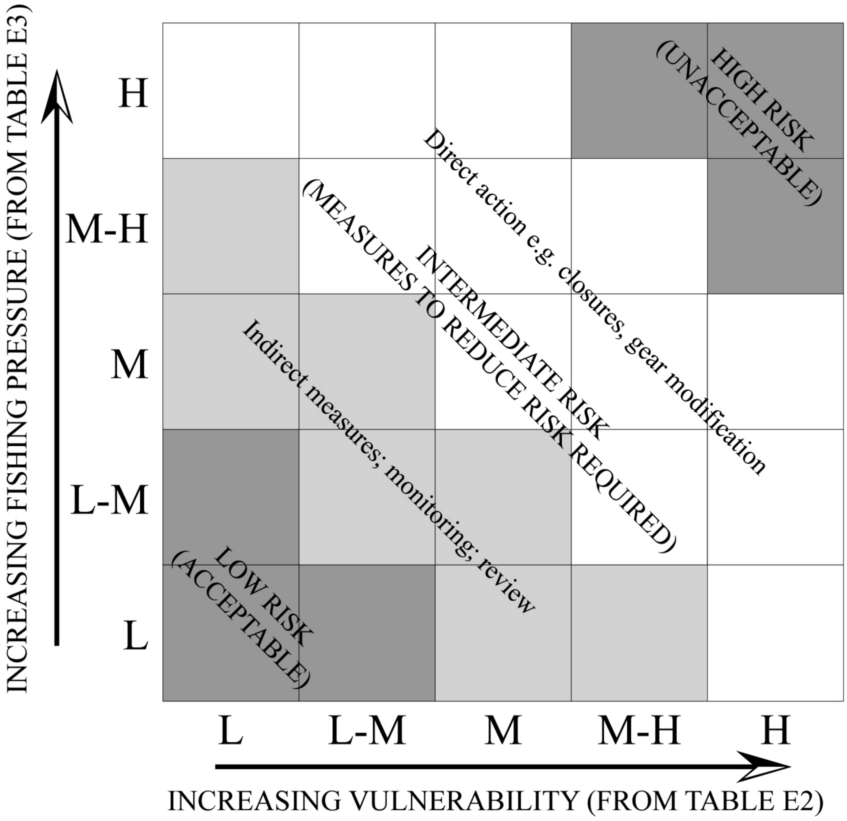

Figure E1. Diagrammatic framework for risk assessment for the principal retained species in the Estuary General Fishery.

Figure E1 shows the framework for risk analysis and assessment (adapted from Harding, 1998) that was used for determining the likelihood of overfishing of the principal retained species in the Estuary General Fishery.

The likelihood of a species being over-exploited is governed by a combination of its vulnerability to overfishing and fishing pressure (see Tables E2 and E3). Each species falls within zones of "low risk", "intermediate risk" or "high risk" according to these factors. Within the zone of intermediate risk, further differentiation is provided in terms of the risk-reduction measures required.

For the Estuary General Fishery, the vulnerability of the species to fishing pressure based on species' biological and habitat attributes was assessed using the species information and references in Appendix B1, with additional expert opinion from fisheries scientists (Table E2).

The vulnerability of a species depends on the following factors.

Reproductive strategy

Broadcast marine spawners with high fecundities and long pelagic larval stages (most species in the fishery) have been classified as having "low" vulnerability. Species or groups believed to spawn exclusively within estuaries (most garfish and some leatherjackets) have been classified as "medium". None of the principal retained species taken in the Estuary General Fishery have such limited reproductive capacities as to warrant a classification of "high" (an example of "high" would be sharks which produce one or two pups every second year).

Tendency to aggregate

Those species, which often form large dense schools, whether for spawning, migration, or any other reason, have been classified as "high". Species that usually form loose aggregations have been classified as "medium", whilst those that do not normally school or aggregate have been classified as "low".

Size (age) when fished

Species mostly retained near or before their size (age) of first maturity are classified as "high" (king prawns); those mostly taken well above their size (age) of first maturity are classified as "low" (e.g. sand mullet and fanbelly leatherjacket); and those typically taken at a wide ranges of sizes (ages) with respect to first maturity are classified medium (e.g. yellowfin bream and luderick). Classifications with respect to this factor are based on available size and age-based catch data and information on life histories (SPCC, 1981b; NSW Fisheries, 2001; Scandol and Forrest, 2001; Appendix B1; Appendix E1).

Position in food web

Species that primarily consume detritus, algae, sessile invertebrates and/or very small (typically planktonic) animals are classified as "low"; those mainly eating fish and/or large invertebrates (i.e. 'predatory' species) are classified as "high"; whilst those species with broad diets, or which prey on small invertebrates such as worms and molluscs, are classified as "medium".

Sensitivity of preferred habitat

Species that usually occur in association with marine vegetation are classified "high"; those thus found only sometimes are classified "medium"; whilst those rarely occurring around marine vegetation are classified "low".

Sensitivity to pollution

Species that regularly enter freshwaters (where water quality is often poor) are classified as "low", while those which are normally only found in marine-dominated waters (where water quality is normally good) are classified as "high". Most of the species taken in the Estuary General Fishery fall between these extremes and are therefore classified as "medium".

Fish passage issues

Species that regularly enter tributary rivers, streams or channels are classified as "high". Species that only occasionally enter such confined waters are classified as "medium", while those that rarely or never enter such waters are classified as "low".

Proportion of habitat fished

Species that are likely to be sought throughout most of their usual habitat range are classified as "high"; these species tend to remain confined to estuaries (fanbelly leatherjacket) and/ or are easily accessible to fishers throughout their adult life (e.g. prawns). Those that often utilise habitats which are inaccessible (e.g. eels in small creeks and swamps) or difficult to fish intensively (e.g. tailor around rocky reefs) are classified as "low". Most species fall between these extremes and are classified "medium".

Table E2. Life history and habitat vulnerability of the principal retained species taken by the Estuary General Fishery.

Explanations of ratings within each of the specific aspects are discussed in the text.

	Vulnerability								
Species/group	**Fishing pressure - life history and behaviour**				**Habitat preference**				**Overall vulnerability**
Specific aspect of vulnerability	reproductive strategy	tendency to aggregate	size (age) when fished	position in food web	sensitivity to preferred habitat	sensitivity to pollution	fish passage issues	proportion of habitat fished	
sea mullet	l	h	m	l	m	l	h	m	M
luderick	l	m	m	l	h	m	m	m	M
yellowfin bream	l	m	m	m	h	m	h	m	M
dusky flathead	l	m	m	h	m	m	m	m	M
sand mullet	l	h	l	m	m	m	m	m	M
silverbiddy	l	m	m	l	m	m	m	m	L-M
sand whiting	l	m	m	m	m	m	m	m	M
longfin river eels	l	l-m	h	h	m	l	h	m	M-H
flat tail mullet	l	h	l	m	h	m	h	m	M
silver trevally	l	h	h	m	l	m	l	m	M-H
mulloway	l	m	m	h	l	m	l	m	M
river garfish	m	m	m	l	m	m	l	h	M
trumpeter whiting	l	l	l	m	l	m	m	m	L-M
shortfin river eel	l	l	h	h	m	l	h	m	M-H
tailor	l	h	m	h	l	m	l	l	L-M
estuary catfish	m	m	m	l	l	l	m	m	M
tarwhine	l	m	h	m	m	m	m	m	M
yellowtail	l	h	l	l	m	m	l	l	L-M
leatherjacket at least 3 species	l	l	m	l	h	m	m	h	M
old maid	l	m	m	m	m	l	m	m	M
pipi	l	m	l	l	l	h	l	m	L-M
school prawn	l	h	h	l	m	m	h	h	M
blue swimmer crab	l	l	m	m	m	m	l	m	L-M
mud crab	m	l	m	m	m	m	h	h	M
eastern king prawn	l	m	h	l	m	m	m	h	M
greasyback prawn	l	m	l	l	m	m	m	h	M
cockle at least 2 species	l	l	m	l	h	m	l	m	L-M
squid at least 4 species	m	m	m	m	m	h	l	m	M
beachworms	l	l	l	l	l	h	l	m	L

The fishing pressure on the species and the relative contribution of the Estuary General Fishery (Table E3) is assessed using the commercial fish catch database harvest tonnage averaged for the years 1997/98, 1998/99 and 1999/00 (NSW Fisheries, 2000). The estimated total harvest by all sectors is based on the commercial fish catch database harvest tonnage averaged for the years 1997/98, 1998/99 and 1999/00, preliminary data from the National Survey of Recreational and Indigenous Fishers (Gary Henry, NSW Fisheries, pers. comm.) and data from Anon (1981), Henry (1984 & 1987), Henry and Virgona (1980), Henry *et. al.* (1987), Steffe *et. al.* (1996a & b), Steffe and Chapman (in review), West and Gordon (1994) and Williams *et. al.* (1993). The preliminary recreational harvest data from the National Survey of Recreational and Indigenous Fishers are the estimates of the total number of kept fish by species, unweighted for the statistical divisions of the States population. The estimates were converted to weights using data on the median length or weight of retained fish for individual fish species from the above referenced recreational fishing surveys. Where necessary the fish and invertebrate lengths were converted to weight using the length/weight conversion keys in Steffe *et. al.* (1996a).

Stock status refers to best available stock assessment information; “l” refers to under-fished; “m” moderately or fully-fished; “h” fully to overfished and “u” unknown or uncertain. When the status is unknown a precautionary approach is used to assess the overall fishing pressure by the Estuary General Fishery.

Table E3. Overall assessment of the pressure associated with each of the principal retained species in the Estuary General Fishery.

* See text for explanation of data sources.

Species/ group	Fishing pressure					
	Average Estuary General harvest (tonnes)*	Estimated average harvest in NSW (commercial + recreational) tonnes*	Estuary general harvest as a percent of total harvest	Level of by-catch taken in the Estuary General fishery	Stock status from Table E1	Overall fishing pressure by the Estuary General Fishery
sea mullet	1,783	3,358	53	l	m	M
luderick	421	754	56	m	m	M
yellowfin bream	283	800	35	m	m	M
dusky flathead	206	387	53	l	m	M
sand mullet	179	181	99	m	u	M-H
silverbiddy	139	150	93	h	u	H
sand whiting	131	182	72	m	m	M-H
longfin river eels	34	40	83	l	m	M-H
flat tail mullet	91	96	94	m	u	M-H
silver trevally	59	372	16	h	h	H
mulloway	47	176	27	h	u	M-H
river garfish	42	54	77	l	u	M
trumpeter whiting	35	92	38	h	u	M
shortfin river eel	34	35	97	l	u	M
tailor	31	276	11	m	u	M
estuary catfish	24	64	37	l	u	M
tarwhine	19	50	38	h	u	M-H
yellowtail	18	495	4	l	m	L
leatherjacket at least 3 species	18	197	9	m	u	M
old maid	18	20	90	m	u	M
pipi	516	538	96	l	u	M
school prawn	325	836	39	l	m	M
blue swimmer crab	204	321	64	h	u	H
mud crab	132	200	66	l	u	M
eastern king prawn	54	903	6	l	m	L-M
greasyback prawn	46	570	81	l	u	M
cockle at least 2 species	36	41	88	l	u	M
squid at least 4 species	26	136	19	m	u	L-M
beachworms	21	24	87	l	u	L-M

The data in tables E2 and E3 were analysed to assess risk levels for each species using the risk framework (Figure E1). As numeric data are not available to estimate likelihoods, a qualitative risk analysis was undertaken. This risk assessment assumes equal weighting of the vulnerability and fishing pressure axes in Figure E1.

The risk assessment (Table E4) shows that nearly all of the principal retained species have an associated risk of "intermediate", with only two falling into the low risk category. One species is within the high risk category where over-exploitation is likely to occur.

Table E4. Risk assessment for each of the principal retained species in the Estuary General Fishery.

"Overall risk" based on the intersection of vulnerability and fishing pressure as per Figure E1 above. "Direct action" refers to management approaches such as fishing closures, gear modifications and size limits; "Indirect measures" refer to approaches such as monitoring and review.

Species/ group	Vulnerability (from Table E2)	Fishing pressure (from Table E3)	Overall risk associated with species (Figure E1)	Required management (see Figure E1)	FMS match to required management
sea mullet	M	M	Intermediate	Direct action	Yes
luderick	M	M	Intermediate	Direct action	Yes
yellowfin bream	M	M	Intermediate	Direct action	Yes
dusky flathead	M	M	Intermediate	Direct action	Yes
sand mullet	M	M-H	Intermediate	Direct action	No
silverbiddy	L-M	H	Intermediate	Direct action	Yes
sand whiting	M	M-H	Intermediate	Direct action	Yes
longfin river eels	M-H	M-H	Intermediate	Direct action	Yes
flat tail mullet	M	M-H	Intermediate	Direct action	Yes
silver trevally	M-H	H	High risk	Direct action	Yes
mulloway	M	M-H	Intermediate	Direct action	Yes
river garfish	M	M	Intermediate	Direct action	Yes
trumpeter whiting	L-M	M	Intermediate	Indirect measures	Yes
short fin river eel	M-H	M	Intermediate	Direct action	Yes
tailor	L-M	M	Intermediate	Indirect measures	Yes
estuary catfish	M	M	Intermediate	Direct action	Yes
tarwhine	M	M-H	Intermediate	Direct action	Yes
yellowtail	L-M	L	Low	Acceptable	Yes
leatherjacket at least 3 species	M	M	Intermediate	Direct action	Yes
old maid	M	M	Intermediate	Direct action	Yes
pipi	L-M	M	Intermediate	Indirect measures	Yes
school prawn	M	M	Intermediate	Direct action	Yes
blue swimmer crab	L-M	H	Intermediate	Direct action	Yes
mud crab	M	M	Intermediate	Direct action	Yes
eastern king prawn	M	L-M	Intermediate	Indirect measures	Yes
greasyback prawn	M	M	Intermediate	Direct action	Yes
cockle at least 2 species	L-M	M	Intermediate	Indirect measures	Yes
squid at least 4 species	M	L-M	Intermediate	Indirect measures	Yes
beachworms	L	L-M	Low	Acceptable	Yes

Among the 26 species in the intermediate risk category, 20 are in the zone where direct management actions are required, whilst seven are in zone where indirect measures such as monitoring and review are likely to be sufficient (Figure E1 and Table E4). Table E4 also shows that fishing pressure, rather than vulnerability, is the major factor contributing to the risks.

In addition to the 29 principal retained species discussed in Table E4 there are a further 55 species, which are retained in the fishery (see Chapter C, section 6(e)(iii)). These 55 species represent less than 3% by weight of the annual catch in the Estuary General Fishery. Further, of these 55 species a risk assessment for 34 is or will be included in the EIS for the Ocean Hauling, Estuary Prawn Trawl, Ocean Trap and Line or Ocean Trawl Fisheries where the species occurs in the principal retained catch. The remaining 20 species which represent less than 1% of the catch, for which no formal assessment has been done are considered to be in a very low risk category due to their extremely low and irregular harvest in this fishery. This highly variable and low harvest in the Estuary General Fishery means monitoring and assessment of harvest against trigger points is impractical, within an acceptable economic framework.

In assessing the draft FMS, all of the species except one have the appropriate level of management response. The management issue for sand mullet relates to problems in catch data recording as outlined in the draft FMS (see Chapter C). The key range of objectives relevant to the species are listed in Table E4 while the full range of management responses are outlined under each objective and are presented in the draft FMS.

b) Assessment of retained species management measures in the draft FMS

i) Adequacy of the draft FMS for the different categories of stock exploitation

Categories of stock status in the Estuary General Fishery

The principal retained species within the Estuary General Fishery have been identified as under fished, moderately fished, fully fished, fully/overfished, or being of uncertain or unknown status (Table E1).

It should be noted that over fished species can be either ‘growth overfished’ and/or ‘recruitment overfished’ (NSW Fisheries, 2001). Growth overfishing refers to the excessive harvesting of relatively young individuals of a stock, such that the biomass yield is reduced. Recruitment overfishing refers to a situation in which fishing pressure has caused a significant reduction in a stock’s reproductive success, such that the recruitment of young fish into the fishery is reduced.

External factors likely to affect stock status

These factors are additional to the fishery-related impacts described throughout this EIS. They include stock resilience and external environmental influences (both human-related and natural). Whilst such factors are beyond the direct control of the fishery, they do need to be considered within the draft FMS, both in terms of allowing for any potential negative influences on stock status, and in terms of their indirect control (as, for example, through Catchment Management Boards).

The “resilience” of a stock refers to that stock’s ability to recover after having being affected by previous fishing pressure (Underwood, 1989; Skilleter, 1995). For the species taken in the Estuary General Fishery, there are no specific information on resilience. However, the ‘aspects of vulnerability’ presented in Table E2 may provide some indication of resilience for each of the principal retained species as recovery potential is likely to be strongly tied to these aspects and especially to reproductive strategy. On the basis of the limited information available (Table E2), it is likely that most of the principal retained species are fairly resilient to fishing pressure, with the possible exception of those species believed to spawn exclusively within estuaries (e.g. fan belly leatherjacket and river garfish). Most of the principal retained species are broadcast marine spawners, with high fecundity and a long pelagic larval stage; features that would assist any recovery, particularly in the case of localised and/or short term depletion (Skilleter, 1995).

A wide range of other external factors, both natural (e.g. climate and ocean currents) and human related (e.g. recreational angling, shipping and urban development), may affect stock numbers and resilience, primarily as a result of damage to or modification of habitats. These factors and their associated effects are discussed in detail in Chapter B section 6 ("Interaction with other fisheries and the environment") and Chapter F section 10 ("Potential impacts of the external environment on the fishery").

Many of the species taken in the Estuary General Fishery use sensitive estuarine habitats (such as seagrass) for at least part of their life cycle (particularly as juveniles) and are therefore relatively vulnerable to these external factors. Not only can stock numbers be directly affected in the event of major habitat loss, but so can the resilience of dependant species. Even if a depleted species can still produce large numbers of widely dispersed larvae, its harvestable population would be unlikely to recover if those larvae had insufficient suitable habitat in which to settle.

The various external factors affecting the fishery have potentially major impacts on fish mortality and habitat condition. The relative contributions of these factors to mortality and habitat condition are currently unknown, meaning that related predictions given in Tables E5 to E8 are indicative only. Whilst the relevant responses in the draft FMS can be expected to (for example) reduce mortality or improve habitat condition, there is no way of predicting the extent to which such benefits will offset adverse influences from the many external factors affecting the fishery.

Under fished species

Among the principal retained species taken in the Estuary General Fishery, only longfinned river eels, *Anguilla reinhardtii* are believed to be under-fished (Table E1), and then only in those catchments where local fishing pressure has been low. In these cases this species has the potential to sustain catches significantly higher than those currently being taken (NSW Fisheries, 2001). The goals and objectives of the draft FMS are focused on improving our knowledge of underfished species and safeguarding them against pressures such as those related to bycatch mortality and habitat damage (Tables E5 and E8).

With respect to longfinned river eels, which are currently assessed as under-fished at the local (catchment) level, the draft FMS is expected to result in:

- an improved knowledge of stock status
- controlled mortality of juvenile (glass) eels through limits on maximum annual catches
- continued protection of key habitats, particularly riverine and wetland habitats
- maintenance of present exploitation rates.

Table E5. Direct actions within the draft FMS most relevant to under-fished and moderately fished species.

Factors listed in the right column are specifically in relation to these species. It should be noted that positive effects given in the right column are indicative only, and that currently available data do not allow absolute or relative (as a proportion of total) estimates of factors such as juvenile mortality or habitat condition to be made.

FMS Measures (Chapter 3)			Summary of purpose/action	Factor(s) likely to be positively affected by implementation of responses
Goal	Objective	Response		
1			Conserve biological diversity	
	1.1		Minimise impact on non-retained fish	
		1.1 (a)	Phase out 70 mm flathead nets	juvenile mortality (reduced)
		1.1 (b)	Modify fishing practices to reduce by-catch	juvenile mortality (reduced)
		1.1 (c)	Use best-practice for handling by-catch	juvenile mortality (reduced)
	1.2		Minimise impact on habitats	
		1.2 (a)	Prohibit all hauling over Posidonia seagrass and prawn hauling over seagrass	habitat condition, mortality (squid)
		1.2 (a)	Avoid places/ times of high juvenile abundance	juvenile mortality (reduced)
		1.2 (b)	Modify ecologically damaging methods	habitat condition
2			Maintain fish populations at sustainable levels	
	2.1		Harvesting does not lead to overfishing	
		2.1 (a)	Gear limits in estuaries	controls catch
		2.1 (d)	Size limits	prevents overfishing
		2.1 (e)	Prohibit taking of female crabs carrying ova	protection of spawning stock
		2.1.2 (a)	Monitor the catch levels of eels by estuary	knowledge, future management
		2.1.4 (a)	Monitor the catch levels of key secondary species	knowledge, future management
		2.1.4 (b)	Monitor the catch levels of all other secondary species	knowledge, future management
	2.3		Prevent activation of latent effort	
		2.3 (a)	Implement owner-operator rule	control of effort
		2.3 (b)	Minimum entry requirements	control of effort
		2.3 (c)	Prohibit unlicensed crews	future management
5			Promote a viable commercial fishery	
	5.1		Optimise biological yield	knowledge, future
7			Improve knowledge of species	
	7.3		Scientific research and monitoring	knowledge, future management

Moderately fished species

Among the principal retained species taken in the Estuary General Fishery, three species are believed to be moderately-fished (Table E1). These are: luderick, sand whiting and river eels (in some catchments). Such species have the potential to sustain only a limited increase in catches (NSW Fisheries, 2001). The goals and objectives of the estuary general draft FMS are focused on improving our knowledge of these species and safeguarding them against pressures such as those related to bycatch mortality and habitat damage (Tables E5 and E8).

With respect to the species currently assessed as moderately-fished, the draft FMS is expected to result in:

- an improved knowledge of stock status
- reduced mortality, particularly through reductions in bycatch and improved fishing/ handling practices
- increased protection of key habitats, particularly mangroves (juvenile luderick) and seagrasses (luderick)
- maintenance of present exploitation rates.

Luderick, and to a lesser extent sand whiting, are likely to benefit from the phasing out of 70 mm flathead nets (Table E5; Response 1.1a). Significant discards of large juvenile luderick have been observed from flathead nets, with some of these fish appearing to suffer injury (Charles Gray unpubl. data). Modifications in fishing practices to reduce bycatch (Table E5; Responses 1.1b, d, e and 1.2a) should reduce mortality amongst all of the moderately fished species, with the exception of river eels. These eels, because of their body shape, escape behaviour and habitat preferences, are not normally taken as bycatch.

Fully fished species

Among the principal retained species taken in the Estuary General Fishery, seven species are believed to be fully fished (Table E1). These are; sea mullet, yellowfin bream, dusky flathead, yellowtail, school prawn, eastern king prawn and river eels (in some catchments). For fully fished species, current catches are sustainable and close to optimal levels, although any significant increase in fishing effort may lead to overfishing and stock depletion (NSW Fisheries, 2001). For these species, the goals, objectives, performance measures and trigger points of the draft FMS extend to the control of overfishing by means such as limiting gear dimensions and the sizes at which individuals can be taken, combined with monitoring total harvest and the consideration of review triggers against the historic harvest.

The ability to predict the effectiveness of the associated responses (Table E6; Goal 2) will improve significantly once robust and reliable fish stock assessments are complete. Controls on active and latent fishing effort (Table E6; Objectives 2.2 and 2.3) will act to restrict overall fishing effort. If necessary for reasons of sustainability, overall fishing effort can actually be decreased depending on the degree of structural adjustment (i.e. size of minimum share holdings) implemented. The setting and subsequent review of minimum shareholdings provides a powerful mechanism for achieving structural adjustment.

For dusky flathead, the size limit has recently been increased from 33 cm to 36 cm (July 2001), with the possibility of an additional increase to 40 cm subject to further review and consultation. Whilst final results from current studies are not yet available, dusky flathead are believed to first reproduce at around 36 to 38 cm in length (Botany Bay Study SPCC, 1981b): these increases are expected to lead to a significantly increased proportion of flathead reproducing before capture, and should therefore assist with stock recovery.

Dusky flathead are likely to benefit from the phasing out of 70 mm flathead nets (Table E6; Response 1.1a) and the above-mentioned increase in their minimum legal length from 33 to 36 cm. Yellowfin bream and sea mullet are also likely to benefit from the phasing out of 70 mm flathead nets (Table E6; Response 1.1a). Significant discards of large juvenile yellowfin bream and sea mullet have been observed from flathead nets, with some of these fish appearing to suffer injury (Charles Gray unpubl. data).

Modifications in fishing practices to reduce bycatch (Table E6; Responses 1.1b, d, e and 1.2a) should reduce mortality among several of the fully-fished species, particularly yellowfin bream, sea mullet and dusky flathead. Some of the fully fished species, particularly yellowtail, longfin river eels and prawns, do not usually feature amongst bycatch in the Estuary General Fishery; these species are not normally taken due to size, body shape, behaviour and/or habitat preference.

On-going refinement of rules relating to size limits and gear specifications (Table E6; Goal 2) will help avoid any of the species becoming over-fished. Current research indicates that an increased size limit for river eels would prevent over harvest of male spawning stocks (Bruce Pease, unpubl. data).

Table E6. Direct actions within the draft FMS most relevant to fully fished, fully/over fished and over fished/depleted species.

Factors listed in the right column are specifically in relation to these species. It should be noted that positive effects given in the right column are indicative only, and that currently available data do not allow absolute or relative (as a proportion of total) estimates of factors such as juvenile mortality or habitat condition to be made.

FMS Measures (Chapter 3)			**Summary of purpose/action**	**Factor(s) likely to be positively affected by implementation of responses**
Goal	**Objective**	**Response**		
1			Conserve biological diversity	
	1.1		Minimise impact on non-retained fish	
		1.1 (a)	Phase out 70 mm flathead nets	juvenile mortality (reduced)
		1.1 (b)	Modify practices to reduce by-catch	juvenile mortality (reduced)
		1.1 (c)	Use best-practice for handling by-catch	juvenile mortality (reduced)
		1.1 (d)	Phase out overnight mesh nets with mesh less than 95 mm	juvenile mortality (reduced)
		1.1 (e)	Reduce the size of fish hauling nets to 500 m	reduce by-catch and effects on
		1.1 (f)	Scientific observer program	understanding by-catch
		1.1 (g)	Restrictions on fishing gear	mortality reduced
		1.1 (h)*	Prohibit using explosive or electrical devices	mortality reduced, protect
	1.2		Minimise impact on habitats	
		1.2 (a)	Prohibit all hauling over Posidonia seagrass and prawn hauling over seagrass	habitat condition, juvenile mortality reduced
		1.2 (a)	Avoid places/ times of high juvenile abundance	juvenile mortality (reduced)
		1.2 (b)	Modify ecologically damaging methods	habitat condition
	1.4		Prevent the introduction of marine pests and diseases	
		1.4 (a)	Imlplement marine pest and disease plans	habitat condition, mortality
2			Maintain fish populations at sustainable levels	
	2.1		Harvesting does not lead to overfishing	
		2.1 (a)	Gear limits in estuaries	risk overfishing, mortality
		2.1 (d)	Size limits	risk overfishing, mortality
		2.1 (f)	Prohibit unregistered nets	risk overfishing, mortality
	2.1.1		Maintain stocks of primary species	
		2.1.1 (a)	Introduce legal lengths that allow 50% of catch to have reached maturity	risk overfishing, mortality (reduced)
		2.1.1 (b)	Formal stock assessment of primary species	knowledge, future management
	2.1.4		Monitor commercial landings	
		2.1.4 (a)	Monitor the catch catch levels of key secondary species	knowledge, future management
		2.1.4 (b)	Monitor the catch levels of all other secondary species	knowledge, future management
4			Appropriately share the resource	
	4.2		Share resource among fisheries	
		4.2 (a)	Monitor primary species that are taken in other fisheries	holistic management
		4.2 (b)	Size at first capture for king and school prawns	mortality reduced
7			Improve knowledge of species	
	7.3		Scientific research and monitoring	knowledge, future management

Fully/over fished

Among the principal retained species taken in the Estuary General Fishery, only one (silver trevally) is believed to be fully/overfished (Table E1). For this species, current fishing levels may be unsustainable and long term yields may be improved if fishing effort is reduced in the short term (NSW Fisheries, 2001). In this case, the goals and objectives of the estuary general draft FMS extend to the control of overfishing by means such as limiting gear dimensions and the sizes at which individuals can be taken (Table E6). The ability to predict the effectiveness of the associated responses (Table E6; Goal 2) will improve significantly once a robust and reliable fish stock assessment is complete. More specifically, Response 2.5.1a calls for consultation with stakeholders in relation to developing a recovery plan and setting an appropriate size limit for silver trevally, although the strategy has not yet proposed any particular size limit. Controls on active and latent fishing effort (Table E8; Objectives 2.2 and 2.3) will act to restrict overall fishing effort. If necessary to assist in stock recovery, overall fishing effort can actually be decreased depending on the degree of structural adjustment (i.e. size of minimum share holdings) implemented. The setting and subsequent review of minimum shareholdings provides a powerful mechanism for achieving structural adjustment and for reducing fishing pressure on fully/overfished species.

With respect to silver trevally, the draft FMS is expected to result in:

- an improved knowledge of stock status
- reduced mortality of juveniles through reductions in bycatch and improved fishing/ handling practices
- a greater proportion of fish reaching reproductive maturity (once an appropriate size limit is introduced)
- a likely increase in recruitment arising from more fish having an opportunity to spawn
- increased protection of habitat used by juveniles, particularly seagrass
- a reduction in present exploitation rates, and an increased probability of stocks re-building to levels that would ultimately sustain higher long term yields.

Modifications in fishing practices to reduce bycatch (Table E6; Responses 1.1b and 1.2a) should reduce mortality amongst silver trevally. Ongoing refinement of rules relating to size limits and gear specifications (Table E6; Goal 2) will assist in the recovery of silver trevally, particularly once an appropriate size limit is introduced.

Uncertain or unknown

Most of the principal retained species taken in the Estuary General Fishery are determined as “unknown” or “uncertain” (Table E1) owing to a lack of information. The goals and objectives of the estuary general draft FMS that specifically relate to these species are focused on improving our knowledge of these species (Table E7).

With respect to the species currently assessed as uncertain, the draft FMS is expected to result in:

- progressive improvements in knowledge of stock status, leading to species being placed in one of the above fishing-level categories and being managed accordingly
- reduced mortality of several species (particularly blue swimmer crab, flat tail mullet and sand mullet) through reductions in bycatch and improved fishing/ handling practices
- increased protection of key habitats, particularly mangroves (mud crab and flat tail mullet) and seagrass (blue swimmer crab, cockle, flat tail mullet and sand mullet)

- adjustment of present exploitation rates (e.g. to avoid overfishing or to re-build overfished stocks) as might prove necessary in the light of improved knowledge.

Among the uncertain species, flat tail mullet and sand mullet are the most likely to benefit from the phasing out of 70 mm flathead nets (Table E6; Response 1.1a), although any reduced mortality would be essentially limited to adult fish owing to these species' body shape and relatively small maximum size. Modifications in fishing practices to reduce bycatch (Table E6; Responses 1.1b and 1.2a) should reduce mortality amongst several of the uncertain species.

Table E7. Indirect measures and direct actions within the draft FMS specifically relevant to unknown and uncertain species.

It should be noted that positive effects given in the right column are indicative only, and that currently available data do not allow absolute or relative (as a proportion of total) estimates of factors such as juvenile mortality or habitat condition to be made.

FMS Measures (Chapter 3)			Summary of purpose/ action	Factor(s) likely to be positively affected by implementation of responses
Goal	Objective	Response		
1			Conserve biological diversity	
	1.1		Minimise impact on non-retained fish	
		1.1 (a)	Phase out 70 mm flathead nets	juvenile and adult mortality (reduced)
		1.1 (b)	Modify practices to reduce by-catch	juvenile and adult mortality (reduced)
		1.1 (c)	Use best-practice for handling by-catch	juvenile and adult mortality (reduced)
		1.1 (d)	Phase out overnight mesh nets with mesh less	adult mortality (reduced)
		1.1 (e)	Reduce the size of fish hauling nets to 500 m	juvenile and adult mortality (reduced), habitat condition
		1.1 (f)	Scientific observer program	knowledge, future management
		1.1 (g)	Restrictions on fishing gear	juvenile and adult mortality (reduced)
		1.1 (h)	Prohibit using explosive or electrical devices	juvenile and adult mortality (reduced), habitat condition
	1.2		Minimise impact on habitats	
		1.2 (a)	Prohibit all hauling over Posidonia seagrass and prawn hauling over seagrass	habitat condition, juvenile mortality (reduced)
		1.2 (a)	Avoid places/ times of high juvenile	juvenile mortality (reduced)
		1.2 (b)	Modify ecologically damaging methods	habitat condition
2			Maintain fish populations sustainable levels	
	2.1		Harvesting does not lead to overfishing	
		2.1 (b)	Monitor commercial landings by estuary	knowledge, future management
		2.1 (c)	Promote stock assessment research	knowledge, future management
		2.1 (e)	Prohibit taking of females crabs carrying ova	protection of spawning stock
	2.1.1		Maintain stocks of primary species	
		2.1.1 (b)	Formal stock assessments of primary species	knowledge, future management
	2.1.2		Maintain local eel populations	
		2.1.2 (a)	Monitor adult eel catches in each catchment	knowledge, future management
		2.1.2 (b)	Allocate maximum glass eel catch	risk overfishing, mortality (reduced)
		2.1.2 (c)	Implement outcomes of review of eel harvesting	various; depends on outcomes
	2.1.3		Maintain mud crab stock, avoid local depletion	
		2.1.3 (a)	Monitor mud crab catches in each estuary	knowledge, future management
		2.1.3 (b)	Implement outcomes of review of trap use	risk overfishing, mortality (reduced)
		2.1.3 (c)	Consider implementing tradeable trap regime	control of future effort
	2.1.4		Monitor commercial landings	
		2.1.4 (a)	Monitor the catch levels of key secondary species	knowledge, future management
		2.1.4 (b)	Monitor the catch levels of all other secondary species	knowledge, future management
4			Appropriately share the resource	
	4.1		Monitor allocation between fishing sectors	
		4.1 (a)	Estimate the size of the non-commercial catch	knowledge, future management
5			Promote a viable fishery	
	5.1		Optimise biological yield	knowledge, future management
7			Improve knowledge of species	
	7.3		Scientific research and monitoring	
	7.4		Improve catch and effort information	
		7.4 (a)	Review and alter catch return form as needed	knowledge, future management

Uncertainty in relation to the management of stocks

It must be accepted that there will remain a high degree of uncertainty in relation to the status of fish stocks affected by the Estuary General Fishery until stock assessments of the relevant species are improved/developed. However, the precautionary management measures adopted in the draft FMS (see also section on ESD assessment below) will ensure that the risk associated with this uncertainty is reduced. Furthermore, the proposed management responses are considered adequate to address potential negative impacts that may arise during the period of data collection and analysis associated with improved stock assessments. For example, analysis of catch data and the uncertainty associated with stock dynamics of flathead and sea mullet has resulted in the establishment of conservative trigger points for these species.

Considering the large-scale picture across the Estuary General Fishery, the major uncertainty in the management of the principal retained species is the variability and uncertainty in catch of an individual species when part of a multi-species (87 species) multi-method (9 major methods) multi-area (113 estuaries) fishery. This is managed in the draft FMS by the appropriate selection of trigger points to reflect the species and fishery data discussed above.

It should also be recognised that variability is inherent within ecosystems and populations of species. Species abundance at any point in time at any location is highly dependent on a range of local and global factors. These may include rainfall, temperature, catchment influences, historical fishing pressure and habitat availability. The draft FMS accounts for potential variation within certain species through wide trigger points (ie. for school and king prawns) as well temporal comparisons (ie. for sea mullet) that compare short-term trends in catch data.

Linked to the above uncertainty is the issue of recording fishers' catches. There is considerable variation in the accuracy and precision of the data supplied by fishers and the timeliness of processing monthly catch returns. This issue is addressed in the draft FMS by Goal 7 and particularly by Objective 7.4. This improvement is considered pivotal to the success of the draft FMS, as any doubts surrounding the data would weaken any stock assessments that are used for future management and would prevent the timely inception of trigger points, which are the overarching tool of the strategy.

Compliance by all sectors (recreational, commercial, Indigenous and non-consumptive) with the fishery management rules is the other uncertainty in the draft FMS. The consequences of non-compliance can negate the management initiatives introduced to ensure stock sustainability. Goal 6 addresses this issue in the draft FMS; the detailed responses and performance monitoring associated with this goal are the basis for constant review and improvement.

Confidence in achieving the planned outcomes of the draft FMS

In general, the impacts on the environment of harvesting and the resilience of the environment are not characterised individually within this EIS, given the lack of data and/or high uncertainty associated with the data that does exist. Instead a risk assessment strategy has been used, as discussed earlier in this chapter, and the levels of confidence in achieving the predicted outcomes were presented within the two-way risk matrix (Figure E1 and Table E4).

The overall impact of the Estuary General Fishery on the environment is largely unknown, however, the draft FMS manages the uncertainty of both individual species and the wider environment through a series of precautionary management responses as detailed above. Both the long term historic catch trends combined with the high proportion of species reaching sexual maturity before harvest, and the broad age distribution of key species in the commercial catch, indicate that the fishery is fairly resilient to change. As a result, any adverse effects from harvesting should be medium term and reversible through appropriate management initiatives.

Both this assessment and the draft FMS have been precautionary in recommendations where uncertainty is high or confidence in an outcome is low. The ultimate success of the draft FMS in achieving the stated goals and objectives is intrinsically linked to the level of acceptance and implementation of the proposed management responses. The greatest risk to the fishery would be represented by the failure to implement the proposed management responses such as the commencement of formal stock assessments for all primary species within five years or the lack of an appropriate review if a trigger point is reached. Despite the lack of quantitative data available, it would appear that the management responses and initiatives of the draft FMS should allow a greater degree of confidence in the sustainability of the Estuary General Fishery.

In terms of planned outcomes, the recovery of species believed to be most heavily exploited (silver trevally) is critical. Recovery of silver trevally stocks is also highly likely, provided that an appropriate size limit is implemented as a matter of urgency. It is more appropriate for the draft FMS to actually commit to the implementation of a specified size limit within a certain timeframe, than to just undertake to commence consultation with stakeholders. In line with the precautionary principle, it would probably prove better in the long term to have initially implemented an unnecessarily restrictive limit, than to have delayed action until an optimal limit could be determined. This may also be true of any other species for which there is concern over size limits (or lack thereof).

Bycatch reduction is another key intended outcome of the draft FMS, and there is little doubt that effective means to achieve this for most methods/situations have or will be developed. However, the ultimate effect of protecting a certain quantity of juvenile or sub-adult fish would be difficult to predict, as it would depend on several factors including individual growth rates and natural mortality. The ability to make such predictions will improve significantly once robust and reliable stock assessments are complete.

In terms of threatened and protected species, the draft FMS is also expected to achieve the desired outcomes, partly because the available evidence suggests that the fishery currently has little overall impact on these species. The proposed measures in relation to threatened and protected species are primarily precautionary in nature.

With respect to habitat protection, the draft FMS provides a range of useful measures to minimise the impact of fishers or their gear on key habitats such as seagrass and mangroves. However, the ability of the draft FMS to deliver better habitat protection is significantly limited by the wide range of external events and activities liable to damage aquatic habitats. Many of these events and activities are essentially beyond the control of the draft FMS. Adoption of the draft FMS as part of a whole-of-government approach would maximise habitat protection.

Overall acceptability of measures proposed in the draft FMS

Factors that affect the resource status of a stock that can be controlled or mitigated by a draft FMS include the harvest of the retained species and bycatch species, juvenile mortality and habitat damage. The draft FMS contains a range of objectives and management measures that address these factors. These measures aim to limit the number of fishers, limit the access fishers have to fishing grounds (closures and zonings), restrict gear types, set size limits for particular species, reduce bycatch of juvenile target and non target species, and protect key habitats.

Given our incomplete understanding of the status of particular stocks and their associated ecological interactions, and the wide range of external environmental influences (both anthropogenic and natural) affecting the fishery, it is impossible to predict the precise effect of the strategy's implementation on the resource status of the principal retained species taken in the Estuary General Fishery. It is, however, reasonable to assume that the strategy's responses in combination should lead to the maintenance of fish stocks with specific stock status categories affected differently. The indirect measures listed in Table E8 are additional to the direct measures applicable to the various stock status categories (Tables E5 to E7).

Table E8. Indirect measures within the draft FMS of key relevance to all principal retained species in the Estuary General Fishery.

It should be noted that positive effects given in the right column are indicative only, and that currently available data do not allow absolute or relative (as a proportion of total) estimates of factors such as juvenile mortality or habitat condition to be made.

FMS Measures (Chapter 3)			**Summary of purpose/ action**	**Factor(s) likely to be positively affected by implementation of responses**
Goal	**Objective**	**Response**		
1			Conserve biological diversity	
	1.1		Minimise impact on non-retained fish	
		1.1 (f)	Scientific observer program	knowledge, future management
		1.1 (g)	Restrictions on fishing gear	reduced fishing mortality
		1.1 (h)	Prohibit using explosive or electrical devices	reduced fishing mortality
	1.2		Minimise impact on habitats	
		1.2 (c)	Code of conduct to minimise impacts	habitat condition
		1.2 (d)	Prohibition of wilful habitat damage	habitat condition
	1.3		Protect ecosystem integrity	
		1.3 (a)	Research ecosystem function	knowledge, future management
	1.4		Prevent the introduction of marine pests and diseases	
		1.4 (a)	Implement marine pest and disease plans	habitat condition
	1.5		Rehabilitation of habitat	
		1.5 (b)	MAC review habitat research proposals	knowledge, future
2			Maintain fish populations at sustainable levels	
	2.1		Harvesting does not lead to overfishing	
		2.1 (a)	Gear limits in estuaries	reduced recruitment overfishing
		2.1 (b)	Monitor commercial landings by estuary	knowledge, future management
		2.1 (c)	Promote stock assessment research	knowledge, future management
	2.1.4		Monitor commercial landings	
		2.1.4 (a)	Monitor the catch levels of key secondary species	knowledge, future management
		2.1.4 (b)	Monitor the catch levels of all other secondary species	knowledge, future management
	2.2		Manage active effort	
		2.2 (a)	Implement zoning scheme	regional management
		2.2 (b)	Minimum shareholdings to limit active effort	control of future effort
		2.2 (c)	Continue licensing arrangements	control of future effort
	2.3		Prevent activation of latent effort	
		2.3 (a)	Implement owner-operator rule	control of future effort
		2.3 (b)	Minimum entry requirements	control of future effort
		2.3 (c)	Prohibit unlicensed crews	constrains fishing effort
	2.4		Minimise impacts of external activities	
		2.4 (a)	Review development applications as needed	habitat condition

Table E8 (cont).

6			Efficient management and compliance	
	6.1		Maximise compliance with strategy	
		6.1 (a)	Compliance plans and voluntary compliance	adherence to rules
		6.1 (b)	Demerit points system	adherence to rules
		6.1 (c)	Publish successful prosecution results	adherence to rules
	6.4		Be consistent with other agencies re ESD	
		6.4 (a)	Manage in line with other agency requirements	future management
		6.4 (b)	Issue permits for research	knowledge, future management
7			Improve knowledge of fishery and resource	
	7.2	7.2 (a)	Publish educational information	general knowledge of fish habitats
	7.3		Scientific research and monitoring	
	7.4		Improve catch and effort information	
		7.4 (a)	Review and alter catch return forms as needed	knowledge, future

An overall management regime based on a combination of input controls and area-based restrictions is in place, and will continue to be refined on the basis of comprehensive and relevant monitoring and research. This management regime does not just consider each species in isolation, or from the point of view of the Estuary General Fishery alone; rather, it considers relationships between species, the relevant habitats and cumulative effects of other fisheries or fishing sectors. Many of the initiatives aimed at ensuring sustainable harvest and protection of key habitats (e.g. size limits and restrictions on activities liable to harm marine vegetation) apply across all relevant fisheries and sectors. Furthermore, bag limits are increasingly being used to control the recreational harvest. The principles of Ecologically Sustainable Development (ESD) are foremost in the philosophy behind how the state's fisheries are managed.

Based on the available data discussed above, the assessment of the draft FMS suggests the proposed harvest strategies will maintain stock levels. Where uncertainty is highest, the draft FMS proposes conservative parameters for future harvesting and management regimes as well as increased focus on performance measures and monitoring and research programs.

On the basis of the information on retained species provided within Chapter E section 1, the proposed measures, as described in the draft FMS, are likely to be acceptable in terms of maintaining stock levels.

ii) ESD assessment

Ecologically Sustainable Development refers to the effective integration of economic, social and environmental considerations in society's decision making process. The four principles of ESD are outlined under section 6 of the *Protection of the Environment Administration Act 1991* and can be summarised as under the following subheadings. In each case an assessment of how the draft FMS addresses each principle is provided.

The precautionary principle

This principle states that if there are threats of serious or irreversible environmental damage, a lack of full scientific certainty should not be used as a reason for postponing measures aimed at preventing environmental degradation. For example, poor information should not be used as a reason to delay the implementation of more stringent management controls in relation to a fish species, if there is already reason to suspect that the species concerned may be over exploited.

This principle requires decision makers to carefully evaluate a given proposal to avoid, wherever practicable, serious or irreversible environmental damage. It also calls for an assessment of the risk-weighted consequences of all feasible options associated with a proposal.

Given the data-poor environment in which the Estuary General Fishery operates, the draft FMS is substantially based on the precautionary principle. Our knowledge of the relevant ecosystems, habitats, threatened species and fish stocks, as well as the interactions between them, is currently limited. Goals 1, 2 and 3 of the draft FMS are therefore largely concerned with the application of the precautionary principle: specific management responses are, for the most part, designed to protect natural values on the basis of educated belief rather than hard scientific evidence. Under this approach, some specific strategies may ultimate prove (in light of further scientific understanding) to have been unnecessarily conservative. However, such an outcome would be far better than a situation under which serious or irreversible environmental damage occurred as a result of not taking action in the first place.

Specific examples of the precautionary principal being adopted in section 4 of the draft FMS include the prohibition of hauling over strapweed (Response 1.2a), the allocation of total allowable catch of glass eels (Response 2.1.2b), and the implementation of precautionary actions during the development of recovery plans for overfished species (Response 2.5c).

Despite a lack of scientific knowledge in many areas, the draft FMS provides a wide range of measures to address each of the main issues associated with the Estuary General Fishery: protection of stocks, bycatch reduction, threatened and protected species, protection of key habitat, and latent effort activation and major effort shift. Furthermore, the draft FMS provides an assessment of the feasible alternative management strategies for the Estuary General Fishery.

The need for inter-generational equity

Under this principle, the present generation needs to ensure that the health, diversity and productivity of the environment are maintained or enhanced for the benefit of future generations. For example, fish stocks need to be preserved so that fishing (whether commercial or recreational) remains viable in the future.

The preservation of inter-generational equity is fundamental to the goals of the draft FMS. The strategy is essentially focused on maintaining and or improving fish stocks, habitats and ecosystems for long-term benefit. The main difficulty is our current lack of knowledge concerning these aspects. However, given this constraint, the draft FMS covers the important issues and adopts the precautionary principle (see above) where knowledge is lacking. Furthermore, the draft FMS contains a range of specific measures to ensure that our knowledge of the relevant fish stocks and their environment will continue to improve. For example, Response 2.1.1b undertakes to “develop a system for and conduct formal stock assessment of the primary species within five years”.

The need for the conservation of biological diversity and ecological integrity

This principle calls for the conservation of all aspects of biological diversity and ecological integrity, including species diversity, genetic variability and community interactions. This principle recognises that the conservation of these aspects should be a fundamental consideration. For example, under this principle the indirect effects of a fishing activity on non-target species need to be considered, even if the affected species are of no direct economic value.

This principle is also fundamental to the goals of the draft FMS, and especially so for goals 1 and 3. These goals relate to "biological diversity" and "threatened species, populations and ecological communities" respectively. Again, the main difficulty is our current lack of knowledge concerning biodiversity and threatened species. However, given this constraint, the draft FMS covers a wide range of important issues relating to these aspects, and adopts the precautionary principle (see above) where knowledge is lacking. Furthermore, the draft FMS contains a range of specific measures to ensure that our knowledge of biodiversity and threatened species, along with that of the associated interactions, will continue to improve. Examples of these measures include Response 1.1f (scientific observer program) and Response 1.3a (collaboration with other institutions to improve understanding of ecosystem functioning).

The need for improved valuation, pricing and incentive mechanisms

This principle recognises that environmental factors should be included in the valuation of assets and services. Essentially, this means that users should pay the full environmental costs of providing goods and services, including those relating to the use of natural resources and waste disposal. The implementation of cost-recovery measures in relation to fisheries management is an example of this principle being put into practice.

It would be difficult to have fishers and/or consumers pay the full environment costs associated with providing fresh seafood from our estuaries. However, it is intended (Response 5.2a of the draft FMS), that "operators need to be in a position after a five year period to afford to pay for the attributable costs of management from their fishing revenue": payment of such costs will go at least part of the way towards achieving full 'environmental cost recovery'. Response 5.2a refers to the use of minimum shareholdings to improve the economic viability of the fishery and its participants: such adjustment will ensure that operators are better able to afford management costs and that they have a greater incentive to support the long term decisions likely to be necessary. Furthermore, Response 5.2b aims to develop an appropriate measure of economic viability at the individual fishing business level, and should therefore improve our ability to recognise any future problems in this area and implement any ameliorative measures that may be needed.

A specific example of 'environmental cost recovery' planned under the draft FMS is the introduction of an industry funded scientific observer program (Response 1.1f).

2. Bycatch (non retained) Species

a) Method based assessment of potential impacts

i) Nature and quantity of bycatch

The main fish and invertebrate species liable to be taken as bycatch by the various main methods used in the Estuary General Fishery are listed in Tables E9, E10 and E11. The fish include juveniles of commercially important species (Table E9) and 'other' (non-commercial) species (Table E10). The latter group makes up a large proportion of the bycatch, and includes a wide range of species and sizes ranging from small gobies and leatherjackets to large porcupine fish and stingrays. Capture of the smaller species/ individuals is often enhanced by their entanglement in loose weed or seagrass. Several protected and/or threatened fish species are also occasionally taken (see Chapter F section 2 and Table F8).

A large number of invertebrate species are liable to be taken as bycatch in the Estuary General Fishery, including juveniles of the principal retained species, and a large number of 'non-commercial' species (Table E11). The biology of these latter species is often poorly known. The sessile species (such as sponges and mussels) provide habitat for other aquatic organisms. Capture of the smaller species/ individuals is often enhanced by their entanglement in loose weed or seagrass.

Various other vertebrate classes (e.g. reptiles, birds and mammals) may occasionally interact with gear used in the Estuary General Fishery. Most of these are classed as 'threatened' or 'protected' under state and/or commonwealth legislation: issues relating to these groups are discussed in Chapter F section 2.

Table E9. List of commercially important fish species likely to be taken as juveniles in bycatch from the Estuary General Fishery, with information on relevant localities, method(s) and size classes.

Information based on Gray (2001), Gray *et al.* (2001) and Charles Gray (pers. comm.).

Species	Types of area/ habitat where caught	Main method(s) of capture (as juveniles in by-catch)	Main size classes affected
sand whiting	sandy shallows over sand and seagrass	fish haul; prawn haul/ seine	small juveniles to sub-adults
yellowfin bream	all habitats throughout estuary	fish haul; prawn haul/ seine; set pocket net; mesh; fish and eel trap	small juveniles to sub-adults
tarwhine	all habitats throughout estuary, except in brackish areas	fish haul; prawn haul/ seine	small and large juveniles
snapper	lower estuary/ more saline areas	fish haul; prawn haul/ seine; fish trap	small and large juveniles
variable and rough leatherjackets	seagrass and kelp in lower estuary/ more saline areas	fish haul; prawn haul/ seine	small and large juveniles
yellowfin and fan-belly leatherjackets	seagrass and macroalgae	fish haul; prawn haul/ seine	small and large juveniles
tailor	all habitats throughout estuary, except in confined tributaries	fish haul; prawn haul/ seine; set pocket net; mesh	small juveniles to sub-adults
garfish, river and sea	shallow waters over sand or seagrass	prawn haul/ seine; set pocket net	large juveniles and sub-adults
luderick	weedy habitats throughout estuary	fish haul; prawn haul/ seine; mesh	small juveniles to sub-adults
sea mullet	shallow water throughout estuary	fish haul; mesh	large juveniles and sub-adults
sand mullet	shallow water throughout estuary	fish haul; prawn haul/ seine	small juveniles to sub-adults
flounders	soft substrates throughout estuary	fish haul; prawn haul/ seine	small juveniles to sub-adults
southern herring	shallow turbid waters	fish haul; prawn haul/ seine; set pocket net	small juveniles to adults

Table E10. List of other fish species/species groups likely to be taken as bycatch in the Estuary General Fishery, with information on relevant localities, method(s) and size classes.

Information based on Gray (2001), Gray *et al.* (2001) and Charles Gray (pers. comm.).

Species/ group	**Types of area/ habitat where caught**	**Main method(s) of capture (as by-catch)**	**Main size classes affected**
stingarees and stingrays	sand/ mud, seagrass and low-profile reef	fish haul; prawn haul/ seine; hand line	small juveniles to adults
fiddler ray	as above, but in lower estuary/ more saline areas	as above	as above
catfishes, including estuary catfish, striped catfish and fork-tail catfish	weed and reef areas; fork-tail catfish most common in north of state and are found well upstream in brackish waters	fish haul; prawn haul/ seine; set pocket net; mesh; fish and eel trap	small juveniles to adults
hardyheads	shallows	prawn haul/ seine; set pocket net	adults
seahorses and pipefishes	seagrass and kelp	fish haul; prawn haul/ seine; set pocket net	large juveniles and adults
scorpionfishes, including fortesque, cobbler and bullrout	variety of habitats; fortesque very common in seagrass; bullrout found well upstream in brackish waters	fish haul; prawn haul/ seine; set pocket net; mesh	small juveniles to adults
perchlets	shallows	prawn haul/ seine; set pocket net	adults
goatfishes, including bar-tail and blue-lined	sand and mud in lower estuary/ more saline areas	fish haul; prawn haul/ seine; set pocket net	small juveniles to adults
little rock-whiting	seagrass and rocky reef in lower estuary/ more saline areas; southern half of state	fish haul; prawn haul/ seine; set pocket net	large juveniles and adults
weedfishes	seagrass and weed in lower estuary/ more saline areas	as above	as above
blennies, gobies and gudgeons	shallows	prawn haul/ seine; set pocket net	adults
bridled and pigmy leatherjackets	seagrass and weed in lower estuary/ more saline areas	fish haul; prawn haul/ seine	large juveniles and adults
toadfishes, including common, smooth and weeping	shallows	fish haul; prawn haul/ seine; set pocket net	as above
porcupinefishes including three-bar	rocky reefs and seagrass	fish haul; prawn haul/ seine; set pocket net; mesh; fish trap	small juveniles to adults

Table E11. Types of invertebrates liable to be taken as bycatch in the Estuary General Fishery, with information on relevant localities, method(s) and key aspects of biology.

Information indicative only and based on body form and likely relationships to substrate. Key aspects of biology from standard texts such as Barnes (1980).

Type of invertebrate	Types of area/ habitat where most likely to be caught	Main method(s) of possible capture	Key aspects of biology
sponges	rocky reef and seagrass in lower estuary/ more saline areas	fish haul; prawn haul	sessile filter feeders, most prolific in deep marine waters; most species occur in areas unsuitable for hauling
jellyfish	water column, most species confined to lower estuary/ more saline areas	fish haul; prawn haul; set pocket net	drift/ swim slowly in water column; some species occur in large aggregations; extremely vulnerable to capture by active netting methods
bivalve molluscs (especially hairy mussels and other spp. that live on top of substrate)	seagrass and sand/ mud	fish haul; prawn haul/ seine	most are sessile filter feeders; hairy mussels (in particular) may occur in large clumps and provide complex habitat for small fish and attachment points for seaweeds.
marine snails	seagrass and sand/ mud	as above	the vulnerable species move about on seabed, either preying on other animals or grazing on algae; usually solitary, but some (herbivorous) species form aggregations
cephalopods (octopus, squids and cuttlefish)	various habitats, but usually confined to lower estuary/ more saline areas	fish haul; prawn haul/ seine; set pocket net; fish trap	mobile carnivores; squid and cuttlefish often in water column, whilst octopus benthic; octopus less vulnerable to hauling methods
crustaceans (including shrimps and crabs)	various habitats	fish haul; prawn haul/ seine; set pocket net; mesh; fish trap	benthic carnivores or scavengers; some species relatively mobile; small species vulnerable to hauling methods; only larger individuals caught by meshing or trapping
echinoderms (including sea-urchins and sea-stars)	various habitats, but mostly seagrass or rocky reef; usually confined to lower estuary/ more saline areas	fish haul; prawn haul	slow moving benthic grazers; sea urchins may form aggregations; such aggregations mainly vulnerable when in seagrass
sea-squirts	rocky reef or shell rubble, usually confined to lower estuary/ more saline areas	as above	sessile filter feeders, most prolific in deep marine waters; most species occur in areas unsuitable for hauling

Hauling

Direct capture

'Hauling' refers to several active methods used to target fish or prawns. 'Beach seining' (or fish hauling) is the most prominent, and is targeted at fish. It generally involves a net several hundred metres long being hauled against a 'back net' placed in shallow water close to shore. 'Bullringing' involves a floating seine net being used to encircle schooling fish. 'Prawn Hauling' is a smaller scale method used to capture prawns whereby nets may be retrieved either mid stream or to shore. 'Prawn seining' (also known as snigging and clover leafing) is a method by which a seine net is deployed with one wing attached to a fixed point and the other wing towed by boat until the net closes.

Beach seining (fish hauling), captures a wide variety of non-target organisms, including many species of fish, crabs, jellyfish and other invertebrates (Tables E9, E10 and E11). For example, a recent study of the commercial beach haul fishery in Botany Bay revealed a total of 77 taxa of discards, most of which were finfish (Gray *et al.,* 2001). A significant portion of these discards consists of undersized individuals of target species; with sand whiting, yellowfin bream, tarwhine, snapper, variable leatherjacket and rough leatherjacket being the most numerous species recorded (Gray *et al.,* 2001). Some of the bycatch is retained as saleable product which would consist of whatever untargeted kinds of edible fish happened to be in the area at the time (e.g. leatherjackets), in addition to any large crustaceans such as blue swimmer crabs.

The total amount of discards from beach hauling can be substantial. Gray *et al.* (2001) estimated that 93 tonnes were discarded from the Botany Bay beach haul fishery over a 12 month period, resulting in an overall retained to discard ratio of almost 2:1. Similar discard ratios have been reported for other multi-species fisheries, including coastal beach-seining (Lamberth *et al.,* 1994), demersal fish trawling off the coast of NSW (Liggins *et al.,* 1997) and Danish seining (Alverson *et al.,* 1994).

Discarded bycatch is likely to represent a substantial portion of the total catch of many species targeted by beach hauling. For example, Gray *et al.* (2001) found 81% of tarwhine, 69% of yellowfin bream, and 32 % of sand whiting caught by the Botany Bay beach haul fishery were discarded. In some cases, however, the discard rates are much lower: in the above fishery, only 7% of silver trevally and 1% of silverbiddies were discarded. This difference probably relates to the lack of a minimum legal length for the latter species, in addition to different markets (Gray *et al.,* 2001).

Whilst no data is currently available, bullringing would be expected to result in few discards because the net is normally kept well clear of the seafloor, and operators usually target a specific school of fish. However, non-target fish species and/or jellyfish would occasionally be trapped and, where bullringing is practiced in shallow areas, significant amounts of bycatch are likely, particularly if seagrass or weed is present.

Prawn hauling often results in relatively little bycatch unless the net is hauled to shore, and research has shown that bycatch is reduced by setting and retrieving the net mid-stream (Charles Gray, pers. comm.). Prawn hauling is likely to result in different species and smaller individuals among the bycatch than does fish hauling (by virtue of the smaller mesh used). The bycatch is normally dominated by small fish of little or no economic value such as southern herring, perchlets and cardinal fish. Among commercially important species, silverbiddies are the most commonly taken, although very low numbers (< 20 individuals per fisher per day) of other important species such as yellowfin bream, dusky flathead and mulloway are occasionally caught (Charles Gray, pers. comm.). New recruits of these and other commercially important species may be most susceptible to capture if the hauling occurs across shallow seagrass beds (Bell and Pollard, 1989) or near an estuary's entrance (Bell *et al.,* 1988; Hannan and Williams, 1998).

Prawn seining appears to result in variable amounts of bycatch, depending on whether the seine is done over bare substrata (less) or seagrass (more). Current research (Charles Gray, pers. comm.) has found bycatch to mostly comprise juveniles of commercially important species including yellowfin bream, tarwhine, trumpeter whiting and silverbiddy. A variety of non-commercial species including gobies and stinkfish are also taken.

Physical contact without capture

All hauling methods can result in certain size fish being 'squeezed' through net meshes. Fish that are too small to be retained by the net, yet too big to swim clean through the mesh, may be affected. Whilst no data is available for the Estuary General Fishery, it is possible that such fish would suffer fin damage, scale loss and/or skin damage, and some degree of subsequent mortality. Based on experiments by Broadhurst *et al.* (1997, 1999) in which juvenile fish were forced through trawl equipment (grids and square meshes) it is likely that such mortality would be low. The number of fish affected will vary according to the mesh of the net used and the sizes of fish present. Seasonal patterns are also likely, with vulnerable size classes being prevalent at certain times of the year, depending on the life cycles of the species concerned.

With most methods of hauling, a wide variety of fish (including bycatch species and smaller individuals of target species) could be affected during a given operation. In the case of Bullringing, effects would mostly relate to smaller individuals of a given target species.

Lost gear (ghost fishing)

Ghost fishing (the on-going capture of fish after gear has been lost or abandoned) does not normally apply to hauling. The different types of hauling are all 'active' methods, whereby the net is continually attended until its retrieval.

Prawning (passive)

Direct capture

There are two main passive prawning methods used in the Estuary General Fishery: 'prawn running net' and 'set pocket net'.

A prawn running net is staked in place to trap travelling prawns. Available data (Charles Gray, pers. comm.) suggest low levels of bycatch, mostly consisting of southern herring, river garfish and silver biddy.

Set pocket netting relies on current (either natural or propeller induced) to sweep prawns into a staked net. Bycatch from set pocket netting has been studied in northern NSW (Andrew *et al.,* 1994, 1995). They conclude "bycatch is relatively small compared with the prawn catch and small in absolute terms in comparison with many prawn trawl fisheries". However, they also noted that bycatch increased dramatically during flood events, and that over 96% of the yellowfin bream caught were taken on less than 4% of the nights fished; the conclusion being that this species moves rapidly downstream during floods in search of saltier waters. The main species of recreational and/or commercial importance taken in the bycatch were yellowfin bream, tailor, river garfish and snub-nosed garfish, most of these being juveniles (Andrew *et al.,* 1995).

Physical contact without capture

The comments applicable to hauling (see above) also apply here, although effects may be less due to the passive nature of these operations.

Lost gear (ghost fishing)

Ghost fishing (the on-going capture of fish after gear has been lost or abandoned) does not normally apply to passive prawning methods. In these cases the net is carefully secured and continually attended until its retrieval.

Meshing

Direct capture

Whilst meshing may not result in as many discards as would fish hauling (see above), the quantities can still be considerable, especially when the nets are set for long periods (i.e. overnight). For example, Gray (2001) estimated total discards among six major estuaries to average approximately 20,000 animals for the wintertime mesh net fishery (three months, overnight sets) and estimates for individual estuaries ranged from less than 100 to more than 70,000 animals. By comparison, Gray *et al.,* (2001) estimated that some 580,000 animals were discarded annually in the Botany Bay beach seine fishery (i.e. equivalent to 145,000 animals in three months).

In terms of weight, Gray (2001) estimated that approximately 34 tonnes were discarded from six estuaries over a three month period, with retained to discard ratios generally between 1.7:1 and 4:1. Similar discard ratios have been reported for other multi-species fisheries, including coastal beach-seining (Lamberth *et al.,* 1994; Gray *et al.,* 2001) and demersal fish trawling and Danish seining (Alverson *et al.,* 1994).

A wide variety of fish are discarded during meshing operations (see also Tables E9 and E10). Gray (2001) recorded 62 fin-fish and two invertebrates among the discards from six estuaries, and found 34 of these (all fish) to be “always discarded”. That study also found that a significant portion of the bycatch consisted of undersized individuals of target species, with luderick, yellowfin bream, blue swimmer crabs and dusky flathead accounting for the greatest numbers of discards. Some of the bycatch from meshing is retained as saleable product; this would consist of whatever untargeted kinds of edible fish happened to be in the area at the time (e.g. leatherjackets), in addition to any large crustaceans such as mud crabs or blue swimmer crabs (NSW Fisheries, 1999c; Gray, 2001).

The research by Gray (2001) demonstrates the effect of mesh size on discard rates. He found that several commercially important species such as yellowfin bream, luderick and tailor displayed high discard rates when smaller (80-83 mm) meshes were used, but much lower rates when larger (95-100 mm) meshes were used. In the case of yellowfin bream, discard rates fell from nearly 83% to about 15% as a result of this change. However, such a change in mesh size did not greatly effect discard rates among several other commercially important species, such as dusky flathead, sea mullet and sand whiting; in these cases discard rates were relatively low for all mesh sizes (Gray, 2001).

To be caught in a mesh net, animals need to be mobile and, in the case of most fin-fish, within a relatively narrow size range corresponding to the selectivity of the mesh being used. Some fish (those with spiny bodies), along with other animals such as crabs, birds and turtles, are liable to be caught over broader size ranges. For example, Gray (2001) observed dusky flathead ranging in length between 20 and 80 cm being caught in 100 mm mesh, and found that this mesh size did not reduce the proportion of undersized flathead caught in comparison to that for 80 mm mesh.

Meshing is liable to catch important non-commercial species. Australian bass, a popular sporting fish whose populations are thought to have declined significantly, are sometimes caught (NSW Fisheries, 2000). They are most likely to be taken in upper estuarine areas or during spawning. Whilst no local data are available, other animals potentially vulnerable to capture include diving birds (e.g. cormorants and penguins), freshwater turtles after floods, marine turtles (particularly in the northern half of the state), and small sharks. Prolonged soak times are likely to increase bycatch rates; entangled animals may progressively attract predators or scavengers, that may themselves end up being caught.

Meshing also has the potential to cause local declines in the sizes and/or abundances of resident rocky reef species such as wrasses and morwongs (Schaap and Green, 1988). These fish and their associated habitat commonly occur within marine-dominated estuaries.

Where the technique of "splashing" is used, bycatch is likely to be relatively low due to the short 'soak time' and consequent reduced opportunity for predators or scavengers to be attracted and caught.

Physical contact without capture

Meshing results in certain size fish squeezing themselves through the net meshes. Fish that are too small to be retained by the net, yet too big to swim clean through the mesh, may be affected. Whilst no data is available for the Estuary General Fishery, it is possible that such fish would suffer fin damage, scale loss and/or skin damage, and some degree of subsequent mortality. Based on experiments by Broadhurst *et al.,* (1997, 1999) in which juvenile fish were forced through trawl equipment (grids and square meshes) it is likely that such mortality would be low. In any case, the number of fish affected will vary according to the mesh of the net used and the sizes of fish present. Seasonal patterns are also likely, with vulnerable size classes being prevalent at certain times of the year, depending on the life cycles of the species concerned. Given the passive nature of meshing, the numbers affected are likely to be less than in the case active methods such as hauling (see above).

Lost gear (ghost fishing)

Ghost fishing is a potential problem with mesh nets (Cappo *et al.,* 1998) because a net lost or abandoned could continue capturing animals indefinitely. Whilst there is no Australian data on associated gear loss rates or occurrence of ghost fishing (Cappo *et al.,* 1998), it is reasonable to assume that estuarine mesh nets would be rarely lost because of their substantial size and because they are usually set in sheltered waters.

Trapping

Direct capture

Trapping within estuaries captures a wide variety of bycatch (D. Ferrell, NSW Fisheries, pers. comm.), although the numbers of animals taken is low. Many species are retained, with the secondary catch including at least 23 species. However, the annual catch from NSW estuaries of any one of these species is estimated to be less than 1 tonne (D. Ferrell, pers. comm.).

Trapping has the potential to cause local declines in the sizes and/or abundances of resident rocky reef species such as wrasses and morwongs, as such species are relatively vulnerable to fishing pressure (Schaap and Green, 1988). These fish and their associated habitat commonly occur within marine-dominated estuaries.

Current research on the trap fishery targeting yellowfin bream in Sydney Harbour (D. Ferrell, pers. comm.) has revealed fishery catch rates of 31.6 bream (all sizes), 1.5 snapper and 2.0 'other species' per trap lift. For every 1kg of legal sized bream, there were 0.17kg of undersized bream captured and only 0.03kg of undersized snapper. The bream included large juveniles and adults, with the smallest observed being 18 cm fork length. Among the 'other species', the fin-fish included silver trevally, tarwhine, luderick, blue morwong, sergeant baker, various leatherjackets, red mullet, six-lined trumpeter, blind shark and boxfish. The invertebrates included octopus, blue swimmer crab, giant cuttlefish, and calamary squid.

Current research on the estuarine eel trap fishery (B. Pease, pers. comm.) has revealed approximately ten eels to every one item of bycatch in a fishery-independent study of the Hacking, Clarence and Hawkesbury Rivers. The animals caught varied according to salinity. In the brackish to freshwater upper estuarine reaches, freshwater turtles were occasionally caught along with low numbers of bullrout and freshwater prawns. In the more saline waters, the bycatch included juvenile bream (which accounted for more than half), mud crabs, silver batfish, six-lined trumpeter, catfish and juvenile tarwhine. Of these species, only the mud crabs are likely to be retained as by-product by eel fishers. Bycatch rates were higher in the more saline waters (0.48 animals per trap day) than in the brackish/ freshwaters (0.15 animals per trap day).

Physical contact without capture

Trapping may result in certain size fish squeezing themselves through the holes or gaps in the sides or top of the trap. Fish that are too small to be retained by the trap material, yet too big to swim clean through the mesh, may be affected. Whilst no data is available for the Estuary General Fishery, it is possible that such fish would suffer fin damage, scale loss and/or skin damage, and some degree of subsequent mortality. Based on experiments by Broadhurst *et al.* (1997, 1999) in which juvenile fish were forced through trawl equipment (grids and square meshes) it is likely that such mortality would be low. Whilst the numbers of fish affected will vary according to the design of the trap used and the sizes of fish present, they are likely to be much lower than the numbers associated with hauling or meshing: trapping is a passive method, and in most cases the materials used to make traps are likely to be more visible (than say mesh nets) to fish contained therein.

Lost gear (ghost fishing)

This is the greatest perceived problem with trap fisheries. It is widely recognised that traps are easily lost (e.g. Cappo *et al.,* 1998) and can continue 'fishing' indefinitely even without bait. However, the real effect of ghost fishing is considered minimal. Although there are no published data for NSW estuaries, a current study using underwater video (D. Ferrell, pers. comm.) in the nearshore trap and line fishery, along with a study by Moran and Jenke (1989) of the Western Australian snapper fishery, provide unequivocal evidence that snapper and other fish escape from fish traps. These studies also found that few fish die in traps that are left on the bottom for a long time.

Handlining

Direct capture

No local information is available on the bycatch arising from commercial hand-lining. It is likely that a variety of non-target species are caught, but in very low numbers. It is possible that birds may be caught on rare occasions if no sinkers are used. The selective nature of commercial hand-lining would be expected to lead to less bycatch than that from a typical angler.

The species of bycatch caught would primarily depend on hook size and the locality fished (Otway and Craig, 1993; Otway *et al.,* 1996). Species with larger mouths would be most vulnerable. Invertebrates such as crabs and squid are not easily caught on rigs intended for finfish. Whilst no data are available for commercial handlining, localised depletion and reduced diversity of reef resident species has been suggested as a consequence of the taking of bycatch in a recreational herring fishery in Western Australia (Cappo *et al.,* 1998).

Physical contact without capture

Some hooked fish escape before being landed, usually by freeing themselves of the hook, or (more rarely) by snapping the line. The survival rates of fish thus affected are unknown. It is possible that affected fish, in having to free themselves, would suffer higher mortalities than the very low rates observed by Broadhurst *et al.* (1999) for fish that were hooked, caught and released.

Lost gear (ghost fishing)

Ghost fishing is not a significant problem with hand-lining. Even if a complete baited rig is lost, it would only remain effective for a short time. However, the nylon line can have adverse effects on sea birds and other animals due to entanglement.

Handgathering

Direct capture

Because handgathering is completely selective, no bycatch is likely.

Physical contact without capture

Some small animals would be affected by handgathering, particularly if implements are used. Disturbance of the sediment (say when digging for worms or pumping ghost nippers) results in displacement and/or injury to non-target animals such as molluscs, crabs and various worms. Animals unable to quickly burrow beneath the sediment surface are liable to be eaten by either birds or fish depending on whether the specific site is exposed at the time.

Lost gear (ghost fishing)

Ghost fishing is not an issue with handgathering.

ii) Likely mortality/injury rates from methods in the Estuary General Fishery

Hauling

The various hauling methods cause (to a greater or lesser extent – see above) considerable mortality amongst discards (juveniles of target species and unwanted species). The mechanisms contributing to this mortality may include:

- stranding (where a back-net is not used)
- being crushed in the cod end
- being stung by jellyfish trapped in the net
- temperature and oxygen stress due to being crowded into shallow water
- damage from contact with the net material
- severe injury through 'spiking' or similar practices (especially for stingrays, catfishes and other venomous species)
- general poor handling, particularly in relation to scale loss
- predation (e.g. by birds) on weakened/ disorientated fish in shallows.

Some species survive these rigours better than others, although no quantitative information is available in relation to the above mechanisms. For example, bream and leatherjackets are far more likely to survive than tailor and silverbiddies; the latter species being particularly susceptible to scale damage. However, even if a fish is able to swim away from contact with a haul net, it may have been seriously stressed as well as be injured in some way, possibly making it more susceptible to subsequent disease.

Nonetheless, evidence is available that suggests that some fish, at least, survive in the long term. West (1993) tagged and released species including yellowfin bream, luderick, sand whiting and dusky flathead that had been captured by beach hauling to determine their movement patterns. Many of these fish were recaptured, sometimes years later. Gray *et al.* (2001) noted that, among the beach haul catches they sampled, "several small fish were observed to have notches on their heads where they had previously been meshed in a net (either gill or seine), indicating that they had previously been captured in a net-based fishery". Comparisons between tag return rates from beach hauling and from trawling suggest that long-term survival rates were higher for the hauled fish (West, 1993).

A particular issue in some areas is the capture of large numbers of small catfish, which prawn fishers are reluctant to handle owing to the high risk of contact with venomous spines. Whilst it is often possible to 'swim' such fish out of a net prior to emptying, many end up being killed by 'spiking' or similar practices.

Prawning (passive)

The two passive prawning methods (running net and set pocket net) are liable to cause some degree of mortality among discards. The mechanisms contributing to this mortality are likely to be similar to those applicable to hauling (see above). However, many these mechanisms are likely to be less important due to the passive nature of the methods. Stranding is unlikely to occur.

In terms of survival, the comments applicable to hauling (see above) would generally apply. Whilst there is no quantitative information available on bycatch survival, it appears that most discards from prawn running nets are in good condition upon release (Charles Gray, pers. comm.). By contrast, Andrew *et al.* (1995) in a study of set pocket netting suggest that, among a range of species including tailor, river garfish and snub-nosed garfish, only yellowfin bream had much chance of survival after release.

Meshing

Meshing is likely to cause a degree of mortality amongst discards. The mechanisms contributing to this mortality (see also Chopin and Arimoto, 1995) are likely to include:

- physical injury from entanglement, which may include strangulation
- being trapped in the net for a long period
- water temperature
- attack by predators or scavengers whilst trapped in the net
- poor handling, in particular 'impatient' removal from the net
- damage from contact with the net material
- predation on weakened/ disorientated animals returned to the water.

Some species are better than others at surviving these rigours, although little quantitative information is available in relation to the above mechanisms. In terms of initial survival, Gray (2001) found that the percentage of discarded fish alive when removed from overnight-set mesh nets ranged from less than 27% for tailor to more than 98% for luderick: amongst the other species, bream, trevally and leatherjackets collectively were all relatively 'hardy' (>90%), while mulloway (at less than 60%) were second only to tailor in terms of sensitivity. Cappo *et al.* (1998) noted that the so-called 'ram-jet ventilators' (many of the fast swimming pelagic fish) die very quickly in mesh nets, an observation that might explain the poor survival of tailor found by Gray (2001). Warmer water (as during summer) is also likely to reduce the survival of discards (Gray, 2001).

Even if an animal is able to swim or fly away after being released, it may have been seriously stressed as well as be injured in some way, possibly making it more susceptible to subsequent disease. Unfortunately, the above-mentioned survival data (Gray, 2001) did not examine any subsequent mortality after release. Post capture mortality has been shown to generally increase after initial release (Chopin and Arimoto, 1995).

For meshing using the splashing technique, any discards are likely to be in better condition and be more likely to survive after being released due to the short soaking times involved with this technique.

Trapping

With trapping, whether for fish, eels or crabs, it appears that the majority of discards swim away apparently unharmed when released. However, potential causes of mortality amongst unwanted discards from trapping include:

- damage from contact with the trap walls
- injury (e.g. over-inflated swimbladder) from rapid depressurisation during trap retrieval
- predation from larger animals (e.g. eels and mud crabs) in trap
- drowning (in the case of air-breathing animals such as freshwater turtles)
- entanglement and strangulation (in the case of 'witches hats' used for blue swimmers)
- loss of condition or starvation during prolonged entrapment
- predation on weakened or disorientated animals returned to the water.

Some species are better than others at surviving these rigours, although no quantitative information is available in relation to the above mechanisms. Also, even if an animal is able to swim away after being released, it may have been seriously stressed as well as injured in some way, possibly making it more susceptible to subsequent disease.

Available evidence (D. Ferrell and B. Pease, pers. comm.) suggests that overall rates of animal injury from fish and eel traps are very low. The same is likely for mud crab traps, as they are based on a similar design. However, higher rates may be associated with witches hats, as they work somewhat like miniature mesh nets. Most estuarine trapping is done in shallow water, and injuries relating to depressurisation would therefore be rare. Also, freshwater turtles would only be taken in the uppermost reaches of estuaries as they normally live in freshwater.

Handlining

Handlining is likely to cause a degree of mortality amongst discards. The mechanisms contributing to this mortality are likely to include:

- physical injury from hook removal
- injury from hook lodgement
- swimbladder over-inflation resulting from rapid ascent
- attack by predators or scavengers during retrieval or soon after release
- damage to skin or scales during handling.

Some species are better than others at surviving these rigours, although little quantitative information is available in relation to the above mechanisms. Studies of hooked yellowfin bream (Broadhurst *et al.,* 1999) suggest that most fish recover from being hooked and released. However, even if a fish is able to swim away after being released, it may have been seriously stressed as well as be injured in some way, making it more susceptible to subsequent disease (Broadhurst *et al.,* 1999).

Handgathering

Although handgathering is unlikely to result in any bycatch, it is likely to cause a degree of mortality amongst indirectly affected organisms. Such organisms include various crustaceans, molluscs and worms. The mechanisms contributing to this mortality are likely to include:

- injury to non-target animals through the action of any implements
- crushing of non-target animals through trampling
- damage/ destruction of burrows, refuges and micro habitat
- exposure of sensitive species to sunlight and/or desiccation
- predation by birds and/or fish on slow moving animals left exposed.

Some species are better than others at surviving these rigours, although no quantitative information is available in relation to the above mechanisms. It is likely that hard-bodied and/or quick-burrowing species may survive quite well, whereas soft-bodied and/or slow moving/burrowing species may fare poorly.

The degree of mortality amongst non-target organisms is likely to depend greatly on the type of handgathering being undertaken. Very little non-target mortality or habitat damage is likely in relation to the gathering of beach worms or pipis: both are taken on open ocean beaches where the clean sand is almost continuously disturbed by waves, and where most other organisms are adapted to regular disturbance. By contrast, estuarine species such as blood worms and cockles are taken from sensitive habitats such as sheltered mud flats and the fringes of saltmarsh or seagrass: in these areas, both the habitat and many of the resident species may be particularly vulnerable to disturbance.

iii) Likely mortality/injury rates from other commercial and recreational fisheries

There is no quantitative information available on bycatch related mortality due to other fisheries for many of the wide variety of fish and invertebrates commonly taken as bycatch in the Estuary General Fishery (see above). However, it is clear that many of these species are taken as bycatch in other commercial fisheries and/or fishing sectors (Table E12), particularly in the estuary prawn trawl and ocean hauling fisheries, and in the recreational sector (angling and/or prawning; the latter mainly affecting smaller individuals and species).

Table E12 assesses the possible mortality/injury rates amongst these other fisheries and sectors. However, the levels given are only indicative, as current knowledge is insufficient to quantify overall bycatch or susceptibility, or to allow meaningful comparisons between species. Nevertheless, Table E12 does provide some basis for nominating indicator groups of bycatch species to be monitored (see section 2(a)(iii) below). It is likely that for many of the species listed (and particularly those with "med-high" or "high" amounts taken/ affected), the bycatch taken by the other fisheries/sectors is at least comparable, or even greater than, the levels associated with the Estuary General Fishery.

Table E12. Information relating to other commercial fisheries/fishing sectors for species commonly taken as bycatch in the Estuary General Fishery.

Fisheries/sectors abbreviated as follows: Rec - recreation, EPT - estuary prawn trawl, OH - ocean hauling, OTL - ocean trap and line, OT - ocean trawling. Relative susceptibility to injury rated "high" for fish that shed scales easily and for invertebrates that have unprotected soft bodies or that normally live attached to the substratum; susceptibility rated "low" for species that have a protective shell or exoskeleton, and "medium" for all other species.

Species/ group	Other fisheries/ sectors where taken as by-catch	Relative amount taken/ affected	Relative susceptibility of species to injury	Possible mortality/ injury rate
Commercially important fish (see also Table E9 above)				
sand whiting	Rec; EPT; OH; OT	high	medium	med-high
yellowfin bream	Rec; EPT; OH; OTL; OT	high	medium	med-high
tarwhine	Rec; EPT; OH; OTL; OT	high	medium	med-high
snapper	Rec; EPT; OTL; OT	high	medium	med-high
leatherjackets	Rec; EPT; OTL; OT	high	medium	med-high
tailor	Rec; EPT; OH	high	high	high
garfish, river and sea	Rec; EPT	medium	high	med-high
luderick	Rec; EPT; OH	medium	medium	medium
Other fish (see also Table E10 above)				
rays	Rec; EPT; OH;OTL; OT	medium	medium	medium
catfishes	Rec; EPT; OTL; OT	high	medium	med-high
hardyheads	Rec; EPT	low	high	medium
seahorses & pipefishes	Rec (prawning); OT	medium	medium	medium
scorpionfishes	Rec; EPT; OTL; OT	medium	medium	medium
perchlets	Rec (prawning); EPT	medium	high	med-high
goatfishes	Rec; EPT; OTL; OT	medium	high	med-high
rock-whiting	Rec; EPT	low	medium	low-medium
weedfishes	Rec (prawning); EPT	low	medium	low-medium
blennies, gobies & gudgeons	Rec (prawning); OT	high	medium	med-high
pigmy & bridled l'jackets	Rec (prawning); EPT	low	medium	low-medium
toadfishes	Rec; EPT; OT	high	medium	med-high
porcupinefishes	EPT; OTL; OT	low	medium	low-medium
Invertebrates (see also Table E11 above)				
sponges	EPT; OT	low	high	medium
jellyfish	Rec (prawning); EPT; OH; OT	high	high	high
bivalves	Rec (prawning); EPT; OT	low	low	low
marine snails	Rec (prawning); EPT; OT	low	low	low
cephalopods	Rec; EPT; OH; OTL; OT	medium	high	med-high
crustaceans	Rec; EPT; OTL; OT	high	low	medium
echinoderms	Rec (prawning); EPT; OT	low	low	low
sea-squirts	EPT; OT	low	high	medium

For these other commercial fisheries/fishing sectors (Table E12), the mechanisms contributing to bycatch mortality are likely to be very similar to those (see previous section) associated with the estuary general methods 'hauling', 'prawning (passive)', 'handlining' and 'handgathering'. However, in addition to these mechanisms, the following are also likely:

- small animals being left amongst weed tossed ashore (recreational prawning)
- deep-water sessile invertebrates (e.g. sponges and sea-squirts) being broken off their substrate (trawling).

Various other vertebrate classes (e.g. reptiles, birds and mammals) may occasionally interact with gear used in the other commercial fisheries or in the recreational sector. Most of these are classed as 'threatened' or 'protected' under State and/or Commonwealth legislation: issues relating to these groups are discussed in Chapter F section 2.

iv) Possible indicator groups of bycatch species to be monitored

The draft FMS proposes to monitor bycatch as per management response 1.1f: "introduce an industry funded scientific observer program to collect information on the quantity and composition of non-retained species for methods where little or no information is known and periodically (every five years) repeat the program". Also, response 3.1a proposes to "modify the catch and effort returns, in consultation with the Estuary General MAC, to collect and monitor information on sightings or captures of threatened species". Whilst these measures are likely to provide adequate information on bycatch associated with the Estuary General Fishery, use of indicator species may facilitate the best possible use of monitoring resources. Such indicator species would include those that are liable to be killed in large quantities (by virtue of their quantity and susceptibility) as a result of overall fishing effort, and those of particular conservation significance (Chapter F section 2). By these criteria the following species should be a priority for monitoring for each of the main methods used in the Estuary General Fishery:

Hauling: all commercially important fish as listed in Table E12, plus jellyfish and cephalopods

Prawning (passive): all commercially important fish as listed in Table E12

Meshing: yellowfin bream, luderick and all reptiles, birds and mammals

Trapping: snapper, yellowfin bream and cephalopods in marine waters; reptiles and platypus in fresh to brackish waters

Handlining: snapper

Handgathering: no direct bycatch, but monitor associated kill of invertebrates, especially in sheltered estuarine areas

It should be noted that this monitoring does not address bycatch issues pertaining to other fisheries/sectors (Table E12), the capture of small fish and invertebrates by recreational prawners being a good example.

b) Method based assessment of bycatch reduction strategies

Hauling

Efforts to minimise the capture of discards in haul fisheries are far less advanced than those relating to trawling (e.g. Kennelly and Broadhurst, 1998). One of the problems is that in many cases, a variety of species of different morphologies are targeted, making it difficult to develop more selective gears (Gray *et al.,* 2001). However, Gray *et al.* (2000) inserted transparent panels into the bunts of commercial haul nets to reduce the quantity of undersized sand whiting caught, and found that an increased proportion of flat tail mullet and silverbiddies also escaped as a result this modification. In recognition of the complexities of the bycatch issue, they suggested that vision was a primary cue for fish escaping through the panels, and that such panels would therefore probably be less effective in turbid water or at night; situations often applicable to estuarine hauling.

Current NSW Fisheries Research (Charles Gray, pers. comm.) has identified a variety of potential means to reduce bycatch from various types of hauling. These are discussed in the following paragraphs.

With respect to hauling for sand whiting in northern estuaries, the following measures have been identified:

- increase bunt mesh size from the current 50 mm to 57 mm;
- insert two ‘clear’ mesh panels in bunt
- issue permits to allow fishers to trial panels.

The use of mesh panels has been shown to greatly improve selectivity, with discard rates decreasing from 50-80% to only 5%. Increasing the bunt mesh size is also likely to be effective in reducing discards, although some fishers currently use the 50 mm mesh as a ‘mesh-net’ to trap just-legal sized sand whiting, meaning that such an increase in mesh size would result in some loss of potential catch.

With respect to hauling for mixed species in coastal lagoons, the following measures have been identified:

- simple increase in mesh size
- insert transparent panel in codend
- use horizontal rather than vertical panels.

In this case, a simple increase in mesh size is unlikely to be very effective, given the wide range of species, sizes and body shapes targeted: any such increase would most likely lead to reduced catches of some species/size classes, and an increased tendency for others to get meshed in the net. Appropriately designed transparent panels may help undersized fish to escape, but may also cause reduced catches of silverbiddy; this small species is often a valuable source of income for fishers, especially in winter. Use of horizontal grid panels may help to retain silverbiddies, although more research in this area is needed.

With respect to prawn hauling, the following measures have been identified:

- adopt current practice as used in the Richmond River as standard where practicable
- avoid hauling to river banks.

These measures would most likely reduce bycatch; recent research within the Manning River found that midstream net retrievals resulted in far less bycatch than did the normal practice of bank retrieval. The problem with bank retrieval is that small fish tend to concentrate in the shallows, and are less able to escape an approaching net in such areas. It is known that current practices within the Richmond River contribute to the low bycatch rates observed with respect to prawn hauling in this estuary. Research into bycatch reduction devices (BRDs) may provide further ways to reduce bycatch, although the slow rate of retrieval of such gears makes the use of conventional BRDs relatively difficult.

With respect to prawn seining (snigging), the following measures have been identified:

- prohibit seining over seagrass

- put the season back a month (e.g. October to November) so that fishers target larger prawns in deeper water.

These measures would most likely reduce bycatch, given the tendency of small fish to concentrate in shallows, and amongst seagrass in particular. Furthermore, the risk of associated habitat damage (e.g. boat propellers uprooting seagrass) would be reduced. The willingness of fishers to exclusively target larger prawns in deeper water would depend on the relative returns of 'deep' and 'shallow' fishing; detailed information on catch rates, growth and mortality would be needed to assist any related management decisions. Research into BRD's may provide further ways to reduce bycatch, although the slow rate of retrieval may make the use of conventional BRD's relatively difficult.

Various other measures are potentially available to reduce bycatch rates and/or subsequent mortality from fish hauling in general. These include:

- avoidance of areas, habitats and/or times likely to be associated with large numbers of juvenile fish or jellyfish
- leaving the codend open until the haul is nearly complete
- undertaking sorting in as deep water as possible
- use of implements such as tongs (rather than spikes) to handle dangerous fish
- use of nets constructed of 'soft' materials that are less injurious to fish
- use of designated mapped haul net landing sites.

These measures would be likely to reduce impacts on bycatch to varying degrees depending on local conditions. Given the well known tendency of fish to aggregate in particular areas, avoidance of such areas has the potential to cause major reductions in bycatch; the main problem being the identification of such areas in the first place. Certain habitats (particularly seagrasses), that are widely recognised as supporting large numbers of small fish, would be an ideal starting point. In fact, in many estuaries it may be relatively easy to designate landing sites that avoid seagrass beds. Avoidance of high concentrations of jellyfish would presumably help reduce the mortality of other bycatch species, although no information is available on jellyfish-induced mortality among fish trapped in a cod end. Leaving the cod-end open may allow many small fish (and jellyfish) to escape, whilst retaining the target fish; there is evidence that the latter are often herded in front of the net and do not attempt to swim back through it until the haul is nearly complete. Achieving the best possible results from this approach requires careful judgement in relation to fish behaviour. In this regard, catch composition, size class, water clarity, depth and habitat characteristics are all likely to be important, making it very difficult to prescribe one set of rules for all cases. Undertaking sorting in the deepest water possible would reduce the chance of oxygen or temperature stress, and give released fish the best possible opportunity to escape any waiting birds. Use of nets made of 'soft' material may also help reduce bycatch mortality, although the cost-effectiveness of using such materials would need to be examined.

Some of the above-mentioned measures may best be implemented by means of an appropriate code of conduct. Such a code could focus on fisher behaviour in and around shallow waters, and near sensitive habitats and shorelines.

One particular aspect of the bycatch issue associated with some hauling methods is the 'spiking' of dangerous fish such as catfish and stingrays. Whilst no specific research has been done on this topic, it is clear that such practice results in very high mortality amongst the affected discards. A far preferable alternative for the handling of dangerous fish would appear to be the use of tongs (specially designed if necessary). Tongs have been successfully used for this purpose by at least some prawn hauling crews (Doug Ferrell, NSW Fisheries, pers. comm.).

Prawning (passive)

The passive nature of the methods may make development of effective gear modifications (including BRDs) relatively difficult. The greatest promise seems to be in relation to the timing, manner and/or location of operations.

With respect to prawn running nets, impacts on bycatch appear to be minimal and the only approach required may be continued attention to retrieval and handling practices. With set pocket nets, the available information (Andrew *et al.,* 1994, 1995) suggests that avoidance of flood periods would greatly reduce bycatch.

With respect to set pocket netting, avoidance of floods would appear to be a straight forward way of minimising bycatch. However, the willingness of fishers to avoid operations during flood periods would depend on the relative costs (in terms of 'missed' catches) of doing so. Research into BRDs may provide further ways to reduce bycatch, although the slow speed of water movement against the net may make the use of conventional BRDs relatively difficult.

Meshing

Efforts to minimise the capture of discards from meshing are far less advanced than those relating to trawling (e.g. Kennelly and Broadhurst, 1998). One of the problems is that in many cases, a variety of species of different morphologies are targeted, making it difficult to develop more selective gears (Gray, 2001). Whilst simply increasing the minimum mesh size would reduce the proportion of discards among species such as bream and luderick, such a change would most likely decrease the retained catches of other species such as sand whiting and sea mullet (Gray, 2001). The problem is further complicated by the fact that the selectivity of mesh nets is not only a function of mesh size and fish shape, but also depends on fish behaviour as well as abiotic factors such as net colour and hanging ratio, water currents and habitat characteristics (Hamley, 1975; Marais, 1985; Acosta, 1994; Hickford *et al.,* 1997).

Current and recent research by NSW Fisheries (Gray, 2001; Charles Gray, pers. comm.) has identified the following potential means to reduce bycatch from mesh netting:

- increased minimum mesh size for standard mesh nets (from the current 80 mm to 95 or 100 mm)
- increased minimum mesh size for 70 mm 'flathead nets'
- changes to rules governing the length of setting time
- experimentation with net materials (e.g. multi-mono vs nylon), ply size, net depth and hanging ratio.

Increasing minimum mesh sizes to 100 mm has been shown to dramatically reduce discard rates (Gray, 2001). Increasing the minimum size of flathead nets will certainly help reduce discards of dusky flathead, especially given that the size limit of this species was recently increased from 33 to 36 cm. Changes to allowed setting times (especially in warmer months) may provide a means to reduce bycatch and to increase the survival of animals caught. At this stage, the potential for reducing bycatch through altering factors such as net material and design is unclear, although research in this area is certainly warranted.

One particular aspect of the bycatch issue with mesh nets is the consumption of just-released fish by waiting seabirds. A possible solution would be to have fish released down a large diameter pipe, through which they would gain immediate access to a reasonable depth beyond the reach of most birds (e.g. Hall *et al.,* 2000). Such a pipe could be attached to the side of a fisher's boat, and would probably prove effective under most circumstances; the only birds likely to be able to eat the (usually quite large) discards would be pelicans, a species that cannot reach far below the surface. Diving birds (e.g. cormorants) would normally find discards from mesh nets too large to eat.

Trapping

There is little information currently available on reducing bycatch from fish or eel trapping. Because of the passive nature of this method, options for BRD use are likely to be very limited. However, manipulations of opening size and/or orientation, and of trap material, may yield some reductions in bycatch depending on the behavioural responses of particular species. Trap designs that minimise sharp edges, hard knots etc. may help to reduce injury among trapped animals, and therefore enhance survival of discards. Optimising soak times (i.e. keeping them relatively short) would possibly help reduce predation by large target animals on smaller unwanted individuals within traps, and would reduce the possibility of trapped animals losing condition. Possible drowning of air-breathing animals such as freshwater turtles can be avoided by putting a BRD in the entrance tunnel or by providing access to the water surface, and such a practice should be considered wherever air-breathing animals are liable to be caught.

Handlining

There is little local information on reducing bycatch from handlining. The targeting of large pelagic species (such as yellowtail kingfish), rather than smaller rocky reef/benthic species, would most likely result in reduced bycatch because baits and rigs intended for the latter would often be more accessible to a wide range of unwanted species. Optimising hook design for the particular species being sought may also help (Otway and Craig, 1993; Otway *et al.,* 1996), and may also reduce injury from lodgement or swallowing. In cases of swimbladder over-inflation, it may be possible to deflate the bladder with a needle, although the precise positioning and degree of penetration required would depend on the species. Damage to skin or scales could be minimised by careful handling, for example by use of a soft wet rag and/or gloves.

Handgathering

Achieving effective reductions to the numbers of organisms harmed as a result of handgathering probably requires a focus on area/habitat based practices. Whilst changes to harvest methods (e.g. implement design and use) may offer some scope, the greatest potential comes from avoiding sensitive habitats or areas likely to harbour large numbers of vulnerable animals. Whilst some habitat damage is inevitable when (say) pumping or digging for blood worms, the focus should be on protecting those habitats that are slow to regenerate once damaged (e.g. saltmarsh, seagrass and mangroves). Adequate protection of these habitats, coupled with practices that avoid localised concentrations of effort in less sensitive habitats such as sand or mud flats, should ensure that associated impacts (on populations of non-target organisms) are acceptable.

All methods

The above discussed alternatives to reduce impacts on bycatch need to be considered in light of the National Policy on Fisheries Bycatch (Anon., 1999). This policy aims "to ensure that bycatch species and population are maintained at sustainable levels", and has three main "sub-objectives": (1) to reduce bycatch; (2) to improve protection for vulnerable/ threatened species; and (3) to minimise adverse impacts of fishing on the aquatic environment. In implementing any of the above-discussed alternatives, the following strategies (quoted directly from this policy) need to be considered:

- prioritization of critical bycatch issues and resourcing requirements
- development of codes of practice to minimise bycatch
- as required, institute fisheries adjustment mechanisms including provision of suitable compensation if required
- development of management plans, legislative arrangements and bycatch action plans which address bycatch in both existing and developing commercial fisheries and the recreational, charter and indigenous sectors
- development of education and training programs aimed at reducing bycatch
- application of economic incentives or adjustment arrangements to reduce bycatch
- development of cooperative bycatch management arrangements for species or fisheries within more than one jurisdiction
- encouragement of research funding organisations and the commercial sector to fund and/or facilitate further work into identifying the impacts of fishing on bycatch, by-product and other species, mitigation techniques and use of bycatch species where appropriate
- regulate for appropriate gear design or fishing practice
- enhancement of the quality and quantity of fisheries data, including bycatch data, and the thorough and efficient use of all existing data sets to assist in achieving ecologically sustainable development.

c) Assessment of bycatch management measures in the draft FMS

i) Adequacy of proposed strategies

Objectives 1.1 and 1.2 of the draft FMS address bycatch reduction. The associated responses are expected to result in:

- improved knowledge of the quantity and composition of non-retained species (Response 1.1f)
- changes to gear specifications that will result in reduced bycatch rates (Responses 1.1a,d&e)
- modified fishing practices, including the adoption of BRDs (Response 1.1b)
- use of best-practice techniques for the handling of bycatch (Response 1.1c)
- closure of specific seagrass areas known to support large numbers of juvenile fish (Response 1.2a).

All of the finfish and mobile invertebrates in the 'fully fished', 'fully/over fished', and 'uncertain' or 'unknown' categories (Table E1) should benefit (in terms of reduced bycatch rates and better handling) from these measures. NSW Fisheries has a responsibility to manage bycatch issues in accordance with the National Policy on Fisheries Bycatch (Anon., 1999) and this policy acknowledges the progress already made with respect to the Estuary General Fishery: "Attention is now turning to addressing the discarding of small fish associated with estuarine prawn and fish hauling. Marked progress has already been made in research into this fishery, with several modifications to gears and fishing practices already tested, and new permits to use them issued to fishers in certain areas".

Whilst recovery of the two most heavily fished species that occur as bycatch (namely snapper and silver trevally) should be assisted by the bycatch reduction measures discussed above, measures taken in other fisheries are likely to also be important. For snapper, the likelihood of recovery will depend (at least in part) on the implementation of bycatch reduction strategies in other fisheries including the Estuary Prawn Trawl and Ocean Prawn Trawl, where large quantities of juvenile snapper are sometimes taken as bycatch (Liggins *et al.,* 1996; Kennelly *et al.,* 1998). Whilst silver trevally might not be taken as bycatch in such quantities as snapper, implementation of appropriate bycatch reduction strategies in other fisheries may help achieve the potential benefits from the planned introduction of a minimum size limit for this species (Chapter E section 1(b).

The development of a code of conduct for fishing operations on or near sensitive habitats (Response 1.2c) will help to reduce indirect harm to invertebrates from activities such as trampling and the use of implements. Species likely to benefit from such measures include ghost nippers and cockles.

The bycatch management measures in the draft FMS are strongly supported by the management of other fisheries and sectors, and by the management of activities in general that might impact on fish or fish habitat. For example, the development of BRDs in NSW trawl fisheries is well advanced (e.g. Kennelly and Broadhurst, 1998), and legislation is in place for their use in both the estuarine and ocean prawn trawl fisheries. Also, size and bag limits to protect juvenile stocks remain an integral part of recreational fishery management, and recreational fishers are being increasingly made aware of appropriate techniques for handling and releasing unwanted fish. Furthermore, NSW Fisheries and other relevant authorities carefully manage a wide range of activities (e.g. dredging, reclamation, foreshore development, river regulation and harm to marine vegetation) to minimise adverse impacts on fish habitat. A major focus of this effort is on the protection of shallow water habitats (e.g. mangroves and seagrass) favoured by juvenile fish, as these habitats are considered the most vulnerable to the affects of land-based activities.

On the basis of the information provided within Chapter E section 2, the proposed measures relating to bycatch described in the draft FMS are likely to be acceptable in terms of minimising adverse impacts.

ii) Summary of the uncertainty associated with the management of bycatch

There are several key aspects to the management of bycatch. These aspects range from educating fishers to predicting the consequence of mortality on stock status, and are listed below in Table E13, along with associated uncertainties and indications of possible consequences.

Our knowledge of bycatch composition (in terms of species and size classes) is acceptable (e.g. Gray, 2001; Gray *et al.,* 2001; see also section 2(a) above), particularly for the major bycatch generating methods used in the Estuary General Fishery (i.e. hauling and meshing). Also, based on the relative ease with which bycatch composition can be measured and documented, the associated uncertainty is rated as low (Table E13). If current knowledge of bycatch composition is wrong, any errors are most likely to relate to the less common species and/or methods, that generates relatively little bycatch. Conversely, a miss-judgement of bycatch composition could involve the rarer threatened or protected species, a potentially more serious consequence. Therefore, the precautionary rating of medium is used for the consequences of uncertainty (Table E13).

Table E13. Consequences and uncertainties associated with the key aspects of bycatch management.

"Consequence of uncertainty" refers to the potential seriousness of a miss-judgement in relation to the aspect in question. The reasoning behind these classifications is discussed in the following text.

Aspect of by-catch management	Associated uncertainty	Consequence of uncertainty
knowledge of bycatch composition	low	medium
knowledge of spatial and seasonal patterns	medium	medium
knowledge of bycatch mortality	medium	medium
effect of by-catch mortality on affected stocks	high	high
design and effectiveness of bycatch reduction devices	low	medium
effectiveness of fisher education/compliance	medium	high

Spatial and seasonal patterns of bycatch are more difficult to measure, and the associated uncertainty has consequently been rated as medium (Table E13). Because of the inherent patchiness of bycatch occurrence, accurate measurement of these patterns requires considerable sample replication both in time and space. The consequences of misunderstanding spatial and seasonal patterns in bycatch might include poorly targeted closures, excessively high bycatch rates in some instances, missed fishing opportunities and wasted effort. However, even in the event of such misunderstanding, it is unlikely that any proposed measures to manage bycatch would 'miss their mark' completely; the potential consequence of the associated uncertainty has therefore been rated as medium (Table E13).

Our knowledge of bycatch mortality relies heavily on a relatively small number of studies of particular methods under specific conditions (e.g. West, 1993; Broadhurst *et al.,* 1997, 1999; Gray, 2001). Whilst these studies provide some basis for estimating bycatch mortality for fish, they do not address other biota such as invertebrates. Also, the results of Broadhurst *et al.* (1997, 1999) are based on prawn trawl BRD interactions, rather than the Estuary General Fishery. Consequently, the uncertainty associated with our current knowledge of bycatch mortality has been rated as medium (Table E13). Whilst the potential consequences of grossly under-estimating bycatch mortality across the whole suite of species involved would be very serious, such a scenario is extremely unlikely given the large variety of species and methods involved. Each species has different susceptibilities and it is very likely that errors (in estimating mortality for each species or bycatch type) would tend to cancel each other, assuming that for each species there is an equal probability of over or under estimating bycatch mortality.

Our knowledge of the ultimate effect of bycatch related mortality on the status of affected stocks remains poor. The challenge is to translate bycatch mortality into adult stock losses, but to do this, a reasonable estimate of natural mortality is required. The best estimate for NSW estuaries was done by Kennelly *et al.* (1993) in relation to juvenile snapper caught by prawn trawling: they suggested that an annual bycatch of 350,000 juvenile snapper may represent 60,000 legal sized fish 3 years later. At the present time, stock assessments for the principal retained species are not sufficiently developed to allow these sorts of estimates to be made for other commercial/recreational species Chapter E section 1(b). Furthermore, we have even less means to estimate the effects of bycatch mortality on non-commercial species. Consequently, the uncertainty associated with our knowledge of the effect of bycatch mortality on affected stocks has been rated as high (Table E13). Also, given the potential importance of ‘fishing’ mortality in contributing to stock decline, the potential consequence of this uncertainty must be rated as high (Table E13).

Much progress has been made in the design and assessment of bycatch reduction devices (see section 2(b)), and good information about this aspect is either already available, or is currently being examined (Gray *et al.,* 2000; Charles Gray, pers. comm.). The protocols for testing the effectiveness of bycatch reduction devices are well developed (e.g. Kennelly and Broadhurst, 1998). Consequently, the uncertainty associated with the design and effectiveness of these devices has been rated as low (Table E13). Nevertheless, the use of ineffective or inappropriate devices could significantly affect overall bycatch rates and associated mortalities. Therefore, the precautionary rating for the potential consequences of uncertainty in relation to device design or effectiveness is medium (Table E13).

Assessing the effectiveness of fisher education and/or compliance in relation to bycatch reduction might appear easy, but is inevitably constrained by the availability of resources. Also, it is sometimes difficult to judge whether fishing practices followed in the presence of an observer are in fact representative of normal practices. Consequently, the uncertainty associated with this aspect of bycatch management has been assessed as medium (Table E13). Any major misjudgement of fisher behaviour in terms of education/compliance (e.g. with respect to adoption of particular devices, or in relation to closures designed to protect juvenile fish) could have major consequences for bycatch management as a whole; the precautionary rating of the potential consequences of the associated uncertainty is therefore high (Table E13).

iii) Current or proposed precautionary management measures and associated levels of confidence

The above-discussed uncertainties, along with their associated consequences, demand some degree of precautionary management in relation to the ecological impact associated with bycatch. Essentially, this impact is one of mortality, which can be addressed by assessing bycatch quantity and bycatch handling. The draft FMS contains precautionary management measures that address the various mechanisms liable to contribute to bycatch mortality as outlined below in Table E14. These mechanisms (particularly in relation to handling) were discussed previously in section 2(a).

In Table E14, “significance of resultant impact” has been judged in terms of the numbers of animals likely to be affected. For example, drowning or hook injury are only likely to affect small numbers of animals and have been assessed as low; whilst stranding/exposure and habitat damage may easily affect large numbers and have been assessed as high. “Acceptability of impact” is judged from the likely point of view of all stakeholders and does not always negatively correlate with the significance of impact. For example, even though very few air-breathing animals are likely to be drowned in fish or eel traps (hence its low significance), the acceptability of such incidents would be low owing to the charismatic nature of the species potentially affected. In general, mechanisms that are highly visible to the public, or that are likely to involve large numbers of animals (even if indirectly, as in damage to habitats), charismatic species and/or perceived ‘cruelty’ are likely to be unacceptable to most stakeholders. The most acceptable mechanisms are likely to be those which are perceived to benefit other animals (especially birds) or which also apply to widely accepted activities elsewhere (e.g. use of hooks by recreational anglers). In the latter case, acceptance would be assisted by the widely held assumption that most fish survive hook injury.

Table E14. Potential mechanisms liable to cause ecological impacts in relation to bycatch, along with corresponding assessments of the significance and acceptability of the impacts.

Current/proposed management measures, along with an assessments of their likely effectiveness, are also included. "Hauling" refers to both fish and prawn hauling. "FMS" refers to the draft Fishery Management Strategy. The reasoning behind assessments is discussed in the text.

Potential mechanism leading to ecological impact	Method(s) potentially involved	Likely significance of resultant impact (in ecological terms)	Acceptability of impact	Precautionary management measures to be used (Responses from FMS)	Confidence that measures will effectively manage impact
by-catch quantity	All methods; especially hauling & meshing	high	low	1.1a, b, d, e, g; 1.2a, b; 2.1a	high
stranding/ exposure	hauling; hand-gathering in sensitive areas	high	low	1.1b, c, g; 1.2a, b, c; 2.1a	high
crushing	hauling; set pocket net	medium	medium	1.1b, e, g; 1.2a; 2.1a	medium
jellyfish stings	hauling; set pocket net; running net	medium (erratic in occurrence)	medium	1.1b, e; g; 1.2a; 2.1a	medium
oxygen/ temperature stress (e.g. in shallows)	hauling; meshing	medium	medium	1.1c, g; 1.2c	medium
injury from net material	hauling; meshing; set pocket net; running net	medium	medium	1.1a, b, d, g	low
injury from trap walls	trapping	low	medium	1.1b, g	medium
entanglement	meshing; trapping (witches hats)	medium	medium	1.1a, b, d, g	medium
spiking or similar	hauling; set pocket net; running net	medium	low	1.1b, c; 1.2c	high
poor handling	all methods	low	medium	1.1b, c; 1.2c	medium
predation by birds etc. on weakened/ trapped fish	all methods; especially hauling & meshing	medium (beneficial to birds)	high	1.1b; 1.2c	medium
predation by other trapped animals	trapping	low	medium	1.1b, g	medium
injury from rapid ascent	trapping	low	medium	1.1b	high
drowning	trapping	low	low	1.1b, g; 1.2a, b, c	high
starvation/ loss of condition	trapping	low	low	1.1b, g; 1.2b	high
hook injury	hand-lining	low	high	1.1b	high
implement injury	hand-gathering	low	medium	1.1b; 1.2a, b, c	high
trampling	hand-gathering	medium	medium	1.2a, c	medium
habitat damage	hauling (in some cases e.g. seagrass); hand-gathering in sensitive areas	high	low	1.1e, g, h; 1.2a, b, c; 2.1a	high

Table E14 shows that most of the mechanisms leading to ecological impacts in relation to bycatch are addressed (at least indirectly) by several responses in the draft FMS (Chapter C). The confidence associated with the collective effectiveness of each set of responses (right hand column of Table E14) varies according to the degree of control that may be exercised over the mechanism in question. For example, little can probably be done to avoid injury from net material, partly because of the likely costs associated with alternative materials. On the other hand, specific fishing practices can be adopted (and often already have) to avoid problems such as stranding, drowning and spiking. Whilst more general problems relating to bycatch quantity and habitat damage are difficult to manage, the use of a wide range of measures engenders a high degree of confidence that impacts will be effectively managed. It should be emphasised that in terms of habitat damage, the high level of confidence relates to bycatch associated issues and not necessarily to habitat management in general (much of which relates to external impacts as discussed in Chapter F section 10).

In some cases, the management responses listed do not specifically address the mechanism in question. For example, the responses listed against "drowning" do not mention putting a BRD in the entrance tunnel of traps or providing access to the water surface; instead they refer to modifying fishing and handling practices in a general sense. It is assumed that specific solutions will follow from each of the responses, wherever such solutions are already (or likely to become) available. The assessment of confidence levels in Table E14 takes the availability of such specific solutions into account.

iv) Level of confidence in achieving predicted outcomes and resilience of environment to change

Given the variable levels of uncertainty associated with the different aspects of bycatch management (Table E13), and the variable levels of confidence associated with the many potential mechanisms by which impacts may occur (Table E14), it is not appropriate to make a single general statement concerning the level of confidence in achieving particular outcomes in relation to bycatch management.

A more realistic approach is to consider predicted outcomes in relation to each of the mechanisms listed in Table E14. Given that the 'predicted outcome' in each case equates to the successful mitigation, rehabilitation and/or compensation of the associated impact, then the level of confidence in achieving these outcomes is given by the ratings in the right hand column. Table E14 shows that the level of confidence is high, where the significance of the resultant impact is likely to be high, and/or where the acceptability of the impact is low.

Where the level of confidence given in Table E14 is only low or medium, it must be assumed that some impact will continue, despite the proposed measures in the draft FMS. Mechanisms for which continued impact is likely can be split into two categories: (1) those for which the likely significance of the impact is low; and (2) those for which the likely significance is medium. Given that none of these mechanisms are associated with low acceptability (Table E14), only those in the latter category are likely to be of any real concern. Specifically, these mechanisms are (from Table E14):

- Crushing
- Jellyfish stings
- Oxygen/ temperature stress (e.g. in shallows)
- Injury from net material
- Entanglement
- Trampling.

These mechanisms may result in harm to a variety of biota (section 2(a)), although impacts are likely to be sporadic in their occurrence. It is likely that the majority of affected fish and invertebrates would be species resilient to such impacts, given the reproductive and dispersal strategies normally employed by such species. Even the loss of a high number of individuals in a particular incident would be quickly 'replaced' by juvenile recruitment and/or dispersal of adults from other areas. Even in the case of trampling, where significant habitat damage could occur, rapid recolonisation by affected invertebrates would be expected.

Bird and mammal species affected by these mechanisms would usually be less resilient to any population loss, particularly in the case of rare or threatened species (Chapter F section 2). However, the numbers of such animals likely to be affected by these mechanisms in NSW estuaries would be extremely low.

In conclusion, the draft FMS will address all of the more important impacts associated with bycatch, and those which are not able to be fully addressed will most likely be sporadic, short-term and readily reversible by natural mechanisms.

3. Bait Resources

Bait is used in the Estuary General Fishery in five main gear types – fish traps, eel traps, crab traps, hoop nets and handlining. A variety of species of fish and invertebrates are used in each of these gear types (Table E15). In addition, the Estuary General Fishery also collects bait for other commercial and recreational fishers. The latter will not be discussed in this section as the impact of this collecting is assessed under retained species (Chapter E section 1).

a) Species, quantity and source of bait species

Table E15 summarises the main species used by Estuary General fishers as bait and the source of this bait. Most fishers will catch their own bait (self in Table E15) which is then immediately used in their traps. Bait caught and used in this way is usually not logged in the fishers catch returns. Since 1997 fishers are required to report on catch used for their own bait. However, recording of these catches has been patchy and further guidance is needed to increase the rate and accuracy of these entries in future. Because reporting to date has been poor, there is little information to determine the quantity of bait taken for fishers' own use. Even when bait is bought from wholesalers, as with pilchards, the quantity purchased is not recorded on catch returns (M. Tanner, pers. comm.). Consequently, the magnitude, duration and extent of the impact of collecting bait in the Estuary General Fishery is unknown.

However, the use of bait in this fishery is small relative to use in other fisheries, such as Ocean Trap and Line (Stewart *et al.,* 1998). For example, in 1998/99 24.7% of the methods used by fishers in the Estuary General Fishery required bait, whilst 76.2 % were non-bait methods (Tanner and Liggins, 1999). Of the total catch landed in Estuary General only 9.8 % was caught by baited methods (Tanner and Liggins, 1999). By contrast, all methods in the Ocean Trap and Line Fishery use bait and bait quantities are large. Therefore, baited methods are a small proportion of the diverse methods used in the Estuary General Fishery and catch a small proportion of the total catch in comparison to other fisheries. Based on this information, the quantity of bait used is estimated to be small. But until proper quantification of the bait caught and used is obtained the real impact on bait resources remains unknown.

i) Impact of collection of bait species within NSW on respective stocks

Most of the bait used in the Estuary General Fishery is from NSW waters. Many of the bait species are also target species or secondary species caught by other gear types in the Estuary General and Estuary Prawn Trawl Fisheries. Consequently, assessment of the impacts on these fish stocks under Chapter E section 1 would also apply to the bait component of these stocks. However, the unknown quantity used for bait increases the uncertainty in relation to the adequacy of the management responses in the draft FMS to sustain these stocks. Therefore, the precautionary principle must be applied until more information is obtained.

Table E15. Summary of major species of fish used as bait in the Estuary General Fishery, by gear type and source of bait.

Species	Gear bait used in					Source of bait
	Fish Trap	Eel trap	Crab trap	Hoop net	Handlining	
Luderick*	Y		Y			Self
Slimy mackerel*	Y				Y	Self
Leatherjacket*	Y		Y			Self
Squid*					Y	Self
Yellowtail*					Y	Self
Pilchards	Y	Y			Y	Imported
Herring*					Y	Self
Mullet*	Y	Y				Bycatch from hauling
Miscellaneous			Y	Y	Y	Self
Other Bycatch	Y		Y		Y	Bycatch from EPT & other

Self – caught by estuary general fisher for own use.
* Commercial species taken by other fisheries

ii) Impacts of use of species sourced from outside NSW

The primary species used for bait sourced from outside NSW are pilchards. These come in large frozen blocks from a variety of places including Indonesia, Japan and Western Australia (Whittington *et al*., 1997). The transfer of disease has been attributed to these imported fish. The mass mortalities of pilchards in southern and southwestern Australia in 1995 and 1998/99 were caused by a herpesvirus, previously unknown to the pilchard stock in these regions (Fletcher *et al.,* 1997; Gaughan *et al.,* 2000 and Whittington *et al.,* 1997). Whilst the origin of the infection agent is still unknown, it is believed to have possibly been introduced by frozen imported bait fish (Gaughan et al., 2000; Griffin *et al.,* 1997; Whittington *et al.,* 1997) used to feed bluefin tuna in seacages in South Australia where the first mass mortalities occurred. Because imported frozen bait fish have not been subject to quarantine inspections (Gaughan *et al.,* 2000), it is considered that there is a high risk of these bait sources introducing previously unknown diseases to Australian fish stocks. However, so far disease from frozen imported pilchards has only affected native pilchard stocks. There has been no evidence that frozen bait pilchards used in the Estuary General Fishery have introduced diseases to estuarine fish species. But given the events that occurred in the 1995 and 1998/99 mass mortalities of pilchards, and despite the quantities used in the bluefin tuna cages being much larger than those used in the Estuary General Fishery, there is still a considerable risk that exotic diseases could be introduced through the use of imported bait.

There are no pest species used as live bait in this fishery and therefore there is no risk of introducing new exotic species into estuaries via live bait use.

b) Assessment of management measures in the draft FMS

The draft FMS does not address bait usage directly. There are no management responses that monitor the species, quantities and methods of capture of bait species. Until the quantity, composition, method of capture, habitats fished and frequency of use of bait species are established it is not possible to determine whether or not bait usage poses an added risk to the fish stocks. A systematic promotion and education campaign, aimed at having fishers record their catches of bait species, is urgently required.

If adequate data are obtained and impacts assessed, the draft FMS should investigate whether there are feasible alternatives to reduce impacts on bait species, as appropriate. Alternatives could include substitution with non-fish bait sources, establishment of a bait aquaculture service where certain species of fish are bred expressly for use as bait in the Estuary General Fishery, and stricter quarantine regulations on imported frozen bait (www.brs.gov.au:80/fish/status99*,* 2001). The draft FMS should consider tighter control of fish imports to reduce potential risks of introducing diseases that could threaten the Estuary General Fishery.

4. Data, Monitoring and Research Adequacy

Data requirements occur in two major components in the draft FMS. The first is research, which incorporates knowledge gaps emerging from the draft FMS. The second is performance and monitoring which incorporates the effectiveness of the strategy in fulfilling its vision and goals for the fishery. Both these components will arise from the issues in the fishery that have been identified in the draft FMS. These two components will be discussed in turn.

a) Data and research

Data and information used to address impacts on fish resources was obtained from catch statistics for 1940-1992 (Pease and Grinberg, 1995), 1998/99 (Tanner and Liggins, 2000) and 1999/2000 (Tanner and Liggins, 2001), peer reviewed scientific papers by fishery scientists and NSW Fisheries internal reports. These are listed in the reference section. The reliability of the information for the stock assessments is given in Table E1. Except for prawns, the assessments of fishing level for all of the main target species are classified as preliminary. The uncertainties associated with the data and assessments are due to the knowledge gaps for principal retained species.

i) Knowledge gaps

The draft FMS has revealed substantial knowledge gaps that affect the management of the Estuary General Fishery. The knowledge gaps cover four main areas - stock assessments of all retained species, bycatch, accuracy and precision of effort data and ecological interactions among retained species. Each of the gaps are discussed below in terms of their role in improving the management of the Estuary General Fishery.

Stock assessments

All retained species in the Estuary General Fishery require proper stock assessments. Some of the target species, namely yellowfin bream, sand whiting, dusky flathead, luderick and sea mullet, have preliminary estimates on the status of their stocks (Gray *et al.,* 2000) in selected locations but further work is required to provide more robust and comprehensive information. Gray *et al.,* (2000) outlines the specific data that is needed and the role of the data in stock assessment for all retained species (Table E16). Broadly, the information is necessary to determine stock health and recruitment variability, and to design scientifically sound long-term monitoring and assessment procedures that will improve the future management of the fishery.

Estimates of harvest rates (e.g. annual landings) are essential to the stock assessment process. Hilborn and Walters (1992, p. 160) state “it is almost impossible to perform stock assessment without knowing the history of the catch”. The primary source of harvest estimates for the commercial sector comes from monthly catch return reports filed by each fisher. Stock assessments should ideally include catch estimates from all sectors and the first estimates of state-wide recreational harvest will be available with the publication of the National Recreational and Indigenous Fishing Survey in late 2001 or early 2002.

There is also little understanding of how fishing pressure affects fish stocks in the Estuary General Fishery. Effects of fishing pressure are many and include recruitment and growth over-fishing, damage to habitats and changes to recruitment patterns (Dayton *et al.,* 1995). Knowledge of these affects would enable more specific input controls to be developed to manage the fishery as well as contributing to improving the accuracy of the stock assessments.

Table E16. Summary of biological data required and their role in providing robust stock assessments for retained species in the Estuary General Fishery.

From Gray, *et al.,* (2000)

	Purpose			
Biological information required	Stock assessments	Desiging long-term strategies for monitoring & assessing stocks of fish in estuaries	Managing fish stocks	Forecasting future catch levels
Landing/harvest estimate	√	√	√	√
Size & age composition of catches	√			
Variability among estuaries, gear types and time	√	√		
Spatial & temporal variation in recruitment & growth of juvenile species	√	√		
Spatial & temporal temporal changes in abundances of different year classes			√	√
Changes in abundance of pre-recruits to the fishery				√

Accuracy and precision of effort data

Currently, effort data is based on the monthly catch returns of the estuary general fishers. The monitoring programmes and many of the trigger points for the key primary retained species rely on the information in these returns. However, there are many factors that influence what fishers record, which can lead to misreporting (Liggins *et al.,* 1996). There is a need therefore, to validate the precision and accuracy of catch returns on a method by estuary by fisher basis. Inaccurate catch data will seriously affect future catch predictions and the management of the fishery as a whole.

Bycatch

Knowledge gaps remain on the quantity and composition of bycatch in the Estuary General Fishery for a few methods such as crab, fish and eel traps and for some specific hauling methods, such as garfish bullringing. However, there is little information on the fate of discards from bycatch for most methods in the fishery. The potential fate of discards includes disease and mortality either immediately on or after release, as might result from damaged scales and fins. Discard mortality may have a substantial affect on fish stocks, particularly if juveniles of commercial and recreational species make up a large proportion of the discards. Without quantifying the level and rate of discard mortality, the estimates of future catches and the capacity of stocks to recover from fishing pressure could be substantially over-estimated. Moreover, determining the nature and causes of discard mortality on a method by method basis will enable the most appropriate solutions to be found.

Ecological interactions among retained species and their habitats

Ecological interactions between retained species and their habitats include things such as predator prey relationships, competition for food and territory and distribution and abundance of species with respect to each other. Whilst there is some basic knowledge about the general biology of the species in the Estuary General Fishery (see Gray *et al.,* 2000) there is little knowledge about how the species interact. Understanding how species in the fishery interact is particularly important in a multi-species fishery like the Estuary General Fishery (Gray *et al.,* 2000). Interactions among species and their habitats may change if one species is being fished more than another (Dayton *et al.,* 1995; Pauly, 1988; Castilla, 2000). These and other changes could result in recruitment failure of a species for one or more years, which could substantially impact the sustainability of fish stocks (Fogarty and Murawski, 1998). Therefore, knowledge of ecological interactions among species will lead to an improved ability to sustain stocks of the Estuary General Fishery.

ii) Research assessment

The draft FMS proposes six areas of research, four of which are directed at filling knowledge gaps about the fishery resource (Chapter C section 6) and the other two areas focused on knowledge gaps concerning impacts on the environment. Table E17 summarises the main research areas, the knowledge gaps they seek to address and the management responses in the draft FMS to which they apply. In general, the research areas cover all of the knowledge gaps identified above. However, there are three specific areas that are not clearly addressed in the proposed research.

Table E17. Summary of knowledge gaps and research areas that address these gaps and relevant objectives and responses of the draft FMS.

Knowledge gap	Research area	Objective	Management response
Stock assessments Accuracy and precision of effort data	Stock assessments	2.1 2.1.1 2.1.2 2.1.3 2.1.4 4.1 4.2	b, c b, c a a a, b a a
Bycatch	Quantification of and reduction of bycatch and discards	1.1	b, f
Ecological interactions among retained species and their habitats	Effects of habitats on fish populations	1.3	b
	Impacts of fishing on trophic interactions and ecosystems	1.3	a, c
	Impacts of fishing on threatened species		

Firstly, determining the accuracy and precision of catch returns is not addressed directly. Instead emphasis is placed on developing better methods for stock assessment. In the long term, stock assessments that do not primarily rely on fishery dependent data will be a vast improvement. But it is also recognised that fishery dependent catch returns will continue to be used as the most efficient means of collecting long term data for catch per unit effort calculations. So in the short to medium term the draft FMS will still rely on catch returns to provide much of the information required to manage the fishery. It is therefore, essential that part of the research proposed for stock assessments addresses the issue of the accuracy and precision of catch returns.

Secondly, the proposed research on bycatch and discards does not address discard mortality. However, it is proposed that specific problems relating to bycatch and discards will be investigated using targeted research projects. The level and impacts of discard mortality for each method in the Estuary General Fishery should be included in these targeted research projects.

Thirdly, the methods by which levels of uncertainty will be measured or identified in the stock assessments have not been made explicit in the research proposed. Consideration of uncertainty in the information provided by scientists to managers has become increasingly important for fisheries management world wide (Patterson *et al.,* 2001). Therefore, research programs need to address the recognition of uncertainty, its quantitative measurement, and how it would be incorporated into the information provided to managers and stakeholders.

There are three broad approaches to how the research will be done. Firstly, observer programs will be used to quantify bycatch and discards in all methods of the fishery. These programs are considered the most reliable and accurate way to assess bycatch and discarding. Secondly, fishery independent methods will be developed for future stock assessments. Current use of fishery-dependent methods to supply data for assessments has numerous short comings which are identified in the draft FMS. These short comings substantially affect the ability to make reliable assessments and predict future catch trends. Consequently, there is an urgent need to develop methods that overcome these problems. The proposed research makes a strong commitment to developing fishery independent methods. Thirdly, targeted research projects will be aimed at specific problems identified in the fishery. These projects would primarily involve manipulative experiments and/or quantitative studies over appropriate spatial and temporal scales. Such experiments are regarded as the most productive way to resolve specific questions relating to a fishery (Underwood, 1990, 1993; Underwood *et al.,* 2000). The combination of these three broad research approaches should adequately address knowledge gaps relating to the Estuary General Fishery.

It is difficult to assess the sufficiency of the research proposed as there are few details as to what specific research will be done, the relevant spatial and temporal scales, who it will be done by and the specific null hypotheses to be tested by the research. However, the overall research needs of all fisheries in NSW are currently being assessed and prioritised, and further details on future research programs will be available after this has process has been completed in 2002.

b) Performance and monitoring

i) Performance indicators and trigger points

Performance indicators are used to gauge whether the goals of the strategy are being met. Trigger points for each indicator set the level at which a review into a particular aspect of the management goals is instigated.

In general, the indicators are appropriate for the goal they are tracking. However, there are some indicators that are either inadequate or inappropriate to measure the performance of particular goals. These are discussed below.

For Goal 1 it is suggested that a performance indicator(s) be developed to monitor impacts on biodiversity. In order to monitor such impacts, they need to be identified and described. However, the research proposed does not explicitly state that an indicator for impacts on biodiversity will be developed. Such research would come under the area of impacts on trophic interactions and ecosystems. As management response 1.3b in section 4 of Chapter C states that an indicator for biodiversity impacts will be developed, it is important that the proposed research follows this through.

The number of MAC meetings held in a year is a measure of Goal 6, which is to ensure a cost-effective and efficient estuary general management and compliance program. Whilst the associated trigger point is a regulatory requirement, the number of meetings does not necessarily indicate whether the Estuary General Fishery is being managed efficiently and cost-effectively. More appropriate indicators should be determined in relation to the function of the committee to advise, monitor and assess (see *Fisheries Management Act 1994*, No. 38, Part 8, Division 2, section 230). For example, an indicator could be developed that monitors how thoroughly and frequently the MAC checks that the objectives of the draft FMS are being met. Any indicators regarding the effectiveness of the MAC should take into account that MAC meetings deal with many contentious issues, which are not always resolved to every member's satisfaction.

For Goal 7 there are three performance indicators, relating to the level of funding for research projects, the number of research grant applications submitted and the rate of successful external research funding. These indicators are not an adequate measure of Goal 7, which is to improve knowledge of the Estuary General Fishery and its resources. If successful grant applications do not involve properly designed research programs (i.e. world's best practice), they will do little to improve knowledge of the fishery. A more important measure is whether the research applications submitted and approved are appropriately designed to address the issues they are investigating, in terms of a set of best research practice criteria. In addition, there needs to be a measure of whether the outcomes of the research are incorporated appropriately into the management of the fishery. At present there is no explicit explanation in the draft FMS as to how research and review are connected to managing the fishery nor what alternative is proposed if the funding from external sources is not received. Measuring these indicators, in addition to those already suggested, will ensure that high quality and robust research is done which will more likely result in improved knowledge of the fishery.

Overall, the trigger points for each performance indicator appear to be appropriate for what they measure. The trigger levels used to monitor the total catch of the primary species of the Estuary General Fishery are dependent on catch return data. Given the inherent problems with these data sets, as outlined above, an estimation of the uncertainty associated with these indicators and triggers needs to be incorporated into the monitoring programmes (Patterson *et al.,* 2001).

A performance indicator that is not mentioned explicitly in the draft FMS, although is inferred, is the implementation of all the management responses. This will be monitored via the implementation plan and presumably will be overseen by the MAC and fisheries managers.

ii) Monitoring and review

There is a specific monitoring programme for each performance indicator (see Chapter C). The proposed monitoring involves observer based programmes, analysis of catch returns on a regular basis, and other specific reviews of regulations and their outcomes. All the proposed monitoring adequately covers the performance indicators. However, reliance on catch returns for a large proportion of the monitoring programmes for primary species makes these programmes vulnerable to error and uncertainty. There is no scope in the proposed monitoring programmes for estimating sources and levels of uncertainty associated with detecting trigger point breaches (Patterson *et al.,* 2001). Given that significant management decisions will be made based on the results of these monitoring programmes, any lack of understanding of the sources and level of uncertainty in the information could lead to inadequate management of the Estuary General Fishery.

The proposed review process incorporates several important aspects which are:

- what factors to review
- recognising the different possible outcomes
- actions required depending upon different outcomes
- allowance for modifications to be made to the strategy depending upon results

- contingencies for unpredictable events
- regular review and update of performance indicators and trigger points in light of on-going development of the strategy and research outcomes.

If these wide ranging aspects are diligently incorporated into the review process, the draft FMS should work properly.

c) Relationship between research, performance indicators and review

An important aspect of assessing the research and monitoring strands of the draft FMS is whether the link between research, performance indicators and review is clear. Figure E2 shows a possible pathway by which the results of research and reviews feed back into each other to produce better management responses. For example, as research provides improved stock assessments for primary species, tighter or even different performance indicators and trigger points can be set. Similarly, as trigger points are reached the review process may discover knowledge gaps that have not previously been identified and require research to address. The dual feedback system of these links between research and review is crucial in the future development and better management of the Estuary General Fishery.

One important element that has not been clearly addressed in the draft FMS is how to measure whether relevant results of research have been adopted into the draft FMS. Chapter C outlines events that will trigger a review of the draft FMS. It includes contingencies for unpredictable events, one of which is the results of research programmes. However, this is entirely couched in terms of unpredictable circumstances. Therefore, research results can only trigger a review of the draft FMS under contingency circumstances determined by either the Minister or the Estuary General MAC. Under these circumstances there is a danger that significant recommendations of research to improve the draft FMS could be overlooked simply because they were not deemed to require contingency measures. A more useful approach to incorporating research outcomes is to include in the draft FMS either an annual or bi-annual review by the MAC of the recommendations of research programmes relevant to the Estuary General Fishery. Furthermore, justification should be given as to why recommendations of research programmes were not adopted. The proportion of research programme outcomes reviewed (of the total number produced within a review period) would be one appropriate measure to monitor the incorporation of research results. In addition, a list of the research outcomes reviewed, adopted or not adopted and their justification would be another useful measure.

Whilst the draft FMS does suggest links between the research and review components of the draft FMS they are not made explicitly clear. A useful flow diagram as illustrated in Figure E2 would clarify these or similar relationships intended in the draft FMS.

d) Timetable for developing information

The draft FMS details monitoring programmes for the Estuary General Fishery in Table C10. Most have been timetabled to begin in 2002, after the new draft FMS begins to be implemented. As many of the knowledge gap areas require the use of long term data sets, the sooner monitoring and research programmes are instigated, the sooner more accurate stock and fishing pressure estimates can be determined.

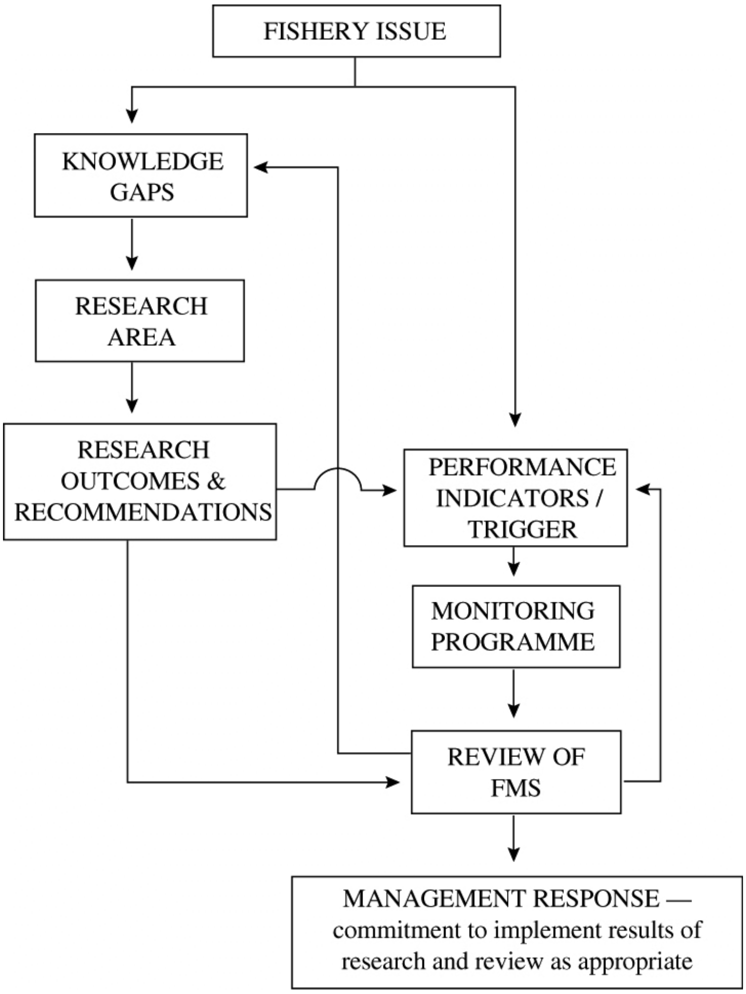

Figure E2. Flow diagram showing links between research, performance indicators and review.

CHAPTER F. IMPACT ON THE BIOPHYSICAL ENVIRONMENT

The purpose of this chapter is to focus on aspects of the general environment of estuaries, beyond those fish and invertebrates that are caught as a result of the fishery. It describes the major types and extents of habitats commonly found in NSW estuaries and describes how each of these and the fauna that depend on them, may be affected by the Estuary General Fishery. It assesses the effectiveness of control measures outlined in the draft FMS to minimise these potential impacts, and the effectiveness of the monitoring and research programs proposed in the draft FMS to provide the information required to adequately assess the potential impacts of the Estuary General Fishery. Physical aspects, such as water and air quality, are also discussed both in terms of the impact that fishing has on them, and how they affect the fishery.

1. Biodiversity and Habitat Issues

At least 690 waterbodies join the Tasman Sea along the NSW seaboard, although the vast majority of these are rarely open to the sea (Williams *et al.,* 1998). Approximately 130 have a water area greater than 0.05 km^2, and the Estuary General Fishery is, or has been, conducted to some degree in most of these larger estuaries (Table F1). The estuaries cover a range of shapes, sizes and geological origins (see Appendix F1), and these factors are largely responsible for determining the distribution and abundance of physical habitats and ecological assemblages. 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 habitats, particularly seagrasses, mangroves, saltmarsh and intertidal sand and mudflats. These habitats are briefly described below (and detailed in Appendix F2), as well as the potential impacts on them due to the fishery and measures within the draft FMS to mitigate those impacts. Marine protected areas and similar such habitats are also discussed in this section as they form part of the ecosystem and habitat management section of the draft FMS.

There have been some attempts to map the distribution of the major vegetated habitats within estuaries in NSW (West *et al.,* 1985; Bucher and Saenger, 1991), however, they do not include other habitats such as rocky reefs or algal beds. Furthermore, information about the distribution of fishing grounds is not yet available (although the declaration of recognised fishing grounds and designated landing sites is proposed in the draft FMS), nor is information available to determine the importance of the above-mentioned 'other' habitats to the assemblages within them or that use them occasionally. Add to that the fact that there is almost no data examining the effects of the methods used in the fishery on habitats and the assemblages within them, and it makes any assessment of the fishery and the draft FMS very limited. As such, commercial fishing data is presented for each estuary in an attempt to determine the degree of pressure that the fishery could exert upon habitats and the fauna that rely upon them. In the absence of data, this assessment uses fishing closures as gazetted by NSW Fisheries, habitat distributions mapped by NSW Fisheries, and principal feeding and roosting grounds for birds as mapped by the Environment Protection Authority (formerly the State Pollution Control Commission) to further examine the degree of protection afforded to habitats and fauna. The limitations of this method are acknowledged, but it is only an indicative, not absolute measure of those estuaries whose biodiversity and habitats are thought to be under the greatest pressure from the fishery.

Table F1 summarises the areal extent of the major vegetated habitats within each estuary, based on a mapping program that was done by NSW Fisheries between 1981 and 1985 (West *et al.,* 1985). It also includes other natural features, such as the existence of nature reserves and National Parks, and use by birds protected under international treaties that could be affected by the fishery. NSW Fisheries is currently reviewing and updating this information, which will also include the distribution of rocky shores. More recent data on the distributions of the major vegetated habitats are also available in numerous Estuary Process Studies done as part of the Department of Land and Water Conservation's Estuary Management Program, and studies done in relation to some large scale developments. The data is of limited use, however, as the process studies only utilised field observations and did not provide any quantitative data, and the other studies only provide information about a very limited number of areas.

a) Major estuarine habitats

i) Seagrasses

Brief description

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 substratum and produce flowers and seeds, similar to terrestrial grasses (Keough and Jenkins, 1995). Six species of true seagrass are found within NSW and there is a general increase in the number of species from north to south (West, 1989). *Zostera capricorni* is the most widespread species, occurring in most estuaries and for considerable distances upstream. Strapweed (*Posidonia australis*) is the other major species in terms of area but is found in only 16 estuaries and prefers areas where salinity is high and nutrient levels are low (Roy *et al.,* 2001)

Distribution

West *et al.* (1985) mapped the distribution of seagrasses and other aquatic vegetation within NSW and their findings are summarised in Table F1. Almost all estuaries (82%) have some cover of seagrass, although four estuaries account for more than 50% of the total area of seagrass in NSW: Wallis Lake 30%; Clarence River 15%; Lake Macquarie 10%; and Tuggerah Lakes 7%. These and other barrier estuaries contain most of the larger seagrass beds, the exception being 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. Whilst accounting for only a small percentage of the total amount of seagrass for the State, several of these smaller intermittent estuaries have the highest percentage cover of seagrass of all estuaries. In particular, Toubouree Lake, Back Lagoon, Bournda Lagoon, Towradgie Creek and Merimbula Lake have greater than 50% seagrass coverage. On a regional basis, Regions 4 and 6 support the largest extent of seagrass, but when compared to water area, Region 2 has the largest percentage cover (approximately 21%).

Table F1. A list of NSW estuaries and various physical (Roy *et al.,* 2001), biological (West *et al.,* 1985) and fisheries attributes (NSW Fisheries Database; SPCC/EPA, 1984 - 1995) used to assess the potential effects of the Estuary General Fishery on the biophysical environment.

Numbers in parentheses in NP/NR are those with marine protected areas. NB: estuaries without fishing data may have been fished, but their catch included under larger systems.

FISHING REGION	ESTUARY			HABITATS				FISHING METHOD & EFFORT (total days from 1985-2000)						FISHING CLOSURES		
	Name	Type	Water area (km^2)	Mangrove area (km^2)	Seagrass area (km^2)	Saltmarsh area (km^2)	National Parks or Nature Reserves	Hand	Hauling	Meshing	Prawning	Trapping	Total	Type	Preserve wader habitat?	Preserve other habitats?
1	TWEED RIVER	3	17.916	3.091	0.331	0.213	3 (3)	121	11899	6613	170	17549	36352	7	n	n
	CUDGEN LAKE	5	1.427	0.094	0	0.561	1 (1)							7	y	y
	CUDGERA CREEK	4	0.238	0.138	0.016	0.016	1 (1)							6	y	y
	MOOBALL CREEK	3	0.492	0.053	0.013	0	1 (1)							6	y	y
	BRUNSWICK RIVER	3	2.222	0.018	0.816	0.056	2 (2)		61	68		167	296	6	y	y
	BELONGIL CREEK	4	0.126	0.050	0	0.054	1 (1)							6	y	y
	TALLOW CREEK	4	0.082	0	0	0.003								6	y	y
	BROKEN HEAD CREEK	4	0.050	0	0	0.036	1							6	y	y
	RICHMOND RIVER	3	19.071	4.949	0.189	0.099	3 (1)	1159	16212	6693	162	10203	34429	7	n	n
	EVANS RIVER	3	1.787	0.330	0	0.375	1	22	78			20	120	4	y	y
	JERUSALEM CREEK	4	0.214	0	0	0.021	1 (1)							6	y	y
			43.625	8.723	1.365	1.434		1302					71197			
2	CLARENCE RIVER	3	89.243	5.208	19.072	1.954	2 (1)	191	39516	40636	39663	61721	181727	7	n	n
	SANDON RIVER	3	1.414	0.533	0.028	0.258	2 (1)		81	600		2141	2822	4	y	y
	WOOLI WOOLI RIVER	3	1.900	0.493	0.028	0.531	2 (1)	27		14		624	665	7	n	n
			92.557	6.234	19.128	2.743		218					185214			
3	STATION CREEK	4	0.306	0	0	0	2 (1)							6	n	na
	CORINDI RIVER	3	0.873	0.189	0.033	0.293	2 (1)			19		28	47	5	y	y
	ARRAWARRA RIVER	4	0.123	0	0.003	0.008								3	y	y
	DARKUM CREEK	4	0.046	0.001	0	0								6	y	y
	WOOLGOOLGA LAKE	4	0.180	0.002	0	0			17	24	9	53	103	6	y	y
	HEARNS LAKE	4	0.106	0.044	0	0								6	y	y
	MOONEE CREEK	3	0.333	0.036	0.004	0.073	1		30	16	2	151	199	6	y	y
	COFFS HARBOUR CREEK	3	0.308	0.167	0.018	0		24	300	56		746	1126	6	y	y

Table F1 (cont)

FISHING REGION	**ESTUARY** Name	Type	Water area (km²)	**HABITATS** Mangrove area (km²)	Seagrass area (km²)	Saltmarsh area (km²)	National Parks or Nature Reserves	**FISHING METHOD & EFFORT (total days from 1985-2000)** Hand	Hauling	Meshing	Prawning	Trapping	Total	**FISHING CLOSURES** Type	Preserve wader habitat?	Preserve other habitats?
3	BOAMBEE CREEK	3	0.573	0.066	0.011	0.158		3	13	13		1730	1759	5	y	y
cont	BONVILLE CREEK	3	1.244	0.053	0.008	0.148		13	24	151		1659	1847	5	y	y
	BELLINGER RIVER	3	6.576	0.847	0.059	0.029		48	1202	2179		4590	8019	7	y	y
	DALHOUSIE CREEK	4	0.051	0	0	0								nc	n	na
	OYSTER CREEK	4	0.084	0	0	0								nc	n	na
	DEEP CREEK	4	1.021	0.008	0.007	0.604		4	4	545		2125	2678	7	y	y
	NAMBUCCA RIVER	3	7.738	0.779	0.224	1.034		44	3479	5087	10	17410	26030	7	y	y
	MACLEAY RIVER	3	18.169	5.201	1.097	3.652	1	500	1602	8033	39	25266	35440	7	n	n
	SALTWATER CREEK	4	0.078	0	0	0	1 (1)							nc	n	na
	SOUTH WEST ROCKS CREEK	4	0.118	0.528	0.024	0.141								5	y	y
	KOROGORO CREEK	3	0.221	0.013	0	0.014	1 (1)							4	y	y
	KILLICK CREEK	4	0.198	0	0.011	0.008	1							6	y	y
	HASTINGS RIVER	3	17.287	2.078	1.141	0.804	2 (1)	337	10655	9868	355	17375	38590	7	n	n
	LAKE INNES/LAKE CATHIE	4	5.821	0.001	0.007	5.972	1 (1)		1090	1673	174	2216	5153	6	y	y
	CAMDEN HAVEN RIVER	3	27.833	0.873	6.336	0.780	1 (1)	34	6795	12523	3885	37307	60544	7	n	n
			89.287	10.886	8.983	13.718		983					181535			
4	MANNING RIVER	3	25.348	3.582	0.329	0.721		199	19151	13996	1506	10782	45634	7	y	y
	KHAPPINGHAT CREEK	4	0.960	0	0.019	0.002	1 (1)							4	y	y
	WALLIS LAKE	3	85.559	0.786	30.785	4.005	7	960	41859	35310	19153	74946	172228	7	n	n
	SMITHS LAKE	4	9.371	0	2.080	0.003	1	429	3779	4689	852	913	10662	7	n	n
	MYALL LAKES	5	101.933	0	0.079	0	1 (1)							7	n	n
	KARUAH RIVER	2	3.876	3.479	0.380	4.828								7	n	n
	MYALL RIVER	3	7.541	1.021	2.736	1.784	1 (1)							7	n	n
	PORT STEPHENS*	2	125.970	23.260	7.453	7.719	4 (4)	965	30320	35867	13193	39593	119938	7	n	n
	HUNTER RIVER	3	30.421	15.481	0.153	5.049	2	390	2599	10205	233	15635	29062	7	n	n
	LAKE MACQUARIE	3	115.112	0.998	13.391	0.705		73	30964	21439	1216	468	54160	7	n	n
	TUGGERAH LAKES	3	70.299	0	11.619	0.007	2	143	27783	33772	19438	2456	83592	7	y	y
	WAMBERAL LAGOON	4	0.495	0	0.245	0	1							2	y	y
	TERRIGAL LAGOON	4	0.258	0	0.046	0								2	y	y

Table F1 (cont)

FISHING REGION	ESTUARY Name	Type	Water area (km^2)	HABITATS Mangrove area (km^2)	Seagrass area (km^2)	Saltmarsh area (km^2)	National Parks or Nature Reserves	FISHING METHOD & EFFORT (total days from 1985-2000) Hand	Hauling	Meshing	Prawning	Trapping	Total	FISHING CLOSURES Type	Preserve wader habitat?	Preserve other habitats?
4	AVOCA LAKE	4	0.649	0	0.161	0								2	y	y
cont	COCKRONE LAKE	4	0.320	0	0	0								2	y	na
			578.112	48.607	69.476	24.823		3159					515276			
5	BRISBANE WATERS	3	27.241	1.635	5.490	0.918	3							2	y	y
	HAWKESBURY RIVER	2	100.005	10.654	0.470	1.126	5 (3)	270	13339	17978	361	29305	61253	7	n	n
	PITTWATER	2	17.314	0.180	1.934	0.026	1 (1)							7	y	y
	NARRABEEN LAGOON	4	2.181	0	0.468	0	1		3	15		1	19	2	y	y
	DEE WHY LAGOON	4	0.238	0	0.034	0.044	1							2	y	y
	HARBORD LAGOON	4	0.058	0	0	0								2	y	na
	MANLY LAGOON	4	0.086	0	0.004	0								2	y	y
	PORT JACKSON	2	49.667	0.914	1.286	0.073	4	23	9514	4342	130	4177	18186	7	y	n
	BOTANY BAY	1	49.100	3.996	3.403	1.601	1 (1)	207	18236	12305	244	10556	41548	7	y	y
	GEORGES RIVER	2	12.466	2.038	0.268	0.247								7	n	n
	PORT HACKING	2	11.298	0.328	0.869	0.106	1 (1)	780	96	39	7	65	987	2	y	y
			269.654	19.745	14.226	4.141		1280					121993			
6	TOWRADGIE CREEK	4	0.060	0	0.036	0								1	y	y
	PORT KEMBLA HARBOUR	3	0.098	0	0	0								4	na	na
	LAKE ILLAWARRA	3	36.270	0	6.116	0.203	1	2024	17058	14816	17516	2828	54242	7	n	n
	BENSONS CREEK	4	0.087	0	0.028	0	1					42	42	1	y	y
	MINNAMURRA RIVER	3	0.601	0.484	0.232	0.197	1	27		22		152	201	5	y	y
	WRIGHTS CREEK	4	0.033	0	0.003	0								nc	n	n
	WERRI LAGOON	4	0.113	0	0.017	0								6	y	y
	CROOKED RIVER	3	0.221	0	0.004	0								6	y	y
	SHOALHAVEN RIVER	3	12.889	0.670	0.340	0.146	1	449	15087	10915	541	5545	32537	7	n	n
	CROOKHAVEN RIVER	3	7.883	2.806	0.678	1.396	1							7	n	n
	LAKE WOLLUMBOOLA	4	6.211	0	1.145	0			16	387	354	27	784	7	n	n
	JERVIS BAY	1	102.129	1.250	9.061	2.330	3	51	7794	101	114	249	8309	7	n	n
	ST GEORGES BASIN	3	38.859	0.252	8.538	0.036	1	459	9954	6458	3133	1316	21320	7	n	n
	SWAN LAKE	4	4.082	0	0.587	0			283	275	73	431	1062	7	n	n

Table F1 (cont)

FISHING REGION	ESTUARY			HABITATS				FISHING METHOD & EFFORT (total days from 1985-2000)						FISHING CLOSURES		
	Name	Type	Water area (km^2)	Mangrove area (km^2)	Seagrass area (km^2)	Saltmarsh area (km^2)	National Parks or Nature Reserves	Hand	Hauling	Meshing	Prawning	Trapping	Total	Type	Preserve wader habitat?	Preserve other habitats?
6 cont	BERRARA CREEK	4	0.124	0	0.006	0	1							6	y	y
	NERRINDILLAH CREEK	4	0.065	0	0.005	0								nc	n	n
	LAKE CONJOLA	3	4.280	0	0.527	0.013		50	889	780	51	347	2117	7	y	y
	NARRAWALLEE INLET	3	0.456	0.378	0.014	0.091	1			39		111	150	nc	n	n
	MOLLYMOOK CREEK	4	0.022	0	0.009	0								1	y	y
			214.483	5.840	27.346	4.412		3060					120764			
7	BURRILL LAKE	3	4.206	0	0.508	0.157		54	751	928	4	476	2213	7	y	y
	TOUBOUREE LAKE	4	1.380	0	1.199	0.010				215		160	375	6	y	y
	TERMEIL LAKE	4	0.445	0	0.070	0			2	242		150	394	nc	n	n
	MEROO LAKE	4	0.635	0	0.115	0			11	79		258	348	nc	n	n
	WILLINGA LAKE	4	0.282	0	0.004	0								5	y	y
	KIOLOA LAGOON	4	0.637	0	0.003	0.006								nc	n	n
	DURRAS LAKE	4	3.214	0	0.509	0.046	1		316	971	200	362	1849	7	y	y
	CLYDE RIVER	2	19.898	2.318	0.092	1.017		71	381	1770	349	1273	3844	nc	n	n
	CULLENDULLA CREEK	3	0.239	0.916	0.064	0.006								nc	n	n
	BATEMANS BAY	1	5.301	0	0.071	0								nc	n	n
	TOMAGA RIVER	3	1.214	0.210	0.046	0.351			1	350	2	101	454	6	y	y
	CANDLAGAN CREEK	3	0.067	0.021	0.016	0.031								4	y	y
	MORUYA RIVER	3	4.222	0.380	0.644	0.674		14	1026	407	247	573	2267	7	y	y
	CONGO CREEK	4	0.128	0	0	0			33	49		174	256	6	y	na
	MERINGO CREEK	4	0.097	0	0	0								nc	n	na
	COILA LAKE	4	6.341	0	1.862	0.317		74	1165	1575	7828	431	11073	7	n	y
	TUROSS LAKE	3	13.299	0.566	0.452	0.401		14	3221	3926	1018	2043	10222	7	n	y
	LAKE BRUNDEREE	5	0.184	0	0.064	0.246				9		40	49	nc	n	n
	LAKE BROU	4	1.663	0	0.078	0.250		2	318	560	2842	139	3861	nc	n	n
	LAKE DALMENY	4	1.393	0	0.294	0.055		1	198	396	136	39	770	2*	y	y
	KIANGA LAKE	4	0.124	0	0.011	0.033			1	6	12	112	131	nc	n	n
	WAGONGA INLET	3	6.276	0.249	1.484	0.056		25	33	4	11	37	110	2	y	y
	NANGUDGA LAKE	4	0.461	0	0.120	0.115			4	155	13	5	177	7	n	n

Table F1 (cont)

FISHING REGION	ESTUARY Name	Type	Water area (km^2)	HABITATS Mangrove area (km^2)	Seagrass area (km^2)	Saltmarsh area (km^2)	National Parks or Nature Reserves	FISHING METHOD & EFFORT (total days from 1985-2000) Hand	Hauling	Meshing	Prawning	Trapping	Total	FISHING CLOSURES Type	Preserve wader habitat?	Preserve other habitats?
7	CORUNNA LAKE	4	1.669	0	0.179	0.033			249	762	472	297	1780	nc	n	n
cont	TILBA TILBA LAKE	4	0.640	0	0	0			69	173	1931	141	2314	nc	n	na
	LITTLE LAKE	4	0.100	0	0.003	0.047			8	8	22	6	44	6	y	y
	WALLAGA LAKE	3	7.805	0	1.343	0.295	1	78	1127	3244	747	1594	6790	7	y	y
	BERMAGUI RIVER	3	1.390	0.434	0.338	1.066		0	32	369	48	345	794	7	n	n
	BARRAGOOT LAKE	4	0.377	0	0.049	0.053			7	82	3	50	142	nc	n	n
	CUTTAGEE LAKE	4	1.410	0	0.430	0.076			17	655	47	139	858	no haul	y	y
	MURRAH LAGOON	3	0.816	0	0.016	0.109			21	89		346	456	nc	n	n
	BUNGA LAGOON	4	0.094	0	0	0.018								nc	n	n
	WAPENGO LAGOON	3	3.191	0.409	0.360	0.319	1		3	360		50	413	7	y	y
	MIDDLE LAGOON	4	0.331	0	0.081	0.011	1		16	152	95	19	282	nc	n	n
	NELSON LAGOON	3	0.713	0.271	0.114	0.063	1	10	124	57	8	50	249	nc	n	n
	BEGA RIVER	3	2.657	0	0.304	0.411	1		1463	1444	21	1151	4079	7	n	n
	WALLAGOOT LAKE	4	3.672	0	0.647	0.014	1		21	893		164	1078	6	y	y
	BOURNDA LAGOON	4	0.058	0	0.043	0	1							5	y	y
	BACK LAGOON	4	0.315	0	0.204	0.018	1			11			11	nc	n	n
	MERIMBULA LAKE	3	4.556	0.377	2.297	0.629		90		33		13	136	6	y	y
	PAMBULA LAKE	3	12.949	0.449	0.868	0.188	1	877	53	1194	11	293	2428	7	n	n
	CURALO LAGOON	4	0.708	0	0.058	0.116		1	63	122		58	244	nc	n	n
	TWOFOLD BAY	1	77.049	0	0.026	0.008		9	1383	33	7	141	1573	7	n	n
	NULLICA RIVER	4	0.244	0	0.020	0		390		25		49	464	nc	n	n
	TOWAMBA RIVER	3	1.427	0.900	0.027	0.009		2	53	276		252	583	7	n	n
	FISHERIES CREEK	4	0.024	0	0.046	0.042	1							nc	n	n
	WOMBOYN RIVER	3	3.616	0	0.237	0.483	1	6		4		29	39	6	y	y
	MERRICA LAKE	4	0.106	0	0	0	1							4	y	na
	NADGEE RIVER	4	0.162	0	0	0	1							4	y	na
	NADGEE LAKE	4	0.968	0	0.075	0	1							4	y	y
			198.753	7.500	15.471	7.779		1718					63150			

Table F1 (cont)

Estuary Type (Roy *et al.*, 2001)	**Methods**
1 = oceanic embayment	Hand = handgathering
2 = tide dominated estuary	Hauling = Prawn seine, general purpose, trumpeter whiting, garfish, pilchard, anchovy, bait, prawn haul, and bullringing (garfish) nets
3 = wave dominated estuary	Meshing = Pound (figure six), bottom set, top set, splashing and flathead nets
4 = intermittently closed estuary	Prawning = Set pocket net and running net
5 = freshwater	Trapping = Fish, crab,and eel traps

Closure Types (at July 2001: NB, these are a summary of the true closures and should not be sourced).

1 = Closed to commercial fishing

2 = Closed to all nets and traps (* Lake Dalmeny closed to haul nets and all traps)

3 = No nets or traps except for recreational nets

4 = Traps permitted

5 = Traps and dip and scoop nets permitted

6 = Recreational nets and all traps permitted

7 = Mixture of gear, time and place

nc = no closure gazetted, refer to Part 3 of the *Fisheries Management (General) Regulation 1995* , for more detail

* denotes that the figures for Port Stephens include those from Myall Lakes and River and Karuah River

Summary of importance

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 (Harlin, 1975; Pollard and Moriarty, 1991)
- restrict water movement which in turn allows for the settlement of plankton (Keough and Jenkins, 1995)
- trap and recycle nutrients (Hemminga *et al.,* 1991)
- provide foraging habitat for many species of birds, particularly cormorants, herons, swans and ducks.

Some studies have also reported the importance of detached seagrass supporting abundant fish communities adjacent to the beaches that 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 consume seagrass directly (Klumpp *et al.,* 1989). Rather, as stated above, its importance to most fauna and other flora is in the provision of food and habitat.

Potential effects of the fishery

The fishery could have numerous potential effects on seagrass beds and their inhabitants, although as stated above, there is no data to determine the extent or magnitude of these impacts (potential effects of each method are discussed in more detail in Chapter F section 1(c)). Furthermore, many of the effects are likely to be indirect because of the role that seagrass plays in the provision of nutrients for estuarine food webs, stabilising sediments and restricting water movement. Some of the more direct effects could include:

- the removal of epiphytes, periphyton or epifauna from seagrass blades
- removal of or damage to seagrass blades or shoots;
- reducing growing conditions by increasing turbidity or destabilising sediments
- introducing contaminants.

Assessment of management responses proposed in the draft FMS

Table F1 suggests that existing closures offer very little protection to seagrass beds, particularly in the larger estuaries where effort is focussed. To address this, the draft FMS proposes to implement the following management responses:

- prohibit the use of hauling nets over beds of strapweed seagrass (*Posidonia australis*)

- prohibit the use of all prawn hauling and prawn seining methods over seagrass areas
- identify designated landing sites for fish hauling nets in estuaries where seagrass exists around shoreline areas
- reduce the maximum allowable length of fish hauling nets to 500 m and restrict the number of shots per day
- develop a code of conduct with respect to operating on or near river banks, mangroves, seagrasses or saltmarsh habitats
- involve the Estuary General Management Advisory Committee in the development of habitat management policies and habitat rehabilitation works
- modify the use of fishing methods that have detrimental impact on fish habitat.

These measures have adopted a precautionary approach in the absence of any data about the effects of the fishery on seagrass. By restricting the types of techniques that can be used in seagrass beds, and restricting the total area of seagrass available to fishing, overall they should reduce the extent and magnitude of potential impacts. The establishment of designated landing sites and beds closed to prawn hauling and seining provide an opportunity to quantify the proportion of seagrass within each estuary that is fished and by which methods. This could assist in prioritising those beds in which to establish research programs, and/or justify the need or otherwise for those programs. It may also aid the determination of seagrass beds and other habitats that require rehabilitation or warrant inclusion in marine protected areas.

The proposed measures appear to acknowledge that hauling is probably having an impact on seagrass and/or its inhabitants, and the draft FMS proposes to modify methods that have a detrimental impact, yet there are no details of the research programs proposed in the draft FMS. As such, it is not possible to determine their adequacy. When determined, the programs should be independently reviewed at both the planning and reporting stages.

ii) Mangroves

Brief description

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 areas 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). Other adaptations to survive in the intertidal zone include: aerial roots (called pneumatophores) which arise vertically out of the sediment and absorb oxygen and other gases; increasing the numbers of pneumatophores in sub-optimal growing conditions; secreting salt through glands in their leaves; excluding salt via a filtering system; or accumulating salt in old leaves (Hutchings and Saenger, 1987).

Distribution

Mangroves are not as widespread as seagrasses because of their reliance upon more marine conditions. Less than 50% of the larger estuaries support mangroves (Table F1). Of over thirty species known in Australia, five have been recorded in NSW, and there is a decline in the number of species moving from north to south (West *et al.,* 1985). Grey mangroves (*Avicennia marina*) are the most widespread species, found in all but one of the estuaries known to support mangroves, followed by river mangroves (*Aegiceras corniculatum*). Milky mangroves (*Excoecaria agallocha*) are found north of Manning River, spider mangroves (*Rhizophora stylosa*) north of Corindi River and large-leafed mangroves (*Bruguiera gymnorrhiza*) north of Clarence River. They are rarely recorded from estuaries that are intermittently open to the sea, which comprise about 50% of all estuaries (Table F1). Furthermore, six estuaries, Port Stephens (25%), Hunter River (15%) Hawkesbury River (10%), Macleay, Clarence and Richmond Rivers (all 5%) account for 65% of the total area of mangroves recorded in NSW. These estuaries are all located in the central and northern regions of the State, are large in terms of surface area and all are permanently open to the sea.

Summary of importance

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). Mangroves are reported to:

- provide organic materials that form the basis of detrital food chains (West, 1985; Robertson and Alongi, 1995)
- stabilise sediments (West, 1985; Robertson and Alongi, 1995);
- recycle nutrients (Robertson and Alongi, 1995);
- provide feeding and roosting habitat for numerous species of birds, particularly pied cormorants and mangrove honeyeater, a vulnerable species (Chapman and Underwood, 1995)
- provide habitat for a variety of fish and invertebrates (e.g. SPCC, 1981a & b; Pollard and Hannan, 1994; Robertson and Alongi, 1995)
- act as a filter system between the land and aquatic environment (NSW Fisheries, 1999a).

Potential effects of the fishery

Mangroves represent a transitional habitat between the land and the sea, and are less vulnerable to impacts due to the fishery. The shallow waters fronting mangroves and the soft sediments that mangroves grow in prohibit the use of most methods adjacent to mangroves, and that are not used as access points. Hauling is rarely done in front of mangroves because of the limited mobility in front of mangrove forests and the soft sediments prevent effective hauling. When hauling is done in front of mangroves, it usually involves a back net set parallel to the shore in about one metre of water. Nets are retrieved into the back net preventing the need to access the shore. Meshing and trapping are common in the channels and flats adjacent to mangroves, but again do not necessitate entering mangroves. Beyond the immediate activity of the fishery, it is likely that in the past, the establishment of infrastructure for the fishery probably affected some areas of mangroves, for example for boat ramps, jetties and marinas. Such development is now strictly controlled, and also serves more of the community than just fishers. Most of the potential impact associated with mangroves is likely to be on fauna that inhabit the forest, particularly nesting and roosting birds, and infauna and epifauna of the mudflats and channels adjacent to mangroves. The movement of nets across the substratum and the placement and removal of traps could also remove flora and fauna, or prevent their establishment, which may otherwise have enhanced the complexity of the largely unvegetated substratum.

Assessment of management responses proposed in the draft FMS

The management responses to minimise the impacts of the fishery on mangroves are primarily the same as for seagrasses. The techniques, and the way they are used adjacent to mangroves, suggests that the fishery is unlikely to be having an impact on them, although it is possible that the fauna within and adjacent to mangroves may be affected. There are no research programs proposed to determine the effects of the fishery on mangroves or their inhabitants, but given the perceived lack of impacts, the proposed code of conduct for operating in those areas may be sufficient to minimise any potential impacts. The scientific observer program that is proposed in the draft FMS, which should be independent of the fishery, should be used to determine if further studies are warranted. For example, it may reveal that operating in front of and accessing the foreshore of mangroves is far more widespread, and thus potentially causes more damage and disturbance, than perceived in this assessment.

iii) Saltmarsh

Brief description

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, 1995). 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 and are more common in barrier and coastal lagoons than other estuaries. Saltmarshes are relatively flat, with shallow pools separated by mounds that are usually vegetated by grasses (Poaceae), saltbushes (Chenopodiaceae), rushes (Juncaceae) and sedges (Cyperaceae), and most assemblages contain only a few species (Morrisey, 1995).

Distribution

Saltmarsh is widely distributed and is reported in 92 estuaries in NSW (Table F1). In, 1985, the total area occupied by saltmarsh within NSW was approximately 57 km^2 (West *et al.,* 1985), and as with other estuarine habitats, only a few estuaries account for more than 50% of the total cover for the State. 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. All of those estuaries except Lake Cathie are in Region 4.

Summary of importance

There has been little work done in Australia on the value of saltmarsh and extrapolations from studies in the Northern Hemisphere are not possible because those 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 role to mangroves in that they are thought to:

- be 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, 1995; Zann, 1995; Zann, 1996)

- provide habitat for some terrestrial species of birds, such as chats and parrots, and several birds of prey, such as brahminy kites, whistling kites and harriers
- filter water draining from the land before it enters estuaries (Adam *et al.,* 1985)
- be 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, 1995; Adam *et al.,* 1985)
- provide habitat for juvenile fish and invertebrates (Thomas and Connolly, 2001; Connolly *et al.,* 1997; Williams *et al.,* 1995; Morton *et al.,* 1987).

Potential effects of the fishery

The extent of fishing adjacent to saltmarsh is unknown. Like mangroves, the main potential effects are likely to arise from hauling, which could involve accessing the foreshore, and general disturbance due to boating or foreshore access. This access would generally be restricted to parking boats on the foreshore to retrieve nets, and could entail trampling the seaward edge of the saltmarsh. Continuous trampling of saltmarsh and the associated compaction of the substratum can cause a decline in the extent of saltmarsh plants because it destroys plants and prevents them from recolonising the area. Compaction makes the soil dense and lowers the height of the ground such that it retains water more often than even saltmarsh plants can tolerate. Crabs, snails and other fauna could also be directly affected, and birds and small mammals could be disturbed during feeding and roosting.

Assessment of management responses proposed in the draft FMS

Given the limited capacity for the fishery to affect saltmarsh and its inhabitants, the responses proposed in the draft FMS, which are generally the same as for seagrass and mangroves, are likely to prove effective in minimising any future potential impacts. As with mangroves and seagrass, the definition of designated landing sites should be used to quantify the areas of saltmarsh that are used on a regular basis, and that information used to determine the need or otherwise for research programs.

iv) Unvegetated soft substrata

Brief description

Unvegetated soft substrata, including intertidal and subtidal mudflats and sandflats, are the most common habitat in estuaries yet are largely ignored because of their lack of physical structure. Unvegetated habitats have not been studied much in Australia (Inglis, 1995), possibly because of their lack of habitat complexity and readily identifiable features. Intertidal shores can comprise both sandflats and mudflats, the major difference being the relative proportions of sand, silt, clay and organic matter in the sediment and deoxygenation of the sediments in mudflats. Sandflats are generally found near the mouths of estuaries, where there are stronger currents and wave action, which deposit marine sands into the lower reaches. 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 (DPWS, 1992).

Distribution

The distribution of unvegetated habitats has not been included in estuarine inventories done in the past in NSW, rather it has been implied during the mapping of seagrass and algal beds (e.g. Bucher and Saenger, 1991; West *et al*., 1985; Bell and Edwards, 1980). Measures of water area and seagrass in those inventories would suggest there is in excess of 1300 km^2 of bare substratum in NSW estuaries, or approximately eight and a half times the area of seagrass. 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 (S. Carter, NSW Fisheries, pers. comm.). Most such areas are found in the lower parts of estuaries where sandflats are utilised, and in the upper parts where mudflats dominate.

Summary of importance

Soft substrata are inhabited by a large variety (often hundreds of species) of invertebrates including polychaete worms, crustaceans, molluscs, ascidians and sponges 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, benthic organisms can be broadly classified according to their method of feeding and include suspension-feeders, deposit-feeders, browsers, predators and scavengers (Morrisey, 1995). Bare substrata are also utilised by a variety of larger invertebrates, such as crabs and prawns, as well as fish and birds. Shallow intertidal sediments are particularly important for wading birds. Despite being broadly referred to as unvegetated sediments, soft substrata can also include microscopic and drifting macroalgae, which provide important food and refuge for fauna.

Potential effects of the fishery

Due to its vast extent, all of the methods used in the fishery could be done in areas of bare substratum, from handgathering in the lower reaches to crab and eel trapping in the upper reaches. The placement, settling, scraping or retrieving of nets across the substratum could result in any combination or all of the following effects:

- damage or remove flora and fauna, thereby reducing habitat complexity
- destabilise sediments, which could increase erosion, decrease water quality and habitat suitability
- resuspend contaminants
- expose infauna to predators
- transfer material, potentially covering or smothering previously exposed sediment.

Assessment of management responses proposed in the draft FMS

There are no management responses in the draft FMS that focus on minimising the potential effects on areas of bare substratum. Most of the previous research into habitats of estuaries has focussed on vegetated habitats, and suggests they are more important than unvegetated areas because they are reported to support more diverse and abundant assemblages. This dearth of information about areas of bare substratum has translated into a lack of specific responses in the draft FMS. The only response that could inadvertently offer some protection to areas of bare substratum is 1.1e, which proposes to minimise the length of general purpose haul nets. Another response that could affect bare substrata is the code of conduct with respect to operating in the vicinity of migratory bird habitat, primarily intertidal areas. Such areas are likely to represent a very small proportion of bare substrata and overall are unlikely to reduce impacts on the substratum. Overall, the draft FMS is considered to offer limited protection to areas of bare substratum, and at this stage proposes very little to improve our understanding of the effects of the fishery on bare substratum and its fauna.

v) Rocky shores and reefs

Brief description

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 and seawalls (SPCC, 1981a; Pollard, 1989). Other man-made structures that provide a source of hard substratum and are abundant within estuaries and include oyster leases, piers, marinas, bridge footings, channel markers and jetties.

Distribution

As with soft substrata, areas of rocky shorelines and reefs have not been mapped in previous inventories. Natural rocky shores are most common in the drowned river valleys such as Port Jackson, Hawkesbury River, Port Stephens and Port Hacking (Morrisey, 1995). Breakwalls are common at the mouths of many barrier estuaries such as Clarence River and Wallis Lake, and the other man-made structures are common in most estuaries.

Summary of importance

Subtidal and intertidal areas of hard substrata enhance habitat complexity by providing a suitable habitat for settlement and recruitment by marine and estuarine species, particularly algae. 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, 1995a). Man-made hard substratum, such as pontoons and piers, also provide alternate types of substratum and are reported to support different assemblages of epibiota compared to adjacent rocky reefs (Glasby, 1999; Connell and Glasby, 1999). The habitat complexity of rocky reefs and other such habitats:

- provide extensive refuge and feeding opportunities for a variety of fish and invertebrates, particularly soft corals, bryozoans, ascidians and sponges (e.g. Butler, 1995; SPCC, 1981b; Jones and Andrew, 1990; Lincoln-Smith *et al.,* 1992; Lincoln-Smith and Jones, 1995)
- may be utilised on a seasonal basis by juveniles of tropical species of fish that 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)

- provide an important part of the lifecycle of many of the protected species of fish in NSW, including grey nurse shark, blue devil fish, elegant wrasse, black cod, estuary cod, blue groper, Australian bass and estuary perch. Rocky reefs would also have provided habitat for the species of algae thought to be extinct, Bennetts seaweed (*Vanvoorstia bennettiana*).

Potential effects of the fishery

Very few of the methods utilised in the fishery could be used on or near rocky reefs or other hard substrata, primarily because of the susceptibility of the gear to damage. Most of the hauling methods are conducted over soft sediments for ease of hauling and to avoid damaging the gear. Garfish hauling and bullringing could be done over and adjacent to reefs, but these methods do not involve contact with the substratum. Handgathering of pipis and beachworms is primarily conducted on ocean beaches, and also targets yabbies on intertidal sandflats and mudflats of estuaries. It also involves a limited amount of diving for cockles and mussels, but given the selectivity and low use of this method, it is unlikely to significantly affect the substratum or its inhabitants. Prawn set-pocket and running nets, and crab and eel traps, are also set over soft sediments of estuaries. Meshing and handlining are the only methods likely to be used in rocky areas, although even these methods would be utilised very little due to the potential for damage to gear. Some of the effects could include damage or removal of flora and fauna causing a reduction in habitat complexity, exposure of previously discrete species, and reducing the abundance of reef species such as some wrasses.

Assessment of management responses proposed in the draft FMS

There are no responses in the draft FMS that relate directly to hard substratum, but this is not surprising given the lack of effort focussed in those habitats and their limited distribution. The potential to encounter some threatened or protected species of fish in estuarine rocky reefs should be accommodated by the observer program, modifications to the catch and effort returns, prohibiting the capture or sale of threatened or protected fish, and the continued prohibition on the use of explosive devices to take fish. These measures should be adequate to minimise potential impacts on rocky reefs and other areas of hard substratum.

vi) Marine protected areas

Marine protected areas are coastal, estuarine or oceanic areas that are managed to conserve marine biodiversity. They range from small, highly protected areas that focus on species or community protection to large multiple use areas that include complex linkages of ecosystems and habitats. Marine protected areas may include reefs, seagrass beds, rocky platforms, mangroves, estuarine waters, mudflats, saltmarshes, shipwrecks, archaeological sites, and coastal and offshore areas of airspace, seabed and water. Internationally, marine protected areas are considered an important tool for achieving conservation objectives in the marine environment. In NSW, marine protected areas consist of Marine Parks, Aquatic Reserves, Intertidal Protected Areas (Table F2), and marine or estuarine extensions of National Parks or Nature Reserves. Coastal parks and reserves often incorporate the beds of adjoining lakes and estuaries, and may include marine extensions to low water and beyond. Other important habitats within estuaries that are protected, although not referred to as marine protected areas because they are protected under International treaties, include Ramsar wetlands and intertidal areas used by migratory waders. These latter areas are generally referred to as JAMBA (Japan-Australia Agreement for the Protection of Migratory Birds, Birds in Danger of Extinction and their Environment) or CAMBA (Agreement between Australia and the People's Republic of China for the Protection of Migratory Birds and their Environment) habitat.

Marine Parks, aquatic reserves, and intertidal protected areas

Table F2 describes the locations and features of existing Marine Parks, Aquatic Reserves and Intertidal Protected Areas of estuaries in NSW. It is important to note that many of the existing marine protected areas were chosen opportunistically, with little consideration of biodiversity conservation, however, there had not and still have not been any studies done to determine areas of high marine biodiversity or conservation significance. Furthermore, both commercial and recreational fishing are permitted in most reserves, minimising their effectiveness to conserve biodiversity. In the absence of clear definitions and studies, areas that appeared to be unique in terms of estuarine habitats were chosen. For example, both Shiprock and Fly Point Aquatic Reserve are examples of near-vertical rock faces that descend to about 15 m depth, a habitat more common on exposed coasts. Towra Point Auatic Reserve/Nature Reserve has extensive areas of seagrass, mangroves and saltmarsh and is utilised by numerous species of waders and other seabirds in an otherwise heavily urbanised and industrial estuary.

Table F2. Location and features of existing marine protected areas within NSW estuaries.

Where AR = Aquatic Reserve, MP = Marine Park, IPA = Intertidal Protected Area.

Marine Protected Areas			
Name	**Location**	**Size (ha)**	**Habitats or organisms protected**
Fly Point AR (also on National Estate)	Port Stephens	75	Subtidal invertebrates and vegetation. No commercial fishing, restricted recreational fishing
North Harbour AR	Port Jackson	250	Subtidal invertebrates and vegetation. Restricted commercial fishing
Towra Point AR (also on National Estate)	Botany Bay	333	All flora and fauna under the FM Act. Restricted commercial and recreational fishing
Shiprock AR	Port Hacking	2	Subtidal invertebrates and vegetation. Port Hacking is closed to commercial fishing
Jervis Bay MP (also on National Estate)	Jervis Bay	21450	All flora and fauna. Restricted commercial and recreational fishing
Solitary Islands MP (also on National Estate)	Coffs Harbour	71000	Proposed zoning (open to public consultation at time of this report) could see Sanctuary Zones created in Sandon River, Wooli River and Station Ck; Habitat Protection Zones in Sandon, Wooli Wooli and Corindi Rivers, Station, Darkum, Willis, Moonee, Arrawarra and Coffs Creeks and Woolgoolga and Hearns Lake
Sydney Harbour IPA	Port Jackson		Invertebrates (except for lobster and abalone) out to 10m from low water mark

Future Marine Protected Areas will be selected on the basis of the National Representative System of Marine Protected Areas (NRSMPA), a strategy that has been endorsed by the States and Territories for the conservation of Australia's marine resources. The Interim Marine and Coastal Regionalisation for Australia report (ANZECC, 1998) provides the general planning framework for developing the NRSMPA. That report identified six discrete regions in NSW, made up of five coastal bioregions and one marine province: the Tweed-Moreton Shelf, Manning Shelf, Hawkesbury Shelf, Batemans Shelf, Twofold Shelf bioregions; and the Lord Howe province. A Marine Park will be established within each bioregion, as well as numerous Aquatic Reserves. The ANZECC (1999) criteria for selection as marine protected areas are outlined below in Table F3, including the definition and measurements applied to those criteria by NSW Fisheries to select candidate sites for estuarine aquatic reserves in NSW.

At the time of writing this report, the assessments for Hawkesbury and Batemans Shelf were complete and had identified 15 rocky shores and seven estuaries (Table F4) as candidate aquatic reserves (NSW Fisheries, 2001b). As these candidates areas are still under investigation, it is not possible to provide details of the levels of protection afforded the various components, assuming they were to be accepted following the public consultation period. It is proposed, however, that like existing reserves, they would give protection to habitats and would comprise a mixture of harvesting, restricted harvesting and no harvesting areas under future management arrangements.

Table F3. Criteria used to select candidate estuarine aquatic reserves.

(Source: Frances, 2001; ANZECC, 1999).

CRITERIA	DEFINITION	MEASUREMENT
Comprehensiveness	First order geomorphological classification	Estuary type
Representativeness	Second order geomorphological classification	Estuary age
Ecological Importance/Uniqueness	Habitat health; Species diversity	Size, health and number of habitats; Species diversity
International/National Importance	Identified species and associated habitats	JAMBA/CAMBA listing; Threatened species sightings
Productivity	Biomass within each habitat type	Size and number of habitats: Commercial fishing statistics
Vulnerability	Degree of urbanisation	CMA maps
Naturalness	Degree of catchment protection	State Forestry maps

It will be important that future reserves implement areas of no harvesting, including recreational, in order to maximise their effectiveness. Furthermore, during the review of the draft FMS, data from the observer or research programs should be collated to define areas of importance in the lifecycle of species targeted in the fishery. An assessment should be made of the need or otherwise to close those areas or to include them into new or existing protected areas, including the establishment of sanctuary zones.

Table F4. Candidate estuarine aquatic reserves.

(Source: NSW Fisheries, 2001b).

Candidate Estuarine Aquatic Reserves (at July 2001)
Fullerton Cove, Hunter River (also on National Estate)
Lake Macquarie (partial, near the town of Swansea)
Wamberal Lagoon
Dee Why Lagoon
Durras Lake
Wallaga Lake
Nelson Lagoon

Estuarine extensions of national parks or nature reserves

Approximately 95 of the larger estuaries have National Parks or Nature Reserves fringing the estuary, and approximately 35 contain marine protected areas and could thus be affected by the fishery (Table F1).

Ramsar wetlands

The Convention on Wetlands of International Importance, signed in the Iranian town of Ramsar in, 1971, aims to halt the loss of wetlands and to conserve the remaining wetlands. Countries that are parties to the Convention nominate wetlands to be listed as Wetlands of International Importance, and following acceptance they become known as Ramsar Wetlands. Countries are expected to manage their Ramsar sites to preserve their unique ecological characteristics, and in Australia are protected under the EPBC Act. Ramsar wetlands within NSW estuaries include

Kooragang Island Nature Reserve (Hunter River), Myall Lakes (Myall River and Myall Lakes) and Towra Point Nature Reserve (Botany Bay).

JAMBA and CAMBA bird habitat

Other applicable international agreements are the Japan-Australia Agreement for the Protection of Migratory Birds, Birds in Danger of Extinction and their Environment (JAMBA), and the Agreement between Australia and the People's Republic of China for the Protection of Migratory Birds and their Environment (CAMBA). Most of the birds protected under these agreements are migratory waders and seabirds (Appendix F3), and could thus be affected by the fishery. There are approximately 90 species of birds covered under these agreements, but only about 44 of those are likely to occur within and adjacent to estuaries of NSW (Appendix F3). The most numerous are from the families Scolopacidae (curlews, sandpipers and godwits), represented by approximately 23 species, Laridae (terns), five species, and Charadriidae (plovers) with four species. Shearwaters (Procellariidae) and skuas (Stercorariidae) have also been considered even though they are primarily oceanic, because many also utilise coastal waters and large bays. The majority of birds migrate to NSW estuaries during spring and summer and return to the northern hemisphere to breed. The few exceptions are wedge-tailed shearwaters and little terns, which arrive in spring to breed and may remain on our coast all year. Other nomadic species (i.e. occur all year and breed in Australia) include white-breasted sea-eagles, caspian terns, crested terns, painted snipes and white egrets.

Unlike Ramsar, however, there are no listed sites because of the periodic preference for certain areas by such birds. For the purposes of this assessment and to provide some estimate of their occurrence within NSW estuaries, those areas identified by the Environment Protection Authority (EPA) coastal resource atlases were used to determine whether or not existing fishing closures offered protection to those areas (Table F1). These areas are usually located in the lower parts of estuaries in intertidal sandflats and mudflats. It is important to note that the areas defined in the EPA atlases were only for waders that used intertidal areas, and did not consider the species that have much broader feeding ranges, such as sea-eagles or shearwaters. The estuaries thought to be most significant for JAMBA or CAMBA birds are listed below in Table F5.

Potential effects of the fishery on marine protected areas

Despite the name, marine protected areas provide only minimal protection for the flora and fauna within them. Commercial and recreational fishing, albeit slightly restricted in terms of the methods that can be used, is permitted in most of the existing Marine Parks and Aquatic Reserves. It is also permitted in the waters adjacent to and on the foreshores of National Parks, Nature Reserves, all four Ramsar sites and most JAMBA or CAMBA bird habitat. More protection from the fishery is offered to the latter habitats in the form of closures designed to address other issues. As with the other habitats, there is no information about how frequently or intensely these habitats are used, nor of the actual effects that the fishery may have had on them. Potential effects are likely to be similar to those described for the individual habitats.

Assessment of management responses proposed in the draft FMS

There are a limited number of responses in the draft FMS that relate to minimising effects of the fishery on marine protected areas, and probably reflects the limited knowledge about the fishery's interaction with such habitats. The responses include:

- using fishing closures to control the time and area fished to minimise impact on nesting and/or feeding areas of migratory shorebirds and on sensitive shoreline habitat
- using fishing closures to control the time and area fished to protect key fish habitat by defining designated landing sites for fish hauling nets
- developing a code of conduct for the fishery with respect to operating in the vicinity of listed Ramsar wetlands or known JAMBA and CAMBA migratory bird habitat in a manner that minimises disturbance
- participating in the management of marine protected areas in estuarine waters.

These measures should provide adequate protection for these habitats. The most readily implemented response is the establishment of designated landing sites for fish hauling. Whilst designed to minimise effects on seagrass, it should also minimise the amount of foreshore of parks and reserves that can be accessed by fishers, minimising the area of any potential impacts.

The proposal to use closures to minimise effects on migratory shorebirds will significantly improve the existing situation and would be enhanced by the code of conduct during periods, or in areas, without closures. Table F5 presents what are thought to be the most important estuaries for migratory birds, but most of the available information is more than five years old and probably requires a review. It is recommended that NSW Fisheries confirm important sites and times with NPWS during the establishment of closure areas and in formulation of the code of conduct, in a process similar to the Regional Liaison Committees established in the Ocean Hauling Fishery. This would ensure that important areas within estuaries are mapped, that the relevant maps would be made available to fishers within each region, and that they would be reviewed each year during the review of the code of conduct.

Table F5. Estuaries (open to commercial fishing) and coastal areas of international significance because they support more than 1% of the estimated Australian population of a given species protected under international treaties or the TSC Act.

(Source: SPCC/EPA Coastal Resource Atlases, 1984 - 1994).

Location	Important species or population
Hunter River	7000-10000 migratory waders; > 5% of world pop. of eastern curlews and golden plovers
Shoalhaven and Crookhaven system	3000-6000 waders; important for Pacific golden plovers, eastern curlews, Mongolian plovers and ruddy turnstones
Clarence River	3000 waders; important for lesser golden plover, bar-tailed godwit, grey-tailed tattler and curlew sandpiper, red knots, red-necked stints, Terek sandpipers and sharp-tailed sandpipers
Richmond River	1700 waders; important for lesser golden plover, bar-tailed godwit, grey-tailed tattler and curlew sandpiper
Port Stephens	The State's most important site for eastern curlew and whimbrel; also important for lesser golden plover
Lake Macquarie	1000-3000 waders; important for Pacific golden plover and eastern curlew
Botany Bay	> 90 species
Tweed River	750 waders; important for eastern curlew, whimbrel and lesser golden plover
Port Jackson	Grey-tailed tattlers, golden plovers and red-necked stints; little penguin population at North Harbour
Hastings River	Whimbrel
Sussex Inlet	The State's most important site for hooded plovers
Ulladulla coastline	Lake Conjola to Lake Tabourie, sooty oystercatchers and hooded plovers
Sawtell, Harrington, Botany Bay, Lake Wollumboola and Farquhar Inlet	Currently the most important breeding sites for little tern

b) Regional habitat damage due to the Estuary General Fishery

There is no data detailing the modification of habitats in NSW estuaries due to techniques used in the Estuary General Fishery at either the estuary or regional level. Nor is there information available about the extent or frequency of foreshore use by fishers, rather it can only be inferred by the use of particular methods. In the absence of such data, this assessment discusses some of the potential effects due to each of the methods used in the fishery, where possible based on similar techniques that have been studied elsewhere. It considers those potential effects against the intensity (measured as total days of effort over the last 15 years) of each of the techniques to provide some indication of the potential magnitude of impacts. At this stage, it is not possible to relate techniques to particular habitats, but closures are used as a surrogate to assess whether or not the potential impacts are limited in their extent (Table F1), and acknowledges the limitations of this method. It is also impossible to define the potential impacts across fishing regions, as the regions consist of different numbers and types of estuaries, different locations and types of habitats, and different closures.

Table F1 summarises the total fishing effort for each estuary and technique from 1985 - 2000, and indicates if existing closures are likely to protect estuarine habitats. This period represents an upper limit of 3900 calender days, based on only being able to fish during the week, i.e. five days, as a weekend commercial closure is common in almost all estuaries. It is only meant to be a guide and does not include any reductions for public holidays or inclement weather. For ease, Table F6 provides a summary of that information for the top five estuaries for each method that will be referred to in the following passages.

Table F6. The top five estuaries in terms of fishing intensity for each method used in the Estuary General Fishery from 1985 – 2000.

(Source: NSW Fisheries Database).

	Method											
Estuary	**Hauling**		**Meshing**		**Prawning**		**Trapping**		**Hand methods**		**All**	
Clarence River	2	39516	1	40636	1	39663	2	61721			1	181727
Wallis Lake	1	41859	3	35310	3	19153	1	74946	4	960	2	172228
Port Stephens	4	30320	2	35867	5	13193	3	39593	3	965	3	119938
Tuggerah Lakes	5	27783	4	33772	2	19438					4	83592
Hawkesbury R							5	29305			5	61253
Lake Illawarra					4	17516			1	2024		
Richmond River									2	1159		
Pambula Lake									5	877		
Camden Haven R							4	37307				
Lake Macquarie	3	30964	5	21439								

Hand methods = Gathering by hand and handlining
Hauling = Prawn seine (snigging), prawn cloverleafing, general purpose, trumpeter whiting, garfish, pilchard, anchovy, bait, prawn haul, beach haul and bullringing (garfish) nets
Meshing = Pound (figure six), bottom set, top set, splashing and flathead nets
Prawning = Set pocket net and running net
Trapping = Fish, crab, eel and lobster traps

Total effort

Table F6 shows that between 1985 and 2000, the larger systems of the north and central coast were the most intensely fished in terms of total fishing effort. Lake Illawarra (54,242 days) and the Shoalhaven/Crookhaven River system (32,537 days) received the greatest effort on the south coast (Table F1). When fishing effort is compared to water area, however, Coffs Harbour Creek, Tilba Tilba Lake, Nambucca River, Boambee Creek, Deep Creek and Brou Lake appear to be under the greatest pressure. Each of these estuaries, except for Nambucca River, is less than 2 km^2. With the exception of Lake Brou, each of these estuaries has closures that are likely to protect both wader bird habitat and seagrasses. For example, in Nambucca River, the most important wader habitats and numerous seagrass beds are in Warrell Creek and the mouth of Nambucca River, which are closed to commercial nets and traps. These areas are open to handgathering, but 44 days out of a possible 3,900 suggests that this activity is extremely infrequent in Nambucca River (Table F1).

Hauling

The methods used in the Estuary General Fishery could largely be described as passive, or non-destructive to habitats, with the possible exception of hauling, the effects of which are not clearly understood (Otway and Macbeth, 1999). Hauling is generally done on broad, primarily sandy shorelines, and can extend over seagrass and algal beds. There are numerous cases of significant seagrass loss throughout Australia, including NSW, however commercial fishing techniques have not been included as a factor thought to be causing the declines (e.g. Shepherd *et al.,* 1989; Walker and McComb, 1992; Otway and Macbeth, 1999).

Some of the potential impacts that could occur as a result of dragging a haul net across the seafloor include: mechanical damage to sedentary organisms (Lamberth *et al.,* 1995; Reimann and

Hoffmann, 1991); entrapment, transport and removal of organisms, including microalgae (Reimann and Hoffmann, 1991); biofilm re-establishment is delayed in areas of moderate current or wave action, and that repeated hauling in such areas could therefore permanently reduce populations of benthic grazers (Hall, 1999; Kaiser and de Groot, 2000) and resuspension of sediments and contaminants (Dayton *et al.,* 1995; Reimann and Hoffmann, 1991). Some indirect effects that could occur as a result of any or all of these effects include: increased turbidity diminishing the survival of seagrasses and its assemblages; a shift in the composition of benthic communities (Dayton *et al.,* 1995); alteration of sediment type and stability (Churchill *et al.,* 1994); and modifications to microbial activity (Meyer *et al.,* 1981). It is important to recognise that these effects are reported for trawls of various kinds, often on the continental shelf of other countries, and the degree to which they occur during the use of haul nets used in the fishery is unknown.

A recent study of the effects of hauling on *Zostera capricorni*, in nine NSW estuaries, reported that hauling may have caused a reduction in leaf length, but there were also increases in shoot and leaf densities (Otway and Macbeth, 1999). It was concluded that any impact on fish and invertebrate recruitment, whilst not directly tested, was unlikely to be major (Otway and Macbeth, 1999).

A study in South Australia of the effects of hauling on beds of *Posidonia* also reported minimal impacts, as a pressure wave was created in front of the net, which flattened the seagrass and only removed some epiphytes and dead blades (in Cappo *et al.,* 1998). Other studies, however, would suggest that this is not a minimal impact, as epiphytes provide food for fish and invertebrates, and dead leaves provide substantial nutrients for the entire food chain (King, 1981a; West, 1989; Keough and Jenkins, 1995).

A recent study in South Africa of the effects of hauling reported no significant impacts on the benthic flora and invertebrate fauna (Lamberth *et al.,* 1995). A video camera mounted in the net showed that it initially sank to the bottom, whereupon it rose to about 10 - 20 cm from the seafloor at the commencement of hauling. The net was reported to maintain the position throughout the haul, and was not observed to disturb infauna, such as *Callianassa kraussi*. This conclusion should be treated with caution, however, as it was conducted in a bay that was dominated by algae and invertebrates that were probably removed from adjacent rocky shores (e.g. *Ulva* spp. and *Pyura stolonifera*), and thus were not resident species. Furthermore, infauna were not sampled and epifauna were recorded by diver surveys and counts of material retained in the seine nets, which at 44 mm would be too large to retain most invertebrates other than crabs or prawns.

An aspect that such studies have not focussed on is that of the intertidal or foreshore areas, which in estuaries are predominantly used by numerous species of birds, including those of international and national significance. These species utilise intertidal mudflats and sandflats for feeding and/or roosting, so there is potential for them to be driven away due to habitat alteration and general disturbance due to noise or presence. The use of both the low tide (net scour, trampling) and high tide (hauling, trampling, parking boats) areas of the shoreline during fishing could have such an effect. Within the NSW Estuary General Fishery, only two of the top ten estuaries in terms of hauling effort have closures that would probably prevent waders and their habitats from disturbance or modification (Table F1 and F6). These are Tuggerah Lakes and Manning River, neither of which is thought to be particularly important to waders, although they are adjacent to some very important estuaries. In contrast, Clarence and Richmond Rivers and Port Stephens, which contain some of the most important and extensive habitats for waders in the State, have closures that offer little or no protection to such habitat. In the case of Clarence River, on any given weekday over the last 15 years, it is estimated that at least ten fishers would have been hauling in the estuary (Table F6). Many of the preferred hauling grounds in the lower Clarence are in, or adjacent to areas utilised by waders and other threatened birds, and until evidence to the contrary is available, the precautionary principle would suggest it is probably having an impact upon them.

Meshing and trapping

Meshing and trapping could have some similar effects as hauling, but to a much lesser degree. Most mesh nets and traps are negatively buoyant and thus could scrape algae and epifauna from the sediment surface during setting and retrieval, and may alter the habitat of infauna during retrieval. The most likely damage to arise, however, is when anchors or other heavy objects are used to maintain nets or traps in position. The anchors could resuspend sediments and contaminants, bury infauna or expose them to predators, and damage seagrass. Like hauling, these effects have potential flow on effects, although there is no data to suggest the extent to which they could occur within estuaries used in the fishery. The resuspension of sediments could increase the turbidity adjacent to the gear, and the sediment could be transported to adjacent environments, such as seagrass, reducing the light available to it and covering the blades. The transport of any contaminants associated with those sediments could affect water quality and reduce the ability of organisms to survive in the sediment. The degree to which these effects could occur would also be determined by the location within the estuary. The lower reaches are predominantly marine sands and would settle rapidly after disturbance. In the muddy, upper reaches of estuaries where finer sediments dominate, continued resuspension and transport, of sediments and fauna, could occur more frequently. Such areas, however, also support fewer species of fish and invertebrates and lower numbers of organisms, reducing the potential impact. Meshing and trapping are also used in nearly every estuary, so any potential impacts are also likely to be widespread. As with hauling, the top five estuaries in terms of effort account for approximately 50% of the total effort, suggesting that any potential impacts are likely to be more pronounced within these estuaries (Table F6).

Prawning

Prawning, by the methods of set pocket and running netting, can also have some effects and it is probable that they are locally intense, as most of these areas are effectively recognised fishing grounds (albeit undeclared) where the techniques are continually practised. It is probable that if there were any effects on the substratum and adjacent habitats due to these methods, that they may be readily distinguishable from similar adjacent areas that have not been consistently fished by these methods. This may be particularly so for set pocket prawning, which takes place in only 11 estuaries and only two of these, Lake Illawarra and Sussex Inlet, are on the south coast. On a regional level, Regions 3 and 4 have four estuaries, and Regions 2, 6 and 7 all have one estuary where set-pockets are permitted. In contrast, running nets dominate on the far south coast, with Lake Macquarie representing the northernmost estuary for this method. Set pocket netting would normally have very little impact upon habitats, but in the Clarence River it can be done using the assistance of boat propellers to create the necessary current, strengthening or imitating ebb tide. When done this way, it is possible that in shallower areas, sediment could be disturbed and seagrass could be affected both directly and indirectly. The foreshore, including the intertidal area, could also be affected by both of these techniques, as they require access to the shore. This increases the potential extent of any impacts, not only by affecting another type of habitat, but the fauna and flora associated with it, such as infauna, birds and beachplants. The continued trampling of a particular area could also increase the potential for erosion of the shoreline, reducing the habitat quality of both the intertidal and subtidal area. Overall, the limited extent of prawn set-pockets, 11 estuaries and in particular places within each estuary, should minimise the potential extent of any impacts within an estuary and across the State, although there is no data to suggest the type or magnitude of those impacts.

Gathering by hand

Gathering by hand occurs regularly on ocean beaches, targeting pipis and worms, and occasionally within estuaries for species such as yabbies, cockles, mussels, fish and shellfish. Other than removal by hand, yabby pumps and knives are used to collect fauna, and as such effects are fairly restricted, but could include disturbance of birds, trampling, increased exposure to predation or mortality of discards, and sediment modifications. These effects can take place during the collection, but also during access to the foreshores. Even in the most intensely fished area, Lake Illawarra and adjacent beaches (2,024 out of a maximum 3,900 days), such effects are likely to be insignificant due to the selectivity of this method and the popularity of the area for recreation. Regions 4 and 6 (of which Lake Illawarra accounts for 65%) are the most intensely fished regions and account for more than 50% of the effort over the last 15 years for this technique. Within Region 4, Port Stephens and Wallis Lake together account for approximately 65% of the effort in the region, suggesting that if gathering by hand had an impact, it may be detected in those estuaries and Lake Illawarra.

Assessment of management responses proposed in the draft FMS

It is clear that there is no information with which to make an accurate assessment of the degree of habitat damage that may have occurred due to the techniques used in the fishery. The lack of any data, but acceptance that the fishery has probably had some as yet unknown impact on biodiversity and habitats, has meant that the draft FMS has taken a precautionary approach to the ongoing management of the environment. This is reflected in several of the management responses, which are adaptive and include data collection programs, and by adopting this 'wait and see' approach whilst data is collected, it allows fishing to continue but sets benchmarks that, if and when reached, may further restrict or modify fishing. It is accepted that there is some uncertainty inherent in such an approach. It is deemed more appropriate, however, to implement those measures while data is being collected, than to either continue fishing in its current pattern suspecting that it may be impacting on the environment, or conversely to terminate fishing on the grounds of that suspicion.

The draft FMS does suggest changes to some methods, which were discussed in Chapter F section 1(a) in relation to each type of habitat. Fish hauling, prawn seining and prawn hauling are generally recognised in the draft FMS as the techniques that need to be either restricted in their area of use, or the gear modified to reduce potential impacts. In the absence of data, it is not unreasonable to assume that by restricting the types and intensity of methods that can be used in the various habitats, that the responses proposed in the draft FMS should minimise, or reduce the extent of, any potential impacts associated with the techniques used in the fishery. That said, alterations to gear and the definition of fished and unfished areas should be capitalised on as opportunities to conduct research that is currently lacking. This should also apply across all methods, not just those generally referred to as hauling. This would serve the dual role of determining the effects of the techniques on different habitats and their fauna, and may define some areas as important in terms of both the fishery and the broader estuarine environment. Such data could be used to base decisions about the need for marine protected areas and the level of protection required within those areas.

c) Level of confidence in achieving predicted outcomes

Section 1(a) of this Chapter outlined the management responses and the confidence levels associated with them for each of the habitats that could be affected by the fishery. The responses are considered in isolation, but they all work towards the primary goal of managing the fishery in a manner that promotes the conservation of biological diversity. Overall, the responses proposed in the draft FMS are deemed to have, at worst, a medium but more likely high probability of achieving its outcomes as they pertain to the management of estuarine biodiversity, and minimising any potential impacts.

This assessment has adopted a precautionary approach in the absence of reliable data about the effects of the fishery on habitats and fauna. Most of the impacts are inferred, based on what are thought to be much more intensive and destructive techniques. Assuming the techniques adopted in the fishery are less destructive than trawling and scallop dredging, for which a lot of research has been done, and pending the results of research programs outlined in the draft FMS, it is probable that any impacts due to the fishery are not long term or permanent. Furthermore, they are likely to be restricted to less than 30 estuaries as they account for 95% of the effort of the fishery. Estuaries are complex environments, with varying salinities, tides, sediments and nutrients. The plants and animals that are adapted to living there have evolved strategies that should allow areas perceived to be adversely affected by fishing, to recover if fishing were to become more restricted in its extent or intensity, as proposed in the draft FMS. Such restrictions need not be permanent, but either way, should ensure that the biodiversity of estuaries utilised by the fishery are maintained and/or improved.

d) Alternate mitigation measures

i) Timing of fishery activities to minimise disturbance

There is yet no data about the effects of the fishery on the biodiversity and habitats of estuaries, so it is difficult if not impossible, to accurately determine how the draft FMS or other proposed measures would affect them. It is the opinion of this assessment, however, that the majority of the responses proposed in the draft FMS should reduce any potential impacts on biodiversity and habitats.

Mitigation measures within the draft FMS include the responses to various management objectives, monitoring programs and the various closures that exist under the FM Act. In particular, the draft FMS aims to minimise the impacts of the fishery on habitats, and hence fauna, and includes responses such as temporary and permanent closures, gear modifications and developing codes of conduct when operating near particular habitats. With respect to timing of activities, the key responses are those that relate to minimising the impact on species during particular periods of their lifecycle. This primarily relates to the disturbance of waders and other birds, usually in spring and summer, and spawning periods for a variety of fish and invertebrates, mostly those targeted in the fishery. Table F1 suggests that more than half of the existing closures currently offers little or no protection to wader bird habitats. There are some closures that cater for seasonal movements of fish and crabs, such as Australian bass, estuary perch and mud crabs, but none related directly to birds. Historically this is understandable, but in light of Ecologically Sustainable Development, the draft FMS should seek to redress this imbalance. The proposed code of conduct for fishers should prove an adequate measure until more information about the distribution of waders is collated and reviewed. Following the review, consideration should be given to the need or otherwise to develop seasonal closures within those estuaries considered to be among the most important for particular species or communities.

ii) Location of fishing activities to minimise impacts

Several estuaries are closed or partially closed to commercial fishing. The draft FMS also proposes to prohibit all hauling over beds of *Posidonia* seagrass, and to prohibit prawn hauling and seining over all seagrass, providing additional protection to a habitat thought to be critical in the lifecycle of numerous fish and invertebrates. Furthermore, several estuaries are currently being considered for inclusion as estuarine protected areas and recreational fishing areas, separately from the draft FMS. The draft FMS adopts a trigger point for such reserves and other closed areas, but considers an overall increase in the number of estuaries open to fishing across the State as the trigger. An additional trigger that should be considered is whether the draft FMS results in an increase in the proportion of the various habitats that are protected in each bioregion. There can be large fluctuations in biodiversity among estuaries and within estuaries through time, and it will be more important to consider closures according to regions, than by the total number of estuaries closed to fishing

On a local level, approximately half (66) of the estuaries have closures in seagrasses and entrance channels that are important for juvenile fish and invertebrate recruitment and migration. Of these, only 12 have a water area greater than 5 km^2, with the majority consisting of smaller estuaries, many of which are open to the sea some of the time and have limited areas of seagrass. It is recommended, as indicated in the responses in the draft FMS, that similar closures be implemented in some of the larger estuaries, including those under the greatest pressure from the fishery. There also needs to be a performance indicator and trigger point established for the area of important habitat that is protected, as discussed above.

Other closures exist that are specific to certain locations to accommodate the seasonal migrations of some freshwater species to estuarine or brackish environments. These are usually in the larger rivers that contain Australian bass and estuary perch in their upper and middle reaches, but which migrate to estuaries in the cooler months to spawn. In these areas, mesh nets must be used by the method of splashing, whereby the net is effectively set near the targeted fish and then retrieved soon afterwards. This ensures that any captured fish can be released quickly and suffer minimal stress or injury. These and the other measures discussed in the draft FMS are considered to be an effective and manageable way of mitigating impacts on the life-cycles of species within the fishery.

iii) Closures in key habitat areas

As discussed above, there are numerous restrictions on fishing activities in key habitat areas for approximately half of the estuaries in the State, and the draft FMS includes strategies to increase these areas. These pertain specifically to using closures to protect key habitats, prohibiting the use of all haul nets over beds of *Posidonia*, temporary closures in areas of high abundance of juvenile fish, and modifying any other techniques that are thought to be having a detrimental impact on habitats. They also include performance indicators to monitor the declaration of protected areas and to monitor interactions with threatened species. As most of the threatened species, and those of international significance, that could be affected by the fishery are birds and as such occupy intertidal habitats, it will be important for future closures to consider those areas as key habitats. These closures, whether gear, time or location specific, need to encompass as many habitats as possible, beyond those historically reserved because they have large areas of aquatic vegetation. The current proposals to declare entire estuaries within the main protected areas framework, whilst not directly part of the draft

FMS, clearly have the potential to strengthen measures in the draft FMS. Extensive closures and/or marine protected areas that include areas of no harvesting, commercial or recreational, are considered to be the most effective, large-scale management tool with which to ensure the fishery has as little impact on biodiversity and habitats as possible.

Following the discovery of the marine algae, *Caulerpa taxifolia*, several estuaries have been closed to some types of commercial and recreational netting. These are summarised below, and their potential impacts and implications are discussed in more detail in section 4 of this Chapter.

Caulerpa is able to regenerate vegetatively, meaning that small pieces that are broken off are able to establish themselves and continue growing, enhancing any infestation that has occurred. Fishing methods, particularly netting, are considered potential vectors for the spread of the algae, within and among estuaries, hence the closures described above. Given the concern over, and the ease with which this algae can spread, it is the opinion of this assessment that marking areas of infestations and closing them to some forms of fishing is inadequate. This does not make sufficient provision for the control of removal and dispersal by users of the estuaries other than commercial fishers. Marking the areas of highest density is appropriate for general awareness, but should not be used as an isolated measure. Furthermore, meshing is allowed in Lake Conjola provided the gear is only used in that estuary, and there are no closures on traps for any estuaries. This places considerable onus on the fishers and assumes that no algae will remain on traps following retrieval.

Table F7. New fishing restrictions in areas affected by the alga *Caulerpa taxifolia*.

Waterway	Commercial Methods	Recreational Methods
Narrawallee Inlet (Ulladulla)	Mesh netting will be banned in the buoyed area	Hand hauled prawn netting will be banned in the buoyed area. Can still line fish and use a landing net
Burrill Lake (Ulladulla)	All netting will be banned in the buoyed area.	Hand hauled prawn and scissor netting will be banned in the buoyed area. Can still line fish and use a landing net.
Lake Conjola (inc. Berringer L) (Ulladulla)	Haul netting will be banned in the whole lake. Can still mesh net with a Lake Conjola specific net only. Commercial fisher's boats and equipment to be quarantined to lake.	Hand hauled prawn and scissor netting will be banned in the buoyed area. Can still line fish and use a landing net.
Careel Bay (Pittwater)	All netting will be banned in the buoyed area.	Hand hauled prawn and scissor netting will be banned in the buoyed area. Can still line fish and use a landing net.
Lake Macquarie	All netting will be banned in the buoyed area	Hand hauled prawn and scissor netting will be banned in the buoyed area Can still line fish and use a landing net
Quibray Bay (near Kurnell, Botany Bay)	No change as all netting is already banned in the buoyed area.	No change as all netting and line fishing is already banned in Quibray Bay.
Port Hacking	No change as all netting is already banned.	No change as all netting is already banned. Can still line fish and use a landing net.

e) Knowledge gaps

It is clear from the assessment that much is known about the biodiversity and habitats within estuaries likely to be affected by the fishery, but there is no data on the magnitude, extent, or even type of effects on those features. The potential effects of the various gear types were based on extrapolations from studies of much larger, more intensive equipment, often from overseas and in marine environments. The few studies of similar gears and habitats, and the study using gear and habitat specific to the fishery, were inconclusive or not readily correlated. As such, there is a fair degree of uncertainty associated with the assessment of impacts of the methods.

Fishing effort and closure information is more readily available, however, and when compared to the distribution of fauna and habitats, has provided an indication of the overall potential impacts of the fishery on biodiversity and habitats. NSW Fisheries is currently mapping the distribution of habitats, fishing closures, marine parks and aquatic reserves within estuaries. This will provide some quantitative data of the proportions of each habitat type that are fished, adding considerable confidence to an assessment of the potential impacts on those habitats. Such a qualitative approach is far from definitive, however, and there is an obvious need for the collection of targeted, quantitative data, and for it to be fed back into the draft FMS for future reviews. The establishment of research or scoping programs, other than the observer program, should also be included as trigger points in the draft FMS.

At this stage, the draft FMS does not propose any research programs examining the effects of methods on habitats and/or biodiversity. The draft FMS is unable to determine, prioritise or fund those projects because they will be determined by the observer survey, which is supposed to identify problems of physical damage on habitats. The proposed observer survey may well be adequate for recording the numbers of directly or indirectly affected threatened or protected species, but will offer little information to prioritise areas of habitat that are damaged. Subjective observation should not be the basis for determining which habitats and techniques warrant manipulative field experiments as proposed in the draft FMS. It is recommended that during the establishment of preferred landing and hauling sites and recognised fishing grounds, impact (fished) and control (non-fished) sites be selected from numerous estuaries for a research program into the effects of the fishery on habitats and biodiversity. As a minimum, and priority, the selection of sites should seek to partition habitats by technique, with the overall aim of determining the proportion of habitats within each estuary that is affected by each of the techniques. This would also allow a regional assessment of potential pressure on seagrass, assist in determining the need and timetable for research, and where justified, provide the scope required of any research.

It is recommended that the draft FMS be modified to include specific details of research programs to investigate the effects of the methods used in the fishery on the habitats in which fishing occurs. As a minimum, any proposed programs should be run over at least a few years, include multiple control locations and an impact location within impacted estuaries, and also include the same number of locations in control estuaries. This will provide an estimate of the spatial extent of the impact of the method. If the impact is restricted to the impact location, then the control locations within the same estuary will be different. If they are not different from the impact location, but are different to the other control locations in adjacent estuaries, then the impact affects other areas within the estuary, not just the location in which fishing was done.

The establishment of aquatic reserves also presents an opportunity to monitor a planned environmental disturbance (in this case a supposedly positive disturbance). By monitoring in a similar way to that described above, but on numerous occasions before and after the reserve was declared, it should be possible to detect any changes attributable to the reserve. This in itself is important, as it has other implications. This also has the advantage of providing an estimate of the resilience of habitats to fishing methods, and may provide information about sizes or features of reserves that are important for maximising diversity. This information could then be used as smaller scale closures in other estuaries that are not aquatic reserves, somewhat similar to crop rotation in terrestrial environments. For example, it may be decided that an area in the lower estuary has been under substantial fishing pressure, but information from the reserve program suggests that closing that area to a particular method for 12 months should be enough for habitats and assemblages to recover to a certain point. This situation, whilst purely hypothetical, indicates the opportunities that readily exist to fill some of the more important gaps in the knowledge that are required to assess the impacts of the fishery.

2. Threatened and Protected Species

a) Threatened species that may be affected by the Estuary General Fishery

Owing to its widespread use and variety of techniques, the Estuary General Fishery has the potential to affect a variety of non-target species, including those broadly described as threatened. As mentioned in previous sections, however, there is a paucity of information about the existence or degree of these effects on any species, let alone threatened species. Furthermore, this does not allow the assessment to focus on particular methods that are thought to be responsible for a decline in any species, as is the case in many oceanic fisheries (e.g. otter trawling and turtles, longline fishing and albatross). To enable as wide a scope as possible, for threatened species of fish, the methods will be presented that could impact on the various species, based on habitat use at particular life stages. For threatened birds, which are largely migratory waders and shorebirds, it will initially be assumed that all methods have an equal impact, as impact is likely to be due to disturbance as opposed to direct capture. An attempt will be made, however, to isolate those methods, such as hauling and bait collecting, which could have a more direct impact as they are more likely to utilise habitats of both waders and shorebirds.

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 or 5 of the *Fisheries Management Act 1994,* Schedules 1 or 2 of the *Threatened Species Conservation Act 1995*, or Subdivisions C or D of the *Environment Protection and Biodiversity Conservation Act 1999*. 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 species considered in the following general assessment under the FM Act, and the TSC Act and EPBC Act, are summarised in Tables F8 and F9, respectively. Detailed species profiles are provided in Appendix F4, and the complete eight-part test referred to below is in Appendix F5.

Based on the various relevant pieces of legislation protecting threatened species and an analysis of their distribution and ecology, it would appear that the Estuary General Fishery has the potential to impact approximately 42 species, one population and one community. Of those species, very few are truly estuarine species and many only inhabit estuaries for a limited period either annually or throughout their life. The species listed have been included because some of their preferred habitat occurs within estuaries and so they could be affected in some manner by the fishery.

Table F8. List of species protected under the *Fisheries Management Act 1994* that could be affected by the Estuary General Fishery.

* denotes species also considered vulnerable under the EPBC Act.

Species/ group	Types of habitat where most likely to be caught or affected	Methods	Main age groups liable to be affected
Endangered Species			
green sawfish*	lower reaches, particularly mouths of estuaries on far north coast	meshing, hauling	all
grey nurse shark*	lower reaches of larger estuaries and bays	meshing and hand-lining	all
Vulnerable Species			
black cod	rocky reef, particularly where caves and/or large drop-offs are present, especially lower estuarine areas	meshing, fish trapping and hand-lining	all, especially juveniles
great white shark*	lower reaches of larger estuaries and bays	meshing and hand-lining	all
Protected Species (Section 19)			
Australian grayling*	brackish to freshwater areas of the south coast	fish hauling	juveniles
eastern blue-devil	rocky reef near estuary entrance, particularly in the south	fish trapping and hand-lining	adults
elegant wrasse	algal beds and reefs in lower estuarine areas	fish hauling, fish trapping, hand-lining and meshing	all
estuary cod	as above, but more prevalent in north of state	fish trapping and hand-lining	all
Queensland groper	rocky reef near estuary entrances, but more prevalent in north of state	fish trapping and hand-lining	all
weedy seadragon	rocky reef and kelp beds near estuary entrance in areas subject to strong marine influence	fish hauling	all
Protected Species (Section 20)			
Australian bass	brackish to freshwater areas; during winter further downstream in estuary proper, particularly after heavy rain	fish and prawn hauling, meshing and eel trapping	all
blue groper	seagrass and rocky reef near estuary entrance	fish hauling, prawn hauling, meshing, fish trapping and hand-lining	juveniles
estuary perch	upper estuaries, sometimes in lower freshwater reaches; during winter may be found well downstream towards estuary mouth	fish hauling, fish trapping, hand-lining and meshing	all

Most of the fish are marine species that inhabit rocky reefs, but have been included because such habitat could be utilised by the fishery, and although it may not cause direct impact through capture, it could compete for similar target species and thus reduce the food available to the threatened species. Australian grayling are a freshwater fish restricted to several coastal drainages of the far south coast, some of which are not open to commercial fishing. They spawn in freshwater and the eggs are carried out to sea or to the lower reaches of estuaries. Maturing juveniles then return to, or swim back up the estuary to freshwater, during which time they could be caught in haul nets or prawn nets.

Of the plants, two occur within saltmarshes in a limited number of coastal lakes of the south coast. It is possible that the plants could be trampled during access to the shoreline or during hauling or prawning operations. The other plant is a fresh to brackish water species of which very little is known, but it is thought possible that it could occur in the upper reaches of Lake Macquarie, near Belmont.

Approximately half of the species of birds are migratory. Most breed in the Northern Hemisphere and arrive in spring and summer to feed on sandflats and mudflats of estuaries and adjacent coastal beaches. Some remain over winter, but do not breed. The others are permanent residents. Some feed and breed exclusively in estuarine and/or adjacent coastal environments, such as oystercatchers, whereas others may breed further inland when conditions are suitable. It is extremely unlikely that any of the threatened species would be caught by any of the methods of the fishery, and most of the potential impact would be indirect. Disturbance during feeding or roosting could affect all species, and disturbance during nesting could affect the resident species. Some species, such as little terns, little penguins, ospreys and oystercatchers could also be affected by reduced food sources through competition with the fishery.

Table F9. List of species protected under the *Threatened Species Conservation Act 1995* or *Environment Protection and Biodiversity Conservation Act 1999* that could be affected by the Estuary General Fishery.

Species/group	Types of habitat where most likely to be affected	Most likely effects	Protective treaties or legislation
Endangered Species			
Wilsonia rotundifolia	Saltmarsh of Lake Wollumboola, Swan Lake, Meringo Lagoon and Lake Coila	trampling	TSC
beach stone-curlew	North of Nambucca River; open beaches, sandflats and mudflats	disturbance - feeding	TSC
bush stone-curlew	Central coast; saltmarsh, mangroves	disturbance	TSC
hooded plover	South of Jervis Bay on long sandy beaches backed by vegetated dunes	disturbance - feeding disturbance - nesting	TSC
little tern	Sand-spits, islands and beaches or feeding at estuary mouths	disturbance - feeding disturbance - nesting	TSC, EPBC, J and C
Zannichellia palustris	Tributaries of Hunter River (Lake Macquarie?)	could be hauled over	TSC
Endangered Populations			
little penguins (population)	North Harbour Aquatic Reserve, entrance to Port Jackson	disturbance - feeding disturbance - nesting	TSC
Endangered Communities			
Taren Point Shorebird Community	Taren Point	disturbance - feeding	TSC
Vulnerable Species			
Plants			
Wilsonia backhousei	Saltmarsh, esp. in Jervis Bay, and north to Wamberal Lagoon	trampling	TSC
Reptiles			
green turtle	Seagrass beds of northern and central NSW	disturbance - feeding	TSC and EPBC
leatherback turtle	Mouths of major rivers - primarily oceanic	disturbance - nesting	TSC and EPBC
loggerhead turtles	Seagrass beds, estuarine and coastal reefs	disturbance - feeding	TSC - vulnerable EPBC - endangered

Table F9 (cont).

Species/group	Types of habitat where most likely to be affected	Most likely effects	Protective treaties or legislation
Vulnerable Species (cont)			
Birds			
Australasian bittern	Saltmarsh	disturbance - feeding disturbance - nesting	TSC
black bittern	Northern half of coast, wetlands and mangroves	disturbance - feeding disturbance - nesting	TSC
black-tailed godwit	Sp. and Su; sandspits and mudflats, esp. Hunter R.	disturbance - feeding	TSC, J and C
broad-billed sandpiper	Sp. and Su; Hunter to Shoalhaven Rivers, sand and mudflats adjacent to mangroves	disturbance - feeding	TSC, J and C
collared kingfisher	Tweed to Ballina, mangroves and creeks	disturbance	TSC
comb-crested jacana	Tweed to Bermagui, upper reaches	disturbance	TSC
freckled duck	Coastal brackish lakes	disturbance - feeding	TSC
great knot	Sp. and Su; sandflats, mudflats, sandy beaches	disturbance - feeding	TSC, J and C
greater sand plover	Su; sandflats and mudflats	disturbance - feedin	TSC, J and C
lesser sand plover	Su; beaches, sandflats, mudflats and mangroves south to Shoalhaven R.	disturbance - feedin	TSC, J and C
mangrove honeyeater	Mangroves from Tweed to Macksville	disturbance - feeding disturbance - nesting	TSC
osprey	Areas of extensive open water	disturbance	TSC
pied oystercatcher	Sandflats, mudflats, beaches	disturbance	TSC
sanderling	Su; mudflats, sandspits, coastal lagoons	disturbance - feeding	TSC, J and C
sooty oystercatcher	Rocky shores, beaches	disturbance	TSC
Terek sandpiper	Sp & Su; mudflats near mangroves, lakes and creeks	disturbance - feeding	TSC, J and C
Marine Mammals			
Humpback whale	Entrance of larger bays and harbours	disturbance	TSC and EPBC
Indo-Pacific humpbacked dolphin	Far North Coast, mouths of larger rivers.	disturbance - feeding capture	TSC - vulnerable; EPBC - insufficiently known
Southern right whale	Entrance of larger bays and harbours	disturbance	TSC and EPBC

Where: Sp = spring
Su = summer
J and C = Threatened species that are also protected under JAMBA and CAMBA (see Appendix F4).

There is much less scope for the fishery to impact marine mammals or reptiles, as they are largely only occasional visitors to coastal waters, and even fewer actually frequent estuaries. Southern right whales and humpback whales are seen off our coastline from about July to October as they migrate to and from breeding grounds. They are not believed to feed off NSW waters, but often enter the larger embayments such as Jervis Bay, Twofold Bay and Sydney Harbour, presumably to rest. Thus there is potential, albeit very limited, for general disturbance and boat strikes, particularly as numbers of the animals increase. There is very little known about the occurrence of Indo-Pacific humpbacked dolphins or any of the turtles in NSW waters, but in other areas they are known to regularly enter estuaries, and their range of distribution includes several north coast estuaries. They could be affected by direct capture, disturbance during feeding, and/or competition for food resources.

The following sections will aim to more precisely define this level of impact, to isolate measures from within the draft FMS designed to mitigate potential impacts, and to determine the effectiveness of those measures.

b) Potential impact due to direct capture or disturbance

As discussed in previous sections, the Estuary General Fishery uses a variety of techniques across all types of habitats, ranging from seagrass and algae to bare substrata and sandy shores. This section will focus on how these techniques may impact on threatened species through either capture or disturbance, or by altering the habitats of the various threatened species. For brevity, generalised statements will be used for species that utilise similar habitats, except where it is apparent that a method or its timing may adversely impact upon a particular species. The conclusion from the eight-part test is included in this section (complete test in Appendix F5), as it must be taken into account in deciding whether there is likely to be a significant effect on threatened species or their habitats.

i) Capture rates and mortality

There are no data about the capture and/or potential mortality associated with it for threatened species within the Estuary General Fishery. Historically, information about capture rates and/or mortality due to fishing of such species has not been recorded as part of the monthly catch returns for estuarine fishers. The concept and legal application of threatened species legislation in itself is still only a relatively recent phenomenon. In 1987, the Commonwealth government protected seals and sea snakes under the *National Parks and Wildlife Conservation Act*, following on from the ban on driftnet fishing in 1986, which was causing a high incidental mortality of dolphins (Eisenbud, 1985; Northridge, 1991; Miller, 1995). Oceanic longlining vessels targeting tuna in the Southern Ocean and waters of the southwestern Pacific were also capturing large numbers of seabirds, particularly albatross and petrels (Environment Australia, undated; Murray *et al*., 1993; Brothers, 1991). The NSW NPWS introduced the concept in 1991 through the Endangered Fauna (Interim Protection) Act, which became the TSC Act 1995, and in 1997, NSW Fisheries included similar amendments to the FM Act 1994. Furthermore, and largely because it is a recent concept, many species that are considered threatened do not have recovery plans, which are a requirement of all threatened species legislation and would detail threatening processes and management measures to mitigate those processes. An example of an existing threat abatement plan is longline fishing and albatross in Australian waters (Environment Australia, undated).

Within the fishery, the closest parallel occurs with hauling in Spring Cove near the little penguin colony. Discussions with staff of the NPWS suggest that although there is a fair degree of community opposition to commercial fishing due to the perceived conflict, there is in fact no evidence of capture by, or mortality directly attributable to, commercial fishing (B. Humphries, NPWS, pers. comm.). The mortality database maintained by NPWS lists numerous other factors, such as gunshot wounds, foxes and dogs that are largely responsible for the 84 deaths that have been recorded since the database was established in 1994.

The draft FMS acknowledges that of the protected species of fish, the fishery occasionally captures Australian bass, estuary perch and estuary cod, although there are no data about where or how frequently these captures occur. Australian bass and estuary perch would most likely be caught in the mid to upper reaches of the larger estuaries with fresh to brackish tributaries. Estuary cod, and several of the other threatened species of fish for that matter, could be caught in the lower reaches where there is rocky reef or other suitable hard substrata. Whilst the methods that can be used in such habitat are limited in terms of type and extent, there is potential for the fishery to capture more species than those mentioned in the draft FMS.

The recovery plan for marine turtles in Australia did not include any commercial fishery of NSW in its list of Australian fisheries known or thought to have a potential impact on marine turtles (Environment Australia, 1998). The plan identified fisheries from Queensland, Northern Territory, Western Australia and Tasmania, and detailed programs to resolve uncertainties about bycatch and mortality of marine turtles in those fisheries.

ii) Habitat disturbance or loss

As previously discussed in Chapter F of section 1, there is little quantitative or qualitative data on the effects of the techniques used in the fishery on aquatic habitats. The fishery has existed for over a hundred years, and it is probable that any changes that might have occurred due to fishing would have taken place early on and any subsequent changes would probably be less visible or dramatic. Furthermore, they may no longer be readily identifiable due to the variety and extent of other factors affecting habitats, e.g. sand and gravel extraction, dredging, urbanisation and industry.

Habitat disturbance, in its various forms, is amongst the processes threatening the survival or viability of many species or communities, particularly threatened birds. For example, commercial fishermen working adjacent to some islands off the coast of Wollongong were reputedly responsible for preventing adult little penguins (not part of the threatened population at Manly) from returning to their nests (NPWS, 2000a). Whilst not intentional, nor part of the Estuary General Fishery, it provides some indication of the sensitivity of certain animals to disturbance and provides some insight as to what may occur elsewhere and for other species or populations. Until more research is done, particularly during the formulation of management and recovery plans for such species, the extent of this impact remains unclear.

iii) Indirect impacts

Whilst not readily quantifiable, indirect impacts such as noise, collision with vessels and alteration of food webs could affect some threatened species during feeding and/or roosting. There are over 180 000 vessels registered by the Waterways Authority in NSW, of which commercial fishing vessels used in the fishery, mainly runabouts of generally between 3 - 6 m in length, account for less than 0.5%. Recreational vessels comprise approximately 96% and other commercial vessels 3.5%. This suggests that the potential impact of estuary general fishing vessels would be much less than that of recreational vessels, especially considering that recreational vessels can generally access all areas, yet closures exist for commercial fishers. Within the smaller estuaries, these closures are often extensive in terms of gear and area, effectively precluding the use of boats from estuaries that could be perceived as more natural and thus more vulnerable to impact. Examination of the effort associated with the fishery also suggests that the majority of it is focussed in 24 estuaries, and that these are predominantly the larger estuaries of the central and north coasts, which are also popular tourist destinations. Furthermore, during setting and retrieval of nets, fishers usually use a smaller motor operated at low speed. This is likely to minimise potential effects due to disturbance or boat strikes, even at night when other boating activities are likely to be minimal.

The Estuary General Fishery catches a combination of predator, prey and scavenger organisms from within the estuarine food web. This can have a myriad of subsequent effects, both favourable and detrimental to all trophic levels (see Chapter F section 3). Such effects are widely speculated, but poorly documented, in the scientific literature. Dayton *et al.* (1995), reported the proliferation of squid populations in the tropics as a result of heavy fishing pressure, and a study in Port Phillip Bay, Victoria, suggested that adult little penguins had died from starvation because fishing had depleted stocks of anchovies and pilchards (Harrigan, 1992). It was later reported that weather patterns, particularly related to the El Nino-Southern Oscillation phenomenon, caused dramatic shifts in baitfish recruitment, schooling behaviour, abundances and distributions, such that penguins were probably unable to catch sufficient food, irrespective of fishing practices (Hoedt *et al.,* 1995; Dayton *et al.,* 1995), also highlighted the problem of catching aggregated prey such as baitfish and were concerned that it could be a significant, but unstudied problem in Australia.

Many of the indirect impacts associated with commercial fishing, particularly the harvest of baitfish adjacent to the little penguin colony at Manly, have been implicated as processes threatening the species (NPWS, 2000a). However, no data to substantiate the claims exists, and fishing is not listed as a Key Threatening Process under the TSC Act. Conversely, some species may benefit by becoming adapted to fishing activities, behaviour common among many species of dolphins, sharks and birds feeding on discards from prawn trawls (Wassenburg and Hill, 1990; Broadhurst, 1998; Blaber *et al.,* 1995).

iv) Summary of the eight-part test

This assessment has considered the eight factors under the relevant sections of the FM Act, TSC Act and the EP&A Act in deciding whether there is likely to be a significant effect on threatened species, populations or ecological communities or their habitats (Appendix F5). The assessment was based on a review of biological information derived from the various agencies responsible for those species, from published literature and from personal communications. The assessment has found that the proposal will not have a significant effect on any threatened species, populations or ecological communities or their habitats, and as such a Species Impact Statement is not required for the draft FMS.

v) Assessment of impact on threatened species

Whilst hardly definitive or based on an abundance of scientific data, the factors listed above would suggest that the Estuary General Fishery is not having a direct and/or adverse impact on any threatened species. The lifecycles, preferred habitats of many threatened species and techniques used in the fishery suggest that there is limited scope for the fishery to have a significant impact on them. There is, however, a high degree of uncertainty associated with this assessment due to the paucity of quantitative data, and reliance upon anecdotal or speculative information. Until data are collected that detail interactions between fishers and threatened species, there will always be a risk that species are being negatively impacted upon without management actions being enacted. Such an approach is also largely reactive, and in order to avoid negative impacts on threatened species, pro-active measures need to be defined in species recovery plans and effectively implemented. At this stage, there are no recovery plans for any marine or estuarine species under the FM Act considered in this assessment, although the NSW NPWS has finalised a recovery plan for the little penguin colony at Manly, and drafted a recovery plan for little terns. Environment Australia has also drafted recovery plans for grey nurse sharks and great white sharks.

The little penguin population is located within and close to North Harbour Aquatic Reserve administered by NSW Fisheries. Despite being listed in the threat abatement plan as a threatening process for the little penguin population, some commercial fishing is allowed in the reserve. Lobster pots and fish hauling are allowed between Manly Point and Cannae Point, the stronghold for the species, and lobster pots are permitted throughout the rest of the reserve. The apparently contradictory status of a potential threatening process being allowed to continue suggests recognition of a lack of data implicating fishing, and an adaptive management regime. Furthermore, the area is not defined as critical habitat. Hauling, in particular, is scrutinised as it can obstruct adult birds from returning to their burrows and may be amplified in the breeding season when adults are forced to remain in the water longer and consume fish that they would otherwise have fed to their chicks. Part of the overall monitoring program of the population is a threat abatement program, which includes the establishment of a mortality register by NPWS and for NSW Fisheries to monitor fishing effort and catches of baitfish in Sydney Harbour, and to record any incidental catches of little penguins. Since the establishment of the register, there have not been any reported deaths associated with commercial fishing. Effort data also suggest that there is minimal potential for an impact on the penguins. There are only two crews that regularly use the area and both concentrate their activities in winter and autumn, which is when mullet and bream make spawning migrations. One of the crews works twice a month at this time, and the other works 2-3 times a week during those periods, which are largely out of the main breeding time for the little penguin. At this stage, it would appear that the fishery is not having an adverse impact upon this little penguin population.

The draft recovery plan for little terns does not specifically mention commercial fishing, but it would be included as a form of human disturbance, for which management actions are listed in the plan. Four breeding sites, at Harrington, Farquhar Inlet, Botany Bay and Lake Wollumboola, were identified as requiring intensive management during the breeding season. The nesting sites at Harrington and Botany Bay were also identified as worthy of inclusion into Crowdy Bay National Park and Towra Point Nature Reserve, respectively. Intensive management would involve signposting the areas and boatramps, a public education campaign, preventing access by humans and animals through fencing, prohibiting off-road vehicles from the vicinity of nesting sites, control of encroaching vegetation and using wardens to patrol the busiest sites. The nesting site at Towra Point is also within the sanctuary zone of Towra Point Aquatic Reserve, administered by NSW Fisheries, which means that fishing is not permitted. The combination of these measures should continue to ensure that commercial fishing has little or no impact on little terns.

The draft recovery plan for grey nurse sharks in Australia did not include any of the techniques used in the Ocean Hauling Fishery in its list of fisheries known or thought to have a potential impact on grey nurse sharks (Environment Australia, 2000a). The plan identified demersal gillnetting, setlining, droplining and fish and prawn trawling as probably being responsible for the incidental catch of grey nurse sharks, but noted that the degree of this impact was unknown. Some of the measures the report recommended were consistent with those proposed in the draft FMS and included:

- assessing commercial data to determine current level of grey nurse bycatch
- modifying fisheries logbooks to record grey nurse catch and biological data
- ensuring existing fishery observer programs record interactions with grey nurse sharks
- developing appropriate mechanisms to protect key sites.

The draft recovery plan for great white sharks in Australia did not include any commercial fishery of NSW, nor any of the techniques used in the Ocean Hauling Fishery, in its list of Australian fisheries known or thought to have a potential impact on white sharks (Environment Australia, 2000b). The plan identified the southern shark fishery, the snapper fisheries in Victoria, the Gulf of St Vincent and the Spencer Gulf, the tuna farming industry and the WA shark fishery as taking or killing significant numbers of sharks as bycatch. The plan detailed programs to resolve uncertainties about bycatch and mortality of white sharks in those fisheries.

Overall, the draft FMS is consistent with the limited number of recovery plans that have been implemented or drafted to date. This should minimise any potential impacts on the threatened species or populations and provide data that can be fed into the recovery plans. Assuming recovery plans are effective and numbers of threatened species increase, there will be an associated increased likelihood of occurrence and interaction within the fishery. It will be important that observer surveys are scheduled every few years to make provision for this, and not as a one-off when the likelihood of occurrence or interaction is very low.

c) Management uncertainty

As discussed in section 2(b) of this chapter, most of the uncertainty related to threatened and protected species lies not with the management of those features, but of the past impacts of the fishery upon them. The lack of any data, but acceptance that the fishery has probably had some as yet unknown impact on them, has meant that the draft FMS has taken a precautionary approach to the ongoing management of those species. This is reflected in several of the management responses, which are adaptive and include data collection programs, and by adopting this 'wait and see' approach whilst data is being collected, it allows fishing to continue but sets benchmarks that, if and when reached, may further restrict or modify fishing activities. It is accepted that there is some uncertainty inherent in such an approach. It is deemed more appropriate, however, to implement those measures while data is being collected, than to either continue fishing in its current pattern suspecting that it may be impacting on threatened species, or conversely to terminate fishing on the grounds of that suspicion. This approach should minimise any potential impacts on threatened species and provide data with which to more accurately determine what, if any, those impacts are.

d) Precautionary management measures

Table F10 which follows summarises the significance and acceptability of the potential impacts that the fishery could have on threatened and protected species. It identifies the management measures presented in the draft FMS designed to mitigate/rehabilitate those impacts, defines the level of confidence that this assessment has in the effectiveness of those measures, and details why those levels were assigned to each measure.

Despite the uncertainty about the impacts that the fishery may have had on threatened species in the past, it is clear that the draft FMS attempts to understand these impacts better and minimise them if and where they do occur. Most of the responses are reliant on data collection from observer programs and studies of the biology and ecology of certain species. Failing to adequately fund those programs, and/or failing to have some done by organisations independent of the fishery, would reduce the confidence associated with achieving their aims.

The proposal to use closures to minimise effects on migratory shorebirds will significantly improve the existing situation and would be enhanced by the code of conduct during periods, or in areas, without closures. As stated previously in Chapter F section 1(iv), it is recommended that NSW Fisheries confirm important sites and times with NPWS during the establishment of closure areas and in formulation of the code of conduct. That information should also be used when determining which regions or estuaries will be the focus of observer surveys. Such a coordinated approach should ensure that the surveys are as comprehensive and effective as possible.

It could be argued that the level of acceptability of any impacts on threatened species should be low. Generally, that would be correct if the fishery was the only source of impact, that the impact was clearly defined, and of such intensity and magnitude as to drive a species to extinction. That is not likely to be the case in the estuarine environment in which the fishery operates. There are multiple user groups, each of which has some unknown degree of impact upon species, and there are many external factors over which NSW Fisheries, through the draft FMS, has limited control. Establishing research programs aims to provide a more accurate assessment of the level of impact that the fishery is having on threatened species, and where appropriate, implement measures to reduce or eliminate that source of pressure on the species.

Table F10. Potential impacts of the fishery on threatened species and the relevant management responses in the draft FMS.

Potential impacts	Significance of impact	Level of acceptance	Management response	Confidence levels	Note
Capture - fish, turtles, mammals, penguins	Medium	Low-medium	1.1 all	High	Prevent and/or minimise direct and indirect effects
			1.2a & b	High	Closures and gear restrictions to avoid interactions
			1.2c	Medium	Code of Conduct
			1.3d	Medium	May increase areas closed to fishing
			3.1a	Medium	Catch & effort return forms
			3.1b	High	Considers threat abatement plans
			3.1c	High	Regulates species
			Goal 6	Med-High	Effective compliance
			Goal 7	Med-High	Community education
Habitat modification	Medium - high	Low	1.1g & h	High	Regulates gear
			1.2 all	High	Increases areas closed to fishing
			1.3d	High	May increase areas closed to fishing
			1.5 all	High	Habitat mapping, rehabilitation and management
			2.4	Medium	Manages externalities
			3.1b	High	Considers threat abatement plans
			7.1, 7.2, 7.3	Med-High	Community education
Disturbance	Medium	Medium	1.1f	Med-High	Data collection - some needs to be fishery independent
			1.2	Med-High	Closures and research programs
					Defines designated landing sites
			1.5 all	High	Habitat mapping, rehabilitation and management
			2.2c	Medium	Licensing arrangements
			3.1	High	Considers threat abatement plans
			Goal 6	Med-High	Effective compliance
Trophic effects	Unknown	Probably low	1.1b	Med-High	Minimises bycatch
			1.3a - c	Low-medium	Likely to be very difficult and expensive to discern

e) Level of confidence in achieving predicted outcomes

Table F10 outlined the management responses to issues concerned with threatened species and the confidence levels associated with them. The responses are considered in isolation, but they all work towards the primary goal of minimising the impact of the fishery on threatened species. Overall, the responses appear to have a high probability of achieving their aims. Those with a low to moderate probability are influenced by multiple external factors and/or will take a long time to elucidate, if at all. Species and population numbers can vary significantly through time and space, and research programs may not be able to detect the degree to which the draft FMS affects species, owing to both the variability and external factors. Importantly, for those aspects where the draft FMS has the greatest control, e.g. closures and bycatch programs, there is a high probability that the draft FMS will have a positive impact upon threatened species. It does this by using closures to protect areas utilised by threatened species, collecting data about direct and indirect effects, and minimising disturbance during fishing operations. These aspects should remove a large proportion of the uncertainty associated with the potential impacts of the fishery on threatened species.

f) Effectiveness of mitigation measures

The content of each of the responses and the monitoring programs designed to test their effectiveness should be able to adequately address the issues as they pertain to threatened species. The underlying assumption is that in the absence of data to the contrary, the fishery in its existing form is thought to be having minimal impact on threatened species, and that the draft FMS will both elucidate those effects and minimise them where they do occur. Despite this, some of the associated trigger points require some refinement.

As discussed in section 1(d)(ii) of this chapter, there should be either an alternative or additional trigger point for the number of estuaries closed to fishing (Goal 1, Trigger 1), which should measure an increase in the proportion of the various habitats that are protected in each bioregion. This would allow closures to be more specific, capitalising on information obtained by recovery teams and observer programs and apportioned in relation to the existing extent of, and habitat types represented in, Marine Protected Areas. This is likely to result in a more efficient and equitable allocation of the resource between user groups, including the environment.

Goal 3, Triggers 1 and 2 of the draft FMS pertain directly to threatened species. Trigger 1 is likely to require some modification. First, the trigger point of 25% or more is to be based on data from the observer program and catch return records, and those data are to be reviewed annually. Initially, such a review is unlikely to be sensitive enough. For example, the available data suggest that there is currently minimal fishing effort adjacent to the penguin colony at Manly, and that the effort is focussed in winter. Subtle shifts in effort and catch could affect the population and it is recommended that catch and effort data receive quarterly analysis in consultation with the Little Penguin recovery team. There needs to be only an annual report each June, and it should incorporate flexibility so that if it were found that in the first year no penguins were caught, the report could recommend biannual or annual reviews thereafter.

Second, it is proposed that fishery participants should fund the observer program. As numerous aspects, stakeholders and much of the confidence in the draft FMS relies on the observer program, there should be more than one source of funding and should include other stakeholders, which will also make the program more equitable and readily accepted by fishers. Some of the data collection should also be done by organisations independent of the fishery.

Third, it is currently proposed to consider only monitoring capture rates. Given that there are very few threatened species that could actually be captured by the fishery, and of those, many are highly improbable based on their habitat requirements, this appears to be a disproportionate distribution of effort. The program should include the capacity to record and document effects on all threatened species due to disturbance and habitat modification.

Summary

The proposal has the potential to affect more than 40 threatened species under the FM Act, TSC Act and the EPBC Act. At this stage, however, there appears to be little or no hard data implicating the fishery in having an adverse impact on any of those species, their habitats or accentuating other circumstances that may be having an adverse impact upon them. It will be important for the observer program discussed within the draft FMS to obtain information about effects due to disturbance, not just direct capture, as this appears to be the most likely form of impact on the majority of threatened species and species of international significance. Half of the estuaries in NSW have existing closures that probably protect many areas of habitat for these species. The draft FMS includes several measures to further mitigate any impact, including complementarity with departmental initiatives to expand the range of marine protected areas, closures and research programs, in addition to concurrent proposals to create recreational fishing areas. These strategies have been considered adequate to mitigate any future potential impacts due to the fishery and should remove a large degree of the uncertainty associated with existing data.

3. Trophic Structure

Very little is known about trophic interactions in relation to the methods used in the Estuary General Fishery. Most of the references cited in this section relate to work on prawn trawling, with the assumption that many of the interactions are likely to be similar, though probably on a smaller scale for most methods used in the Estuary General Fishery.

The magnitude of any trophic structure effects is likely to vary considerably among methods used in the Estuary General Fishery, essentially in accordance with the likely amounts of bycatch involved (Chapter E section 2). Hauling, meshing and some types of gathering by hand are much more likely to cause trophic effects than are trapping or hand-lining. In the case of gathering by hand, any effects would be extremely localised, essentially relating to small organisms killed or displaced by trampling or use of implements.

a) Species likely to be affected by the fishing activity

NSW estuaries are host to a large number of bird, fish and invertebrate species and most of these are potentially affected by trophic interactions arising from fishing activities (Cappo *et al.,* 1998; Jennings and Kaiser, 1998; Hall, 1999). The species most likely to be significantly affected (because of discard provisioning) include various seabirds and benthic scavengers/ omnivores (Jennings and Kaiser, 1998; see also sub-section (c) following). Within NSW estuaries, the latter include crabs as well as finfish such as yellowfin bream (Table F11).

Trophic structure effects may be direct (i.e. discard provisioning) or indirect (arising from the removal or attraction of particular species). These effects are discussed in the following sections.

b) Likely productivity/flows and associated impacts of removing predators, prey or competitors

These are flow-on or indirect consequences of a fishing gear's use. Estuarine communities are structured by complex arrays of interspecific factors such as competition and predation (Cappo *et al.,* 1998; Hall, 1999; Kaiser and de Groot, 2000) and changes to any one component (say through a reduction in the abundance of a particular species or size class) may have a range of consequences for other components, whether they are competitors, predators or prey. Plausible food web/community effects (see also Kennelly, 1995b; Cappo *et al.,* 1998; Hall, 1999) arising from estuary general fishing methods include:

- a local decline in the abundance of an apex predator (e.g. tailor, dusky flathead or even seabirds) caused by the selective removal of prawns or baitfish (Dayton *et al.,* 1995; Cappo *et al.,* 1998)
- increased survival (and therefore abundance) of some prey species (e.g. small fish, squid and shrimps), particularly those eaten by target species such as flathead or bream (e.g. Dayton *et al.,* 1995; Engel and Kvitek, 1998)
- the favouring of mobile opportunists, better able to 'follow' food supplies created by hauling operations, at the expense of less mobile or less aggressive species (Dayton *et al.,* 1995)

- less efficient predator foraging due to the dispersal of prey aggregations, resulting in lower reproductive success and/or reduced populations among predator species (Dayton *et al.,* 1995)
- changes to the condition of seagrasses or other marine vegetation through the removal of species (e.g. luderick and leatherjackets) that are likely to graze on epiphytic growth
- changes to benthic invertebrate communities through the removal of fish such as sand whiting that eat benthic invertebrates
- changes to benthic communities arising from removal of sea mullet, a species that ingests (and turns over) the substratum to feed on micro-algae and detritus
- short-term increases in the abundances of scavenger or predator species (fish, crabs or birds) as a result of large numbers of dead or injured fish being made available as food during or after a fishing operation (Table F11)
- longer term increases in the abundances of scavenger or predator species (fish, crabs or birds) as a result of large numbers of trapped, dead or injured animals being made available in regularly fished areas (e.g. Blaber and Wassenberg, 1989; Wassenberg and Hill, 1990).

From these examples it is apparent that food web and community effects are complex and far reaching, and that their prediction in any given case would be very difficult (Cappo *et al.,* 1998; Jennings and Kaiser, 1998; Hall, 1999). Also, a further 'generation' of flow-on or cascading effects through the food web would be possible in each case (e.g. Kennelly, 1995b in relation to prawn trawling), although such affects have proven very difficult to demonstrate conclusively, particularly in species-rich communities (Jennings and Kaiser, 1998; Hall, 1999).

Scavengers or predators initially concentrated in an area as a result of a fishing operations could end up being caught (e.g. Jennings and Kaiser, 1998) but, in any case, would have to rely on other food sources once the initial supply of dead fish etc. was consumed. This may adversely affect other species in the area, as might a sudden increase in a particular prey species (second point above) which may even alter habitat conditions. Also, whilst the availability of discards could cause nesting populations of some seabird species to increase, it may (in turn) caused the depletion of other bird species (Cappo *et al.,* 1998), possibly through competition for nesting sites (Ross, 1996). It has even been suggested that larger predators that were initially attracted by discards (Cappo *et al.,* 1998; Blaber *et al*., 1990) could eat smaller target species. In the case of the Estuary General Fishery, the target species that could conceivably be affected this way include prawns and garfish. On the other hand, the incidental capture and subsequent mortality of small fish as a result of hauling may reduce significant rates of predation by small fishes on prawns (Salini *et al*., 1990; Brewer *et al*., 1991).

Despite the possibility that virtually all elements of the state's estuarine biota may be affected in some way, extensive evidence from overseas studies (Jennings and Kaiser, 1998; Hall, 1999) suggests that indirect trophic effects of the sort discussed above are unlikely to have significant impacts on diverse communities, such as those occuring in NSW estuaries. This is because predator-prey relationships within such communities are often relatively weak and, in response to natural population changes, quite variable. Jennings and Kaiser (1998) emphasises the importance of natural environmental factors (albeit in conjunction with fishery-related factors) in causing population changes amongst marine species.

c) Likely food provisioning from discards

Under ‘natural’ (unfished) conditions within NSW estuaries, there are likely to be relatively weak trophic links between surface/ pelagic species and benthic/demersal species. Food provisioning is likely to strengthen these links, particularly in an ‘upward’ direction, with a whole range of new food sources becoming available to certain seabirds (Table F11). Benthic scavengers and/or omnivores are also likely to benefit, though not to the same degree (Jennings and Kaiser, 1998; sub-section (b) above).

The effects of discard provisioning would depend on whether the discards floated or sank upon return to the water (Harris and Poiner, 1990; Hill and Wassenberg, 1990; Wassenberg and Hill, 1990). Floating discards would be readily available to birds, whilst sinking animals could be taken in mid-water by fish or squid, or by fish and a variety of invertebrates (particularly crabs) on the seafloor.

In the context of the Estuary General Fishery, the major beneficiaries of discard provisioning are likely to be pelicans, seagulls and both blue-swimmer and mud crabs (Table F11). Marine mammals and reptiles are relatively rare within most of the state’s estuaries, as are fairy penguins: these groups are unlikely to benefit greatly. Diving birds such as cormorants would benefit to a fair degree (Table F11), but would not be able to exploit the full size range of discarded material. Pelicans would possibly benefit the most because they can eat larger discards than other species, and could supplement their normal feeding behaviour, which restricts them to small prey items and the shallow margins of estuaries.

Large gatherings of pelicans around commercial fishers are a common sight. Whilst no data are available for NSW, the blue swimmer crab has been shown to be readily attracted to trawl discards in Moreton Bay: these discards apparently contribute to the success of the local blue swimmer crab fishery, and are probably important in maintaining populations of the major scavengers present (Wassenberg and Hill, 1987, 1990).

Table F11. Summary of discard provisioning (by trophic level/feeding group) that may arise from fishing operations (particularly hauling and meshing) within sub-tidal estuarine waters in NSW.

'Discards' may be live or dead and may result from either capture or contact with fishing gear.

Trophic level/ feeding group	Representative species/types	Normal prey/food source	Additional food sources facilitated by fishery operations	Likely overall effect on food availability/feeding options
diving birds	cormorants, fairy penguins, terns	surface swimming baitfish	small/juvenile fish associated with benthic habitat/marine vegetation	slight increase
other seabirds	pelicans, seagulls	'external items' from terrestrial habitats and/or near water's edge	fish from all trophic levels/feeding groups	large increase
pelagic predators (fish)	tailor	surface swimming baitfish	small/juvenile fish associated with benthic habitat/marine vegetation	slight increase
'surface swimming' baitfish	garfish, whitebait	plankton	none	no change
plankton	zooplanktion (including fish and invertebrate larvae), phytoplankton	NA	NA	NA
benthic omnivores/scavengers	yellowfin bream, trumpeter whiting, blue swimmer crab	benthos	fish from all trophic levels/feeding groups	large increase
herbivorous/detritivorous fish	sea mullet, luderick	algal slime and detritus	none	no change
benthic predators (fish)	dusky flathead	benthos, particularly larger mobile forms	'surface swimming' baitfish	slight increase
small/ juvenile fish associated with benthic habitat/ marine vegetation	juvenile bream, luderick & leatherjackets; gobies, pipefishes	plankton, epiphytes & small invertebrates associated with seagrass	none	no change
benthos	worms, marine snails, bivalves,	algal 'slime' mud and detritus	none	no change
seagrass/other marine	seagras, macroalgae	NA	NA	NA
algal 'slime' mud and detritus	various small algae, including microscopic forms	NA	NA	NA

d) Risk and uncertainty of the fishery disrupting trophic structure and the necessary management measures to address this risk

It is possible that disruptions to trophic structure within the area of the fishery's operation could cause long-term changes in community structure (e.g the loss/replacement of particular species). Changes to fishing practices aimed at reducing bycatch could even adversely affect certain bird species (e.g. pelicans) that may have come to depend on the associated provisioning (Jennings and Kaiser, 1998). Long term community shifts may also result from differing abilities to survive the rigours of being caught, sorted and discarded. For example, Greenstreet and Hall (1996) found that dogfish and skates, being relatively resilient to fishing pressure, have replaced gadoid finfish on the Georges Bank trawl ground in the North Atlantic. Further impacts may also be introduced by the fact that fishing effort is directed at the predators themselves (Cappo *et al.;* 1998, Kaiser and de Groot, 2000). Unfortunately the level of competition between predators and commercial fisheries for baitfish has not been studied, although it may be of concern (Dayton *et al.;* 1995, Hall, 1999). NSW estuaries are inhabited by a variety of predatory fish and seabirds that mostly feed on bait fish (e.g. SPCC, 1981b). The dispersal of baitfish schools, particularly as a result of purse seining or bull-ringing, may cause these predators to move elsewhere or to have difficulty in finding sufficient food (Cappo *et al.,* 1998). Furthermore, it is not known whether increased food supplies associated with certain fishing operations actually result in increased populations of the attracted species, or just locally increased abundances. It is conceivable, for example, that fishing operations may result in populations of such species being reduced, due to their being concentrated in areas where they are more liable to capture (NSW Fisheries, 1999b). A similar question has been widely asked in relation to fish attracted to artificial reefs (Pickering and Whitmarsh, 1997).

Unfortunately, there remains a great deal of uncertainty in relation to trophic impacts associated with fishing (Cappo *et al.,* 1998; Jennings and Kaiser, 1998; Hall, 1999). Despite specific evidence in a few cases (e.g. on temperate rocky reefs), Jennings and Kaiser (1998) argue that it is wrong to assume that most predator-prey relationships are so tightly coupled that the removal or proliferation of one species would result in detectable changes in ecological processes. They state that "simplistic models of predator-prey interactions often take no account of prey switching, ontogenic shifts in diet, cannibalism or the diversity of species in marine ecosystems and thus often fail to provide valid predictions of changes in abundance".

It appears that the risks of significant or irreversible trophic effects is low for most elements of the estuarine biota, the most likely exceptions being some of the sea birds. Even where localised effects do occur, the dispersed nature of fishing effort within the Estuary General Fishery needs to be considered from which we might conclude wide scale impacts are very unlikely. Jennings and Kaiser (1998) conclude that most marine trophic relationships are weak, and that environmental influences are normally paramount.

The range of management measures contained within the draft FMS aimed at reducing bycatch and controlling overall exploitation levels should be sufficient to safeguard community integrity.

4. Translocation of Organisms and Stock Enhancement

a) Background

Translocation of an aquatic organism can be generally defined as "the movement of live aquatic material (including any stages of the organisms' lifecycle and any derived, viable genetic material) beyond its accepted distribution, or to areas which contain genetically distinct populations, or to areas with superior disease or parasite status." (MCFFA, 1999).

The introduction of exotic species into new environments can pose a major threat to the integrity of natural communities, the existence of rare and endangered species, the viability of living resource-based industries and pose risks to human health. Marine pests can be as damaging as polution events but their effects are much more persistent (CRIMP, 2000a).

The risks associated with the translocation of any organism include the potential for the establishment of feral populations, environmental impacts and genetic shifts in wild populations. There is a wide range of species that have been introduced into Australia (Pollard and Hutchings, 1990a&b). Some of the more notable marine translocations which have occurred in Australia include Northern Pacific Seastars (*Asterias* sp.) and the Japanese seaweed (*Undaria* sp.).

Translocated species, if introduced to a new water body under the right conditions, may grow or breed prolifically and adversely affect other species or habitats; for example an introduced marine snail may compete with local snails, whilst a macroalgae (such as *Caulerpa taxifolia*) may smother seagrasses.

i) Possible mechanisms of translocation

Live aquatic organisms may be transported either deliberately through the trade in live product or the use of live bait, or inadvertently, through the movement of water or through the movement of vessels (hull fouling, ballast water and/or internal waters) and gear. Some invertebrates and macroalgae readily survive transport if lodged amongst damp equipment, and in some cases only a small fragment of macroalgae is necessary for propagation.

ii) Deliberate translocation

Currently there is no trade in live organisms derived from this fishery. Given the species concerned, it is considered unlikely that this will develop in the future unless there is a significant increase in market value or demand for live products.

The fishery does not routinely use live bait species, and it is not anticipated that this practice would be introduced into the fishery. With the limited amount of handlining undertaken, the risk of effective translocations through this process is extremely small.

iii) Inadvertent translocation

Movement of water

There is a risk that some vessels will retain water in their bilges, which could be transferred between locations, but routine practice is to drain trailered vessels each time they are removed from the water.

The target species are not normally part of the live fish trade in NSW and the use of live bait is very minimal and consequently the inadvertent translocation of species, from carrying live fish for sale or for bait, is highly unlikely.

Should live product trade or live bait practices be introduced on a significant scale, the fate of the transport medium is of some concern as undesirable organisms may be transported with it. This is of particular concern if the stock is being sourced from an area where pests, red tides, algal blooms or disease outbreaks are current and or common, and there is a possibility of subsequent release into natural waterbodies.

The risk may be minimised through appropriate treatment and disposal of transport medium, including the appropriate treatment (cleaning etc.) of equipment. The risk can be further minimised through obtaining material (catches and or bait) from areas where there have been no associated pest species or disease outbreaks.

Movement of fishing vessels

As the vessels used in this fishery are predominantly trailer boats, there is little risk of transmission of organisms through the fouling of hulls or their internal water supply systems as the vessels are removed from the water when fishing has been completed and stored out of the water until the next fishing operation.

Movement of fishing equipment

Some of the commercial fishing methods used in estuaries such as hauling, meshing and trapping, are very likely to involve the transport of equipment between estuaries within different areas of the state and may therefore result in the translocation of organisms beyond their current ranges. The relatively small boats used for handling, meshing and trapping are easily trailered between estuaries, so it is likely that the gear may be transported in damp or wet conditions inside the hull.

The movement of haul nets and mesh nets between fishing grounds is a significant vector for the movement of some hardy species, particularly if the net is not thoroughly cleaned after each fishing operation, and it is rolled or bundled so it remains damp until the next operation. A number of species, of algae and molluscs for example, can remain alive in damp conditions for several days and could be routinely and inadvertently translocated by this means.

b) Species likely to be translocated by fishing equipment

For an organism to be successfully translocated as a result of fishing activities it will need to survive collection, transportation and release.

Species that are most likely to be translocated by fishing equipment are those that are vulnerable to capture by, or attachment to, the gears used, and not susceptible to mortality as a consequence of the collection, transport or release. These will include species that are found on the fishing grounds and in association with target species or their habitat, are hardy, and can survive out of water for reasonable periods.

Organisms that may be subject to translocation can include species native to NSW that are moved between existing populations; native species that are moved to new locations (range extensions); or exotic species which having been established in one location (in NSW or possibly another state) could be spread further by their movement by fishing equipment or vessels.

While some organisms that are translocated do not establish feral populations, they could still pose a risk of introducing disease and or parasites from their original environment by direct impact such as predation or competition with species in the new environment. However, the primary threat of translocation comes from those species, which are able to adapt and survive and form viable populations in the new environment.

The species most likely to be translocated successfully through operations of the NSW Estuary General Fishery include any number of native species of aquatic plants and animals, but those more likely are molluscs, echinoderms and algae.

In addition, there is an increasing number of introduced species which are in NSW or neighbouring states, or could become established in NSW waters, which may be subject to translocation by fishing activities in the future. These include species that have been listed as ‘trigger’ species for national emergency response procedures, including:

Caulerpa taxifolia* (Vahl.) C. Agardh (1822)

An invasive strain of this macroalgae has become established in a number of locations in NSW water including Port Hacking, Lake Conjola, Careel Bay (Pitt Water), Lake Macquarie, Botany Bay, Burrill Lake and Narrawallee Inlet. In the northern hemisphere the species is known to compete with seagrass populations and colonise a wide range of habitats, reducing biodiversity and possibly fisheries productivity. It is very difficult to eradicate and can be spread readily through fishing gear, anchor chains and boating activities (CRIMP, 2000b; Grey, 2001). Fishing gear has been identified as a possible vector for the movement of the species.

Mytilopsis sallei

This species (known as the black striped mussel) is similar to the zebra mussel which has invaded the Great Lakes in North America and resulted in annual control costs of over US$30 million. It forms massive monocultures of up to 24000/m^2, out-competing native species and threatening maritime industries through fouling. Although it was eradicated following a $2 million emergency response program, the introduction of the species into Darwin in 1999 threatened the pearl culture industry and could have spread to northern Australian coastal waters between Sydney and Perth (CRIMP, 2001a).

***Undaria pinnatifida* (Harvey) Suringer**

This Japanese seaweed is extensively cultivated as a food plant in Japan, and was introduced to New Zealand and Australia most likely as a result of hull fouling or ballast water. The species is highly invasive, grows rapidly and has the potential to overgrow and exclude native marine vegetation. It also has the potential capacity to create major fouling problem for marine farmers. (CRIMP, 2000c). It is present in Tasmania and Victoria.

***Maoricolpus roseus* (Quoy and Gaimard, 1834)**

Although a native to the South Island of New Zealand, the NZ screw shell has been reported from waters of NSW since having spread from populations established as the result of translocations into Victoria and Tasmania. The species is known to establish extremely dense populations and compete with native mollusc species. Its superabundance on some fishing grounds is likely to result in economic losses and the high possibility of further translocation. It is present in NSW waters.

Asterias amurensis **(Lutken, 1871)**

The northern pacific seastar is arguably the most significant marine pest established in Australian waters. In 1998 some 50 juveniles were found in Port Phillip Bay (www.brs.gov.au, 2000) and in June 2001 that population has grown to an estimated 130 million (Rod Gowans, pers. comm.). The species is a significant predator and a threat to native marine communities and commercial shellfish farming operations. Although its translocation is most likely in the larval form in ballast water, an individual has been found in the water intakes of a coastal vessel, and movement of adults in fishing gear is possible (CRIMP, 2000d). It is present in Tasmania and Victoria.

Codium fragile tomentosoides **(Sur.) Hariot subsp. (Van Goor) Silva**

This species is regarded as a pest because of its invasive capabilities and reported impacts on shellfish farms in the United States of America. It is also reported to settle on native algae and to foul commercial fishing nets. Its habitats include intertidal and subtidal estuaries and ocean sites on hard substrata. (CRIMP, 2001b). It is present in NSW waters.

c) Risks/implications likely to be associated with translocations

The translocation of aquatic organisms raises many issues relating to the maintenance of local biodiversity including genetic shift in wild populations; establishment of feral populations; environmental impacts from the release of the species, and translocation of associated species (MCFFA1999). The social and economic impacts of established feral populations resulting from translocations can be very significant, as evidenced by the financial and amenity costs associated with management of the introduced zebra mussel in the Great Lakes of North America.

The introduction of parasites and diseases as a consequence of translocations can also have implications for both biodiversity and social and economic values.

Genetic shift in wild populations

Genetic diversity is recognised as one of the three levels of biodiversity which should be preserved to ensure the conservation of biological diversity. Genetic shift is a change in the composition of a population which results in a loss of biodiversity. Translocated individuals may interbreed with distinct resident populations of the same species, and this may result in the genetic shift in the local population through the introduction of foreign genetic material.

Although there is evidence that translocations have resulted in genetic shifts in native populations (Sheridan, 1995), there are little data available on the genetic composition of populations of aquatic organisms in NSW and no evidence of any such changes in NSW to date.

Establishment of feral populations

Feral populations are defined as populations that successfully establish as a result of the escape or release of organisms. Translocated organisms may establish feral populations and these can have a range of negative environmental effects including competition, predation and environmental modification.

There are a number of feral populations of marine organisms already established in coastal waters of NSW, including fish, sea squirts, bryozoans, gastropd and bivalve molluscs, isopods, crabs, barnacles and annelids (Furlani, 1996).

Environmental impacts from escaped organisms

Regardless of their ability to establish self sustaining populations in receiving waters, if translocated organisms are able to survive long enough in natural waterways they may have other impacts including competition, displacement, predation and habitat alteration.

Translocated organisms may compete with and displace local species, potentially causing long lasting changes to the community structure. Additionally, translocated organisms may eat endemic species. In many cases endemic species will be at greater risk to the translocated predator than to local predators because there would have been no similar predator-prey co-evolution. This may be particularly devastating if the local species are not normally eaten, and consequently have not developed defence mechanisms or appropriate defensive behaviours.

Translocated organisms may alter the habitats of natural waterways, for example the case of the marine alga *Caulerpa taxifolia.* This species has established marine vegetation communities at the expense of native seagrasses but these are not able to be consumed by native species, and do not provide a suitable environment for epiphytic organisms which are important in the food chain.

Implications for aquaculture

Some introduced species such as the northern Pacific seastar, could prey on aquaculture species such as mussels and oysters. Other species such as marine algae could overgrow equipment and sites causing economic losses, and control measures such as obligatory cleaning of mussel ropes, washing or sterilisation of gear etc could impose additional operational and financial burdens on farmers.

As a result of the establishment of the populations of *Caulerpa taxifolia* in Lake Conjola, the oyster farmer who holds leases in the area has been obliged (under the conditions of his permit) to ensure that his dinghy and gear is clean, and inspected, before he moves it between the Lake and other sites. Furthermore, the depuration water from Lake Conjola oysters must not be released into waterways.

Implications for other water users

Introduced species can have a direct impact not only on aquatic biodiversity and fisheries production, but also on other water users.

Feral populations of pest fouling organisms such as mussels and algae could result in loss of amenity and additional costs to all water users, and tourism and the community in general. The introduction of the invasive zebra mussel into the Great Lakes has resulted in fouling of fishing vessels, pleasure craft, stormwater outlets, marinas and moorings, boat ramps and beach amenities.

Implications for the environment

The establishment of introduced species breaks down the isolation of communities of co-evolving species of plants and animals. Such isolation is essential for the evolution and maintenance of biodiversity. Disturbance of this isolation by alien species can interfere with the dynamics of natural systems and cause shifts in predator/prey relationships, and ultimately, premature extinction of species (www.iucn.org, 1995, see Sheridan (1995) for a review).

Diseases and parasites

As a consequence of translocations, there is the risk of introduction of an exotic disease or parasite (bacteria, virus, protozoan or other organisms eg. worms, nematodes) into natural water bodies and subsequent infection of fish stocks or aquatic vegetation. The translocation of endemic diseases and parasites to new areas is also a major concern.

Parasites and disease are an integral part of any natural system. However, the introduction of disease or parasites (not necessarily exotic) into a natural water body could change the existing "parasite and disease status" of the waters. This introduction may perpetuate or aggravate existing diseases by increasing their incidence, virulence, potency and frequency. This impact may apply to parasites such as ecto-parasites on fish, fungal flora and gut parasites.

i) Proposed mitigation measures

As translocation requires the movement of an organism from one water body to another where it is not normally found, the more mobile the fishery and the greater degree of flexibility of operators to move around the state, the greater is the risk of translocation regardless of the means.

In the case of the Estuary General Fishery, fishing activities are now restricted to specific zones and fishers can generally not operate outside these zones.

As the geographic range of each zone is limited (the maximum is less than 200 km of coastline), the risk of fishers translocating organisms into areas that they do not normally exist is small.

Marine pests

There are currently no formal processes in place for the management of introduced marine pests in NSW, although the state is committed to the development of such processes in the short term.

The NSW Government has endorsed the recommendations of the National Taskforce on the Prevention and Management of Marine Pest Incursions. These recommendations included the requirement for all states and territories to provide resources for the interim and/or long term for:

- effective and timely implementation of interim arrangements for managing marine pest incursions pending the development of a National System for the Prevention and Management of Marine Pests;
- the development and implementation of a NSW Emergency Marine Pest Management Plan (EMPMP)
- data collection and dissemination on pests and response processes
- a review of legislative powers to act in the event of an emergency
- communication and information programs
- the development of the National System for the Prevention and Management of Introduced Marine Pests
- plans for the mitigation of impacts of established marine pests
- the inclusion of marine pests provisions in port environment management plans

- investigating the issue of liabilities for persons involved in dealing with emergency responses
- agreement to contribute to interim national cost sharing arrangements for emergency responses comprising a 50:50 share between the States and the Commonwealth, with the States' contribution calculated on a simple per capita basis
- agreement to contribute to a national funding base for the support of the National System in the long term including port baseline surveys, community preparedness, education and training, research and development and monitoring (AFFA, 2000).

The NSW EMPMP will include details of the mitigation methods proposed and these will be in accordance with the guidelines laid down in the Taskforce Report (AFFA, 2000). These will include general protocols for the transport and handling of equipment being moved between estuaries in the event of an outbreak of marine pests in any region.

ii) Contingency plan for pest species management in NSW

In the event of an outbreak of marine pests in the intervening period, NSW will adopt the draft Australian Emergency Marine Pest Plan as detailed in the report of the Taskforce on the Prevention and Management of Marine Pest Incursions.

Education programs are required to make boat operators and owners aware of the potential for their vessels to transport exotic fouling organisms and the steps they should take to minimise the risk of this occurring.

Codes of practice are required to ensure that fishing operations do not facilitate the spread of exotic organisms through the movement of equipment between areas. This will involve industry awareness programs and the development of treatment (‘sterilisation’) protocols for gear and equipment. In Victoria for example, research is currently underway to develop ways of treating mussel grow-out lines to kill exotic species before lines are moved between coastal waters (CRIMP, 2000a). Similar protocols are imposed in NSW for the management of *Caulerpa taxifolia*.

Current situation: Caulerpa taxifolia

Following the identification of invasive populations of the marine algae *Caulerpa taxifolia*, in NSW the Minister for Fisheries announced a series of restrictions, including prohibition on the removal of equipment from already affected estuaries, area specific fishing nets and boats, and the closure of certain waterways to netting activities. These actions complement an intensive public education and awareness campaign on the nature and impact of the species, and the declaration of the species as noxious marine vegetation.

Small Ports Project

NSW Fisheries is working in association with the Victorian Department of Natural Resources and Environment, local Port Managers, the Centre for Research on Introduced Marine Pests and other agencies to develop practical ways to assist fishers, vessel operators and port managers to reduce the risk of spreading marine pests. The key focus is on ways to reduce the spread of marine pests through gear and hull fouling and will take the form of a series of guidelines (DNRE, 2000).

Diseases and parasites.

The *Fisheries Management Act 1994* contains provisions for response to disease of fish or marine vegetation. These include the powers to declare a disease, establish quarantine areas, prohibit the sale or movement of diseased fish or marine vegetation and control the release or transmission of the disease. In addition, plant diseases can also be declared and subsequently managed in a similar manner under the provisions of the *NSW Plant Diseases Act 1924*.

Following its endorsement by the Commonwealth Ministerial Council on Forestry Fisheries and Aquaculture, NSW (along with all States and Territories) is committed to the management of aquatic animal health through AQUAPLAN. This plan is a broad, comprehensive strategy that outlines objectives and projects to develop a national approach to emergency preparedness and response to the overall management of aquatic animal health in Australia (AFFA, 1999). Within AQUAPLAN there are a series of programs, including quarantine, surveillance, monitoring and reporting, preparedness and response, and awareness, that will address aquatic disease management issues.

In a manner similar to that for marine pests, it will be important to ensure that fishing operations do not facilitate the spread of disease through the movement of equipment between areas. Depending on the nature of the disease this may include industry awareness programs and/or the development of treatment ('sterilisation') protocols for gear and equipment. Alternatively, the closure of areas to fishing can be ordered by the Minister under the provisions of Section 8 of the *Fisheries Management Act 1994*.

Stock enhancement

There are currently no proposals for the artificial enhancement of populations of species which are the target for this fishery and none are anticipated in the immediate future.

All such proposals would be subject to separate environmental impact assessment processes in accordance with the provisions of the *Fisheries Management and Environmental Assessment Legislation Amendment Act 2000*.

5. Fish Health and Disease

a) Impacts of gear types and fishing methods

It is considered that the gear used in the Estuary General Fishery is unlikely to have a significant impact on the health of the target or non-target organisms. While it is possible that some individuals will be physically injured or damaged by the direct effect of fishing gears, there is no evidence to suggest that fishing activities are having any impact on the health of the individuals in the ecosystem, or are promoting increased disease risks.

There is no information available on the levels of stress, injury or susceptibility to disease that might be imposed as a consequence of the activities of the fishery.

b) Use of bait

The Estuary General Fishery includes a small component of handlining, including the use of aquatic species as bait. In the large majority of cases, the fishers would routinely collect their own bait from the immediate vicinity of the area in which they are fishing (Stewart *et al.,* 1998). It is unlikely that there is any additional risk of transmission of diseases using bait under these circumstances.

Imported bait

Imported seafood products are regularly used in Australia as bait, and have been associated with a number of fish disease incidents in recent years. There is some concern that the use of imported bait presents a significant disease risk (Fletcher *et al.,* 1997; Gaughan *et al.,* 2000; and Whittington *et al.,* 1997).

The use of imported raw prawns as bait in Australia has recently been identified as a matter of concern, with the knowledge that some imported species carry white spot syndrome virus (WSSV). Although there are restrictions in place for the use of these imported prawns as bait as opposed to human consumption, their use is likely to continue at least on a small scale (www.affa.gov.au, 2001). While it is possible that some imported prawns destined for human consumption do find their way to the bait trade and could be purchased by estuary general fishers, it is much less likely than the fishers collecting their own prawns for bait.

Notwithstanding the limited amount of bait use that takes place, and the ready availability of local species, it is considered that the extent of use of imported bait presents a small risk of disease introduction.

Minimising impacts on health of wild fish resources

Although the use of imported bait is limited, there is nonetheless a requirement for the use of pilchards and these have been traditionally obtained from overseas. Although there is no evidence to suggest that the use of imported species by the Estuary General Fishery has resulted in the introduction of disease to NSW to date, there is still a risk that this could occur.

While ever the imported bait can not be assured to be disease free, the use of imported bait will present a risk. The Commonwealth Government through the Australian Quarantine and Inspection Service (AQIS) is currently developing import risk analyses on imported fish products for use as feed or bait, and this is likely to result in the development of new import protocols which should reduce the risks of diseased product being imported (www.brs.gov.au; 80/fish/status99, 2001). However, to minimise the risk it would be appropriate to avoid the use of imported bait and promote the use of alternative products derived from local species.

c) Stock enhancement

The deliberate translocation of any target species resulting from stock enhancement would present a risk of disease and parasites although this can be mitigated by the use of fingerlings/fry which had been raised in accordance with appropriate health protocols.

However, as previously noted, there are currently no proposals for the artificial enhancement of populations of species which are the target for this fishery and none are anticipated in the immediate future.

All such proposals would be subject to separate environmental impact assessment processes in accordance with the *Fisheries Management Act 1994*.

6. Water Quality Issues

a) Potential sources of pollutants related to the proposal

Table F12 summarises the characteristics, likely magnitude, and probable frequency of pollutant related events that may impact on the operation of the fishery.

Table F12. Characteristics, likely magnitude and probable frequency of pollutant related events derived from operations associated with the Estuary General Fishery.

Magnitudes and frequencies are given in relative terms, bearing in mind that the (invariably small) vessels used in the fishery account for less than 0.5% of the vessels registered in NSW. In terms of magnitude, "Low" means no measurable effect likely from an individual incident; "Moderate" means localised and/or short term effects likely; and "High" means widespread and/or long term effects likely.

Source	Characteristics/ issue	Magnitude	Frequency
Antifouling treatments	Toxic chemicals leached into water, more toxic forms particularly harmful to sessile invertebrates	**Low** - less harmful compounds now in use; slow rate of release into environment	**Low** - possibly one treatment per vessel per year among less than 0.5% registered vessels
Chemicals, fuels etc.	Toxic chemicals discharged into water; variable effects depending on compound	**Low** to **Moderate,** depending on actual incident	Fuels and chemicals: **Low** except for extremely minor incidents; Bilge water: **Moderate**
Debris	Solid material, generally non-toxic; but may injure or interfere with marine life	**Low** - minor accidental dumping only likely; most fishers increasingly conscious of gross pollution	**Low**
On-board processing waste	Organic material likely to be consumed by marine life; can have undesirable trophic effects, and is a source of (usually undesirable) nutrients.	**Low** - vessels used in fishery too small to facilitate substantial on-board processing	**Moderate** in relation to small amounts of waste (e.g. less than a fish box); **Low** otherwise

i) Antifouling agents

Antifouling agents are painted on boat hulls to reduce marine growth and the consequent loss of performance. In recent years, much concern was raised about the environmental affects of tributyl-tin based compounds. However, these have now been banned on all vessels less than 25 metres in length, and are no longer allowed to be used on boats in the Estuary General Fishery. Substitute treatments are far less damaging to the environment. Many vessels used in the Estuary General Fishery are regularly moved between brackish and high salinity areas, reducing the need for regular antifouling.

ii) Discharge of chemicals, fuel or bilge water

Accidental or (very rarely) deliberate discharges of chemicals, fuel or bilge water are likely to occur in relation to vessels used in the Estuary General Fishery. However, serious discharges would be very rare. Modern engines and fuel systems are compact and easily managed (particularly on the small vessels used), meaning that individual spills of fuel and/or oil are likely to be extremely minor. Also, the size of the vessels used means that larger than usual catches often have to be temporarily held on board in open boxes or even directly in the hull; this means that fishers have a strong incentive to keep their boats as clean as possible. 'Bilge water' would be the most likely discharge from these small vessels. However, bilge water, as its name suggests, is mostly water, with variable amounts of organic matter (from having fish aboard etc.) and small amounts of fuel and/or oil mixed in: such discharge would be only mildly toxic and unlikely to have any major effects considering the volumes involved.

iii) Discharge / dumping of debris

A variety of debris may potentially be dumped or lost from fishing vessels. Examples include plastic, paper and pieces of fishing gear. Such materials are mostly non-toxic, but may injure or interfere with marine life. Such interference or injury would be rare, simply because most debris would not be of a shape and/or material likely to trap or ensnare birds or other animals. Also, species likely to ingest items such as plastic bags (e.g. turtles) are relatively uncommon in NSW estuaries. Members of the public are now very conscious of gross litter (Zann, 1995) and commercial fishers in particular are becoming increasingly conscious of any obvious pollution within their working environment. It is therefore likely that most incidents would be very minor.

iv) Discharge / dumping of on-board processing waste

On board processing waste is likely to consist of liquid ‘slurry’ containing body juices, scales etc. All of this material would be readily decomposed or eaten, although not without possible trophic effects (see Chapter F section 3) and/or impacts associated with nutrient enhancement (see Chapter F section 10). It is likely, due to the small sizes of vessels used in the fishery, that most on-board processing would be restricted to small amounts of catch. Substantial amounts are most likely to be processed at shore-based facilities (particularly at ‘fisherman’s co-ops’).

b) Associated risks to water quality

The sources of pollution associated with fishing operations are likely to be of low magnitude and of low to moderate frequency (Table F12 and discussion above). The number of vessels used in the Estuary General Fishery represent less than 0.5% of the more than 180,000 vessels registered by the Waterways Authority in NSW, and the vessels used in the fishery are almost invariably small, at between three and six metres: the collective potential for pollution from these vessels is likely to be only a tiny fraction of that associated with boating generally. Furthermore, these fishing vessels are widely dispersed between and within estuaries. Unlike some other fisheries, there are no major ‘home ports’ containing large numbers of vessels in one location. Fishing effort (i.e. operations) are also similarly dispersed: problems caused by the cumulative impact of many small sources in one area are unlikely to occur, even within those estuaries (e.g. coastal lagoons) where water circulation is poor. Even under abnormal conditions, such as during stratification after heavy rain, or during prolonged periods of entrance closure associated with drought, pollution arising from fishing operations is unlikely to have any significant effects in the context of other vessels, and the wide range of land-based sources of pollution (Chapter F section 10).

On the basis of the above, it is assumed that the risk to water quality associated with fishing operations in the Estuary General Fishery is very small, and does not require any further management given existing controls as administered by the Waterways Authority and the Environment Protection Authority.

There is however, some potential for localised impacts from on-shore facilities associated with the fishery. Whilst any effects related to vessel maintenance are likely to be insignificant in relation to the number and sizes of vessels maintained within NSW generally, significant (though highly localised) effects from on-shore fish processing facilities (i.e. ‘fishermans co-ops) are possible.

Discharge from such facilities would primarily consist of non-toxic organic waste derived from cleaning fish. This would be expected to have some localised trophic effects (e.g. attract scavengers) and would contribute nutrients to receiving waters. However, in the context of the plethora of major land-based sources of nutrients (Chapter F section 10), any such effects are likely to be minor.

c) Baseline studies in areas of significant impact

There are unlikely to be any areas of significant impact, and no baseline studies are therefore necessary. Existing controls (administered by the Environment Protection Authority) on shore-based activities liable to cause pollution are sufficient to effectively manage activities such as on-shore processing and vessel maintenance.

7. Noise and Light Impact Assessment

The following summary is based on the detailed consultants report prepared by SMEC Australia Pty Ltd and presented in Volume 4 Appendix CF1.

a) Noise impact on residents adjoining estuaries

Noise from estuary general fishing may cause adverse effects to residents where houses are close enough to the estuary for the fishing activity to cause disturbance. Given the type of activity and likely low sound power level of the potential noise sources, it is probable that there is only a potential for disturbance during night-time operations and complaints related to fishing activity are minimal. The potential for disturbance would be determined by the following factors, the:

- size of the boat motor and whether it is an outboard or in-board motor
- duration and type of fishing activity
- number of other boats operating in the same area
- position of the house, both its distance from the activity and intervening topography
- land-based activity in the vicinity of the house.

A house in a coastal town or close to a main road could be expected to have a higher background noise level to an isolated farm house.

b) Noise impact on wildlife

Noise from estuary general fishing activities would only affect wildlife when:

- fishing is undertaken in areas where wildlife that is sensitive to noise is present; and/or
- noise from fishing activities disturbs wildlife either due to the volume or type of noise generated.

Noise impacts could result from fisherman's voices, the sound of equipment contacting boats, motors and the splashing of water. Wildlife that could be affected may include birds, terrestrial and arboreal mammals, aquatic mammals and non-target fish. Any such wildlife that is disturbed may:

- remain in the area but become inactive (i.e. hide)
- temporarily move away from the area to return when the disturbance has ceased
- may permanently move away from the area (this is more likely if the disturbance is prolonged or occurs frequently).

The significance of the disturbance to wildlife would vary depending on the species and on the timing of the disturbance. The greatest impacts could be expected during the nesting or breeding season. At these times, any disturbance could impact upon the reproduction of a species and may endanger the viability of local populations. This would be particularly be the case if the disturbance were a frequent, regular or ongoing activity.

Species most likely to be impacted by commercial fishing during the nesting or breading season would include birds that nest in aquatic or riparian vegetation or in vegetation near the water's edge. Non-target fish could similarly be impacted if fishing is undertaken near nurseries or breeding habitat such as mangroves and areas of seagrass.

c) Noise mitigation measures

A potential for some adverse effects caused by noise from estuary general fishing on people and wildlife has been identified. This is not a new phenomenon as commercial estuary fishing has been a continuing industry for more than 100 years. There are existing controls on the Estuary General Fishery including:

- A **code of conduct** in the Clarence River administered by the Waterways Authority that establishes maximum acceptable noise levels for prawn set pocket net fishing operations
- **Location controls:** Refers to restrictions on the parts of the estuary where commercial fishing can be done, and where certain types of equipment may or may not be used
- **Time controls:** Refers to daily time restrictions on when commercial fishing may be done, and at what times of day certain equipment can be used
- **Weekend/public holiday/school holiday closures:** Refers to a total closure or closures to netting on commercial fishing activity during the specified times
- **Seasonal controls:** Refers to restrictions on what periods of the year certain commercial fishing activities may be done
- **Total closure:** Means that the estuary is closed to commercial estuary general fishing.

These controls were instigated for a number of reasons including wildlife conservation and to prevent disturbance to people living close to the estuaries.

It is proposed to monitor the levels of complaints received concerning noise levels from the commercial Estuary General Fishery. Two authorities currently receive complaints, local councils (who tend to refer these to NSW Fisheries) and regional offices of NSW Fisheries. The number and type of complaints will be used as input into future reviews of the draft FMS.

d) Light impact on residents

The only potential for adverse effects from lights used in the fishery would be from spotlights used as part of the fishing activity. Navigation lights or deck lighting would not have a potential for significant adverse effects. Spotlights would only cause an adverse effect where these were shone into houses adjoining the estuary. The activities of the estuary general fishers generally do not require intensive use of spotlights nor high strength lights. It is not anticipated that this type of lighting would have a potential for significant adverse impacts.

e) Light impact on wildlife

Impacts from light upon wildlife are unlikely to be significant unless light beams repeatedly or continuously affect the same individuals. The severity of this impact would increase with the intensity of the light.

Wildlife most susceptible to impacts from light would be those occurring in the water, on aquatic vegetation or near the water edge. Species would include aquatic mammals, non-target fish, arboreal and terrestrial mammals and birds. Nocturnal species would be most likely to be impacted. However, diurnal species disturbed from their sleep could also be impacted.

f) Light mitigation measures

Mitigation measures outlined for noise impacts are generally applicable for reducing the potential for adverse effects from lighting. In summary these were:

- existing controls to limit the location and hours of fishing
- monitoring of levels of complaint.

8. Air Quality

The following summary is based on the detailed Consultants report prepared by SMEC Australia Pty Ltd and presented in Volume 4 Appendix CF1.

The identified sources of air emissions from the Estuary General Fishery are emissions from boat engines. These emissions do not have a potential to significantly affect air quality. They:

- do not represent a concentrated source of inputs as they occur along the NSW coast
- vary according to both season and time of day
- are from relatively small engines.

Mitigation measures to reduce air quality emissions are the same as those proposed to reduce energy and greenhouse inputs. These are discussed in the following section.

9. Energy and Greenhouse Issues

The following summary is based on the detailed Consultants report prepared by SMEC Australia Pty Ltd and presented in Volume 4 Appendix CF1.

a) Description of fishing fleet

Boats used in the Estuary General Fishery are generally small ‘run-about’ or ‘punt’ style vessels generally of aluminium, wood or fibreglass construction using petrol or marine engines/motors.

Table F13 contains a summary of the characteristics of the estuary general fishing fleet.

No data were available for the typical use of boats in terms of hours used. This would vary according to the fishing business, the estuaries operated in and the time of year. Similarly, there is no quantitative information on the catch/effort characteristics of the different methods of fishing.

Table F13. Fishing fleet characteristics.

Characteristic	Sample size	Median	80% Range	Range
Motor (kilowatt)	457	18.6	7.4 to 44.7	3.4 to 150
Boat Length (metres)	562	5.1	4.0 to 5.9	2.5 to 9.0

Source: Data supplied to SMEC by NSW Fisheries

Petrol and diesel fuels have similar CO_2 emission factors as shown in Table F14. On that basis, the fuels are not dissimilar in their potential greenhouse impact although this would depend on other factors such as comparative efficiency between diesel and petrol motors and motor size availability.

Table F14. CO_2 emission factors.

Fuel	CO2 Emission Factor
	(kg CO2/GJ)
Petrol	65.3
Diesel	69

Source: *Factors and Methodologies* (Greenhouse Challenge, AGO, 2001)

b) Energy and greenhouse assessment

Energy and greenhouse effects are considered together because the only potential for greenhouse gas inputs is from the energy consumed in the boat motors. Overall, the numerical size of the fleet and the size of the boats and motors used means that the overall consumption of energy resources and subsequent greenhouse gas emissions are not significant. The Estuary General Fishery consists of many small businesses operating in a low technology environment. Potential measures to reduce energy and greenhouse emissions may not be practicable for many of these ventures due to their initial cost.

Renewable energy sources for fishing vessel operation could include solar and wind energy. However utilisation of these energy alternatives is not currently considered economically viable for general estuarine commercial fishing vessels.

10. External Impacts on the Fishery

The purpose of this section is to outline the sources of external impacts that could occur on the Estuary General Fishery, a discussion of their effects and magnitude on the fishery and any mitigative management responses to combat these impacts.

a) Land based activities likely to affect the environment on which the fishery relies

i) Urban foreshore development

Urban foreshore development includes the construction of marinas, the clearing of foreshore vegetation, drainage of wetlands and reclamation. The environmental effects associated with these developments are discussed in NSW Fisheries (1999a) and are outlined in the following paragraphs.

Marinas, jetties and similar structures may have a variety of effects on nearby fish habitats (NSW Fisheries, 1999a; Hannan, In prep.). They may cause direct damage to sensitive habitats during construction: for example, seagrasses may be destroyed by piles, and mangroves may be cut to make way for walkways or ramps. These structures may also cause overshadowing of marine vegetation, with seagrasses (especially strapweed, *Posidonia australis*) being particularly sensitive (Fitzpatrick and Kirkman, 1995; Glasby, 1999a and b; Shafer and Lundin, 1999). Also, interference with waves and/or currents may result from the physical bulk of the underwater portion of a structure. Such interference (say from a large pylon) may cause localised scouring of the seabed and destruction of any seagrass in the affected area. Depending on prevailing wave and current conditions, initial damage to seagrass may progressively expand through continued undermining of the exposed seagrass edges. Although the loss of habitat associated with any individual structure may be small, cumulative impacts and fragmentation (especially with respect to sensitive habitat such as seagrass) may be significant along highly developed shorelines (Shafer and Lundin, 1999).

The clearing of foreshore vegetation, say to make way for buildings or recreational facilities, can also have a range of detrimental effects on fish habitats (Hannan, 1997; NSW Fisheries, 1999a). Intertidal vegetation such as mangroves or reeds may form habitat corridors for species such as Australian bass and bully mullet, whose juveniles migrate from estuaries to freshwater at a young age: breaks in such corridors may hinder such migration by making the juveniles more prone to predation, by reducing food availability, and/or by altering their behaviour. Foreshore vegetation is the ultimate source of snag material, which in turn provides favoured habitat for a variety of fish and invertebrates; by providing shelter (from predators and/or strong currents) and food supply. Also, the overhanging branches provide terrestrial food such as insects. Loss of snag material and/or overhanging vegetation is likely to significantly alter fish community structure in the effected area (Gehrke *et al.,* 1996; Growns *et al.,* 1996). Foreshore vegetation can also help to absorb and slow runoff, thereby trapping sediments and nutrients before they reach the waterway. Loss of foreshore (riparian) vegetation exacerbates the pollution related problems (see sub-sections ii and iv which follow) associated with land clearing and urban development.

Wetlands include mangrove forests, saltmarshes and brackish/ freshwater swamps. They provide habitat for a wide variety of fish and invertebrates. They also tend to trap/absorb in-flowing pollutants and therefore contribute to better downstream water quality. Major wetland loss within a particular catchment is likely to impact on fish communities and exacerbate problems relating to nutrient or sediment inputs. For example, a perceived decline in fish populations within the lower Clarence River over recent decades has been blamed on the widespread drainage of associated swamps, these having provided important nursery and feeding habitats for local estuarine fishes (Pollard and Hannan, 1994). A lack of wetlands (whether natural or artificial) within most urban areas contributes to problems associated with storm water runoff (see sub-sections (ii and (iv) which follow). Furthermore, the drainage and/or excavation of wetlands is also a common cause of acid runoff, which may result in massive fish kills under certain conditions (see sub-section iii which follows).

Reclamation is often the most damaging type of activity associated with foreshore development, as it usually causes the total destruction (as opposed to modification) of aquatic habitat. Reclamation can also interfere with water circulation, and possibly result in a range of indirect effects beyond the actual works area. These may include increased siltation, reduced water quality and habitat (e.g. seagrass) loss. Major reclamation works, such as those for the runways and port works in Botany Bay (Sydney) can result in the loss of large areas of seagrass and other shallow habitat. Apart from reducing the area available to fishing, such works may have major impacts on an estuary's productivity. In the case of Botany Bay, it is known that reclamation for the third runway resulted in the loss of a particularly productive juvenile habitat, where consistently outstanding recruitment of juvenile tarwhine, luderick and yellowfin leatherjacket had been previously noted by McNeill *et al.* (1992).

ii) Stormwater and sewage outfalls

Stormwater and sewage carry a wide range of pollutants, the most notable being pathogens, nutrients and sediment. The nature and impacts of the various other pollutants are discussed under "Pollution from point and diffuse sources" (sub-section (iv)).

Excessive pathogen concentrations, whilst of primary concern to swimmers, are also likely to affect fish and other aquatic life. Many types of pathogens (particularly bacteria) are not host-specific, and are capable of infecting aquatic animals, particularly when such animals have already been injured in some way. Fish that have suffered damage to their skin or gills are particularly susceptible. Also, many types of mollusc (including oysters and mussels) are filter-feeders and tend to concentrate pathogens in their gut, thereby posing a risk to human consumers. In regularly affected areas, the resultant marketing problems (discussed below) tend to include all types of seafood (including finfish).

High nutrient concentrations can, under the right conditions, promote excessive growths of microscopic algae (such as cyanobacteria and dinoflagellates) in the water. Such 'algal blooms' can become toxic, to the point that other aquatic life are harmed. Also, humans can become ill from consuming affected seafood (especially filter feeding molluscs), leading to marketing problems as discussed below (See also Chapter H section 2.1).

Suspended sediments can clog fish gills and block the filter-feeding systems of invertebrates. In reducing underwater visibility, they can also reduce the feeding ability of sight based predators, including many types of carnivorous fish.

Impacts on habitat

Seagrass habitats are particularly vulnerable to the effects of pollution. Urban runoff (stormwater), sewage overflows and septic seepage threaten seagrass habitat through the continuing addition of suspended sediments and nutrients. These inputs cause greater than natural turbidity, both directly and from excessive phytoplankton growth. Such turbidity is most evident where flushing is poor and inputs are great. Increased turbidity reduces the light available to seagrass, with the deeper parts of a bed being particularly vulnerable to consequent damage (Shepherd *et al.,* 1989; Fitzpatrick and Kirkman, 1995). Whilst extra nutrients can actually enhance seagrass growth, very high levels are likely to cause heavy epiphytic growth that can smother and shade seagrass, and eventually lead to its decline (Shepherd *et al.,* 1989). Nutrient enrichment may also promote the competitive replacement of seagrass by *Caulerpa* spp., which are green macroalgae morphologically similar to seagrass.

Also, sedimentation gradually makes areas too shallow for seagrass, particularly in bays receiving urban stormwater runoff. Heavy loads of fine sediment washed down after heavy rain can coat seagrass leaves, reducing photosynthetic efficiency and therefore vigour (Poiner and Peterken, 1995). As a result seagrass is especially vulnerable to being coated in sheltered bays where waves and currents are slight. Where sediment inputs are particularly great, seagrasses can be completely buried. Sedimentation also alters the nature (particularly with respect to parent material and grain size composition) of substrata supporting seagrass which can cause both changes in the seagrass itself, and in the invertebrate community associated with the substrata.

Other habitats can also be seriously effected by sediment-laden runoff. Macroalgae (an important component of rocky reefs) are liable to be affected in the same ways as seagrasses. Macroalgal assemblages on rocky reefs are complex (Kennelly, 1995; Kennelly and Underwood, 1992) and their recover after smothering could take years because some species of algae will recolonise faster (such as green turfing algae) than other species (such as kelp). In fact Kennelly (1987) found that early colonisers of turfing algae can inhibit the later colonisation of kelp species. Sessile invertebrates (another major component of rocky reef habitat; Chapter F section 1) are vulnerable to suspended sediments, which can interfere with their feeding and respiration. Rocky reef itself is vulnerable to being buried by sediment derived from new urban developments and rural erosion; for example within many of the sheltered bays and inlets in and around Sydney, depositions of sand or mud are slowly encroaching on adjacent rock habitat.

Impacts on seafood marketability

Filter feeding bivalve molluscs (such as oysters, mussels and pipis) are very efficient at concentrating within their guts any bacteria, viruses or toxic algae that might be present in seawater. Whilst these organisms might not harm the mollusc, they can cause serious illness in human consumers, particularly when the mollusc is eaten raw (See also Chapter H section 2.1). The risk of human illness is greatly increased when the water from which the mollusc is harvested has been recently contaminated with sewage effluent, stormwater or an algal bloom. Such contamination has the potential to cause many cases of illness, as illustrated in the recent cases of hepatitis attributed to Wallis Lake oysters (NSW Fisheries, Internal Report). These cases were believed to have resulted from poorly treated sewage effluent (NSW Fisheries, Internal Report).

Areas that have been associated with multiple cases of seafood-borne illnesses are likely to acquire a reputation of being ‘polluted’ and treated with extra caution by members of the public, leading to on-going marketing problems. Furthermore, any negative perceptions (whether based on reality or not) are likely to extend to other types of seafood, such as finfish.

iii) Disturbance/drainage of acid sulphate soils

Floodplain drainage, excavation or dredging associated with the installation of floodgates or other in-stream works (and in some circumstances the works described in sections 10(a)(i) and 10(b)(ii) can expose acid sulfate soils to air.

Impacts of acid water

The effects of acid sulphate soil drainage on aquatic biota can be described at the ecosystem, population and species level. In general the effects can be categorized as mortality of fish and invertebrates; increased susceptibility to disease especially epiozotic ulcerative syndrome (EUS); physiological effects (related to reduced growth, visual and olfactory impairment, bone disorders); and avoidance responses (Sammut *et al.,* 1993; Sammut *et al.,* 1995). The cause of the observed effects is not fully understood but the interrelation of pH and its effect on the chemistry of iron and aluminum and their respective toxicity are the key contributors to the impacts on biota.

The physiological effects of low pH and its association with aluminum and iron is well studied for northern hemisphere freshwater fish and other aquatic organisms (Erichsen Jones, 1969; Lloyd, 1992; Howells, 1994). However, data for Australia are limited to the work by Wilson and Hyne (1997) and Hyne and Wilson (1997) on Sydney rock oyster embryos and larvae of Australian Bass and the Richmond River study on estuarine fish and benthic communities (Roach, 1997).

The associations between acid drainage, *Aphanomyces* fungal infection and "red-spot" ulcer disease or EUS and fish kills have been reviewed by Callinan *et al.* (1989, 1993, 1995a, b).

Hydrology and rainfall in the catchments govern acid production in a sequence of events that have the following major features and impacts (adapted from the reviews of Alabaster and Lloyd, 1980; Cappo *et al.,* 1997; Howells, 1994; Sammut *et al.,* 1993, 1995, 1996; Willet *et al.,* 1993). After rainfall events and a rise in the water table, aluminium, iron, manganese and other ions are stripped out of the soil by sulphuric acid originating from the oxidation of pyritic sediments. The significant quantities of aluminium and iron derive from aluminosilicate clays commonly associated with coastal estuaries. The lower the pH, the greater the amount of aluminium and other ions that are mobilised. In addition, low dissolved oxygen in water bodies has also been linked to the suspension of iron monosulfides in drains.

Floods and other high flow events drain large "slugs" of this low pH water through floodgates to meet higher pH bicarbonate rich estuarine water. This can produce aluminium hydroxide and iron hydroxide flocs in massive amounts. About one tonne of iron floc is produced for every tonne of pyrite oxidised. The aluminium and iron flocs disperse through the estuary producing a bluey-green stain. The flocs then bind to clay particles and settle out to produce clear estuarine waters. Smothering of the substratum with flocs of iron hydroxide (up to one metre deep) can result in the death of most gilled, benthic life. During this time fish and invertebrate kills occur for a variety of reasons that depend on the prevailing pH.

- acid kills most fish and invertebrates at approximately pH 3 - 3.5
- aluminium hydroxide flocs bind to clays and attach to skin and block gills at higher pH
- above pH 4, iron oxyhydroxides are precipitated and may cause suffocation
- inorganic monomeric aluminium [$AlOH_2^{++}$] toxicity kills most fish at pH 5

- lack of dissolved oxygen can occur when oxidation of iron occurs from the ferrous iron to ferrihydrate

Fish with epithelial defenses weakened by metal flocs and acid suffer from *Aphanomyces* fungal infections. These infections produce extensive ulcers (red-spot, EUS, Bundaberg Disease) on fish that often are so deep that the caudal rays or neural spines of the backbone are visible. Survivors of these attacks invest so much energy in healing that there is no reproduction until condition is regained in subsequent years.

Fish with ulcers or healed ulcer scars are unmarketable and have, at times, comprised up to 30% of some catches of whiting, bream, mullet and flathead. Lower growth rates of prawns in pond aquaculture occurs because less bicarbonate is available to them in the low pH water and they will not molt. In the Tweed and Hastings Rivers, the role of acid drainage in oyster mass mortality, disease, shell erosion and low growth performance has been apparent.

The impacts of acid water on non aquatic fauna includes poor crop and pasture growth in acidified parts of the floodplains, lower dairy and beef animal production, corrosion of pipes and cement structures and acidification of aquifers and potential human health problems from groundwater consumption (high aluminium, acidity) (Anon, 2000).

Impacts of floods

The impact of major flooding due to climatic events can adversely affect fish resources and result in significant fish kills. The February/March 2001 floods and resultant fish kills in the Richmond River and Macleay River are examples. The floods initially resulted in minor fish kills, but within a week had escalated to become unprecedented relative to available records. Surveys revealed tonnes of dead and dying fish and invertebrates from juveniles to adults, throughout the river.

These were sudden floods, the water level peaked quickly and dropped very fast with large volumes of water inundating the floodplain. Then, the weather cleared with high daytime temperatures. Much of the decaying organic material on the floodplain drained into the river over a few days, reducing oxygen levels. Sampling of the water on the floodplain and in the rivers showed acceptable acidity, but the dissolved oxygen levels were below one part per million.

The relationship between the floodplain and the fishery is not fully understood and more investigation is needed to identify specific problem areas. However, the changed nature, management and use of the floodplain has altered natural drainage patterns. Flood waters used to take 100 days or more to drain back into the river, now they take about five to seven days and this has significant impact on water quality.

iv) Pollution from point and diffuse sources

Unpolluted water is the most critical component of fish habitat, with few fish species being able to survive in badly polluted water. Pollutants affect fish and other aquatic animals in a variety of ways, including direct toxicity, interference with feeding and respiration, altered behaviour, increased susceptibility to disease and reduced reproductive success. Even if pollution does not directly kill affected animals, a variety of chronic or sub-lethal effects can occur.

A wide variety of pollutants enter estuaries and associated rivers and streams. Common pollutants include pathogens, nutrients, sediments and a wide range of toxic chemicals such as heavy metals, oil and pesticides (Table F15).

Table F15. Types and sources of pollutants affecting estuaries.

Further information provided in Birch *et al.* (1996), NSW Fisheries (2000), and Irvine and Birch (in press). Those pollutants strongly associated with stormwater and sewage outfalls (pathogens, nutrients and sediment) have been discussed above under Section (ii); the remainder are discussed in the following paragraphs.

Type of pollutant	Specific examples	Main sources
pathogens	bacteria and viruses	discharges from sewage treatment works; sewerage overflows; stormwater runoff from urban areas
nutrients	nitrogen and phosphorus	discharges from sewage treatment plants; sewerage overflows; stormwater runoff from urban areas; agricultural runoff from fertilised areas
sediment	silt, mud, sand; coal wash and clay	land clearing; erosion; building sites; dredging; mining; stormwater runoff
heavy metals	copper, mercury and zinc	current and former industrial sites; refuelling and boating facilities; airborne dust; sewage overflows; waste dumps; stormwater runoff from urban areas
oil	crude oil, diesel and petrol	accidental spillage during transport (e.g. ship or road tanker); refineries and associated berthing facilities
pesticides	various organo-chlorine compounds; dieldrin, heptachlor	agricultural runoff; aerial spraying
acid	sulphuric acid, hydrochloric acid	runoff from acid sulfate soils that have been exposed to air; accidental spillage/discharge during transport or industrial process
other toxic chemicals	dioxin, alkalis,	current and former industrial sites; accidental spillage/discharge during transport or industrial process
thermal	excessively hot or cold water	power stations (hot water); discharges from large reservoirs (cold water)

The sources of pollution as listed in Table F15 fall into two categories: point sources and diffuse sources. Point source pollution originates from a specific identifiable site, such as a discharge point from a sewage treatment plant or industrial site, an accidental spillage or a particular activity (such as dredging or mining). Diffuse source pollution arises from a large area and/or a collection of unidentifiable sites, such as is the case with urban or agricultural runoff. Following is a discussion of the nature and impact of the main types of point source and diffuse source pollutants not already dealt with under section (ii) of this chapter "Stormwater and sewage outfalls".

Heavy metals and organo-chlorine compounds, if present in unnaturally high concentrations, tend to accumulate within fish tissue in a process termed bio-accumulation (e.g. Scanes and Scanes, 1995; Birch *et al.,* in press), in some cases leading to 'biomagnification', whereby top predators may have very large concentrations of contaminants even without being exposed to the original source (Scanes and Scanes, 1995). Biomagnification occurs because such metals are not easily excreted and because, at each level in the food chain, a particular fish (or other animal) must consume, in the course of its life, many times its own weight in prey (whether that prey be another smaller animal or plant matter). Consequently, tissue concentrations of such substances progressively increase as one goes up the food chain, resulting in particularly high concentrations in long-lived, top predators. Such concentrations, whilst unlikely to kill these predators outright, are likely to have a range of (unknown) chronic effects on growth and reproduction. Affected seafood may, in severe cases, pose risks to human consumer, and associated marketing problems are likely in relation to areas perceived to be polluted by heavy metals or organo-chlorines. Sediments subjected to runoff from urban/industrial areas progressively accumulate heavy metals and other toxic chemicals (Shotter *et al.,* 1995; Birch, 1996; Birch *et al.,* 1996, 1997; Irvine and Birch in press). Of particular concern is the fact that previously contaminated sediments continue to affect associated biota (particularly benthic, but also the fish that feed on it), even though waste disposal practises have since improved (Scanes and Scanes, 1995).

Oil and related products can harm fish and other aquatic organisms in several ways. Not only do oil spills release off toxins, but they can also cover intertidal invertebrates, resulting in suffocation and disruption of feeding mechanisms. In severe cases whole intertidal communities can be affected, denying dependent fish species an important food resource. The short-term effects of an oil spill depend greatly on weather and sea conditions, as well as the clean up method(s) used. Ultimate recovery depends on the recruitment of organisms from other unaffected areas. Mangroves and saltmarsh are most vulnerable to water pollution during high tides, at which time they can be affected by events such as oil spills (Allen *et al.,* 1992a,b), acid soil leachate or toxic spills.

Most aquatic organisms can only tolerate a relatively narrow range of pH values; for example most estuarine fish prefer pH values between 6.5 and 8.5 (Howells, 1994). Values outside of this range (whether caused by acid or alkali) cause irritation and injury to skin, gills and other membranes. This damage subsequently leaves fish more vulnerable to disease. For example, acidic water derived from the disturbance of acid sulfate soils has been shown to cause 'red-spot disease' in fish (NSW Fisheries, 2000). Extreme pH values, such as these might be caused by concentrated runoff or spillage in a confined area, quickly kill fish and other aquatic organisms. Furthermore, the activity of other chemicals present in a water body is strongly influenced by its pH value: for example the bio-availability of nutrients, heavy metals and organo chlorines may be increased under low pH conditions.

Thermal pollution, whether caused by unnaturally hot or cold water, will kill or repel less tolerant aquatic organisms from the affected area (Hannan, 1985 and 1989). Those species remaining will often experience altered growth, feeding and/or reproduction. Within NSW estuaries, the main cause of thermal pollution is the discharge of heated cooling water from facilities such as power stations and refineries. In the case of the power stations on the central coast (in Lake Macquarie and Tuggerah Lakes), discharge temperatures may exceed 35°C in summer and are commonly around 20-22°C in winter. The associated plumes may cover many hectares and have been shown to have a range of effects on local fish and invertebrate communities (Friedlander, 1980; Virgona, 1983; King, 1986; Hannan, 1989). These effects include:

- year-round reduction in the abundance of certain species, particularly those closely associated with seagrass (e.g. leatherjackets and pipefishes)
- increased abundances of many species during winter, including most commercially important species
- reduced abundances of most species during summer (but through emigration to other areas rather than through mortality)
- presumed possible increases in overall growth rates
- a range of possible effects relating to increased predation and/or exploitation of fish concentrated as a result of warm waters during winter
- locally altered benthic communities, including the occurrence of tropical species not normally found in central NSW
- habitat alteration, particularly in relation to seagrasses (see discussion below).

Whilst the central coast power stations may be providing a net benefit to fisheries production within the affected estuaries, it is difficult to determine whether the warm water is actually causing an overall improvement, or whether it is merely concentrating fish from other areas and at the same time making them more vulnerable to exploitation (Hair and Bell, 1992).

A database of fish kills in NSW is maintained by NSW Fisheries. Of the more than 400 kills reported from estuarine areas since the early 1970s (Allan Lugg, NSW Fisheries, pers. comm.), approximately 53 % were attributable to a particular cause (Figure F1). ‘Pollution’ in the simplest sense (i.e. toxic chemicals, pesticides and sewage) was blamed for nearly 18% of those kills, while runoff from acid sulfate soils is considered to have caused nearly 16%. Whilst nearly half of the kills able to be attributed to a particular cause were linked to potentially natural processes such as de-oxygenation or algal growth, many of these processes would have been the result of human-related factors such as nutrient enrichment and/or the alteration of natural water circulation.

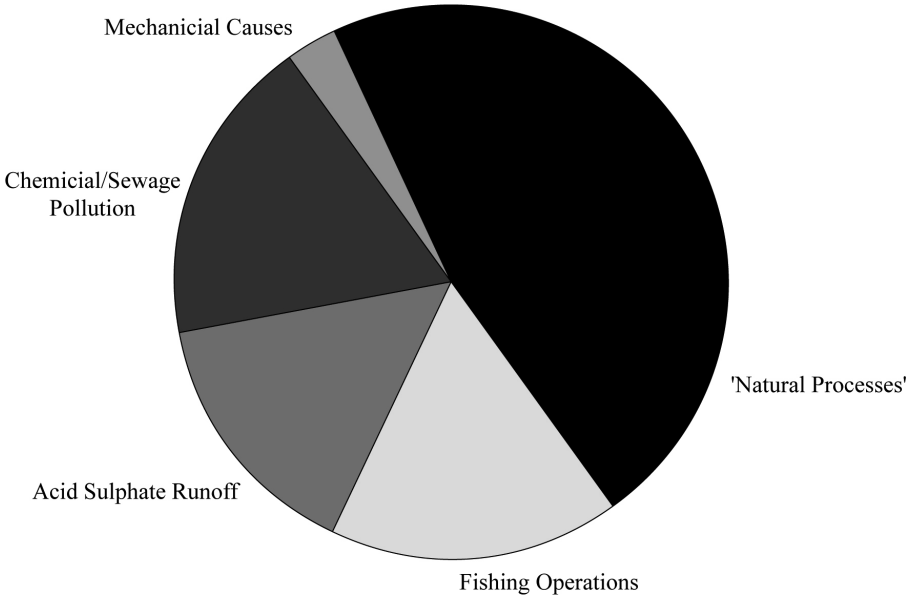

Figure F1. Breakdown of all fish kills in NSW estuaries attributable to a particular cause (data from 1970 to 2000 inclusive).

‘Natural’ processes include events such as water column de-oxygenation and algal blooms; chemical and sewage pollution includes toxic spills, pesticide contamination and sewage discharge; acid sulfate runoff refers to the low pH waters generated from the exposure of acid sulfate soils; fishing operations relate mainly to the discard of unwanted commercial catches; and mechanical causes include underwater explosions and impingement on intake screens. (Allan Lugg, NSW Fisheries, pers. comm.).

Whilst the number of reported fish kills in NSW estuaries directly attributed to pollution (including industrial chemicals, pesticides, sewage or acid runoff) only averages around 10 to 15 per year (Allan Lugg, NSW Fisheries, pers. comm.), many of these kills involve thousands of fish and several species. In severe cases, such as a major spillage into a confined creek, whole fish communities can be killed within the affected area.

With respect to the above-discussed forms of pollution, some estuaries or parts thereof are intrinsically more vulnerable than others. The lower reaches of large ‘drowned valley’ type estuaries such as Sydney Harbour are kept relatively clean by efficient tidal exchange with ocean waters. However, coastal lagoons which are intermittently open to the sea, and barrier estuaries which have restricted tidal exchange, are particularly susceptible to water pollution. In these cases the reduced tidal flushing means that any pollutants readily accumulate. Even within generally well flushed estuaries, pollutants (including sediment) often accumulate in upper reaches and in tributary bays (Birch, 1996; Irvine and Birch, in press). Also, estuaries with heavily urbanised or intensively farmed catchments suffer far more pollution and/or fish kills than those with unaltered (e.g. forested) catchments. Furthermore, within altered catchments, a greater proportion of incident rainfall ends up as overland runoff, resulting in a more direct and efficient delivery of pollutants to receiving waters.

Overall these pollutants affect the Estuary General Fishery chiefly through decreasing water quality which can lead to deformities in fish and decreasing abundance and diversity of targeted fish species. Generally, if polluted waters are identified they would be avoided by commercial fishers and who would fish elsewhere. Thus pollutants could temporarily or permanently close an area/estuary to fishing.

b) Water based activities likely to affect the environment on which the fishery relies

i) Vessels

A variety of vessel activities may affect the Estuary General Fishery, including commercial shipping, vessels from other commercial fisheries and recreational boating. The associated effects are outlined in the following paragraphs.

Commercial shipping is concentrated in a small number of deepwater ports, particularly Newcastle Harbour, Port Jackson, Botany Bay and Port Kembla. Large scale shipping operations are generally incompatible with commercial fishing, especially where hauling or meshing are concerned. However, the effected areas represent only a very small fraction of the potentially available fishing area within the state's estuaries, and are usually characterised by very deep water and a lack of productive shallow water habitats. Commercial shipping does bring with it the risk of a major pollution incident such as an oil spill. Whilst such incidents can cause significant damage to shallow water and intertidal habitats (e.g. mangroves and rocky shores), major events are very rare, and are unlikely to have major long term effects. Chronic or repeated pollution, as from some land-based activities, is likely to be far more serious in this regard (Skilleter, 1995). Commercial shipping may also result in introductions of exotic pest or disease organisms with potentially serious ecological consequences (section 4 of this chapter).

Berthing facilities for large ships typically include large 'finger wharves' and/or smooth vertical walls plunging into deep water. Whilst the wharves have some value as artificial habitat for certain species, their shear size means that extensive dark areas are created. Such areas have been shown to affect significantly fish behaviour, particularly in relation to feeding. For example, (Glasby, 1999) found that species were less abundant under large wharves than in either open areas or unshaded areas with pylons. Also, the smooth vertical walls typical of berthing facilities provide few opportunities for small fish to hide, and are likely to be far less attractive as habitat than natural rocky reef or structures made of broken rock (Coleman and Connell, 2001)

The only commercial fishery other than the Estuary General Fishery that operates within estuaries to any significant extent is the Estuary Prawn Trawl Fishery, although lobsters are occasionally trapped as part of the Lobster Fishery over rocky reefs near the entrances of larger (drowned valley) estuaries such as Sydney Harbour. Estuary prawn trawlers only operate in five estuaries: Clarence River, Hunter River, Hawkesbury River, Sydney Harbour and Botany Bay. Estuarine prawn trawlers capture (either as bycatch or as target species) several of the primary target species taken in the Estuary General Fishery. The associated mortality, along with trophic effects related to discards, and the possible habitat damage relating to trawl net operations, may affect the Estuary General Fishery (Alverson *et al.,* 1994; Kaiser and de Groot, 2000). However, whilst specific information on the magnitude of some of these interactions is lacking (an exception is the bycatch of the Estuary Prawn Trawl Fishery), they are not likely to have any significant effect on the Estuary General Fishery as a whole, as the affected areas represent only a very small fraction of the fishing area that it potentially available to the Estuary General Fishery within the state's estuaries.

Unlike commercial shipping, and vessel activity associated with other commercial fishers, recreational boating significantly affects most estuaries within the state. On many of the more popular waterways, weekend closures affecting estuary general operations have been established to minimise conflicts between estuary general fishers and recreational users. Cumulatively, these closures affect a large portion of the state's estuaries. Recreational boating is also associated with competition for fish stocks from recreational fishers (West and Gordon, 1994) and possible damage to habitats such as seagrasses (Hannan and Simpson, 1999). Whilst the ultimate effect of these interactions is difficult to quantify, it is clear that recreational boating and its associated activities have had a major influence on the development and operation of the Estuary General Fishery.

ii) Dredging

Dredging refers to the removal of substrata (e.g. sand, mud or rock) from aquatic or intertidal areas. Apart from the direct loss or modification of habitats in the immediate works area, dredging is likely to cause increased turbidity and/or sedimentation over a much wider area, depending on the nature of the sediments involved and the prevailing waves and currents (NSW Fisheries, 1999a). Habitats such as seagrass and rocky reef may therefore be degraded well outside of the actual area dredged. Dredging may also create stagnant deep holes, alter currents, cause seabed or river bed erosion and liberate pollutants previously trapped in sediments (Scanes and Scanes, 1995; NSW Fisheries, 1999a). Dredging can, however, be used to rehabilitate fish habitats: in some situations appropriate dredging can improve water circulation and quality and promote habitat diversity (NSW Fisheries, 1999a).

The long term effects of dredging on fish habitats can be far reaching. Quigley and Hall (1999) found that a control site 500 metres away from the dredged site had been affected and both areas had not recovered six months after dredging ceased. *Posidonia* (strapweed) seagrass, if removed, will take many decades to recover, if it occurs at all (King, 1981; Keough and Jenkins, 1995). Even with more vigorous seagrasses such as *Zostera* (eelgrass), recovery may be prevented by instability of the remaining sediment, particularly in areas subject to strong waves or currents (Hannan, in prep).

Whilst most dredging projects involve small-scale works and only localised effects, large scale works for projects such as port development or entrance maintenance can have estuary-wide effects involving to altered tidal and/or wave regimes. Possibly the best example of such effects can be found in Botany Bay, where configuration dredging was done in the early, 1970s. This dredging altered the path of incoming swells, substantially increasing wave heights on the southern shores, including those at Towra Point. Seagrasses were damaged, and many sections of shoreline began eroding at accelerated rates. Consequently, protective works such as rocky groynes and concrete seawalls have had to be installed and the availability of shorelines for commercial fishing operations has been compromised. The rocky groynes have not only interfered with some fishing operations but they have also modified the habitat. Seagrasses and benthos have been directly lost, although the effects of this on associated fish communities is unknown. However, habitat diversity has been increased (by the addition of rocky substrata) and anecdotal information suggests that certain species such as luderick have benefited.

iii) Structural engineering works

These include barriers to river flow (such as dams and weirs), groynes and training walls. Potentially these works can impact on the fishery, either on operations, or through effects on fish communities and/or their habitats.

Groynes are normally constructed out of large rocks and are used to prevent shoreline erosion. They work by intercepting longshore drift and the associated sand movement: sand becomes trapped on the up-drift side, thereby stabilising the shoreline in this area. Unfortunately, this process deprives the beach on the down-drift side of sand, thereby worsening any erosion in that area. So, consequently, several groynes are often needed to stabilise a substantial length of shoreline. Groynes have both negative and positive effects on fish habitats. Whilst their construction is often at the expense of seagrass, they provide good substitutes for natural rocky reef habitats (SPCC, 1981a; Burchmore *et al.,* 1985; Lincoln-Smith *et al.,* 1992). Groynes can interfere with fishing operations, particularly beach hauling. Large numbers of groynes have been placed within Botany Bay (see also under 'dredging' above), but in general they are rare or non-existent in most estuaries.

Training walls are used to stabilise estuary entrances. They are constructed with the same material as groynes and have similar implications for fish habitat. Training walls normally ensure that an estuary entrance remains open either permanently, or at least more consistently than would otherwise be the case. They can therefore have far-reaching effects on an estuary's ecology: essentially they promote greater tidal exchange, which in turn leads to higher salinities and better overall water quality. Larval distributions, patterns of juvenile recruitment, and overall community structure among fish and invertebrates are also likely to be affected due to reduced effective distance from the ocean (Bell *et al.,* 1988; Hannan and Williams, 1998) and by altered salinity regimes and habitat condition. Furthermore, productivity may be reduced due to increased flushing by ocean waters which may lower nutrient concentrations and therefore reduced phyto-plankton numbers. This possibility is partly supported by the findings of Gibbs (1997) who, in an analysis of south coast commercial catch data, found that intermittently open estuaries are frequently more productive (in terms of reported values and weight of finfish and prawn catches) than are permanently open estuaries. Although the above-mentioned effects are potentially very significant, and training walls are present at the entrances of many of the state's estuaries, there is no clear evidence of any overall negative impact on the Estuary General Fishery.

There are more than 2,500 barriers to river flow, including dams, weirs and floodgates within the freshwater reaches of the major coastal catchments of NSW (Thorncraft and Harris, 2000). On the basis of field observations and or literature review 4,229 structures impeding tidal flow were found in NSW estuaries, with 1,388 considered to have remediation potential (Williams and Watford, 1996). These structures serve various purposes including the supply of drinking and irrigation water, flood mitigation and the improvement of in-stream aesthetics. Dams are the largest of these structures, many being more than 50 metres high. Weirs are essentially low dams and are typically between 0.5 and 5 metres high. Floodgates (also known as 'tidal barriers') are specialised structures designed to exclude tides and backed-up floodwaters whilst allowing local runoff to escape. Among the major coastal river systems, the Tweed, Richmond, Clarence, Bellinger, Macleay, Hasting, Hunter, Hawkesbury and

Shoalhaven rivers all have at least 100 barriers of one kind or another (Thorncraft and Harris, 2000). Other in-stream structures that result in at least a partial barrier include road crossings and culverts (Williams and Watford, 1996; NSW Fisheries, 1999b). These structures are quite numerous, particularly in urban and well populated rural areas.

These various barriers can have a range of environmental impacts, the most notable relating to fish passage, environmental flows and thermal (cold water) pollution. These are discussed in the following paragraphs.

Fish passage

Fish passage is the process by which fish move around within their environment (NSW Fisheries, 2000). These movements can be for a variety of reasons including reproduction, feeding and habitat selection. Fish populations subject to restricted passage are likely to suffer reductions in overall distribution, reduced juvenile recruitment, increased predation and/or disease at sites of enforced overcrowding and/or reduced genetic diversity. Even the best possible habitat is of no value to fish if they cannot reach it.

Structures such as dams, weirs, floodgates, culverts and road crossings present a physical barrier that completely or partially blocks fish passage, by creating either a complete break in the aquatic medium, a tight constriction or an impassable current. Partial blockage occurs where a weir or road crossing is low enough for fish to negotiate under high flows, where a culvert admits water at high tide or where a floodgate leaks.

Complete barriers such as dams and high weirs have the most dramatic effects on fish passage. For example, nine species are now locally extinct upstream of Tallowa Dam on the Shoalhaven river (NSW Fisheries, 2000). Within the coastal rivers of NSW, species such as sea mullet, freshwater (pink eye) mullet, Australian bass and Australian grayling have become extinct upstream of major barriers (NSW Fisheries, 2000). Each of these species have life cycles that involve juveniles migrating upstream from estuarine waters (McDowall, 1996), making them particularly vulnerable to such barriers. Whilst the adults may be able to descend some major barriers under certain conditions, they (like the juveniles) cannot return upstream. In fact, only specialised species such as eels and galaxiids are likely to be able to ascend these barriers.

Partial barriers, such as most weirs, can still have dramatic effects on fish populations. Such barriers are generally only passable by upstream-migrating fish when the structure is ‘drowned out’ by floods. Under these (relatively rare) conditions, fish are able to swim around the structure by keeping close to the waters edge where currents remain weak. The problem is that, within the coastal river systems of NSW, most of the species affected by in-stream barriers have specific seasons for upstream migration, particularly as juveniles (McDowall, 1996) so, any given species, correspondence between the timing of a suitable flood and juvenile migration would be rare: in the case of a particular community of species, it would probably never happen. Furthermore, the suppression of flows by river regulation (as discussed below) has compounded the effects of barriers such as weirs by making them less likely to ‘drown out’, and by denying many species the environmental cues needed for spawning and migration.

Even relatively modest structures can seriously affect fish passage. Bridges, road crossings, culverts, floodgates and causeways can impede or prevent fish passage because of factors such as excessive water velocity or turbulence, dark passages, sudden drops in water level across the structure, loss of tidal exchange and poor maintenance (Pollard and Hannan, 1994; NSW Fisheries, 1999b;

Williams *et al.,* unpublished data). Small juveniles that recruit to shallow habitats can thus be denied access to creeks, drainage channels, saltmarsh and shallow lagoons. This problem is often compounded by habitat modifications above the barrier. For example, a lack of tidal flushing can result in poor quality water and the loss of mangroves upstream of a structure. Furthermore, if the barrier stops all saline water intrusion, the area above will become freshwater wetland.

Of the species regularly taken in the Estuary General Fishery, only sea mullet regularly travels far into freshwater, and this species would probably be the most affected in terms of spatial extent of habitat lost due to barriers. However, many other commercially important species, including yellowfin bream, tarwhine, luderick, silverbiddy, flat tail mullet and yellowfin leatherjacket might just as seriously be affected in terms of the amount of habitat lost, judging by the results of Pollard and Hannan (1994) and Williams *et al.,* (unpublished data).

Environmental flows

Dams not only block fish passage, they alter natural river flow patterns. In most cases, overall flows are reduced as a consequence of water being removed from the system for drinking supply and/or irrigation. In highly regulated rivers, such as the Hawkesbury-Nepean west of Sydney, only the largest floods are likely to wash down through the whole length of the system. More specifically, dams affect downstream flows in the following ways (NSW Fisheries, 1999a).

- suppression of moderate flows and minor floods, as they are normally taken up by spare capacity in the reservoir rather than allowed to pass downstream
- changes in the seasonal pattern of flows
- reduction in the variability of flows
- increased rates of change in flow volumes due to the sudden ‘switching’ on or off of spillways etc. as reservoir levels change.

Water abstraction also reduces overall stream flows, and consequently the amount of fish habitat available in a stream. ‘Water abstraction’ refers to the manipulation and/or diversion of river flows to supply needs such as irrigation, urban and industrial use, and hydro-electric power generation (NSW Fisheries, 1999a). In eastern NSW, the greatest amount of abstraction is likely to occur in those catchments where dams and weirs are most numerous. According to Thorncraft and Harris (2000), these catchments are those of the Richmond, Clarence, Bellinger, Macleay, Hastings, Hunter, Hawkesbury, Shoalhaven and Bega rivers.

Secondary effects of reduced flows (whether caused by abstraction or dams) may include increased summer water temperatures, alteration of habitat from a running water to a still water environment, and reduction in water quality (NSW Fisheries, 1999a).

Alteration to natural flow regimes are most noted for their effects on freshwater fish communities (Pollard and Growns, 1993; NSW Fisheries, 1999a). However, such changes also affect some estuarine fish and invertebrates. Species that migrate upstream into freshwaters (such as sea mullet and eels) are likely to be affected by a loss of habitat wherever suppressed flows reduce either the area of suitable habitat, or access to such habitat. Sea mullet, in particular, are also more likely to become trapped in freshwater areas (e.g. lagoons and billabongs) under a regulated flow regime, and whilst affected individuals may grow to large sizes, they are prevented from spawning (at sea) and therefore from recruiting to populations. Some species, however, are unable to tolerate low salinities, and may be flushed out of upper estuarine areas during natural flood events. Under such conditions, these species may be rendered more vulnerable to capture by commercial fishers. This is the likely reason behind the association between high catches of school prawns and increases in river discharge (NSW Fisheries, 2000). It follows that any suppression of major discharge events (say as a result of river regulation) may adversely affect estuarine prawn fisheries. Also, the distributions and abundances of a wide range of organisms may be altered because of changed salinities associated with altered flow regimes (Pollard and Growns, 1993). For example, some estuarine species may extend further upstream than before the altered flow regimes. Such changes may have far-reaching food web and community effects, and may therefore also affect commercial fishing.

Unnaturally rapid recession of flood waters, as a result of river regulation (particularly due to large dams), can result in bank slumping (Pollard and Growns, 1993). Sudden drops in water level leave banks saturated with water, but without the support of surrounding floodwaters. The resultant bank collapses release sediment that may then cover fish habitats such as macrophyte beds and snags. Also, banks affected by slumping are left vulnerable to on-going erosion of the exposed sediment. River systems badly affected by sedimentation are likely to provide fewer suitable fish habitats for species such as sea mullet, yellowfin bream, Australian bass and estuary perch.

Thermal Pollution

Water released from the deeper layers of large reservoirs (such as Lake Burragorang on the Nepean River) can be up to 15 degrees cooler than surface waters (Pollard and Growns, 1993; NSW Fisheries, 1999a). Such cold waters have been shown to have profound effects on the distribution and abundance of native fish in coastal and inland river systems, and effects have been noted up to 400 km downstream (Pollard and Growns, 1993; NSW Fisheries, 1999a; Astles *et al.,* 2000). Within estuaries, the possible effects of upstream releases include reductions in juvenile abundance and growth (particularly for species that spend significant amounts of time in upper estuaries, such as sea mullet, eels and school prawns), reductions in abundance of prey, and shifts in community composition (NSW Fisheries, 1999a). Such changes could easily have flow-on effects on commercial fishing, particularly in upper estuarine areas.

iv) Other issues

Sea level rise

Sea level is predicted to rise over the next 40 years (Eliot *et al.,* 1999). For estuarine areas this poses a potentially serious threat as it could result in the loss of fish habitat and numerous fishing areas. The effects of sea-level rise will vary depending upon the type of estuary (drowned river valley to barrier estuary) and whether it is located in a temperate or tropical environment (Dame *et al*., 2000). A study on South African estuaries concluded that sea level rise will increase the occurrence of extreme flood and erosional events (Hughes and Brundrit, 1995). Similar events are likely to occur in NSW estuaries. It is clear from a number of studies that the impacts of sea level rise and its accompanying climatic changes will vary from place to place. In NSW the best predictor of change is an analysis of structure and function of existing estuaries compared to their size and distribution of habitats in the postglacial marine transgression (Roy *et al.,* 2001). The comparison indicates that drowned river valleys may have less shallow habitats while barrier estuaries will have increased shallow habitats. Therefore, it is impossible to predict precisely what impact sea level rise will have in NSW. However, the vulnerability of the Estuary General Fishery to impacts from sea-level will need to be assessed in more detail for each estuary.

Recreational Fishing

Recreational fishing is an increasingly popular past time. The activities of recreational fishers impacts estuarine environments in a number of ways including bait collection (Cryer *et al.,* 1987; Underwood and Kennelly, 1990), trampling (Keough and Quinn, 1998), physical damage to habitats, lost or discarded fishing gear, hook and handling damage of fish and landings of commercial fish species (West and Gordon, 1994). The large numbers of people engaged in this type of fishing suggests that the collective impact of these activities could be quite large.

A management strategy is to be developed for the recreational fishing sector as required under the *Fisheries Management Act 1994*. As part of this an environmental impact assessment is to be done on all aspects of how this fishery may impact the environment and other fishing sectors. Therefore, whilst it is acknowledged that recreational fishing is potentially having a substantial impact on the Estuary General Fishery a comprehensive assessment of these impacts will be given in the environmental impact study of the recreational fishery management strategy.

Aquaculture

Aquaculture in NSW estuaries largely consists of oyster leases and more recently cages for rearing of cultured fish (McGhie *et al.,* 2000). Mather (1993) gives a review of the environmental impact of all types of aquaculture in Australia. For estuaries these include introduced species, alterations to trophic structures, sediment degradation and hydrological modifications (Mather, 1993). Such is the extent of and growth of aquaculture in NSW that the NSW Government has developed the NSW North Coast Sustainable Aquaculture Strategy (2000). This strategy covers all isuues to do with the environmental impacts of aquaculture and includes management responses to mitigate these impacts. Further strategies are being developed for other parts of coastal NSW (D. Ogburn, pers. comm.).

c) Dredging works necessary to maintain access necessary for the fishery activities proposed under the strategy

Dredging specifically to maintain or provide access for vessels used in the Estuary General Fishery is not likely to be required: the vessels are relatively small (usually between 3 to 6 metres) and general navigation dredging (as administered by NSW Waterways, Department of Land and Water Conservation and/or NSW Fisheries) is likely to be sufficient. This dredging is carefully managed, with a range of safeguards to minimise environmental harm (NSW Fisheries, 1999a). Under these present circumstances, there is minimal risk to boats or fisher access of in the Estuary General Fishery.

d) Management measures necessary to limit impacts of external factors

i) Landuse planning and development controls

A wide range of landuse planning and development controls, including controls on infrastructure design and operation, are necessary to minimise the various impacts of external factors to the Estuary General Fishery. These controls need to focus on habitat protection, and must operate within a total catchment management (TCM) framework. The new catchment management boards will be instrumental in the development and on-ground application of these controls. The necessary controls are discussed under the following subheadings.

Urban landuse

Much of the pollution entering the State's estuaries originates from diffuse urban-related sources, and is transported via stormwater. To tackle effectively the serious issue of stormwater runoff from urban areas, a catchment-focused approach is required. In terms of landuse planning and development controls, the following measures are likely to be needed to protect nearby estuaries and their biota:

- provision of sufficient space for stormwater treatment devices (including artificial wetlands)
- preservation or restoration of all natural creek lines, including adequate provisions for protecting/ restoring aquatic habitats and fish passage
- provision of vegetated buffer zones along all creeks (including intermittent) and around all wetlands
- maximum possible use of on-site retention and porous surfaces
- stringent environmental safeguards in relation to all construction and associated works.

The preservation or restoration of natural creeks not only provides fish habitat, it helps in the treatment of runoff. Natural creeks (and properly restored ones) have aquatic vegetation, gravel and detritus to help filter and treat polluted runoff before it reaches an estuary or river. Concrete-lined drains, with their far less quantity of biologically active surfaces and their uninterrupted flows, are much less effective in this way. Riparian vegetation and porous surfaces also help to retard and filter stormwater flows.

Whilst these measures are likely to be very expensive, particularly in existing urban areas, they raise the broader planning issue of how and where people wish to live. Society must recognise the respective environmental costs of increased urban density and of urban expansion, and decide on the best trade-off between these in terms of environmental, social and economic needs. Recognising the pressures for development, particularly along the NSW coast, society must decide to what extent the state's estuaries can support further development in their catchments, and at what cost.

Treatment

Major point sources of pollution (such as an industrial discharge or major sewer overflows) can be addressed by upgraded treatment standards and/or engineering works at specific sites. This has been done successfully in many instances. For example, upgrades to sewage treatment plants along the Hawkesbury-Nepean River since the early 1980s resulted in improved water quality (in particular phosphorus levels) chlorophyll-a concentrations and turbidity (Williams *et al.,* 1993; Kerr, 1994). Also, the recently completed Northside Storage Tunnel and associated works are expected to reduce dramatically sewer overflows into the northern parts of Sydney Harbour. In terms of adequately protecting receiving waters, existing Environment Protection Authority requirements are likely to be sufficient for most point sources.

However, diffuse source pollution is far more difficult to isolate and treat, particularly in urban areas. In rural areas, individual farmers can at least be encouraged to follow best practice with respect to erosion prevention and the use of chemicals such as pesticides and fertilisers. However, in urban areas there are so many sources and individuals involved that it is extremely difficult to rely on education/encouragement alone. Stormwater runoff, in particular, requires a range of prevention and treatment measures to protect nearby estuaries and their biota. These measures are likely to include:

- pppropriate land use and planning controls as outlined above
- on-going community education, with an emphasis on source control
- use of large numbers of relatively small stormwater treatment devices located high in the catchment, rather than a few large devices close to receiving waters or major streams
- provision of artificial wetland(s) so that total area of wetlands (available to retain and treat stormwater) represents at least 3 to 5% of the urban area within the catchment
- adequate provision for the on-going maintenance of all treatment devices.

Whilst past efforts at stormwater treatment have often been focused on the protection of the ultimate receiving waters, councils are increasingly recognising the need to not only protect the main river, lake or estuary, but to also protect the major tributary creeks. However, given the ecological links between even small intermittent creeks and downstream waters (in terms of energy flows and fish passage), even minor creeks should be protected by placing devices higher in the catchment or offline wherever possible.

A fundamental problem is that urban areas, with their high proportion of hard surfaces and plethora of potential pollution sources, represent a highly artificial environment. Furthermore, the volume and rate of surface runoff is greatly enhanced with respect to that from more natural environments, thereby ensuring the rapid and efficient delivery of pollutants to receiving waters. The challenge is therefore to slow the passage of the runoff and its pollutants, so that natural and artificial treatment processes have an opportunity to work. However, to do this effectively is a complex and expensive exercise somewhat analogous to the setting up of a marine fish tank. A small aquarium with some fish and corals may require many hundreds of dollars worth of filtration, skimming and sterilisation equipment to maintain the necessary water quality, while an urban area is likely to require a commensurate expenditure on artificial wetlands and other stormwater treatment devices.

The fish tank analogy:

An urban area is like a crowded fish tank, in that it generates an unnaturally high amount of wastes which then have to be treated by an correspondingly extensive system of purpose-built 'filters' if adequate receiving water quality is to be maintained.

In most cases the required suite of measures, along with the necessary land acquisitions and changes to urban design, are likely to be very expensive. For established urban areas, the above planning and treatment measures could most realistically be considered as a long-term goal. However, for new or expanding areas, much money can be saved by making provisions for these measures in advance. Also, the 'polluter-pays' principle need to be implemented where feasible (NSW Fisheries, 1999a), possibly in the form of the environmental levies that have already been used by some local councils.

Sediments contaminated as a result of past industrial practices pose their own special problems, because they do not normally comply with guidelines for offshore dumping or 'clean fill' and have to be taken to special waste facilities for treatment and/or disposal. Remediation attempts, such as recently undertaken in Sydney's Homebush Bay, are therefore difficult and expensive. In most such cases it is likely that removal of the worst contamination, in conjunction with the capping of the remainder with clean sediment, would be the most feasible option.

Foreshore works, dredging and reclamation

Existing fisheries legislation and policy (particularly the *Fisheries Management Act 1994*, the Policy and Guidelines: Aquatic Habitat Management and Fish Conservation, 1999, and Habitat Protection Plan No. 2: Seagrasses) provide effective means to ensure that current and future works do not unduly affect fish or fish habitats (as discussed above under sections a(i) and b(ii) of this chapter). Specific information to allow foreshore structures to be designed in a way that minimises damage to sensitive habitats such as seagrass is now available (Shafer and Lundin, 1999; Hannan, in prep.). Essentially, jetties and similar structures should be designed to take into account prevailing conditions (such as waves or currents) and, ideally not built where highly sensitive habitats are present.

However, past works (particularly those done before the late 1980s) were not subject to the same degree of control. Some of these earlier works have consequently caused impacts that might not have been accepted today. Also, many works (including some of those undertaken in recent years) have been related to major projects of state or national interest (e.g. the ‘Third Runway’ in Botany Bay). In these cases, possible habitat protection measures were often constrained by overwhelming social and/or economic considerations, and outright refusals or major modifications based solely on fishery or habitat grounds would have been unrealistic.

Other measures are available to help mitigate the impacts of future works. Of fundamental importance is prior consultation with commercial fishers. Such consultation allows fisher’s concerns to be taken into account at an early stage of a project, at which time any suggested changes are more likely to be accommodated. Project planning would also be greatly assisted by an updated documentation of all recognised fishing grounds within NSW estuaries. More specifically, structures such as seawalls and berthing facilities can be designed to provide the best possible fish habitat consistent with their function and reasonable costs. For example, instead of a smooth vertical wall, one with indentations could be used to provide a greater surface area for sessile invertebrates and better opportunities for juvenile fish to hide (Chapman and Blockley, 1999).

Fish passage

Under the *Fisheries Management Act 1994*, NSW Fisheries may order that a fishway be installed on new weirs and dams, or on any that are being repaired or refurbished. NSW Fisheries policy also requires that all proposals for the construction/modification of dams, weirs, floodgates or any other such structure on a waterway be referred to the department for assessment (NSW Fisheries, 1999a). NSW Fisheries has also developed specific policies for addressing fish passage (and other environmental issues) associated with road crossings and related works (NSW Fisheries, 1999b).

Under the NSW Weir Policy, the NSW Government is attempting to reduce the environmental impacts of weirs. In particular, the construction/enlargement of existing weirs is discouraged; weirs no longer serving any useful purpose are to be removed where possible; and owners are encouraged to alter retained weirs to reduce their environmental impact. The State Weir Review Committee oversees the implementation of the policy. The committee has undertaken a comprehensive review of the states weirs and suggested actions for remediating the impacts of these structures.

A number of fishway options suitable for native fish such as mullet and bass have been developed (NSW Fisheries, 1999a, 2000). The best choice for a particular barrier depends on factors such as barrier height, flow rates and the species of fish present. For barriers up to six metres high, the most suitable option is likely to be the ‘vertical slot’ fishway. This is essentially a series of covered pools, each slightly higher than the last, through which the fish progressively ascend. The pools are linked by narrow vertical openings, through which currents are sufficiently restricted to allow native fish to pass. For low barriers (up to one metre high), a rock ramp fishway with a slope of 1:20 or less may be appropriate. Rock ramp fishways essentially mimic natural riffle zones instead of an impassible single fall, fish are presented with a series of small rocky pools each separated by transverse rock bars and a slight change in water level. Other fishway options, such as Denil fishways, lock systems, trap and transport and by-pass channels may also be suitable in some circumstances. Whilst these fishway types may be less expensive than vertical slot designs, their use in coastal streams remains experimental, and in need of further evaluation. For high barriers such as dams, trap and transport fishways offer the best potential. A system by which fish are attracted, trapped and then pumped through a pipe and over the barrier, is currently being considered for Tallowa dam on the Shoalhaven River. As an interim measure pending fishway construction, NSW Fisheries supports the periodic release of flows to drown-out weirs and other barriers to enable upstream fish passage (NSW Fisheries, 1999a).

In relation to road –related barriers, NSW Fisheries have developed the *Policy and Guidelines for Bridges, Roads, Causeways, Culverts and similar structures 1999* (NSW Fisheries, 1999b), which sets minimum preferred solutions depending on the value of fish habitat affected. In general terms, bridge or tunnel crossings are preferred, particularly where major fish habitat is concerned. Under the Policy and Guidelines where culverts are to be used, large box culverts are preferred to round pipes as the former provide a greater volume of water for fish movement. Also, causeways should be designed so that stream flows and stream widths remain unchanged. In relation to culverts, NSW Fisheries (1999a) provides the following specific guidelines to ensure habitat continuity and therefore assist fish passage:

- The cross-sectional area of the culverts should equal or exceed the cross-sectional area of the stream
- They should be as short as possible, so that dark passages are not created
- They should be as level as possible, so that natural flow velocities are maintained
- Their base should be set into (rather than on) the stream bed so that natural sediments can cover the bottom.

The timing of associated works is also important (NSW Fisheries, 1999b). Wet months should be avoided and every effort should be made to avoid predicted rain events. Also, known migratory seasons should be avoided, for example, juvenile sea mullet are known to recruit to estuaries during winter and spring and are likely to be moving up creeks and rivers during this period (SPCC, 1981b; Hannan and Williams, 1998).

NSW Fisheries is currently developing strategies for the opening regimes for floodgates (NSW Fisheries, 2000). Previous studies (Gibbs *et al.,* 1999) have shown that 'leaky' floodgates allow estuarine (rather than freshwater) habitats to be maintained above the gates as well as allow the recruitment of estuarine fish and invertebrates to these habitats.

Environmental flows

The issue of environmental flows is being addressed as part of the State government's Water Reform Package. The NSW Government has been developed Interim River Flow Objectives for most of the State's catchments. Particular flow issues being addressed include the need to protect low flows, freshes and natural variability and the importance of factors like floodplain connection, rates of rise and fall in river height, groundwater interactions, impact of weirs, estuarine processes and the quality of storage releases (NSW Fisheries, 1999a). Essentially what is needed is the "formal recognition of the environment as a water user" along with support for "changes which allow more water for the environment in over-allocated systems" (NSW Fisheries, 1999a).

Provision of appropriate environmental flows helps to ensure fish passage, water quality and maximum habitat availability. Also, the maintenance of natural rates of fall in river height helps to prevent bank slumping and associated erosion and sedimentation.

Under the Water Reform Package, the state government can also limit future abstraction from sensitive river systems. The placement of an appropriate 'cap' on abstractions from such systems, backed by strategies to reduce water consumption and increase efficiency of use, can help allow for environmental flows. Measures to reduce consumption could include the use of drought-resistant crops, the ongoing education of landholders with respect to current best practice, and the installation of water-efficient irrigation systems. In urban areas, the provision of advisory material to householders can help reduce town water consumption.

Thermal pollution

The release of unnaturally cold water from reservoirs can be avoided by the installation of variable-level offtakes and/or de-stratification by aeration or other mechanical means (NSW Fisheries, 1999a). The big challenge is retro-fitting the necessary works on existing dams. To do this cost-effective engineering solutions need to be further developed (Sherman, 2000). NSW Fisheries has recently held discussions with Department of Land and Water Conservation (DLWC) and State Water on progressing actions to address cold water pollution on State government owned structures.

Release of artificially warmed water from power stations into estuaries can cause a significant drop in species richness and decreased biomass of fish in the vicinity of their outlet works (Scanes, 1988). Solutions such as installing new designs of outfalls which enhance rapid stratification have been considered (Scanes, 1988).

Acid sulfate soils and flooding

Authorities are now well aware of issues relating to acid sulfate soils and proponents for developments are invariably required to test for the presence of such soils in areas where they may occur. A series of acid sulfate soil maps has been published by the DLWC. These maps show the risk of acid sulfate soil being present for any particular location in coastal NSW. Protocols such as keeping works shallow and not allowing the ground to dry out have been developed to minimise the likelihood of acid formation in high risk areas. Also, treatment with lime may help to neutralise any acid that forms. Protocols currently being developed for the management of barriers such as floodgates may also play a role in helping to mitigate the impact of chronic acid drainage (NSW Fisheries, 2000).

Major flooding and drainage from the river floodplains, which can result in significant fish kills, were addressed in section 10(a)(iii) of this chapter. Management measures to limit these impacts require coordination with the floodplain management and estuary management programs supported by the DLWC. The Estuary Management Manual currently being revised by DLWC also assists in the future management of these external factors affecting the Estuary General Fishery.

ii) Measures in the draft FMS with regard to fishery practices

A range of fishery practices can be adopted to minimise the impacts of external factors on the Estuary General Fishery. Useful measures include:

- closures of badly affected areas as occurred in the Richmond and Macleay Rivers after the February and March 2001 floods and as provided for in the draft FMS
- protocols to reduce risks to consumers (e.g. temporary closures triggered by particular environmental conditions – as has been done with pipis)
- consultation with commercial fishers to assist them in recognising and avoiding adverse conditions
- education of consumers, emphasising appropriate storage and preparation, and the low risk normally associated with most types of seafood
- fisher representation on boards and committees where decisions are made concerning catchment works and/or landuse liable to affect fish or fish habitats.

11. Data Requirements in Relation to Assessment of Impacts on the Biophysical Environment

a) Data and research

Data and information used to assess the impacts on the biophysical environment were obtained from a variety of sources, primarily state and commonwealth government agencies and peer reviewed scientific publications. Government agencies include the National Parks and Wildlife Service threatened species unit, Environment Protection Authority, Environment Australia and Australian Museum. The reliability of this information is variable. Peer-reviewed scientific publications clearly provide the most robust information for the assessments. The reliability of information from government agencies could range from low-medium to high depending upon the quality of the research that undergirds them. It was not possible to make a detailed assessment of this information. It should be recognised that information on many of the issues relating to impacts on the biophysical environment is not available from any source. The uncertainties associated with the data and assessments of the impacts are due to the gaps in knowledge of the effects of fishing, particularly in reference to the impacts of fishing on threatened and protected species and habitats.

i) Knowledge gaps

There are at least seven areas where we have little or no knowledge regarding the impact of the Estuary General Fishery on the biophysical environment. These are:

- knowledge of fish stocks
- relationship between fish stocks, habitats and biodiversity
- effects of recreational fishing
- effects on trophic structures in estuaries
- effects of different gear types on fish and habitats
- effects of fishing on threatened species
- potential for introduction of disease and foreign species.

The above knowledge gaps are in addition to those discussed in section 1(c) of this chapter. The seven knowledge gap areas are discussed below.

Knowledge of fish stocks

Significant gaps exist in our knowledge of the natural variability of distribution, abundance, mortality and recruitment patterns of the retained species of in the Estuary General Fishery. The most significant amount of information exists for the general ecology of two species of fish, yellowfin bream and sea mullet (Pollard, 1991; Vigona *et al.,* 1998; Gray *et al.,* 2000). But as noted in Chapter E very little else is known of the other retained species. Building a knowledge base on the ecology of the retained species will enable more realistic assessments to be made of the resilience of their populations (Underwood, 1989) to fishing pressure by Estuary General Fishery and other sectors.

Relationship between fish stocks, habitats and biodiversity

The relationship between fish stocks, their habitiats and biodiversity is an extension of the previous knowledge gap. Very little is known about how many of the retained species interact with their habitats, nor even what habitats are important to them. In addition, there are significant knowledge gaps about how retained species contribute to maintaining biodiversity in estuarine environments. Understanding these complex interactions will enable better strategies to be developed to protect threatened habitats, enhance biodiversity and maintain viable stocks of retained species for all fishing sectors.

Effects of recreational fishing

The Estuary General Fishery is one of a number of commercial fisheries in NSW that strongly interacts with recreational fishers because estuaries are among the most accessible and safest places for amateur fishers to fish (Henry and Vigona, 1984). The major proportion of recreational fishing occurs in estuaries and recreational fishers will often target the same species as does the Estuary General Fishery. For example, West and Gordon (1994) reported that recreational fishers in the Richmond River harvested yellowfin bream, dusky flathead and tailor in substantially greater quantities than commercial fishers in the same estuary. Given the large overlap between the two fishing sectors, there is substantial potential for there to be major effects of recreational fishing on retained species in estuaries (Lal *et al.,* 1992). Lack of knowledge concerning the magnitude, frequency and extent of the effects of recreational fishing inhibits our ability to develop effective management responses.

Effects on trophic structure within estuaries

Very little is known of the trophic structure within estuaries and the effects the Estuary General Fishery has on this. Given the extent over which fishing occurs in estuaries, trophic structures may be affected at several spatial and temporal scales but little is known specifically on what these affects are. Studies overseas have shown a number of effects on trophic structure that have been caused by commercial fishing (Dayton *et al.,* 1995). For example, large removals of schooling prey result in wider dispersal of these species increasing the difficulty for predators to capture their prey (Murphy, 1980). Other trophic changes could occur by substantially reducing the abundance of major algal feeders which could have effects on benthic habitats such as overgrowth by algae (Hatcher *et al.,* 1989). It is not known whether the magnitude of catches of certain species are substantial enough to affect biodiversity in some estuaries. Lack of understanding of the interactions between different trophic levels and the Estuary General Fishery adds to the uncertainty in the risks associated with the fishery.

Effects of different gear types on fish and habitats

There are few comprehensive studies that specifically test the effects of different fishing gears used in the Estuary General Fishery on fish (Broadhurst *et al.,* 1997; Broadhurst *et al.,* 1999; Gray *et al.,* 2000). For example, after hauling or meshing, discarded finfish (such as juveniles of commercial species) can suffer fin or scale damage making them susceptible to disease (Broadhurst *et al.*, 1999; Gray *et al.,* 2001). However, effects of gear on habitats has received relatively little attention for NSW estuaries. Some methods of fishing in the Estuary General Fishery not only affect mobile species but also potentially affect benthic flora and fauna in estuaries. Different forms of hauling and seining can affect the seabed by disturbance of the upper layer, damage or removal of epibenthos and macroalgae and damage to seagrassess. Apart from a study on the effects of hauling over seagrass (Otway and Macbeth, 1999), effects of other gears on seagrass and on other habitats in NSW estuaries have not been studied. Lack of knowledge of these effects contributes to the uncertainty of the effectiveness associated with the management strategy's input controls on gear types and usage. Therefore, it will be essential to understand the magnitude and extent of the effects of gear types on fish and habitats in order to determine more appropriate input controls on the Estuary General Fishery to maintain biodiversity within estuaries.

Effects of fishing on threatened species

There is currently little scientific data on the interaction between fishers and threatened species in the Estuary General Fishery. Despite the increasing awareness by the general public and the listing of numerous threatened species under several Acts (e.g. *Fisheries Management Act 1994*; *Threatened Species Conservation Act 1995*), little effort has been directed at understanding the effects of commercial fishing on these species. A lack of knowledge in this area seriously restricts our ability to make reliable predictions about the impacts of the proposed harvest strategy of the draft FMS on threatened species, or whether the management responses designed to protect threatened species and populations will be effective.

Potential for introduction of disease

Our understanding of the potential for the introduction of disease through imported bait products is limited. Given the recent outbreaks of a herpesvirus in the wild pilchard populations in southern Australia (Whittington *et al.*, 1997) this lack of knowledge poses a risk to the effectiveness of the draft FMS.

ii) Research assessment

All six of the proposed research areas potentially include the knowledge gaps outlined above (Table F16), with two exceptions: the potential for introducing diseases; and effect of recreational fishing. The former knowledge gap is more likely to be better addressed by another government department or organisation such as Center for Research on Introduced Marine Pests. But a process of communication between such groups needs to be acknowledged and established to ensure the issues, results and recommendations of research areas inform the on-going implementation of the draft FMS.

The latter knowledge gap, effect of recreational fishing, is not explicitly mentioned in the proposed research of the draft FMS. Theoretically it could be covered under effects of fishing methods but it would need to be explicitly identified as a need. The effect of recreational fishing on fish stocks and the environment is part of a wider issue of the interaction between other fishing sectors and their effects on fish stocks and the environment. For example, estuarine prawn species, such as school prawns, are fished by two estuarine commercial fisheries (estuary general and estuary prawn trawl) and also by recreational fishers in large quantities. These interactions could have a substantial effect on the estuarine environment as well as the prawn stocks themselves. There are no proposed research programs in the draft FMS that deal with these interactions and their effects. Clearly, a coordinated approach across fishing sectors is required to identify specific knowledge gaps and research needs.

Table F16. Summary of knowledge gaps and the research areas that can address them.

	Research Area					
Knowledge gap	**Stock assessments**	**Quantification of and reduction of bycatch and discards**	**Effects of fishing methods on habitats**	**Effects of habitats on fish populations**	**Impacts of fishing on trophic interactions and ecosystems**	**Impacts of fishing on threatened species**
Fish stocks	√					
Relationship between fish stocks, habitats & biodiversity			√	√		
Effects of recreational fishing			√		√	
Effects of trophic structures in estuaries					√	
Effects of different gear types on fish and habitats			√			
Effects of fishing on threatened species		√			√	√
Potential for introduction of disease and foreign species		√				

In designing projects within each research area, specific knowledge gaps will need to be articulated and addressed. For example, research into stock assessments will need to focus on aspects of the ecology of fish stocks, such as habitat use, juvenile mortality, feeding habits, life cycles etc, as well as traditional stock assessment information to fill knowledge gaps on the basic ecology of these species. Moreover, the interlinkage of research areas needs to be recognised and built into the research programmes. For example, research into the effects of fishing methods on habitats will need to use the outcome of research into the effects of habitats on fish populations in order to identify what habitats are important to target in the research. In addition, some knowledge gaps could be addressed by more than one research area depending upon the issue (Table F16). These linkages between research areas in addressing knowledge gaps on the impact on the biophysical environment will need to be clearly identified and addressed.

As in Chapter E section 4 it is difficult to assess the sufficiency of the research proposed as there are few details as to what specific research will be done, over what spatial and temporal scales, who it will be done by and the specific null hypotheses to be tested by the research. However, overall research needs are being discussed and prioritised (see Chapter C) and further details on the research programs will be available after this has process has been completed in 2002.

b) Performance and monitoring

i) Performance indicators and trigger points

Performance indicators relating to impacts of the fishery on the biophysical environment relate specifically to Goals 1 and 3. These indicators and their trigger points seem appropriate for gauging whether the goals are being met. Further discussion on the performance indicators and trigger points can found in Chapter E section 4 of the EIS.

ii) Monitoring and review

The proposed monitoring and review process for the biophysical environment is similar to that for the fishery resource, with two exceptions: monitoring for captures of threatened species; and reports of marine pests and disease. These monitoring programs depend on groups either outside of NSW Fisheries (e.g. NPWS) or in another division of NSW Fisheries, i.e. Office of Conservation. In order for these monitoring programs and consequent reviews to occur, a deliberate pathway or process between these groups will need to be made explicit. Such a process is suggested in the monitoring program but not elaborated upon. Clear communication between and within government departments will be essential for the proposed monitoring programs to be effective.

c) Relationship between research, performance indicators and review

The relationship between research and review has been discussed in Chapter E section 4(c). The same principles identified in that section are equally important to impacts on the fishery.

d) Timetable for developing information

The implementation timetable for research and monitoring is as set out in Chapter C section 4 of the draft FMS under each management response. However, a precise timeframe cannot be finalised for the research projects until priorities have been agreed to by all stakeholders.

CHAPTER G. ECONOMIC ISSUES

This is the first formal incorporation of an economic assessment of a management plan in the fisheries of NSW. It has been compiled from a limited amount of existing information, augmented by the results of economic and social surveys initiated by NSWF and undertaken by Roy Morgan Research (Roy Morgan, 2001a&b).

The following summary is based on the detailed Consultants report prepared by Dominion Consulting Pty Ltd and presented in Appendix CG1. The Consultants report on economic issues is in two sections; a review of existing information and then an assessment of the impacts and issues in the Estuary General draft FMS, examined against the DUAP guidelines.

1. Existing Information

Existing information is available from NSW Fisheries records and provides information on licensing, effort and catches at the primary level. Price, at first sale in Sydney, is also available and this enables an imputed Sydney fish price to be generated. This Sydney price probably underestimates landed value by between 12% and 21% in the Estuary General Fishery, as estimated by the recent economic survey (Roy Morgan, 2001a). Data on the fish processing industry is limited, being collected only from registered fish receiver annual registration forms. The seafood processing, wholesale and retail industry in NSW requires further study.

An economic survey was undertaken by mail to enable a profile of the commercial fishers to be developed (Roy Morgan, 2001a). The statewide economic survey has a response rate of 16%, 259 fishers from 1,640 completing the questionnaire of which 147 were active Estuary General fishers. The social survey sample size was greater than the economic survey by approximately 100 people due to businesses owned by companies or partnerships where more than one person is involved. The survey enabled the economic performance of businesses in the estuary general catching sector to be appraised. It also gave an indication as to the position of industry to pay additional charges and purchase shares under the proposed draft FMS.

A rapid social appraisal telephone survey was undertaken by Roy Morgan Research (Roy Morgan, 2001b) and had a response rate of 50%, with 870 fishers completing the questionnaire of which 502 estuary general fishers (58%) completed surveys. This social survey included some economic questions and enabled the assessment process to have up to date information on industry, its social profile and an indication of the potential social impacts of changes under the draft FMS which are examined in Chapter H.

The review of existing catch, effort and endorsement information, indicated the Estuary General Fishery is based predominantly north of Sydney (80% of estuary general endorsements) and there are a diverse range of businesses with endorsements in several managed fisheries. The Estuary General Fishery is seasonal with a low period in June to August and is predominantly one person businesses, with partnerships between fishers and a limited amount of corporate involvement. The social survey enabled the relationships between the estuary general fishers and their non-fisheries work to be examined.

Endorsement holdings in the estuary general indicated that in 1999-2000 only 623 of 1,003 fishers (as opposed to 944 businesses) entitled to fish were active, with 380 fishers as latent effort - not having submitted a catch return in any fishery during 1999-2000. Of the 623 active fishers, 533 had fished in estuary general and 90 had chosen to fish solely in other fisheries in NSW. Of those 533 who fished in the estuary general, 360 were estuary general only fishers and 173 were in estuary general and other fisheries.

The employment associated with estuary general endorsed fishing businesses was examined in the social survey and estimated as 566 employees. Given there are 632 active fishers, and 1,003 endorsed fisher, the total employment estimate is between 1,198 to 1,569 persons including full time and part time fishers. This also includes processing staff and needs further research as a statewide profiling exercise in order to avoid double counting and accurate assessment in the fishing and processing sectors.

The economic survey obtained data on industry operating costs, revenues and capital for one financial year only. The fishery is highly variable in activity and capital investment levels, some fishers having low capital investment. Survey returns were analysed to measure economic profit and to estimate a net economic contribution to the economy.

Estimates of operating profit were made, as many operators did not include owner's payment from fishing. An economic approach was used to review long term viability. The economic test of long term viability subtracts economic costs from revenues and tests for evidence of a surplus. The economic costs have operating costs, fixed costs, including opportunity costs of capital, labour and economic depreciation. Having imputed a 7% risk adjusted opportunity cost of capital and imputed labour costs for all days worked from survey information, an estimate of economic depreciation was applied to test for long run viability, evidence of capacity to replace capital in the long term. Given the variation in the scale and scope of fishing operations, results were divided into estuary general fishers only, estuary general plus other fisheries over $60,000 p.a. revenue, and estuary general plus other fisheries under $60,000 p.a. revenue.

Economic surplus exists for 20% of all estuary general fishing businesses examined, and was greatest in the higher grossing multi-fishing businesses which returned an economic rate of return to capital of 11%. The average economic rate of return to capital across all the businesses was negative (–17%), the median being (–30%). The results are consistent with previous studies (IPART, 1998), but are for one financial year 1999-2000, and further economic annual surveying is required to monitor economic performance in the longer term.

The businesses currently operating below the long term viability criteria, are effectively subsidised by forgoing returns on capital and particularly on labour. This may be to accommodate lifestyle, or indicate barriers to fishers exiting the industry, such as lack of alternative employment in rural areas.

For these less viable operators, increased charges and requirements to purchase shares, will significantly reduce operational viability. There is a large range of operator performance given numerous part time fishers, multiple fishing interests, and fishers with involvement in industries outside fishing, including subsidies from welfare. This is common in other rural industries, such as the NSW dairy industry, and requires on-going research on social structure of the industry and the economics of fishers households and communities.

Trends in licence values show no significant rise in estuary general endorsement values in the last eight years, but this is a limited measure of economic performance due to the restriction on transfers of endorsements and poor perceptions of management among fishers.

Limited information is available on non-Sydney market fish prices. Exporting of seafood out of Australia was estimated as between 2% and 13% of gross sales, for estuary general only and estuary general plus other fishers respectively (Roy Morgan, 2001a).

Regional economic information on the fishing industry is limited to several studies in northern and southern NSW in the late 1980s. Economic multipliers in the fishing industry are low and total effects are generally between 1.5 and 2.0 times the direct effect (Tamblyn and Powell, 1988; Powell *et al*., 1989). Existing information from expenditures outside local towns infers that approximately 70% of expenditure stays in the local communities generating local multiplier effects (McVerry, 1996). This is an area for future research work. The social survey examined the regional purchase behaviour for major purchases made by estuary general fishers, showing the importance of business links between estuary general fishers and Sydney, Newcastle and Brisbane.

2. Assessment

The assessment of the draft FMS draws on this background information and the responses under the draft FMS are ranked on their potential for larger scale economic impacts. There is insufficient cost and benefit information for a definitive ranking. The following issues are assessed.

Zoning policies mean that operators will be constrained to one zone for operation, in order to regionalise fishers in management regions. Under stage one of this process, the impact will be differing degrees of economic and operational dislocation, significantly impacting 17-41 fishers in a range of regions. Mitigation through stage two is recommended in order to enable fishers to adjust to new arrangements.

The change from 1,000 m and 725 m haul nets to operation of a maximum length of 500 m in estuaries with further restrictions to one shot per crew per day, will impact 20-30 fishers with large hauling nets, but may benefit the fish stock and improve the public perception of fishing. The cost impact on fishers is significant and immediate. Fishers query the perceived benefits of the policy. This policy may be mitigated by implementing a change to 725 m nets and then appraising the distributional impacts on fishers.

The intention under the draft FMS is to continue the annual 3% per annum reduction in the number of fishing businesses seen under the Recognised Fishing Operation policy, to control effort in industry through the category 2 share management regime and give the remaining fishers improved fishing rights. For assessment purposes a 15% reduction in business numbers under the first five years of the FMS is envisaged, reducing 944 fishing businesses in 2001, to 802 in 2006, 141 choosing to exit. The basis of share allocation has yet to be decided. It is envisaged that minimum share holdings may translate into businesses having to pay between \$500-\$1,000 per year to remain in the fishery, in addition to new management charges. Some businesses will exit, the most likely being latent effort holders and those businesses grossing below \$10,000 per year. Shares will be more readily purchased by those 20% of businesses in economic surplus. To the majority of fishers without an economic surplus, there is an incentive to increase effort to cover the new payments. It is essential to monitor latent effort and contain active effort levels within historical guidelines, as stated in the strategy. Given the low output associated with exiting fishers, the economic flow-ons from exiting businesses will be low. Social costs may be significant as reported in Chapter H, social issues.

A similar shareholding provision at the endorsement level will be implemented within estuary general regions and minimum share holdings set by endorsement type. A 15% reduction has been envisaged for assessment purposes equating to a payment of \$150-\$240 per year to retain a crab endorsement, or \$450-\$720 p.a. for three endorsements. For a fisher with several method endorsements, this minimum shareholding may reduce the endorsements they wish to hold. Again, it is likely that latent effort holders, and those businesses grossing less than \$10,000 per year, may sell. With 15% of endorsements exiting in five years, this may represent approximately 150 small businesses. However, the effect of business and endorsement level adjustment is cumulative. A 15% adjustment in both business shareholdings and endorsement share holdings is predicted to equate to approximately 20% of businesses exiting the industry. This would equate to 188 businesses exiting through business and endorsement shareholding arrangements. Active effort levels would be monitored in regions. The economic impacts of the move to manage fishing capacity by minimum shareholding can be mitigated in the setting of rates of minimum shareholding. High rates of change in minimum shareholding levels would risk effort levels increasing to pay for adjustment and stagnation in the share market if sellers outnumber buyers. Mitigation of this may involve financial assistance from government.

Less impacting elements of the draft FMS are assessed, such as net and gear changes, alterations to fish size regulations, changes in crab management arrangements and changes in icing and food safety practices. These have minor impacts in comparison to reallocative consequences of share management arrangements.

The costs and benefits of the major elements of the draft FMS are appraised through an environmental account of the management of the fishery. To the estimate of economic surplus from fishing operations, the subsidised costs of management, research and compliance are added. Any change in the level of stocks is also counted to give a statement of current fishery status under environmental accounting principles. New costs to industry from the FMS and share trading, are estimated and incorporated in the cost benefit analysis.

The fishery has a significant economic deficit at the commencement of the FMS and seeks to move towards economic viability by 2006. Costs to fishers from new management charges and share purchase are substantial as the fishery moves towards full cost recovery in the years 2005 to 2008.

The economic achievement of the objectives of the draft FMS depends on the category 2 shareholding proposal being as effective as envisaged in the plan. This is new territory in fisheries management and fuller economic investigation of share allocation and subsequent monitoring of restructuring is warranted. Mitigation may involve shares being related to an amount of total effort, as opposed to a share of access.

By 2006, changes arising from the FMS will alter industry operations and cost recovery policy will address subsidies, moving towards full cost recovery by 2008. The draft FMS enables this process to occur and monitors the health of stocks underpinning industry and fishery viability. The FMS is a first step towards a more economically sustainable fishery in accordance with ESD principles.

3. Conclusions

This is one of the first economic analyses of a FMS in Australia and is done against a background of little available economic information. The major thrust of the draft FMS is to assist industry to adjust to more economically viable and sustainable harvesting. The analysis of the core costs and benefits of the management plan, indicate that the fishery will be more profitable by 2006-07. However, the level of achievement of the desired draft FMS objectives through the new category 2 share management need to be monitored, as this is a new untested allocation regime. There are significant economic costs and social impacts for industry under the plan, as 150 to 188, of 944 businesses exit the Estuary General Fishery in the 2002-2007 period. Many of these will be small businesses and lessen the regional impact of adjustment due to their low output. The draft FMS should be seen as a significant first step in a longer path towards achieving ESD objectives.

4. Data Requirements in Relation to the Assessment of the Impacts on the Economic Issues

a) Reference to technical data and other information relied upon to assess impacts

The data used in the assessment is from several sources. The catch and effort data is from NSW Fisheries and is logbook data joined with NSW Fisheries licensing data for tables which contain endorsements. Both districts and zones are used for spatial analysis and as districts are less aggregated there may be occasions that fishery activity in an estuary traverses two zones. Effort data at the days fished level is complicated by the logbook system where fishing three methods in one day ends up being records as one day of effort against each of three methods. This limits the potential for accurate production modelling or bio-economic analysis.

A significant issue for fishers is the use of the Sydney price index for price imputation on declared catches. The monthly average price for a species from Sydney Fish Market is multiplied by the declared catch for a species. This enables both fishery wide and individual fisher revenue estimation. There are several cautionary notes in doing this.

Some species such as squid may not have a representative monthly average price. The imputed price will likely be a minimum estimate of the price of species which are in demand. For example seafood such as larger prawns, are unlikely to be sent to Sydney market as local demand is strong at higher prices without commission and freight. In some cases fishers in areas outside Sydney may on occasions receive prices closer to Sydney retail levels for valuable species. Similarly fish with added value capacity, through sashimi grade handling etc, may better the Sydney index and prices for say female mullet in roe in the north of the state may on occasions be several times the Sydney price.

In contrast the estimate of price at first sale does not deduct between 11% and 23% of gross revenue for market and handling expenses. Therefore to a fisher adjacent to Sydney landing to the fish market, the imputation is potentially too high to the extent of marketing fees.

The economic survey asked fishers to declare gross revenue from catch in 1999-00 and this was compared with the predicted Sydney index for each fisher to see the inter-relationship. Preliminary examination suggests the Sydney index may under estimate actual prices in estuary general businesses by between 12% and 21% (preliminary results requiring further validation).

There are also uncertainties in the value of estuary general businesses and endorsement values. Diversity among business packages mean the true value of access is difficult to determine. The move to share management will require examination of the structure of business and endorsement values.

b) Important knowledge gaps

Several gaps are apparent. The major one is the lack of an industry wide profile of the seafood industry in NSW, including processing, wholesaling and the movements and values of seafood in the marketing chain. This would enable an evaluation of the secondary stages of the fish catch including processors, exports, imports and employment derived from the NSW fish resource. It could also extend to retailing.

Multipliers could be estimated and contribute to future assessments. The regional importance of the seafood industry in each region could be evaluated. Part of this could use the Registered Fish Receiver annual renewal forms to include more information on processing activity in relation to the fisheries under management.

Several of the assessment issues involving fishing gear selection require fish length and price relationships for micro evaluation of gear changes - costs and benefits. This requires investigation of the finer scale data potentially available.

Price information outside Sydney needs to be collected on a regional and fishery basis. This is required as several of the future assessment issues such as the optimal harvesting time of prawns will require bio-value models using biological and size and price information for different prawn species during their estuary to sea migrations.

Business values, endorsement values and shares valuation is an area requiring more research. Similarly longer term planning needs to be able to monitor the cost of operations and this could use existing survey information to establish a representative "fishing cost index". This would monitor cost changes for producers and could parallel the Sydney price index for fish revenues.

Economic inter-relationships between fishing communities and within the fishing industry has been briefly addressed in the current social survey and could be augmented through time.

c) Timetable for developing the data sets

Data needs can be addressed in the next five year period through development of a strategy for improving the following data:

- investigation of available price data in respect of fishery valuations and for modelling resource management scenarios such as maximising prawn bio-value through harvesting
- examination of the viability of businesses, business values, endorsement and share values and the basis of share allocation prior to trading. Subsequently, monitoring of share values to ensure industry viability and the achievement of the FMS
- surveying of the economic performance of businesses after the implementation of the plan (year 2-3)
- consider developing a statewide fishing industry economic restructuring model for predicting and appraising fishing business adjustments across fishery administrative divides
- revising the collection of effort data to enable more sensible modelling of catch per unit effort and productivity data. This would involve changing the fishery data logbook system and needs to happen within five years in preparation for long term sustainability issues, including economic modelling and monitoring
- developing an economic profile of the regional fishing and seafood processing industry in NSW. This could include marketing, economic infrastructure and regional benefits. This needs to be progressed by area and in conjunction with social community profiling as a basis for longer term planning.

CHAPTER H. SOCIAL ISSUES

This is the first formal incorporation of a social assessment of a management strategy in the fisheries of NSW. It has been compiled from a limited amount of existing information, augmented by several NSW Fisheries initiatives, including a social survey (Roy Morgan, 2001b).

The following summary is based on the detailed Consultants report prepared by Dominion Consulting Pty Ltd and Umwelt (Australia) Pty Ltd and presented in Appendix CH1and CH2. The report on social issues is in multiple sections; a review of existing information, an assessment of the draft FMS against the DUAP guidelines, health issues, heritage issues, Indigenous issues and data issues.

1. Existing Information

Existing social data on fishers and their communities is limited to licence data records and was supplemented by obtaining access to ABS data[7] and through implementing a telephone questionnaire (Roy Morgan, 2001b).

The regional and community location of fishers was identified from licensing data and compared with the ABS data for a range of social indices, at the postcode level. This included local population, unemployment and fisher employment data from the 1996 National census and the SEIFA[8] index of disadvantage for rural communities (ABS, 1996). The fishing communities tend to focus around key estuaries and towns, though a significant number of fishers reside in smaller communities. More in depth studies of fishing communities is an area for future work. A rapid social assessment telephone survey contacted 502 estuary general fishers with a range of questions relevant to the draft FMS.

Total employment in businesses with an estuary general endorsement, is estimated as between 1,198 and 1,569 persons (full time and part time), though those directly associated with the Estuary General Fishery would be less. Some of the employees are probably in processing and there is no measure of the extent of part time involvement. This requires further studies as recommended.

A demographic profile of fishers was generated describing, age, education levels, marital status and dependent children and relatives. The way of life of estuary general fishers was investigated through questions on working hours in the normal, high and low seasons, and details of industrial injury through fishing. The estuary general fishers were found to be an aged, highly resident population, with substantial fishing experience and strong family involvement with fishing, 53% of fishers having had more than two generations of family in the fishing industry. However, 47% are first generation fishers. Fishers in excess of 60 years of age comprise 20% of all estuary general fishers and a wide range of fishers of all ages are evident in the fishery.

The skill sets of fishers were examined through the social survey and only 100 from 502 (20%) worked outside fishing, 34% of the 100 being capable of working in another occupation full time. Further investigation suggests that up to 25% of the estuary general fisher population could consider working in other industries full time or part time. However, approximately 70% were insistent about

[7] Thanks to staff of the Social Science Unit, Bureau of Rural Science, Canberra.
[8] (Social and economic index for areas)

their identity as fishers and were unable, or unwilling, to consider re training. This "physic income" from fishing and problems in mobility of fishers is similar to NSW dairy farmers and a range of issues are discussed. These require future research. Regional unemployment in NSW is higher on the north coast of NSW (14%) and areas outside Sydney, and is a significant issue for older fishers considering alternative employment to fishing.

There is little independent opinion on community perceptions of fishing activities. In a community telephone survey in 1999, there was general concern among a random selection of the population for the well being of the fishery environment and for the need to manage and conserve fish stocks (Roy Morgan, 1999). Other community opinion about fishers, is less formal and is an area requiring development. Much commercial fishing activity is not seen by the public. The community may take the provision of fish by commercial fishers for granted and may not relate environmental management issues to seafood supply.

Recreational fishers are becoming more aware of the commercial fishery and conflict over commercial fishing methods, such as hauling, is common. The draft FMS seeks to reduce the conflict among commercial fishers and between commercial and recreational fishers. The recreational fishing area program is addressing these issues outside the FMS process with unknown impact on the draft FMS.

2. Assessment

The social assessment followed the DUAP guidelines, but as there is no established social impact assessment framework for fishery management plans, an approach was developed from guidelines and available literature. The draft FMS management responses were ranked into high and low impacts: firstly, those socio-economic issues arising from policy changes that could have broad impacts; secondly, issues of social process, where policy changes require these processes to function properly for management to be most effective.

The most highly impacting issues include the changes to zoning, hauling net lengths and to minimum shareholdings, as discussed in the economic assessment. Each of these changes has the capacity to impact many families, local communities and regions, the assessment being able to examine regional and predicted family impacts from available data. Each of the impacts are assessed and mitigation is suggested where applicable.

The major social changes in the plan involve the displacement of between 150-200 fishers, through management cost increases and the implementation of minimum shareholdings. These will probably impact part time and older fishers, as 20% of fishers are over 60 years old. A diverse range of people who are either latent endorsement holders or fishing businesses owners grossing less than $10,000 per year may also be impacted.

The predicted social impacts assume a 20% displacement of business/fisher numbers over the first five years of the FMS. The numbers of dependants associated with 150-200 typical EG fishers is between 220 and 294. This is an upper estimate, as if older fishers exit the fishery, then the number of dependent children below 16 reduce substantially. Exiting fishers are likely to be low catchers, or have other income sources, if they are currently latent effort. This reduces the proportion of social impact attributable to the exiting of fishers under the draft FMS.

The draft FMS will have different regional community impacts as indicated by the SEIFA index of disadvantage for fishing communities. On implementation of the draft FMS, the most vulnerable estuary general districts are Clarence, Wallis Lake and Far South Coast. Other communities outside Sydney and the Hawkesbury are also potentially disadvantaged to a lesser but significant extent. Social impacts on communities will also depend on the economic responses of fishers to category 2 share management, which will not be uniform. The social impacts of the draft FMS may be mitigated by the rate at which adjustment of minimum shareholdings occurs. The funds from the recreational fishing area process may impact the adjustment process indirectly and to an unknown extent.

Other measures in the draft FMS will require functioning social processes to ensure effective management. Responses involving communication, compliance, codes of conduct and new gear regulation require cooperation between management and industry and a reduction in conflict to make the FMS successful. The draft FMS seeks to reduce conflict among estuary general commercial fishers and between commercial and recreational fishers. This needs to be monitored to ensure the effective implementation of the plan.

3. Conclusions

This is the first social assessment of a FMS in NSW and little previous information. Available data and specially commissioned survey results, are used to describe the fishers and communities in the Estuary General Fishery. It is notable that several rural areas away from Sydney on the north and south coast, are socio-economically disadvantaged and will be less resilient to impacts under the draft FMS.

Most of the social issues arise from reallocation under category 2 share management and will impact fishers, employees, families and communities associated with the exiting 188 estuary general businesses. It is predicted that older fishers, businesses earning less than $10,000 per year and latent effort holders, will be likely to exit, with low levels of regional economic impact, due to the small loss of output associated with these fishers. An estimated 150-200 fishers, with up to 220-294 dependants, will be impacted to differing extents in proportion to their age and income dependence on the Estuary General Fishery.

The social impact will be significant, given the place of fishing among fishers and estuary general fishing communities, and the lack of alternative employment for many fishers. Other social aspects of NSW fishing communities require further research in the next five years. A priority should be to understand fishing communities, as a basis to appraise the impacts of successive fishery plans on a community. This would give greater clarity and reduce the risk of cumulative impacts on communities through a series of different fishery management strategies. The current draft FMS is a first step in moving towards ESD objectives in the management of the Estuary General Fishery.

4. Health Issues

a) Health risks related to the environment

The seafood safety scheme is based on the premise that some species and/or activities represent a potentially higher food safety risk than others. The highest food safety risk is associated with bivalve molluscan shellfish because they can readily accumulate harmful contaminants (bacteria, viruses, algal toxins and heavy metals) from their environment and transmit these to the consumer.

Within the context of the Estuary General Fishery only those engaged in the harvesting of bivalve molluscs need special arrangements. Because of past problems arising from the accumulation of algal biotoxins those engaged in the pipi fishery are already required under NSW Fisheries legislation to have in place biotoxin management plans. Pipi harvesters have grouped themselves (usually geographically) into small collectives each of which has a plan endorsed by NSW Fisheries and audited by an external provider. These plans have, and continue to be, effective in their operation. With the introduction of the seafood safety scheme Regulation responsibility for this sector in terms of food safety will pass to SafeFood. It is anticipated that the food safety programs/plans of pipi harvesters will include similar provisions for biotoxin management.

b) Handling and processing health risks

The activities conducted and species targeted in the Estuary General Fishery pose little in the way of food safety risks, with the few possible exceptions discussed above.

As food producers, the provisions of current NSW food legislation, namely the *Food Act 1989* and the *Food Regulations 2001*, bind participants in the fishery. Vessels are included in the definition of “vehicles” in the *Food Act 1989*. There are no specific provisions relating to seafood specifically in the context of this fishery but general requirements about hygiene and cleanliness, keeping good records and keeping products cool apply to the handling of all foods including fish.

The *Food Production (Seafood Safety Scheme) Regulation 2001* due to be introduced by December 2001 will require all seafood businesses including those in the catching/harvest sector to be licensed with SafeFood Production NSW and prepare a Food Safety Program in respect of their activities.

With respect to the Estuary General Fishery this will apply from the point at which the catch is brought on board the vessel, or in the case of pipis at the point of harvest. Where the same business or individual further processes or handles products on shore (after landing) the Food Safety Program will have to encompass each and all of those other activities.

For most participants who simply catch fish and transport them to land, the basic requirements would already be understood and met since they involve good handling and hygienic practices. However, given the range of scale and sophistication of vessels and businesses engaged in the fishery it is likely that some improvements will need to be made, primarily of a minor nature.

Participants who currently collect from wild sources, other bivalve molluscs such as mussels and cockles, will also be covered by the *Food Production (Seafood Safety Scheme) Regulation* provisions and will be integrated into the shellfish food safety program which is already established for cultured bivalves (i.e. aquaculture permit holders under fisheries legislation).

Essentially the major food safety requirements on all participants in the Estuary General Fishery are keep the catch clean, keep it cold and keep good records. The current level of compliance is largely unknown but with the introduction of the Seafood Safety Scheme all participants will be licensed and subject to audit and inspection.

c) Health risks to fishers

There are a variety of occupational health and safety risks associated with the activity of fishing in the Estuary General Fishery. These are related to the use of machinery, boats, powered winches, etc. Workcover administers the legislation, which controls these activities and protects the workers health. The fishing businesses in the Estuary General Fishery are required by law to operate in a manner consistent with the occupational health and safety (OH&S) legislation. The draft FMS is not required to provide additional specific management responses to OH&S issues.

5. Heritage Issues

The following summary is based on the detailed Consultants report prepared by Umwelt (Australia) Pty Ltd and presented in Appendix CH2.

a) European heritage

European heritage sites reflecting the importance of maritime activities in the past development of NSW are located in many estuaries. The assessment considers potential impacts of estuary general fishing activities on those European heritage sites that are listed in inventories maintained by the NSW Heritage Commission, the National Estate and the Australian Shipwreck register.

Historic heritage has been differentiated between the transport and structural contexts and this differentiation is essentially dictated by the base source(s) or recording database(s) from which data has been derived. The transport context is specifically represented in the record of shipwrecks. The structural environment includes such resources as boatsheds, landing ramps, seawalls, breakwaters, wharves and boat harbours but also includes such developments as structures for oyster culture, groynes and piles, which may have no physical connection to the shoreline.

i) The interaction of commercial fishing with historic heritage resources

The activities associated with the Estuary General Fishery are limited to the use of a variety of netting styles, traps and static and mobile handlines, as well as the manual recovery of some species. The physical and spatial presence of heritage resources within estuaries is likely to have only a marginal interaction with commercial fishing operations. With regard to shipwrecks, it appears likely that commercial fishing will have no impact on residual material evidence, having regard to the likely nature, bulk and mass of any residual material and the potential for sub-surface material to be covered by silt/sand.

It is considered that there is a low risk that estuary general fishing activities will impact on heritage sites although some shipwreck sites may present safety risks to estuary fishers.

b) Aboriginal heritage

There is abundant ethnographic and archaeological evidence for past use of estuaries and beaches by Aboriginal people, and of the importance of resources from these environments to Aboriginal economies and lifestyles.

Known Aboriginal sites are recorded in the NPWS Aboriginal Sites Register, and there are thousands of known sites located on the banks of estuaries or along beaches. Sites are known from the banks of virtually every estuary in NSW, and middens are reported from many beaches (although the distribution of midden sites is heavily influenced by the nature of the beach and dune system). Very few (if any) known Aboriginal sites are located within the channel of estuaries that are used for commercial fishing activity.

i) Interactions between Estuary General Fishery and Aboriginal heritage sites

The draft FMS provides a framework for commercial use of estuarine fish species, and also for commercial harvesting of beach pipis and worms.

Estuary general fishing activities are most unlikely to impact on the stability of estuary banks or beds. The nature of estuary fishing means that although the banks of estuaries are lined with known Aboriginal sites, there is a low risk that sites will be impacted by estuary fishing activity.

There is potential for fishery related activities to impact on Aboriginal sites at restricted locations along estuarine waterways, for instance at boat ramps, and localities that are used for storage and maintenance of equipment. The extent of the risk associated with these activities will vary from one estuary to another, and definition of the risk for an individual estuary will depend heavily on the availability of local knowledge (e.g. provided by discussions with local Aboriginal people and local NPWS officers).

Where potential impacts on Aboriginal sites are known to exist, it is important that they are addressed by liaison and management actions at the local level. This will ensure compliance with the requirements of the NPW Act, and will also enhance co-operation and understanding of cultural concerns.

In general, the physical evidence of past Aboriginal occupation of estuary banks is most severely threatened by land uses other than estuary general fishing. Large midden sites in the Hunter estuary and north coast estuaries were exploited for lime in the nineteenth century, and sometimes also for road base. Many sites have also been destroyed by agricultural land uses, urban and tourist development and some have been destroyed by bank erosion (that may have natural or anthropogenic causes).

In the cases of both Aboriginal sites along the banks of estuaries, and Aboriginal sites along the dunes of ocean beaches, the overall risk that activities authorised by the draft FMS will detrimentally impact on cultural heritage evidence is considered to be low.

ii) Protocols to reduce the risk of harm to sites

Notwithstanding the low risk of impact on Aboriginal cultural heritage, several management actions are proposed to ensure that risks to archaeologically sensitive areas are minimised. These include:

- consultation with local Aboriginal community representatives in relation to any proposed commercial fishery facility that would be located on the bank. This would include maintenance of existing ramps, new launching ramps, wharves and regional boat storage or maintenance sites
- preparation of cultural awareness information for holders of beach pipi and worm authorisations. In particular, these operators should be aware of the nature of pipi and other midden sites along ocean beaches, and that such sites are protected by the NPW Act
- ongoing consultation with local Aboriginal communities about developments in the commercial sector. This will occur, for instance, through Aboriginal representation on regional management advisory committees (MAC).

The following proposals were also included in the draft FMS following stakeholder comment but subsequent to the consultants report:

- an explicit objective within the draft FMS is to minimise any impacts of the fishery on Aboriginal cultural heritage (see objective 4.4)
- consultation with Local Aboriginal Land Councils and review of the Aboriginal Sites Register administered by the NPWS when identifying designated landing sites for hauling nets, to avoid wherever possible hauling onto areas that are known Aboriginal sites.

6. Indigenous Issues

The following summary is based on the detailed Consultants report prepared by Umwelt (Australia) Pty Ltd and presented in Appendix CH2.

It is important to note that there are several other concurrent policy development initiatives by NSW Fisheries that will affect the interaction of Aboriginal fishers with the Estuary General Fishery. In particular, NSW Fisheries is currently working with the Aboriginal community to develop an Indigenous Fisheries Strategy, that will provide a new framework for the management of Indigenous fishing. The information presented in this assessment draws on the work in progress towards the Indigenous Fisheries Strategy, and outlines a process for ongoing review of regulatory relationships, but in no way pre-empts the outcomes of that strategy.

a) Current access of Aboriginal communities to estuary fishery resources

Commercial fishing has existed in NSW estuaries since the mid nineteenth century. Commercial fishing operations commences around Sydney then moved to more remote estuaries early in the twentieth century. Thus, the interaction of traditional Aboriginal fishing activity in estuaries (and shell fishing on beaches) with the commercial estuary sector spans approximately 150 years in the Sydney area, and 100 years elsewhere on the NSW coast. In many Aboriginal communities, at least some members held general commercial fishing licences, and participated in the commercial sector, as well as fishing to support family and friends.

From the late nineteenth century, a number of estuaries (or parts of estuaries) were closed to commercial fishing, generally to conserve or to allow the regeneration of fish stocks. Traditional Aboriginal fishers would have continued to have access to the aquatic resources of these waterways during periods of commercial closure.

Since the mid 1980s, a number of new regulations have been introduced by NSW Fisheries. The broad objective of these regulations was to enhance the efficiency of the commercial fishery, and introduce greater control over fishing effort and impact. The number of Aboriginal people who are licensed as commercial fishers in the Estuary General Fishery and the relative scale of their fishing effort, is not known.

The introduction of greater regulation in the Estuary General Fishery from the mid 1980s had several unintended consequences in relation to the access of Aboriginal communities to the estuary fishery. The impacts of the regulations continue to be of concern to Aboriginal fishers.

b) Management of Indigenous fishing and Estuary General Fishery interactions

Outstanding issues of concern to coastal Aboriginal communities

The level of Aboriginal participation in the commercial fishery sector (based on interview data) appears to have declined substantially over the last twenty years. There are now perhaps less than fifteen active fishing licences (estuary general and beach haul) held by Aboriginal families along the coast. However, the lack of commercial participation is not an indication of declining Indigenous participation in fishing generally. There are four main categories of outstanding issues of concern to the Aboriginal community in relation to their participation in the management of fisheries in NSW (NSW Fisheries, 2000) and each of these is also relevant to the impact of the draft FMS on Aboriginal communities:

- lack of recognition and accommodation of traditional Indigenous fishing practices
- declining participation of Aboriginal people in commercial, recreational and aquaculture fisheries
- insufficient meaningful presence and participation of Aboriginal people in the process for managing and conserving fisheries resources
- need for better communication and consultation with Aboriginal people.

Actions to address Aboriginal concerns in the draft FMS

The draft FMS identifies Indigenous people as stakeholders in the Estuary General Fishery, noting that these interests arise from:

- direct participation in the fishery as commercial fishers
- traditional fishing practices, whereby people catch fish on behalf of themselves and their community
- lodging native title claims over estuarine areas that are used for commercial fishing.

Existing legislation does not currently recognise Indigenous fishers as a separate sector of the fishing population, and this is a large part of the reason, that none of the legislative reviews to date have given extensive consideration to Aboriginal community concerns.

The draft FMS does not specifically address the Aboriginal community's view that the evolution of the fisheries legislation in NSW has gradually but consistently undervalued the interests of Aboriginal people in the estuary fishery. The draft strategy does, however, foreshadow future amendments to the strategy to better accommodate Aboriginal community interests. For instance, objective 4.1 aims to monitor and provide an appropriate allocation of the fisheries resource between fishing sector groups.

In the draft FMS the performance indicator listed for appropriate sharing of the Estuary General Fishery resource is the catch level (including estimates) of the commercial, recreational and Indigenous fishing sectors. A trigger point for review is noted as a shift of relative catch levels of 25% between sectors over the term of the strategy.

It is important to note that such a shift in relative catch is unlikely to occur without significant changes to policies affecting access to the resource.

Towards a NSW Indigenous Fisheries Strategy

NSW Fisheries has recognised that coastal Aboriginal communities have long standing and legitimate interests in the fishery resources of estuaries, as well as pipis and beach worms. The NSW Government now also acknowledges that Indigenous community interests in the estuary fishery are contemporary and do not relate only to past history. The traditional access of Aboriginal communities to natural resources has been restricted by existing fisheries management policies and legislation.

A recent working paper prepared by NSW Fisheries (2000) indicates that consultation is progressing about how best to recognise and accommodate the rights and interests of Aboriginal people in the estuary fishery and other commercial fisheries. The working paper is part of the process for the development of an Indigenous Fisheries Strategy for NSW.

Interaction of the draft FMS and the Indigenous Fisheries Strategy

The time frame for the finalisation of the Indigenous Fisheries Strategy is not clear, and there are many complex issues to be resolved before a sustainable strategy is agreed by the stakeholders. It is most probable that the draft FMS will be assessed and will commence before negotiations about the Indigenous Fisheries Strategy are complete.

The preliminary indications are that the Indigenous Fisheries Strategy will address many of the issues that remain as outstanding concerns to the Aboriginal community in relation to the Estuary General Fishery. It is also possible that the strategy will include a staged series of actions to gradually improve Indigenous access to the natural resources of estuaries and other fisheries, so that any necessary changes to the draft FMS will also be gradual.

Ongoing review of the FMS will be essential to ensure that changes in the policy approach to Indigenous fisheries are adopted within the FMS. It is proposed that the FMS should be reviewed in two years, with particular attention to ensuring consistency between any Indigenous Fisheries Strategy that exists at that time, and the management protocols contained in the FMS.

c) Summary

As noted above, the risk of impacts on Aboriginal sites from Estuary General Fishery activities is considered to be low at the whole of industry level, although specific local issues will need careful management.

Many of the concerns of Aboriginal communities about the impact of current commercial fishery regulations on their livelihoods and lifestyles are being addressed through the partnership with NSW Fisheries to develop an Indigenous Fisheries Strategy. However, this process may take some time, both to finalise to the satisfaction of all stakeholders, and to implement through changes to other strategies and legislation.

7. Data Requirements in Relation to the Assessment of the Impacts on the Social Issues

a) Reference to technical data and other information

Prior to this study there was little social information on commercial fishers in NSW. The survey data comes from a rapid social appraisal questionnaire executed by a telephone survey, which is a first step towards the incorporation of social information in the management of fishers in NSW. The survey is not a definitive social profiling exercise. Given the complexity of the fisheries production inter relationships, multiple communities and political climate among industry members facing significant allocation issues, the survey sought to gain a rapid over view of social issues raised under the draft FMS.

The survey revealed some inconsistencies in answers involving fisher income and these have been investigated by matching with the available Sydney price index information and preliminary results from the economic survey. There are some occasions in which the absence of a fisher submitting a catch return in the required time period will give inconsistent results.

b) Important knowledge gaps

The social profile of estuary general fishers can be augmented through time by further studies. Regional analysis of fisher communities is a priority integrating with economic information on the importance of the fishing activity to the community infrastructure of towns in NSW. Other approaches examine expenditures by businesses, employees, and examines employee residential locations and social infrastructure services and existing social networks (Fenton and Marshall, 2001). Future social survey work should address community structure and inter-relationships at a regional level and articulate with regional economic studies previously recommended in Chapter G. This could be developed to monitor community impacts through all the fishery management strategies being developed in the next few years.

c) Timetable for developing the data sets

More comprehensive social profiles and regional analysis should be undertaken in the next five years to assist in monitoring the impacts of adjustment and in preparation for appraisal of future management strategies. The survey information recently obtained can have existing NSW Fisheries data added to it for analysis, but has a limited shelf life.

More complete regional industry and fishing community studies need to be undertaken recognising that communities can be impacted through the implementation of multiple fisheries management strategies. In time it is desirable for the fishing community profile and characteristics to be more clearly identified. This would enable impacts from different FMSs to be monitored. In the longer term repeating social impact assessments for each fishery FMS risks ending up as a piecemeal and duplicative process if progress is not made in more fundamental fishery community profiling and monitoring in the next five years.

CHAPTER I. JUSTIFICATION FOR THE PROPOSED COMMERCIAL FISHING ACTIVITY

1. The Need for the Estuary General Fishery

This section examines the need for undertaking the fishing activity proposed in the draft FMS and the consequences of not undertaking the activity. The Estuary General Fishery exists because it satisfies a number of significant community needs, each of which are discussed separately below.

a) Employment

There have been no targeted social surveys undertaken in relation to the NSW fishing industry, and there is generally a lack of information and data on which to base sound conclusions. The economic and social survey undertaken by Roy Morgan Research and analysed by Dominion Consulting Pty Ltd on behalf of NSW Fisheries has provided some information, however, and allows a rudimentary assessment of the nature and scale of employment associated with the fishery.

There are currently 944 fishing businesses in NSW that hold one or more endorsements to fish in the Estuary General Fishery, comprising approximately 1,003 individual licensed fishers. Taking into account the number of people who assist in the operation of fishing businesses with entitlements in the Estuary General Fishery (both directly and indirectly), there is estimated to be between 1,198 and 1,569 persons employed in association with estuary general fishing. This does not include people employed in subsidiary industries such as fish processing, transport or the retail sector. The estuary general fishing community tends to focus around key estuaries and towns, though a significant number of fishers reside in smaller communities.

While the total employment estimate shows a significant number of people who are involved in the fishery, fishers operating in NSW are generally diverse, operating in a number of different fisheries. In fact, of the endorsement holders that actively fish in the Estuary General Fishery, about 48% operate in this fishery only and 52% operate also in other fisheries. This EIS has documented the large component of small and relatively inactive entitlement holders in the Estuary General Fishery.

It is not known how fishers would change their business structure if the Estuary General Fishery ceased to operate, however it is reasonable to expect that the number of people who would have to find alternative employment would be in excess of 1,000. This is in the knowledge that 71% of estuary general fishers believe they would be unable to gain employment outside of fishing, and 73% of these people have stated that they would not consider retraining. A proportion of estuary general fishers would be expected to concentrate their activities in other fisheries or seek alternative employment.

b) Supply of seafood to the community

The Estuary General Fishery provides, on average, approximately 5,000 tonnes of fresh seafood annually for general consumption by the community. There are no data available on the exact proportion of the estuary general catch that is exported, although the economic survey indicates that between 2% and 13% of gross sales from businesses with estuary general entitlements is exported from Australia. Accordingly, it is believed that most of the catch is sold and consumed locally. The supply of fish by commercial fishers satisfies demand from consumers who do not wish to, or are unable to, venture out and catch the fish themselves.

A survey of the importance of local seafood to the catering and tourism industries in NSW has shown 40% of businesses felt it was important to offer local seafood to visitors. Fifty percent of businesses promote the local product (Ruello, 1996). A repeat survey four years later has indicated this trend has continued to increase and the importance of fresh local seafood to both consumers and businesses has increased (Ruello & Associates Pty Ltd, 2000). This trend is also found in north Queensland where 78% of restauranteurs said customers expect local seafood on the menu (JCU, 1993).

The importance of commercial fishing to local communities is often overlooked. Between 1991 and 1999 annual per capita fish and seafood consumption (from all sources) in Sydney increased by 12.7%, from 13.5 kg to 15.1 kg edible weight. In-home consumption rose by 8.4% while the increase in out-of-home consumption was much greater at 19.0% (Ruello & Associates Pty Ltd, 2000).

The Estuary General Fishery supplies many species of fish and crustaceans that generally have a lower per unit value than many species taken in other fisheries (e.g. dusky flathead compared with tuna). The sale of these types of species supplies a low value species market niche that is quite different to that of the high value species.

Maintenance of a viable estuary general commercial fishery is clearly necessary to satisfy the high community demand for seafood.

c) Economic benefits

The average value of the catch from the Estuary General Fishery is estimated to be worth approximately $18.1 million annually[9] (see Chapter G for further information). This revenue for the fishery provides an important source of employment for fishers and has multiplier effects in regional communities. Economic multipliers in the fishing industry are, however, low and total effects are generally between 1.5 and 2 times the direct effect (Tamblyn and Powell, 1988; Powell *et al*., 1989).

The economic survey conducted during the preparation of this EIS and other studies conducted on the expenditure of fishers in NSW (see McVeery, 1996) have shown that 27% of fishing business expenditures move outside the region of operation, leaving approximately 70% of the first sale value of catch within the communities where fishing takes place. This translates to approximately $12.7 million of fishing revenue generated from the Estuary General Fishery that is potentially spent in the local regions. These economic benefits would be forgone if the Estuary General Fishery failed to exist.

[9] Based on average Sydney Fish Market price, and does not include higher prices received for product sold to other markets (eg. locally) or exported from Australia

2. Sensitivity Analysis

Based on the discussion and logic presented in Chapter D in relation to alternative management strategies, it is apparent that there are few high level feasible and economically viable or appropriate alternatives to the suite of controls proposed in the draft FMS. Therefore, the sensitivity analysis focusses on the 97 proposed management responses in Chapter C section 4.

The alternative management regimes discussed in Chapter D to address each of the key management issues typically involves using one of the responses already proposed in the draft FMS, but to a much greater (or lesser) extent relative to other controls. Consequently, the sensitivities of most of the alternative management regimes are covered in the sensitivity analysis carried out with respect to the management regime proposed in the draft FMS. There are a few exceptions to this and they are discussed at the end of this section.

In each case, a qualitative sensitivity analysis has been undertaken as insufficient quantitative data exists for all three components of ESD: biological, economic costs and benefits, and social (Table I1). The qualitative analysis has been undertaken as proposed in the DUAP guidelines for environmental assessment of commercial fisheries (DUAP, 2001).

In this analysis, the qualitative sensitivity is the relationship between the degree of change in the management responses (the variable) versus the likelihood of achieving the draft FMS goals (the desired outcome) within an ESD framework. In this context, each of the management responses have been assessed in terms of its likelihood in achieving the following target:

The proposed harvest strategy in the estuary general draft FMS aims to manage the fishery in a way that maintains sustainable fish stocks and a healthy ecosystem, while maximising the biological and economic yield and appropriately sharing the resource.

In this sensitivity analysis the linkages between goals and responses which are presented in the draft FMS (in Chapter C section 4) have been incorporated as the cross reference between a specific management response for a goal and the other six goals. That is, in the analysis, Goals 1, 2, 3 and 7 relate to biological considerations, Goals 5, 6 and 7 relate to economic factors and Goals 4, 6 and 7 relate to social factors.

A common mistake in interpreting the analysis in Table I1 is to confound ‘sensitivity’ with the ‘impact’ of the management response on the biophysical, economic and social environment. The clearest way to interpret the table is to remember: “if a little change in the management response causes a big change in the likelihood of achieving the above target, sensitivity is high. If a little change in the management response causes a little change in achieving the target, the sensitivity is low.”

Table I1. Qualitative sensitivity analysis of the proposed FMS management responses.

(H = high sensitivity, M = medium sensitivity, L = low sensitivity, ? = unknown sensitivity, - = not applicable)

Management response*	Biological	Economic	Social
1.1 (a) Increase minimum mesh size of flathead nets from 70mm	M	L	-
1.1 (b) Modify fishing practices to reduce by-catch	H	-	H
1.1 (c) Use best practice handling techniques for incidental catch	L	-	M
1.1 (d) Phase out <95mm set mesh nets between sunrise & sunset	M	-	-
1.1 (e) Reduce max. allowable length of fish hauling nets to 500m	H	-	H
1.1 (f) Introduce scientific observer program	H	L	?
1.1 (g) Continue restrictions on the use and dimensions of fishing gear	M	L	L
1.1 (h) Continue prohibition on use of explosives and electrical devices	H	-	?
1.2 (a) Continue to use fishing closures	H	H	H
1.2 (b) Modify gear use that detrimentally impacts habitat & threatened species	M	-	M
1.2 (c) Develop a code of conduct for the fishery	L	L	H
1.2 (d) Continue prohibition on wilfully damaging marine vegetation	H	-	M
1.3 (a) Improve understanding of ecosystem functioning and fishing impacts	-	?	M
1.3 (b) Contribute to relevant biodiversity monitoring programs	L	L	M
1.3 (c) Conduct risk assessment of fishery impacts on ecosystem components	H	L	L
1.3 (d) Participate in the management of marine protected areas	M	L	H
1.4 (a) Implement measures required for marine pest or disease management	H	M	L
1.4 (b) Continue prohibition on taking noxious fish	M	-	-
1.5 (a) Map key habitat areas for rehabilitation	H	L	M
1.5 (b) Review habitat rehabilitation and conservation research programs	M	L	L
1.5 (c) Review estuarine habitat management and rehabilitation strategies	M	L	L
1.5 (d) Review habitat rehabilitation and research applications	L	L	L
1.5 (e) Nominate priority areas of habitat for protection	M	L	L
1.5 (f) Review role and responsibilities of habitat monitor program	L	L	L
2.1 (a) Limit size and dimensions of gear to those specified in the estuary based	M	M	M
2.1 (b) Monitor commercial landings by estuary	H	L	L
2.1 (c) Promote research that contributes to more robust fish stock assessment	H	L	M
2.1 (d) Continue use of size limits on selected species	M	M	L
2.1 (e) Continue prohibition on taking female crabs carrying ova	H	-	-
2.1 (f) Continue prohibition on the use of unregistered nets	M	L	L
2.1.1 (a) Introduce min. legal length in primary finfish species to 50% mature	H	M	L
2.1.1 (b) Develop and conduct formal stock assessment for primary species	M	L	M
2.1.1 (c) Set maximum level of effort on prawn stocks through the Total Allowable Catch Setting and Review Committee	H	-	L
2.1.2 (a) Monitor catch of adult eels by-catchment	M	L	L
2.1.2 (b) Allocate a max. quantity of glass eels to be taken annually, and monitor	M	-	L
2.1.2 (c) Implement outcomes of 2001 eel harvest review	?	-	?
2.1.3 (a) Monitor catch level of mud crabs in each estuary	M	-	L
2.1.3 (b) Implement outcome of review of trapping endorsement scheme	L	M	M
2.1.3 (c) Consider the feasibility of a tradeable crab trap regime	L	M	L
2.1.4 (a) Monitor total catch of each key secondary species	M	L	M
2.1.4 (b) Monitor catch level of all other secondary species	L	L	M
2.2 (a) Implement a zoning scheme in the fishery	M	-	H
2.2 (b) Implement min. shareholdings to ensure historical active effort levels	H	M	H
2.2 (c) Continue licensing arrangements outlined in proposed harvesting strategy	H	M	M
2.3 (a) Implement an owner-operator rule, except in cases of short term illness	M	M	H
2.3 (b) Establish business level minimum requirements for new entrants	M	M	M
2.3 (c) Continue the prohibition on using unlicensed assistants/crew	H	M	M
2.4 (a) NSW Fisheries to review development applications to minimise impacts	M	L	M

Table I1 (cont).

Management response*	Biological	Economic	Social
2.4 (b) MAC to consider the impacts of activities external to the fishery	L	M	M
2.4 (c) Contribute to development of relevant policies by other govt. agencies	L	L	L
2.5 (a) Develop recovery plan for overfished species if major harvester	H	M	M
2.5 (b) Contribute to development of recovery plan for overfished species if minor harvester	H	M	M
2.5 (c) Implement precautionary actions during development of recovery plan	H	H	M
2.5.1 (a) Contribute to development of recovery plan for silver trevally	H	L	M
2.5.2 (a) Prevent the capture of sea garfish whilst recovery plan is being developed	H	M	M
3.1 (a) Modify catch returns to monitor threatened species interactions	H	L	M
3.1 (b) Implement provisions of threatened species recovery plans or TAPs**	H	L	H
3.1 (c) Continue the prohibition on taking protected fish	H	-	H
4.1 (a) Estimate the size of the non-commercial catch, and impacts	M	L	H
4.1 (b) Continue the requirement to adhere to species trip limits where applicable	M	-	L
4.2 (a) Monitor catch of primary species taken in other commercial fisheries	L	L	L
4.2 (b) Determine an appropriate size at first capture for king and school prawns	M	H	H
4.2 (c) Review the use of garfish hauling and bullringing nets	L	L	L
4.3 (a) Monitor catch of primary & secondary species taken by EG method	M	L	M
4.3 (b) Prohibit shareholders from more holding more than 5% of total shares	-	H	H
4.4 (a) Participate in development and reviews of Indigenous Fisheries Strategy	-	L	H
4.4 (b) Consult the Aboriginal Sites Register when identifying designated landing	-	H	H
4.5 (a) Define and declare recognised fishing grounds	-	L	H
4.5 (b) Continue to administer the Clarence River set pocket net code of conduct	L	L	H
5.2 (a) Use minimum shareholdings to economic viability of fishery	M	H	M
5.2 (b) Develop measure of economic viability at fishing business level	L	M	L
5.2 (c) Develop cost recovery framework	-	M	L
5.3 (a) Implement Category 2 share management regime	-	H	H
5.4 (a) Cooperate in the development of food safety programs	-	H	H
5.4 (b) Prohibit the processing or mutilation of fish on or adjacent to water	L	L	-
6.1 (a) Develop a compliance and advisory strategic plan	M	M	M
6.1 (b) Implement an endorsement suspension and share forfeiture scheme	L	M	H
6.1 (c) Publish successful prosecution results to discourage illegal activity	L	L	H
6.1 (d) Continue the prohibition on interfering with fishing gear set by others	-	L	H
6.1 (e) Continue the requirement to mark all fishing gear	L	L	L
6.1 (f) Continue the requirement to sell fish through registered market	L	M	?
6.2 (a) Continue to use conditions on licences, endorsements and permits	M	L	L
6.2 (b) Continue requirement for fishers to adhere to prawn net determinations	L	L	L
6.2 (c) Continue the requirement to comply with Fisheries Officer directives	-	L	L
6.3 (a) Continue to utilise the MAC as the primary consultative body	-	L	M
6.3 (b) Continue to utilise the services of an independent chair in the MAC	-	L	M
6.3 (c) Establish local joint committees to advise on local arrangements	M	L	L
6.4 (a) Manage the fishery consistently with other programs	H	M	H
6.4 (b) Provide for the issue of s.37 permits for research and other purposes	M	L	M
7.1 (a) Make the FMS, EIS and other documentation widely available to public	L	L	M
7.1 (b) Produce brochures, etc., and use targeted advisory programs	L	L	M
7.1 (c) Respond to industry and public inquiries	L	L	H
7.2 (a) Publish educational information on protection of fish habitat	M	L	H
7.3 (a) Determine priorities for research	M	M	L
7.3 (b) Allocate resources and seek funding in accordance with research priorities	M	M	L
7.4 (a) Periodically review catch returns and implement appropriate changes	H	L	M
7.4 (b) Determine accuracy of species identification in catch records	H	L	L

* The management responses outlined here have been abbreviated for the purpose of completing the table. Please refer to section 4 of Chapter C for the complete wording of each response.
** TAPs = threat abatement programs

The only management response in Table I1 that shows a high sensitivity to all three facets of ESD is the proposal to use fishing closures to: protect key habitat, specifically prohibit the use of all hauling nets over beds of strapweed seagrass (*Posidonia australis*); protect key habitat and reduce bycatch by defining designated landing sites for hauling nets in estuaries where seagrass exists around shoreline areas; reduce bycatch in areas and at times of high abundance of jellyfish or juvenile fish; reduce bycatch by identifying areas of seagrass which should be closed to prawn hauling and prawn seining methods; avoid direct interactions with marine and terrestrial threatened species, populations or ecological communities; harvest fish at a size that maximises economic return; avoid direct interactions with threatened species, populations or ecological communities; and, equitably share the resource between estuary general fishers and other stakeholders; minimise impacts on nesting and/or feeding areas of migratory birds; minimise impacts on sensitive shoreline habitat (see response 1.2a in section 4 of Chapter C).

The sensitivity analysis indicates that fishing closures are a very effective tool for achieving the biological, economic and socially orientated goals in the draft FMS. As an historical aside, the NSW *Fisheries Act 1865*, which was the first Act dealing with fisheries in Australia, used closures as a fisheries management tool. This tool remains one of the most powerful management controls for our estuary fisheries.

There are ten of the 97 management responses which have a low sensitivity across all areas of ESD, mainly relating to very specific issues within the fishery or issues external to the fishery. For example, the responses relating to reviewing the role and responsibilities of the habitat monitor program (1.5f), fishers adhering to Fisheries Officer determinations with respect to prawn nets (6.2b) and the marking of fishing gear (6.1e) have generally low overall sensitivities.

There are several management responses that have a high sensitivity with respect to two facets of ESD, indicating that they are an important part of the overall proposed management strategy. These include:

- modifying fishing practices to reduce bycatch (1.1b)
- reducing the maximum length of fish hauling nets to 500 metres (1.1e)
- implementing minimum shareholdings to ensure that the level of active effort does not exceed historical or sustainable levels (2.2b)
- implementing precautionary actions during the development of a recovery plan for overfished species (2.5c)
- implementing the provisions of any threatened species recovery plans or threat abatement plans (3.1b)
- continue the prohibition on the taking of protected fish, or fish protected from commercial fishing (3.1c)
- through the prawn resource forum, determine an appropriate size at first capture for king and school prawns and modify the use of prawn gear appropriately (4.2b)
- prohibit shareholders from owning more than 5% of the total number of shares issued in the fishery (4.3b)
- consult the Aboriginal Sites Register and Aboriginal Land Councils when identifying designated landing sites (4.4b)

- implement the category 2 share management provisions of the *Fisheries Management Act 1994* (5.3a)
- cooperate in the development and implementation of food safety programs relevant to the fishery (5.4a)
- manage the Estuary General Fishery consistently with other jurisdictional or natural resource management requirement, such as the marine parks program, aquatic biodiversity strategy, threatened species program and others (6.4a).

These programs, along with the use of fishing closures, address each of the four key high risk areas that were identified in an early iteration of this EIS.

The sensitivity of the aspects of the alternative management approaches discussed in Chapter D but not covered in Table I1 are presented in Table I2 below.

Table I2. Qualitative sensitivity analysis of the alternate management controls not already covered in the sensitivity analysis of the draft FMS proposals.

(H = high sensitivity, M = medium sensitivity, L = low sensitivity, ? = unknown sensitivity, - = not applicable)

Alternative management control	Biological	Economic	Social
Introduce a total allowable catch	H	H	M
Reduce commercial fishing subsidies	M	M	?
Limit the species able to be taken	H	M	M
Prohibit non-selective gear	M	M	M
Provide alternative habitats - 'mitigation banking'	M	L	L
Promote stonger reliance on fishery-dependent catch data for stock assessment	M	L	L

The analysis in Table I2 indicates that introducing a total allowable catch would have a high sensitivity with respect to two of the three facets of ESD, and can be quite a powerful management control for the Estuary General Fishery. While this may be the case, the introduction of a total allowable catch for any species in the Estuary General Fishery, based on the reasons outlined in Chapter D, is not considered appropriate at this stage.

The remaining alternative management responses generally have a medium sensitivity and likewise are not recommended over the proposals in the draft FMS.

3. Justification of Measures in Terms of ESD Principles

The impact of the Estuary General Fishery, within the carrying capacity of the estuarine environment, is assessed in the EIS by an analysis of the risks associated with the proposed harvest strategy outlined in section 6 of Chapter C. The risks associated with the draft FMS are partitioned into two components related primarily to (1) the retained species and (2) the ecological impacts of the harvest methods used in this multi-species multi-method fishery on bycatch, threatened and protected species, habitat damage and other associated activities.

The risk of over exploitation at the species level is fully detailed in Chapter E of the EIS and summarised in Table E13 one species was assessed at an unacceptable risk level (silver trevally).

The Estuary General Fishery is primarily managed by using fishing closures and controlling the fishing methods able to be used by endorsement holders. The impact of the various methods used in the Estuary General Fishery on bycatch, threatened and protected species and habitat is fully reviewed and discussed in Chapter E section 2 and Chapter F sections 1 to 9 of this EIS. To summarise all the above data, a qualitative risk assessment of the ecological impact of the major methods has been undertaken, and an evaluation of the ability of the draft FMS to address the known or perceived concerns has been made.

The draft FMS **directly** addresses risks identified for specific methods and is summarised in Table I3 at the objective level, by incorporation of specific management responses, which target the known or estimated impacts. The draft FMS objectives and management responses are presented in section 4 of Chapter C. In addition, except for the handgathering of beachworms and other molluscs, all the methods used in the Estuary General Fishery are **indirectly** addressed by objectives in the draft FMS primarily under Goal 1.

Table I3. Ecological impacts of fishing methods used in the Estuary General Fishery, with overall impact broken down into specific aspects relating to efficiency, bycatch and habitat.

Explanations of ratings within each of the specific aspects are given in the text.

General method	**Specific method (or target species)**	**ECOLOGICAL IMPACT**								
		Efficiency of method (harvest rate)	BYCATCH			HABITAT		OVERALL	Directly addressed by the FMS	Relevant objectives in the FMS
			Overall amount	Charismatic species	Provisioning etc.	Direct damage	Associated activities			
Hauling	Fish hauling	h	h	m	h	h	m	H	Y	1.1-1.4; 2.1.4; 3.1; 6.1; 7.3
	Prawn hauling	h	h	l	h	h	m	H	Y	1.1-1.4; 2.1.4; 3.1; 6.1; 7.3
Passive prawning	Set pocket and prawn running nets	h	m	l	m	l	m	M	Y	1.1-1.4; 2.1.4; 3.1; 6.1; 7.3
Meshing	Set net	h	m	h	h	l	l	H	Y	1.1-1.4; 2.1.4; 3.1; 6.1; 7.3
	Splashing	h	m	m	m	l	l	M	Y	1.1-1.4; 2.1.4; 3.1; 6.1; 7.3
	‘Flathead net’	h	h	h	h	l	l	H	Y	1.1-1.4; 2.1.4; 3.1; 6.1; 7.3
	‘Bullringing’	h	m	l	h	l	l	M	N	
Trapping	Fish trapping	m	l	m	l	l	l	L	N	
	Eel trapping	m	l	m	l	l	l	L	Y	1.1-1.4; 2.1.4; 3.1; 6.1; 7.3
	Crab trapping	m	l	l	m	l	l	L	N	
Handlining	Pelagic species	l	l	l	l	l	l	L	N	
	Bottom species	l	l	m	m	l	l	L	N	
Gathering by hand	Beachworms	m	l	l	l	l	l	L	N	
	Pipis	m	l	l	l	l	l	L	N	
	Other molluscs	m	m	l	l	m	m	L-M	N	

Efficiency of method: Net-based methods (hauling and meshing) are all rated as "high" owing to their ability to capture many hundreds of fish in a single shot. Handlining results in the capture of far fewer fish and has been rated "low". The remaining methods (trapping and handgathering) result in the capture of intermediate numbers of fish (or invertebrates) and have been rated "medium".

Bycatch: Related impacts are split into three categories: "Overall amount", "Charismatic species" and "Provisioning etc.". For "overall amount", each method is rated high, medium or low according to the typical quantities of bycatch taken as a result of that method's use. "Charismatic species" include fish of particular conservation significance, as well as reptiles, birds and mammals: each method is rated according to its potential for the capture of such species. "Provisioning etc." refers to the attraction of scavengers and/or predators to dead or injured discards, as well as associated food web effects: each method is rated according to potential to cause such attraction and its associated effects.

Habitat: Related impacts are split into two categories: "Direct damage", which refers to damage caused by physical contact with fishing gear, and "Associated activities", which refers to habitat damage from activities such as boating, 4WD vehicle use and trampling where they occur in association with the use of a fishing method. For both categories, each method is rated according to the amount of habitat damage likely to result from its use.

A review of the principles of ESD

The preferred rules in the draft FMS which provide for an appropriate allocation of the resource and incorporate the measures necessary to achieve resource sustainability and address the principles of ESD in the following ways.

Precautionary principle

The precautionary principle is defined in the May 1992 *Intergovernmental Agreement on the Environment* as "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" (Deville and Harding, 1997). The introduction of the precautionary principle has, as described by Deville and Harding (1997), shifted the 'onus of proof' regarding impacts away from regulatory bodies and more towards those whose actions may cause damage. Those undertaking the activity are required to provide a convincing argument that their actions will not have serious or irreversible impacts on the environment exceeding long-term benefits.

As recognised in the assessment guidelines under which this EIS was prepared, scientific research into the size and characteristics of fish stocks is inherently complex and costly. Fish populations and the aquatic environment inhabited by them are extremely dynamic. This means that the level of scientific uncertainty associated with fish stocks and aquatic communities is generally very high, especially for species that are of low commercial or recreational value. This situation is by no means unique to NSW or indeed Australian fisheries.

Many of the management rules that have historically operated in the Estuary General Fishery, such as fishing closures and controls on gear use, have been adopted on a precautionary basis to provide an 'insurance policy' against over exploitation. The measures proposed in the draft FMS embrace this approach by continuing the existing controls on fishing and by proposing new initiatives to deal with the uncertainty surrounding the impact of gear types on bycatch and habitat. For example, the proposals to reduce the maximum length of 1,000 metre and 725 metre fish hauling nets to 500 metres, and to modify the use of hauling nets over seagrass areas, are positive precautionary steps that will minimise the impacts (known and presumed) of these gear types on the environment. Additionally, the past and present research programs, and those planned, into the impacts of fishing gear on habitats and bycatch reduction pro-actively address the information deficiencies in those areas.

The performance monitoring system established by the proposed FMS also provides a necessary safeguard in case there are changes in the operation of the fishery or fish stocks which could compromise the long term sustainability of the fishery.

Intragenerational equity

Intragenerational equity relates to distributing the costs and benefits of pursuing ESD strategies as evenly as practicable within each generation.

Intragenerational equity in the context of the Estuary General Fishery is extremely complex, due largely to the multi-species multi-method nature of the fishery but also because the fishery operates in estuary waters often surrounded by high residential populations and a host of other waterway activities. Most of the species retained by the fishery are taken in other commercial fisheries or by other sector groups, such as the recreational fishery. As well as the question of allocation of fish stocks, there are issues relating to the allocation and management of often conflicting user activities within estuaries (i.e. commercial fishing, sailing, water skiing, swimming, etc).

The proposed measures in the draft FMS distribute, as far as practicable, a fair and equitable sharing of the fisheries resource amongst fishers and the community. The operation of the fishery provides fresh local seafood to satisfy an ever increasing consumer demand for seafood. However, gear controls in this fishery limit the catches of endorsed fishers, thus making the fishery resources available to other stakeholders, including other commercial, recreational and Indigenous fishers and conservationists. Fishing closures are also used extensively to share the resource between users by specifying times or places when and where estuary general fishing can occur (eg. many estuaries and/or gear types are subject to fishing closures on weekends).

The draft FMS contains proposals to assess the size of the non-commercial catch so that distribution of the resource with the generation is known, and contains performance measures to monitor and manage the distribution of catches of the retained species throughout time.

Intergenerational equity

Intergenerational equity relates to the present generation ensuring that the health, diversity and productivity of the environment are maintained or enhanced for the benefit of future generations.

In the context of the Estuary General Fishery, intergenerational equity means ensuring that the fishery operates in a manner that minimises the impact of gear use on habitat, bycatch and threatened species, populations and ecological communities, as well as maintaining healthy and viable stock levels of the retained species.

The draft FMS contains seven broad goals which, if realised, will provide future generations with the same or improved opportunities to benefit from the valuable natural resources. Management measures proposed within the draft FMS to achieve the specified goals and hence intergenerational equity include:

- implementation of more secure fishing rights to promote resource stewardship

- fishery restructuring to manage levels of fishing effort on the retained species, and to promote a long term viable fishing industry
- modification of fishing gear and the manner in which the gear is used to minimise any impacts on the general environment (including bycatch and habitat)
- continued use of fishing closures
- introduction of new compliance and advisory programs to deter illegal activity and educate the broader community
- a comprehensive performance monitoring and review program.

Furthermore, future generations will benefit from the data collected through the monitoring programs and future research proposed by the draft FMS. There will also be substantial benefits to future generations from the declaration of a comprehensive, adequate and representative system of marine protected areas (such as marine parks, aquatic reserves and intertidal protected areas) that includes a full range of marine biodiversity at ecosystem, habitat and species levels (Marine Parks Authority, 2000).

Conservation of biodiversity and ecological integrity

This principle incorporates the notion that conservation of biological diversity and ecological integrity should be a fundamental consideration in resource decision making. The draft FMS strongly adopts this principle, with one of the seven major goals being "to manage the Estuary General Fishery in a manner that promotes the conservation of biological diversity in the estuarine environment". There are five objectives beneath that goal which specifically aim to address the following issues:

- minimising the impact of the fishery on bycatch
- minimising the impact of the fishery on marine and terrestrial habitat
- reducing the likelihood of the fishery changing species, populations and ecological communities in a manner that threatens ecosystem integrity (i.e. composition and function)
- preventing the introduction and translocation of marine pests and diseases
- to facilitate the rehabilitation of priority areas of estuarine fish habitat to assist in the long term sustainable management of the fishery.

In order to achieve those goals and objectives, there are numerous management responses in the draft FMS that directly address biodiversity and ecological integrity issues, including modifying the gear permitted in the fishery and the use of gear, establishing a scientific observer program to record actual levels of bycatch and interactions with threatened species, using fishing closures, developing a code of conduct for the fishery, undertaking monitoring and research on ecosystem functioning, providing for industry assistance in determining priority fish habitat areas, and improving marine pest and disease management.

The draft FMS also contains proposals which attempt to monitor the impact of the fishery on biodiversity, such as the number of areas closed to estuary general fishing, bycatch levels and trophic levels of the commercial catch, and mechanisms for taking action if the performance changes to a significant degree.

In conclusion, the proposed FMS contains a comprehensive package of measures for ensuring that the impacts of estuary general fishing on biodiversity are properly managed.

Improved valuation, pricing and incentive mechanisms

This principle relates to the use of schemes like user pays and incentive structures to promote efficiency in achieving environmental goals. The Estuary General Fishery, along with most other marine commercial fisheries in NSW, was proclaimed a category 2 share management fishery on 23 March 2001. This management framework provides for the issue of long term (15 year) shares to eligible fishers and provides for the existence of a market based trading scheme. The share management scheme for the Estuary General Fishery will provide greater incentives for stewardship and long term sustainability of the resource because the value of shares when traded are likely to be linked to potential investors' views about the health of the fishery and the anticipated returns on investment.

The share management regime also provides greater flexibility for shareholders in the fishery to be able to trade shares with each other. This will enable fishers to change the structure of their fishing businesses to minimise the economic and social impacts of the share based restructuring scheme proposed by the draft FMS. It enables fishers to sell shares in the fisheries (or parts of fisheries) that they do not rely on in order to purchase shares in the fisheries (or parts of fisheries) that are most important to their fishing businesses.

The share management scheme incorporates the notion of a user pays system as there is a $100 annual rental charge payable by each shareholder additional to the normal licensing and management fees. Furthermore, the current Government policy is to phase in full cost recovery in the fishery between the years 2005 and 2008.

CHAPTER J. REFERENCES

Articles that have not been externally peer reviewed and published in a journal or book are denoted *

*ABS (1996). Housing and Population Census Results. Australian Bureau of Statistics.

Acosta, A.R. (1994). Soak time and net length effects on catch rates of entangling nets in coral reef areas. *Fisheries Research* **19**, 105-119.

*Adam, P., Urwin, N., Weiner, P. and Sim, I. (1985). Coastal Wetlands of New South Wales. A survey and report prepared for the Coastal Council of New South Wales.

Adam, P., Wilson, N.C. and Huntley, B. (1988). The phytosociology of coastal saltmarsh vegetation in New South Wales. *Wetlands (Australia)* **7(2)**, 35-85.

*AFFA (1999) AQUAPLAN – Australia's National Strategic Plan for Aquatic Animal Health 1998-2003. Agriculture, Forestry, Fisheries, Australia, Canberra ACT. 72 pp.

*AFFA (2000) Report of the National Taskforce on the Prevention and Management of Marine Pest Incursions. Environment Australia/Agriculture, Forestry, Fisheries, Australia, Canberra ACT. 231 pp.

*AFFA (2001) AQIS tightens prawn import controls. Agriculture, Forestry, Fisheries, Australia, Canberra, February 2001, [http://www.affa.gov.au:80/docs/quarantine/bulletin/ab0201_2.htm]

Alabaster, J.S. and Lloyd, R. (1980). *Water Quality Criteria for Freshwater Fish.* Butterworths, London. 297 pp.

*Allen, J., Harris, J. and McEnally, J. (1992a). Coastal Resource Atlas for oil spills from Point Danger to the Clarence River. Environment Protection Authority, Sydney, 107 pp.

*Allen, J., Harris, J., McEnally, J. and Zekanovic, I. (1992b). Coastal Resource Atlas for oil spills in Broken Bay, Pittwater and the Hawkesbury River. Environment Protection Authority, Sydney, 58 pp.

Alverson, D.L., Freeberg, M.H., Murawski, S.A. and Pope, J.G. (1994). A global assessment of fisheries bycatch and discards. *FAO Fisheries Technical Paper* No. 339. 233 pp.

*Andrew, N.L., Jones, T. and Terry, C (1994). A review and evaluation of the set pocket net prawn fishery in NSW. Project 89/15 FRDC Final Report. 86 pp.

Andrew, N.L., Jones, T., Terry, C. and Pratt, R. (1995). Bycatch of an Australian stow net fishery for school prawns (*Metapenaeus macleayi*). *Fisheries Research* **22**, 119-136.

*Andrew, N.L., Worthington, D., Chick, R., Brett, P. and Avery, R. (1996). An assessment of the NSW abalone, sea urchin and turban fishery for 1995. NSW Fisheries, Fisheries Research Institute, Cronulla. 65 pp plus appendices.

*Anon. (1880). Fisheries Inquiry Commission - Minutes of Evidence, Friday, 30 January 1880. notation 2773-2982.

*Anon. (1981). Amateur angling in Botany Bay. Botany Bay Study No. 24. SPCC and NSW State Fisheries.

*Anon. (1999). National Policy on fisheries bycatch. Department of Agriculture, Fisheries and Forestry – Australia. Fisheries and Aquaculture Branch. 14 pp.

*Anon. (2000). National strategy for the Management of Coastal Acid Sulfate Soils. NSW Agriculture Wollongbar Agriculture Institute Bruxner Highway, Wollongbar, NSW, Australia. 39 pp.

*Anon. (2001). Age & weight of NSW finfish. In: *Fisheries New South Wales*. Spring 2000/ Summer 2001 (ed. Smith, D.) pp. 26-27.

*ANZECC (1998) Interim marine and coastal regionalisation for Australia: an ecosystem based classification for marine and coastal environments. Version 3.3, IMCRA Technical Group, Environment Australia, Commonwealth Department of the Environment, ACT. 104 pp.

*ANZECC (1999). Strategic plan of action for the national representative system of Marine Protected Areas: a guide for action by Australian Governments. Environment Australia, Canberra. 80 pp.

*Astles, K.L., Winstanley, R.K., Harris, J.H. and Gehrke, P.C. (2000). Regulated Rivers and Fisheries Restoration Project – Part 1: Experimental study of the effects of cold water pollution on native fish. Unpublished Report, Project No. SW 1. NSW Fisheries Office of Conservation and CRC for Freshwater Ecology, Taylors Beach NSW. 51 pp.

*Australian Greenhouse Office (2001). Factors and methodologies, the greenhouse challenge. Commonwealth of Australia, Canberra.

*Bannister, J.L., Kemper, C.M. and Warneke, R.M. (1996). The action plan for Australian cetaceans. Australian Nature Conservation Agency.

Barnes, R.D. (1980). *Invertebrate Zoology*. 4th Edition. Holt-Saunders Japan. 1089 pp.

*Begg, G. (1991). Comparison of the juvenile fish fauna between an estuary (Lake Macquarie, New South Wales) and its backwaters. Unpublished B.Sc. (Hons.) Thesis. University of NSW.

*Bell, F.C. and Edwards, A.R. (1980). An environmental inventory of estuaries and coastal lagoons in New South Wales. Total Environment Centre, Sydney. 187 pp.

Bell, J.D., Pollard, D.A., Burchmore, J.J., Pease, B.C., and Middleton, M.J. (1984) Structure of a fish community in a temperate tidal mangrove creek in Botany Bay, New South Wales. *Australian Journal of Marine and Freshwater Research* **35 (1)**, 33-46.

Bell, J.D. and Pollard, D.A. (1989). Ecology of fish assemblages and fisheries associated with seagrasses. In: *Biology of Seagrasses* (eds. Larkum, A.W.D., McComb, A.J. and Shepherd, S.A.) pp. 565-609. Elsevier, Amsterdam.

Bell, J.D., Steffe, A.S. and Westoby, M. (1988). Location of seagrass beds in estuaries: effect on associated fish and decapods. *Journal of Experimental Marine Biology and Ecology* **122**, 127-146.

Birch, G.F. (1996). Sediment-bound metallic contaminants in Sydney's estuaries and adjacent offshore, Australia. *Estuarine, Coastal and Shelf Science* **42**, 31-44.

Birch, G.F., Evenden, D. and Teutsch, M.E. (1996). Dominance of point source in heavy metal distributions in sediments of a major Sydney estuary (Australia). *Environmental Geology* **28(4)**, 169-174.

Birch, G.F., Ingleton, T. and Taylor, S. (1997). Environmental implications of dredging in the world's second largest coal exporting harbour, Port Hunter, Australia. *Journal of Marine Environmental Engineering* **4**, 133-145.

Birch, G.F., Shotter, N. and Steetsel, P. (in press). The environmental status of Hawkesbury River sediments. *Australian Geographical Studies*.

Blaber, S.J.M. and Blaber, T.G. (1980). Factors affecting the distribution of juvenile estuarine and inshore fish. *Journal of Fish Biology* **17**, 143-162.

Blaber, S.J.M., Brewer, D.T., Salini, J.P. and Kerr, J. (1990). Biomasses, catch rates and abundances of demersal fishes, particularly predators of prawns, in a tropical bay in the Gulf of Carpentaria, Australia. *Marine Biology* **107(3)**, 397-408.

Blaber, S.J.M., Milton, D.A., Smith, G.C., and Farmer, M.J. (1995). Trawl discards in the diets of tropical seabirds of the northern Great Barrier Reef, Australia. *Marine Ecology Progress Series* **127**, 1-13.

Blaber, S.J.M. and Wassenberg, T.J. (1989). Feeding ecology of the piscivorous birds *Phalacrocorax varius*, *P. melanoleucos* and *Sterna bergii* in Moreton Bay, Australia: Diets and dependence on trawler discards. *Marine Biology* **101(1)**, 1-10.

Borowitzka, M.A.B. and Lethebridge, R.L. (1989). Seagrass epiphytes. In: *Biology of Seagrasses* (eds. Larkum, A.W.D., McComb, A.J. and Shepherd, S.A.) pp. 458-499. Elsevier, Amsterdam.

Brewer, D.T., Blaber, S.J.M. and Salini, J.P. (1991). Predation on penaeid prawns by fishes in Albatross Bay, Gulf of Carpentaria. *Marine Biology* **109**, 231-240.

Broadhurst, M.K, Kennelly, S.J. and Barker, D.T. (1997). Simulated escape of juvenile sand whiting (*Sillago ciliata*, Cuvier) through square-meshes: Effects of scale-loss and survival. *Fisheries Research* **32**, 51-60.

Broadhurst, M.K. (1998). Bottlenose dolphins, *Tursiops truncatus*, removing bycatch from prawn-trawl codends during fishing in New South Wales, Australia. *Marine Fisheries Review* **60 (3)**, 9-14.

Broadhurst, M.K., Barker, D.T. and Kennelly, S.J. (1999). Scale-loss and survival of juvenile yellowfin bream, *Acanthopagrus australis*, after simulated escape from a Nordmore-grid guiding panel and release from capture by hook and line. *Bulletin of Marine Science* **64 (2)**, 255-268.

Brothers, N. (1991). Albatross mortality and associated bait loss in the Japanese longline fishery in the Southern Ocean. *Biological Conservation* **55**, 255-268.

Bucher, D. and Saenger, P. (1991). An inventory of Australian estuaries and enclosed marine waters: an overview of results. *Australian Geographical Studies* **29 (2)**, 370-381.

Burchmore, J.J., Pollard, D.A, Bell, J.D., Middleton, M.J., Pease, B.C. and Matthews, J. (1985). An ecological comparison of artificial and natural rocky reef fish communities in Botany Bay, New South Wales, Australia. *Bulletin of Marine Science* **37(1)**, 70-85.

*Bureau of Resource Science (2000). Aquatic Pests and Diseases. Bureau of Rural Sciences, Agriculture, Forestry and Fisheries, Australia, [http://www.brs.gov.au:80/fish/status99 /aquatic.html}. June 2000.

Butler, A. (1995). Subtidal rocky reefs. In: *Coastal Marine Ecology of Temperate Australia*, Ch. 6 (eds. Underwood, A.J. and M.G. Chapman) pp. 83-105. UNSW press.

Callinan, R.B., Fraser, G.C. and Virgona, J.L. (1989). Pathology of red spot disease in sea mullet, *Mugil cephalus* L. from eastern Australia. *Journal of Fish Diseases* **12**, 467-479.

Callinan, R.B., Fraser, G.C. and Melville, M.D. (1993). Seasonally recurrent fish mortalities and ulcerative disease outbreaks associated with acid sulphate soils in Australian estuaries. In: Selected papers from the Ho Chi Minh City Symposium on acid sulphate soils (eds. Dent, D. L. and van Mensvoort, M.E.F.) pp. 403-410. ILRI Publication No. 53.

Callinan, R.B., Paclibare, J.O., Bondab-Reantaso, M.G., Chin, J.C. and Gogolewski, R.P. (1995a). *Aphanomyces* species associated with epizootic ulcerative syndrome (EUS) in the Philippines and red spot disease (RSD) in Australia: preliminary comparative studies. *Diseases of Aquatic Organisms* **21**, 233-238.

Callinan, R.B., Paclibare, J.O., Reantaso, M.B., Lumanlan-Mayo, S.C., Fraser, G.C. and Sammut, J. (1995b). EUS outbrakes in estuarine fish in Australia and the Phillipines: associations with acid sulphate soils, rainfall and *Aphanomyces*. In: *Diseases in Asian Aquaculture II* (eds. Shariff, M.A., Arthur, J.R. and Subasinghe, R.P.) pp. 291-298. Asian Fisheries Society, Manilla.

Campbell, D., Brown, D., Battaglene, T. (1999). Individual transferable catch quotas: Australian experience in the southern bluefin tuna fishery. *Marine Policy* **24** (2000), 109-117.

Campbell, HF and RB Nicholl (1994). The economics of the Japanese tuna fleet. In: *The Economics of PNGs Tuna Fisheries* (eds. Campbell, H. and Owen, A). ACIAR monograph No. 28.

*Cappo, M., Alongi, D.M., Williams, D.M and Duke, N. (1997). A review and synthesis of Australian fisheries habitat research. Major threats, issues, and gaps in knowledge of marine and coastal fisheries habitats - a prospectus of opportunities for the FRDC. FRDC Project 95/055 Final Report. AIMS, Townsville, Queensland.

*Cappo, M., Alongi, D.M., Williams, D.M. and Duke, N. (1998). A review and synthesis of Australian fisheries habitat research. FRDC Project No. 95/055. AIMS, Townsville, Queensland. 3 Vol.

*Carter, S. (1994). Coastal Resource Atlas for Oil Spills from Barrenjoey Head to Bellambi Point. Environment Protection Authority, Sydney. 78 pp.

*Carter, S. (1994). Coastal Resource Atlas for Oil Spills in Port Jackson. Environment Protection Authority, Sydney. 39 pp.

*Carter, S. (1995). Coastal Resource Atlas for Oil Spills from Bass Point to Wheelers Point. Environment Protection Authority, Sydney. 50 pp.

*Carter, S. (1995). Coastal Resource Atlas for Oil Spills from Crowdy Head to Port Stephens. Environment Protection Authority, Sydney. 87 pp.

*Carter, S. (1995). Coastal Resource Atlas for Oil Spills from Redhead Point to Cape Three Points. Environment Protection Authority, Sydney. 49 pp.

*Carter, S. (1995). Coastal Resource Atlas for Oil Spills from St Georges Head to Cape Dromedary. Environment Protection Authority, Sydney. 80 pp.

*Carter, S. (1995). Coastal Resource Atlas for Oil Spills from Trial Bay to Crowdy Head. Environment Protection Authority, Sydney. 73 pp.

*Carter, S. (1995). Coastal Resource Atlas for Oil Spills in Brisbane Waters. Environment Protection Authority, Sydney. 33 pp.

Castilla, J.C. (2000) Roles of experimental marine ecology in coastal management and conservation. *Journal of Experimental Marine Biology and Ecology* **250**, 3-21.

Catterall, C.P. and Poiner, I.R. (1987). The potential impact of human gathering on shellfish populations, with reference to some N.E. Australian intertidal flats. *Oikos* **50**, 114-122.

*Chapman, M.G. and Blockley, D. (1999). Intertidal assemblages on seawalls at Berry Island and Blues Point before and after the oil spill, August 1999. Uncommissioned Report for the NSW Environment Protection Authority.

Chapman, M.G. and Underwood, A.J. (1995). Mangrove forests. In: *Coastal Marine Ecology of Temperate Australia* (eds. Underwood, A.J. and Chapman, M.G) pp. 187-204. UNSW Press.

Chopin, F.S. and Arimoto, T. (1995). The condition of fish escaping from fishing gears – a review. *Fisheries Research* **21**, 315-327.

Christy, F. (2000). Common property rights: An alternative to ITQs. In: Use of property rights in fisheries management (ed. Shotton, R.). Proceedings of the Fishrights99 Conference. Fremantle, Western Australia, 11-19 November 1999. Mini-course lectures and core conference presentations. *FAO Fisheries Technical Paper*. No. 404/1. Rome, FAO. 342 pp.

Churchill, J.H. Wirick, C.D., Flagg, D.N. and Pietrafesa, L.J. (1994). Sediment resuspension over the continental shelf east of the Delmarva Peninsula. *Deep Sea Research, Part II-Tropical Studies in Oceanography* **41**, 241-363.

Coleman, M.A. and Connell, S.D. (2001). Weak effects of epibiota on the abundances of fishes associated with pier pilings in Sydney Harbour. *Environmental Biology of Fishes* **61**, 231-239.

Connell, S.D. and Glasby, T.M. (1999). Do urban structures influence local abundance and diversity of subtidal epibiota? A case study from Sydney Harbour, Australia. *Marine Environmental Research* **47**, 373-387.

Connolly, R.M. (1994). A comparison of fish assemblages from seagrass and unvegetated areas of a southern Australian estuary. *Australian Journal of Marine and Freshwater Research* **45**, 1033-1044.

Connolly, R.M., Dalton, A. and Bass, D.A. (1997). Fish use of an inundated saltmarsh flat in a temperate Australian estuary. *Australian Journal of Ecology* **22**, 222-226.

*CRIMP (2000a). Vessel and Gear Fouling. CRIMP Infosheet 3, Centre for Research on Introduced Marine Pests, CSIRO, Hobart. 2 pp.

*CRIMP (2000b). Aquarium Caulerpa (*Caulerpa taxifolia*). CRIMP Infosheet 13, Centre for Research on Introduced Marine Pests, CSIRO, Hobart. 1 pp.

*CRIMP (2000c). Japanese Seaweed (*Undaria pinnatifida*). CRIMP Infosheet 12, Centre for Research on Introduced Marine Pests, CSIRO, Hobart. 1 pp.

*CRIMP (2000d). Northern Pacific Seastar (*Asterias amurensis*). CRIMP Infosheet 4, Centre for Research on Introduced Marine Pests, CSIRO, Hobart. 1 pp.

*CRIMP (2001a). Black-striped Mussel (*Mytilopsis sallei*). CRIMP Infosheet 10, Centre for Research on Introduced Marine Pests, CSIRO, Hobart. 1 pp.

*CRIMP (2001b). Broccoli Weed (*Codium fragile ssp. tomentosoides*). CRIMP Infosheet 14, Centre for Research on Introduced Marine Pests, CSIRO, Hobart. 1 pp.

Cryer M., Whittles, G.N. and Williams, R. (1987). The impact of bait collection by anglers on marine invertebrates. *Biological Conservation* **42**, 83-93.

*CSIRO (1994). Jervis Bay Baseline Studies, Volume 2. CSIRO Division of Fisheries, Commonwealth of Australia. 406 pp.

Dame, R., Alber, M., Allen, D., Mallin, M. Montague, C., Lewitus, A., Chalmers, A., Gardner, R., Gilman, C., Kjerfve, B. and Pinckney, J. (2000). Estuaries of the South Atlantic coast of North America: their geographical signatures. *Estuaries* **23**, 793-819.

Das, P., Marchesiello, P. and Middleton, J.H. (2000). Numerical modelling of tide-induced residual circulation in Sydney Harbour. *Marine and Freshwater Research* **51**, 97-112.

Day, J.H. (1980). What is an estuary. *South African Journal of Science* **76**, 198.

Day, J.H., Blaber, S.J.M., and Wallace, J.H. (1981). Estuarine fishes. In: *Estuarine Ecology with Particular Reference to Southern Africa* (eds. Day, J.H. and Balkema, A.A.) pp. 197-221. Rotterdam.

Dayton, P.K., Thrush, S.F., Agardi, M.T. and Hofman, R.J. (1995). Viewpoint: Environmental effects of fishing. *Aquatic Conservation: Marine and Freshwater Ecosystems* **5**, 205-232.

Deville, A. and Harding, R. (1997). *Applying the Precautionary Principle*. The Federation Press, Sydney. 79 pp.

*DNRE (2000). Marine pests in local ports. Pamphlet. Department of Natural Resources and The Environment, Victoria. 2 pp.

*DUAP (2001). Guidelines for the Environmental Impact Assessment of Draft Fishery Management Strategies for Commercial Designated Fishing Activities. Department of Urban Affairs and Planning, 6 June 2001. 31 pp.

Eisenbud, R. (1985). Problems and prospects for the pelagic driftnet. *Environmental Affairs* **12**, 473-490.

Eliot, I., Finlayson, C. M. and Waterman, P. (1999). Predicted climate changes, sea-level rise and wetland management in Australian wet-dry tropics. *Wetlands Ecology and Management* **7**, 63-81.

Engel, J. and Kvitek, R. (1998). Effects of Otter Trawling on a Benthic Community in Monterey Bay National Marine Sanctuary. *Conservation Biology* **12(6)**, 1204-1214.

*Environment Australia (undated). Threat Abatement Plan for the Incidental Catch (or bycatch) of Seabirds During Oceanic Longline Fishing Operations. Environment Australia, Canberra, ACT. 61 pp.

*Environment Australia (1998). Draft recovery plan for marine turtles in Australia. Environment Australia, Canberra. 107 pp.

*Environment Australia (2000a). Draft recovery plan for grey nurse sharks *Carcharias taurus* in Australia.

*Environment Australia (2000b). Draft recovery plan for great white sharks *Carcharodon carcharias* in Australia.

Erichsen Jones, J.R. (1969). *Fish and River Pollution*. Butterworths, London. 203 pp.

Fagan, P., Miskiewicz, A.G. and Tate, P.M. (1992). An approach to monitoring sewage outfalls: a case study on the Sydney deepwater sewage outfalls. *Marine Pollution Bulletin* **25(5-8)**, 172-180.

Fairweather, P.G. (1990). Ecological changes due to the use of the coast: research needs verses effort. *Proceedings of the Ecological Society of Australia* **16**, 71-77.

*Faragher, R.A. (1995). A survey of the threatened fish, Australian grayling *Prototroctes maraena* Gunther: distribution and abundance in New South Wales. Report prepared for the Cooperative Research Centre for Freshwater Ecology, NSW Fisheries Research Institute, Cronulla, NSW.

*Fenton, M. and Marshall, N. (2001). A Guide to the Fishers of Queensland (Draft report). CRC Reef Research Centre, James Cook University, Townsville, Queensland.

*Ferrell, D. and Sumpton, W. (1997). Assessment of the fishery for snapper (*Pagrus auratus*) in Queensland and New South Wales. Fisheries Research and Development Corporation report No. 93/074. NSW Fisheries and Queensland Department of Primary Industries. 143 pp.

Ferrell, D.J. and Bell, J.D. (1991). Differences among assemblages of fish associated with *Zostera capricorni* and bare sand over a large spatial scale. *Marine Ecology Progress Series* **72**, 15-24.

Fitzpatrick, J. and Kirkman, H. (1995). Effects of prolonged shading stress on growth and survival of seagrass *Posidonia australis* in Jervis Bay, New South Wales, Australia. *Marine Ecology Progress Series* **127**, 279-289.

*Fletcher, W.J., Jones, B., Pearce, A.F. and Hosja, W. (1997). Environmental and biological aspects of the mass mortality of pilchards (Autumn 1995) in Western Australia. Fisheries Western Australia, Fisheries Research Report No. 106. 111 pp.

Fogarty, M.J. and Murawski, S.A. (1998). Large-scale sidturbance and the structure of marine systems: fishery impacts on Georges Bank. *Ecological Applications* **8**, S6-S22.

Fonseca, M.S., Fisher, J.S., Zieman, J.C. and Thayer, G.W. (1982). Influence of the seagrass *Zostera marina* L., on current flow. *Estuarine and Coastal Shelf Science* **15**, 357-364.

Fonseca, M.S., Thayer, G.W. and Kenworthy, W. (1985). The use of the ecological data in the implementation and management of seagrass restorations. In: Proceedings of the symposium on subtropical – tropical seagrasses of the southeastern United States. pp. 175-188.

*Frances, J. (2001). Identification of Candidate Sites for Estuarine Aquatic Reserves in the Hawkesbury and Batemans Shelf Bioregions. Report prepared for Environment Australia by the Office of Conservation, NSW Fisheries, Sydney. 126 pp.

Francis, R.I.C.C. and Shotton, R. (1997). *"Risk" in Fisheries Management: a Review*. pp. 1699-1715.

*FRDC (2000). Retail Sale and Consumption of Seafood, Fisheries Research and Development Corporation, Canberra.

*FRDC (2001). Investing for Tomorrow's Fish: the FRDC's Research and Development Plan, 2000 to 2005. Fisheries Research and Development Corporation, Canberra.

*Friedlander, J.C. (1980). A study of the community in the *Zostera capricorni* beds of Myuna Bay, in Lake Macquarie, New South Wales. M.Sc. Thesis. University of NSW, Sydney. 212 pp.

*Furlani, D. (1996). A guide to the introduced marine pests in Australian waters. Technical Report Number 5. Centre for Research on Introduced Marine Pests, June 1996, CSIRO.

*Gaughan, D.J., Mitchell, R.W., Blight, S.J. (2000). Impact of mortality, possibly due to herpesvirus, on pilchard *Sardinops sagax* stocks along the south coast of Western Australia in 1998-99. Reserarch Division, Fisheries WA, Western Australian Marine Research Laboratories. pp. 601-612.

*Gehrke, P.C., Growns, I.O. and Astles, K.L. (1996). A comparison of fish communities associated with grassed and well vegetated river banks in the Hawkesbury-Nepean River, NSW. In: *Fish and Fisheries of the Hawkesbury-Nepean River System*, Ch 9 (eds. Gehrke, P.C. and Harris, J.H.) pp. 145-170. Final report to the Sydney Water Corporation, July 1996. NSW Fisheries, Fisheries Research Institute, Sydney, and Cooperative Research Centre for Freshwater Ecology.

*Gibbs, P. (1997). A review of information on NSW South Coast estuarine fisheries. NSW Fisheries Research Institute. Cronulla. 74 pp.

*Gibbs, P.J. (1987). Five New South Wales barrier lagoons: Their macrobenthic fauna and seagrass communities. Ph.D. Thesis. University of NSW. 177 pp.

*Gibbs, P., McVea, T. and Louden, B. (1999). Utilisation of restored wetlands by fish and invertebrates. FRDC Project No. 95/150. NSW Fisheries Office of Conservation, Pyrmont, Australia.

Gill, A.C. and Reader, S.E. (1992). Fishes. In: Reef Biology. A Survey of Elizabeth and Middleton Reefs, South Pacific, by the Australian Museum. *Kowari* **3**, 90-92. ANPWS, Canberra.

Gillanders, B. (1999). Blue groper. In: *Under Southern Seas: The Ecology of Australia's Rocky Reefs*, Ch 22 (ed. Andrew, N.) pp. 188-193. UNSW press.

Glaister, J.P. (1978). Impact of river discharge on distribution and production of the school prawn *Metapenaeus macleayi* (Haswell) (Crustacea: Penaeidae) in the Clarence river region, northern New South Wales. *Australian Journal of Marine and Freshwater Research* **29**, 311-323.

Glaister, J.P., Montgomery, S.S. and McDonnal, V.C. (1990). Yield-per-recruit analysis of eastern king prawns *Penaeus plebejus* Hess, in eastern Australia. *Australian Journal of Marine and Freshwater Research* **41 (1)**, 175-197.

Glasby, T.M. (1999). Differences between subtidal epibiota on pier pilings and rocky reefs at marinas in Sydney, Australia. *Estuarine, Coastal and Shelf Science* **48**, 281-290.

Gordon, G.N.G., Andrew, A.L. and Montgomery, S.S. (1995). A deterministic compartmentalised model for the eastern king prawn, Penaeus plebejus (Hess). *Australian Journal of Marine and Freshwater Research* **46**, 793-807.

*Goulstone, A. (1996). Fisheries Management Techniques. Fishnote DF 61. NSW Fisheries, March 1996.

Gray, C.A. (2001). Catch composition and relative selectivity of commercial gill nets set overnight in New South Wales estuaries. *Fisheries Research*. In press.

Gray, C.A., Gale, V.J., Stringfellow, S.L., and Raines, L.P. (in review a). Variations in sex, length and age compositions of commercial catches of *Platycephalus fuscus* (Pisces: Platycephalidae). Submitted to *Fisheries Research*.

Gray, C.A., Gale, V.J. and Raines, L.P. (in review b). An initial assessment of the yellowfin bream (*Acanthopagrus australis*) stock and fishery in NSW. NSW Fisheries Resource Assessment Series.

Gray, C.A., Kennelly, S.J., Hodgson, K.E, Ashby, C.J.T. and Beatson, M.L. (2001). Retained and discarded catches from commercial beach-seining in Botany Bay, Australia. *Fisheries Research* **50**, 205-219.

Gray, C.A., Larsen, R.B. and Kennelly, S.J. (2000). Use of transparent netting to improve size selectivity and reduce bycatch in fish seine nets. *Fisheries Research* **45**, 155-166.

Gray, C.A., McDonall, V.C. and Reid, D.D. (1990). Bycatch from prawn trawling in the Hawkesbury River, New South Wales: species composition, distribution and abundance. *Australian Journal of Marine and Freshwater Research* **41**, 13-26.

Gray, C.A., McElligott, D.J. and Chick, R.C. (1996). Intra- and inter-estuary difference in assemblages of fishes associated with shallow seagrass and bare sand. *Journal of Marine and Freshwater Research* **47**, 723-735.

*Gray, C.A., Pease, B.C., Stringfellow, S.L., Raines, L.P., Rankin, B.K. and Walford, T.R. (2000). Sampling estuarine fish species for stock assessment. FRDC Project No. 94/042. NSW Fisheries Final Report Series No. 18. 194 pp.

Greenstreet, S.P.R. and Hall, S.J. (1996). Fishing and the ground-fish assemblage structure in the north-western North Sea: an analysis of long-term and spatial trends. *Journal of Animal Ecology* **65**, 577-598.

Greboval, D. and Munro, G. (1999). Overcapitalization and excess fishing capacity in world fisheries: Underlying economics and methods of control. In: Managing fishing capacity: selected papers on underlying concepts and issues (ed. Greboval, D.). *FAO Fisheries Technical Paper*. No.386. Rome, FAO. 206 pp.

*Grey, D. (2001). Invasive weed prompts response actions. *Fisheries New South Wales*, Spring 2000/Summer 2001 edition, pp. 4-5.

*Grey, D.L., Dall, W. and Baker, A. (1983). A guide to the Australian penaeid prawns. Northern Territory Department of Primary Production. 140 pp.

Griffin, D.A., Thompson, P.A., Bax, N.J., Bradford, R.W. and Hallegraeff, G.M. (1997). The 1995 mass mortality of pilchards: no role found for physical or biological oceanographical factors in Australia. *Marine and Freshwater Research* **48**, 27-42.

*Growns, I.O., Pollard, D.A. and Gehrke, P.C. (1996). A comparison of fish communities associated with degraded and well-vegetated river banks, above and within nutrient enriched areas of the Hawkesbury-Nepean River, NSW. In: *Fish and Fisheries of the Hawkesbury-Nepean River System*, Ch 8 (eds. Gehrke, P.C. and Harris, J.H.) pp. 122-144. Final report to the Sydney Water Corporation, July 1996. NSW Fisheries, Fisheries Research Institute, Sydney, and Cooperative Research Centre for Freshwater Ecology.

*Hair, C.A. and Bell, J.D. (1992). Jervis Bay marine ecology study: enhancing the settlement of fish to artificial structures. Final Report, December 1992. Fisheries Research Institute, NSW Fisheries, Cronulla. 67 pp.

Hall, M.A., Alverson, D.L. and Metuzals, K.I. (2000). Bycatch: Problems and Solutions. *Marine Pollution Bulletin* **41** (1-6), 204-219.

Hall, S.J. (1999). *The Effects of Fishing on Marine Ecosystems and Communities*. Fish Biology and Aquatic Resources Series 1. Blackwell Science. 274 pp.

*Hamer, G. (1986). Abalone biology and management. Agfact F1.0.1, 1st edition. Department of Agriculture New South Wales, Division of Fisheries, Sydney. 6 pp.

Hamley, J.M. (1975). Review of gillnet selectivity. *Journal of the Fisheries Research Board of Canada* **32**, 1943-1969.

Handmer, J (1995). Risk and uncertainty in environmental management. In: Fenner Conference on the Environment (eds. Norton, T.W., Beer T. and Dovers S.R.) pp. 86-171. Australian Academy of Science, Nov 1995, Canberra.

*Hannan, J. (1985). A comparison of shallow water fish faunae in Mannering Hole and nearby Lake Macquarie (New South Wales). B.Sc. (Hons.) Thesis. University of NSW, Sydney. 111 pp.

*Hannan, J. (1989). The seagrass fish fauna of Lake Macquarie, New South Wales. M.Sc. Thesis. University of NSW, Sydney. 49 pp. plus figures and tables.

*Hannan, J. and Simpson, A. (1999). Scarred Seagrass. *Fisheries NSW* **2(4)** Spring 1999, 32.

*Hannan, J.C. (1997). A status report on the key fish habitats in the Hawkesbury-Nepean Catchment. NSW Fisheries, Sydney. 68 pp.

*Hannan, J.C. (In. prep). Policy and guidelines for jetties, ramps, pontoons and similar foreshore structures. NSW Fisheries.

Hannan, J.C. and Williams, R.J. (1998). Recruitment of juvenile marine fishes to seagrass habitat in a temperate Australian estuary. *Estuaries* **21(1)**, 29-51.

Harden Jones, F.R. (1994). Fisheries Ecological Sustainable Development: Terms and Concepts, IASOS, University of Tasmania.

Harding, R. (1998). *Environmental Decision-making: the Roles of Scientists, Engineers and the Public*. Federation Press. 366 pp.

Harlin, M.M. (1975). Epiphyte-host relations in seagrass communities. *Aquatic Botany* **1**, 125-131.

Harrigan, K.E. (1992). Causes of mortality of little penguins *Eudyptula minor* in Victoria. *Emu* **91(5)**, 273-277.

Harris, J.H. (1984). Impoundment of coastal drainages of south-eastern Australia, and a review of its relevance to fish migrations. *Australian Zoologist* **21(3)**, 235-250.

Harris, J.H. (1986). Reproduction of the Australian bass, *Macquaria novemaculeata* (Perciformes : Percichthyidae), in the Sydney Basin. *Australian Journal of Marine and Freshwater Research* **37**, 209-235.

Harris, A.N. and Poiner, I.R. (1990). Bycatch of the Prawn Fishery of Torres Strait; composition and Partitioning of the Discards into Components that Float or Sink. *Australian Journal of Marine and Freshwater Research* **41**, 37-52.

Hatcher, B.G., Johannes, R.E. and Robertson, A.I. (1989). Review of research relevant to the conservation of shallow tropical marine ecosystems. *Oceanographical Marine Biological Annual Review* **27**, 337-414.

Heemstra, P.C. and Randall, J.E. (1993). FAO Species Catalogue Volume 16 Groupers of the World (family Serranidae, Subfamily Epinephelidae). Food and Agriculture Organisation of the United Nations, Rome. pp. 382.

Hemminga, M.A., Harrison, P.G. and Vanlent, F. (1991). The balance of nutrient losses and gains in seagrass meadows. *Marine Ecology Progress Series* **71**, 85-96.

*Henrisson, C. and Smith, A. (1994). Black rock cod – a protected fish. Fishnote DF/39. NSW Fisheries, Sydney. 2 pp.

*Henry, G.W. (1984). Commercial and recreational fishing in Sydney estuary. *Fisheries Bulletin* No. 1. Department of Agriculture and Fisheries.

*Henry, G.W. (1987). Recreational fishing in Lake Conjola. NSW Fisheries, unpublished report.

*Henry, G.W., Neave, P. and House, R. (1987). A survey of recreational fishing in the Port Hacking estuary. Internal Report No. 40. Department of Agriculture and Fisheries.

*Henry, G.W. and Virgona, J.L. (1980). The impact of Munmorah Power Station on the recreational and commercial finfish fisheries of Tuggerah Lakes. Report prepared for the Electricity Commission by NSW State Fisheries.

*Henry, G.W and Virgona, J.L. (1984). Why is angling so popular ? *Australian Fisheries* **43(5)**, 32-33.

Hickford, M.J.H., Schiel, D.R. and Jones, J.B. (1997). Catch characteristics of commercial gill-nets in a nearshore fishery in central New Zealand. *New Zealand Journal of Marine and Freshwater Research* **31**, 249-259.

Hilborn, R. and Walters, C.J. (1992). *Quantitative Fisheries Stock Assessment: Choice, Dynamics and Uncertainty*. Chapman and Hall, New York. 563 pp.

Hill, B.J. and Wassenberg, T.J. (1990). Fate of discards from prawn trawlers in Torres Strait. *Australian Journal of Marine and Freshwater Research* **41**, 53-64.

Hillman, K., Walker, D.I., McComb, A.J. and Larkum, A.W.D. (1989). Productivity and nutrient availability. In: *Biology of Seagrasses* (eds. Larkum, A.W.D., McComb, A.J. and Shepherd, S.A.) pp. 458-499. Elsevier, Amsterdam.

Hoedt, F.E., Dimmlich, W.E., and Dann, P. (1995). Seasonal variation in the species and size composition of the clupeoid assemblages in Western Port, Victoria. *Marine and Freshwater Research* **46 (7)**.

Howells, G. (1994). *Water Quality for Freshwater Fish: further advisory criteria.* Gordon and Breach Science Publishers. 115 pp.

Hughes, P. and Brundrit, G.B. (1995). Sea level rise and coastal planning: a call for stricter control in river mouths. *Journal of Coastal Research* **11**, 887-898.

Hutchings, P.A. and Recher, H.F. (1974). The fauna of Careel Bay with comments on the ecology of mangrove and seagrass communities. *Australian Zoologist* **18**, 99-128.

Hutchings, P.A. and Saenger, P. (1987). *Ecology of Mangroves*. University of Queensland Press, St Lucia, Queensland.

Hutchins, B. and Swainston, R. (1986). *Sea fishes of southern Australia*. Swainston Publishing, Perth, W.A. 180 pp.

Hyne, R.V. and Wilson, S.P. (1997). Toxicity of acid-sulphate soil leachate and aluminium to the embryos and larvae of Australian Bass (*Macquaria novemaculeata*) in estuarine water. *Environment Pollution* **97**, 221-227.

Ibsen, T. (1999). Sustainable fisheries: the linkage with trade and environment. *Linkages Journal* **4(2)**, 2-4. www.iisd.ca/journal/link0402e.pdf.

Inglis, G.J. (1995). Intertidal muddy shores. In: *Coastal Marine Ecology of Temperate Australia* (eds. Underwood, A.J. and Chapman, M.G.) pp. 171-186. UNSW Press.

*Independent Pricing and Regulatory Tribunal (IPART) (1998). Pricing Principles for Management Charges in NSW Commercial Fisheries – Final Report. Report prepared for the Minister of Fisheries. 63 pp.

Irvine, I. and Birch, G.F. (in press). Distribution of heavy metals in surficial sediments of Port Jackson, Sydney, New South Wales. *Australian Journal of Earth Sciences*.

*IUCN (1995). IUCN Position Statement on Translocation of Living Organisms. International Union for the Conservation of Nature, Gland, Switzerland. 9 pp. [http://www.iucn.org/themes/ssc/pubs/policy/transe.htm]

*JCU (1993). An examination of links between tourism, tourist expectations and the importance of seafood in restaurants of the Cairns region. James Cook University Geography Department. Report for the Queensland Commercial Fishermen's Organisation. 54 pp.

Jennings, S. and Kaiser, M.J. (1998). The Effects of Fishing on Marine Ecosystems. In: *Advances in Marine Biology*, Vol. 34 (eds. Blaxter, J.H.S., Southward, A.J. and Tyler, P.A.) pp. 202-353. Academic Press.

Jones, A.R. (1997). Botany Bay benthos: status and management. *Wetlands (Australia)* **16(1)**, 11-24.

Jones, A.R., Watson-Russell, C.J. and Murray, A. (1986). Spatial patterns in the macrobenthic communities of the Hawkesbury estuary, New South Wales. *Australian Journal of Marine and Freshwater Research* **37**, 521-543.

Jones, G. and Candy, S. (1981). Effects of dredging on the macrobenthic infauna of Botany Bay. *Australian Journal of Marine and Freshwater Research* **32**, 379-398.

Jones, G.P. and Andrew, N.L. (1990). Herbivory and patch dynamics on rocky reefs in temperate Australasia: the roles of fish and sea urchins. *Australian Journal of Ecology* **15**, 505-520.

Kailola, P.J., Williams, M.J., Stewart, P.C., Reichelt, R.E., McNee, A. and Grieve, C. (1993). *Australian Fisheries Resources*. Bureau of Resource Sciences and the Fisheries Research and Development Corporation. Commonwealth of Australia. 422 pp.

Kaiser, M.J. and de Groot S.J. (2000). *The Effects of Fishing on Non-target Species and Habitats: Biological, Conservation and Socio-economic Issues*. The European Commission Fisheries, Agriculture and Agroindustrial Research Program (FAIR), 399 pp.

*Kaufmann, B., Geen, G. and San, S. (1999). Fish futures: Individual transferable quotas in fisheries. Fisheries Research and Development Corporation and Fisheries Economics, Research and Management Pty Ltd. Kiama, Australia. 240 pp.

Kearney, R.E. (2000). Fisheries property rights and recreational/commercial conflict: implications of policy developments in Australia and New Zealand. *Marine Policy* **25** (2001), 49-59.

Kennelly, S.J. (1995a). Kelp beds. In: *Coastal Marine Ecology of Temperate Australia* (eds. Underwood, A.J. and Chapman, M.G.) pp. 106-120. UNSW press.

Kennelly, S.J. (1995b). The issue of bycatch in Australia's demersal trawl fisheries. *Reviews in Fish Biology and Fisheries* **5**, 213-234.

Kennelly, S.J. (1987). Physical disturbances in an Australian kelp community. II. Effects on understorey species due to differences in kelp cover. *Marine Ecology Progress Series* **40**, 155-165.

*Kennelly, S.J. and Broadhurst, M.K. (1998). Development of bycatch reducing prawn trawls and fishing practices in NSW's prawn-trawl fisheries (and incorporating an assessment of the effect of increasing mesh size in fish trawl gear). FRDC Project No. 93/180. NSW Fisheries Final Report Series No. 5, July 1998.

Kennelly, S.J., Kearney, R.E., Liggins, G.W. and Broadhurst, M.K. (1993). The effect of shrimp trawling bycatch on other commercial and recreational fisheries – an Australian perspective. In: International Conference on Shrimp Bycatch (ed. Jones, R.P.) pp. 97-114. Lake Buena Vista, Florida. Tallahassee, FL: Southeastern Fisheries Association. May 1992.

Kennelly, S.J., Liggins, G.W. and Broadhurst, M.K. (1998). Retained and discarded bycatch from oceanic prawn trawling in New South Wales, Australia. *Fisheries Research* **36**, 217-236.

Kennelly, S.J. and Underwood, A.J. (1992). Fluctuations in the distributions and abundances of species in sublittoral kelp forests in New South Wales. *Australian Journal of Ecology* **17**, 367-382.

Keough, M.J. and Jenkins, G.P. (1995). Seagrass meadows and their inhabitants. In: *Coastal Marine Ecology of Temperate Australia* (eds. Underwood, A.J. and Chapman, M.G.) pp. 221-239. UNSW Press.

Keough, M.J. and Quinn, G.P. (1998). Effects of periodic disturbances from trampling on rocky intertidal algal beds. *Ecological Applications* **8**, 141-161.

*Kerr, R.J. (1994). Water Quality, Hawkesbury-Nepean River System, June 1990 to June 1993. Environment Protection Authority, Sydney. 193 pp.

King, R.J. (1981a). Marine angiosperms: seagrasses. In: *Marine botany: an Australian perspective* (eds. Clayton, M.N. and King, R.J.) pp. 201-210. Longman Cheshire, Australia.

King, R.J. (1981b). Mangroves and saltmarsh plants. In: *Marine botany: an Australian perspective* (eds. Clayton, M.N. and King, R.J.) pp. 308-328. Longman Cheshire, Australia.

King, R.J. (1986). Aquatic angiosperms in coastal saline lagoons of New South Wales. Part I: The vegetation of Lake Macquarie. *Proceedings of the Linnean Society of New South Wales* **109(1)**, 11-23.

Klumpp, D.W., Howard, R.K. and Pollard, D.A. (1989). Trophodynamics and nutritional ecology of seagrass communities. In: *Biology of seagrasses. A treatise on the biology of seagrasses with special reference to the Australian region* (eds. Larkum, A.W.D., McComb, A.J. and Shepherd, S.A.) pp. 394-437. Elsevier, New York / Amsterdam.

Kuiter, R. (1993). *Coastal Fishes of South-Eastern Australia*. Crawford House Press, Bathurst. 437 pp.

*Lal, P., Holland, P. and Power, P. (1992). Competition between recreational and commercial fishers: management options and economic research. Australian Bureau of Agricultural and Resource Economics. Research Report No. 92.11, p. 70.

Lamberth, S.J., Bennett, B.A. and Clark, B.M. (1994). Catch composition of the commercial beach-seine fishery in False Bay, South Africa. *South African Journal of Marine Science* **14**, 69-78.

Lamberth, S.J., Bennett, B.A., Clark, B.M. and Janssens, P.M. (1995). The impact of beach-seine netting on the benthic flora and fauna of False Bay, South Africa. *South African Journal of Marine Science* **15**, 115-122.

Larkum, A.W.D. (1981). Marine primary productivity. In: *Marine botany: an Australian perspective* (eds. Clayton, M.N. and King, R.J.) pp. 369-385. Longman Cheshire, Australia.

Larkum, A.W.D. and West, R.J. (1990). Long-term changes of seagrass meadows in Botany Bay, Australia. *Aquatic Botany* **37**, 55-70.

*Leadbitter, D., Ward, T. and Ridge, K. (1999). Maintaining Biodiversity in Sustainable Marine Fisheries – A Review and Scoping of Future Directions. Department of the Environment and Heritage, Commonwealth of Australia. 86 pp.

Lenanton, R.C.J., Robertson, A.I. and Hansen, J.A. (1982). Nearshore accumulations of detached macrophytes as nursery areas for fish. *Marine Ecology Progress Series* **9**, 51-57.

Liggins, G.W., Bradley, M.J. and Kennelly, S.J. (1997). Detection of bias in observer-based estimates of retained and discarded catches from a multi species trawl fishery. *Fisheries Research* **32**, 113-147.

Liggins, G.W., Kennelly, S.J. and Broadhurst, M.K. (1996). Observer-based survey of bycatch from prawn trawling in Botany Bay and Port Jackson, New South Wales. *Marine and Freshwater Research* **47**, 877-888.

Lincoln-Smith, M.P. and Jones, G.P. (1995). Fishes of shallow coastal habitats. In: *Coastal Marine Ecology of Temperate Australia*. (eds. Underwood, A.J. and Chapman, M.G.) pp. 240-253. UNSW Press.

*Lincoln-Smith, M.P., Hair, C.A. and Bell, J.D. (1992). Jervis Bay marine ecology study. Project 4: Fish associated with natural rocky reefs and artificial breakwaters. Final Report, December 1992. NSW Fisheries, Fisheries Research Institute, Cronulla. 210 pp.

Lincoln-Smith, M.P., Bell, J.D., Pollard, D.A. and Russell, B.C. (1989). Catch and effort of competition spearfishermen in southeastern Australia. *Fisheries Research* **8**: 45-61.

Lloyd, R. (1992). *Pollution and Freshwater Fish.* Blackwell Scientific Publications, London. 176 pp.

McDowall, R.M. (1996). *Freshwater Fishes of South-Eastern Australia*. Reed Books, Sydney. 247 pp.

*McEnally, J. and Thompson, G. (1984). Coastal Resource Atlas for Oil Spills in Botany Bay. State Pollution Control Commission, Sydney. 27 pp.

*McEnally, J. and Thompson, G. (1989). Coastal Resource Atlas for Oil Spills in Jervis Bay. State Pollution Control Commission, Sydney. 32 pp.

*McEnally, J., Eskdale, I., Thompson, G. and Zekanovic, I. (1990). Coastal Resource Atlas for Oil Spills in and around Twofold Bay. State Pollution Control Commission, Sydney. 36 pp.

*McEnally, J., Eskdale, I., Thompson, G. and Zekanovic, I. (1992). Coastal Resource Atlas for Oil Spills from Cape Dromedary to Cape Howe. State Pollution Control Commission, Sydney. 61 pp.

*McEnally, J., Eskdale, I., Thompson, G., Harris, J., Zekanovic, I. and Otto, K. (1992). Coastal Resource Atlas for Oil Spills from the Clarence River to Smoky Cape. Environment Protection Authority, Sydney. 102 pp.

*McEnally, J., Thompson, G. and Zekanovic, I. (1989). Coastal Resource Atlas for Oil Spills in and around Port Kembla. State Pollution Control Commission, Sydney. 32 pp.

*McEnally, J., Thompson, G. and Zekanovic, I. (1989). Coastal Resource Atlas for Oil Spills in and around the Port of Newcastle. State Pollution Control Commission, Sydney. 32 pp.

McGhie, T.K., Crawford, C.M., Mitchell, I.M. and O'Brien, D. (2000). The degradation of fish-cage waste in sediments during fallowing. *Aquaculture* **187**, 351-366.

McNeill, S.E., Worthington, D.G., Ferrell, D.J. and Bell, J.D. (1992). Consistently outstanding recruitment of five species of fish to a seagrass bed in Botany Bay, NSW. *Australian Journal of Ecology* **17**, 359-366.

*McVeery, S. (1996). A socio-economic evaluation of the Clarence River commercial fisheries. Unpublished undergraduate study, Faculty of Resource Science and Management, Southern Cross University.

Marais, J.F.K. (1985). Some factors influencing the size of fishes caught in gillnets in eastern cape estuaries. *Fisheries Research* **3**, 251-261.

Marchant, S. and Higgins, P.J. (1993). *Handbook of Australian, New Zealand and Antarctic Birds*. Oxford University Press, Melbourne.

*Marine Parks Authority (2000). Draft framework for establishing a system of marine protected areas in NSW. NSW Fisheries and National Parks and Wildlife Service, June 2000. 64 pp.

*Marsden, T.J. and Gehrke, P.C. (1996). Fish passage in the Hawkesbury-Nepean River System. In: *Fish and Fisheries of the Hawkesbury-Nepean River System*, Ch 11 (eds. Gehrke, P.C. and Harris, J.H.) pp. 200-218. Final report to the Sydney Water Corporation, July 1996. NSW Fisheries, Fisheries Research Institute, Sydney, and Cooperative Research Centre for Freshwater Ecology.

*Mather, G. (1993). *Aquaculture: an Australian Environmental Review*. Total Environment Centre Inc., Sydney. 88 pp.

*MCFFA (1999). National Policy for the Translocation of Live Aquatic Organisms – Issues, Principles and Guidelines for Implementation. Ministerial Council on Forestry, Fisheries and Aquaculture. Canberra, ACT. 31 pp.

*Metzner, R. and Rawlinson, P. (1998). Fisheries Structural Adjustment: towards a national framework. Commonwealth Department of Primary Industries and Energy, Canberra. p. 2.

Meyer, T.L., Cooper, R.A. and Pecci, K.J. (1981). The performance and environmental effects of a hydraulic clam dredge. *Marine Fisheries Review* **43**, 14-22.

Middleton, M.J., Bell, J.D., Burchmore, J.J., Pollard, D.A. and Pease, B.C. (1984). Structural differences in the fish communities of *Zostera capricorni* and *Posidonia australis* seagrass meadows in Botany Bay, New South Wales. *Aquatic Botany* **18**, 89-109.

Miller, B. (1995). Combating drift-net fishing in the Pacific. In: *The Law of the Sea in the Asia Pacific Region* (eds. Crawford, J. and Rothwell, D.) pp. 155-170. Martinus Nijhoff, Boston.

*Miskiewicz, A.G. (1987). Taxonomy and ecology of fish larvae in Lake Macquarie and NSW coastal waters. Ph.D. thesis. University of NSW, Sydney, Australia. 191 pp.

*Montgomery, S.S. (2000). Status of eastern king and school prawn stocks. In: Proceedings of Juvenile Prawn Summit June 26-27. NSW Fisheries Publication. Sydney. pp. 28-47.

*Montgomery, S.S. and Reid, D.D. (1995). Assessment of recreational fishing of prawn stocks on the commercial fishery for prawns off New south wales. Final report to the Fisheries Research & Development Coorporation. Project 91/88. NSW Fisheries, Sydney.

Moran, M.J. and Jenke, J. (1989). Effects of fish trapping on the Shark Bay snapper fishery. *Fisheries Report* **82**, 1-29.

Morrisey, D. (1995). Saltmarshes. In: *Coastal Marine Ecology of Temperate Australia* (eds. Underwood, A.J. and Chapman, M.G.) pp. 205-220. UNSW press.

Morrisey, D.J., Howitt, L., Underwood, A.J. and Stark, J.S. (1992a). Spatial variation in soft-sediment benthos. *Marine Ecology Progress Series* **81**, 197-204.

Morrisey, D.J., Underwood, A.J., Howitt, L. and Stark, J.S. (1992b). Temporal variation in soft-sediment benthos. *Journal of Experimental Marine Biology and Ecology* **164**, 233-245.

Morton, R.M., Pollock, B.R. and Beumer, J.P. (1987). The occurance and diet of fishes in a tidal inlet to a saltmarsh in southern Moreton Bay, Queensland. *Australian Journal of Ecology* **12**, 217-237.

Murphy, G.I. (1980). Schooling and ecology and management of marine fish. In: *Fish Behaviour and its Use in the Capture and Culture of Fishes* (eds. Bardach, J.E., Magnusuon, J.E., May, .J.J. and Reinhart, R.C.J.M.) *ICLARM Conference Procedures* **5**, 400-414.

*Murphy, P. (1999). Licensing. Paper delivered at the Commercial Fishing Industry Summit Proceedings by NSW Fisheries. pp. 53-58.

Murray, T.E., Bartle, J.A., Kalish, S.R. and Taylor, P.R. (1993). Incidental capture of seabirds by Japanese southern bluefin tuna longline vessels in New Zealand waters, 1988-1992. *Biological Conservation International* **3**, 181-210.

Norman, M. (1999). Octopuses & their relatives. In: *Under Southern Seas: The ecology of Australia's rocky reefs* (ed. Andrew, N.) pp. 86-97. UNSW Press.

Northridge, S. (1991). Driftnet fisheries and their impacts on non-target species: a worldwide review. *FAO Technical Paper* No. 230.

*NSW Department of Public Works and Services (1992). Draft Estuary Management Manual. NSW Government Printer. 194 pp.

*NSW Fisheries (1991). Solitary Islands Marine Reserve - A guide to recreational and commercial use of the reserve. NSW Fisheries. 40 pp.

*NSW Fisheries (1997a). Protected Marine Fish Species Sighting Sheet Program - status report 1997. Fishnote DF69. NSW Fisheries, Sydney. 6 pp.

*NSW Fisheries (1997b). NSW Fisheries Heritage and Conservation Register.

*NSW Fisheries (1999a). Policy and Guidelines: Aquatic Habitat Management and Fish Conservation 1999 (eds. Smith, A.K. and Pollard, D.A.). NSW Fisheries, Port Stephens Research Centre. 86 pp.

*NSW Fisheries (1999b). Policy and Guidelines for Bridges, Roads, Causeways, Culverts and Similar Structures 1999 (eds. Fairfull, S. and Carter, S.) NSW Fisheries, Sydney. 19 pp.

*NSW Fisheries (1999c). Commercial Fishery Profile – Estuary General. Commercial Management Branch, Cronulla Fisheries Centre, Sydney. 11 pp.

*NSW Fisheries (2000). NSW Fisheries 2000 Research Report. Internal Report. Cronulla Fisheries Centre, Sydney. 499 pp.

*NSW Fisheries (2001a). Status of fisheries resources 2000. Internal Report. Cronulla Fisheries Centre, Sydney. 306 pp.

*NSW Fisheries (2001b). Consultation Paper: Selection process for candidate aquatic reserves for rocky shores and estuaries (Batemans Shelf and Hawkesbury Shelf bioregions). NSW Fisheries, Sydney. 64 pp.

*NSW National Parks and Wildlife Service (2000a). Recovery Plan for the endangered population of little penguins (*Eudyptula minor*) at Manly. NSW NPWS, Hurstville.

*NSW National Parks and Wildlife Service (2000b). Little Tern Recovery Plan. NSW NPWS, Hurstville.

*NSWF (2000a). Juvenile prawn summit: summary of proceedings. Proceedings of summit held 26-27June, 2000 at Cronulla, Sydney.

*NSWF (2000b). Options for the Implementation of an All-Waters Recreational Fishing Licence in NSW. New South Wales Fisheries, Cronulla, Sydney.

*O'Loughlin, E., Roberts, D. and Sainty, G. (1999). Guidelines to management of wetlands in lower south coast, NSW. Sainty and Associates Pty. Ltd. Sydney. 34 pp.

Otway, N.M. and Craig, J.R. (1993). The effects of hook-size on the catches of undersized snapper, *Pagrus auratus* (Bloch and Schneider). *Marine Ecology Progress Series* **93**, 9-15.

*Otway, N.M. and Macbeth, W.G. (1999). Physical effects of hauling on seagrass beds. FRDC Project Nos. 95/149 & 96/286. NSW Fisheries Final Report Series No. 15. Cronulla Fisheries Centre, Sydney. 86 pp.

Otway, N.M., Craig, J.R. and Upston, J.M. (1996). Gear-dependent size selection of snapper, *Pagrus auratus*. *Fisheries Research* **28**, 119-132.

Patterson, K., Cook, R., Darby, C., Gavaris, S., Laurence, K., Lewy, P., Mesnil, B., Punt, A., Restrepo, V., Skagen, D.W. and Stefansson, G. (2001). Estimating uncertainty in fish stock assessment and forecasting. *Fish and Fisheries* **2**, 125-157.

Pauly, D. (1988). Fisheries research and the demersal fisheries of Southeast Asia. In: *Fish Popoulation Dynamics*, 2nd edn. (ed. Gulland, J.A.) pp. 329-348. John Wiley and Sons, Chichester.

Pease, B.C. (1999). A spatially oriented analysis of estuaries and their associated commercial fisheries in New South Wales, Australia. *Fisheries Research* **42(1),** 67-86.

*Pease, B.C. (2000). NSW commercial eel fishery. In: Strategies and techniques for sampling adult anguillid eels (eds. Walford, T. and Pease, B.C.). Proceedings of a workshop held at FRI, Cronulla, August 1999. Fisheries Research Report Series 5. NSW Fisheries. Cronulla.

*Pease, B.C. and Grinberg, A. (1995). New South Wales commercial fisheries statistics 1940 to 1992. Fisheries Research Institute, Cronulla NSW. 351 pp.

Pickering, H. and Whitmarsh, D. (1997). Artificial reefs and fisheries exploitation: a review of the "attraction versus production" debate, the influence of design and its significance for policy. *Fisheries Research* **31**, 39-59.

Pizzey, G. and Doyle, R. (1984). *A field guide to the birds of Australia.* Collins, Sydney, 460 pp.

*Pogonoski, J.J., Pollard, D.A. and Paxton, J.R. (in preparation). Conservation Overview and Action Plan for Australian Threatened and Potentially Threatened Marine and Estuarine Fishes. Report to Environment Australia Biodiversity Group by the NSW Fisheries Research Institute and the Australian Museum.

*Poiner, I.R. and Peterken, C. (1995). Seagrasses. In: *The State of the Marine Environment Report for Australia. Technical Annex 1: The Marine Environment* (eds. Zann, L.P. and Kailola, P.) pp. 107-117. Great Barrier Reef Marine Park Authority, Townsville.

Pollard, D.A. (1984). A review of ecological studies on seagrass-fish communities, with particular reference to Australia. *Aquatic Botany* **18**, 3-42.

Pollard, D.A. (1989). Artificial habitats for fisheries enhancement in the Australian region. *Marine Fisheries Review* **51(4)**, 11-26.

*Pollard, D.A. (1991). Spatial and temporal variability in the recruitment of a common esturaine fish, the yellowfin bream (*Acanthopagrus australis*, Sparidae), in south-eastern Australia. In: Recruitment processes, Australian Society for Fish Biology Workshop Proceedings No. 16 (ed. Hancock, D.A.) pp. 85-88. Australian Government Publishing Service.

Pollard, D.A. (1994). Opening regimes and salinity characteristics of intermittently open and permanently open coastal lagoons on the south coast of NSW. *Wetlands (Australia)* **13(1)**, 16-35.

*Pollard, D.A. and Growns, I.O. (1993). The fish and fisheries of the Hawkesbury-Nepean River System, with particular reference to the environmental effects of the Water Board's activities on this system. Interim report to the Water Board – April 1993. NSW Fisheries, Fisheries Research Institute, Cronulla. 291 pp. plus appendices.

Pollard, D.A. and Hannan, J.C. (1994). The ecological effects of structural flood mitigation works on fish habitats and fish communities in the lower Clarence River system of south-eastern Australia. *Estuaries* **17(2)**, 427-461.

Pollard, D.A. and Hutchings, P.A. (1990a). A review of exotic marine organisms introduced into the Australian region. I, Fishes. *Asian Fisheries Science* **3**, 205-221.

Pollard, D.A. and Hutchings, P.A. (1990b). A review of exotic marine organisms introduced into the Australian region. II, Invertebrates and Algae. *Asian Fisheries Science* **3**, 223-250.

Pollard, J. (1969). *Australian and New Zealand Fishing*. Paul Hamlyn Pty. Ltd., Dee Why West, NSW. p. 13.

Pollard, P.C. and Moriarty, D.J.W. (1991). Organic carbon decomposition, primary and bacterial productivity, and sulphate reduction in tropical seagrass beds of the Gulf of Carpentaria, Australia. *Marine Ecology Progress Series* **69**, 149-159.

Pollock, B.R. (1982). Movements and migrations of yellowfin bream, *Acanthopagrus australis* (Gunther), in Moreton Bay, Queensland as determined by tag recoveries. *Journal of Fish Biology* 20 (3), 245-252.

*Porter, G. (1998). Too much fishing fleet, too few fish. A proposal for eliminating global fishing overcapacity. World Wildlife Fund. pp. 8 & 12.

*Powell, R.A., Jensen, R. and Horwood, L. (1989). The effects of policy change on South-East Trawl fishing communities. Report to the Steering Committee on Long-Term Management of the South East Trawl Fishery. University of New England and Department of Primary Industries and Energy, Canberra.

Quigley, M.P. and Hall, J.A. (1999). Recovery of macrobenthic communities after maintenance dredging in the Blyth Estuary, north-east England. *Aquatic Conservation: Marine and Freshwater Ecosystems* **9**, 63-73.

Quinn, G.P., Fairweather, P.G and Keough, M.J. (1996). Shoreline Harvesting. In: SOMER Technical Papers: Fisheries (ed. Zann, L.P.). The State of the Marine Environment Report for Australia. Technical Summary, 34. GBRMPA.

Quinn, T.J. and Deriso, R.B. (1999). *Quantitative Fish Dynamics*. Oxford University Press, Oxford.

Rainer, S.F. (1982). Trophic structure and production in the macrobenthos of a temperate Australian estuary. *Estuarine, Coastal and Shelf Science* **15**, 423-441.

*Reid, C. and Campbell, H. (1998). Bio-economic analysis of the Queensland beam trawl fishery.

Reimann, B. and Hoffman, E. (1991). Ecological consequences of dredging and bottom trawling in the Limfjord, Denmark. *Marine Ecology Progress Series* **69**, 171-178.

Ricker, W.E. (1975). Computation and Interpretation of biological statistics of fish populations. *Fisheries Research Board of Canada Bulletin* **191,** 136-146.

Roach, A.C. (1997). The effect of acid water inflow on estuarine benthic and fish communities in the Richmond River, NSW Australia. *Australian Journal of Ecotoxicology* **3**, 25-56.

*Roy Morgan (1999). Recreational fishing Licence survey. Roy Morgan Research, Sydney.

*Roy Morgan (2001a). Social survey preliminary results. Roy Morgan Research, Sydney.

*Roy Morgan (2001b). Economic survey preliminary results. Roy Morgan Research, Sydney.

Roberts, D.E. (1996). Patterns in subtidal marine assemblages associated with a deep-water sewage outfall. *Marine and Freshwater Research* **47**, 1-9.

Robertson, A.I. and Alongi, D.M. (1995). Mangrove systems in Australia: structure, function and status. In: *The State of the Marine Environment Report for Australia. Technical Annex 1: The Marine Environment* (eds. Zann, L.P. and Kailola, P.) pp. 119-133. Great Barrier Reef Marine Park Authority, Townsville.

*Robinson, K. and Gibbs, P. (1982). *A field guide to the common shelled molluscs of New South Wales estuaries*. Coast and Wetlands Society, Sydney. 56 pp.

*Robinson, K.I.M. (1982). The structure of benthic macrofaunal communities in Lake Macquarie, N.S.W. Ph.D. thesis. University of NSW, Sydney.

Rooker, J.R. and Dennis, G.D. (1991). Diel, lunar and seasonal changes in a mangrove fish assemblage of southwestern Puerto Rico. *Bulletin of Marine Science* **49**, 684-698.

Ross, G.J.B. (1996). Status of Australia's seabirds. In: SOMER Technical Papers: Status of Marine Biodiversity (ed. Zann, L.P.). The State of the Marine Environment Report for Australia. Technical Summary, 17. GBRMPA.

Roughley, T.C. (1951). *Fish and Fisheries of Australia*. Angus and Robertson, Sydney. p. 318, plate 80, p. 322.

*Rowling, K.R. and Raines, L.P. (2000). Description of the biology and an assessment of the fishery for silver trevally *Pseudocaranx dentex* off New South Wales. FRDC Project No. 97/125. New South Wales Fisheries, Cronulla. 69 pp.

Roy, P.S, Williams, R.J., Jones, A.R., Yassini, I., Gibbs, P.J., Coates, B., West, R.J., Scanes, P.R., Hudson, J.P., and Nichol, S. (2001). Structure and function of southeast Australian estuaries. *Estuarine, Coastal and Shelf Science* **56** in press.

*Roy, P.S. (1982). Evolution of estuaries in N.S.W. Water Research Foundation of Australia Symposium paper. 27 pp.

Roy, P.S. (1984). New South Wales estuaries: their origins and evolution. In: *Coastal Geomorphology in Australia* (ed. Thom, B.) pp. 99-121. Academic Press, Australia.

Roy, P.S., Thom, B.G. and Wright, L.D. (1980). Holocene sequences on an embayed high-energy coast: An evolutionary model. *Sedimentary Geology* **26**, 1-19.

*Ruello, N.V. (1971). Some aspects of the ecology of the school prawn *Metapenaeus macleayi* in the Hunter region of New South Wales. MSc. Thesis. University of Sydney. 145 pp.

Ruello, N.V. (1973). Influence of rainfall on the distribution and abundance of the school prawn *Metapenaeus macleayi* (Haswell) in the Hunter river region, Australia. *Marine Biology* **23**, 221-228.

*Ruello, N.V. (1996). A study of the demand and importance of seafood sourced in NSW and elsewhere to the catering and tourism industries in NSW. FRDC, NSW. 157 pp.

*Ruello & Associates Pty. Ltd. (2000). Retail sale and consumption of seafood. Report prepared for the Fisheries Research and Development Corporation. July 2000. 14 pp.

*Sainsbury, K., Hawward, K., Kriwoken, L., Tsamenyi, M. and Ward, T.. (1997). Multiple Use Management in the Australian Marine Environment: Principles, Definitions and Elements. Oceans Policy Issues Paper 1. Environment Australia, Canberra.

Sainty, G.R. and Jacobs, S.W.L. (1981). *Waterplants of New South Wales*. Water Resources Commission of New South Wales. 550 pp.

Salini, J.P., Blaber, S.J.M. and Brewer, D.T. (1990). Diets of piscivorous fishes in a tropical Australian estuary, with special reference to predation on penaeid prawns. *Marine Biology* **105**, 363-374.

*Sammut, J., Callinan, R.B. and Fraser, G.C. (1993). The impact of acidified water on freshwater and estuarine fish populations in acid sulphate soil environments. Proceedings of National Conference on Acid Sulphate Soils. Coolongatta, Australia. pp. 26-36.

Sammut, J., Melville, M.D., Callinan, R.B. and Fraser, G.C. (1995). Estuarine acidification: impacts on aquatic biota of draining acid sulphate soils. *Australian Geographical Studies.* **33(1)**, 89-100.

Sammut, J., White, I. and Melville, M.D. (1996). Acidification of an estuarine tributary in eastern Australia due to drainage of acid sulphate soils. *Marine and Freshwater Research* **47**, 669-684.

*Scandol, J.P. and Forrest, R.E. (2001). Modelling services for the NSW Estuary General Fishery. Draft Report for NSW Fisheries. July 2001. Centre for Research on Ecological Impacts of Coastal Cities, University of Sydney, NSW. 114 pp.

*Scanes, P.R. (1988). The impact of Eraring Power Station on the fish and fisheries of Lake Macquarie. Report prepared for the Electricity Commission of New South Wales. New South Wales Fisheries, Fisheries Research Institute, Sydney, Australia. 111 pp.

Scanes, P.R. and Scanes, K. (1995). Environmental problems due to disposal of wastes. In: *Coastal Marine Ecology of Temperate Australia*, Ch. 19 (eds. Underwood, A.J. and Chapman, M.G.) pp. 297-310. UNSW press.

*SCFA (2001). Ecologically Sustainable Development and Fisheries. Standing Committee on Fisheries and Aquaculture and Fisheries Research and Development Corporation (FRDC) project.

*Schaap, A. and Green, R. (1988). Fish communities on reefs subjected to different levels of fishing pressure. Technical Report of the Marine Laboratory, Deep Sea Fisheries Tasmania. No. 31, pp. 1-44.

Scoffin, T.P. (1970). The trapping and binding of subtidal carbonate sediments by marine vegetation in Bimini Lagoon, Bahamas. *Journal of Sedimentary Petroleum* **40**, 249-273.

*Shafer, D.J. and Lundin, J. (1999). Design and construction of docks to minimise seagrass impacts. WRP Technical Notes Collection (TN WRP-VN-RS-3.1). U.S. Army Engineer Research and Development Center, Vicksburg, MS. 6 pp.

Shepherd, S.A., McComb, A.J., Bulthuis, D.A., Neverauskas, V., Steffensen, D.A. and West, R. (1989). Decline of seagrasses. In: *Biology of Seagrasses* (eds. Larkum, A.W.D., McComb, A.J. and Shepherd, S.A.) pp. 346-393. Elsevier, Amsterdam.

Sheridan, A.K. (1995). The genetic impacts of human activities on wild fish populations. *Reviews in Fisheries Science* **3(2)**, 91-108.

*Sherman, B. (2000). Scoping options for mitigating cold water discharges from dams. Report to: Agriculture, Fisheries and Forestry – Australia, NSW Fisheries, CRC for Freshwater Ecology, and NSW Department of Land and Water Conservation as part of the NHT Murray-Darling 2001 FishRehab Program. Consultancy Report 00/21. CSIRO Land and Water, Canberra. May 2000.

*Shotter, N., O'Donnell, M., Steetsel, P. and Birch, G.F. (1995). The environmental status of a large NSW estuary under threat - the Hawkesbury River System. In: Proceedings of the 29th Newcastle Symposium on "Advances in the study of the Sydney Basin". Department of Geology, University of Newcastle. pp. 59-65.

Simenstad, C.A. and Thom, R.M. (1996). Functional equivalency trajectories of the restored Gog-Le-Hi-Te estuarine wetland. *Ecological Applications* **6(1)**, 38-56.

Simpson, K. and Day, N. (1996). *Field guide to the birds of Australia.* Penguin Books Australia Ltd, 400 pp.

Skilleter, G.A. (1995). Environmental disturbances. In: *Coastal Marine Ecology of Temperate Australia*, Ch. 17 (eds. Underwood, A.J. and Chapman, M.G.) pp. 263-276. UNSW press.

*Smith, A., Pollard, D. and Gillanders, B. (1996). The blue groper in NSW. Fishnote DF/63. NSW Fisheries, Sydney. 2 pp.

Smith, A.K, Holliday, J.E. and Pollard, D.A. (1997). Management of seagrass habitats in NSW Estuaries. *Wetlands (Australia)* **16(2)**, 48-54.

*State Pollution Control Commission (SPCC) (1981a). The ecology of fish in Botany Bay - community structure. Environmental Control Study of Botany Bay. Sydney, Australia. Report No. BBS 23A. 127 pp.

*State Pollution Control Commission (SPCC) (1981b). The ecology of fish in Botany Bay - biology of commercially and recreationally valuable species. Environmental Control Study of Botany Bay. Sydney, Australia. Report No. BBS 23B. 287 pp.

*Steffe, A.S. and Chapman, D.J. (in review). A Survey of Daytime Recreational Fishing During the Annual Period, March 1999 to February 2000, in Lake Macquarie, New South Wales.

*Steffe, A.S., Murphy, J.J., Chapman, D.J., Tarlington, B.E., Gordon, G.N.G. and Grinberg, A. (1996a). An assessment of the impact of offshore recreational fishing in New South Wales on the management of commercial fisheries. FRDC Project No. 94/053.

*Steffe, A.S., Staines, J.F. and Murphy, J.J. (1996b). Recreational use of fisheries resources in northern New South Wales. Natural Resources Audit Council Project S7.

*Stewart, J., Ferrell, D.J. and Andrew, N.L. (1998). Ageing yellowtail (*Trachurus novaezelandiae*) and blue mackerel (*Scomber australiasicus*) in NSW. NSW Fisheries Final Report Series No. 3. FRDC Project No. 95/151.

*Tamblyn, C. and Powell, R.A. (1988). Input and output study of the north coast agriculture and fisheries industries. NSW Department of Agriculture, Wollongbar.

*Tanner, M. and Liggins, G.W. (1999). New South Wales Commercial Fisheries Statistics 1993/94 to 1997/98. NSW Fisheries Research Institute, Cronulla.

*Tanner, M. and Liggins, G.W. (2000). New South Wales Commercial Fisheries Statistics 1998/99. NSW Fisheries, Cronulla Fisheries Centre. 21 pp.

*Tanner, M. and Liggins, G.W. (2001). New South Wales Commercial Fisheries Statistics 1999/00 (draft). NSW Fisheries, Cronulla Fisheries Centre.

Thomas, B.E. and Connolly, R.M. (2001). Fish use of subtropical saltmarshes in Queensland, Australia. Relationships with vegetation, water depth and distance onto the marsh. *Marine Ecology Progress Series* **209**, 275-288.

*Thompson, G. and McEnally, J. (1985). Coastal Resource Atlas for Oil Spills in Port Jackson. State Pollution Control Commission, Sydney. 27 pp.

Thompson, L.G. (1893). *History of the Fisheries of New South Wales.* Charles Potter, Government Printer, Sydney. p. 96.

Thomson, J.M. (1959a). Some aspects of the ecology of Lake Macquarie, N.S.W., with regard to an alleged depletion of fish. VIII. Trends of the commercial fish catch and management of the fishery. *Australian Journal of Marine and Freshwater Research* **10**, 354-364.

Thomson, J.M. (1959b). Some aspects of the ecology of Lake Macquarie, N.S.W., with regard to an alleged depletion of fish. IX. The fishes and their food. *Australian Journal of Marine and Freshwater Research* **10**, 365-374.

Thorhaug, A. (1990). Restoration of mangroves and seagrasses – economic benefits for fisheries and mariculture. In: *Environmental restoration science and strategies for restoring the earth* (ed. Berger, J.J.). Island Press, Washington.

*Thorncraft, G. and Harris, J. (2000). Fish Passage and Fishways in New South Wales: A Status Report. Cooperative Research Centre for Freshwater Ecology Technical Report 1/2000.

Underwood, A.J. (1989). The analysis of stress in natural populations. *Biological Journal of the Linnean Society* **37**, 51-78.

Underwood, A.J. (1990). Experiments in ecology and management: their logics, functions and interpretations. *Australian Journal of Ecology* **15**, 365-389.

Underwood, A.J. (1993). The mechanics of spatially replicated smapling prgrammes to detect environmental impacts in a variable world. *Australian Journal of Ecology* **18**, 99-116.

Underwood, A.J., M.G. Chapman & S.D. Connell (2000). Observations in ecology: you can't make progress on processes without understanding the patterns. *Journal of Experimental Marine Biology and Ecology* **250**, 97-115.

Underwood, A.J. and Kennelly, S.J. (1990). Pilot studies for designs of surveys of human disturbance of intertidal habitats in New South Wales. *Australian Journal of Marine and Freshwater Research* **41**, 165-173.

Van Den Heiligenberg, T. (1987). Effects of mechanical and manual harvesting of lugworms *Arenicola marina* L. on the benthic fauna of tidal flats in the Dutch Wadden Sea. *Biological Conservation* **39**, 165-177.

*Virgona, J.L. (1983). Lake Macquarie fish study. Report prepared for the Electricity Commission of New South Wales. NSW Fisheries, Cronulla. 131 pp.

*Virgona, J.L. (1995). Sea Mullet. Fishnote DF/49. NSW Fisheries, Sydney.

*Virgona, J., Deguara, K., Sullings, D., Halliday, I. and Kelly, K. (1998). Assessment of the stocks of sea mullet in New South Wales and Queensland waters. FRDC Project No. 94/024. New South Wales Fisheries, Cronulla. 104 pp.

Walker, D.I. and McComb, A.J. (1992). Seagrass degradation in Australian coastal waters. *Marine Pollution Bulletin* **25**, 191-195.

*Ward, T., Alder, J., Margules, C., Sainsbury, K., Tarte, D., Zann, L. (1997). Australia's Oceans Policy: Biodiversity Conservation. Oceans Policy Issues Paper 7. Environment Australia, Canberra.

Wassenberg, T.J. and Hill, B.J. (1987). Feeding by the sand crab *Portunus pelagicus* on material discarded from prawn trawlers in Moreton Bay, Australia. *Marine Biology* **95**, 387-393.

Wassenberg, T.J. and Hill, B.J. (1990). Partitioning of material discarded from prawn trawlers in Moreton Bay. *Australian Journal of Marine and Freshwater Research* **41(1)**, 27-36.

*West, R.J. (1985). Mangroves. Agfact F2.0.1. NSW Agriculture and Fisheries, Fisheries Research Institute, Cronulla. 15 pp.

*West, R.J. (1989). Seagrasses. Agfact F2.0.2. NSW Agriculture and Fisheries, Fisheries Research Institute, Cronulla. 8 pp.

*West, R.J. (1993). Northern Rivers Report Part A – Estuarine Fisheries Resources Internal Report, NSW Fisheries, Sydney. 173 pp. plus appendices.

West, R.J. and Gordon, G.N.G. (1994). Commercial and recreational harvest of fish from two Australian coastal rivers. *Australian Journal of Marine and Freshwater Research* **45 (7)**, 1259-1279.

West, R.J. and King, R.J. (1996). Marine, brackish, and freshwater fish communities in the vegetated and bare shallows of an Australian coastal river. *Estuaries* **19**, 31-41.

*West, R.J., Thorogood, C., Walford, T. and Williams, R.J. (1985). An estuarine inventory for New South Wales, Australia. Fisheries Bulletin 2. Department of Agriculture New South Wales, Division of Fisheries, Sydney. 140 pp.

Whittington, R.J., Jones, J.B., Hine, P.M. and Hyatt, A.D. (1997). Diseases of Aquatic Organisms. Epizootic mortality in the pilchard *Sardinops sagax neopilchardus* in Australia and New Zealand in 1995. I Pathology and epizootiology. Vol. 28. pp. 1-16.

*Wilkinson, J. (1997). Commercial fishing in NSW: Origins and development to the early 1990s. NSW Parliamentary Library Research Service.

Willett, I.R., Melville, M.D. and White, I. (1993). Acid drainwaters from potential acid sulphate soils and their impact on estuarine ecosystems. In: Selected papers from the Ho Chi Minh City Symposium on acid sulphate soils (eds. Dent, D.L. and van Mensvoort, M.E.F.). ILRI Publication No. 53. Pp. 419-425.

*Williams, R.J., Henry, G.W., Murphy, J.J., Smith, A.K., Grima, D.M. and Harvey, J.R. (1993). Jervis Bay Marine Ecology Study. Project 9: Commercial and recreational fishing and diving in Jervis Bay. NSW Fisheries, Cronulla NSW.

Williams, R.J. and Watford, F.A. (1996). An inventory of impediments to tidal flow in NSW Estuarine Fisheries Habitat. *Wetlands (Australia)* **15(2)**, 44-54.

*Williams, R.J. and Watford, F.A. (1997). Change in the distribution of mangrove and saltmarsh in Berowra and Marramarra Creeks, 1941 - 1992. NSW Fisheries, Fisheries Research Institute, Cronulla. 21 pp.

Williams, R.J. (1990). Projecting a greenhouse rise in sea level on saltmarsh and mangrove habitats in New South Wales. *Wetlands (Australia)* **10(1/2)**, 15-19.

*Williams, R.J., Hannan, J. and Balashov, V. (1995). Kooragang Wetland Rehabilitation Project: fish, decapod crustaceans and their habitats. First Interim Report, Summer 1993/94. NSW Fisheries, Fisheries Research Institute, Cronulla. 106 pp.

Williams, R.J., Watford, F.A., Taylor, M.A. and Button, M.L. (1998). New South Wales Coastal Aquatic Estate. *Wetlands (Australia)* **18**, 25-48.

*Williams, S., Badcock, C. and Roberts, E. (1993). Water quality in the Hawkesbury-Nepean River and Tributaries, 1977 to 1992. Report No. 93/20 prepared for Headworks Water Resource Planning, AWT Science and Environment, Sydney Water Board. 117 pp.

Wilson, S.P. and Hyne, R.V. (1997). Toxicity of acid-sulphate soil leachate and aluminium to embryos of the Sydney rock oyster. *Ecotoxicology and Environmental Safety* **37**, 30-36.

Yapp, G.A. (1986). Aspects of population, recreation and management of the Australian coastal zone. *Coastal Zone Management* **14**, 47-66.

Zann, L.P. (1995). Our Sea, Our Future. Major findings of the State of the Marine Environment Report for Australia. Great Barrier Reef Marine Park Authority for the Department of the Environment, Sport and Territories. Ocean Rescue 2000 program. Commonwealth of Australia. 112 pp.

*Zann, L.P. (1996). State of the Marine Environment Report for Australia: Technical Summary. Great Barrier Reef Marine Park Authority for the Department of the Environment, Sport and Territories. Ocean Rescue 2000 program. Commonwealth of Australia. 531 pp.

Zedler, J.B., Nelson, P. and Adam, P. (1995). Plant community organisation in New South Wales saltmarshes: species mosaics and potential causes. *Wetlands (Australia)* **14(1)**, 1-18.