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Appendix 1.

Ecological Reserve Guidelines to identify MPAs in NSW

(from Ron Avery in Breen *et al.* 2004)

Ecological viability requires consideration of reserve design including size, shape, replication and the configuration of reserves within a network. Reserve design criteria aim to ensure that individual MPAs and the overall reserve system remain ecologically viable. Marine reserve design guidelines frequently cited in the scientific literature include the following.

Establish clear objectives

The primary objectives of any MPA need to be stated clearly. A reserve's location, design and management should reflect its intended purpose. Reserve design for fisheries management, sedentary organisms, birds and whole ecosystems may differ considerably (Agardy 2000, Planes *et al.* 2000, Roberts and Hawkins 2000, Salm *et al.* 2000).

Select, design and manage the MPA in line with these objectives

The biology of the target organisms including their life cycles, movements, feeding, behaviour and physiology all need to be considered in reserve design. Even where a range of biodiversity is targeted, careful consideration should be given to the ecology of the organisms the MPA is designed to protect.

Conduct site assessments

Once candidate MPA sites have been identified at a regional level, more detailed site studies are required to assess the validity of broadscale predictions, collate any detailed information available and specifically assess local patterns of biodiversity, threats and issues for future management.

Use natural boundaries and include whole ecosystems and habitats

Where possible, the natural limits of ecosystems or habitats should be used to help define marine protected area boundaries (Salm *et al.* 2000). Where an entire ecosystem or habitat is important for conservation, all of its area should be protected (Roberts and Hawkins 2000, Salm *et al.* 2000). Reservation of an entire system is likely to enhance protection by:

- taking advantage of the unit's natural isolation from threatening processes
- inhibiting excessive spill over of mobile organisms from the reserve
- protecting the full range of variation occurring within a unit.

Use core and buffer zones

Highly protected core conservation areas should be surrounded by an appropriate buffer zone to avoid sudden transitions from highly protected areas to areas with relatively little protection. High value conservation sites that are vulnerable to human use should be protected in core protection zones. Buffer zones may also be used to provide important corridors between areas.

Use highly protected areas

The concept of minimum or optimum MPA size should be applied to core sanctuary zones, not to the total extent of a multiple-use MPA (Salm *et al.* 2000). Most evidence of the beneficial effects of MPAs is related to core sanctuary (or ‘no take’) areas where extractive use is prohibited.

Ensure adequate size and number of reserves

There are few general rules for determining the best size and arrangement of MPAs as biologies and life histories vary widely among species and with season and location (Roberts and Hawkins 1997, Crosby *et al.* 2000, Roberts 2000, Salm *et al.* 2000). However, protected areas should be as large as possible and should not be smaller than the average size for a given habitat type (Salm *et al.* 2000).

Where MPAs target particular species, and where sufficient data exist, attempts can be made to estimate an appropriate MPA size and configuration. MPA size may also be determined by examining the percentage of species richness represented with increasing reserve size (Salm *et al.* 2000), or through fisheries and other modelling techniques (Crosby *et al.* 2000).

One trend however, persists: the larger the MPA, the more species that will be represented, and the more likely their populations are to survive disturbances (Salm *et al.* 2000).

Maximise habitat complexity

Representation of species and habitat diversity can be enhanced by establishing MPAs in locations with a wide range of physical environments (e.g. estuaries, islands and headlands with significant depth gradients and both protected and exposed aspects). Different organisms associate with different marine structures and high habitat complexity is often associated with high species diversity. For example, the species richness of rocky reef fish communities is greatest in areas with high habitat complexity (Garcia-Charton *et al.* 2000).

Maximise the connection between neighbouring habitats

Many species selectively use different habitats at different times, seasons or stages in their life history. Protection of organisms in one habitat may be compromised unless other locations on which they depend are also managed for conservation (Salm *et al.* 2000).

Complement existing MPAs

Reserve design should consider the role of individual MPAs in contributing to the overall complement of biodiversity represented in reserves and should also consider the role of MPAs in the ecological functioning of the reserve system (Crosby *et al.* 2000, Salm *et al.* 2000).

Coordinate management across marine and terrestrial environments

Coordinated management of marine and terrestrial systems can help conserve ecosystem function and mitigate against catchment based threats. Increasing urban development and inappropriate land use in coastal catchments are recognised as major threats to marine biodiversity in New South Wales. With the population in the non-metropolitan coastal areas of NSW increasing by 45% between 1981–1991, the terrestrial reserve system and improved integrated planning are seen as key mechanisms for conserving marine and coastal biodiversity (NSW Government 1997).

Build a network of MPAs for all ecosystems, communities and species to:

- represent the full regional range of marine biodiversity
- insure against risk through replication
- ensure connectivity between ecosystems and populations
- provide scientific reference sites
- intersperse replicate study sites for research, monitoring and adaptive management
- promote ‘spill over’ effects to surrounding areas
- provide for the recovery of damaged environments
- provide opportunities for understanding, sustainable use and enjoyment
- provide opportunities for community input and stewardship.

Exercise risk management and the uncertainty principle

Information for management of marine biodiversity will never to be perfect and identification and selection criteria can only hope to approximate ideal objectives and goals. In setting and implementing criteria, the NSW Government has adopted a precautionary approach to managing MPAs i.e. ‘Where there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation’ (National Strategy for Ecologically Sustainable Development 1992).

Appendix 2. Options for MPAs in the Manning Shelf Marine Bioregion

2.1 A multiple-use marine park in the Manning Shelf Bioregion

The primary identification criteria for comprehensiveness and representativeness are most easily met, and for some features can only be met, in the region between Stockton Beach and Wallis Lake. Under the adopted criteria, comprehensiveness requires conserving examples of ‘the full range of marine ecosystems and habitats across the marine environment’. According to the environmental classification adopted for the study, this means representation of each of the five major estuary ecosystems, the four ocean ecosystems classified by depth, and the nine habitat surrogates (mangrove, seagrass, saltmarsh, subtidal sediment, beach, intertidal rocky shore, subtidal reef and island).

Each of these ecosystems and habitats can be represented in the region between Stockton Beach and Wallis Lake, in many cases by the most extensive examples of their type in New South Wales. This represents an opportunity to manage within one area, conservation of some of the state’s most important resources for marine biodiversity and sustainable use.

For reserve design, including many interrelated features within one MPA means the potential to conserve whole ecosystems, processes, communities and populations throughout the duration and spatial extent of entire life cycles. This may help to maintain connectivity among different ecosystems and their diverse components, and provides for greater control over threatening processes operating from within and outside MPAs.

The region not only includes the largest areas of most ecosystem and habitat types, but also a greater number and variety of often larger features. This replication of habitats in different areas is likely to include a greater diversity of life forms and provide better protection against disturbance. Having many features spread over broader areas also provides for greater flexibility in multiple-use zoning with more opportunities to provide for a range of conservation values, sustainable use and stakeholder interests.

There are also practical advantages in focusing broad-scale ecosystem management strategies in an area with so many important features. There are compliance benefits for more efficient monitoring and surveillance, in simplifying education, and in better communication generally. A large marine park of national and international significance will also promote widespread awareness of the area’s values and the benefits MPAs can have for biodiversity and sustainable use.

The outstanding natural features of the estuaries, coast and ocean between Wallis Lake and Stockton Beach that identify it as a candidate site for a large multiple-use marine park are as follows.

- Port Stephens (tide-dominated drowned river valley) and the Myall Lakes (brackish barrier lake ecosystem) are the only major examples of their ecosystem type in the Manning Shelf Bioregion and the largest of their type in New South Wales.
- Port Stephens includes the largest area of mangrove forest in New South Wales (27 km² or 21% of the state total), the largest area of saltmarsh in the state (14 km² or 13% of the state total), and the second largest area of seagrass in the bioregion (8 km² or 5% of the state total).
- Myall Lakes connects with Port Stephens via the Myall River, which has the highest proportional cover of seagrass (71% of open water) in the bioregion and forms a unique link between brackish and marine estuarine ecosystems.
- Smith's Lake is the largest example of an intermittent coastal lagoon in New South Wales and lies immediately between Myall Lakes to the south and Wallis Lake to the north.
- Wallis Lake is the largest example of a tide-dominated barrier estuary in the Manning Shelf Bioregion. The lake includes the largest area of seagrass (31 km² or 21% of the state total) and the northern most beds of *Posidonia* in the state, as well as extensive areas of saltmarsh (4 km² or 7% of the state total).
- In ocean ecosystems, the sections of coast and ocean between Wallis Lake and Stockton Beach include all offshore depth zones including the 60–200 m depth zone within the state 3 nm limit.
- The sections of coast between Wallis Lake and Stockton Beach also include:
 - 1 more inshore and offshore islands
 - 2 more inshore and offshore subtidal reef
 - 3 more intermediate, reflective and estuarine beach habitat
 - 4 more rocky intertidal habitat with more sites representing all five identified 'community' types (boulder, cobble, platform, crevice, pool).
- Summed irreplaceability for a hypothetical 20% representation of each ecosystem and habitat type was highest for Port Stephens, Wallis Lake, Myall Lakes and the coast and ocean sections between Myall Lakes and Stockton Beach.
- The numbers of species of juvenile fishes and invertebrates caught in surveys by NSW Fisheries were high for Wallis Lake and Port Stephens and summed irreplaceability for representation of each species was highest for these estuaries.
- The numbers of commercial fish and invertebrate species in NSW Fisheries catch return records for 1997–98, and the summed irreplaceabilities for representation of each species were highest for Port Stephens and Wallis Lake.
- Port Stephens, Wallis Lake and Myall Lakes have large areas of important bird habitat for threatened species, species protected under JAMBA/CAMBA international treaties and for other native species. The ocean coast between Smiths Lake, Myall Lake, Port Stephens and

the Hunter River supported the most area of important bird habitat for threatened, JAMBA/CAMBA and other species.

- On average, 38% of Grey Nurse Sharks sighted in surveys of all New South Wales between 1998 and 2000 were recorded between Wallis Lake and Port Stephens at the Pinnacle, Latitude Rock, Seal Rocks and Broughton Island.
- The endangered Gould's Petrel (*Pterodroma leucoptera*) breeds only on Cabbage Tree and Boondelbah Islands off the coast of Port Stephens and has been sighted near Wallis Lake.
- The endangered Little Tern (*Sterna albifrons*) has significant nest sites at Wallis Lake and has been sighted at Myall Lakes and Port Stephens.
- The endangered plant, coastal spurge (*Chamaesyce psammogeton*) has been found growing on the main sandbar at the entrance of Smiths Lake (Webb *et al.* 1998).
- RAMSAR wetlands of international importance have been identified for Myall Lakes National Park including:
 - Myall Lakes
 - Yaccaba Headland, Fame Cove and Corrie Island Nature Reserve in Port Stephens
 - the southern shores of Smiths Lake
 - the ocean coast between Smiths Lake and Port Stephens.
- Wallis Lake, Myall Lakes and Port Stephens are included in the 'Directory of Nationally Important Wetlands'.
- From 10–20% of lands adjoining Port Stephens and Myall and Wallis Lakes are classed as SEPP 14 important coastal wetlands. Corrie, Swan and Wurrung Islands and several wetlands surrounding the Port Stephens estuary are listed as SEPP 14 coastal wetlands. In Wallis Lake, SEPP 14 coastal wetlands include part of Regatta, Yahoo, Big, Snake, Goodwin and Wallis Islands and areas surrounding the lake and its tributaries to the north and west. Several areas within Myall Lakes National Park have been listed as SEPP 14 coastal wetlands.
- Port Stephens estuary is on the Interim list for the Register of the National Estate. The Fly Point – Halifax Bay area within the Port Stephens estuary supports a high diversity and abundance of sedentary marine animals, particularly sponges (Australian Heritage Commission 1998) and is listed on the Register of the National Estate.
- Myall Lakes National Park is registered on the National Estate. Wallis Lake is listed as an indicative place on the Register of the National Estate and Bandicoot Island Nature Reserve, Yahoo Island Nature Reserve and Wallis Island Nature Reserve are all listed on the Register of the National Estate.
- There are a number of areas of particular conservation significance in the Port Stephens estuary system due to the presence of mangrove, seagrass, saltmarsh and wetland complexes with relatively natural or protected subcatchments. These include the lower Myall River, the Corrie Island area, Kore Kore Creek system, Fame Cove and Creek, Bundabah Creek

(North Arm), Deep Creek system (Karuah River), Reedy Creek, Swan and Worimi Island complex, the northern shores of Big Swan Bay, Twelve Mile Creek system, Tilligerry Creek, Fenninghams Island Creek, Wallis Creek complex and Cromartys Bay.

- The *Independent Inquiry into Coastal Lakes* (Healthy Rivers Commission 2002) recommends Myall Lakes for significant protection, Smiths Lake for significant protection and Wallis Lake for secure 'healthy modified conditions'.
- Myall Lakes and the Myall River are the only estuaries in the bioregion classified with a very low degree of disturbance in the 'Environmental inventory of estuaries and coastal lagoons' (Bell and Edwards 1980).
- Short (1995) recommends four intertidal rock platforms between Wallis Lake and Stockton Beach for protection.
- The only rock platform in the Manning Shelf Bioregion recommended for protection by Griffiths (1982) is Bald Head, near Smiths Lake.
- The area includes Sugar Loaf Point (Seal Rocks), a major separation point for the East Australian Current (Godfrey *et al.* 1980, Cresswell 1983 and 1998) and also includes a range of sediment types identified by Colwell *et al.* (1981).
- Catchments for Myall Lakes, Port Stephens and Smiths and Wallis Lakes are largely undisturbed when compared with the heavily cleared catchments of the main branches of the Macleay, Hastings, Manning and Hunter River estuaries.
- Estuarine waters in Myall Lakes, Port Stephens and Smiths and Wallis Lakes are in relatively good condition, although problems with blue green algae in Myall Lakes and sewage contamination in Wallis Lake indicate how seriously this situation can change. The above areas are not, however, as affected by flood mitigation works. In particular, the drainage of acidic water to estuaries from 'reclaimed' wetlands is not as serious as has occurred in the Macleay, Hastings, Manning and Hunter River estuaries.
- All of the Myall Lakes (the largest MPA in New South Wales managed by NSW National Parks), some adjacent exposed coast and several locations in Port Stephens are already marine protected areas under the *National Parks and Wildlife Act* but this legislation, on its own, does not provide protection for fish or aquatic invertebrates from fishing.
- Most adjacent lands around the Myall Lakes, the major offshore islands, the coast and many areas around Port Stephens and Smiths and Wallis Lakes are managed as national park or nature reserve. Wallis Island is partly dedicated as nature reserve and Yahoo, Regatta and Bandicoot Islands are dedicated as nature reserves. These adjoining terrestrial reserves help provide protection from land-based threats and may also provide an indication of the condition of adjacent waters.
- Local and state agencies and infrastructure already exist in the region to provide support for management, research and education for marine conservation.

- Because of its natural attractions, proximity to major urban centres, improvements in transport and access, and its development as a tourism, holiday and residential area, the region is increasingly vulnerable to impacts from high levels of use and development.
- A large, multiple-use marine park would provide for more comprehensive management of these important marine areas and the increasing levels of human activity in the region.

Significant areas in relatively unimpacted, small estuaries

2.2 Khappinghat Creek

Khappinghat Creek is the largest intermittent creek in the bioregion and contains small areas of seagrass and extensive areas of sand, mud flats and rocky shores. The creek system includes large areas of *Casuarina*, *Melaleuca* and *Juncus* wetlands protected under SEPP 14. Areas of littoral rainforest near the creek entrance are protected under SEPP 26. The extensive reef systems occurring offshore are unusual for the northern half of the Manning Shelf Bioregion which is often dominated by large expanses of sand and limited nearshore reef.

All of the Khappinghat Creek estuary, most of the shores, and 57% of lands within 1 km are already protected within Khappinghat Nature Reserve. Prior to declaration of the nature reserve in 1993 the area was managed as state forest and some sand mining for minerals occurred. However the catchment, waters and intermittent entrance appear to remain in a relatively natural condition and there are few neighbouring built-up areas or disturbed acid sulphate soils. The *Australian River and Catchment Disturbance* indicators show little disturbance to flow or catchment. Khappinghat Creek may be the only opportunity in the bioregion to protect an estuary for which both waters and surrounding lands have been left relatively undisturbed.

2.3 Lakes Innes & Cathie

The estuary is the second largest intermittent lagoon in the bioregion and after Port Stephens and includes the second largest area of saltmarsh (6 km²). Saltmarsh occupies 51% of the estuary area including the largest single patch of saltmarsh (3.2 km²) in the bioregion.

The site provides outstanding opportunities for the scientific study of coastal geomorphology and wetlands processes, particularly in relation to the study of ecological succession during the process of estuary infilling. The site contains coastal wetlands, including extensive areas of saltmarsh and adjoining wet heath, *Melaleuca*, *Casuarina* and rainforest. The area is particularly diverse in terrestrial fauna and provides habitat for twenty threatened fauna species including Ospreys and Australasian Bittern.

The estuary was rated by the *Inventory of Estuaries and Coastal Lakes* (Bell and Edwards 1980) to have waters, shore and catchment in good condition, and by the *Australian Estuaries Database* to be only slightly affected by human activity. Land capability of surrounding areas is generally most suitable for forest or undisturbed natural vegetation and least suitable for

cultivation or grazing. Australian River and Catchment Disturbance indices are generally low to medium for surrounding areas. The *Independent Inquiry into Coastal Lakes* recommends Lake Innes for 'significant protection' and Lake Cathie for 'secure healthy modified condition'.

Almost all of the Lake Innes and Lake Cathie estuary and most of adjacent lands (59% within 1 km) are included within Lake Innes Nature Reserve. Much of the nature reserve is designated under SEPP 14 as protected coastal wetland and it may represent one of the few major wetlands on the NSW coast which is not affected by flood mitigation and drainage schemes (NPWS 1995).

2.4 Camden Haven River, Queens Lake, Watson Taylors Lake and Gogleys Lagoon

After Wallis Lake and Port Stephens, Camden Haven includes the third largest area of seagrass (6.3 km²) in the bioregion and the seventh largest area of seagrass in New South Wales. Queens Lake contains the most extensive seagrass beds, while smaller amounts of seagrass, mangrove and saltmarsh are distributed throughout the estuary system.

Watsons Taylors Lake and the Crowdy Bay National Park wetland system are listed in the *Directory of Important Wetlands* and Gogleys Lagoon near the mouth of the Camden Haven River is considered to be a geomorphically significant feature (Eric Claussen pers. com.). The lagoon contains mangrove, saltmarsh and littoral rainforest communities, and provides important habitat for migratory waders (David Scott pers. comm.). The close proximity to the subtidal habitats of Perpendicular Headland provide an immediate connection between estuarine and ocean habitats.

The Camden Haven estuary is rated by the *Australian Estuaries Database* to have high fisheries value and a 'slightly affected' ecological status. Land capability for surrounding lands is low for cultivation and Australian River and Catchment Condition indices for disturbance are low to medium. The *Independent Inquiry into Coastal Lakes* recommends Queens Lake for 'significant protection' and Watson Taylor Lake for 'secure healthy modified condition'.

Most of Watsons Taylors Lake is included in the northern end of the Crowdy Bay National Park but Queens Lake and several of the major tributaries lie outside the national park and are subject to increasing development pressures. Queens Lake is subject to a long-standing reserve proposal including areas of vacant Crown lands.

2.5 Korogoro Creek

The significance of Korogoro Creek lies in its hydrological relationship with extensive fresh water wetlands of the Swan Pool swamp (listed as an important Australian flood plain wetland), and the transition between freshwater and estuarine vegetation communities.

Korogoro Creek supports limited areas of estuarine vegetation including a low mangrove forest of *Avicennia marina* and isolated *Aegiceras corniculatum*. Saltmarshes in areas of infrequent tidal inundation include *Sporobulus virginicus* and *Sarcocornia quinqueflora*. Further up-stream the sedge *Baumea juncea* and maritime rush *Juncus kraussii* give way to swamp forests dominated by *Casuarina* spp. (NPWS 1998a).

Hat Head National Park includes wetlands behind the frontal dune systems of Smokey and Killick Beaches, fresh water wetlands of the Swan Pool (swamp) to the west of Hat Head Village, and the beach dunal systems (NPWS 1998a). The park provides important habitat for many species of wader birds for feeding and resting on sand and mud flats, rock platforms and beaches, including at least ten JAMBA/CAMBA species (NPWS 1998a).

The upper reaches of Korogoro Creek and 57% of adjoining lands within 1 km are included within Hat Head National Park.

2.6 South West Rocks Creek

For its size, this small creek system has a relatively high proportion of its area covered by mangrove (67%), saltmarsh (18%) and seagrass (20% of open water). Although most of the area is protected by SEPP 14 zoning there are currently no MPAs in the estuary, no adjoining national parks or nature reserves and 20% of land within 1 km is in built-up areas.

2.7 Saltwater Creek and Saltwater Lagoon

Both Saltwater Creek and Saltwater Lagoon are protected by SEPP 14, while NSW National Parks estate includes the whole of Saltwater Lagoon and part of the immediate catchment of Saltwater Creek. Built-up areas within the small catchment pose a potential threat to the condition of the creek and lagoon. The *Independent Inquiry into Coastal Lakes* describes the lagoon as having an extreme natural sensitivity and has recommended that the lagoon be secured in a 'healthy modified condition'.

2.8 Killick Creek

Killick Creek has no MPAs, 17% of adjoining land within 1 km inside Hat Head National Park and 26% of lands within 1 km classed as SEPP 14. The proximity of built-up areas poses a potential threat to the condition of the creek and there has been extensive catchment clearing in the immediate area.

2.9 Unamed Creek (Big Hill Point)

Unamed Creek has no MPAs but 49% of lands within 1 km lie within SEPP 14 areas and Limeburners Creek Nature Reserve. A further 40% of adjacent lands are classified as wilderness, with no mapped built-up areas, low land capability for cultivation or grazing, and low disturbance from settlement, land use or extractive industry (ARCCD). Despite these apparently favourable indicators there is little natural riparian vegetation with clearing for a camp ground, golf course and low-density tourist development.

Significant areas in less impacted parts of the major estuaries

2.10 Limeburners Creek and Saltwater Lake – Hastings River

The wetlands of the Limeburners Creek area have been listed in the Directory of Important Australian Wetlands and the nature reserve is registered on the National Estate. Much of the lower Limeburners Creek system including the extensive estuarine vegetation lie outside the protected areas but are worthy of marine protection.

Much of the area (51%) has been designated as a coastal wilderness by independent state and national wilderness assessments, and the lake is identified as one of the most natural coastal lakes on the NSW coast. It is listed as 'near pristine' by the Healthy Rivers Commission and is the only coastal lake in the bioregion recommended for comprehensive protection by the *Independent Inquiry into Coastal Lakes*.

The *Environmental Inventory of Estuaries and Coastal Lagoons* (Bell and Edwards 1980) rates disturbance to shore, waters and catchment as low. Mean *Australian River and Catchment Disturbance* indices for the subcatchment are generally low for settlement, land use, infrastructure and extractive industry. There are few built-up areas adjacent to this section of the estuary but a high percentage of high risk or disturbed acid sulphate soils within 1 km.

Species listed under JAMBA and CAMBA which use the nature reserve include the nationally endangered Little Tern (*Sterna albifrons*).

The terrestrial conservation values of the site include the presence of a wide range of landforms providing evidence of past and present coastal processes. These landforms support a very extensive mosaic of vegetation communities including littoral and subtropical rainforest, mangrove forest and woodlands, wet and dry sclerophyll forests, shrublands, swamps, coastal heathland, saltmarsh and dune grasses. Extensive wetlands drain into the Saltwater Lake and Limeburners Creek estuary. During prolonged periods of rain the generally saline Saltwater Lake becomes brackish to fresh. The area supports a diverse range of wildlife communities including threatened species and birds protected under international agreements (NPWS 1998b).

During the Pleistocene period (~60,000 years ago) Point Plomer, Big Hill and Queens Head were islands separated from the mainland. They have since merged with the mainland as a

consequence of sand deposition. An unusual limestone outcrop at Big Hill Point (including a natural arch and sea cave) is a record of the coral reefs that once existed along the ancient NSW coast.

Most of the upper reaches and land within 1 km of Limeburners Creek and Saltwater Lake are included within Limeburners Creek Nature Reserve (58%) and SEPP 14 wetland (70%).

2.11 Kooragang Island and Fullerton Cove

The Hunter River estuary includes the second largest area of mangrove habitat (15.5 km²) after Port Stephens and the third largest area (5 km²) of saltmarsh in the bioregion. Much of this vegetation is found in the Kooragang Island–Fullerton Cove area.

Fullerton Cove is a large shallow embayment north of Kooragang Island. It has a depth of two to three metres at its centre and at low tide, large areas of mudflats are exposed. Kooragang Nature Reserve (including Fullerton Cove) is recognised as a nationally and internationally important wetland (listed by the *Directory of Important Wetlands* and RAMSAR) providing habitat for many species of migratory waders and species listed as endangered at a national level including the Little Tern (*Sterna albifrons*). Species which are considered vulnerable at a state level include the Freckled Duck (*Stictonetta naevosa*), Pied Oystercatcher (*Haematopus longirostris*), Mongolian Plover (*Charadrius mongolus*), Large Sandplover (*Charadrius leschenaultii*), Black-tailed Godwit (*Limosa limosa*), Terek Sandpiper (*Xenus cinereus*), Great Knot (*Calidris tenuirostris*) and Broad-billed Sandpiper (*Limicola falcinellus*).

In general the area has undergone significant manipulation. Kooragang Island originally consisted of several smaller islands or bars. Several attempts to control deposition and siltation of the Newcastle port area resulted in the agglomeration of these islands into a smaller number of larger units by the artificial filling of channels and the construction of training walls. In 1970, a levee bank was built around Fullerton Cove in an effort to ameliorate flooding in low-lying areas of Newcastle, downstream of Kooragang Island. Drains were installed to reclaim the significant wetland areas behind the levees for agriculture (*Directory of Important Wetlands of Australia* 1996).

Past filling has destroyed up to 10 km² of estuarine wetlands, but remaining wetlands remain in a healthy condition. The estuarine herb *Zannechellia palustris*, considered endangered at a state level has been recorded immediately adjacent to the western end of the reserve. This herb is found in New South Wales only in the Newcastle/Lake Macquarie area and along Ironbark Creek (*Directory of Important Wetlands of Australia* 1996).

After Myall Lakes, Kooragang Nature Reserve is the second largest MPA in New South Wales managed by NSW National Parks.

2.12 Macleay River Delta and Macleay Arm

This area includes Clybucca Creek downstream of Clybucca, Macleay River downstream of Rainbow Reach, Macleay Arm and associated intertidal wetlands. The area is listed on the Directory of Important Australian Wetlands and contains five categories of wetland including subtidal aquatic beds, estuarine waters, intertidal flats, intertidal marshes and intertidal forested wetlands. The wetlands are also important habitat for animal taxa at vulnerable stages in their life cycles, provide a refuge during adverse conditions, and are of outstanding historical or cultural significance (*Directory of Important Wetlands of Australia* 1996).

This site is considered to be a good example of estuarine wetlands on the north coast and includes large areas of mangroves and saltmarsh in a healthy condition (West *et al.* 1985). Large riverine estuaries such as the Macleay are a characteristic feature of the northern half of the bioregion and should be represented within the reserve system.

The wetlands include 520 ha of mangroves, 191 ha of seagrasses and 365 ha of saltmarsh (West *et al.* 1985). Mangrove species within the estuary include Grey Mangrove (*Avicennia marina*), River Mangrove (*Aegiceras corniculatum*) and Milky Mangrove (*Excoecaria agallocha*). The saltmarsh community includes species such as Couch (*Sporobolus virginicus*), Sedge (*Cyperus polystachyos*), Sea Rush (*Juncus kraussii*), the sedge *Fimbristylis ferruginea*, Seaberry Saltbush (*Rhagodia candolleana* sp. *candolleana*) and Ruby Saltbush (*Enchylaena tomentosa*). Freshwater swamp forest also occurs along the estuary and includes species such as Paperbark (*Melaleuca quinquenervia*), Willow Bottlebrush (*Callistemon salignus*) and Swamp Oak (*Casuarina glauca*).

The area is potentially an important habitat for many species of migratory waders. The Osprey (*Pandion haliaetus*) and Magpie Goose (*Anseranas semipalmata*), considered vulnerable at a state level, have been recorded within the Clybucca Estuary. The White-bellied Sea-eagle (*Haliaeetus leucogaster*) listed under CAMBA, has been recorded within the estuary. The Whimbrel (*Numenius phaeopus*), Common Sandpiper (*Actitis hypoleucos*) and the Marsh Sandpiper (*Tringa stagnatilis*) occur within the estuary and are listed under JAMBA and CAMBA (NPWS 1998b).

Other bird species recorded within the estuary include the Australian White Ibis (*Threskiornis molucca*), Straw-necked Ibis (*Threskiornis spinicollis*), Pied Oystercatcher (*Haematopus longirostris*), Pelican (*Pelecanus conspicillatus*), Whimbrel (*Numenius phaeopus*), Pied Cormorant (*Phalacrocorax varius*), Little Pied Cormorant (*Phalacrocorax melanoleucos*), Welcome Swallow (*Hirundo neoxena*) and Azure Kingfisher (*Alcedo azurea*). As with other areas of estuarine wetland, Clybucca Creek Estuary is an important habitat for many commercial fish species.

2.13 Warrell Creek – Nambucca River

Warrell Creek may represent the single largest area of wetland and dune complex vegetation remaining in the Nambucca River estuary (LandSat7 imagery 2000). It contains extensive areas of protected SEPP 14 wetlands and includes examples of freshwater wetlands including Swamp Oak forests, Swamp Mahogany forests, Broad Leaved Paperbark forests and open freshwater wetlands dominated by sedges and reeds, as well as examples of SEPP 26 rainforest and moist coastal vegetation (i.e. Scribbly Gum dominated forests and areas of Wet Heath) (Graham in prep.).

Wetlands of the Nambucca River provide habitat for a number of threatened species including the Osprey, Jabiru, Pied Oystercatcher, Sanderling, Little Tern, Loggerhead Turtle, Beach Stone-curlew, Black Bittern and Terek Sandpiper. Threatened plant species in the Nambucca River wetlands include Grove's Melaleuca and the endangered ecological community 'Lowland rainforests on floodplain in the NSW North Coast Bioregion' (*Threatened Species Conservation Act*) (Graham in prep.).

2.14 Manning River (Harrington) and Manning River South Channel (Farquhar Inlet)

Much of the Manning River delta area has been cleared for agriculture (LandSat7 imagery 2000) although remnant vegetation still remains around the mouth of the Farquhar Inlet and the Manning River channel. Both the north and south channel have moderately built-up urban areas near their mouths (i.e. Harrington and Old Bar). Important values of both sites include the presence of estuarine vegetation along edge of the river channel, significant littoral rainforest communities and the presence of significant Little Tern breeding sites. No terrestrial reserves currently occur near either mouth.

2.15 Intertidal rocky shores and inshore reefs

NSW Fisheries (Otway and Morrison in prep.) is currently analysing species composition data for rocky intertidal shores in the Manning Shelf Bioregion. Initial surveys have mapped 52 shores and scored the number of 'community types' (platform, boulder, cobble, pool, crevice) present on each shore. Twenty-one shores included all five community types, 15 shores included four community types and 15 shores included three community types.

The National Trust Headland and Rock Platform survey in 1982 identified only one rock platform, Bald Head, for protection in the Manning Shelf Bioregion. The survey carried out by the Total Environment Centre in 1995 identified 19 rock platforms in the Manning Shelf Bioregion for protection. Until detailed surveys and recommendations for aquatic reserves are complete this study defers from making any more specific conclusions until this information is available.

2.16 Offshore reefs, islands, and aggregations of Grey Nurse Sharks

Significant offshore reefs, islands, and aggregations of Grey Nurse Sharks occur at:

- Fish Rock and Green Island near South West Rocks
- the Cod Grounds near Laurieton
- the Pinnacle near Cape Hawke and Forster
- Big Seal and Little Seal rocks near Sugarloaf Point
- Broughton Island near Port Stephens.

These sites represent offshore islands, rocks or pinnacles in deep water (30–40 m), often influenced by the East Australian Current and renowned for their diverse and abundant fish and invertebrate fauna. They include the largest aggregations of threatened Grey Nurse Sharks (*Carcharias taurus*) sighted in Eastern Australia and have together accounted for over 50% of all recent Grey Nurse sightings in New South Wales.

Reports of threatened and protected species have been made from Fish Rock, including Grey Nurse Shark, Black Cod, Queensland Groper and Loggerhead Turtles. Reefs offshore of South West Rocks support some of the southern-most sub-tropical coral communities in Australia (Harriott *et al.* 1999).

These areas are among the most popular offshore dive and fishing sites in New South Wales and current and future human activities have the potential to impact on the conservation values and the sustainable use of these areas. Otway and Parker (2000) and Otway *et al.* (2003) have recommended that these sites be considered for declaration as aquatic reserves for the long term conservation of Grey Nurse Sharks. Critical habitat areas for these species were declared at these sites in December 2002.

Extensive areas of subtidal reef were also mapped offshore of:

- the coast between Crowdy Head and Diamond Head
- the coast between the Hallidays Point, Khappinghat Creek and the Manning River

For large areas of less prominent reef and intervening sediment there was little broad-scale survey information on habitats and associated biodiversity. While variation in depth provides approximate indicators of offshore biodiversity, more work is required to collate and analyse data available in individual geological reports and establish baseline biological surveys for these important areas.

▪ Appendix 3.

▪ Options for MPAs in the Hawkesbury Shelf Marine Bioregion

3.1 Option A. Hunter River to Avoca Lake

The main features of the estuaries, coast and ocean between the Hunter River and Avoca Lake are as follows:

- Option A includes two of the four estuarine ecosystem types that occur in the Hawkesbury Shelf bioregion: wave dominated barrier estuaries (Hunter River, Lake Macquarie and Tuggerah Lakes) and intermittent estuaries (Wamberal, Terrigal and Avoca Lagoons).
- Together with existing MPAs, this option would help represent almost 80% of the area of wave dominated barrier estuaries and 30% of intermittent estuaries. It would not add to the 7% of tide dominated drowned rivers in the bioregion already represented in North Sydney Harbour Aquatic Reserve, Shiprock Aquatic Reserve and the national parks and nature reserves in the Hawkesbury River and Port Hacking. Nor would it add to the 26% of ocean embayment already represented in Towra Point Aquatic Reserve and Towra Point Nature Reserve (**Error! Reference source not found.**).
- Option A includes sites at Fullerton Cove, Lake Macquarie and Wamberal Lagoon, previously listed as candidates in a NSW Fisheries² assessment of estuarine aquatic reserves (Frances 2000). The sites in the Hunter River and Lake Macquarie were, however, excluded after community consultation at that time.
- This option would contribute large areas of ocean ecosystems between 0-20 m (38% of this zone within NSW coastal waters) and 20-60 m (38% of this zone within NSW coastal waters). However, deeper areas in the 60-200 m zone for this option, all lie outside the 3 nm limit to State waters.
- Option A includes Lake Macquarie and Tuggerah Lakes which include the two largest areas of seagrass habitat in the bioregion. Together with existing MPAs, this option would help include 60% of the bioregion's seagrass habitat within MPAs.
- Option A includes the estuary with the largest area of mangrove habitat in the bioregion, the Hunter River. Together with existing MPAs, this option would include 55% of the bioregion's mangrove habitat in, or directly adjacent to MPAs.
- The largest areas of saltmarsh habitat also occur in the Hunter River. Together with existing MPAs, this option would include a total of 61% of this habitat in, or directly adjacent to some form of MPA.

² now within the NSW Department of Primary Industry

- Option A would contribute large areas of exposed intertidal beach (54% by area for all MPAs combined), exposed intertidal rocky shore (41%), inshore shallow reef (40%), inshore sand (45%) and islands (16%) to a system of MPAs in the bioregion.
- This option includes Towoon Point (south of The Entrance), selected in the NSW Fisheries² assessment to identify aquatic reserves for rocky intertidal shores and Nobby's Head (south of the Hunter River) and Yumool Point (south of Bateau Bay) originally short listed for investigation by an advisory panel of stakeholders and community representatives (Otway 1999).
- Nine rock platforms in this option were recommended for protection in an assessment by Short (1995).
- Summed irreplaceability scores for representation of 20% of estuarine habitats and ecosystems for the Hunter River, Lake Macquarie and Tuggerah Lakes are the highest in the bioregion and scores for the Hunter-Lake Macquarie and Munmorah-Tuggerah sections of ocean and coast are exceeded only by the Stanwell Park-Shellharbour sections of the bioregion.
- Option A for a large, multiple-use marine park could contribute towards representing a total of approximately 750 km² of marine habitat in some form of MPA in the Hawkesbury Shelf bioregion. This would represent 37% of estuarine and coastal waters under NSW jurisdiction (within 3nm) in the bioregion.
- This option includes no aquatic reserves but does include the marine components of Kooragang Island Nature Reserve (Fullerton Cove), Hexham Swamp Nature Reserve and Wamberal Lagoon Nature Reserve.
- Option A includes sightings of threatened and protected fish species including Black Cod, Grey Nurse Shark, Bleeker's Devil Fish and Weedy Sea dragon.
- Moon Island and Caves Beach Reef off Swansea, Wybung Head Reef, Hargraves Reef and Three Mile Reef off Norah Head, and Foggy's Cave and East Bombora off Terrigal are all sites where threatened Grey Nurse Shark have been observed in the past or recorded in recent surveys.
- The Hunter River, Lake Macquarie and Tuggerah Lakes all have a relatively diverse and productive commercial fish catch.
- The option includes previous nesting sites of the Little Tern at the Hunter River, Redhead, Swansea, Budgewoi and The Entrance.
- Option A includes areas with the highest diversity and abundance of threatened bird species in the bioregion.
- Kooragang Island and Fullerton Cove include the largest areas of mangrove and saltmarsh habitat in the Hawkesbury Shelf bioregion. This area is recognised as a nationally and internationally important wetland by the Directory of Important Wetlands, RAMSAR and

the Register of National Estate. It provides habitat for many species of migratory waders (ANCA 1996) and endangered bird species including the Little Tern (*Sterna albifrons*).

Large areas of tidal mudflats in Fullerton Cove are visited by up to 10,000 waders each summer including the vulnerable Freckled Duck (*Stictonetta naevosa*), Pied Oystercatcher (*Haematopus longirostris*), Mongolian Plover (*Charadrius mongolus*), Large Sandplover (*Charadrius leschenaultii*), Black-tailed Godwit (*Limosa limosa*), Terek Sandpiper (*Xenus cinereus*), Great Knot (*Calidris tenuirostris*) and Broad-billed Sandpiper (*Limicola falcinellus*).

The estuarine herb *Zannechellia palustris*, considered endangered at a state level and found in NSW only in the Newcastle/Lake Macquarie area, has been recorded immediately adjacent to the western end of the Reserve (ANCA1996).

After Myall Lakes, Kooragang Nature Reserve is the second largest MPA in NSW managed by the National Parks and Wildlife Service¹ but the area has no direct protection for fish and aquatic invertebrates from fishing.

- Hexham Swamp, located on the Hunter River at Ironbark Creek, is listed in the Directory of Important Wetlands. Before the construction of floodgates in 1971, approximately one third of the swamp was estuarine wetland. Existing vegetation includes mangrove forests with Grey (*Avicennia marina*) and River Mangrove (*Aegiceras corniculatum*), saltmarsh including Samphire (*Sarcocornia quinqueflora*) and Marine Couch (*Sporobolus virginicus*), Water Buttons (*Cotula coronopifolia*), Sea Rush (*Juncus krausii*), Water Couch (*Paspalum distichum*), Common Reed (*Phragmites australis*), Broad-leaved Cumbungi (*Typha orientalis*) and Swamp Oak (*Casuarina glauca*).

The estuarine wetlands were used as feeding habitat by migratory waders and many other birds. The endangered Black-necked Stork (*Ephippiorhynchus asiaticus*) and Green and Golden Bell Frog (*Litoria aurea*) and the vulnerable Magpie Goose (*Anseranas semipalmata*), Freckled Duck (*Stictonetta naevosa*), Australasian Bittern (*Botaurus poiciloptilus*), Painted Snipe (*Rostratula bengalensis*) and Comb-crested Jacana (*Irediparra gallinacea*) have been recorded from the swamp. Hexham swamp is the most important habitat in the Hunter region for the migratory Latham's Snipe (*Gallinago hardwickii*) listed under JAMBA and CAMBA. Prior to the floodgates the estuarine wetland also provided habitat for other species listed under JAMBA and CAMBA, including the Red-necked Stint (*Calidris ruficollis*), Bar-tailed Godwit (*Limosa lapponica*), Eastern Curlew (*Numenius madagascariensis*), Whimbrel (*Numenius phaeopus*), Grey-tailed Tattler (*Tringa brevipes*), and Greenshank (*Tringa nebularia*). These and other migratory waders would be expected to return to Hexham Swamp if the estuarine habitats were re-established (ANCA 1996).

¹ now within the NSW Department of Environment and Conservation

Historical records indicate that the waters of Hexham Swamp were also an important fisheries habitat prior to construction of the floodgates.

- Option A includes Moon Island, Bird Island Nature Reserve and Wamberal Lagoon Nature Reserve, all of which are on the Register of the National Estate.
- Moon Island, a 1 ha island located 1 km north-east of Swansea, is a breeding site for the Wedge-tailed Shearwater (*Puffinus pacificus*), Little Penguins (*Eudyptula minor*), Black Backed Gull (*Larus dominicus*), Sooty Oystercatcher (*Haematopus fuliginosus*) and the Crested Tern (*Sterna bergii*).
- Bird Island is a 7 ha, island approximately 60 m high and 1.6 km offshore of Lake Munmorah. Twelve species of seabird listed under JAMBA and CAMBA have been recorded from the island including the threatened Sooty Oystercatcher (*Haematopus fuliginosus*), the Wedge-tailed Shearwater (*Puffinus pacificus*), Short-tailed Shearwater (*P. tenuirostris*), Ruddy Turnstone (*Arenaria interpres*), Eastern Curlew (*Numenius madagascariensis*), Whimbrel (*Numenius phaeopus*), Bar-tailed Godwit (*Limosa lapponica*), Red-necked Stint (*Calidris ruficollis*), Arctic Jaeger (*Stercorarius pomarinus*), Caspian Tern (*Sterna caspia*), Common Tern (*Sterna hirundo*), White-fronted Tern (*Sterna striata*) and the endangered Little Tern (*Sterna albifrons*) (Commonwealth of Australia 2003).
- Lake Macquarie includes the largest area of seagrass habitat in the bioregion, and includes important habitat for fish (Miskiewicz 1987) and invertebrates (Gibbs 1987). The area between Swansea Heads, Wangi Wangi, Belmont and Crangan Bay was identified by an expert panel in a NSW Fisheries² assessment as a first priority candidate for an estuarine aquatic reserve (Frances 2000, NSW Fisheries 2001). The site was, however, excluded during subsequent community consultation.
- Tuggerah Lake is listed in the Directory of Important Wetlands and is important for its swamps of Paperbark (*Melaleuca quinquenervia*), Casuarina (*Casuarina glauca*), Swamp Oak, extensive beds of seagrasses (*Zostera capricorni*, *Halophila ovalis* and *Ruppia megacarpa*), and saltmarshes including Samphire (*Sarcocornia quinqueflora*), Saltwater Couch (*Paspalum vaginatum*) and Rushes (*Juncus sp.*) (ANCA 1996).
The area is a priority wetland for waders with up to 2500 migratory birds present in late spring and summer and up to 2000 Black Swans (*Cygnus atratus*), Chestnut Teal (*Anas castanea*) and Grey Teal (*Anas rhynchotis*) which feed on the exposed seagrass beds. The lake shores in summer are used by migrant waders listed under JAMBA or CAMBA including Bar-tailed Godwits (*Limosa lapponica*), Curlew Sandpiper (*Calidris ferruginea*), Sharp-tailed Sandpiper (*Calidris acuminata*), Red-necked Stint (*Calidris ruficollis*) and Red

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Knot (*Calidris canutus*). White-breasted Sea-Eagles (*Haliaeetus leucogaster*) and Whistling Kites (*Haliastur sphenurus*) nest around the lake (ANCA 1996).

- Budgewoi Lake Sand Mass on the eastern side of Budgewoi Lake is listed in the Directory of Important Wetlands and is the most important area of waterbird feeding habitat in the Tuggerah Lakes. It is a broad sand flat occupying about 30% of the lake floor in depths less than a metre. Seagrasses (*Zostera capricorni*, *Halophila ovalis* and *Ruppia megacarpa*) border the western side of the sand flat and adjacent habitat includes Samphire (*Sarcocornia quinqueflora*), Saltwater Couch (*Paspalum vaginatum*), Sea Rush (*Juncus kraussii*), Common Reeds (*Phragmites australis*), Swamp Oak (*Casuarina glauca*), Broad-leaved Paperbark (*Melaleuca quinquenervia*) and scattered Cabbage Tree Palms (*Livistona australis*) (ANCA 1996).

Large numbers of Black Swans (*Cygnus atratus*) feed on the seagrasses and many Grey Teal (*Anas gracilis*), Chestnut Teal (*Anas castanea*) and Shoveller (*Anas rhynchos*) have been observed at this site. Caspian Tern (*Sterna caspia*), Little Tern (*Sterna albifrons*) and Gull-billed Terns (*Sterna nilotica*) feed in the shallows during summer and waders listed under JAMBA and CAMBA, such as Bar-tailed Godwits (*Limosa lapponica*), Red Knots (*Calidris canutus*) and Curlew Sandpiper (*Calidris ferruginea*) are present each summer on the mud and sand flats. Less common waders like Grey Plover (*Pluvialis squatarola*), Double-banded Plover (*Charadrius bicinctus*) and Greenshank (*Tringa nebularia*) also occur (ANCA 1996).

- Colongra Swamp, listed in the Directory of Important Wetlands, is located on the west side of Lake Munmorah. It is a small, shallow freshwater wetland with Broad-leaved Paperbark (*Melaleuca quinquenervia*) and reedbeds of Cumbungi (*Typha augustifolia*) and Sea Rush (*Juncus kraussii*) (ANCA 1996).
- Up to 200 breeding pairs of Great Cormorant (*Phalacrocorax carbo*), Pied Cormorant (*Phalacrocorax varius*), Little Pied Cormorant (*Phalacrocorax melanoleucos*) and Little Black Cormorants (*Phalacrocorax sulcirostris*) occur here with smaller numbers of Darters (*Anhinga melanogaster*), Royal Spoonbill (*Platalea regia*) and White Ibis (*Threskiornis molucca*) also nesting. White-bellied Sea-Eagles (*Haliaeetus leucogaster*) and Whistling Kites (*Haliastur sphenurus*) nest in the swamp, and Black Swans (*Cygnus atratus*) nest in the reedbeds. Hoary-headed Grebes (*Polyocephalus polyocephalus*) occur in winter. Species listed under JAMBA or CAMBA include the White-bellied Sea-Eagle (*Haliaeetus leucogaster*) and Crested Tern (*Sterna bergii*) (ANCA 1996).
- Wamberal Lagoon Nature Reserve includes reed beds, sedgeland and important habitat for fish, molluscs, crustaceans and a range of migratory waders.
- All of the waters and 16% of the lands surrounding Wamberal Lagoon are included in nature reserve. However with the exception of Fullerton Cove in the Hunter River, less than 5% of the lands around other estuaries in this option are protected in terrestrial reserves.

Sections of ocean coast in this option all include less than 20% of adjacent lands in national park or nature reserve.

- With the exception of the Hunter River, most estuaries in this option had 20-50% of adjacent lands in urban development. The ocean coast between the Hunter River and Tuggerah Lakes had less than 20% of adjacent lands in urban development, and the Tuggerah-Avoca section had greater than 50% of the coast built on.
- The estuaries and coast in this option tended to have a relatively high percentage of adjacent land with disturbed or high risk acid sulphate soils.
- Mean river and catchment disturbance indices were low to moderate for most estuaries and sections of coast.
- Much wetland habitat has been lost in the Hunter River catchment and many estuarine and floodplain wetlands have been alienated from the river and substantially degraded. The diversity of estuarine habitat has declined due to losses in shoreline length, saltmarsh area and open water and at least 18 of the 33 species of migratory wading birds using the estuary have declined in numbers. The estimated mean number of birds fell by nearly 50% between the 1970s and 1990s (Healthy Rivers Commission 2002b).
- Kooragang Island originally consisted of several smaller islands and bars, but attempts to control siltation has aggregated these areas into larger units by filling channels, constructing training walls, building levee banks and draining wetland areas for agriculture. Past filling has destroyed up to 10 km² of estuarine wetlands, but the remaining wetlands remain in a healthy condition (ANCA1996).
- Industries on the Hunter River (previous steelworks, associated industry and port), Lake Macquarie (two power stations and a smelter) and Tuggerah Lakes (power station) have had at least localised impacts on marine habitats in these estuaries.
- The Healthy Rivers Commission Independent Inquiry into Coastal Lakes rates the catchment condition of Lake Macquarie and Tuggerah Lakes as modified, the condition of Lake Macquarie as severely affected and the condition of Tuggerah Lakes as moderately affected. Both estuaries were rated as having a high conservation value but were “targeted for repair”.
- As with many coastal areas in the Hawkesbury Shelf bioregion some of the most valuable areas for conservation of biodiversity and sustainable use of marine resources are threatened by increasing urban development and industrialisation.

3.2 Option B. Lake Munmorah (Wybung Point) to Narrabeen Lakes

The main features of the estuaries, coast and ocean between Lake Munmorah (Wybung Point) and Narrabeen Lakes are as follows:

- Option B includes three of the four estuarine ecosystem types that occur in the Hawkesbury Shelf bioregion including tide dominated river valleys (Hawkesbury River and Pittwater), barrier estuaries (Brisbane Water and Tuggerah) and intermittent estuaries (Wamberal and Terrigal Lagoons and Avoca, Cockrone and Narrabeen Lakes).
- Together with existing MPAs, this option would account for a total of 64% of the area of tide dominated drowned estuaries, 41% of wave dominated barrier estuaries and 81% of the area of intermittent estuaries. However, this option would not add to the 26% of ocean embayment already represented in Towra Point Aquatic Reserve and Nature Reserve.
- Option B would add large areas of the ocean ecosystems between 0-20 m (38% of this zone within NSW coastal waters) and 20-60 m (38% of this zone within NSW coastal waters). However, it would not represent deeper areas in the 60-200 m zone, which lie outside the 3 nm limit to State waters.
- Option B includes estuaries with the second (Tuggerah Lakes) and fourth (Brisbane Water) largest areas of seagrass habitat in the bioregion as well as significant areas of seagrass in Pittwater, the Hawkesbury River and several of the intermittent lagoons. If adopted, it would help contribute to a total of 48% of the bioregions seagrass habitat protected within MPAs.
- Option B includes the Hawkesbury River, with the second largest area of mangrove habitat in the bioregion and other significant mangrove habitats in Brisbane Water and Pittwater. If adopted, it would help contribute to a total of 53% of the bioregion's mangrove being included in, or directly adjacent to MPAs.
- This option includes the third and fourth largest areas of saltmarsh habitat in the bioregion in the Hawkesbury River and Brisbane Water and would contribute to a total of 23% of this habitat included in, or directly adjacent to some form of MPA.
- Together with existing MPAs, Option B could include large areas of exposed intertidal beach (36%), exposed intertidal rocky shore (34%), inshore shallow reef (39%), inshore sand (32%) and islands (11%) within a system of MPAs in this bioregion.
- Towoon Point (south of The Entrance) and Tudibaring Head (north of Cochrone Lake) were both selected as candidate sites for aquatic reserves in an assessment of intertidal rocky

shores by NSW Fisheries². Yumool Point (south of Bateau Bay) was originally short listed for investigation by an advisory panel of community and stakeholders (Otway 1999).

- Nine rock platforms in this option were recommended for protection by Short (1995).
- Summed irreplaceability scores for representation of 20% of all estuarine habitats and ecosystems were high for Tuggerah Lakes, the Hawkesbury River and Brisbane Water and for the Munmorah-Tuggerah and Tuggerah-Avoca sections of ocean and coast.
- Option B for a large marine park covers approximately 710 km² representing 35% of NSW waters in the Hawkesbury Shelf bioregion.
- This area includes existing aquatic reserves at Barrenjoey and Narrabeen Heads, Intertidal Protected Areas at Bungan and Mona Vale Heads, and the marine components of Wamberal Lagoon, Muogamarra, Pelican and Riley's Island Nature Reserves and Ku-ring-gai Chase, Brisbane Water and Bouddi National Parks.
- Option B includes sightings of threatened and protected fish species including Black Cod, Grey Nurse Shark, Bleeker's Devil Fish and Weedy Sea dragon.
- Wybung Head Reef, Hargraves Reef and Three Mile Reef off Norah Head, Foggy's Cave and East Bombora off Terrigal, South Palm Beach Reef and Hole in the Wall are all sites where threatened Grey Nurse Shark have been sighted in the past or recorded in recent surveys.
- The Hawkesbury River and Tuggerah Lakes have a relatively diverse and productive commercial fish catch.
- Option B includes previous nesting sites of the Little Tern at Budgewoi and The Entrance.
- This option includes the greatest diversity of threatened bird species, most sightings of threatened birds and the largest area of significant shore bird habitat.
- Lion Island, Long Island, Riley's Island, Pelican Island, Spectacle Island and Muogamarra Nature Reserves in the Hawkesbury River, Wamberal Lagoon Nature Reserve, and the Long Reef to Barrenjoey Coastal Rocks are all on the Register of the National Estate.
- Lion Island provides breeding habitat for Wedge-tailed Shearwater (*Puffinus pacificus*), Sooty Shearwater (*Puffinus griseus*) and the Little Penguin (*Eudyptyla minor*).
- Wamberal Lagoon Nature Reserve includes almost all of Wamberal Lagoon and reed beds, sedgeland and important habitat for fish, molluscs, crustaceans and a range of migratory waders.

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- Bird Island Nature Reserve (east of Lake Munmorah) is listed on the Register of National Estate as an important nesting site for seabirds and described in detail in Option A.
- Tuggerah Lake, Budgewoi Lake Sand Mass and Colongra Swamp are listed in the Directory of Important Wetlands and these areas are described in detail in Option A.
- Brisbane Water is listed in the Directory of Important Wetlands, includes large areas of Grey Mangrove (*Avicennia marina*) and River Mangrove (*Aegiceras corniculatum*) and extensive seagrass beds. Swans feed on the seagrass beds in spring and summer and the area is an important nursery and spawning ground for fish and crustaceans.

Riley's Island and Pelican Island Nature Reserves provide critical feeding and breeding areas for a range of migratory wader species, twelve of which are listed in JAMBA or CAMBA. The site is also important for the Bush Stone-Curlew (*Burhinus grallarius*), Pied Oystercatcher (*Haematopus longirostris*), Eastern Curlew (*Numenius madagascariensis*) and a pelican rookery.

- In an assessment of estuaries by NSW Fisheries², Brisbane Water was identified by an expert panel as a second priority candidate (after Lake Macquarie) for an aquatic reserve (Frances 2000, NSW Fisheries 2001). The estuary includes a rare combination of fish species (D. Hoese, pers. comm. in Frances 2000) and it remains the only barrier estuary in the bioregion with an entrance not kept open by artificial breakwalls.
- Narrabeen Lakes and Wamberal Lagoon were identified by an expert panel in the NSW Fisheries² assessment as first and second priority candidates for estuarine aquatic reserves (Frances 2000). Narrabeen Lakes include unique and ecologically important habitats and 42 species of benthic infauna have been recorded from the area (Patterson Britton and Partners 1995). Wamberal Lagoon has recorded the most diverse and abundant fish assemblages of those lagoons between the Hawkesbury River and Tuggerah Lakes (Frances 2000).
- Option B includes the marine extension to Bouddi National Park within which fishing is currently prohibited through a temporary (five year) fisheries closure. The vulnerable Sooty Oystercatcher, endangered Little Tern, and Osprey are found in the marine section of the national park and several species of migratory waders use the Brisbane Water section of the Park (NPWS 1999).
- Much of the catchment and shoreline of Option B is included in national park or nature reserve and much is inaccessible except by boat or on foot. The Hawkesbury River (with 42% of land within 1 km included in national park or reserve), Pittwater (45%), Brisbane Water (15%) and Wamberal Lagoon (all waters and 16% of land within 1 km) all have significant proportions of adjacent lands included in national park or nature reserve.

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- The Avoca-Brisbane Water section of ocean and coast in Option B has 42% of adjoining land included in national parks and nature reserves while other sections in this option have approximately 12% of adjacent land in terrestrial reserve.
- The Hawkesbury River has the least proportion of urban development (0.6%) within 1 km of its shores in the bioregion, but sections of ocean coast, particularly Tuggerah-Avoca (60%) and Brisbane Water–Narrabeen (58%) have a relatively high degree of urban development.
- The Hawkesbury River has a relatively low percentage of disturbed or high risk acid sulphate soils on adjacent lands, while Brisbane Water and Tuggerah Lakes have a moderate proportion of acid sulphate soils on adjacent land.
- Mean river and catchment disturbance indices were low to moderate for most estuaries and sections of coast in this option.
- The “Independent Inquiry into Coastal Lakes” carried out by the Healthy Rivers Commission rates the catchment condition of Tuggerah Lakes as modified and the lake condition as moderately affected with a high conservation value and a management recommendation of “targeted for repair”. A power station on Lake Munmorah discharges heated water into the upper part of the Tuggerah Lakes estuary.
- Many parts of the Hawkesbury and Nepean River are in relatively good condition due to the protection of catchment and shoreline in national park or nature reserve. However smaller urbanised sections of the catchment have poor water quality, particularly near centres like Goulbourn, Lithgow, Penrith, Hornsby and between Windsor and Sackville. Water quality is generally better in the lower reaches of the Hawkesbury estuary but there is concern over the potential for blue-green algae blooms and the presence of toxic dinoflagellate cysts in sediments (Healthy Rivers Commission 1998).
- Of the four scenarios described in this report, Option B is probably one of the least affected by heavy industry but may be affected by sewage input into the upper Hawkesbury River and urban development along the central coast and far northern beaches of Sydney.

3.3 Option C. Avoca Lake to Port Hacking

The main features of the estuaries, coast and ocean between Avoca Lake and Port Hacking are as follows:

- Option C would represent all four estuarine ecosystem types that occur in the Hawkesbury Shelf bioregion including tide dominated river valleys (Hawkesbury River, Pittwater, Parramatta River, Georges River and Port Hacking), barrier estuaries (Brisbane Water), intermittent estuaries (Avoca, Cockrone, Narrabeen, Dee Why, Harbord and Manly Lagoons) and ocean embayments (Botany Bay).
- Together with existing MPAs this option would account for a total of 100% of the area of tide dominated drowned rivers, 15% of wave dominated barrier estuaries, 92% of the area of intermittent estuaries and 100% of ocean embayments.
- It would add large areas of ocean ecosystems between 0-20 m (32% of this zone within NSW coastal waters) and between 20-60 m (34% of this zone within NSW coastal waters), and a significant proportion (55%) of those areas of the 60-200 m zone that lie within the 3 nm limit to State waters.
- Option C includes Brisbane Water which has the fourth largest area of seagrass habitat in the bioregion, as well as significant areas of seagrass in Pittwater, the Hawkesbury River, Parramatta River, Botany Bay, Port Hacking and several intermittent lagoons. Adopting this option could help protect 32% of the bioregions seagrass habitat within MPAs.
- Option C includes the Hawkesbury River, which has the second largest area of mangrove habitat in the bioregion, as well as significant mangrove habitats in Brisbane Water, Pittwater, Port Jackson, Botany Bay and the Georges River. If adopted, it would contribute toward a total of 67% of mangrove habitat in the bioregion in, or adjacent to MPAs.
- Option C includes estuaries with the second (Botany Bay), third (Hawkesbury River) and fourth (Brisbane Water) largest areas of saltmarsh habitat in the bioregion and could contribute to a system of MPAs with 40% of this habitat in, or adjacent to some form of MPA.
- Option C would contribute to representation of large areas of exposed intertidal beach (24%), exposed intertidal rocky shore (35%), inshore shallow reef (34%), inshore sand (30%) and islands (12%) within MPAs.
- Eleven rock platforms in this option were recommended for protection by Short (1995).
- Summed irreplaceability scores for representation of 20% of all habitats and ecosystems were moderately high for most estuaries and sections of ocean and coast in this option.

- Option C for a large marine park covers approximately 840 km² representing 42% of NSW waters in the Hawkesbury Shelf bioregion.
- This area includes existing aquatic reserves at Barrenjoey Head, Narrabeen Head, Long Reef, Cabbage Tree Bay, North Sydney Harbour, Bronte-Coogee, Cape Banks, Towra Point, Boat Harbour and Ship Rock.
- It includes Intertidal Protected Areas at Bungan Head, Mona Vale Head, Dee Why Head, Shelly Beach Head, Sydney Harbour, Bondi, Long Bay, Inscription Point and Cabbage Tree Point.
- It includes the marine components of the Wamberal Lagoon, Muogamarra, Pelican Island, and Rileys Island Nature Reserves and Brisbane Water, Ku-ring-gai Chase, Bouddi, Lane Cove and the Royal National Parks.
- Option C includes sightings of threatened and protected fish species including Black Cod, Great White Shark, Grey Nurse Shark, Bleeker's Devil Fish, Elegant Wrasse, Estuary Cod, Queensland Grouper and Weedy Sea Dragon.
- South Palm Beach Reef, Hole in the Wall and Long Reef are all sites where threatened Grey Nurse Shark have been sighted in the past and Magic Point at South Maroubra is an important aggregation site included within critical habitat for this endangered species.
- The Hawkesbury River and other estuaries in the area have yielded relatively diverse and productive commercial fish catches.
- The area includes previous nesting sites of the Little Tern at Dee Why Lagoon, Homebush Bay, Maroubra, and Boat Harbour and a significant current nesting site at Towra Spit, Botany Bay.
- The Parramatta River has the second highest diversity and summed irreplaceability for threatened bird species.
- Lion Island, Long Island, Rileys Island, Pelican Island, Spectacle Island and Muogamarra Nature Reserves in the Hawkesbury River, the Long Reef to Barrenjoey Coastal Rocks, Dee Why Lagoon Reserve, North Head, Sydney Harbour National Park, Parramatta River wetlands, North Bondi Cliffline, Cape Banks, Kurnell and Towra Point and Voyager Point, are all on the Register of the National Estate (Commonwealth of Australia 2003).
- Important conservation values for Lion Island, Long Island, Rileys Island, Pelican Island, Spectacle Island and Muogamarra Nature Reserves are described in Option B.
- Brisbane Water is listed in the Directory of Important Wetlands as described in Option B.
- Dee Why Lagoon Reserve is listed on the Register of the National Estate. It is considered one of the best examples, in the Sydney Region, of an estuarine lagoon (Commonwealth of

Australia 2003) and one of the few in the region remaining in good condition. The saltmarsh around the lagoon is a relatively diverse and uncommon remnant, formerly more widespread in the Sydney Region. Other aquatic vegetation includes *Zostera capricorni*, saltmarsh (*Suaeda australis*) and rushes (*Juncus kraussi*, *J. acutus*). The lagoon supports several species of waders and cryptic species such as the Tailor Cisticola (*Cisticola exilis*) and the Tawny Grassbird (*Megalurus timoriensis*). It provides habitat for fish species including pilchard (*Sardinops neopilchardus*), sand whiting (*Silago cilliata*), silver biddy (*Gerres ovatus*) and sand mullet (*Myxus elongatus*).

Dee Why Lagoon was identified by an expert panel in a NSW Fisheries² assessment as a first priority candidate for an estuarine aquatic reserve. It has the most diverse fish community of any mature intermittent estuary in the Hawkesbury Shelf bioregion (D. Hoese pers. comm. in Frances 2000).

- Nine significant wetland remnants on the upper Parramatta River (Ermington Bay, Meadowbank Park, Yarralla Bay, Majors Bay, Mason Park, Homebush Bay, Silverwater Saltmarsh, Lower Duck River and Haslem's Creek) are listed on the register of the National Estate. Newington Wetlands is listed in the Directory Of Important Wetlands and includes mangrove and saltmarsh habitats bordering four brackish ponds. These areas were once part of extensive mangrove and saltmarsh wetlands on the Parramatta River. The saltmarsh communities are in good health and display a species composition uncommon in the Sydney area and include Samphire (*Sarcocornia quinqueflora*), Seablite (*Suaeda australis*), Sand Couch Grass (*Sporobolus virginicus*), the restricted saltmarsh species, *Lampranthus tegens* (small pig face), an important stand of native rush (*Juncus kraussi*), the Chenopod *Halosarcia pergranulata* and one of the largest remaining populations of the uncommon *Wilsonia backhousei*, which is at its northern limit in Sydney (ANCA 1996, Commonwealth of Australia 2003).

The wetlands support seventy-five bird species, of which thirty-seven species occur regularly, and the area provides breeding habitat for seventeen species. The wetlands have been ranked sixth in importance for waders in New South Wales and they provide habitat for twenty species listed under JAMBA and 19 species listed under CAMBA, including Pacific Golden Plover (*Pluvialis fulva*), Latham's Snipe (*Gallinago hardwickii*), Bar-tailed Godwit (*Limosa lapponica baueri*), Sharp-tailed Sandpiper (*Calidris acuminata*), Curlew Sandpiper (*Calidris ferruginea*) and Greenshank (*Tringa nebularia*).

Two endangered species, the Little Tern (*Sterna albifrons*) and the Black Tailed Godwit (*Limosa limosa*), are found here and the wetland also supports one of the two Sydney colonies of the White Fronted Chat (*Epthianura albifrons*); one of the largest populations of

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Chestnut Teal (*Anas castanea*) in NSW; a regionally significant population (200-400 individuals) of the Black-winged Stilt (*Himantopus himantopus*); and more than one percent of the Australian population of the Lesser Golden Plover (*Pluvialis dominica*). The endangered Green and Golden Bell Frog (*Litoria aurea*) has also been recorded from the area (Commonwealth of Australia 2003).

- Towra Point Nature Reserve, Aquatic Reserve and Taren Point in Botany Bay are included in the Directory of Important Wetlands and include a variety of estuarine habitats including spits, bars, mudflats, dunes and beaches. The extensive tidal wetlands, include approximately 600 ha of seagrasses including *Posidonia australis*, *Zostera capricorni*, and *Halophila ovalis* and *H. decipiens*. There are 400 ha of mangroves including the Grey (*Avicennia marina*) and River Mangrove (*Aegiceras corniculatum*) and 161 ha of saltmarshes, representing one of the few large remnant systems near Sydney (ANCA 1996).

NSW Fisheries² has described over 230 species of fish and invertebrates in the Towra Point Aquatic Reserve and the area supports commercial and recreational fish stocks in the coastal Sydney region.

Towra Point is an important bird feeding, roosting and nesting site for migratory waders and waterfowl and is listed under the Ramsar Convention. Approximately 200 bird species have been recorded from the Towra Point area including 31 of the 66 species listed under JAMBA (References in ANCA 1996). Towra Point has a regular occurrence of 2% of the Australian population of the Eastern Curlew (*Numenius madagascariensis*), 6% of the Lesser Golden Plover (*Pluvialis dominica*) and 1% of the Ruddy Turnstone (*Arenaria interpres*) (References in ANCA 1996). The sand spit area is also breeding habitat for threatened species like the Little Tern (*Sterna albifrons*), Pied Oystercatcher (*Haematopus longirostris*) and the Terek Sandpiper (*Xenus cinereus*) (ANCA 1996). The Taren Point Shorebird Community is listed as an endangered ecological community.

There are significant threats to this location from heavy industry and port facilities around the shores of the bay, including pollution, dredging, changes in wave action by revetment walls, and shoreline instability and erosion. The sand flats and beach at the eastern end of Towra Point and the western end of Towra Spit are being damaged by coastal erosion with the spit extending in a south-westerly direction.

- Eve Street Marsh, on the Cooks River near Arncliffe is listed in the Directory of Important Wetlands and includes diverse saltmarsh habitat including Sea Rush (*Juncus kraussi*), Seablite (*Suaeda australis*), Samphire (*Sarcocornia quinqueflora*) and the uncommon Creeping Monkey-flower (*Mimulus repens*) (References in ANCA 1996). The marsh

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provides habitat for six JAMBA / CAMBA species including the Great Egret (*Ardea alba*), Greenshank (*Tringa nebularia*), Curlew Sandpiper (*Calidris ferruginea*), Red-necked Stint (*Calidris ruficollis*), Sharp-tailed Sandpiper (*Calidris acuminata*) and Bar-tailed Godwit (*Limosa lapponica*).

- Voyager Point Wetlands at the junction of the Georges River and Williams Creek are listed on the Register of the National Estate (Commonwealth of Australia 2003). The area includes wetlands characteristic of the Georges River including mangroves and *Casuarina glauca*. Saltmarsh species here include *Samolus repens*, *Suaeda australis*, *Sarcocornia quinqueflora*, *Sporobolus virginicus* and *Cotula coronopifolia* and a pure stand of the uncommon species *Wilsonia backhousei*. Estuarine sedgeland here includes *Juncus kraussi*, *Baumea juncea* and *Phragmites australis*. The freshwater wetlands are characterised by paperbark swamps and emergent and submerged aquatic vegetation including *Eleocharis sphacelata*, *Triglochin procera typha orientalis* and species of *Myriophyllum*, *Utricularia*, *Nymphoides* and *Persicaria*. Threats to the area include changes in water quality, wash from speedboats and drainage from nearby housing developments.
- Option C includes within its boundaries, the majority of coastal and estuarine marine habitats in the Sydney Metropolitan area. It includes areas ranging from the most impacted locations to relatively unaffected areas in the Hawkesbury River and Port Hacking. The Hacking River (with 64% of adjacent land in national park), Hawkesbury River (42%), Pittwater (45%), Brisbane Water (15%) and Wamberal Lagoon (all waters and 16% of adjacent land in reserve) all have significant proportions of adjacent lands included in national parks or nature reserves. However Botany Bay, the Parramatta River and Georges River all have less than 10% of their shores in terrestrial reserves.

The Avoca-Brisbane Waters (42% of land within 1 km of the coast) and Botany-Port Hacking (26%) have moderate proportions of adjacent lands in national parks and nature reserves but other sections of coast in this option have less than 12% of adjacent land in terrestrial reserves.

- Option C includes the most extensive urban and industrial areas in NSW. While the Hawkesbury River has a relatively low level of urban development (0.6%) within 1 km of its shores, estuaries between Dee Why and the Georges River all had over 50% of their shores built on. Over 50% of the ocean coast between Barrenjoey and Cape Banks is adjacent to urban areas.
- Mean river and catchment disturbance indices for this option were generally the highest in the State with the exceptions of Port Hacking and the Hawkesbury River. Inputs from sewage and stormwater outlets throughout the Sydney area are also likely to be higher than elsewhere in the bioregion and there is evidence of contamination of estuarine sediments

with heavy metals and PCBs in sections of the Parramatta River, Botany Bay and the Georges River (Birch 1995).

- The Healthy Rivers Commission “Independent Inquiry into Coastal Lakes” rates the catchment condition of Dee Why, Curl Curl and Manly Lagoons as severely modified and the lake conditions as severely affected with recommended management as “targeted for repair”.
- Many shores in the Sydney Metropolitan area have been substantially modified or replaced with walls, wharves or marinas, particularly in Sydney Harbour. However a number of studies have shown that these may support very diverse assemblages of marine species and that despite an extremely high level of urban development, marine biodiversity may be very high (Chapman and Bulleri 2003). It can also be argued that irreplaceable areas at risk should be given priority over remote locations, which may be in better condition, but may require less immediate protection.

3.4 Option D. Cape Banks to Shellharbour

The main features of the estuaries, coast and ocean between Cape Banks and Shellharbour are as follows:

- Option D includes three of the four estuarine ecosystem types that occur in the Hawkesbury Shelf bioregion including a tide dominated river valley (Port Hacking), barrier estuaries (Lake Illawarra and Port Kembla) and intermittent estuaries (Towradgi and Benson Creeks).
- Together with existing MPAs, this option would account for a total of 12% of the area of tide dominated drowned rivers in the bioregion, 18% of wave dominated barrier estuaries and 11% of the area of intermittent estuaries. However, this option would not add to the 26% of ocean embayment already represented in Towra Point Aquatic Reserve and Nature Reserve.¹
- Option D would add large areas of ocean ecosystems between 0-20 m (39% of this zone within NSW coastal waters) and between 20-60 m (31% of this zone within NSW coastal waters), and a significant proportion of those deeper areas in the 60-200 m zone (63%) that lie within the 3 nm limit to State waters.
- Option D includes Lake Illawarra which has the fourth largest area of seagrass habitat in the bioregion. There are also significant areas of seagrass in Port Hacking. Together with existing MPAs this option would help protect 22% of the bioregion's seagrass habitat in MPAs.
- Port Hacking includes small areas of mangrove habitat adding slightly to existing habitats already protected in MPAs for a total of 23% of the bioregion's mangrove habitats included in, or adjacent to MPAs.
- Port Hacking and Lake Illawarra include small areas of saltmarsh adding slightly to a total of 6% of this habitat included in, or adjacent to some form of MPA.
- Option D would add large areas of exposed intertidal beach (29%), exposed intertidal rocky shore (40%), inshore shallow reef (41%), and inshore sand (34%) to the total area of these habitats protected in MPAs.
- The majority of the area of inshore and offshore islands in the Hawkesbury Shelf are found in this option. Together with existing MPAs, this marine park option would help contribute towards protecting 73% of the area of islands in the bioregion within MPAs.
- Six rock platforms in this option were recommended for protection by Short (1995).

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¹ Although a variation on this option might also include Botany Bay and the Georges River, thereby representing all estuarine ecosystem types within one large multiple-use marine park.

- This option also includes Brickyard Point (north of Wollongong), selected as a candidate site for a marine protected area in the NSW Fisheries² assessment to identify aquatic reserves for rocky intertidal shores (Otway 1999).
- Summed irreplaceability scores for representation of 20% of habitats and ecosystems were low for Port Hacking but relatively high for Lake Illawarra and the highest in the bioregion for the Towradgi-Shellharbour section of coast and ocean. The latter score strongly reflects the presence of offshore islands in this area.
- Option D for a large marine park covers approximately 570 km² representing 28% of NSW waters in the Hawkesbury Shelf bioregion.
- This area includes existing aquatic reserves at Boat Harbour and Ship Rock, Intertidal Protected Areas at Inscription Point (Kurnell) and Cabbage Tree Point in Port Hacking, and the marine components of the Royal National Park in Cabbage Tree Basin, South West Arm, the Hacking River and Wattamolla Lagoon.
- The area includes sightings of threatened and protected fish species including Black Cod, Grey Nurse Shark, Bleeker's Devil Fish, Elegant Wrasse and Weedy Sea dragon.
- Gibbon Bombora, Marley Point, Toothbrush Island and Windang Island are all sites where threatened Grey Nurse Shark have been sighted in the past or recorded in surveys.
- Port Hacking has a relatively small commercial catch and diversity of species, while Lake Illawarra has a somewhat larger catch and greater diversity of species in catches.
- The area includes previous nesting sites of Little Tern at Boat Harbour, Bellambi Point, Towradgi Beach, South Wollongong Beach, Port Kembla Harbour, Port Kembla Beach, Lake Illawarra and Shellharbour.
- A high number of threatened bird species, sightings, and a moderate summed irreplaceability are recorded for Lake Illawarra and a moderate number of species and sightings reported for the Towradgi-Shellharbour section.
- Coomaditchy Lagoon, a small coastal dunal lake at the original entrance to Lake Illawarra, is listed in the Directory of Important Wetlands (ANCA 1996). The lagoon is only slightly brackish, probably sourcing some sea water through diffusion. It provides habitat for a variety of birds, reptiles, frogs and fish and contains a reed swamp and sedge swamp on the southern and western shores used as breeding sites for waterbirds. The area includes remnant hind dune and littoral rainforest vegetation, a population of endangered Green and Golden Bell Frog (*Litoria aurea*) and is the only area in the Illawarra region to record Wandering Whistling Duck (*Dendrocygna arcuata*). JAMBA or CAMBA species observed include the Great Egret (*Ardea alba*), White-bellied Sea-Eagle (*Haliaeetus leucogaster*),

Latham's Snipe (*Gallinago hardwickii*), and Sharp-tailed Sandpiper (*Calidris acuminata*) (references in ANCA 1996).

- Five Islands Nature Reserve is listed in the Directory of Important Wetlands, is an important area for seabird breeding and provides habitat for many migratory birds. The islands are important for the vulnerable Sooty Oystercatcher (*Haematopus fuliginosus*) with 30% of the NSW population breeding on the islands and relying on the intertidal zone around the islands for foraging. The vulnerable Black-browed Albatross (*Diomedea melanophrys*) has also been recorded here and JAMBA/ CAMBA species observed include the Wedge-tailed Shearwater (*Puffinus pacificus*), Lesser Frigatebird (*Fregata ariel*), Eastern Reef Egret (*Egretta sacra*), and Crested Tern (*Sterna bergii*) (references in ANCA 1996).
- Lake Illawarra is listed in the Directory of Important Wetlands (ANCA 1996). Berkeley Nature Reserve, which includes Gooseberry and Hooka Islands in Lake Illawarra, is on the Register of the National Estate. Seagrasses such as *Zostera* sp. and *Ruppia* sp. provide food for waterfowl on the Lake. A total of 24 species of waterbirds are recorded from here, including Grey Teal (*Anas gibberifrons*), Chestnut Teal (*Anas castanea*), Black Swan (*Cygnus atratus*) and Australasian Little Grebe (*Podiceps novaehollandiae*). Foreshore vegetation includes saltmarsh with Samphire (*Sarcocornia quinqueflora*), Shore Rush (*Juncus kraussii*), Common Reed (*Phragmites australis*), Swamp Oak (*Casuarina glauca*), and Creeping Saltbush (*Atriplex australasica*) (ANCA 1996).

Endangered species recorded within Lake Illawarra include the Little Tern (*Sterna albifrons*) and the Hooded Plover (*Thinornis rubricollis*). Vulnerable species include the Freckled Duck (*Stictonetta naevosa*), Australasian Bittern (*Botaurus poiciloptilus*), Black Bittern (*Ixobrychus flavicollis*), Sanderling (*Calidris alba*), Great Knot (*Calidris tenuirostris*), Black-tailed Godwit (*Limosa limosa*), Terek Sandpiper (*Xenus cinereus*), Pied Oystercatcher (*Haematopus longirostris*), Greater Sand Plover (*Charadrius leschenaultii*) and the White Tern (*Gygis alba*) (ANCA 1996).

Species listed under JAMBA or CAMBA recorded near Lake Illawarra include the Sooty Shearwater (*Puffinus griseus*), Brown Booby (*Sula leucogaster*), Great Egret (*Ardea alba*), Cattle Egret (*Ardea ibis*), Eastern Reef Egret (*Egretta sacra*), White-bellied Sea-Eagle (*Haliaeetus leucogaster*), Common Sandpiper (*Actitis hypoleucos*), Ruddy Turnstone (*Arenaria interpres*), Sharp-tailed Sandpiper (*Calidris acuminata*), Red Knot (*Calidris canutus*), Curlew Sandpiper (*Calidris ferruginea*), Pectoral Sandpiper (*Calidris melanotos*), Red-necked Stint (*Calidris ruficollis*), Latham's Snipe (*Gallinago hardwickii*), Grey-tailed Tattler (*Heteroscelus brevipes*), Wandering Tattler (*Heteroscelus incanus*), Bar-tailed Godwit (*Limosa lapponica*), Eastern Curlew (*Numenius madagascariensis*), Common Greenshank (*Tringa nebularia*), Marsh Sandpiper (*Tringa stagnatilis*), Lesser Golden

Plover (*Pluvialis dominica*), Grey Plover (*Pluvialis squatarola*), White-winged Black Tern (*Chlidonias leucopterus*), Crested Tern (*Sterna bergii*), Caspian Tern (*Sterna caspia*), Common Tern (*Sterna hirundo*), and Fork-tailed Swift (*Apus pacificus*) (ANCA 1996).

Macquarie Rivulet in Lake Illawarra was identified by an expert panel in a NSW Fisheries² assessment as a third priority candidate (after Lake Macquarie and Brisbane Water) for an estuarine aquatic reserve (Frances 2000, NSW Fisheries 2001). The estuary has a distinctive fish assemblage (R. West, pers. comm. in Frances 2000) and Macquarie Rivulet has, in the past, provided important habitat for the Australian Grayling (*Prototroctes maraena*) (Farragher, in press cited in Frances 2000). Threats to this area include pollution and loss of habitat from urban development and industry (ANCA 1996).

- When compared to all other areas in the bioregion, Port Hacking had the highest proportion of adjacent land in national parks and nature reserve (64% of land within 1 km) and the Port Hacking-Stanwell Park section had most adjacent coast in terrestrial reserves (92%).
- Port Hacking (31%) and Lake Illawarra (42%) had a moderate proportion of adjacent lands in urban areas while much of the area adjacent to Port Kembla (88%) and Towradgi Creek (72%) was heavily developed or industrialised. The Port Hacking-Stanwell Park section (1.2%) had the least proportion of coast within built-up areas.
- Port Hacking had the lowest percentage of disturbed or high risk acid sulphate soils in adjacent lands in the bioregion, while Port Kembla had the highest.
- Mean river and catchment disturbance indices were lowest in the bioregion for Port Hacking and the Port Hacking-Stanwell Park section. Disturbance indices were generally low to moderate for other estuaries and sections of coast in this option but high for the Towradgi-Shellharbour coast.
- The Healthy Rivers Commission “Independent Inquiry into Coastal Lakes” rates the catchment condition of Lake Illawarra as modified and the lake condition as severely affected but with a high conservation value and recommended management as “targeted for repair”.
- A large proportion of Option D is likely to be relatively unaffected by urban development, industry or agriculture. This is largely due to the presence of the Royal National Park which borders the southern shores of Port Hacking and the coast between Port Hacking and Stanwell Park.
- South of the national park, there are increasing levels of urban settlement on the narrow coastal strip beneath the Illawarra Escarpment, and heavy industry around the shipping port at Port Kembla. As for other locations in the Hawkesbury Shelf bioregion, these developed areas often adjoin some of the most important and vulnerable sites for marine conservation.

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Appendix 4.

Options in the Batemans and Twofold Shelf Bioregions

4.1 Option A. Shellharbour to Jervis Bay Marine Park (Batemans Shelf)

The main ecological features that Option A could include are as follows:

- All estuarine ecosystem types, except tide dominated drowned river valley and extensive examples of estuarine habitats partially represented in Jervis Bay Marine Park.
- All ocean ecosystem depth zones occurring in NSW waters and all ocean habitats.
- Jervis Bay, the largest ocean embayment with the largest area of seagrass in the bioregion. The Bay, its associated wetlands and the Jervis Bay Sea Cliffs are listed in the Directory of Important Wetlands and the Register of the National Estate. The area includes a very wide diversity of habitats including tidal, intertidal and estuarine wetlands, freshwater lagoons, swamp, saltmarsh, sedgeland, sheltered and exposed rocky shores, beaches, reef, subtidal sediments and non-tidal forested wetlands (ANCA 1996).

The bay has extensive beds of *Posidonia*, *Zostera* and *Halophila* seagrasses and the largest beds of *Posidonia australis* in NSW. Jervis Bay also includes areas of the seagrasses *Heterozostera tasmanica* and *Zostera muelleri*, both uncommon in NSW. Mangrove species include River (*Avicennia marina*) and Grey Mangrove (*Aegiceras corniculatum*). Saltmarsh species include *Sarcocornia quinqueflora*, *Wilsonia backhousei*, and *Sporobolus virginicus*. The saltmarsh on the cliff tops of Bowen Island is unique in that it receives its moisture from sea spray (ANCA 1996).

Bowen Island supports a colony of Little Penguins, three shearwater species and sea eagles. The rare Pied Oystercatcher (*Haematopus longirostris*) nests near the bay and 27 wader species, 17 of which are listed under JAMBA or CAMBA use the area. The Green and Golden Bell frog (*Litoria aurea*) is found on Bowen Island and in the northern part of the Jervis Bay area (ANCA 1996).

The sea cliffs on the Beecroft and Bherwerre Peninsulas are some of the tallest on the NSW coast and include incised inlets such as Eves Ravine and Devils Inlet, islets like the Drum and Drum Sticks and marine caves, overhangs, tunnels and crevices.

- The Shoalhaven River, the second largest wave dominated barrier estuary in the bioregion with the largest area of mangrove habitat, the second largest area of saltmarsh in the bioregion and the highest summed irreplaceability score for estuarine ecosystems and habitats.

The river includes important habitat for Australian Bass and the Australian Grayling and was identified as a third priority candidate aquatic reserve in a previous NSW Fisheries² assessment for estuarine MPAs.

The lower estuary is listed in the Directory of Important Wetlands. Wetland plants include River Mangrove (*Aegiceras corniculatum*), Sea Rush (*Juncus kraussii*), *Juncus polyanthemus*, Common Reed (*Phragmites australis*), Swamp Oak (*Casuarina glauca*), Samphire (*Sarcocornia quinqueflora*), *Sporobolus virginicus*, Seablite (*Suaeda australis*), Goosefoot (*Chenopodium glaucum*) and New Zealand Spinach (*Tetragonia tetragonoides*). The largest remaining area of littoral rainforest on the south coast occurs on the south-western side of Comerong Island (ANCA 1996).

This estuary is one of five coastal wetlands considered to be the second most important for shorebirds on the NSW coast. It supports the endangered Little Tern (*Sterna albifrons*), Beach Thick-knee (*Esacus neglectus*) and Hooded Plover (*Thinornis rubricollis*), and vulnerable species including the Mongolian Plover (*Charadrius mongolus*), Large Sand Plover (*Charadrius leschenaultii*), Sooty Oystercatcher (*Haematopus fuliginosus*), Pied Oystercatcher (*Haematopus longirostris*), Terek Sandpiper (*Xenus cinereus*), Broad-billed Sandpiper (*Limicola falcinellus*), Great Knot (*Calidris tenuirostris*), the Black-tailed Godwit (*Limosa limosa*) and Osprey (*Pandion haliaetus*).

Species found here and listed under JAMBA or CAMBA include the Wedge-tailed Shearwater (*Puffinus pacificus*), Short-tailed Shearwater (*Puffinus tenuirostris*), Cattle Egret (*Ardeola ibis*), Great Egret (*Egretta alba*), Grey Plover (*Pluvialis squatarola*), Lesser Golden Plover (*Pluvialis dominica*), Ruddy Turnstone (*Arenareia interpres*), Eastern Curlew (*Numenius madagascariensis*), Whimbrel (*Numenius phaeopus*), Grey-tailed Tattler (*Tringa brevipes*), Common Sandpiper (*Tringa hypoleucos*), Greenshank (*Tringa nebularia*), Marsh Sandpiper (*Tringa stagnatilis*), Latham's Snipe (*Gallinago hardwickii*), Asian Dowitcher (*Limnodromus semipalmatus*), Bar-tailed Godwit (*Limosa lapponica*), Red Knot (*Calidris canutus*), Sharp-tailed Sandpiper (*Calidris acuminata*), Red-necked Stint (*Calidris ruficollis*), Long-toed Stint (*Calidris subminuta*), Curlew Sandpiper (*Calidris ferruginea*), Sanderling (*Calidris alba*), White-winged Tern (*Chlidonias leucoptera*), Caspian Tern (*Sterna caspia*), Common Tern (*Sterna hirundo*) and Crested Tern (*Sterna bergii*). The endangered Green and Golden Bell Frog (*Litoria aurea*) has also been found here (ANCA 1996).

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- Lake Wollumboola, the largest intermittent estuary in the bioregion and a first priority candidate in a NSW Fisheries² assessment for estuarine aquatic reserves. The lake is now included within Jervis Bay National Park. It is the fourth largest and second most successful nesting area for the endangered Little Tern in NSW. It supports 11 threatened bird species, at least 24 JAMBA/CAMBA species and is listed in the Directory of Important Wetlands.

The lake includes beds of seagrass and the surrounding wetlands include Casuarina forest, teatree, saltmarsh, sedgelands and species including Common Reed (*Phragmites australis*), Salt Rush (*Juncus kraussii*), Sedge, *Baumea juncea*, *Wilsonia rotundifolia*, Samphire (*Sarcocornia quinqueflora*), Paperbark (*Melaleuca* sp.) and Swamp She-oak (*Casuarina glauca*) (ANCA 1996).

The lake is important as feeding habitat for Black Swans and Chestnut Teal and supports vulnerable bird species including the Little Shearwater (*Puffinus assimilus*), Broad-billed Sandpiper (*Limicola falcinellus*) and Lesser Sand Plover (*Charadrius mongolus*) (ANCA 1996).

Species listed under JAMBA or CAMBA include the Bar-tailed Godwit (*Limosa lapponica*), Great Egret (*Ardea alba*), Cattle Egret (*Ardea ibis*), White-bellied Sea-Eagle (*Haliaeetus leucogaster*), Latham's Snipe (*Gallinago hardwickii*), Common Greenshank (*Tringa nebularia*), Grey Plover (*Pluvialis squatarola*), White-winged Black Tern (*Chlidonias leucopterus*), Crested Tern (*Sterna bergii*) and Caspian Tern (*Sterna caspia*) (ANCA 1996). Pollard (references in ANCA 1996) recorded 41 fish species from the lake of which 26 were of commercial importance.

- Killalea Lagoon, listed in the Directory of Important Wetlands, and breeding habitat for large numbers of Black Swans and vulnerable species including Pied Oystercatcher (*Haematopus longirostris*), Comb-crested Jacana (*Irediparra gallinacea*), Blue-billed Duck (*Oxyura australis*) and Australasian Bittern (*Botaurus poiciloptilus*) (References in the ANCA 1996).

Species listed under JAMBA or CAMBA found here include The Great Egret (*Ardea alba*), Cattle Egret (*Ardea ibis*), Glossy Ibis (*Plegadis falcinellus*), White-bellied Sea-Eagle (*Haliaeetus leucogaster*), Sharp-tailed Sandpiper (*Calidris acuminata*), Red-necked Stint (*Calidris ruficollis*), Latham's Snipe (*Gallinago hardwickii*), Bar-tailed Godwit (*Limosa lapponica*), Common Greenshank (*Tringa nebularia*), Marsh Sandpiper (*Tringa stagnatilis*), Wood Sandpiper (*Tringa glareola*), Common Sandpiper (*Actitis hypoleucos*), Curlew Sandpiper (*Calidris ferruginea*), Crested Tern (*Sterna bergii*) and the Caspian

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Tern (*Sterna caspia*). Other waterbird species include Pied Cormorant (*Phalacrocorax varius*), Little Black Cormorant (*Phalacrocorax sulcirostris*), Pelicans and Black Duck (*Anas superciliosa*) (References in the ANCA 1996). The area also provides habitat for the endangered Green and Golden Bell Frog (*Litoria aurea*) (References in the ANCA 1996).

- The Minnamurra River, an important wetland with significant mangrove and saltmarsh communities supporting vulnerable bird species and 7 JAMBA/CAMBA species. The river has Grey Mangrove (*Avicennia marina*) and River Mangrove (*Aegiceras corniculatum*) with saltmarsh, *Casuarina* and rushes in tidal areas. Saltmarsh species include Samphire (*Sarcocornia quinqueflora*), Salt Couch (*Sporobolus virginicus*) and pigface. The floodplain area is crossed by a number of creeks which support fringes of mangroves. Species present also include Swamp She-oak (*Casuarina glauca*), Northern Boobialla (*Myoporum acuminatum*), Salt Rush (*Juncus kraussii*), Club Rush (*Isolepis nodosa*), Seablite (*Suaeda australis*), Salt Couch (*Sporobolus virginicus*), Salt Rush (*Juncus kraussii*), Streaked Arrowgrass (*Triglochin striata*) and Creeping Brookweed (*Samolus repens*) (ANCA 1996).

Bird species listed as threatened include the Australasian Bittern (*Botaurus poiciloptilus*), Comb-crested Jacana (*Irediparra gallinacea*), Sooty Oystercatcher (*Haematopus fuliginosus*) and the Black Bittern (*Ixobrychus flavicollis*) (ANCA 1996).

Birds listed under JAMBA or CAMBA include the Great Egret (*Ardea alba*), Cattle Egret (*Ardea ibis*), Glossy Ibis (*Plegadis falcinellus*), White-bellied Sea-Eagle (*Haliaeetus leucogaster*), Whimbrel (*Numenius phaeopus*), Crested Tern (*Sterna bergii*) and the Caspian Tern (*Sterna caspia*) (ANCA 1996).

- Bass Point, an aggregation site and declared critical habitat for the endangered Grey Nurse Shark. The site was previously proposed as a candidate for an Aquatic Reserve and is listed on the Register of the National Estate.

The area includes relatively undisturbed examples of high diversity, fringing reef, intertidal pool and boulder field communities with soft corals, gorgonian sea fans, sponge gardens and many crustacean, mollusc and cnidarian species not commonly found in the Illawarra region (Commonwealth of Australia 2003).

The protected Bleeker's Devilfish (*Paraplesiops bleekeri*), Black Rock Cod (*Epinephelus daemeli*) and Elegant Wrasse (*Anampses elegans*) and 151 other fish species have been recorded from this area, a higher number than found at similar sites (Commonwealth of Australia 2003). At least seventeen rare or uncommon fish species occur in the area, as well as a rare zoanthid, two rare coral species, a rare sea pen, eight rare or uncommon

molluscs, four rare crustaceans, two rare sea spiders, four rare echinoderms and two rare or uncommon ascidians. The broach shell (*Trigonia strangeii*) and the sand dollar (*Clypeaster tumidus*) are also thought to occur here (Commonwealth of Australia 2003).

- Bushrangers Bay, an aquatic reserve listed on the Register of the National Estate. This small, rocky, semi-enclosed oceanic bay includes boulder, reef and sand habitats, an area of *Posidonia australis*, and a diverse fish and invertebrate fauna including cuttlefish, sea dragons, nudibranchs, leather jackets, bream, yellowtail, bullseyes, stingrays, squid, octopus, morwongs, blue groper, starfish, feather stars, hawkfish, catfish, moray eels and nudibranchs. Beyond the entrance there are also sponge gardens and soft corals (Commonwealth of Australia 2003).
- Bombo Head, previously proposed as an aquatic reserve by NSW Fisheries² and listed on the Register of the National Estate for its geological significance. Penguin Head at Culburra, Black Head at Gerroa, and the Kiama Blowhole and Little Blowhole are geological sites also listed on the Register of the National Estate.
- Jervis Bay, the Shoalhaven River and the coast between Shellharbour and Lake Wollumboola score highly in summed irreplaceability analyses as they include habitats and ecosystems not readily found elsewhere in the bioregion.
- Jervis Bay Marine Park already includes some of the most important areas in the Batemans Shelf bioregion for marine biodiversity. This option adds large areas of barrier estuary, intermittent lagoon, deeper ocean ecosystems and mangrove and saltmarsh habitats not well represented in the existing marine park. Option A, however, does not include tide dominated, drowned river valley ecosystems.
- Many parts of the Shoalhaven River are in relatively good condition. However Tallowa Dam obstructs 80% of the catchment and there are many other obstructions to fish passage. Inappropriate land use and increasing urban development in the lower parts of the river have also caused oxidation of acid sulphate soils, bank erosion and loss of wetlands (Healthy Rivers Commission 1999).
- Areas of coast and estuary in the south of Option A are protected in Comerong Island Nature Reserve and Jervis Bay and Seven Mile Beach National Parks. However, the aquatic components of these reserves do not have direct protection for fish or aquatic invertebrates from fishing. The areas in the northern part of Option A are vulnerable to urban and industrial development.

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4.2 Option B. Termeil Lake to the Moruya River (Batemans Shelf)

The main ecological features that Option B could include are as follows:

- All estuarine ecosystem types found in the bioregion and substantial areas of estuarine habitats partially represented in Jervis Bay Marine Park.
- All ocean ecosystem depth zones within NSW waters and significant examples of all mapped ocean habitats.
- Termeil, Meroo and Durras Lakes, intermittent estuaries with near pristine catchments protected in national parks. These lakes were recommended for comprehensive protection by the Coastal Lakes Inquiry.
- Durras Lake, the fifth largest intermittent estuary in the bioregion. The lake was previously proposed as a candidate for an estuarine aquatic reserve and is now included within Jervis Bay National Park. It is listed in the Directory of Important Wetlands and the adjoining swamp and forest is listed in the Register of the National Estate. The lake has extensive seagrass beds of *Zostera capricorni*, with Swamp Oak forest (*Casuarina glauca*), sedge, Sea Rush (*Juncus kraussii*), Bare Twig-rush (*Baumea juncea*) and Spotted Gum (*Eucalyptus maculata*) forest surrounding most of the lake.

Species listed here as endangered include the Hooded Plover (*Thinornis rubricollis*) and vulnerable species include the Little Shearwater (*Puffinus assimilus*), Flesh-footed Shearwater (*Puffinus carneipes*), Shy Albatross (*Diomedea cauta*), Black-browed Albatross (*Diomedea chlororhynchos*), Osprey (*Pandion haliaetus*), Sooty Oystercatcher (*Haematopus fuliginosus*), Pied Oystercatcher (*Haematopus longirostris*), Greater Sand Plover (*Charadrius leschenaultii*), Sooty Tern (*Sterna fuscus*) and Black Bittern (*Ixobrychus flavicollis*) (ANCA 1996).

Species listed under JAMBA or CAMBA include the Short-tailed Shearwater (*Puffinus tenuirostris*), Great Egret (*Ardea alba*), Eastern Reef Egret (*Egretta sacra*), White-bellied Sea-Eagle (*Haliaeetus leucogaster*), Sharp-tailed Sandpiper (*Calidris acuminata*), Red Knot (*Calidris canutus*), Red-necked Stint (*Calidris ruficollis*), Bar-tailed Godwit (*Limosa lapponica*), Eastern Curlew (*Numenius madagascariensis*), Crested Tern (*Sterna bergii*), Caspian Tern (*Sterna caspia*) and Common Tern (*Sterna hirundo*) (ANCA 1996).

- The Clyde River, the only tide dominated, drowned river valley in the bioregion. The estuary includes the second largest area of mangrove habitat in the bioregion, large areas of saltmarsh, and has the second highest summed irreplaceability score for estuarine ecosystems and habitats (after the Shoalhaven). Much of the river's catchment and shores

are within State Forest and it is listed in the Directory of Important Wetlands and the Register of the National Estate.

The Clyde River is “important in the evolution of Australia’s fauna and flora as a complete ecosystem relatively untouched by human habitation”. Approximately 95% of the catchment of the Clyde River is uncleared and it may be the “only river left on the NSW coast that flows uninterrupted from its source to the sea” (Commonwealth of Australia 2003).

Native fish species found in the river include gudgeons (*Hypseleotris*), Australian Smelt (*Retropinna semoni*), eels, bullrouths, Australian Bass (*Macquarie novemaculeata*) and Australian Grayling (*Prototroctes maraena*). Three endangered fish species have been recorded from the river. The river also provides potential habitat for migratory waders, but is poorly studied. Vulnerable waterbird species found in the estuary include the Sooty Oystercatcher (*Haematopus fuliginosus*).

Cullendulla Creek Embayment, a drowned creek gully on the Clyde River, is listed in the Directory of Important Wetlands and the Register of the National Estate. The beach chenier here is uncommon in NSW and provides a record of shoreline trends during the Holocene (from 10 000 years ago). The embayment is a good example of a low energy beach ridge and mud flats in an enclosed bay (ANCA 1996). *Limonium australe* occurs in the saltmarsh and is probably the largest population in NSW. The White-bellied Sea-Eagle (*Haliaeetus leucogaster*) listed under CAMBA also occurs here.

- Batemans Bay, the second largest ocean embayment in the bioregion after Jervis Bay. The bay includes offshore island and reef habitats and an important aggregation site declared as critical habitat for the endangered Grey Nurse Shark (*Carcharias taurus*). At the Tollgate Islands, sharks have been observed during 90% of surveys in numbers representing 8.9% of the observed NSW population and 15.4% of the observed female population. This site is the most important known aggregation site for females, and it is thought that females may be gestating at this site during summer and autumn.
- The Moruya River is an example of a wave dominated barrier estuary with significant areas of saltmarsh listed in the Directory of Important Wetlands and the Register of the National Estate. The estuary includes a “number of extensive, modified salt and brackish marshes...all of conservation significance, and due to their variability, of considerable floristic interest (Adam 1992 cited in ANCA 1996).

These diverse saltmarshes include Samphire (*Sarcocornia quinqueflora*), Seablite (*Suaeda australis*), Sea Rush (*Juncus kraussii*), Streaked Arrowgrass (*Triglochin striata*), Native Sea Lavender (*Limonium australe*), Creeping Monkey-flower (*Mimulus repens*), scattered Chaffy Saw-sedge (*Gahnia filum*) and Saltbush (*Atriplex australasica*). The

upper marsh includes species such as *Selliera radicans*, New Zealand Spinach (*Tetragonia tetragonioides*), *Leptinella longipes*, Sea Celery (*Apium prostratum*), Creeping Brookweed (*Samolus repens*) and Swamp Oak (*Casuarina glauca*). Grey (*Avicennia marina*) and River Mangrove (*Aegiceras corniculatum*) grow on the channels draining the saltmarsh (ANCA 1996).

The endangered Wandering Albatross (*Diomedea exulans*) and Hooded Plover (*Thinornis rubricollis*), and the vulnerable Shy Albatross (*Diomedea cauta*), Black-browed Albatross (*Diomedea melanophrys*), Square-tailed Kite (*Lophoictinia isura*), Sanderling (*Calidris alba*), Great Knot (*Calidris tenuirostris*), Black-tailed Godwit (*Limosa limosa*) and Pied Oystercatcher (*Haematopus longirostris*) are recorded from the estuary. Species listed under JAMBA or CAMBA from the estuary include the Ruddy Turnstone (*Arenaria interpres*), Red Knot (*Calidris canutus*), Latham's Snipe (*Gallinago hardwickii*), Bar-tailed Godwit (*Limosa lapponica*), Eastern Curlew (*Numenius madagascariensis*), Whimbrel (*Numenius phaeopus*) and Grey Plover (*Pluvialis squatarola*).

- The Willinga-Durras section of ocean coast has some of the largest areas of inshore reef and island habitat, includes significant offshore habitats and had the second highest summed irreplaceability score for ocean ecosystems and habitats.
- Option B includes the most seabird breeding islands and the greatest diversity and abundance of breeding seabirds in the bioregion. Belowla and Brush Islands are listed on the Register of the National Estate and Brush Island, in particular, provides important nesting habitat for Little Penguins, Wedge Tailed Shearwaters, Short Tailed shearwaters and the Sooty Oyster Catcher.
- The Clyde and Moruya Rivers and the coast between Willinga Lake and Durras Lake score very highly in summed irreplaceability analyses as they include ecosystems and habitats not readily found in other parts of the bioregion.
- Between 40 and 75% of the ocean coast and most islands in the sections of coast between Termeil Lake and Durras Lake are within national parks and this option includes some of the most pristine waterways and catchments in the Batemans Shelf Bioregion.
- Areas of Termeil and Meroo Lakes are already protected in national parks but have no direct protection for fish or aquatic invertebrates.

4.3 Option C. Durras Lake to Wallaga Lake (Batemans Shelf)

The main ecological features that Option C could include are as follows:

- All ocean depth zones within NSW waters and the most extensive examples of mapped ocean habitats in the bioregion.
- All estuary ecosystem types and substantial areas of estuarine habitats partially represented in Jervis Bay Marine Park.
- Durras Lake (described in 5.2), the fifth largest intermittent estuary in the bioregion. The lake was proposed as a candidate for an estuarine aquatic reserve and was recently included within Jervis Bay National Park. It provides important habitat for threatened birds and migratory waders protected under JAMBA and CAMBA agreements and is listed in the Directory of Important Wetlands and the adjoining swamp and forest is listed in the Register of the National Estate.
- The Clyde River (described in 5.2), the only tide dominated, drowned river valley in the bioregion. The river includes the second largest area of mangrove habitat in the bioregion and large areas of saltmarsh. It has the second highest summed irreplaceability score (after the Shoalhaven) for estuarine ecosystems and habitats. Much of its catchment and shores are within State Forest and the Clyde River is listed in the Directory of Important Wetlands.
- Batemans Bay (described in 5.2), the second largest ocean embayment in the bioregion after Jervis Bay with important sheltered rocky shores, beaches and offshore island and reef habitats.
- Montague Island, the largest offshore island in NSW with the exception of Lord Howe Island. Montague Island has been classified by the National Trust as a Landscape Conservation Area for its scenic, scientific and historical values. The island is the most northerly and only remaining haul out site in NSW for Australian fur seals. It is one of the most important sea bird breeding islands in NSW and the second largest breeding area in Australia for Little Penguins. The threatened sooty oystercatcher (*Haematopus fuliginosus*) breeds here and the wandering albatross (*Diomedea exulans*) and fleshy-footed shearwater (*Puffinus carneipes*) have been recorded on the island or in adjacent waters (NPWS 1995). Montague Island is also important for the high diversity and biogeographic significance of its marine algae (Alan Millar pers. comm., National Herbarium of New South Wales).

- Montague Island and the Tollgate Islands are two important aggregation sites and areas of critical habitat for the Grey Nurse Shark (*Carcharias taurus*). At the Tollgate Islands, sharks have been observed during 90% of surveys in numbers representing 8.9% of the observed population and 15.4% of the observed female population.

At Montague Island, sharks aggregate mainly at the northern tip of the island but also at three sites on the western side of the island. Sharks were observed during 20% of surveys in numbers representing 1.3% of the total observed NSW population. Most sharks surveyed here were females and a number of these may have been pregnant.

- Tuross Lake, Wallaga Lake, Wagonga Inlet and the Moruya River (described in Section 14.2), the largest wave dominated barrier estuaries in the bioregion after the Shoalhaven River and St. Georges Basin.
- Coila Lake, the largest intermittent estuary in the bioregion and Durras, Brunderee, Tarourga, Brou, and Nargal Lakes, intermittent estuaries with near pristine catchments that have been recommended for comprehensive protection by the Coastal Lakes Inquiry.
- Coila Creek Delta is listed in the Directory of Important Wetlands and has important areas of saltmarsh in good condition and includes Samphire (*Sarcocornia quinqueflora*), *Wilsonia rotundifolia*, Sea Rush (*Juncus kraussii*), *Selliera radicans*, Creeping Monkey-flower (*Mimulus repens*) and Swamp Oak (*Casuarina glauca*) forest. The large, healthy population of *Wilsonia rotundifolia* is near its northern extent and has high conservation significance (Adam 1992 in ANCA 1996). Algae, Seagrass (*Zostera* sp.), Sea Tassel (*Ruppia* sp.) and Sea Wrack (*Halophila* sp.) are also present adjoining the saltmarsh (ANCA 1996). The vulnerable Pied Oystercatcher (*Haematopus longirostris*) has been recorded within the lake and species listed under JAMBA or CAMBA include the Great Egret (*Ardea alba*), White-bellied Sea-Eagle (*Haliaeetus leucogaster*) and the Crested Tern (*Sterna bergii*) (ANCA 1996).
- The Tuross River Estuary delta is listed in the Directory of Important Wetlands and provides a diversity of habitats along its extensive shoreline. The delta islands support a variety of plant and animal communities including mangroves (*Avicennia marina*), saltmarsh (*Sarcocornia quinqueflora*), *Casuarina* swamp, littoral rainforest, *Zostera*, *Halophila* and sand and mud flats.

The endangered Little Tern (*Sterna albifrons*) and Hooded Plover (*Thiornis rubricollis*) and the vulnerable Black-tailed Godwit (*Limosa limosa*), Pied Oystercatcher (*Haematopus longirostris*) and Lesser Sandplover (*Charadrius mongolus*) have been recorded from the estuary.

Species listed under JAMBA or CAMBA include the Great Egret (*Ardea alba*), White-bellied Sea-Eagle (*Haliaeetus leucogaster*), Common Sandpiper (*Actitis hypoleucos*), Ruddy Turnstone (*Arenaria interpres*), Sharp-tailed Sandpiper (*Calidris acuminata*), Red Knot (*Calidris canutus*), Curlew Sandpiper (*Calidris ferruginea*), Red-necked Stint (*Calidris ruficollis*), Bar-tailed Godwit (*Limosa lapponica*), Eastern Curlew (*Numenius madagascariensis*), Whimbrel (*Numenius phaeopus*), Marsh Sandpiper (*Tringa stagnatilis*), White-winged Black Tern (*Chlidonias leucopterus*) and Crested Tern (*Sterna bergii*). Cormorant rookeries are also found in upper parts of the area (ANCA 1996).

- Wallaga Lake was proposed as an estuarine aquatic reserve in a previous assessment by NSW Fisheries² and is listed in the Directory of Important Wetlands. The lake has large areas of sand flat exposed at low tide near the entrance, a number of inflowing tributaries and open forest, with Swamp Oak (*Casuarina glauca*) and Swamp Paperbark (*Melaleuca ericifolia*) along much of the shoreline and islands within the lake. The upper tributaries have saltmarsh habitats with mangroves and seagrasses (*Zostera* and *Halophila*). The sand flats provide habitat for foraging and resting waterbirds and seabirds.

The endangered Little Tern (*Sterna albifrons*) nests on the fore dunes of the beach and fledglings and adults feed in the estuary. The endangered Hooded Plover (*Thiornis rubricollis*) and vulnerable Pied Oystercatcher (*Haematopus longirostris*) and Osprey (*Pandion haliaetus*) occur in the estuary.

Species listed under JAMBA or CAMBA recorded at Wallaga Lake include the Great Egret (*Ardea alba*), White-bellied Sea-Eagle (*Haliaeetus leucogaster*), Sharp-tailed Sandpiper (*Calidris acuminata*), Curlew Sandpiper (*Calidris ferruginea*), Red-necked Stint (*Calidris ruficollis*), Bar-tailed Godwit (*Limosa lapponica*), Eastern Curlew (*Numenius madagascariensis*), Lesser Golden Plover (*Pluvialis dominica*), Crested Tern (*Sterna bergii*), Caspian Tern (*Sterna caspia*) and Common Tern (*Sterna hirundo*) (ANCA 1996).

- Nargal Lake is listed in the Directory of Important Wetlands and is one of the few dune-swale freshwater lakes in the region (along with Bondi Lake). The shoreline includes small areas of Swamp Oak (*Casuarina glauca*) forest and sedgelands of Spike-rush (*Eleocharis sp.*) which provide shelter for waterbirds including Musk Duck (*Biziura lobata*) and breeding areas for Black Swan (*Cygnus atratus*). A herbfield of *Selliera radicans* and other species occurs on the eastern shoreline. The White-bellied Sea-Eagle (*Haliaeetus leucogaster*) listed under CAMBA has been recorded here (ANCA 1996).

² now within the NSW Department of Primary Industry

- The Wagonga-Wallaga section of ocean coast, includes the largest area of rocky intertidal shore and offshore islands in the bioregion, and the second largest area of offshore reef in the bioregion. Wagonga Head was proposed as an aquatic reserve in a previous assessment of intertidal rocky shores by NSW Fisheries². The shore is also a significant fossil site listed in the Register of the National Estate.
- The Clyde, Moruya and Tuross Rivers and the coast and ocean between Wagonga and Wallaga Lakes score very highly in summed irreplaceability analyses as they include ecosystems and habitats not readily found in other parts of the bioregion.
- Approximately 75% of the ocean coast between Durras Lake and Batemans Bay and 30% of the coast between Tuross Lake and Wagonga are included in national park, but there is less national park bordering other sections of the coast in this option. As with Option B, this option includes some of the most pristine waterways and catchments in the Batemans Shelf bioregion but there has been significant development at a number of urban centres.
- Parts of Congo Creek, Meringo Creek, Lake Brunderee, Lake Tarouga, Lake Brou and Mummuga Lake and sections of ocean beach and rocky shore are already included in Eurobodalla National Park but have no direct protection for fish or aquatic invertebrates from fishing.

² now within the NSW Department of Primary Industry.

4.4 Option D. Middle Lagoon to Twofold Bay (Batemans / Twofold Shelf)

The main ecological features that Option D could include are as follows:

- All ocean ecosystem depth zones within NSW waters of the Twofold Shelf bioregion and representative examples of mapped ocean habitats from the NSW section of the bioregion.
- All estuary ecosystem types found in the NSW section of the Twofold Shelf bioregion and the most substantial areas of estuarine habitat from the NSW section of the bioregion. These estuarine habitats and ecosystems may not be represented in MPAs in the Victorian or Tasmanian sections of the Twofold Shelf bioregion.
- Pambula Lake, the largest wave dominated barrier estuary in the NSW section of the Twofold Shelf bioregion. The lake has the second largest area of seagrass, the largest area of mangrove and the third largest area of saltmarsh in the NSW section of the bioregion. This estuary type occurs in the Victorian section of the bioregion but is not represented in MPAs. Areas upstream of the lake include channels, sand flats, mangroves, saltmarsh, and brackish and freshwater assemblages listed in the Directory of Important Wetlands.
- Merimbula Lake, the second largest barrier estuary in the NSW section of the bioregion. The lake includes the largest area of seagrass habitat, the second largest area of mangrove and the largest area of saltmarsh in the NSW section of the bioregion. The lake is at the southern limit for River Mangrove (*Aegiceras corniculatum*) and includes a significant population of the Saltbush *Sclerostegia arbuscula* (P. Adam in ANCA 1996). The area provides habitat for endangered and vulnerable bird species and waders protected under JAMBA and CAMBA and is listed in the Directory of Important Wetlands.

The endangered Hooded Plover (*Thinornis rubricollis*) and vulnerable Australasian Bittern (*Botaurus poiciloptilus*), Sooty Oystercatcher (*Haematopus fuliginosus*) and Pied Oystercatcher (*Haematopus longirostris*) have been recorded from the lake (ANCA 1996).

Species listed under JAMBA or CAMBA include the Great Egret (*Ardea alba*), White-bellied Sea-Eagle (*Haliaeetus leucogaster*), Latham's Snipe (*Gallinago hardwickii*), Bar-tailed Godwit (*Limosa lapponica*), Eastern Curlew (*Numenius madagascariensis*) and Whimbrel (*Numenius phaeopus*) (ANCA 1996).

- Nelson Lagoon, proposed in a previous NSW Fisheries² assessment as an estuarine aquatic reserve and Bondi and Bournda Lagoons, all intermittent estuaries with near pristine catchments and slightly affected to pristine waters. All are recommended in the Coastal Lakes Inquiry for comprehensive protection. Nelson Lagoon is listed in the Directory of Important Wetlands and the area around the lagoon includes saltmarshes of significant conservation value (Adam 1992 in ANCA 1996).
- Bondi Lake is listed in the Directory of Important Wetlands. Although it is generally fresh, the lake appears to become more saline as its volume diminishes. The 200 ha catchment is wholly within Bournda National Park. Species listed under JAMBA or CAMBA include the White-bellied Sea-Eagle (*Haliaeetus leucogaster*), Sharp-tailed Sandpiper (*Calidris acuminata*), Curlew Sandpiper (*Calidris ferruginea*), Red-necked Stint (*Calidris ruficollis*) and Common Greenshank (*Tringa nebularia*) (references in ANCA 1996).
- Wallagoot Lake, the largest intermittent lagoon in this option, occurs at the border of the Twofold and Batemans Shelf bioregions. The lake is listed in the Directory of Important Wetlands and has extensive sand spits and sandy islets at the east end of the lagoon and extensive seagrass beds (including *Posidonia*), rushes, sedges, Saltmarsh (*Sarcocornia quinqueflora*), Streaked Arrow-grass (*Triglochin striata*), Saw-sedge (*Gahnia* sp.) and Common Reed (*Phragmites australis*).

Endangered species sighted here include the Little Tern (*Sterna albifrons*) and the Hooded Plover (*Thinornis rubricollis*). Vulnerable species sighted here include Pied Oystercatcher (*Haematopus longirostris*), Australasian Bittern (*Botaurus poiciloptilus*) and Sanderling (*Calidris alba*).

Species listed under JAMBA or CAMBA include the Short-tailed Shearwater (*Puffinus tenuirostris*), Great Egret (*Ardea alba*), White-bellied Sea-Eagle (*Haliaeetus leucogaster*), Ruddy Turnstone (*Arenaria interpres*), Sharp-tailed Sandpiper (*Calidris acuminata*), Curlew Sandpiper (*Calidris ferruginea*), Red-necked Stint (*Calidris ruficollis*), Bar-tailed Godwit (*Limosa lapponica*), Eastern Curlew (*Numenius madagascariensis*), Common Greenshank (*Tringa nebularia*), Common Redshank (*Tringa totanus*), Lesser Golden Plover (*Pluvialis dominica*), Grey Plover (*Pluvialis squatarola*), Crested Tern (*Sterna bergii*), Caspian Tern (*Sterna caspia*), Common Tern (*Sterna hirundo*) and the White-throated Needletail (*Hirundapus caudacutus*) (ANCA 1996).

² now within the NSW Department of Primary Industry

- Twofold Bay, the only ocean embayment in the Twofold Shelf bioregion within NSW or Victoria. The bay and the four intermittent and barrier estuaries that flow into it are listed in the Directory of Important Wetlands. The sheltered rocky shores, beaches, reefs, deep water areas, sand flats and wetlands around the bay provide important habitat for marine life, cetaceans and threatened and migratory birds (ANCA 1996).

The endangered Hooded Plover (*Thiornis rubricollis*) and the vulnerable Shy Albatross (*Diomedea cauta*), Black-browed Albatross (*Diomedea melanophrys*), Sooty Albatross (*Phoebastria fusca*) and Pied Oystercatcher (*Haematopus longirostris*) have been recorded from Twofold Bay.

Humpback Whales (*Megaptera novaeangliae*) are regularly sighted here when migrating north and south. Southern Right Whales (*Eubalaena australis*) and the Blue Whale (*Balaenoptera musculus*) also visit the bay occasionally as well as other cetaceans including dolphins and Pilot Whales. The bay is a known resting locality for cetacean migrants (ANCA 1996).

Species listed under JAMBA or CAMBA include the Short-tailed Shearwater (*Puffinus tenuirostris*), Australian Reef Egret (*Egretta sacra*), White-bellied Sea-Eagle (*Haliaeetus leucogaster*) and Grey Plover (*Pluvialis squatarola*) (ANCA 1996).

- The Middle-Wallagoot section of ocean coast includes the largest area of islands between Bega and Victoria. The rocky shores and subtidal reef south of Tathra are important for the high diversity and biogeographic significance of the marine algae found there (Alan Millar pers. comm., National Herbarium of New South Wales). Tathra Head was short listed as an aquatic reserve candidate by a community advisory panel in a previous assessment of intertidal areas by NSW Fisheries².
- Bondi Lake and Bournda Lagoon are surrounded by national park, and most of Nelson and Middle Lagoon, and approximately 40% of Pambula and Wallagoot Lakes are surrounded by national park.
- Over 60% of the ocean coast between Middle and Wallagoot Lakes, 30% of the coast between Wallagoot and Pambula and 95% of the coast between Pambula and Twofold Bay is within national park.

² now within the NSW Department of Primary Industry.

4.5 Option E. Twofold Bay to Nadgee

Twofold Shelf

The main ecological features that Option E could include are as follows:

- All ocean ecosystem depth zones within NSW waters of the Twofold Shelf bioregion and representative examples of mapped ocean habitats from the NSW section of the bioregion.
- All estuary ecosystem types found in the NSW section of the Twofold Shelf bioregion and relatively small areas of estuarine habitat from the NSW section of the bioregion. These estuarine habitats and ecosystems may not be represented in MPAs in the Victorian or Tasmanian sections of the Twofold Shelf bioregion.
- Twofold Bay (described in Section 14.4), the only ocean embayment in the Twofold Shelf bioregion within NSW or Victoria.
- Towamba and Wonboyn Rivers, representative barrier estuaries in a largely unmodified condition and Wonboyne Lake, recommended by the Coastal Lakes Inquiry for significant protection.
- Saltwater, Woodburn and Bittangabee Creeks, which are entirely surrounded by Ben Boyd National Park.
- Wirra Birra, Table and Little Creeks, Merrica River, Nadgee River and Nadgee Lake, which are entirely included in the Nadgee Nature Reserve and Wilderness area.
- The ocean coast between Twofold Bay and Wonboyn River which includes the largest area of mapped inshore reef in NSW south of Tuross Heads. The section includes small areas of inshore islands and rocks and the largest area of intertidal rocky shore of all sections in the Batemans Shelf bioregion or the NSW section of the Twofold Shelf bioregion.
- Almost all the ocean coast between Twofold Bay and the Victorian border is included in national park or nature reserve and much of it is in the declared Wilderness area. These areas are likely to be among the least disturbed coastal areas in NSW.
- Nadgee Lake and River, Table and Little Creek, Merrica River, and Saltwater and Woodburn Creeks are protected in national park but have no direct protection for fish or aquatic invertebrates from fishing.
- This option would adjoin the Cape Howe Marine National Park in Victoria, which lies immediately south of the NSW border.

Appendix 5. Steering and expert committee members for the Great Barrier Reef Representative Areas Project

Scientific Steering Committee

Mr Richard Kenchington (former Executive Director, GBRMPA)

Dr Bruce Mapstone (James Cook University/CRC Reef)

Dr Rob Coles (QDPI) Dr Peter Doherty (AIMS)

Dr Dave Williams (AIMS/CRC Reef)

Dr Terry Done (AIMS)

Prof Helene Marsh (JCU)

Dr Ian Poiner (CSIRO, Marine Division)

Dr Trevor Ward (University of Western Australia)

Dr Glenn De'ath (CRC Reef).

Reef Panel:

Dr Tony Ayling (Consultant, Sea Research)

Dr Terry Done (AIMS)

Dr Katharina Fabricius (AIMS & CRC Reef)

Dr Laurence McCook (AIMS & CRC Reef)

Lyle Squires (Consultant, Cairns Marine Aquarium Fish)

Dr David Williams (AIMS & CRC Reef).

Non-reef Panel:

Dr Rob Coles (QDPI)

Dr Miles Furnas (AIMS)

Dr Chris Jenkins (Ocean Sciences Institute University of Sydney)

Dr John Hooper (Queensland Museum)

Dr Patricia Hutchings (Australian Museum)

Mr Warren Lee Long (QDPI)

Dr Roland Pitcher (CSIRO)

Dr David Williams (AIMS & CRC Reef).

Appendix 6. Survey of scientists for the GBRMPA Representative Areas Program

Survey of reserve habitat requirements for adequate representation and protection of biological diversity in the Great Barrier Reef Region

As part of the Representative Areas Program, we are surveying a select group of experts researching different groups of organisms in the Great Barrier Reef Region.

Our aims are to describe:

- the prime habitat requirements of different groups of organisms,
- the main causes and patterns of diversity for those groups,
- appropriate reserve designs for these organisms
- additional sources of data and expertise
- any areas of special importance for the maintenance of marine ecosystem diversity and function.

While we realise that information may be incomplete, we urge you to use your expert opinion and judgement in answering this survey as best you can. If you would like to qualify your response or are unable to complete the survey please give reasons in the spaces below or on the spare sheets provided.

Please consider the following questions in the context of choosing representative areas of habitat to be protected by Marine Park zoning. This relates particularly to the scale of information you provide. For practical reasons protected areas are likely to range in size from a few km to 100s of km's. For example zoning decisions are more likely to be influenced by environmental variation among different reefs than variation within a single reef.

You may wish to fill out the electronic version of this form by typing responses in the shaded yellow boxes and drawing lines and labels on the maps with the drawing tools provided, or you may wish to print out this form and write and draw on the paper copies.

More detailed maps of each section of the Marine Park are attached to this e-mail if you require them.

1. Your name?
2. Your position?
3. Your organisation?

4. Which groups (eg. populations, taxa, or communities) of organisms are you most familiar with (eg. southern Dugong, butterfly fishes, soft bottom infauna) in the GBR region?

Group 1

Group 2

Group 3

Group 4

Group 5

For **one of these groups** please attempt to answer the following questions. (Feel free to provide information for **additional groups** on separate copies of this survey.)

5. Organism group (eg. algae)

6. What environmental **factors** (or even approximate surrogate variables) and **categories** would best define the most distinct **spatial patterns in diversity and abundance** for this group?

		Categories				
	Factor	1	2	3	4	5
<i>Example 1</i>	<i>salinity</i>	<i>0-5 o/oo</i>	<i>5-20 o/oo</i>	<i>20-30 o/oo</i>	<i>>30 o/oo</i>	
<i>Example 2</i>	<i>slope</i>	<i>flat</i>	<i>moderate</i>	<i>steep</i>		
Factor 1						
Factor 2						
Factor 3						
Factor 4						
Factor 5						
Factor 6						

Please answer the following questions with regard to maintaining representative diversity in the organism group described, while allowing for reasonable use.

(To allow for uncertainty feel free to provide a range of values eg. "between 20-30%")

7. Is any particular shape, orientation or configuration of reserve of value in preserving the organism group?

8. Is any particular shape, orientation or configuration of reserve to be avoided?

9. If several reserves are used, what distance apart should they be to maintain connectivity among organisms?

10. Are there any environmental boundaries that need to be considered when siting protected areas?

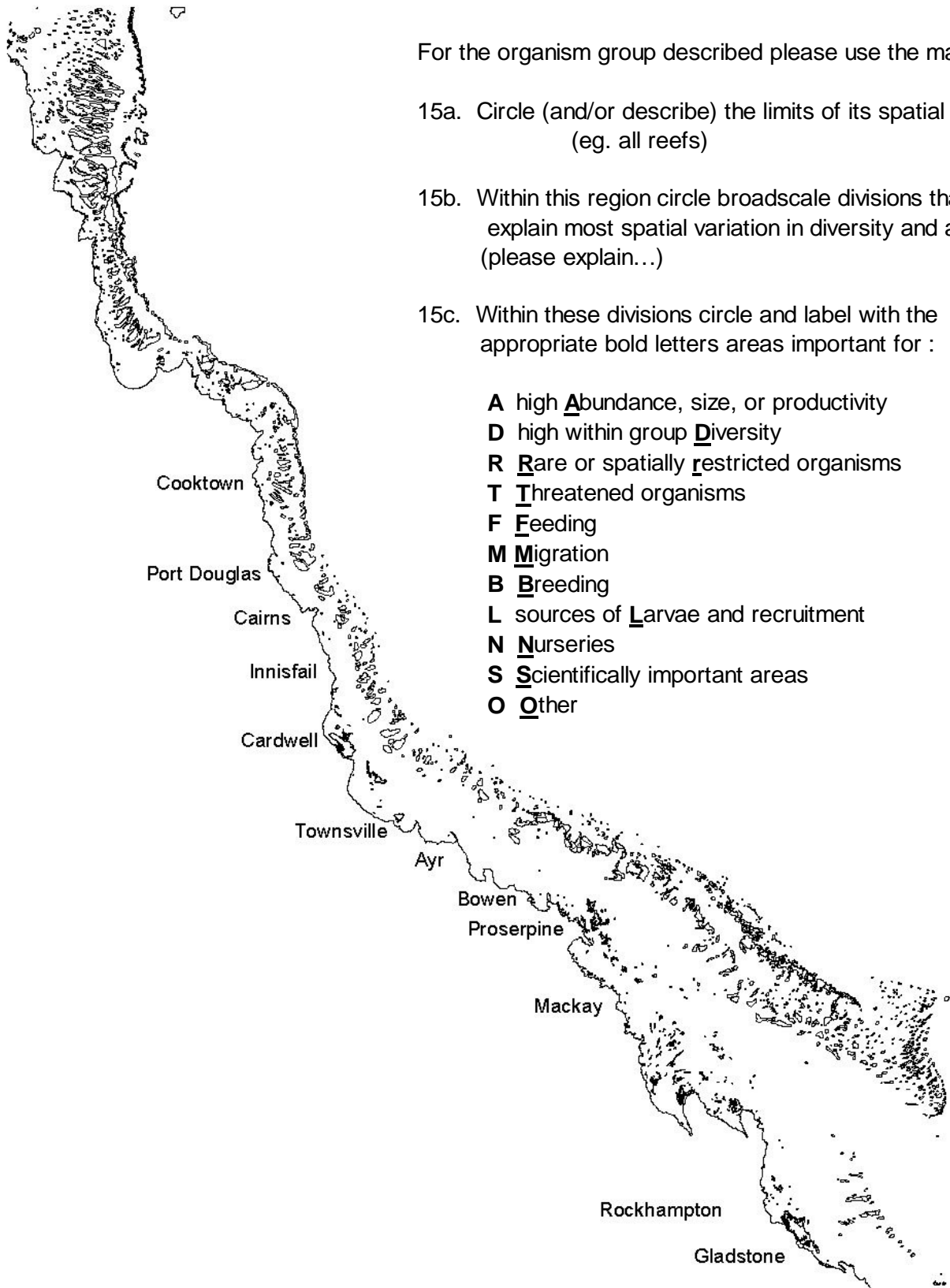
11. What major threats need to be considered for the conservation of this group of organisms?

12. Assuming zoning is effective what other strategies are required to protect these organisms?

13. Can you provide any other relevant data, information or references to other sources? (see attached contact list)

14. Would you like to provide additional information during the selection of Representative Protected Areas and the subsequent rezoning process?

Please turn over to the map below or if required use the more detailed section maps in the attached .exe files.



For the organism group described please use the map to:

- 15a. Circle (and/or describe) the limits of its spatial distribution (eg. all reefs)
- 15b. Within this region circle broadscale divisions that explain most spatial variation in diversity and abundance. (please explain...)
- 15c. Within these divisions circle and label with the appropriate bold letters areas important for :

- A** high Abundance, size, or productivity
- D** high within group Diversity
- R** Rare or spatially restricted organisms
- T** Threatened organisms
- F** Feeding
- M** Migration
- B** Breeding
- L** sources of Larvae and recruitment
- N** Nurseries
- S** Scientifically important areas
- O** Other

Thank you for your help, if you have any inquiries please call Dan Breen at GBRMPA at (07) 4750 0700.

Appendix 7. Protected Area Management Categories from “Guidelines for Protected Area Management Categories” IUCN (1994).

CATEGORY I Strict Nature Reserve/Wilderness Area
: protected area managed mainly for science or wilderness protection

CATEGORY Ia Strict Nature Reserve: protected area managed mainly for science

Definition

Area of land and/or sea possessing some outstanding or representative ecosystems, geological or physiological features and/or species, available primarily for scientific research and/or environmental monitoring.

Objectives of Management

- to preserve habitats, ecosystems and species in as undisturbed a state as possible;
- to maintain genetic resources in a dynamic and evolutionary state;
- to maintain established ecological processes;
- to safeguard structural landscape features or rock exposures;
- to secure examples of the natural environment for scientific studies, environmental monitoring and education, including baseline areas from which all avoidable access is excluded;
- to minimise disturbance by careful planning and execution of research and other approved activities; and
- to limit public access.

Guidance for Selection

The area should be large enough to ensure the integrity of its ecosystems and to accomplish the management objectives for which it is protected. The area should be significantly free of direct human intervention and capable of remaining so. The conservation of the area's biodiversity should be achievable through protection and not require substantial active management or habitat manipulation (c.f. Category IV).

Organizational Responsibility

Ownership and control should be by the national or other level of government, acting through a professionally qualified agency, or by a private foundation, university or institution which has an established research or conservation function, or by owners working in cooperation with any of the foregoing government or private institutions. Adequate safeguard and controls relating to long-term protection should be secured before designation. International agreements over areas subject to disputed national sovereignty can provide exceptions (e.g. Antarctica).

Equivalent Category in 1978 System

Scientific Reserve / Strict Nature Reserve

**CATEGORY Ib Wilderness Area:
protected area managed mainly for wilderness protection**

Definition

Large area of unmodified or slightly modified land, and/or sea, retaining its natural character and influence, without permanent or significant habitation, which is protected and managed so as to preserve its natural condition.

Objectives of Management

- to ensure that future generations have the opportunity to experience understanding and enjoyment of areas that have been largely undisturbed by human action over a long period of time;
- to maintain the essential natural attributes and qualities of the environment over the long term;
- to provide for public access at levels and of a type which will serve best the physical and spiritual wellbeing of visitors and maintain the wilderness qualities of the area for present and future generations; and
- to enable indigenous human communities living at low density and in balance with the available resources to maintain their life style.

Guidance for Selection

The area should possess high natural quality, be governed primarily by the forces of nature, with human disturbance substantially absent and be likely to continue to display those attributes if managed as proposed. The area should contain significant ecological, geological, physiogeographic, or other features of scientific, educational, scenic or historic value. The area should offer outstanding opportunities for solitude, enjoyed once the area has been reached, by simple, quiet, non-polluting and non-intrusive means of travel (i.e. non-motorised). The area should be of sufficient size to make practical such preservation and use.

Organizational Responsibility

As for Sub-Category Ia.

Equivalent Category in 1978 System

This sub-category did not appear in the 1978 system, but has been introduced following the IUCN General

Assembly Resolution (16/34) on Protection of Wilderness Resources and Values, adopted at the 1984 General

Assembly in Madrid, Spain.

**CATEGORY II National Park:
protected area managed mainly for ecosystem protection and recreation**

Definition

Natural area of land and/or sea, designated to (a) protect the ecological integrity of one or more ecosystems for present and future generations, (b) exclude exploitation or occupation inimical to the purposes of designation of the area and (c) provide a foundation for spiritual, scientific, educational, recreational and visitor opportunities, all of which must be environmentally and culturally compatible.

Objectives of Management

- to protect natural and scenic areas of national and international significance for spiritual, scientific, educational, recreational or tourist purposes;
- to perpetuate, in as natural a state as possible, representative examples of physiographic regions, biotic communities, genetic resources, and species, to provide ecological stability and diversity;
- to manage visitor use for inspirational, educational, cultural and recreational purposes at a level which will maintain the area in a natural or near natural state;
- to eliminate and thereafter prevent exploitation or occupation inimical to the purposes of designation;
- to maintain respect for the ecological, geomorphologic, sacred or aesthetic attributes which warranted designation; and
- to take into account the needs of indigenous people, including subsistence resource use, in so far as these will not adversely affect the other objectives of management.

Guidance for Selection

The area should contain a representative sample of major natural regions, features or scenery, where plant and animal species, habitats and geomorphological sites are of special spiritual, scientific, educational, recreational and tourist significance. The area should be large enough to contain one or more entire ecosystems not materially altered by current human occupation or exploitation.

Organizational Responsibility

Ownership and management should normally be by the highest competent authority of the nation having jurisdiction over it. However, they may also be vested in another level of government, council of indigenous people, foundation or other legally established body which has dedicated the area to long-term conservation.

Equivalent Category in 1978 System

National Park

**CATEGORY III Natural Monument:
protected area managed mainly for conservation of specific natural features**

Definition

Area containing one, or more, specific natural or natural/cultural feature which is of outstanding or unique value because of its inherent rarity, representative or aesthetic qualities or cultural significance.

Objectives of Management

- to protect or preserve in perpetuity specific outstanding natural features because of their natural significance, unique or representational quality, and/or spiritual connotations;
- to an extent consistent with the foregoing objective, to provide opportunities for research, education, interpretation and public appreciation;
- to eliminate and thereafter prevent exploitation or occupation inimical to the purpose of designation; and
- to deliver to any resident population such benefits as are consistent with the other objectives of management.

Guidance for Selection

The area should contain one or more features of outstanding significance (appropriate natural features include spectacular waterfalls, caves, craters, fossil beds, sand dunes and marine features, along with unique or representative fauna and flora; associated cultural features might include cave dwellings, cliff-top forts, archaeological sites, or natural sites which have heritage significance to indigenous peoples). The area should be large enough to protect the integrity of the feature and its immediately related surroundings.

Organizational Responsibility

Ownership and management should be by the national government or, with appropriate safeguards and controls, by another level of government, council of indigenous people, non-profit trust, corporation or, exceptionally, by a private body, provided the long-term protection of the inherent character of the area is assured before designation.

Equivalent Category in 1978 System

Natural Monument / Natural Landmark

**CATEGORY IV Habitat/Species Management Area:
protected area managed mainly for conservation through management intervention**

Definition

Area of land and/or sea subject to active intervention for management purposes so as to ensure the maintenance of habitats and/or to meet the requirements of specific species.

Objectives of Management

- to secure and maintain the habitat conditions necessary to protect significant species, groups of species, biotic communities or physical features of the environment where these require specific human manipulation for optimum management;
- to facilitate scientific research and environmental monitoring as primary activities associated with sustainable resource management;
- to develop limited areas for public education and appreciation of the characteristics of the habitats concerned and of the work of wildlife management;
- to eliminate and thereafter prevent exploitation or occupation inimical to the purposes of designation;
- and to deliver such benefits to people living within the designated area as are consistent with the other objectives of management.

Guidance for Selection

The area should play an important role in the protection of nature and the survival of species, (incorporating, as appropriate, breeding areas, wetlands, coral reefs, estuaries, grasslands, forests or spawning areas, including marine feeding beds). The area should be one where the protection of the habitat is essential to the well-being of nationally or locally-important flora, or to resident or migratory fauna. Conservation of these habitats and species should depend upon active intervention by the management authority, if necessary through habitat manipulation (c.f. Category Ia). The size of the area should depend on the habitat requirements of the species to be protected and may range from relatively small to very extensive.

Organizational Responsibility

Ownership and management should be by the national government or, with appropriate safeguards and controls, by another level of government, non-profit trust, corporation, private group or individual.

Equivalent Category in 1978 System

Nature Conservation Reserve / Managed Nature Reserve / Wildlife Sanctuary

**CATEGORY V Protected Landscape/Seascape:
protected area managed mainly for landscape/seascape conservation and recreation**

Definition

Area of land, with coast and sea as appropriate, where the interaction of people and nature over time has produced an area of distinct character with significant aesthetic, ecological and/or cultural value, and often with high biological diversity. Safeguarding the integrity of this traditional interaction is vital to the protection, maintenance and evolution of such an area.

Objectives of Management

- to maintain the harmonious interaction of nature and culture through the protection of landscape and/or seascape and the continuation of traditional land uses, building practices and social and cultural manifestations;
- to support lifestyles and economic activities which are in harmony with nature and the preservation of the social and cultural fabric of the communities concerned;
- to maintain the diversity of landscape and habitat, and of associated species and ecosystems; to eliminate where necessary, and thereafter prevent, land uses and activities which are inappropriate in scale and/or character;
- to provide opportunities for public enjoyment through recreation and tourism appropriate in type and scale to the essential qualities of the areas;
- to encourage scientific and educational activities which will contribute to the long term well-being of resident populations and to the development of public support for the environmental protection of such areas; and
- to bring benefits to, and to contribute to the welfare of, the local community through the provision of natural products (such as forest and fisheries products) and services (such as clean water or income derived from sustainable forms of tourism).

Guidance for Selection

The area should possess a landscape and/or coastal and island seascape of high scenic quality, with diverse associated habitats, flora and fauna along with manifestations of unique or traditional land-use patterns and social organisations as evidenced in human settlements and local customs, livelihoods, and beliefs. The area should provide opportunities for public enjoyment through recreation and tourism within its normal lifestyle and economic activities.

Organizational Responsibility

The area may be owned by a public authority, but is more likely to comprise a mosaic of private and public ownerships operating a variety of management regimes. These regimes should be subject to a degree of planning or other control and supported, where appropriate, by public funding and other incentives, to ensure that the quality of the landscape/seascape and the relevant local customs and beliefs are maintained in the long term.

Equivalent Category in 1978 System

Protected Landscape

**CATEGORY VI Managed Resource Protected Area:
protected area managed mainly for the sustainable use of natural ecosystems**

Definition

Area containing predominantly unmodified natural systems, managed to ensure long term protection and maintenance of biological diversity, while providing at the same time a sustainable flow of natural products and services to meet community needs.

Objectives of Management

- to protect and maintain the biological diversity and other natural values of the area in the long term;
- to promote sound management practices for sustainable production purposes;
- to protect the natural resource base from being alienated for other land-use purposes that would be
- detrimental to the area's biological diversity; and
- to contribute to regional and national development.

Guidance for Selection

The area should be at least two-thirds in a natural condition, although it may also contain limited areas of modified ecosystems; large commercial plantations would *not* be appropriate for inclusion. The area should be large enough to absorb sustainable resource uses without detriment to its overall longterm natural values.

Organizational Responsibility

Management should be undertaken by public bodies with a unambiguous remit for conservation, and carried out in partnership with the local community; or management may be provided through local custom supported and advised by governmental or non-governmental agencies. Ownership may be by the national or other level of government, the community, private individuals, or a combination of these.

Equivalent Category in 1978 System

This category does not correspond directly with any of those in the 1978 system, although it is likely to include some areas previously classified as “Resource Reserves”, “Natural Biotic Areas/Anthropological Reserves” and “Multiple Use Management Areas / Managed Resource Areas”.

Appendix 8.
Electronic copy of thesis and data files.

Glossary

Adequacy	The maintenance of the ecological viability and integrity of populations, species and communities (ANZECC 1999).
Biodiversity	The variety of life forms: the different plants, animals and micro-organisms, the genes they contain, and the ecosystems they form (NSW National Parks 1999).
Bioregion	An area defined by a combination of biological, social and geographic criteria, rather than by geopolitical considerations. Generally, a system of related, interconnected ecosystems (ANZECC 1999).
Comprehensiveness	Includes the full range of ecosystems recognised at an appropriate scale within and across each bioregion (ANZECC 1999).
Ecologically sustainable use	Using, conserving and enhancing the community's resources so that ecological processes, on which life depends, are maintained and the total quality of life, now and in the future can be increased.
Ecosystem	All of the organisms in a community in a given area in interaction with their abiotic (non-living) environment and each other.
Endemism	Originating in a given area and confined to that area (NSW National Parks 1999).
Habitat	The living space of a species or community, providing a particular set of environmental conditions (NSW National Parks 1999).
Irreplaceability	Irreplaceability is a measure designed to estimate the likelihood of a site being required to meet a conservation target or the extent to which conservation options are reduced if that site is unavailable. <i>Summed</i> irreplaceability is calculated by adding the individual feature irreplaceabilities for all the features at a site.
Naturalness	The extent to which an area is free from human induced change.
NSW waters	Waters within 3 nautical miles of the NSW coast and islands, under the jurisdiction of the State of NSW.
Representativeness	Those marine areas that are selected for inclusion in reserves should reasonably reflect the biotic diversity of the marine ecosystems from which they derive (ANZECC 1999).

Abbreviations

AHO	Australian Hydrographic Office
AMBIS	Australian Marine Boundary Information System
ARCCD	Australian River and Catchment Condition Database
ANZECC	Australian and New Zealand Environment and Conservation Council
CAR	Comprehensive, adequate and representative
DEC	NSW Department of Environment and Conservation
DIPNR	NSW Department of Infrastructure, Planning and Natural Resources
DPI	NSW Department of Primary Industries
EEZ	Exclusive economic zone
EPA	NSW Environmental Protection Authority
FMA	<i>Fisheries Management Act 1994</i>
IMCRA	Interim Marine and Coastal Regionalisation for Australia
IUCN	World Conservation Union (formerly known as International Union for the Conservation of Nature and Natural Resources)
MPA	Marine protected area (includes marine and estuary areas)
MPAC	Marine Park Advisory Council
NPWS	National Parks and Wildlife Service
NPWAC	National Parks and Wildlife Advisory Council
NRSMPA	National Representative System of Marine Protected Areas
NSWMPA	NSW Marine Parks Authority
NSWSMPA	NSW System of Marine Protected Areas
SEPP	State Environmental Planning Policy