APPENDIX F

APPENDIX F1 ESTUARY CHARACTERISTICS

The estuary general fishery is conducted to some degree in most of the estuaries along the NSW coast. The estuaries have a range of shapes, sizes and geological origins, and these factors are largely responsible for determining the distribution and abundance of physical habitats and ecological assemblages.

1. General Characteristics

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

2. Main Estuary Types Occurring in NSW

There are at least 950 water bodies joining the Tasman Sea along the New South Wales seaboard (Williams *et al.,* 1998), however, the majority of these are very small and only intermittently opened to the sea. Only 130 have a water area greater than 0.05 km^2 and are regularly referred to as estuaries. Various attributes of these 130 estuaries have been documented by Bell and Edwards (1980), West *et al.,* (1985) and Roy *et al.,* (2001).

Based on geological criteria and the degree of marine influence, Roy *et al.,* (2001) recognise five coastal water body groupings in eastern Australia: (1) Bays; (2) Tide-dominated estuaries; (3) Wave-dominated estuaries; (4) Intermittent estuaries; and (5) Freshwater bodies. Within these groups are 13 water body types, most of which occur in NSW (Roy *et al.,* 2001). This classification scheme builds on the earlier work of Roy *et al.,* (1980) and Roy (1982, 1984). Whilst truly estuarine environments (and the majority of NSW estuaries) fall into groups 2 to 4, the remaining groups include types that either comply with Day's (1980) definition of an estuary, or are directly linked to estuarine environments at least part of the time. The various estuary types (at least those with a water area greater than 0.05 km^2) differ in their frequency of occurrences and respective distributions along the NSW coastline (Roy 1982; West *et al.,* 1985; Roy *et al.,* 2001).

a) Bays or open ocean embayments

Ocean embayments are rare (five in total) and, with the exception of Sydney's Botany Bay, are all located on the south coast: Jervis Bay; Ulladulla Harbour; Batemans Bay; and Twofold Bay. These are characterised by marine waters and have little freshwater inflow; they are transitional between true

estuaries and the coastal ocean. Within such embayments, tides are unimpeded, and ocean swells retain a strong influence well inside the entrance. These estuaries are normally wide and reasonably deep, and internal currents are therefore usually weak, but considerable wave-induced water movement can occur in the shallows.

b) Tide-dominated estuaries

Tide-dominated estuaries are represented in NSW by drowned valley estuaries such as Broken Bay and Sydney Harbour (Roy *et al.*, 2001). Drowned valley estuaries are also relatively uncommon (eight in total), and are concentrated on the central part of the NSW coast, especially near Sydney (e.g. Broken Bay, Port Jackson, Georges River and Port Hacking). These estuaries are characterised by convoluted shorelines, with deep sheltered tributaries and lots of sheltered bays. These estuaries are subject to most of the oceanic tidal range throughout all but their uppermost reaches. Currents are usually weak within the sheltered bays and tributaries, but may be moderately strong within the main water body, particularly where a point or island impinges on the main tidal flow. Complex tidal circulation patterns involving eddies and back-flows are typical (e.g. Das *et al.*, 2000). Ocean swells normally only penetrate the lower reaches, and river discharge has little influence, except during floods. Drowned valley estuaries are typically larger than the other types of estuary occurring along the NSW coastline (West *et al.*, 1985; Roy *et al.*, 2001).

c) Wave-dominated estuaries

There are 49 wave-dominated estuaries in NSW, and are represented by barrier estuaries such as Lake Macquarie and by interbarrier estuaries such as Tilligerry Creek, Port Stephens, of which there are only six (Roy *et al.*, 2001). The characteristics of barrier estuaries depend greatly on the degree of infilling or maturity (Roy 1982; Roy *et al.*, 2001).

Immature barrier estuaries, such as Lake Macquarie, Wallis Lake and Brisbane Waters have a wide basin (lagoon) linked to the ocean by a narrow entrance channel, which in most cases remains open to the ocean. In such estuaries, tidal range normally decreases dramatically as one travels upstream through the entrance channel, such that within the basin, the range is usually only a small fraction of that of the open ocean. Tidal currents are strong in the entrance channel, but very weak within the basin itself where local wind waves and wind-induced water movements are the dominant sediment transporting mechanisms. Also, ocean swells are quickly attenuated in the lower end of the entrance channel.

Mature barrier estuaries such as Tweed, Richmond, Clarence, Hunter and Shoalhaven Rivers have become infilled to the point where a distinct basin is lacking, the entrance channel configuration continues throughout the estuary. In such cases freshwater input is usually high (probably explaining the high degree of historical infilling) and the main river channel (possibly split into two or more arms) essentially continues all the way to the ocean. Such estuaries have become river dominated (Roy *et al.*, 2001). True wave-domination has been lost, currents (due to a combination of river discharge and tidal action) are normally moderate to strong throughout most of the system, and tidal range decreases only gradually with distance upstream. As in immature barrier estuaries, ocean swells do not penetrate far beyond the entrance. Whilst barrier estuaries occur behind a single coastal sand barrier, interbarrier estuaries occur between two such barriers of differing geological age.

d) Intermittent estuaries

Intermittent estuaries are represented in NSW by saline coastal lagoons such as Smiths Lake, and by small coastal creeks such as Harbord Lagoon (Roy *et al.,* 2001). There are 57 saline coastal lagoons in NSW and they are especially common in the south. The larger and/or better known examples include Lake Innes/Lake Cathie, Smiths Lake, Narrabeen Lagoon, Lake Wollumboola, Swan Lake and Coila Lake. Small coastal creeks are quite rare in NSW, with only five examples, all of which are in the northern half of the State.

These are similar to the immature barrier estuaries discussed above, except that are only periodically open to the ocean. Because of relatively small catchments and therefore river discharges, beach sand blocks their mouths for much of the time. Openings, usually in the form of a narrow entrance channel, normally occur as a result of heavy rainfall within the catchment, possibly in conjunction with high tides and heavy seas. Such lakes may open naturally, or be opened mechanically to alleviate flood threats (NSW Fisheries 1999a; O'Loughlin *et al.,* 1999; Roy *et al.,* 2001). Whilst open, their hydrology usually becomes similar to that of immature barrier estuaries. During periods of closure tidal influence ceases, however longer term changes (over weeks or months) in water level may occur according to the balance between inflow and evaporation (NSW Fisheries 1999a). Intermittent estuaries are typically smaller than the other types of estuary occurring along the NSW coastline (West *et al.,* 1985; Roy *et al.,* 2001).

e) Freshwater bodies

Coastal freshwater bodies are represented in NSW by 'brackish barrier lakes' such as Myall Lakes, of which there are only four, and by backswamps such as Everlasting Swamp in the Clarence River system. Many of the backswamps have been drained or modified. These water body types have at least occasional linkages (particularly during floods) to either the sea or a true estuary. These linkages facilitate the passage of nutrients, organic matter and aquatic organisms.

APPENDIX F2 ESTUARINE HABITAT DESCRIPTIONS

1. Seagrass

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

Seagrass is widely recognised as an important habitat for juvenile fish (e.g. SPCC 1981a; Pollard 1984; Bell and Pollard 1989; Connolly 1994), but it serves many more roles than the mere provision of food and habitat for species of economic value. They are also reported to: prevent erosion by restricting water movement and binding sediment (Fonseca *et al.,* 1982; Scoffin 1970); form the basis of food webs through high productivity and providing detritus (Borowitzka and Lethebridge 1989; Hillman *et al.,* 1989); provide surfaces for colonisation by epiphytes and periphyton (Harlin 1975; Pollard and Moriarty 1991); and trap and recycle nutrients (Hemminga *et al.,* 1991). Some studies have also reported the importance of detached seagrass supporting abundant fish communities adjacent to the beaches upon which it washes up on, forming accumulations known as wrack (Lenanton *et al.,* 1982). In northern Australia, seagrasses form a major component of the diet of dugongs and turtles, but in more temperate environments such as NSW, few animals actually directly consume seagrass (Klumpp *et al.,* 1989). Rather, as stated above, its importance to most megafauna is in the provision of food and habitat for the species upon which they feed.

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

are larger, often predatory, mobile animals that are associated loosely with the seagrass bed itself rather than individual leaves, and include crabs, prawns and fishes.

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

Almost all estuaries have some cover of seagrass, but four estuaries account for more than 50% of the total area of seagrass in NSW: Wallis Lake 30%; Clarence River 15%; Lake Macquarie 10%; and Tuggerah Lakes 7%. These and other barrier estuaries contain most of the larger seagrass beds, the exception is Jervis Bay (6%), which is an open ocean embayment. Those estuaries thought to have little or no seagrass are predominantly very small, intermittently open estuaries. It is not only the distribution that is important, it is also the composition and quality of the seagrass beds. For example, in poorly flushed estuaries such as Tuggerah Lakes, some seagrass has been smothered by algae, whilst in Botany Bay, altered wave regimes have caused sea bed erosion and seagrass loss (West 1989; Keough and Jenkins 1995). In other estuaries, the species composition of seagrass beds has been altered. Eelgrass has replaced strapweed in parts of Botany Bay (Keough and Jenkins 1995), and paddleweed has replaced eelgrass in parts of Lake Macquarie (King 1986). As discussed above, such changes have implications for the types of assemblages that beds, and ultimately estuaries, can support.

2. Mangroves

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

Like seagrasses, mangroves have been widely recognised as important ecological communities, and some studies suggest they are the most productive (in terms of organic matter produced per hectare per year) of all estuarine habitats (Larkum 1981). They: provide habitat for a variety of fish and invertebrates (e.g. SPCC 1981a & b; Pollard and Hannan 1994; Robertson and Alongi 1995); provide organic materials that form the basis of detrital food chains (West 1985; Robertson and Alongi 1995); provide feeding and roosting habitat for numerous species of birds (Chapman and Underwood 1995); stabilise sediments (West 1985; Robertson and Alongi 1995); recycle nutrients (Robertson and Alongi 1995); and act as a filter system between the land and aquatic environment (NSW Fisheries 1999a). Many commercially important marine and estuarine species live in mangrove channels as small juveniles including yellowfin bream, luderick, dusky flathead, silver biddy, sea mullet, flat-tail mullet, prawns and mud crabs. They also feed and shelter in mangrove channels as adults, as do several non-commercial species (Bell *et al.*, 1984). As mangroves are partially drained at low tide, there are few resident fishes of mangroves, rather they are visited during high tide by species from adjacent habitats (Hutchings and Recher 1974; Rooker and Dennis 1991). Resident species are likely to include gobies, perchlets and toadfish.

Mangroves are not as widespread as seagrasses because of their reliance upon more marine conditions. As such, they are rarely recorded from estuaries that are intermittently open to the sea, which comprise about 50% of all estuaries. Further, three estuaries, Port Stephens (25%), Hunter River (15%) and Hawkesbury River (10%) account for 50% of the total area of mangroves recorded in NSW. These are all located in the central region of the State, are large in terms of surface area and are permanently open to the sea.

3. Saltmarsh

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

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

as energy pathways, and the export of detritus to adjacent habitats, is very limited and invariably from overseas studies in different types of saltmarsh to those in NSW (Morrisey 1995; Adam *et al.,* 1985).

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

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

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

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

4. Unvegetated soft substrata

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

In comparison to vegetated habitats such as seagrass and mangroves, intertidal shores 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.

Sandflats are generally found near the mouths of estuaries, where there are stronger currents and wave action, and sand. Mudflats are located further upstream in more sheltered environments, where silt and clay that has been carried downstream from the upper catchment settles out in response to a reduction in flow and mixing with more saline waters (DPWS 1992). Mudflats remain saturated during low tide due to their smaller particle size and chemical properties prohibiting the creation of large spaces between particles (Inglis 1995). This also causes minimal flushing with oceanic water, and combined with the decomposition of organic matter, causes all but the top few centimetres of sediment to become deoxygenated (Inglis 1995). As most animals can not survive anoxic conditions, mudflats are comprised of a distinct set of fauna, which is discussed in detail below.

Most of the studies of assemblages of fish associated with unvegetated sediments have been done in comparison to vegetated habitats such as seagrass (e.g. Gray *et al.,* 1996; Connolly 1994; Ferrell and Bell 1991; SPCC 1981a). Such studies generally found that seagrasses supported more diverse and abundant assemblages, but that bare sand was also important for some species, particularly sand whiting, sand mullet, silver biddy, snapper, flatheads and flounders (SPCC 1981a; Gray *et al.,* 1990; Ferrell and Sumpton 1997). Bare substrata are also important habitat for many species of baitfish, particularly sprats and sardines (Clupeidae), hardyheads (Atherinidae) and anchovies (Engraulidae) (Lincoln Smith and Jones 1995). SPCC (1981a) recorded 102 species from soft bare substrata within Botany Bay and, in relation to other habitats types within the bay, concluded that many species of marine and estuarine fishes inhabit soft bare substrata during at least part of their life cycle. Whilst not generally recognised as nursery habitat to the same extent as are vegetative habitats such as seagrass, bare substrata, particularly that adjacent to seagrasses, provides further habitat complexity within an estuary and important habitat for the adults of many species.

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

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

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

5. Rocky Shores and Reefs

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

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

Many species of fish and invertebrates depend on rocky reef habitat for some or all of their life (e.g. SPCC 1981b; Hamer 1986). Species of economic importance include rock blackfish, red morwong, luderick, bream, octopus, eastern rock lobster and abalone. Also, many of the protected aquatic species in NSW depend on rocky reef habitat for part, if not most of their life cycle, including grey nurse shark, blue devil fish, elegant wrasse, black and estuarine cod, blue groper, Australian bass and estuary perch (NSW Fisheries 1999a).

Diverse assemblages of brown, red and green macroalgae, along with sponges, ascidians and other sessile invertebrates enhance habitat complexity of rocky shores and reefs and provide many opportunities for specialisation (e.g. Jones and Andrew 1990; Lincoln Smith and Jones 1995). The large macroalgae (such as kelp) that partially cover most rocky reefs enhance overall species diversity by providing patches of shaded habitat favoured by distinct assemblages of organisms (Kennelly 1995). Also, rocky reefs along most of the NSW coast, including those within estuaries, are utilised on a seasonal basis by juveniles of tropical species. These juveniles are swept southward by the East Australian Current each summer and autumn (Kailola *et al.*, 1993; Kuiter 1993), but do not usually survive the winter or, if they do, they fail to establish breeding populations (Lincoln Smith and Jones 1995). Rocky reef provides refuge and feeding opportunities for a variety of fish and mobile invertebrates (e.g. SPCC 1981b; Jones and Andrew 1990; Lincoln Smith *et al*., 1992; Lincoln Smith and Jones 1995). Small fish and invertebrates can escape predators by hiding in cracks and crevices and larger fish such as yellowfin bream, sergeant baker, wirrah and red rock cod, along with octopus and cuttlefish appear to use rocky reef as cover from which they can ambush passing prey. Pelagic fish including kingfish, tailor and Australian salmon are also attracted to rocky reef areas by aggregations of small baitfish such as yellowtail. Some fish, such as luderick, herring cale, surgeon fishes and drummers along with abalone and sea urchins eat drift and/or attached algae associated with rocky reefs (e.g. Hamer 1986; Jones and Andrew 1990).

It is apparent that there are numerous aquatic habitats within estuaries, and that they all serve different and important functions for fish and invertebrates targeted in the estuary general fishery. Rather than attempt to prioritise habitats in terms of importance however, it is more important to realise that they are interconnected. Loss of one habitat type or area is unlikely to be compensated for by the existence of an adjacent habitat. Studies suggest that in terms of habitat for juvenile fish and invertebrates, seagrass is the most important habitat, but if adjacent mangroves and saltmarsh are lost, then there is likely to be a drop in productivity and an increase in sediments and nutrients entering the system. These inputs could diminish the value of seagrass habitat or ultimately lead to its disappearance, with the resultant change in faunal composition. With this in mind, the following sections will highlight those areas of particular conservation significance within estuaries and assess the potential impact that the proposal is having, or could have on those habitats and areas.

APPENDIX F3 JAMBA AND CAMBA BIRDS

(Source: Simpson and Day 1996; Pizzey and Doyle 1984; NPWS Atlas of Wildlife database).

FAMILY	COMMON NAME	SCIENTIFIC NAME		DISTRIBUTION		
				region	timing	breeding
Procellariidae	Streaked Shearwater	*Calonectris leucomelas*	J,C	All	Su	no
	Wedge-tailed Shearwater	*Puffinus pacificus*	J	All	Sp & Su	all
	Fleshy-footed Shearwater	*Puffinus carneipes*	J	All	Su & Au	no
	Sooty Shearwater	*Puffinus griseus*	J,C	All	Sp, Su & Au	no
	Short-tailed Shearwater	*Puffinus tenuirostris*	J	All	Sp, Su & Au	no
Ardeidae	Cattle Egret	*Bubulcus ibis*	J,C	All	Winter	no
	White Egret	*Egretta alba*	J,C	All	All	all
	Eastern Reef Egret	*Egretta sacra*	C	All	All	no
Scolopacidae	Turnstone	*Arenaria interpres*	J,C	All	Sp & Su	no
	Eastern Curlew	*Numenius madagascariensis*	J	All	Sp, Su & Au	no
	Whimbrel	*Numenius phaeopus*	J,C	All	Sp & Su	no
	Little Whimbrel	*Numenius minutus*	J,C	1-4	Sp & Su	no
	Little Greenshank	*Tringa stagnatilis*	J,C	All	Winter	no
	Greenshank	*Tringa nebularia*	J,C	All	Sp & Su	no
	Wood Sandpiper	*Tringa glareola*	J,C	All	Sp & Su	no
	Grey-tailed Tattler	*Tringa brevipes*	J,C	All	Sp & Su	no
	Wandering Tattler	*Tringa incana*	J,C	1-5	Sp & Su	no
	Common Sandpiper	*Tringa hypoleucos*	J,C	All	Sp, Su & Au	no
	Terek Sandpiper	*Xenus cinereus*	J,C	All	Sp & Su	no
	Japanese Snipe	*Gallinago hardwickii*	J,C	All	Sp & Su	no
	Black-tailed Godwit	*Limosa limosa*	J,C	All	Sp & Su	no
	Bar-tailed Godwit	*Limosa lapponica*	J,C	All	Sp & Su	no
	Red-necked Stint	*Calidris ruficollis*	J,C	All	Aug-May	no
	Long-toed Stint	*Calidris minutilla*	J,C	All	Sp & Su	no
	Sharp-tailed Sandpiper	*Calidris acuminata*	J,C	All	Aug-Apr	no
	Curlew Sandpiper	*Calidris ferruginea*	J,C	All	Sp & Su	no
	Knot	*Calidris canutus*	J,C	All	Aug-Apr	no
	Great Knot	*Calidris tenuirostris*	J,C	All	Sp & Su	no
	Sanderling	*Crocethia alba*	J,C	All	Sp & Su	no
	Broad-billed Sandpiper	*Limicola falcinellus*	J,C	All	Sp & Su	no
	Ruff	*Philomachus pugnax*	J,C	1-4	Sp & Su	no
Rostratulidae	Painted Snipe	*Rostratula benghalensis*	C	All	All	all
Charadriidae	Mongolian Sand-Plover	*Charadrius mongolus*	J,C	All	Sp & Su	no
	Large Sand-Plover	*Charadrius leschenaultii*	J,C	All	Aug-May	no
	Eastern Golden Plover	*Pluvialis dominica*	J,C	All	Aug-Apr	no
	Grey Plover	*Pluvialis squatarola*	J,C	All	Aug-Apr	no
Stercorariidae	Pomarine Skua	*Stercorarius pomarinus*	J,C	All	Sp & Su	no
	Arctic Skua	*Stercorarius parasiticus*	J	All	Sp & Su	no
Laridae	White-winged Black-tern	*Chlidonias leucoptera*	J,C	All	Sp & Su	no
	Crested Tern	*Sterna bergii*	J	All	All	all
	Asiatic Common Tern	*Sterna hirundo*	J,C	All	Sp & Su	no
	Little Tern	*Sterna albifrons*	J,C	All	Sp & Su	Scattered*
	Caspian Tern	*Sterna caspia*	C	All	All	4-7
Accipitridae	White-bellied Sea-Eagle	*Haliaeetus leucogaster*	C	All	All	all

* denotes that little terns have historically bred in approximately 70 estuaries, but the numbers of successful sites is diminishing. The most successful sites at the time of this report were Harrington, Farquhar Inlet, Sawtell, Botany Bay and Lake Wollumboola.

APPENDIX F4 PROFILES OF THREATENED SPECIES

1. Fisheries Management Act 1994

a) Endangered species

Green sawfish (*Pristis zijsron*)

The following information was taken from the NSW Fisheries Scientific Committee's website (www.fsc.nsw.gov.au), which provides profiles of species listed in the *FM Act*. Green sawfish have been recorded in the tropical Indo-West Pacific from eastern Australia and Papua New Guinea through to western India, with a disjunct population off Mozambique and eastern South Africa. In Australia, the species occurs mainly in the tropics from Broome to southern Queensland, with individuals found as far south as Sydney and a single record from Glenelg, South Australia. In NSW, specimens have been collected from Byron Bay in the north to Parramatta River in the south, plus an unofficial record from Jervis Bay. The species is thought to grow to approximately 7.3 m in length and has been reliably recorded at 5 m, with males maturing by 4.3 m. This is a species with low fecundity and it is thought that they may have up to 20 young. They feed on fishes and benthic invertebrates, using the saw as a club to stun schooling fishes such as mullet, and as a shovel to uncover benthic animals (Allen 1989). Green sawfish have suffered a serious population decline in NSW. Prior to 1972, the species was regularly found in the shallow waters at the mouths of the Tweed, Clarence and Richmond Rivers and on outside ocean beaches such as Yamba. The last specimen from the Sydney region was taken in 1926. The causes of this decline are thought likely to include:

- bycatch in shallow water prawn trawling, and other netting methods in shallow water, as they would rarely have been returned to the water alive;
- targeted harvest for flesh, fins and saws. The fins command a high price in the shark fin trade and the saws are used in traditional medicine and were sold as curios; and
- habitat degradation.

Sawfish are also listed as vulnerable under the *EPBC Act* 1999.

Grey nurse shark (*Carcharias taurus*)

Grey nurse sharks are found around the world in inshore waters, primarily in sub-tropical and temperate regions around the main continental landmasses, with the exception of the eastern coast of North and South America and Antarctica. Known key sites for grey nurse sharks or major aggregations of the species in NSW can be found at reefs off Port Stephens, Seal Rocks, Forster, Laurieton, Batemans Bay and South West Rocks. Relatively little is known about the migratory habits of Australian grey nurse sharks. There is evidence from Australian data that suggests migrational movement, probably in response to water temperatures, up and down the coast. At certain times of the year, grey nurse sharks aggregate according to sex. Males are predominant in southern Queensland during July to October, while a high proportion of sharks off central NSW at the same time of year is composed of females. Grey nurse sharks are often observed just above the seabed in or near deep sandy-bottomed gutters or rocky caves, in the vicinity of inshore rocky reefs and islands, generally between 15 m and 25 m. They have also been recorded in the surf zone, around coral reefs, and to

depths of around 200 metres on the continental shelf. The diet of the adult grey nurse shark consists of a wide range of fish, other sharks, squids, crabs and lobsters, and some observations also suggest that schools of grey nurse sharks can feed cooperatively by concentrating schooling prey before feeding on them (Environment Australia 2000a).

In Australia, two populations are thought to exist, one on the east coast and one on the west. The east coast population has been recorded from as far north as Mackay and extends south around the greater part of the southern half of the continent. On the west coast, the population extends as far north as the North West Shelf. They are still found within this general historical range, but the east coast population is thought to have declined considerably. During the 1960s and 1970s, spearfishers took large numbers of grey nurse sharks and reduced the population to a low level. Setlining by commercial fishers also continues to take a small number each year, and the beach meshing program was also responsible for catching large numbers of grey nurse sharks up until 1975. Despite protection since 1984 in NSW waters, the species has not shown an increase in population size. Current research (quarterly surveys from November 1998) indicates a much lower adult population size than when the species was recommended to be listed as a vulnerable species in NSW (early 1999), and the status of juvenile numbers in the sampled population is uncertain (www.fsc.nsw.gov.au, 1999). These factors were also largely responsible for its listing as a vulnerable species under the *EPBC Act*.

b) Vulnerable species

Black cod (*Epinephelus daemelii*)

Black cod are found on estuarine and inshore reefs and deeper offshore reefs in temperate and subtropical waters of the southeastern Pacific. In Australia, they are found from Queensland to Kangaroo Island, although they are rare and probably only represented by non-breeding migrants in more southern areas. Hence, they are found along the entire NSW coastline, which is also the centre of the species' Australian mainland distribution (Heemstra and Randall 1993; Pogonoski *et al.,* In prep). Their maximum size is 1 - 2 metres in length, but are commonly only found up to 0.8 m (Hutchins and Swainston 1986). Smaller fish are females, which change sex to become male at around 1 m in length (Pollard unpublished). They are an aggressive, highly territorial species, and are usually found in association with caves, ledges or large underwater structures such as bridge pylons that they may occupy for life (Gill and Reader 1992; Henrisson and Smith 1994). Their numbers are reported to have declined significantly as a result of spearfishing pressure in the 1970s (Pogonoski *et al.,* In prep.). Lincoln Smith *et al.,* (1989) reported that 137 black cod were caught in spearfishing competitions in NSW in 1976 alone. Their territorial and curious nature, combined with their slow movement, is thought to have made them an easy target and a prize catch by both line and spearfishers, although they are no longer thought to be targeted by either group of fishers. Commercial fishers still report occasional captures, particularly from deeper offshore reefs. Historical, anecdotal evidence suggests that a decline in abundance in the Sydney region occurred around 1900 when coastal towns became populous and fishing and shipping pressures increased (Roughley 1916). Their slow growth and territoriality probably also prevents rapid recovery from decreases in population size. Despite protection in NSW waters since 1983, there is no evidence of an increase in their abundance.

Great white shark (*Carcharodon carcharias*)

White sharks are found worldwide in temperate, coastal waters but are rare in tropical waters. In Australia, they have been recorded from southern Queensland to northwestern Western Australia. There are no reliable estimates of the number of white sharks in Australian waters, but it is thought

that the numbers of fish are decreasing. Based on data sets from the region between Port Stephens and Wollongong, great whites appear to have suffered a population decline in NSW, with a reported decreases in annual catches in beach meshing from 1950s to 1990s, and less compelling evidence of decline from game-fishing landings (www.fsc.nsw.gov.au, 1998).

In many places around the world the white shark is a protected species (Environment Australia 2000b). This happened first in South Africa in 1992, then in Namibia, the Maldives, and in Florida and California. This species is now protected in all Australian states and territorial waters. It is believed that a white shark of 5 - 6m in length is likely to be 15 - 25 years old, and the most commonly encountered white sharks are between 3 - 4 m in length. Females mature at 4.5 - 5 m in length and males at probably less than 4 m, and as the fish matures, its diet changes. Fishes to about 2 metres normally eat squid and other fishes such as stingrays and other sharks. Adults eat seals, sea lions, dolphins and dead whales, although some will continue to eat fishes such as snapper. They have also been known to eat elephant seals, sea otters, turtles and sea birds. Great white sharks are also listed as vulnerable under the *EPBC Act*.

c) Protected species - Section 19 (totally protected)

Australian grayling (*Prototroctes maraena*)

Australian grayling are essentially a freshwater fish that inhabits coastal streams in southeastern Australia, including Tasmania. It is the only extant species in the family Prototroctidae, as the New Zealand grayling (P. *oxyrhynchus*) is presumed extinct. Australian grayling grow to about 300 mm or about 6 years, but are more common at around 250 mm. They form aggregations and spawn in freshwater between mid-May and mid-July, and many are thought to die shortly after spawning, at about 2 - 3 years of age. The larvae are apparently swept downstream to the estuary or the sea and sub-adult fish, 55 - 75 mm in length, return to freshwater habitats six months later (Faragher 1995). In the past, anglers often caught them during spawning aggregations, but they are now totally protected. Their diet includes small crustaceans, insects and their larvae and algae. Australian grayling appear to undergo long-term fluctuations in population abundance, with spawning success and larval survival governed by highly variable flows and unobstructed passage to the sea. These requirements are thought to have restricted their distribution to several river catchments on the far south coast of NSW (Faragher 1995). This species is also listed as vulnerable under the *EPBC Act* 1999.

Eastern blue devil (*Paraplesiops bleekeri*)

Eastern blue devils are recorded from coastal waters of southern Queensland to southern NSW, and seem common only south of Sydney to Ulladulla (Kuiter 1993). They grow to 40 cm in length and inhabit rocky reefs in both estuaries and offshore, in from 3 - 30 m depth. Eastern blue devil fish are totally protected.

Elegant wrasse (*Anampses elegans*)

Elegant wrasse are recorded from the southwestern Pacific, generally from central to southern NSW, Lord Howe Island, Easter Island and northern New Zealand. Juveniles are found in weeds in coastal bays and harbours, larger juveniles in small aggregations on coastal and estuarine rocky reefs and adults usually deeper to about 30 m (Kuiter 1993). They feed on a variety of invertebrates and algae. Females often occur in aggregations of up to 80 or more fish, in contrast to the singular, territorial males, and grow to about 30 cm. Elegant wrasses are totally protected.

Estuary cod (*Epinephelus coioides*)

Estuary cod are found on estuarine and inshore reefs along the NSW coastline from about Sydney northwards (Heemstra and Randall 1993; Pogonoski *et al.*, In prep.). They are reasonably territorial, but have been found in a wide variety of estuarine and marine habitats: within NSW estuaries, they are most likely to occur around drop-offs or in caves (Pogonoski *et al.*, In prep.). Estuary cod grow to about 1 metre in length (Kuiter 1993), and although they were probably never abundant in NSW estuaries, are considered vulnerable to a variety of fishing pressures including demand for the live fish trade (Pogonoski *et al.*, In prep.). Consequently, they are totally protected in NSW waters.

Queensland groper (*Epinephelus lanceolatus*)

The Queensland groper is fairly similar to the estuary cod, and has a similar range and habitat preference within NSW (Pogonoski *et al.*, In prep). They do, however, grow to a much larger size of up to 3 metres (Kuiter 1993). Queensland groper is totally protected within NSW waters for similar reasons to those applicable to the estuary cod (see above).

Weedy seadragon (*Phyllopteryx taeniolatus*)

Seadragons are a member of the family Syngnathidae, which also includes seahorses and pipefishes. An unusual feature of this family of small fishes is that the male broods the young, which leave the brood pouch at a relatively advanced stage (Kuiter 1993). Weedy seadragons are found on estuarine and inshore reefs along the NSW coastline north to about Port Stephens (Hutchins and Swainston 1986). Their preferred habitat appears to be the interface between kelp beds and sand (Kuiter 1993). Their maximum size is about 45 cm (Kuiter 1993). The species is quite common in its preferred habitat and population numbers are not thought to have declined (Pogonoski *et al.*, In prep.), however, due to its vulnerability to over-collecting for the aquarium trade, it is totally protected within NSW waters.

d) Protected species - Section 20 (protected from commercial fishing)

Australian bass (*Macquaria novemaculeata*)

Australian bass are primarily a freshwater fish, found in coastal rivers, lakes and estuaries along the entire NSW coastline (Pollard and Growns 1993). They occur from as far north as Fraser Island off Queensland, to Wilsons Promontory in Victoria. Adults migrate downstream to breed in estuaries during winter, with spawning success and subsequent recruitment linked to flooding (Harris 1986). They feed on prawns, fish, molluscs and insects. Australian bass are a prized sportfish among anglers and are protected from commercial exploitation in NSW. Populations have declined in the face of previous harvesting of spawning aggregations, river regulation (affecting both fish passage and the frequency of flooding), and catchment alteration (Harris 1984; Pollard and Growns 1993).

Blue groper (*Achoerodus viridis*)

The blue groper is a marine fish that inhabit inshore rocky reefs along the entire NSW coastline (Kuiter 1993). Their young recruit to sheltered habitats that provide physical structure, including estuarine seagrass beds (Gillanders 1999). Larger juveniles are common around sheltered rocky reefs within the lower reaches of marine-dominated estuaries, and appear to move out to inshore reefs gradually as they grow (Gillanders 1999). They are a popular angling species, attaining at least 1.2 metres in length (Kuiter 1993). Populations appeared to decline sharply in the 1960s because of

fishing pressure and, although significant recovery has occurred in recent years, the species remains protected from spearfishing and commercial exploitation within NSW in view of its curious behaviour and popularity with SCUBA divers (Smith *et al.*, 1996).

Estuary perch (*Macquaria colonorum*)

The estuary perch has a similar distribution and biology to that of the Australian bass but it prefers slightly more saline waters, and is therefore more likely to be found in upper estuarine/ brackish water rather than freshwater areas (Merrick and Schmida 1984). Spawning occurs in saltwater areas of estuaries when temperatures reach 14.5 - 16^{o}C. Each female releases several hundred thousand eggs that float to the surface, where hatching occurs 2 - 3 days later. The diet of larger fish consists of prawns, worms, bivalve molluscs and fishes (Allen 1989). In view of its similarity to the bass, the estuary perch is subject to the same bag and size limits, and is also protected from commercial exploitation in NSW.

2. Threatened Species Conservation Act 1995

Unless otherwise specifically referenced, the following species profiles were obtained from the website of the NSW National Parks and Wildlife Service, at www.npws.nsw.gov.au/2001. The profiles for marine turtles and dolphins were obtained from the website of Environment Australia, at www.environment.gov.au , respectively.

a) Endangered species

Plants

Wilsonia rotundifolia

Wilsonia rotundifolia is a dwarf subshrub of the family Convolvulaceae. It is salt tolerant and occurs in coastal saltmarshes and inland saline sites. In coastal NSW, it is known from four coastal populations at Lake Wollumboola, Swan Lake, Meringo Lagoon and Lake Coila, and the total number of plants in coastal sites is only a few hundred. It occurs in mid marsh, mixed with *Sporobolus virginicus* and *Sarcocornia quinqueflora*. Trampling, by humans or cattle, results in stem breakage, and populations are potentially threatened by urban development (NPWS Scientific Committee Final Determination newsletter).

Birds

Beach stone-curlew (*Esacus magnirostris*)

Beach stone-curlews are exclusively coastal and have been recorded around the north coast of Australia and associated islands from Onslow in Western Australia to the Nambucca River in NSW, and rarely southwards to Forster (Marchant and Higgins 1993). They have largely disappeared from the southeastern part of its former range and are now rarely recorded on ocean beaches in NSW. They prefer open, undisturbed beaches, islands, reefs and estuarine intertidal sandflats and mudflats with mangroves nearby. They also frequent river mouths, offshore sandbars associated with coral atolls, reefs and rock platforms and coastal lagoons. They forage at low tide in search of crabs and other marine invertebrates. Threats to the species include loss of habitat due to residential and industrial development, human disturbance through beach-combing, boating and 4WD vehicles, predation by raptors, cats and dogs, nest destruction by pigs or high tides and nest desertion.

Bush stone-curlew (*Burhinus grallarius*)

Bush stone-curlews are widespread in the north and northeast of Australia (Marchant and Higgins 1993). This species has largely disappeared from the southern part of its former range, probably because of extensive clearing of woodlands. Records indicate that the species was once common throughout eastern NSW, but it is now restricted to populations at Gosford, Port Macquarie, Grafton, Port Stephens and Karuah. They prefer lightly timbered open forest and woodlands, particularly of casuarina, eucalyptus, acacia or polycarpa. They are occasionally recorded in mangroves and saltmarsh, especially when bordered by casuarinas, and have been recorded nesting within saltmarsh (Marchant and Higgins 1993). They feed on insects, molluscs, centipedes, crustaceans, spiders, frogs, lizards, snakes and some vegetation and seeds (Marchant and Higgins 1993). Threats to the species include loss of habitat due to residential and industrial development, intense cultivation, small subdivision, overgrazing and burning (Marchant and Higgins 1993).

Hooded plover (*Thinornis rubricollis*)

Hooded plover occur on sandy beaches and inland saltlakes of southeastern and southwestern Australia. They are endemic to southern Australia and are found along the coast from Jervis Bay to the western Eyre Peninsula in South Australia, along the coast of Tasmania, the Bass Strait Islands and from 30^{o}S on the Western Australia coast to the western edge of the Great Australian Bight. Occasional strays are recorded as far north as Sydney, but the most important sites for the species are on the south coast. Sussex Inlet, particularly on Bhewerre and Cudmirrah Beaches, is thought to support the highest density of hooded plovers, followed by the coastline between Lake Conjola and Lake Tabourie (Carter 1995). A survey in 1988 suggested the NSW population might be as low as 62 individuals of a total population of approximately 5000 (Marchant and Higgins 1993). Hooded plover are found most often on long stretches of sandy shore, backed by tussock or dunes covered in creeping plants with nearby inland lakes. Their preferred habitat has a wide wave-wash zone with beachcast seaweed for feeding, backed by sparsely vegetated sand dunes for shelter and nesting. Their diet includes polychaete worms, molluscs, crustaceans, insects, waterplants and seeds. Threats to the species include artificially high populations of silver gulls around human settlements leading to increased predation, predation by foxes and raptors, loss of habitat due to development for housing and recreation, human disturbance during the summer breeding season, particularly four-wheel driving along sand dunes and beaches, and destruction of nests by stock.

Little tern (*Sterna albifrons*)

Little terns are migratory or partly migratory seabirds. They occur from Shark Bay in Western Australia, around northern and eastern Australia, to the east coast of Tasmania and around to the Gulf of St Vincent in South Australia. In NSW, a second population of the subspecies *sinensis* predominantly occurs, which is migratory, breeding in the spring and summer along the entire east coast from Tasmania to northern Queensland. The other population of the subspecies breeds in Asia and migrates to Australia in summer, masking the size of the threatened, eastern Australian population. Little terns have been recorded nesting at 70 sites along the NSW coast, but at only 31 since 1987 and 11 in 1998/99. Since 1995, the largest, most successful colonies have been at Sawtell, Harrington, Botany Bay, Lake Wollumboola and more recently Farquhar Inlet (formerly known as Old Bar) (NPWS 2000b). In NSW, the species is strictly coastal. Most of the nesting sites are sand-spits, sand islands or beaches within or adjacent to the estuaries of rivers, creeks and coastal lakes. Nesting also occurs at some sites on ocean beaches well away from estuaries, but often with a large coastal lake nearby. Little terns in NSW feed predominantly, perhaps exclusively, on fish less than 10 cm long

and often generally referred to as whitebait. They include perchlets (*Ambassis* spp.), surfsardines (*Iso rhothophilus*) and sprats (Clupeidae), but may also include juvenile mullet, gudgeons, tailor and whiting. Most feeding occurs inside or at the mouths of estuaries and up to 500 m offshore. There are numerous threats to the species, and human disturbance has been identified as a major, and often the most important, factor leading to poor breeding success and abandonment of nest sites. Human disturbance can range from the extreme of 4WD and trail-bike use through to walking or simply sitting or fishing on the beach, all of which may keep the terns off nests. Others include adverse weather conditions, nesting at locations prone to flooding, predation by foxes, dogs, cats, rats and a variety of birds, coastal development, availability of food, damage to estuarine habitats and pollution (NPWS 2000b). It is also listed as endangered under the *EPBC Act* 1999.

Zannichellia palustris

Zannichellia palustris is a submerged, weakly rhizomatous aquatic annual or perennial plant. It has a cosmopolitan distribution, but in Australia is known only from the Murray River estuary in South Australia and the lower Hunter region in NSW. It is considered to be indigenous to NSW and is recognised as rare nationally. It occurs in fresh to brackish, still to slowly-moving waters, and recent collections of *Zannichellia palustris* in NSW are from Ironbark Creek and tributaries at Shortland and Wallsend, in Black Creek at Cessnock and in ponds on Kooragang Island. It has also been recorded from near Belmont. NSW populations of *Zannichellia palustris* behave as annuals and dieback completely each summer. The individual patches range from about 5 m^2 to 100 m^2, but vary from year to year. None of the known sites of *Zannichellia palustris* in NSW are formally protected, and none are managed in any way for the conservation of the species. Further, all the known sites are in areas where considerable changes have, and are continuing, to take place in their catchments. These changes in catchment land use may result in changes in hydrological conditions and water quality, which may affect the ability of the species to persist in areas where it is known to occur.

b) Endangered populations

Little penguins (*Eudyptula minor*) at Manly, Sydney Harbour

Little penguins, only found in Australia and New Zealand, once ranged from Swan River in Western Australia through Tasmania and up to Moreton Bay in Queensland, and may still occasionally venture that far. They are relatively common in the waters of southern Australia, breeding mainly on offshore islands. They generally breed from south of Port Stephens in NSW, including the Sydney region, along the coast through Victoria, South Australia, Tasmania and as far as Fremantle in Western Australia. In 1986, it was estimated that the total breeding population in eighteen known colonies in NSW consisted of 17,000 pairs, most at the large colonies on Montague, Tollgate and Brush Islands. It is now believed to be closer to 49,000 birds at 22 known sites, however, the population in North Harbour/Manly is the only population known to breed on mainland NSW, and consists of only approximately 50 breeding pairs.

Little penguins nesting habitat normally consists of burrows built in sand dunes, rockpiles, sea caves and occasionally under buildings. At Manly, a range of nest types are utilised, including under rocks on the foreshore, rock falls under seaside houses, garages, under stairs, in wood piles and under overhanging vegetation. Male penguins return to their colonies between June and August to reconstruct or dig new burrows and to attract females. About 3 months later, fledglings leave the nest and only return annually to moult until they are about 3 - 4 years old, when they return to breed.

Little penguins appear to be opportunistic feeders, foraging in relatively shallow waters. Their diet consists mainly of small schooling fish, like anchovies (*Engraulis australis*), pilchards (*Sardinops neopilchardus*), squid (Order Teuthida) and to a lesser extent, krill (Euphausiids). The population of penguins on Lion Island, in the Hawkesbury River, is also known to feed on blue sprats (*Spratelloides robustus*), small-mouthed hardyheads (*Atherinosoma microstoma*) and Ogilby's hardyheads (*Atherinomorus ogilbyi*).

The major threat to the Manly population is the loss of suitable habitat. Past development has greatly reduced available habitat in the area. Disturbance of little penguins and their habitat is also a major threat to the population. Predators such as dogs, cats, and foxes are known to take penguins from shallow burrows and as they move between the water and their nesting habitat. Commercial fishing has also been listed in the threat abatement plan as a threatening process, although there is currently no data to support the claim and fishing is not listed in the Act as a Key Threatening Process. Fishing, primarily hauling in this area, provides competition for food resources, disturbance due to noise outside burrows and may obstruct penguins from returning to their nests (NPWS 2000a).

c) Endangered communities

Shorebirds at Taren Point

The Taren Point Shorebird Community is the community of shorebirds that uniquely occurs on the relict marginal shoal of the Georges River that occurs between Taren Point and Shell Point in Botany Bay. This bird community is part of the highly diverse shorebird assemblage characteristic of rich coastal mudflats of eastern Australia dominated by species from the Order Charadriiformes (also known as waders). The features that distinguish the Taren Point Shorebird Community from other assemblages in Botany Bay is the unique occurrence of the vulnerable species Terek sandpiper, and a greater abundance of the small shorebirds such as red-necked stint, ruddy turnstone, red knot, curlew sandpiper, Pacific golden plover and grey-tailed tattler. There is also a general absence of sand plovers, which occur elsewhere in Botany Bay. The Taren Point Shorebird Community occupies an area that is defined by the distinct geological feature, which is a relict muddy-sand marginal shoal of the Georges River that was formed during the Holocene. The northern boundary is a small spit on the eastern side of the Captain Cook Bridge and the southern boundary is the terminal lobe of Shell Point. Threats to the survival of the community include intensification or alteration of uses of the area utilised by the community, and changes to the extent and distribution of the fringing mangrove community. Towra Point Nature Reserve is adjacent to the area occupied by this shorebird community, but it is of different geomorphological origin and does not provide alternative habitat for the Taren Point Shorebird Community.

d) Vulnerable species

Plants

Wilsonia backhousei

Wilsonia backhousei is a perennial, matforming, prostrate subshrub of the family Convolvulaceae. It often occurs as pure, or nearly pure, stands. At most sites, stands are limited in extent (in the order of a few $10m^2$). The most extensive stands occur around Jervis Bay. It is found in intertidal saltmarshes and, more rarely, on seacliffs. In NSW, *Wilsonia backhousei* is scattered along the coast, reaching its northern limit at Wamberal Lagoon. There has been a considerable decline in

the abundance of the species this century, largely because of loss of habitat. It is also readily damaged by trampling and vehicle use, and recovery from damage is slow (NPWS Scientific Committee Final Determination newsletter).

Reptiles

Green turtle (*Chelonia mydas*)

Green turtles occur worldwide and are found in tropical and subtropical waters. They inhabit seagrass beds and coral reefs with a good cover of seaweed. Adult turtles are herbivores, feeding on seaweeds and seagrasses, whereas immature turtles feed on jellyfish, small molluscs, crustaceans and sponges. Green turtles grow to an average of about 1 metre and are sexually mature generally between 91.5 – 122.5 cm CCL. They may migrate up to 3000 km from feeding grounds in Indonesia, Papua New Guinea, New Caledonia, Fiji, Queensland, Northern Territory and Western Australia to breed and nest in southern and northern Great Barrier Reef, northwest Northern Territory, Gulf of Carpentaria, Western Australia, Coral Sea and Ashmore Reef. Nesting generally occurs from late November to January and earlier in the Northern Territory from July to December. They recruit from the pelagic phase as immature turtles (CCL = 40 - 50 cm) to inhabit subtidal and intertidal coral and rocky reefs and seagrass meadows of the continental shelf. While they are most abundant within 1000 km of their nesting beaches, they live year round in coastal waters from central Western Australia, through Northern Territory and Queensland to central New South Wales, continuing to feed in waters as cool as 15°C. Green turtles are also listed as vulnerable under *EPBC Act* 1999.

Leatherback turtle (*Dermochelys coriacea*)

Leatherback turtles are the largest of the marine turtles, with shells averaging 1.6 metres in length and with a total weight of up to 500 kg. They are so named because of their leathery shell, which is black with lighter spots and has five ridges. They inhabit tropical and warmer temperate waters, feeding on jellyfish and other soft bodied invertebrates. Unlike other marine turtles, leatherbacks spend almost their entire life feeding within the water column and are generally regarded as an oceanic species. Leatherback turtles do not nest in Australia in any numbers. Only a small population of leatherback turtles has been found breeding and nesting in eastern Australia, mainly from December to January. In Queensland, 1 - 3 females per year nest on Wreck Rock and adjacent beaches, and sporadic nesting occurs at other widely scattered sites in Queensland, New South Wales and the Northern Territory. In Western Australia, there are 2 - 6 sightings off the mid-west coast per year. The major breeding and nesting sites in the Asia/Pacific occur in Indonesia, Malaysia, Papua New Guinea and the Solomon Islands. They are listed as vulnerable under *EPBC Act* 1999.

Loggerhead turtle (*Caretta caretta*)

Loggerhead turtles are found worldwide, inhabiting tropical and warmer temperate waters such as coral reefs, bays and estuaries. While they are most abundant within 1000 km of their nesting beaches, they live year round in coastal waters from southern Western Australia, through the Northern Territory and Queensland to southern New South Wales. The southern Great Barrier Reef and adjacent mainland near Bundaberg is the breeding centre of the eastern Australian population. Breeding is centred on Dirk Hartog Island (Shark Bay), Muiron Islands, Ningaloo and the North West Cape area for the western population. Loggerhead turtles eat shellfish, crabs, sea urchins and jellyfish. They reach sexual maturity at about 30 years or more and grow to an average of 1 metre in size. Loggerhead turtles migrate from feeding grounds in the Northern Territory, New South Wales and Queensland to the above nesting sites on the eastern and western Australian coastlines. Mating occurs from late

October to early December, followed by nesting from late October to early March. They recruit from the pelagic phase as immature turtles (CCL = 70 - 80 cm, >10 years) to inhabit subtidal and intertidal coral and rocky reefs and seagrass meadows as well as deeper soft-bottomed habitats of the continental shelf. They are listed as endangered under *EPBC Act* 1999.

Birds

Australasian bittern (*Botaurus poiciloptilus*)

The Australasian bittern occurs from southern Queensland to Tasmania and southeastern South Australia, including most of Victoria and New South Wales. It also occurs in the southwestern corner of Western Australia. In NSW, the species has been recorded along the coast as well as in wetlands of the Murrumbidgee and Lachlan Rivers and is frequently recorded in the Murray-Darling Basin. It inhabits terrestrial and estuarine wetlands, generally where there is permanent water with dense vegetation including sedges, rushes and reeds. Essentially a freshwater species, it also occurs in dense saltmarsh vegetation in estuaries and flooded grasslands. At dusk, the species forages in shallow water up to 30 cm deep, primarily feeding on frogs, fish, invertebrates (including crayfish), leaves and fruit. The major threats to the species include grazing and trampling of riparian vegetation and siltation of waterbodies by livestock, predation by foxes, regulation of waterways, clearing and draining of habitat, salinisation and pollution of wetlands and degradation of drought refuges.

Black bittern (*Ixobrychus flavicollis*)

The black bittern occurs from southern New South Wales, north to Cape York and along the entire northern coast to the Kimberley region. They also occur in the southwestern corner of Western Australia. In NSW, the species has been recorded scattered along the coast, rarely south of Sydney or inland. They inhabit freshwater and estuarine wetlands, generally where there is permanent water with dense vegetation. They occur in flooded grassland, forest, woodland, rainforest and mangroves. At dusk and at night, the species forages for reptiles, fish and invertebrates, including dragonflies, shrimp and crayfish. The major threats to the species include grazing and trampling of riparian vegetation by livestock, predation by feral cats, clearing and draining of habitat, and salinisation and pollution of wetlands.

Black-tailed godwit (*Limosa limosa*)

Godwits are migratory wading birds that breed in Mongolia and Siberia, and visit Australia during the summer, arriving in August and leaving in March. They are most common between Weipa and Darwin, but are also found in small numbers along much of the Queensland coast south of Cairns, south of Derby in Western Australia, the southeast of South Australia, and mainly around Port Phillip Bay in Victoria. In NSW, they have been regularly recorded only on Kooragang Island (Hunter River), with scattered sightings from both coastal and inland areas. Inland records, particularly within the Murray-Darling Basin, indicate that a regular inland passage is used. Godwits are primarily found along the coast on sand spits, lagoons and mudflats, and inland on mudflats of lakes and swamps. They have also been recorded in meadows and sewage treatment works. Their diet includes a variety of invertebrates such as insects and larvae, earthworms, crustaceans, molluscs, spiders, spawn and tadpoles of frogs and fish eggs. Threats to the species include hydrological changes to inland lakes and tourism or agricultural developments reducing coastal and inland habitat areas.

Broad-billed sandpiper (*Limicola falcinellus* subsp. *sibirica*)

This subspecies of sandpiper are migratory wading birds that breed in north and northeastern Soviet Union, and visit India, southeast Asia and Australia during the summer. In Australia, they are most common along the northern coasts, particularly the northwest, with occasional birds seen on the southern coasts and very few inland. In NSW, the main site for the species is the Hunter River, with records along the coast south to Shoalhaven River. They are known to favour estuarine sand- and mudflats, particularly areas of soft mud on the seaward side of mangroves, saltmarshes and reefs as feeding and roosting habitat. They have also been recorded in shallow freshwater lagoons and sewerage treatment works. Their diet includes insects, worms, crustaceans, molluscs and seeds. Threats to the species include hydrological changes to inland lakes (for individuals that remain in Australia over winter) and development of coastal estuaries, mudflats and saltmarshes.

Collared kingfisher (*Todiramphus chloris*)

Also called the mangrove or white-collared kingfisher, this species occurs in the northern half of Australia, from Carnarvon, Western Australia, to Ballina, NSW (Pizzey and Doyle 1984). They are commonly found in plant associations of the littoral zone, particularly mangroves, but also tidal creeks and adjacent beaches, mudflats and around jetties. They also nest in hollows in mangrove trees or cavities tunnelled into termite mounds. Unlike the azure kingfisher (*Ceyx azureus*), they do not feed exclusively over water, but forage mostly over land. Their diet includes reptiles, small mammals, nestlings and eggs of birds, and fish. Near water, they feed from the surface of the water and from mangrove mud.

Comb-crested jacana (*Irediparra gallinacea*)

In Australia, comb-crested jacanas occur in the north and northeast of the country, originally from the Kimberley region east to about the Hunter region in NSW. They are thought to have expanded this range, however, and are now recorded as far south as Bermagui (Marchant and Higgins 1993). They are found primarily in freshwater wetlands, lagoons, billabongs, swamps, lakes and rivers where there is an abundance of floating aquatic vegetation, particularly waterlilies, nardoo or milfoil. They feed on seeds and aquatic insects from amongst aquatic vegetation and debris. They nest on loosely constructed platforms of aquatic vegetation up to 10 m wide and in NSW, breeding takes place between September and April.

Freckled duck (*Stictonetta naevosa*)

Essentially a freshwater species, freckled ducks also occur in coastal districts of southeastern and southwestern Australia, particularly during drought years. Eastern breeding grounds include the Murray-Darling Basin, Lake Eyre and southwestern Queensland. In coastal areas, they prefer swamps heavily vegetated with ti-trees. They feed on algae, seeds and the vegetative parts of various aquatic grasses and sedges, small crustaceans, zooplankton, worms, insects and small fish. Threats to the species include loss of habitat and breeding sites, river regulation and illegal hunting.

Great knot (*Calidris tenuirostris*)

Knots are migratory wading birds that breed in Siberia and migrate to Australia in large numbers from late August, leaving in March and April. Some individuals may stay over winter. They occur throughout Australia, including the coastal islands of Tasmania, but is most common and abundant in the north, and uncommon to rare further south. In NSW, they have been recorded in scattered sites along the coast to about Narooma, and are primarily found within sheltered, coastal

habitats containing large intertidal sand- and mudflats, including in inlets, bays, harbours, estuaries and lagoons. They have also been recorded on exposed reefs or rock platforms. Their diet includes bivalve molluscs, gastropods, polychaete worms and crustaceans. Threats to the species include hydrological changes to inland lakes (for those that remain over winter) and tourism or agricultural developments reducing coastal and inland habitat areas.

Greater sand plover (*Charadrius leschenaultii*)

Sand plovers are migratory wading birds that breed in central Asia and migrate to Australia in summer. The species is commonly recorded on the west coast, but is apparently rare on the east coast. In NSW, they have been recorded in coastal areas from the northern rivers region south to Shoalhaven Heads, with the majority of birds recorded in the Clarence and Richmond Rivers. They forage on intertidal sand- and mudflats in estuaries, and roost during high tide on sandy beaches or rocky shores. They have also been recorded on inshore reefs, rock platforms, and small rocky islands and sand cays on coral reefs. Their diet includes insects, molluscs and crustaceans. Threats to the species include hydrological changes to the Clarence and Richmond Rivers and tourism or agricultural developments reducing coastal and inland habitat areas.

Lesser sand plover (*Charadrius mongolus*)

Lesser sand plovers are migratory wading birds that breed in eastern Siberia, southern Mongolia, western China and the Himalayas and migrate to the coasts of eastern and southern Africa, the Middle East, India, Southeast Asia and Australia in summer. The species occurs around the entire coastline of Australia but is most abundant in the Gulf of Carpentaria and along the east coast of Queensland and northern NSW. They are rarely recorded south of Shoalhaven River. They favour beaches, sandflats, mudflats and mangroves within estuaries, and roost during high tide on sandy beaches or rocky shores. In NSW, important estuaries for them include Port Stephens, Harrington Inlet and the Clarence and Richmond Rivers. Their diet includes crustaceans, molluscs, insects and polychaete worms. Threats to the species include hydrological changes to the Clarence and Richmond Rivers and tourism or agricultural developments reducing coastal and inland habitat areas.

Mangrove honeyeater (*Lichenostomus fasciogularis*)

Mangrove honeyeaters are found in mangroves and adjacent woodlands of coastal northeastern Australia, from Townsville in Queensland to Macksville in NSW (Pizzey and Doyle 1984; Simpson and Day 1996). Their nest consists of a deep cup of fine dry grass or dried seagrass in the fork of mangrove trees down to 60 cm above the high water mark. They usually feed on the blossoms of mangrove trees, but also descend to the mangrove floor at low tide to feed among the trunks and roots.

Osprey (*Pandion haliaetus*)

Ospreys have a disjunct distribution around the Australian coastline, occurring in the north from Broome in WA to the south coast of NSW, in the south from Kangaroo Island to the Great Australian Bight, and from Esperance to Cape Keraudren in the west (Marchant and Higgins 1993). In NSW, the osprey occurs primarily along the coast, south to about Womboyn Lake and is found in greater numbers in the north of the state (Marchant and Higgins 1993). They require extensive areas of clear, open water for fishing, often ranging up into freshwaters of larger rivers. They are found on offshore islands, littoral habitats, terrestrial wetlands and coastal lands of tropical and temperate Australia (Marchant and Higgins 1993). They nest in prominent positions near the ocean or large waterbodies, on rocky headlands, stacks, cliffs, palm trees, in tall dead trees, and on artificial

platforms (Marchant and Higgins 1993). More recently, particularly on the north coast of NSW, ospreys have been nesting on electrical supply poles as they provide the type of vantage points of their former natural habitat. The NPWS and NorthPower have been working together to customise these poles to avoid electrocution and to provide stable nesting platforms. They feed mostly on fish, clutching them from the surface of the water or diving to less than 1 m, and are able to eat toxic (Diodontidae, Tetraodontidae) and spiny fishes (Balistidae and Acanthuridae). They also feed on terrestrial vertebrates, seabirds and crustaceans (Marchant and Higgins 1993). Osprey are tolerant of human activity, often nesting within or adjacent to urban areas, but over clearing and degradation of water quality are likely to have an adverse impact on their nesting and feeding habitat (Marchant and Higgins 1993).

Pied oystercatcher (*Haematopus longirostris*)

The pied oystercatcher is distributed along the entire Australian coastline and offshore islands, with most key sites located in the southeast. These include The Coorong in SA, Derwent River in Tasmania and Corner Inlet in Victoria (Marchant and Higgins 1993). They roost and forage on sandy beaches, mudflats, sandbanks and rocky shores, and occasionally roost in mangroves. They also forage on oyster leases, but are more common at the low water mark on beaches where they probe soft substrata for molluscs, worms and crabs and sometimes take small fish from shallow water. They nest on sandy beaches, sandbars and along estuaries, immediately above the high water mark, as well as on sand dunes or saltmarshes and mudflats (Marchant and Higgins 1993). Threats to the species include alteration of habitat, human disturbance, destruction of nests and predation by foxes.

Sanderling (*Calidris alba*)

Sanderlings are an uncommon to locally common migrant from Siberia and other breeding grounds within the Arctic. They generally spend the summer in coastal areas of northern and eastern Australia and some individuals remain over winter. Sanderling prefer open sandy beaches exposed to open sea-swell, exposed sand bars and spits, and are also found in coastal areas on low beaches of firm sand, near reefs and inlets, along tidal mudflats and bare coastal lagoons. In NSW, important estuaries for them include Harrington Inlet and Old Bar at the mouth of Manning River. They forage at the edge of the water in the wave-washed zone and sometimes among rotting kelp, as well as at the edges of shallow pools on sandspits and mudflats. Their diet consists of insects and their larvae, crustaceans, jellyfish, fish, spiders, worms, plants and seeds, and larger molluscs and crustaceans are also taken as carrion. Threats to the species include hydrological changes to estuaries and similar waterbodies that may modify or remove habitat, and tourism or agricultural developments reducing coastal and inland habitat areas.

Sooty oystercatcher (*Haematopus fuliginosus*)

Sooty oystercatchers are endemic to Australia and are widespread along the east, west and south coasts, with scattered records from northern Australia. There are thought to be only small numbers of birds in NSW distributed evenly along the coast (Marchant and Higgins 1993), although the coastline between Lake Conjola and Lake Tabourie is thought to support more than 1% of the Australian population (Carter 1995). They are a strictly marine coastal species, preferring rocky intertidal shorelines with a minimal cover of foliose algae, coral reefs or sandy beaches near intertidal mudflats. They also occasionally forage on oyster leases, but are more common on intertidal rock platforms where they feed on molluscs, crustaceans, ascidians, echinoderms and small fish. When feeding on beaches, they take worms, larvae of seaweed flies and sandhoppers. They nest on offshore

islands and rock stacks, often close to rocky coasts, and sometimes on remote headlands, promontories or steep beaches (Marchant and Higgins 1993).

Terek sandpiper (*Xenus cinereus*)

The Terek sandpiper is a non-breeding migratory visitor to Australia's west, north and east coasts. In NSW, the species has been recorded from the Northern Rivers region south to Lake Wollumboola. The two main sites are the Hunter and Richmond Rivers, with the Hunter identified as nationally and internationally important for the species. They prefer muddy beaches near mangroves, coastal mudflats, lagoons, creeks and estuaries, but have been observed on rocky pools and coral reefs and occasionally up to 10 km inland around brackish pools. Their diet consists of polychaete worms, crustaceans, small shellfish, beetles, waterbugs, and the adults and larvae of various flies. Threats to the species include hydrological changes to estuaries that may modify or remove habitat, tourism or agricultural developments reducing coastal and inland habitat areas, urban and industrial development, and disturbance by recreational activities.

Marine mammals

Humpback whale (*Megaptera novaeangliae*)

Humpbacks have a worldwide distribution, but spend the summer months feeding in pelagic waters of Antarctica, generally between 60 – 70°S. In winter and spring, they migrate to warmer breeding grounds, 15 – 20°S, and are recorded in coastal waters off all states of except for the Northern Territory. There is distinct Northern and Southern Hemisphere populations based on temporal migration separation, and there are thought to be at least six Southern Hemisphere populations. Two of these populations are recorded off Australia's coastline, one off the west coast and the other off the east coast. There is thought to be a sex ratio bias towards males in east coast migration, and a possibility that not all females migrate north each year. Key localities within Australian waters include: Cape Naturaliste/Geographe Bay, north of Rottnest Island, Shark Bay, North West Cape, off Dampier Archipelago and coastal islands off Kimberley in Western Australia; southern coast, off Coffs Harbour and Cape Byron in New South Wales; Stradbroke Island, Hervey Bay, and islands in Great Barrier Reef, especially Whitsunday Passage area off Queensland. The exact locations of breeding grounds are unknown, although breeding occurs in central Great Barrier Reef area and there is probably a wide range of opportunity for breeding over several degrees of latitude on both the east and west coasts. Humpbacks feed mainly in Antarctic waters almost exclusively on krill (*Euphausia superba*). Elsewhere they feed on small shoaling fish and occasionally benthic organisms, and there is some evidence of feeding on fish and plankton swarms in warmer waters, e.g. off Eden and on larval *Munida gregaria* during their southern migration off New Zealand. Catches in the subtropics off northwest Western Australia and eastern Australia showed almost no evidence of local feeding. They feed by variety of methods, generally determined by their location. In the Southern Hemisphere, they feed by swallowing large volumes of prey and water or by disturbing the water, creating a washing machine effect. In the Northern Hemisphere, they feed by lunging and bubble feeding, which involves production of a bubble net formed by exhalation under water, concentrating prey. Humpbacks were heavily exploited by commercial operations until about 1970, and estimates suggest the population may have been reduced to 5% of its initial size by 1963. Despite international protection since then, recovery seems to have been delayed until mid-1970s, possibly mainly through continued illegal catches until about 1970. Current threats are thought to include direct disturbance on migration path and in breeding areas by:

- whale watching and research vessels/aircraft, pleasure craft, swimmers and divers;
- coastal seismic operations;
- defence operations;
- collision with large vessels;
- entanglement in fishing gear/shark nets; and
- pollution, including increasing amounts of plastic debris at sea, oil spills and dumping of industrial wastes into waterways and the sea, leading to accumulation of toxic substances in body tissues, although this is likely to be minimal given that it rarely feeds in low latitudes (Bannister *et al.*, 1996).

Humpback whales are also classified as vulnerable under the *EPBC Act*.

Indo-Pacific humpbacked dolphin (*Sousa chinensis*)

This dolphin occurs in southern China, through the Indo–Malay Archipelago to northern and northeastern Australia, where it is most regularly recorded in Western Australia (north of 24°S), Northern Territory and Queensland, with occasional strandings reported in New South Wales (mostly north of 29°S). They are primarily a coastal species, occurring in estuaries and rivers of tropical and subtropical climates. They occur close to the coast, in less than 20 m depth, although aerial surveys in the Great Barrier Reef region may have located them in waters between the outer reef and the mainland, further from shore than has been previously reported in the literature. Key localities for the species in Australia include Moreton Bay, Tin Can Inlet and Great Sandy Strait in Queensland. Their diet consists of a variety of species of fish, some cephalopods and crustaceans. They have been known to feed in association with prawn trawlers in Moreton Bay, and presumably elsewhere throughout their range in Australia. There is no reliable data on mortality rates or on abundance. In Moreton Bay, 36% of dolphins show evidence of shark attack, suggesting mortality from sharks may be significant. In South Africa, many animals also have very high levels of organochlorines, probably sufficiently high to kill a female's first calf, and it is possible that similar high pollutant loads occur in dolphins of Moreton Bay, but no data are available at present. Threats to the species are thought to include habitat destruction and degradation, noise pollution, harassment or disturbance (particularly close to major cities as in Moreton Bay), incidental capture in shark nets and trawl-nets, illegal killing, and overfishing of prey species. They are also prone to live capture for display purposes, in Queensland (permits granted for up to 12 per year at present) and northern NSW. Other potential threats include pollution and mass mortalities induced by pathogens.

Southern right whale (*Eubalaena australis*)

Southern right whales are circumpolar and only found in the southern hemisphere between approximately 30° and 60°S. They move from pelagic waters of higher latitudes where feeding occurs in summer, to warmer, lower latitudes for breeding in winter, when they approach close to the coast. In Australia, they are distributed around the southern coastline from Perth, WA to Sydney, NSW, including Tasmania. Their range is possibly extending, with recent sightings from Shark Bay and North West Cape, WA and north of Sydney to Cape Byron, NSW. Adult females are sighted most frequently close to coast, coming inshore to give birth on a mainly three-year cycle. Little is known about the diet of southern rights, but observations, lack of suitable prey and whaling data imply that they do not feed near the coast in winter, with calving females effectively fasting for at least four months. Prey is thought to be mainly pelagic larval crustaceans, particularly *Munida gregaria* and

copepods. They are taken primarily during summer in the open ocean, south of about 40°S. Threats to the species are thought to include historical gross exploitation at least into the late 1960s, and despite international protection, is likely to have prevented significant recovery until recently. More recent threats are thought to include direct disturbance, particularly in near-shore concentration/calving areas, from:

- whale watching and research vessels/aircraft, pleasure craft, swimmers and divers;
- low-flying aircraft;
- coastal industrial activity, e.g. seismic, drilling, sandmining and shipping operations;
- defence operations;
- collision with large vessels, particularly on shipping routes on eastern seaboard, in Bass Strait and across the Great Australian Bight; and
- entanglement in fishing gear.

Potential threats are thought to include increased whale watching pressure, industrial activity and pollution levels, and these may all be compounded by an increase in right whale numbers. The latter will also affect availability of suitable coastal calving habitat (Bannister *et al.*, 1996). Southern right whales are also classified as vulnerable under the *EPBC Act*.

APPENDIX F5 THE EIGHT PART TEST

The various pieces of legislation under which this assessment is being done require the determination of whether there is likely to be a significant effect of the estuary general fishery on any threatened species, populations or ecological communities or their habitats. This requires consideration of the matters listed in s5A of the *EP&A Act*, generally referred to as the Eight Part Test and itemised in italics below. If the test reveals that a significant impact is likely then a Species Impact Statement (SIS) will be required, or the draft FMS may be modified such that a significant effect is unlikely. Further, a SIS would have to be prepared if the strategy incorporated land or water that was declared as critical habitat.

a) Part 1 — Life cycle of threatened species

In the case of a life cycle of threatened species, whether the species is likely to be disrupted such that a viable local population of the species is likely to be placed at risk of extinction.

The estuary general fishery is highly unlikely to place any species, at a State or regional level, at risk of extinction by interrupting their life cycle. In other words, the fishery does not impact on species such that they can neither breed, feed, roost, migrate nor otherwise disperse. Despite this, those threatened species perhaps at the greatest risk include little terns and hooded plovers.

The most important nesting sites for little terns are likely to be patrolled by wardens to prevent access by humans and other animals. This should prevent disturbance of nesting sites by commercial fishers. Further, three of the four currently most successful breeding sites, at Sawtell, Old Bar and Botany Bay, are closed to net fishing, reducing the likelihood of any impact due to fishing.

The area currently thought to be the most important for hooded plover in NSW is Sussex Inlet, particularly on Bherwerre and Cudmirrah Beaches, followed by the coastline between Lake Conjola and Lake Tabourie. The only activity within the estuary general fishery that could affect coastal beaches is hand gathering. The assessment found that effects are unlikely due to the lack of intensity of the method, its selectivity and the popularity of recreation in areas where it can be done. There is unlikely to be any effect on the life-cycle of hooded plover, however, any management or recovery plan for the species should incorporate more extensive analysis of all uses of that stretch of coastline.

b) Part 2 — Endangered population.

In the case of an endangered population, whether the life cycle of the species that constitutes the endangered population is likely to be disrupted such that the viability of the population is likely to be significantly compromised.

The little penguin population at North Harbour is the only population that could be affected by the fishery. That population is unlikely to be significantly compromised by the continuation of commercial hauling or lobster trapping. Little penguins are known to travel between 10 and 30 km in foraging for food during nesting and much further during the non-breeding period (review by Gibbs 1997). As foraging is not restricted to the small area between Cannae Pt and Manly Pt, where hauling is permitted, it is highly unlikely that such an interaction could affect the lifecycle of the species.

Disturbance during hauling operations, such as preventing adults from returning to their fledglings with food, (similar to that which has been reported at a colony offshore from Wollongong) has not been reported for the Manly colony (NPWS 2000b). If such events were reported, the breeding success could be compromised. It will be important for the recovery team, recovery plan and future

monitoring programs for this colony to ensure that they consider the potential for such interactions and to record occurrences and outcomes.

The likelihood of this occurring is further reduced due to the periods of greatest activity adjacent to the colony. The peak hauling seasons are winter and autumn, and even then, there are only two crews that haul in this area. One of them visits the area twice a month and the other 2-3 times a week. Even if this activity were taking place in summer, it is unlikely to drive the population to extinction.

c) Part 3 — Regional distribution of habitat.

In relation to the regional distribution of the habitat of a threatened species, population or ecological community, whether a significant area of known habitat is to be modified or removed.

The literature review for this assessment found little or no data about the effects of the fishery on habitats of estuaries. Examination of effort data and closures suggested that only about half of the estuaries in the State had closures that would protect habitats, but it is not known to what degree those habitats are utilised by threatened species.

Most of the threatened species of fish considered in this assessment are marine species that could occupy suitable habitats in estuaries, primarily rocky reef. Given the extent of this type of habitat along the coast, and the limited scope for the techniques used in the fishery to affect this type of habitat, the fishery is considered unlikely to modify or remove a significant area of rocky reef.

The fishery would not modify or remove a significant area of habitat for turtles, whales or dolphins.

The little penguin population at Manly, by definition, is likely to have a significant area of known habitat affected by the fishery, but this is unlikely to occur to the extent that it modifies or removes any habitat.

There is currently very little known about the distribution and abundance of hooded plover, but studies would suggest that it is extremely limited in both extent and number. The coastal beaches between St Georges Head and Brush Island on the South Coast appear to be the most important sites for this species. Hand gathering is the only fishing technique that could be done on those beaches, and it has been done on less than 500 occasions over the last 15 years, providing little opportunity for habitat modification. Further, there is abundant potential habitat remaining, thus this fishery would not modify a significant area.

d) Part 4 — Isolated habitat.

Whether an area of known habitat is likely to become isolated from currently interconnecting or proximate areas of habitat for a threatened species, population or ecological community.

The estuary general fishery will not isolate any areas of habitats, nor will it fragment them such that they could become progressively isolated. Further, the connectivity of marine and estuarine systems is such that reproductive isolation is almost impossible, especially in terms of the techniques used in the fishery.

The penguin population at North Harbour and the shorebird community at Taren Point that have become isolated have not done so because of commercial fishing, nor is it causing an incremental isolation. Expanding urban development and a natural geographic formation are largely responsible

for the isolation of these two groups, respectively. The fishery is also unlikely to prevent any possible further expansion of these areas.

e) Part 5 — Critical habitat

Whether critical habitat will be affected.

Critical habitats have not been defined for any of the species considered in this assessment. Irrespective of this, a precautionary approach would suggest that the habitats occupied by the little penguin population and Taren Point shorebird community are critical to their survival. At the time of writing this report, the NSW NPWS was considering a proposal to list parts of North Harbour Aquatic Reserve as Critical Habitat for the species. As stated above, however, the fishery is unlikely to modify or remove the habitats, or restrict their distribution. As such, there will be few or no effects on those habitats.

f) Part 6 — Adequate representation in conservation areas.

Whether a threatened species, population or ecological community, or their habitats, are adequately represented in conservation reserves (or other similar protected areas) in the region.

It is important to note that very little is known about the distribution within estuaries of most of the threatened species of fish. Further, this part of test (and most of it for that matter) is designed to examine whether affecting a small area of habitat or small number of a species might be offset by their occurrence in protected areas. Very little is known about the biodiversity of our marine protected areas, and even less of aquatic threatened species, so it is impossible to assess whether the species or their habitats are adequately represented in conservation reserves or the like.

Numerous conservation reserves along the coast provide habitats for the various threatened species considered in this assessment. The endangered population of little penguins occurs in an Aquatic Reserve and representative habitats of most of the other species occur adjacent to National Parks, Nature Reserves or areas closed to commercial fishing.

Only the shorebird community at Taren Pt does not occur in a conservation reserve of some form. Much of the habitat within it could be found elsewhere within Botany Bay, but the geographic formation of the shoal at Taren Pt is considered unique, and as such maintains a unique community. Irrespective of this, the estuary general fishery is unlikely to place this bird community at risk of extinction.

g) Part 7 — Threatening processes.

Whether the development or activity proposed is of a class of development or activity that is recognised as a threatening process.

There are currently no declared threatening processes under the *FM Act*, nor is commercial fishing listed as a threatening process under the *TSC Act*. Further, the activities undertaken in this proposal are considered highly unlikely to exacerbate existing threatening processes under the TSC Act.

The recovery plan for little penguins at North Harbour does recognise commercial fishing as a threatening process to the colony, and as such this assessment accepts that there is potential for it to constitute a threatening process under the *TSC Act* in future. At this stage, the fishery does not appear

to be adversely affecting two or more threatened species, one of the criteria necessary for an activity to be declared a threatening process.

The only processes related to fishing under the *EPBC Act* are the incidental catch (bycatch) of sea turtle during coastal otter-trawling operations within Australian waters north of 28° South, and the incidental catch (or bycatch) of seabirds during oceanic longline fishing operations. Neither of these techniques applies to the estuary general fishery.

h) Part 8 — Limit of known distribution.

Whether any threatened species, population or ecological community is at the limit of its known distribution.

The endangered population of little penguins at North Harbour and the shorebird community at Taren Pt must be at the limits of their distributions. The proposal will not reduce or affect the ability of these entities to expand their ranges. Other birds whose distribution limits are likely to occur in NSW include beach stone-curlew, bush stone-curlew, hooded plover, black bittern, collared kingfisher, comb-crested jacana and mangrove honeyeater.

The three plant species considered in this assessment are all at the northern limits of their distribution in NSW.

Green sawfish are more common in the north of eastern Australia, and the northern rivers region probably represents the southern limits for these species.

i) Conclusion

This assessment has considered the eight factors under s5A of 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. 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 estuary general fishery.