4. Review of Protection of NSW Marine Habitats and Ecosystems

The coastal zone of NSW extends over a range of over 1,300 km, and together with the NSW component of the Lord Howe Island Province, its territorial waters encompass an area of over 1 million hectares (ha).

Approximately 30% of the coastline consists of rocky foreshores and headlands[139] and the remaining 70% is made up of 721 ocean beaches.[140] NSW ocean waters also contain 44 offshore islands. There are approximately 2,100 ha of mapped shallow reefs and shoals with a great deal more unmapped mid-depth and deep rocky reef. There are about 950 water courses along the NSW coastline, including 130 estuaries (72 permanently open to the sea), 15 major river systems, about 50 minor rivers, 88 coastal lakes and eight drowned river valleys.[141]

Within these estuaries and coastal watercourses, mapping has provided areas of about 13,000 ha of mangrove, 18,000 ha of seagrass and almost 7,000 ha of saltmarsh (this figure may include areas of more open high level tide flat).

4.1. NSW Estuarine Ecosystems

Estuaries are not a single habitat, but rather a complex and interrelated web of habitats defined and distinguished by the interplay of geology, river-flows, tides, and other environmental factors. Together these factors affect the composition, distribution and productivity of the biological communities that make up the living component of NSW estuaries. Abiotic (non-biological) factors such as river, wave and tidal action generate significant variation in attributes that distinguish estuary ecosystems such as tide and wave-dominated systems.[142]

These variations, mediated by ecological and biological processes, correlate with patterns of estuarine fish assemblages.[143] Within estuary ecosystems, species composition and richness are mediated further by abiotic processes. For example, the numbers of benthic species (eg polychaetes, nematodes, oligochaetes, turbellarians and copepods) have been shown to be greater (>50%) at estuary mouths compared to localities further upstream.[143]

Many studies support management programs that incorporate the surrogate approach to conserving the biodiversity of estuarine assemblages by combining regional and estuary scales in defining networks of reserve systems.[143] As it has been suggested that about 60% by weight and 70% by value of the commercial fishery catch in New South Wales is estuarine dependent, [144] protecting representative areas of estuarine habitats and ecosystems is an important goal for both biodiversity conservation and fishery sustainability.

There are 160 estuaries and river mouths mapped and differentiated into ecosystem classes in NSW. Not all of these are true estuaries, but for assessment purposes they have been divided into six categories. Estuaries in NSW contain important wetlands that are under-represented in the NSW reserve system. Many of these are below the high tide mark and

[139] Andrew, 1999
[140] Short, 1993
[141] Williams *et al*., 1998
[142] Ley, 2005
[143] Dye, 2006
[144] Leadbitter & Doohan 1991

unable to be included in terrestrial reserves under current legislative frameworks. For example, of the 164 coastal wetland communities remaining on the NSW North Coast, only 19 (mainly heathland communities associated with dunal environments) are adequately represented in the reserve system.[145]

NSW estuaries are generally characterised by wave-dominated systems with few tide-dominated systems.

Table 10: NSW estuary ecosystems[$]

Estuary	Number	Area (ha)	IUCN Ia (ha)	IUCN Ia (%)	IUCN VI (ha)	IUCN VI (%)
Undefined	2	7	0	0	0	0
Brackish	3	10,794	3,636	33.5	249	2.3
Freshwater	5	411	0	0	0	0
Intermittent	79	6,911	849	12	576	8.5
Ocean embayment	6	24,734	3,777	13	12,917	52
Tide dominated	9	38,637	2,697	7	3,508	9
Wave dominated	56	96,450	577	0.6	2,666	2.76
Total	**160**	**177,944**	**11,537**	**6.5**	**19,918**	**20.5**

Overall, about 6.5% of the total area of NSW estuaries is represented in IUCN Category Ia sanctuaries. Wave dominated estuaries are very poorly represented with only 0.6% of the total area of the ecosystem conserved within IUCN Category Ia sanctuaries.

[145] Griffith, 2005

Brackish Barrier Lakes

These bodies of fresh to brackish water have only a tenuous connection to the sea and are generally dominated by freshwater species. They are relatively rare in NSW (e.g. Myall Lakes).[146]

There are only three Brackish Lakes in NSW, covering an area of over 10,000 ha.

Table 11: NSW brackish lakes[$]

Bioregion	Number	Area (ha)	IUCN 1a (ha)	IUCN 1a (%)	IUCN VI (ha)	IUCN VI (%)
Tweed-Moreton	2	314	0	0	90	28.5
Manning	1	10,480	3,636	34.5	250	2.5
Total	**3**	**10,794**	**3,636**	**34**	**340**	**3**

Brackish Lakes are unrepresented in IUCN Category Ia sanctuaries within the Tweed-Moreton marine Bioregion and poorly represented in IUCN Category IV reserves in NSW.

Intermittent Lagoons and Creeks

These are intermittently open to the ocean, are usually associated with small catchments and small fluvial inputs, and are often non-tidal and brackish (e.g. Durras Lake, Narrabeen Lakes, Smiths Lake). [148]

Mangroves are generally absent, with sea rush (*Juncus kraussii*) often dominant. Benthic species diversity is often low, but there are sometimes extreme variations in abundance.[148]

There are 79 intermittent lagoons and creeks in NSW covering and area of almost 7,000 ha.

Table 12: NSW intermittent estuaries[$]

Bioregion	Number	Area (ha)	IUCN Ia (ha)	IUCN Ia (%)	IUCN VI (ha)	IUCN VI (%)
Tweed-Moreton	14	397.5	23	6	40.5	7.3
Manning	7	1,735.5	443	25.5	217.5	12.5
Hawkesbury	10	475	0	0	0	
Batemans	36	4,003	406	10	325.5	8
Twofold	12	300	0	0	0	0
Total	**79**	**6,911.5**	**872**	**12.5**	**583.5**	**8.5**

Intermittent estuaries are not comprehensively protected in NSW marine protected areas, as they lack representation in IUCN Category Ia or VI marine reserves within the Hawkesbury Shelf and Twofold Shelf marine Bioregions.

[146] Breen, Avery & Otway, 2005a

Ocean Embayments

These semi-enclosed bays are transitional zones between estuaries and the ocean, and include communities typical of both environments. They generally have low turbidity, oceanic tidal ranges and salinities, and include sandy areas with seagrass beds in protected locations (e.g. Jervis Bay, Batemans Bay, Botany Bay).[147]

There are six ocean embayments in NSW covering an area of almost 25,000 ha.

Table 13: NSW ocean embayments[$]

Bioregion	Number	Area (ha)	IUCN Ia (ha)	IUCN Ia (%)	IUCN VI (ha)	IUCN VI (%)
Hawkesbury	2	5,339	550	9.5	850	17
Batemans	3	16,304	3253	20	1,209	7.5
Twofold	1	3,084	0	0	0	0
Total	**6**	**24,727**	**3,803**	**15.5**	**2,059**	**8.5**

Ocean embayments are not comprehensively protected in NSW marine protected areas, as they lack representation in IUCN Category Ia or VI marine reserves within the Twofold Shelf marine Bioregion.

Tide Dominated, Drowned River Valleys

These are tidal, generally deep, narrow estuaries with rocky shores, and sometimes with large, submerged, sand deltas extending up the estuary (e.g. Port Stephens, Hawkesbury River and Clyde River estuary).[148]

Table 14: NSW tide dominated, drowned river valleys[$]

Bioregion	Number	Area (ha)	IUCN Ia (ha)	IUCN Ia (%)	IUCN VI (ha)	IUCN VI (%)
Manning	2	15,554	2,450.5	16	2,120	13.5
Hawkesbury	5	21,445.5	1.6	0	1,406	6.5
Batemans	1	1638	246	15	1,132.5	69
Total	**8**	**38,637.5**	**2,698**	**7**	**4,658.5**	**12**

Tide dominated, drowned river valleys are virtually unrepresented in IUCN category Ia and VI marine reserves within the Hawkesbury Shelf marine Bioregion.

Wave Dominated Barrier Estuaries

Young barrier estuaries in the early stages of infilling have large shallow lagoons with dense seagrass beds away from the main tidal channels (e.g. Lake Macquarie, St Georges Basin, Tuross Lake). Mature estuaries in the late stages of infilling form a riverine estuary with extensive flood plains and coastal wetlands. They often have narrow, elongated entrance channels and broad barrier sand flats (e.g. Shoalhaven River).[149]

[147] Breen, Avery & Otway, 2005a
[148] Breen, Avery & Otway, 2005a

Wave dominated barrier estuaries make up over 35% of all NSW estuaries. These estuary ecosystems dominate the NSW coastline, with 57 in total covering an area of over 95,000 ha, or over 50% of the total area of NSW estuaries.

Table 15: NSW wave dominated barrier estuaries[$]

Bioregion	Number	Area (ha)	IUCN Ia (ha)	IUCN Ia (%)	IUCN VI (ha)	IUCN VI (%)
Tweed-Moreton	15	23,697	140	0.65	435	1.8
Manning	8	24,104	67	0.3	47	0.2
Hawkesbury	8	33,629	0	0	10	3
Batemans	22	13,534	370.5	2.7	2,095	15.5
Twofold	4	1486.5	0	0	0	0
Total	**57**	**96,451**	**577.5**	**0.5**	**2,587**	**2.5**

Wave dominated estuaries are very poorly represented in both IUCN Category Ia and VI marine reserves. A mere 0.5% of these highly diverse ecosystems are represented in NSW marine sanctuaries. These important ecosystems lack any representation in marine sanctuaries within both the Hawkesbury and Twofold Shelf marine Bioregions. Wave dominated estuaries are a high priority for conservation in NSW.

4.1.1. Near Pristine Estuaries

Near-pristine estuaries tend to be located along the most remote and inaccessible parts of the coastline. They have not been altered by humans in a significant way. Therefore they are not used for aquaculture, and the water movements through the estuaries and fringing wetlands have not been altered by roads or engineering structures.[149]

Near-pristine estuaries retain most of their natural vegetation cover and are not heavily urbanised nor used for large-scale farming.[152] Sediment and nutrients that are delivered to these estuaries in stream flow are near the levels they would be if European-style living and farming practices had never been introduced to Australia.[152]

[149] NLWRA, 2002

Table 16: Criteria of near-pristine estuary [150]

Physical Characteristics	Condition
Natural catchment cover	>90%
Land use	Limited roads and disturbance to natural conditions and processes
Catchment hydrology	No dams or impoundments, virtually nil abstraction
Tidal regime	No impediments to tidal flow, changes from natural morphology (e.g. training walls, barrages, bridges and causeways)
Floodplain	Wetlands intact in vegetation and hydrology, no alterations to flood pattern
Estuary use	Extractive activities limited to indigenous or limited and sustainable commercial and recreational fishing, no aquaculture
Pests and weeds	Minimal impact on estuary from catchment weeds and limited pests and weeds within estuary
Estuarine ecology	Ecological systems and processes intact (e.g. benthic flora and fauna)

The National Land and Water Resource Audit (NLWRA) assessed 132 of the ~160 estuaries and river mouths in NSW.[152] The 14 estuaries classified as near pristine cover an area of only ~871 ha out of a total of almost 178,000 ha of estuary in NSW. This is less than 0.005% of the total area of NSW estuaries. Twelve of these 14 are intermittent estuaries, one is a brackish lake and one a wave dominated estuary.

The principle of representativeness implicitly requires that the MPA system include those marine ecosystems that are rare, vulnerable or endangered.[150] Near pristine estuaries are demonstrably rare and in some cases highly vulnerable, making such ecosystems irreplaceable to any marine protected area system.

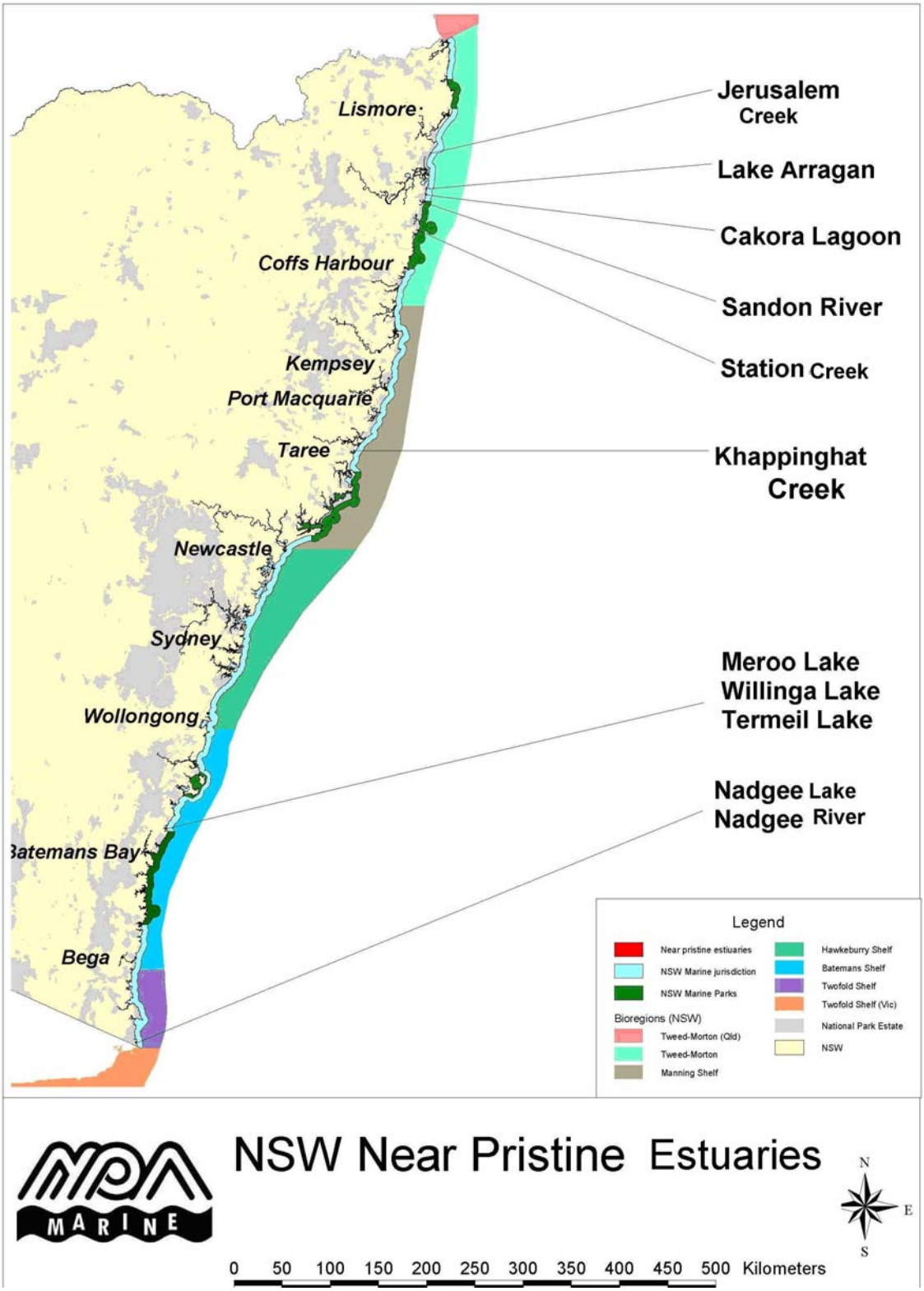
[150] ANZECC TFMPA, 2000, Task 3: 'Vulnerable' Ecosystems' (Action 4)

Table 17: NSW near pristine estuaries[$;151]

Bioregion	Name	Ecosystem	Opening	Age	Area (ha)
Tweed-Moreton	Jerusalem Creek	Intermittent	Intermittent	Intermediate	34.5
	Cakora Lagoon	Intermittent	Intermittent	-	37
	Sandon River	Wave dominated	Open	Mature	187.5
	Station Creek	Intermittent	Intermittent	Mature	34
	Lake Arragan	Brackish lake	-	-	95
					388
Manning Shelf	Khappinghat Creek	Intermittent	Intermittent	Mature	132
					132
Batemans Shelf	Lake Brunderee	Intermittent	Intermediate	Semi - mature	9.5
	Lake Tarouga	Intermittent	Intermittent	-	26
	Termeil Lake	Intermittent	Intermittent	Semi - mature	55
	Willinga Lake	Intermittent	Intermittent	Mature	35.5
	Meroo Lake	Intermittent	Intermittent	Semi - mature	103
					229
Twofold Shelf	Merrica Lake	Intermittent	Intermittent	Intermediate	11
	Nadgee Lake	Intermittent	Semi - mature	-	97
	Nadgee River	Intermittent	Intermittent	Mature	15
					123
Total					**871.5**

Recomendation 17:

That all 14 near pristine estuaries identified by the 2002 National Land and Water Resources Audit be declared as Aquatic Reserves sanctuaries by 2011.



Map 6: NSW Near Pristine Estuaries

4.1.2 Estuarine Vegetation

Three main types of estuary vegetation have been used in this analysis based on available data detailed in the references of this report. These include mangrove, saltmarsh and seagrass. Seagrass is divided into further categories based on genera. The datasets relied upon are over 20 years old and are therefore indicative only. Fine-scale estuarine vegetation mapping is required to be undertaken for greater accuracy and to account for habitat alteration during the mid 1980s.

The tables 18-21 identify areas of mapped estuarine vegetation types existing in each Bioregion using West *et. al*.,1985. However, a more recent and incomplete dataset (New South Wales Fisheries, 2006) reveals significant differences in estuarine vegetation that should be considered when interpreting these tables. Data made available on estuarine vegetation of Port Stephens (New South Wales Fisheries, 2006) is compared to data for the same area by West *et. al.,* 1985 and reveals the following:

- An overall reduction in area of mapped estuarine vegetation of 14.5%
- 100% increase (880 ha-1770ha) in area of mapped saltmarsh/mangrove
- 92% reduction (89 ha- 7 ha) in area of mapped *Halophila sp.* dominant seagrass beds
- 25% increase in area of mapped *Posidonia australis* dominant seagrass beds
- 4% reduction in area of mapped saltmarsh
- Total areas of mapped mangrove and *Zostera spp* remain about the same.

Table 18: NSW estuary vegetation types[#]

Bioregion	Habitat	Area	IUCN Ia (ha)	IUCN Ia (%)	IUCN VI (ha)	IUCN VI (%)
Tweed-Moreton	Mangrove	2,294	42	2	37	3
	Saltmarsh	700	6	1	3	1
	Seagrass	2,103	3	0.13	14	0.7
		5,097	**51**	**1**	**54**	**1**
Manning	Mangrove	5,264	251	5	178	3.5
	Saltmarsh	3,974.5	43.5	1	62.5	1.5
	Seagrass	6,231	460	7.5	225	3.5
		15,469.5	**754.5**	**5**	**465.5**	**3**
Hawkesbury	Mangrove	3,995	221	5.5	127	3
	Saltmarsh	1,151	10	0.1	16.5	1.5
	Seagrass	5,467.50	104.5	2	172.5	3
		10,613.50	**335.5**	**3**	**316**	**3**
Batemans	Mangrove	1,344	102.5	7.5	191	14
	Saltmarsh	1,005	63	6.5	72.5	7
	Seagrass	3,700.5	741	20	629	17
		6,049.5	**906.5**	**15**	**892.5**	**15**
Twofold	Mangrove	76	0	0	0	0
	Saltmarsh	161.5	0	0	0	0
	Seagrass	390.5	0	0	0	0
		628	**0**	**0**	**0**	**0**
Total		**37857.5**	**2047.5**	**5.5**	**1728**	**4.5**

The Manning and Hawkesbury Shelf Marine Bioregions contain the majority of extant vegetation types and the Batemans Shelf Marine Bioregion has the greatest area protected in IUCN Category Ia and Category VI reserves.

Overall, estuarine vegetation types are poorly represented in both IUCN Category Ia and Category VI reserves. All three vegetation types are particularly under-represented in IUCN Category Ia and Category VI marine reserves in the Tweed-Moreton, Manning and Hawkesbury Shelf Marine Bioregions. There are no areas of estuarine vegetation represented in either IUCN Category within the NSW section of Twofold Shelf.

Seagrass

Seagrasses are flowering plants that live and reproduce completely submerged in sea water, producing flowers and seeds similar to terrestrial grasses.[151] Seagrasses form 'beds' in near-shore brackish or marine waters in temperate and tropical regions.

Australia has approximately 51,000 km^2 of seagrass beds, comprising the most diverse array of seagrass species in the world.[152] In NSW, the most common species are *Zostera capricorni* (eelgrass), *Halophila spp* (paddleweed) and *Posidonia australis* (strapweed).

While seagrasses are also found in protected near shore coastal areas, detailed mapping of seagrass has only been completed for estuaries in NSW, where they are found in the intertidal and sub-tidal zones. Six species of true seagrasses are found in NSW, generally increasing in number from north to south.[153]

Seagrasses are an important link in the 'critical chain' of habitats required for sustainable fisheries production.[154] They are extremely productive areas, containing high biodiversity, and provide nursery habitat for an abundance of fish, crustaceans and molluscs, including many commercially valuable species.[155] Studies have found that the abundances for some marine species are up to 70 times greater on seagrass than on unvegetated substrates.[156]

A number of important commercial and recreational fishery species appear to benefit from seagrass habitats, including: whiting *(Sillago ciliata*), yellowfin bream *(Acanthopagrus australis)*, black bream (*Acanthropagus butcheri)*, garfish (*Hyporhamphus australis),* rock flathead *(Leviprora laevigatus)*, luderick (*Girella tricuspidata)*, eastern rock lobster (*Jasus verreauxi)* and eastern king prawn *(Penaeus plejejus)*.[157]

Seagrasses provide an important 'nursery habitat' for the juveniles of many fishes such as luderick (*Girella tricuspidata),* tarwhine (*Rhabdosargus sarba),* eastern blue groper (*Achoerodus viridis)* and yellow-finned leatherjacket (*Meuschenia trachylepis).*

Most of these fish leave the seagrass beds and migrate to other habitats, such as kelp beds and rocky reefs, as they get older.[158] For many other fishes such as pipefishes, white's seahorse *(Hippocampus whitei),* southern pygmy leatherjacket *(Brachaluteres jacksonianus)* and blue-spot goby *(Pseudogobius olorum)* seagrasses provide lifelong habitat.[159]

[151] Keough & Jenkins, 1995
[152] Butler, 1999
[153] West *et al.*, 1989
[154] Cappo *et al.,* 1995.
[155] Loneragan *et al*., 1994
[156] McNeill *et al.*, 1992
[157] NSW SOE, 2006
[158] AMONLINE, 2002

It is likely that many other species are reliant on seagrasses.[159] Movement of larvae from coastal rocky reefs to estuarine seagrass beds, and the movement of juveniles and adults from estuarine seagrass to coastal reefs, are common and well-documented patterns for fish and invertebrates using seagrass beds.[160] Areas of seagrass in close proximity to rocky reefs are therefore high conservation priorities.

Seagrasses bind sediment and help to stabilise shorelines against erosion.[161] The baffling effect of water movement causes the deposition of suspended sediment and organic matter.[162] Baffling may also impede the mixing process which destabilises water column stratification, thereby influencing the dissolved oxygen status of bottom waters.[162]

There has been a severe decline in the extent of seagrasses in NSW.[162] At least half of the State's estuarine seagrass has been lost over recent decades.[163] Most of this loss is due to eutrophication of estuarine waters leading to increased algal growth that has led to seagrass dieback occurring.

The condition of seagrasses in NSW is highly variable, but in general, seagrass beds near urban or industrial areas are degraded, while more isolated seagrass areas are in good health.[164] Seagrass is highly vulnerable due to its poor recovery from disturbances and slow growth rate. This is particularly true for *Posidonia australis*.[165]

Commercial and recreational fishing impacts on seagrass by causing disturbance, increasing turbidity and destabilising sediments with nets and anchors. This reduces growing conditions, removes epiphytes and epifauna, damages seagrass beds and introduces contaminants and invasive weeds. Other impacts associated with fishing include lost fishing gear, which gets tangled in seagrass stems further inhibiting growth, diminishing habitat quality and entrapping fish and invertebrates.

Many NSW estuaries have been known to contain infestations of the introduced aquarium seaweed *Caulerpa taxifolia* that can adversely affect marine biodiversity by quickly colonising native seagrass beds. While ongoing research is looking into ways of eradicating this marine pest, anchoring and commercial and recreational netting are likely to be responsible for its spread.

[159] Bell, & Pollard, 1989
[160] Bell & Worthington, 1993
[161] Butler, A.J. 1999
[162] McNeill, 1996
[163] Poiner & Peterken, 1995
[164] NSW Fisheries, 1999b
[165] Larkum *et al*., 1989

Table 19: NSW estuary seagrass types*

Vegetation	Area (ha).	IUCN Ia (ha)	IUCN Ia (%)
Halophila sp.	380	18	4.5
Halophila sp./#Ruppia sp.	266	0	0
Halophila sp./Zostera sp.	1,258	147	11
P. australis/Halophila sp.	18	0	0
P. australis/Zostera sp.	182	40.5	22
Posidonia australis	2,575	540	21
#Ruppia sp.	2,694	41	1.5
#Ruppia sp./Zosteraceae	11	0	0
Zostera sp.	9,470.5	517.5	5.5
Zostera sp./#Ruppia sp.	993.5	0	0
Zosteraceae/#Ruppia/Halophila spp	45.5	0	0
Total	**17,893**	**1,304**	**7.5**

*includes mapped areas above mean high water mark #Ruppia is mapped as seagrass in the spatial data used.

Eight of the 11 seagrass communities mapped in NSW are poorly represented in marine sanctuaries. These include *Ruppia* (1.5%) – which is not a true seagrass, but for assessment purposes has been included as such – *Zostera* (5.5%) and *Halophila* (4.5%).

Mangrove

The two most common species of mangroves that grow along the shores of many NSW estuaries are *Avicennia marina* (grey mangrove) and *Aegiceras corniculatum* (river mangrove). Mangrove communities are increasingly threatened by development and reclamation.

Mangrove communities provide essential ecological services such as nursery habitat for larval and juvenile fish, the regulation of water quality,[166] and the stabilisation and buffering effect that protects the banks of rivers and estuaries from storms and erosion. The regulation of water quality is of particular importance where the surrounding region contains seagrass, as this habitat is vulnerable to deterioration if water quality declines.[167] Mangrove creeks are an important fish habitat. Mangroves supply the bottom of the food chain with large amounts of organic matter and help maintain water quality by filtering silt from runoff and recycling nutrients.[167] Mangroves are the most productive, in terms of organic matter produced, of any estuarine ecosystem.[168]

Many commercially important fish such as leatherjacket, flounder, sea mullet (*Mugil cephalus)*, yellowfin bream (*Acanthopagrus australis)*, luderick (*Girella tricuspidata)* and dusky flathead (*Platycephalus fuscus)* spend much of their juvenile life in mangrove creeks before moving out into deeper water as adults.[168] Other fish common in the mangroves around Sydney are the common toadfish (*Tetractenos hamiltoni)* and striped scat or striped butterfish *(Selenotoca multifasciata).*[169]

Mangrove communities are impacted by fishing through the removal of fish and invertebrates from adjacent mudflats and channels, and the associated disturbance of nesting and roosting birds. Discarded and lost fishing gear such as nets, monofilament line, hooks and sinkers trap and entangle birds and marine fishes and invertebrates.

Table 20: NSW mangrove types*

Vegetation	Area (ha)	IUCN Ia (ha)	IUCN Ia (%)
A. corniculatum/A. marina	1,953.5	84	4.5
A.corniculatum/Saltmarsh	955	68	7
Aegiceras corniculatum	7	0	0
Avicennia marina	4,106	382	9.5
Mangrove (undefined)	4,996	60	1
Mangrove/Saltmarsh	90	0	0
Total	**12,108**	**595**	**5**

includes mapped areas above mean high water mark

Mangroves are poorly represented in IUCN Category Ia sanctuaries in NSW (5%). About 55% of all NSW mangroves exists above the mean high water mark and cannot be protected from fishing related impacts through either the *Fisheries Management Act* or the *Marine Parks Act*.

[166] Nickerson, 1999
[167] Larkum, 1981
[168] AMONLINE, 2002

However, approximately 30% (3,684 ha) of NSW mangroves exist within the NSW National Park estate, of which about half is above the high tide mark and about 17% (2,007 ha) exists within the National Park estate below the high tide mark and is thus exposed to fishing impacts. Areas of mangroves below the mean high tide mark are a high priority for conservation.

Saltmarsh

Coastal saltmarsh is a community of salt tolerant plants and animals that grow along the upper-intertidal zone of coastal waterways. Saltmarshes are common in most estuary ecosystems but are most common in tide-dominated and wave-dominated estuaries.[169]

The diversity of plant species in saltmarsh increases with the higher latitudes of temperate waters, whereas the diversity of mangroves is highest in the lower latitudes of the tropics. Where saltmarshes and mangroves coexist, saltmarshes are typically found at slightly higher elevations than the mangroves, which are closer to the tidal flooding source.

A recent trend has been the expansion of mangroves into nearby saltmarsh areas. The total area of coastal saltmarsh in NSW in the mid-1980s (when the datasets used in this report were developed) was distributed in fragmented patches, usually of less than 100 ha.[170] Since the mapping by West *et. al*.(1985), further reduction and fragmentation have occurred.[171]

By the latter part of the last century, 25–30% of the remaining saltmarsh had been lost to mangrove encroachment.[172] The main driver of mangrove invasion is likely to be regional rises in sea level due to climate change.[173] Due to the decline of saltmarshes in NSW, they are now listed under the *Threatened Species Conservation Act* as an endangered ecological community.

Saltmarsh will be under continued threat as the predicted sea level rise resulting from climate change manifests. Development on estuarine foreshore must be prohibited if this important habitat is allowed to ingress with rising sea levels.

The soils of saltmarshes may have salinity levels much higher than that of seawater, may be anoxic and have accumulated iron sulphides,[174] making them a potential source of acid sulphate soils. Disturbing these soils can cause sulphuric acid to drain into coastal waterways.

Saltmarshes are essential components of estuarine food chains and a primary productivity support resource for estuarine food webs.[175] They mediate a balance of nutrients and organic matter between saltmarsh and mangroves, seagrass beds and open water systems.[176]

Saltmarshes protect coastlines from the erosive effects of storms and extreme tides, trap and bind sediment, and maintain the quality of groundwater as they filter water that drains from the land.

Saltmarshes are used by a large variety of migratory and resident birds, including terns, egrets, sandpipers, curlews, whimbrels, plovers, dotterels and stilts, for feeding, roosting and breeding. Conservation of waders is a matter for international concern and the

[169] Heap *et al.,* 2001
[170] West *et al*., 1985
[171] Adam 2002; Harty & Cheng 2003; Hughes 2003; Kelleway 2005
[172] Mitchell & Adam 1989; Saintilan & Williams 1999; Saintilan & Williams 2000.
[173] Rogers *et al*., 2006.
[174] King, 1983
[175] Cappo *et al* ., 1995

Commonwealth is signatory to three agreements (the Ramsar Convention, the Japan-Australia Migratory Birds Agreement and the China-Australia Migratory Birds Agreement) which impose obligations to protect habitats utilised by migratory waders.

Saltmarshes may be impacted by fishing through damage associated with tramping that compacts the soil and damages plants when hauling, netting, trapping, line fishing and bait collecting, as well as suffering from the effects of monofilament line and other gear lost during recreational and commercial fishing. Fishing activities also disturb roosting, nesting and wading birds.

Saltmarshes are areas of significant bioproductivity. While early studies indicated that at least some saltmarshes provide habitats utilised by fish,[176] they were thought to provide fewer fish habitats than other estuarine communities, as they generally have few permanent creeks and pans.

Recent studies, however, have shown that a substantial component of zooplankton inputs and outputs in temperate estuaries are from the larvae of saltmarsh dependant crabs.[177] Itinerant fish exiting near the saltmarsh with the ebbing tide have been shown to contain extremely high proportions of crab larvae in their guts, suggesting a direct trophic link between secondary production of saltmarsh and itinerant fish, and a significant ecological role in the trophic food web of temperate estuarine systems for burrowing crabs.[178] Indeed, fish densities have been found to be higher within saltmarsh than adjacent mangroves when corrected for water volume, suggesting a significant role for saltmarsh as a fish habitat in the estuaries of south-eastern Australia. [178]

When saltmarshes are found adjacent to seagrass beds and mangroves, many material links and shared plant and animal communities exist.[178] Such areas are essential for many juvenile fish and invertebrates, and are high priorities for marine biodiversity conservation.[179]

Table 21: NSW saltmarsh types*

Vegetation	Area (ha)	IUCN Ia (ha)	IUCN Ia (%)
Saltmarsh comm./*A. marina*	865	19.5	2
Saltmarsh	6,982	125.2	1.8
Total	**7,847**	**144.7**	**1.8**

Includes areas above mean high water mark

A mere 1.8% of mapped saltmarsh is protected within IUCN Category Ia sanctuaries. However, almost 75% of all saltmarsh in NSW exists above the mean high water mark, and cannot be protected from fishing related impacts through either the *Fisheries Management Act* or the *Marine Parks Act*.

About 2,117 ha (27%) of extant saltmarsh is protected in the NSW National Park estate. The balance of 2,000 ha (26%) of this essential and vulnerable habitat is below the high tide mark outside of the National Park estate, and is a high priority for conservation.

[176] Gibbs, 1986
[177] Mazumder *et al.*, 2006
[178] Fortes, 1994
[179] Thomas & Connolly, 2001

4.2. NSW Coastal Habitats

Five broad coastal habitats have been used in this analysis - beaches, islands and rocks, reefs and shoals, rocky intertidal and subtidal sand.

The Manning Shelf Marine Bioregion contains the greatest overall area of coastal habitats as a consequence of its greater total area. As the dominant northward 'long-shore drift', which refers to the movement of waterborne sediments drifting northward along the NSW coastline, sandy beaches and subtidal sand predominate in the northern Bioregions and rocky intertidal and reef habitats predominate in southern Bioregions.

The Manning Bioregion contains the greatest area of beach, subtidal sand and island and rocks habitat. The Batemans Marine Bioregion contains the greatest area of reef and shoal and rocky intertidal habitat.

Table 22: NSW coastal habitats[#]

Bioregion	Habitat	Area (ha)	IUCN Ia (ha)	IUCN Ia (%)	IUCN VI (ha)	IUCN VI (%)
Tweed-Moreton	Beaches	1,034	36	3.5	140	23
	Islands and rocks	85	4	5	13	40
	Reefs and shoals	6,684	617	9	2,082	34
	Rocky intertidal	152	14	9	20.5	41
	Subtidal sand	20,284	2,268	11	5,813.50	29
		28,247	**2,939**	**9.5**	**8,070**	**26.5**
Manning	Beach	1,195	42.5	3.5	197.5	19
	Island and rock	395	20.5	5	70	18
	Reef and shoal	3,659	311	8.5	14,13.5	42.5
	Rocky intertidal	190	8.5	4.5	73.5	40
	Subtidal sand	25,804.50	556	2	5,089	25
		31,253.50	**938.5**	**3.5**	**6843.5**	**27**
Hawkesbury	Beach	566.5	4	1	7	1
	Islands and rocks	50	0	0	0.01	1
	Reef and shoal	4,882.5	83.5	2	168.5	3.5
	Rocky intertidal	494	15	3	16	3
	Subtidal sand	7,711	11	0.14	32	0.5
		13,739	**113.5**	**1**	**223.51**	**1.5**
Batemans	Beach	948	66.5	7	155	16.5
	Islands and rocks	199.5	13.5	7	10	5
	Reef and shoal	8,319	944	11.5	1,803.50	22
	Rocky intertidal	840.5	86	10	167.5	20
	Subtidal sand	13,234	1,082.50	8	3,036.50	23
		23,541	**2,192.50**	**10.5**	**5,172.50**	**20.5**
Twofold	Beach	300.5	0	0	0	0
	Islands and rocks	5.5	0	0	0	0
	Reef and shoal	867.5	0	0	0	0
	Rocky intertidal	421.5	0	0	0	0
	Subtidal sand	3,201	0	0	0	0
		4,796	**0**	**0**	**0**	**0**
Total		**101,524**	**6,183.50**	**6**	**18,895**	**18.5**

4.2.1. Rocky Shores and Headlands

Intertidal rocky shores and headlands provide habitat for the settlement and recruitment of many marine and estuarine species. Diverse assemblages of brown, red and green macro algae, sponges, ascidians and other sessile invertebrates enhance habitat complexity of rocky shores and headlands, and provide enormous opportunity for ecological specialisation. Large macro-algae (such as kelps that should cover most reefs) enhance species diversity by providing patches of shaded habitat favoured by distinct assemblages of organisms.

Rocky headlands usually form the extremities of ocean beaches. They provide a variety of habitats, including the rock platform itself, rock pools and boulder fields, as well as subtidal rocky reef habitats. Species assemblages on exposed shores and headlands are often long-lived species, which appear to be especially vulnerable to collecting and trampling disturbance and thus are priorities for conservation.

The conservation of rocky intertidal shores depends on the control of habitat destruction, illegal harvesting, pollution, and physical disturbance.[180] Exploited species include abalone, elephant snails, dog winkles, limpets, top shells, crabs and cunjevoi. Some of the once-common snails are now rarely seen.[183]

Intertidal rocky shore habitats are often limited in area. They are highly vulnerable to human impacts. Threats to shore communities include over-harvesting of molluscs, crustaceans, echinoderms and ascidians for food and bait, trampling by fishers and other visitors, oil slicks and other pollutants which float on the sea surface, and loss of habitat. In NSW, significant areas of shores around coastal cities and towns have been 'reclaimed' or alienated by seawalls, port development, industry, housing and tourism, and recreational facilities. [181]

Table 23: NSW rocky intertidal habitat[#]

Habitat	Area (ha)	IUCN Ia (ha)	IUCN Ia (%)	IUCN VI (ha)	IUCN VI (%)
Rocky intertidal	2,091	106	5	330	16

NSW rocky intertidal habitats are poorly represented in IUCN Category Ia sanctuaries.

4.2.2. Sandy Beaches

There are two broad types of sandy beaches recognised in NSW, reflective and intermediate.

Reflective beaches are composed of coarse sand and gravel, have steep faces and waves usually less than half a meter high. They do not have a surf zone. Rather, waves surge up the beach. This produces a short but strong swash, which coupled with coarse sediments, makes these beaches least suitable for organisms. Reflective beaches are more common on the south coast and at the more protected ends of long surf beaches and in sheltered deeply embayed beaches.

Intermediate beaches account for 70% of NSW beaches. They develop where waves are half to two meters high and the sediment is fine to medium. They have a surf zone up to 100m wide and contain alternating bars and rip channels. These beaches support more diverse and abundant fauna populations than reflective beaches due to the ability of finer sediments to retain moisture and detritus.

[180] Zann, 1995

Beach flora consists of benthic micro-algae and phytoplankton, as well as microscopic bacteria and fungi.

Sandy beaches provide important habitat for a variety of fauna and flora on an intermittent basis. Sandy beaches with lower shores and less exposure generally support more diverse and abundant species assemblages. This is particularly so on the northern ends of NSW beaches, where pippies and other shellfish are often harvested commercially.

Fishing impacts beach communities by reducing ecological complexity through hand gathering for bait, digging for molluscs, net hauling and line fishing, as well as disturbance to birdlife and marine turtles. Indirect impacts of fishing include damage and disturbance associated with increased four-wheel drive activity.

Table 24: NSW beach habitat.#

Habitat	Area (ha)	IUCN Ia (ha)	IUCN Ia (%)	IUCN VI (ha)	IUCN VI (%)
Beach	3,865	117	3	623	16

NSW beach habitats are poorly represented in IUCN Category Ia sanctuaries, with a mere 3% being represented.

4.2.3. Sub-tidal Rocky Reefs

In NSW, key species such as large brown algae provide food and a complex physical structure for fish and many other animals on reefs.

NSW temperate reefs are extraordinarily diverse. Red and brown algae, ascidians, bryozoans and crustaceans have much higher species richness than in temperate habitats elsewhere in the world.[181] Australia's reefs are distinctive in their ecological processes. On the temperate east coast of Australia the brown algae *Ecklonia* and *Phyllospora* are dominant.[182]

Sub-tidal reefs are extremely important and dynamic coastal environments.[182] Reef systems provide extensive refuge and feeding opportunities for a huge number of fish and invertebrates, including soft corals, bryozoans, ascidians and sponges. Reefs provide an important part of the life cycle of many protected and threatened fish in NSW, including grey nurse shark, blue devil fish, elegant wrasse, black cod, blue groper, sygnathids and estuary perch.

Little is known of the effects of anthropogenic activities on temperate reefs.[183] The most serious potential effects are those on the habitat-forming species, particularly the large algae, whose loss may have dramatic effects on other species.

The impacts of fishing includes habitat damage from anchors, traps, nets and sinkers as well as lost fishing gear which continues to entangle and trap fish, invertebrates and habitat forming vegetation for many years after the gear is lost. However, one of the major impacts fishing has on reef communities is the removal of predators, which has severe trophic level consequences.

Urchins are important algal grazers on temperate reefs. Dominant genera in NSW open coastal reef environments are *Centrostephanus* and *Heliocidaris*.[184]

[181] Kelleher *et al.,* 1995
[182] Parson *et al.*, 2004

Table 25: NSW mapped sub-tidal rocky reef habitat.[#]

Habitat	Area (ha)	IUCN Ia (ha)	IUCN Ia (%)	IUCN VI (ha)	IUCN VI (%)
Reef and shoal	24,359	1,868	7.5	5591	23

The area of mapped reef habitat is limited to that which is visible from air photos (<20m). Many times more reef habitat exists that has not been mapped, particularly in mid-depths (20-60m) and deep water (60-200m) off the NSW coast. Reef systems are a high conservation priority.

Recommendation 18:
That all NSW reef habitats be comprehensively mapped by 2011.

Seaweed (Macroalgae)

Seaweeds differ from seagrasses in that they are not flowering plants, but macroalgae. Kelps are probably the best locally known brown seaweed type. There are approximately 800 species of seaweeds in NSW. Seaweeds are one of the main energy-producing organisms of the ocean and are important in providing food and/or shelter for a large range of fish and other aquatic animals. Seaweeds are found at shallow depths where light can penetrate. Dead seaweed also forms habitat and is an important part of the food chain.

Habitat protection is important to protect seaweed; however, protecting seaweed from being impacted directly is a limited response. The removal of large predators by fishing has impacted on seaweed habitat by allowing herbivores such as sea urchins to overgraze it, leading to an increase in the area of “urchin barrens” – deforested areas dominated by coralline algae (on which urchins do not graze), and devoid of foliose algae such as kelp and other seaweed. Seabed mapping in south-eastern Australia has determined that urchin barrens comprise as much as 50% of the area of near-shore reefs in New South Wales.[183]

In many subtidal reef systems throughout the world, a reduction in algal forests and an increase in urchin barrens have been linked to fisheries-related declines in urchin predators.[184] Fishing reduces populations of target fish species, reducing predation on sea urchins, intensifying herbivory, and causing "urchin barrens" of encrusting coralline algae. Protection from fishing of top predators has been shown lead to the reinstitution of a more natural predator/prey balance.[185]

Mortality of sea urchins has been shown to be significantly higher in marine sanctuaries than in adjacent areas open to fishing.[186] Studies in New Zealand have shown that snapper are up to 9 times more abundant inside long-established marine reserves and spiny lobster up to almost 4 times more abundant, than in adjacent unprotected areas. Both of these predators, which actively prey on urchins, significantly reduce their numbers inside reserves, compared to outside reserves.[187]

Rock lobsters have a significant impact on sea urchin populations. While juvenile sea urchins are eaten more frequently than larger sea urchins by all sizes of rock lobsters, only the largest rock lobsters (> 120 mm carapace length) are able to consume large adult sea urchins.[189]

[183] Andrew and O’Neil, 2000
[184] Sala *et al.*, 1998
[185] Behrens & Lafferty, 2004
[186] Pederson & Johnson, 2006
[187] Shears & Babcock, 2002

Large adult sea urchins experience higher predation mortality than juveniles, and predators, particularly large rock lobsters, exert significant predation mortality. [189] Studies have concluded that fishing of rock lobsters is likely to reduce an important component of mortality in sea urchin populations. [189]

Parsons *et al.* (2004) mapped the changes in community structure of sub-tidal reef habitat within the 22 year old no-take Leigh Marine Reserve on New Zealand's North Island and found that the total disappearance of "urchin barrens" across all depths and the recovery of kelp forests in water was caused by the recovery of marine predators.[188]

These authors suggested that

… reserve status has allowed this section of coast to return to a similar state to that which may have existed before high fishing pressure with a few sea urchins and high macroalgal abundance.

They continued:

The large-scale decline in the extent of urchin grazed barrens habitat is consistent with higher predation levels on sea urchins and an increased abundance of previously targeted predator species in the marine reserve associated with the cessation of fishing (eg snapper Pagrus auratus and spiny lobster Jasus edwardsii). Anecdotal reports gathered from Dromgoole (1964) suggest that at many sites throughout north-eastern New Zealand 'urchin barrens' replaced areas of kelp forest sometime after 1950, which coincides with a sudden increase in snapper landings and a drop in spawning biomass.

As seaweed has not been comprehensively mapped in NSW marine waters, it is difficult to determine whether urchin barrens are increasing in area.

Recommendation 19:

That the extent and type of seaweed present be comprehensively mapped in NSW waters by 2011.

4.2.4. Offshore Islands and Emergent Rocks

There are 44 named offshore islands in the NSW marine jurisdiction and a further 1000 or so mapped emergent rocks. Offshore islands and emergent rocks provide important habitats for numerous species, some of which are threatened with extinction due to fishing practices. Islands and emergent rocks form important haul out sites for Australian and New Zealand fur seals and essential rookery sites for little penguins and other sea birds such as the endangered Gould's petrel. Rocky islands are surrounded by fringing reef habitats, often harbouring distinct macro-algae assemblages and sometimes shelter seagrass communities.

Table 26: NSW islands and emergent rock habitat[#]

Habitat	Area (ha)	IUCN Ia (ha)	IUCN Ia (%)	IUCN VI (ha)	IUCN VI (%)
Islands and rocks	735	36.5	5	96	13

NSW islands and rocks are poorly represented in IUCN Category Iª sanctuaries.

[188] Parsons *et al.*, 2004

4.2.5. Sub-tidal Sand

Many soft-substrate ecological communities occur on sub-tidal sand.[189] Organisms that inhabit these habitats include polychaete worms, bivalve molluscs, gastropods, sand stars and sand dollars, sea pens and sea pansies, and other suspension feeders.

Organisms in these regions are confronted by a physically rigorous and structurally unstable but relatively predictable and homogeneous habitat.[191] The benthic environment changes markedly from nearly constant sweeping surge and continually shifting sands near-shore to gentle surge and relatively stable sands at distances well beyond the surf zone.[191] These habitats, because of their physically stressful nature and relatively depauperate appearance, have been little studied.[191]

Table 27: NSW sub-tidal sand habitat#

Habitat	Area (ha)	IUCN Ia (ha)	IUCN Ia (%)	IUCN VI (ha)	IUCN VI (%)
Sub-tidal sand	64967	3893	6	13996.5	21.5

Sub-tidal sand habitat is poorly represented in IUCN Category Ia sanctuaries in NSW waters.

4.3.Ocean ecosystems

While the NSW Marine Parks Authority have an ongoing sea bed mapping program, only a fraction of the sea bed of the NSW marine jurisdiction have been mapped.

To account for the lack of comprehensive sea bed mapping in NSW waters, broad surrogate ecosystems using bathymetric data and depth contours have been used to identify sections of the marine environment that are likely to harbour distinct ecological communities.

Depth zones (0-20m, 20-60m and 60-200m) have been used to characterise the dominant ecological gradients in light, wave action and currents across the shelf. These gradients have been related to corresponding differences in the diversity of algae, sponges, benthic fauna, fish assemblages, sediments, currents, sea surface temperatures, salinity and water chemistry.[190]

[189] Morin *et al*., 1985
[190] Breen, Avery & Otway, 2004

Table 28: NSW ocean ecosystems by bioregion[#]

Bioregion	Ecosystem	Area (ha)	IUCN Ia (ha)	IUCN Ia (%)	IUCN VI (ha)	IUCN VI (%)
Tweed-Moreton	0 - 20m	47,114	4537	9.5	13,221	28
	20 - 60m	151,939	9137	6	30,879	20
	60 -200m	8,476	426	5	352	4
		207,529	**14,100**	**7**	**44,452**	**21.5**
Manning	0-20m	46,270.5	1,291.5	3	9,856.5	21
	20-60m	132,519	5,186.5	4	22,859	17
	60-200m	29,250.5	3,949	13	1,971.5	8
		208,040	**10,427**	**5**	**34,687**	**17**
Bioregion	**Ecosystem**	**Area (ha)**	**IUCN Ia (ha)**	**IUCN Ia (%)**	**IUCN VI (ha)**	**IUCN VI (%)**
Hawkesbury	0 - 20m	23,529	274	1.2	163	0.7
	20 - 60m	94,597	10.5	0.005	0	0
	60 -200m	20,460	0	0	0	0
		138,585	**285**	**0.2**	**163**	**0.1**
Batemans	0 - 20m	31,104.5	3,134.5	10	5,397.5	17.5
	20 - 60m	104,563.5	8,336.5	8	19,215	18.5
	60 – 200m	53,178	4,125	8	10,971.5	20.5
		188,846	**15,596**	**10**	**35584**	**19**
Twofold	0 - 20m	6,708.5	0	0	0	0
	20 - 60m	30,638.5	0	0	0	0
	60 -200m	20,201	0	0	0	0
		57548	0	0	0	0
Total		**800,549**	**40,407**	**5**	**114, 886**	**14.5**

The NSW section of the Manning Shelf has by far the greatest area of 0-20m depth range. The NSW section of the Tweed-Moreton Bioregion has the greatest area of 20-60m depth range, and the Batemans Shelf has the greatest 60-200m depth range. However, the Twofold Shelf has the greatest proportion of ocean ecosystems in the 60-200m depth range (35%).

Ecosystem	Area (ha)	IUCN Ia (ha)	IUCN Ia (%)	IUCN VI (ha)	IUCN VI (%)	GUZ (ha)	GUZ (%)
0 - 20m	155,399	9,243	6	28,528	18.5	5,940	4
20 - 60m	516,905	22,963	4.5	100,716	19.5	57,710	11
60 -200m	133,318	8,652	6.5	13,118	10	29,119	22
Total	**806,298.5**	**40,913.5**	**5**	**142,442**	**17.5**	**92,777**	**11.5**

Table 29: NSW ocean ecosystems[#]

Overall, NSW ocean ecosystems are poorly represented in IUCN Category Ia sanctuaries, with mid-depth areas (20-60m) being the most poorly represented.