Assessment of the Environmental Impacts of Recreational Fishing in NSW (Saltwater) – Background Report

Prepared by the Department of Primary Industries and Bond University

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1 Purpose of this Report

The NSW Department of Primary Industries (DPI) is undertaking an environmental assessment (EA) of recreational fishing in NSW. The complete environmental assessment will consider the environmental, cultural, social and economic impacts of recreational fishing.

This report assesses the environmental impacts of recreational fishing on the saltwater environment and will update the recreational fishing component of the NSW Marine Estate Statewide Threat and Risk Assessment Final Report completed in 2017 (2017 TARA). It will provide a more detailed assessment and includes offshore waters which was not previously assessed in 2017 TARA.

The 2017 TARA assessed recreational boat-based and shore-based line and trap fishing and hand gathering as a priority threat to environmental assets. This assessment, supported by additional or new evidence where available, along with the information compiled for the 2017 TARA, provides a more detailed and revised analysis of the various threats from recreational fishing activities to environmental assets.

Preparation of this specific recreational fishing EA will help to identify key threats from the recreational fishery and facilitate development of a recreational fishing management strategy (RFMS). The RFMS will be developed to set out an appropriate management framework and regime to address and mitigate key threats identified in the EA to ensure the recreational fishery continues to operate in a way that conserves fish stocks and provides quality recreational fishing opportunities now and into the future.

2 Description of Recreational Fishing

2.1 Definition of Recreational Fishing

Recreational fishing may be defined as "the fishing of aquatic animals that do not constitute the individual's primary resource to meet basic nutritional needs, and are not generally sold or otherwise traded on export, domestic, or black markets" (FAO, 2012). As defined in the *Fisheries Management Act 1994* (FMA), recreational fishing means fishing other than commercial fishing or Aboriginal cultural fishing. It is socially and economically important to the NSW community and occurs in marine, estuarine and fresh waters. It contributes to both recreation and supports nutritional requirements for individuals and families (Cooke et al., 2018). Recreational fishers are important stakeholders in fisheries management and marine conservation (McPhee, 2008). They are a diverse group, and part of the appeal of recreational fishing is that it crosses social, economic, and cultural divides.

2.2 History of Recreational Fishing in NSW

Taking of fish by Indigenous Australians and the first European settlers was a matter of survival more than recreation. But it was not long before the settlers started to fish for recreation (PRC., n.d). In the 1800s it is understood that fishing group catches of a thousand fish in Sydney Harbour and surrounds were common. In the absence of any real legislative control, a Royal Commission into the Fisheries of New South Wales was appointed in January 1880. This was due to catch declines and from perceived overfishing of inshore resources with Sydney and surrounds. The Royal Commission recommended that a Fisheries Commission be established, and a year later the Colonial Government obtained passage of the *Fisheries Act 1881,* which provided the first rules and regulations for fishing and paved the way for future governance and legislation. Recreational fishing has been an increasingly important part of the total fisheries harvests in South East Australia. Despite growing awareness of the significance of recreational fisheries in Australia, information and assessments remained scarce until 2000, when Commonwealth, state and territory fisheries agencies implemented the National Recreational Fishing Survey (Henry and Lyle, 2003). The survey provided the first estimates of Australian recreational catch, effort and rate of fishing participation by state, and thus established an important baseline against which trends can be compared. In 2000 the rate of recreational fishing participation was about 17% of the population in New South Wales (PRC., n.d).

Today, saltwater recreational fishing in NSW consists of several different fishing activities which vary in effort along the NSW coast. It satisfies a number of significant community needs and contributes to fulfilling the primary objective of the *Fisheries Management Act 1994* (FMA) which is 'to conserve, develop and share the fishery resources of the State for the benefit of present and future generations'.

Key components of saltwater recreational fishing include shore-based and boat-based activities. This includes estuary, coastal and offshore environments as well as hand gathering (shore based), spearfishing and underwater harvesting. There is also a charter fishery that is specifically regulated in NSW, covering all boat-based charter fishing. In NSW Aboriginal fishers may participate in recreational fishing in addition to undertaking cultural fishing activities.

Estuarine waters are the largest component of the saltwater recreational fishery in terms of fishing effort and it is a multi-gear and multi-species fishery. Coastal waters include beaches, headlands, and inshore ocean waters (within three nautical miles offshore of the high tide mark). Offshore waters (beyond three nautical miles) include many of the species in the coastal fishery and several deep-water fish species.

2.3 Fishing Methods

There are a number of different saltwater methods that recreational fishers use in various habitat types, that are either shore based or boat based (see below). These occur in estuary, coastal (i.e., beaches, headlands and inshore ocean waters within 3 nautical miles) and offshore (beyond 3 three nautical miles) environments and also include hand gathering (shore based), spearfishing and underwater harvesting. A further description of estuarine, coastal and offshore waters is given in section 3. There is also a charter fishery specifically regulated in NSW, covering all boat based charter fishing activities. Although line fishing is the dominant activity, recreational fishing in NSW consists of several different activities using different apparatus targeting various target species (Murphy et al., 2022).

2.3.1 Line Fishing

Line fishing is used to catch finfish and squid/ cuttlefish in NSW and includes rod and line fishing or the use of a hand line. Line fishing is by far the most popular fishing method at 88% of the total effort as at 2019/20 (Murphy et al., 2022).

It accounts for the largest harvest and largest number of finfish species caught and occurs across all regions and habitat types. Line fishing includes the use of bait and lures;

- Bait fishing techniques include drifting, casting and retrieving, float fishing, bottom fishing and float lining.
- Lure fishing techniques include the use of hard body lures, soft plastic lures and metal spinning lures all of which can be trolled, jigged or cast and retrieved, and
- Saltwater fly fishing which is usually fished as cast and retrieve.

In 2019/20, line fishing with bait accounted for most (58%) fisher days, with lure and jig fishing at 22% of the total and the use of both line fishing methods (within the one fishing event) at 16% (Murphy et al., 2022).

2.3.2 Trap Fishing (including crab nets)

Trap fishing involves the setting of a baited trap (or net) on the seabed in order to trap or entangle the intended target species. Trapping is a much more specialised form of fishing compared with line fishing and catches a relatively small number of species; with crab traps and crab nets used to target crabs (Blue Swimmer Crabs, Mud Crabs and Spanner Crabs), a lobster trap for lobster (mostly Eastern Rock Lobster) and a bait trap which is mainly used to target small (poddy) mullet. Pot/ trap fishing accounted for 4.7% of all saltwater fisher days in 2019/20 (Murphy et al., 2022).

There are two main types of crab gear regularly used to target Blue Swimmer and Mud crabs. There are crab traps which can be circular or rectangular, and crab nets which consist of “witches hats” and lift nets. The crab nets are generally constructed from a steel hoop with either a shallow inverted net or include an additional steel hoop connected by a collapsible mesh wall.

Spanner Crabs are targeted by using lift nets (commonly called dillies) that are flat, rectangular steel frames which have a net over the frame and bait in the centre of the net. These nets are designed specifically to target Spanner Crabs and are typically used in sandy habitat to depths of more than 100m.

Lobster traps in NSW are usually dome shaped, though may be rectangular and are commonly made of rigid wire mesh or wicker. The traps are limited to a maximum depth of 10m and are usually set overnight from ocean rock platforms.

The use of a single bait trap is also permitted per person. Bait trapping involves the trapping of small finfish such as juvenile (poddy) mullet with the intention of using the collected species as bait.

2.3.3 Hand Gathering (including prawn netting)

Hand gathering involves the taking of marine animals and plants using only your hands or approved handheld gear such as a nipper pump, a dip net, a knife or pliers. Hand-gathering methods accounted for a total of 6.6% of all saltwater fisher days – comprised of 4.0% hand gathering using a tool e.g., nipper pump, 0.7% prawn netting and 1.9% collecting by hand (Murphy et al., 2022). Hand gathering of invertebrates and algae for food and bait occurs in intertidal and shallow subtidal habitats in all NSW regions (Kingsford et al. 1991, Underwood, 1993; Keough and Quinn, 2000). Harvested species in estuaries are dominated by crustaceans (Ghost Nippers and prawns), various molluscs (e.g. limpets, Turban Snails, periwinkles, whelks) polychaetes (e.g. beach worms, squirt worms, blood worms) and ascidians (e.g. Cunjevoi).

Prawn netting is used to target Eastern King, School and Greentail Prawns in estuaries. Individuals are currently permitted to use one dip net; one hand hauled prawn net and one scissors (push) net. All three net types have specific requirements and must be continuously and manually pulled. The scoop or dip net is the most used type of net. Prawn netting is popular in the warmer months of the year at a small number of locations and is usually undertaken at night during the periods that prawns are most active, particularly around the times of the new moon when they “run’ to sea. Prawning occurs mainly in estuaries around the shallow margins towards the mouth of the estuary, where fishers can intercept the prawns as they migrate to the sea.

Beachworms and Pipis are gathered from ocean beaches for use as bait. Beachworms are collected by attracting worms to the beach surface in the intertidal zone using bait held within a sock/stocking that lets out a scent in the wash zone. The worms move up to the beach surface in the immediate area where they are gathered by hand individually. Pipis are collected using the collectors' feet to sift through the beach sand and feel for and then pick-up the Pipi shells.

Collecting marine animals and plants from rock platforms is a popular activity and may be undertaken only by hand picking (gloves are permitted) or with a single blade knife with a blade longer than it is wide. Common species targeted whilst gathering from rock platforms include Turban Snails, sea urchins, Blue Mussels, various crab species, as well as Sea Lettuce and bait weed (both being algae species). Anglers are prohibited from using instruments such as hammers, chisels and other instruments not specified in legislation.

2.3.4 Spearfishing (including underwater harvest)

Spearfishing is the use of hand-held underwater harvesting gear to capture marine finfish, while underwater harvest is the gathering of invertebrates underwater (e.g., lobster, abalone and sea urchins). Spearfishing and underwater harvesting account for 3.3% of saltwater fisher days in NSW – comprising 2.8% for spearfishing and 0.5% for underwater harvesting (Murphy et al., 2022).

Spearfishing is limited to breath-holding. In NSW, spearfishers are permitted to only use a snorkel when taking fish, SCUBA gear is permitted for scallops and sea urchins only, and bare or gloved hands only may be used to take lobsters, which significantly limits the capacity of the fishing technique. It is also dependent on water visibility to target fish and is depth limited. It is one of the most selective forms of recreational fishing and catches a relatively small number of fish species, but also has the capacity to target larger individuals in fish schools (Frisch et al., 2008; Sbragaglia et al., submitted).

Spearfishers target a wide variety of species, particularly many reef associated species such as Red Morwong, Luderick, Rock Blackfish, Yellowfin Bream, various leatherjackets, but also other key species such as Dusky Flathead, Snapper and Mulloway. More experienced spearfishers target a wider range of species across numerous habitats and also target pelagic species such as Yellowtail Kingfish, Mahi Mahi, Spanish and Spotted Mackerel and large highly migratory species such as tunas and billfish. Inexperienced spearfishers, often using hand spears, tend to target various reef fish species (e.g., aplodactylids, monacanthids, and cheilodactylids) (Curley et al. 2013).

The spatial distribution of spearfishing activity has not been well studied in NSW. However, it is known to occur most regularly over rocky reefs around headlands and islands, the beach side of river entrance-training walls, and in open waters with some limited fishing in estuaries. Popular open water sites include offshore fish aggregation devices (FADs), which are deployed along the NSW coast by NSW DPI between September and June (Recreational Fisheries Management 2011). Studies in the Sydney area show that the activity of spearfishers is spatially variable, but can be intense – particularly in shallow, sheltered areas (Kingsford et al. 1991, Lincoln-Smith et al. 1989).

2.3.5 Charter Fishing

Charter fishing is an important component of recreational fishing in NSW. Charter fishing activities are a form of marine tourism which provide opportunities for recreational anglers to undertake estuarine or marine fishing (McPhee, 2008). Operators derive a profit from the use of fishery resources by hiring out their knowledge and equipment to recreational fishers. The dominant fishing activity by charter boats is line fishing although some charters will provide guiding of all recreational fishing methods. Well-equipped boats and localised fishing expertise help recreational anglers to fish successfully across a range of fishing types and species, and to access productive fishing locations.

All NSW charter fishing boats are required to be licensed, with the total number of available licences capped. This scheme was introduced to ensure the sustainable harvest of the resource by capping the total effort (see section 2.5 for more detail).

The fishery is in effect a sub-set of the overall recreational fishery (and for this reason hasn't been assessed separately) with existing recreational fishing rules also applying to fishers' onboard charter fishing boats. These rules are designed to ensure the ongoing sustainable harvest of the resources and to share the resource between user groups. The primary controls implemented to restrict catch and effort applying to charter fishing vessels are species that may be taken, bag and size limits, waters closed to fishing and lawful fishing gear.

It is also a requirement of NSW charter fishing operators to submit monthly catch and effort information through the charter industry logbook program. This collects spatial and temporal data on retained catch and fishing effort and is used for monitoring the fishery. An on-board observer program collects complementary data on catch, discards, client demographics and interactions with protected species.

In addition to the controls highlighted above, the NSW charter fishery operates under a Code of Practice (introduced in 2020) to demonstrate greater responsibility and accountabilities for sustainable harvest and bettering clientele experience.

2.3.6 Fishing Tournaments

In NSW fishing tournaments have been developed to provide fishing opportunities for people and to help the sport, while bringing additional economic benefits to the hosting communities. Fishing tournaments include game fishing, spearfishing, general coastal (mixed species) and inland events and a number of specialist species competitions such as Snapper, bream, Dusky Flathead, bass and Golden Perch. Online fishing tournaments are also increasing in popularity and are run Australia wide with thousands of dollars' worth of prizes offered to winning fishers each month. Game fishing tournaments increase economic activity by attracting visitors to regional coastal communities (Pepperell, 2002; Ward et al., 2012).

There are estimated to be over 800 fishing clubs operating in NSW and most of these operate regular fishing competitions, however most clubs are small with limited numbers of participants regularly participating in events. It is likely that fishing club participation is reducing in line with general reductions in recreational fishing participation seen within NSW and internationally.

Spearfishing competitions occur less frequently than line fishing tournaments and are subject to limits on the species that can be taken, and with often only one individual fish of any one eligible species being permitted for weigh-in (Lincoln Smith et al., 1989). There is also usually an additional competition-based minimum weight or length limit applied.

2.4 Rates of Participation and Fishing Effort

2.4.1 Temporal Changes

Overall global trends in recreational fishing participation in developed countries identify that in urbanized areas, participation rates have been declining (Arlinghaus et al., 2015; 2021).

The trends in participation rates are partly offset by population increases in urbanized areas. Most recently, increases in participation rates and demographic changes have been recorded in several studies in response to COVID-19 restrictions where local recreational fishing has remained permissible but other leisure activities have not (Gundelund and Skov, 2021; Midway et al., 2021; Ryan et al., 2021). Such changes are also likely to have occurred in NSW. It is uncertain whether the changes identified will persist over time as COVID-19 restrictions ease. Within this overall context of changing patterns of global participation, there can be finer scale changes including in the prevalence of certain recreational fishing activities relative to others.

The 2019/20 recreational fishing survey showed lower recreational fishing participation compared with previous survey years across both freshwater and saltwater fishing. Participation in 2019/20 was ~18% lower than in 2017/18, and ~27% lower than 2013/14. The 2019/20 survey also showed lower fishing effort and catch compared with 2017/18 (by ~23%) and 2013/14 (by ~31%) (Murphy et al., 2022) (Figure 1.).

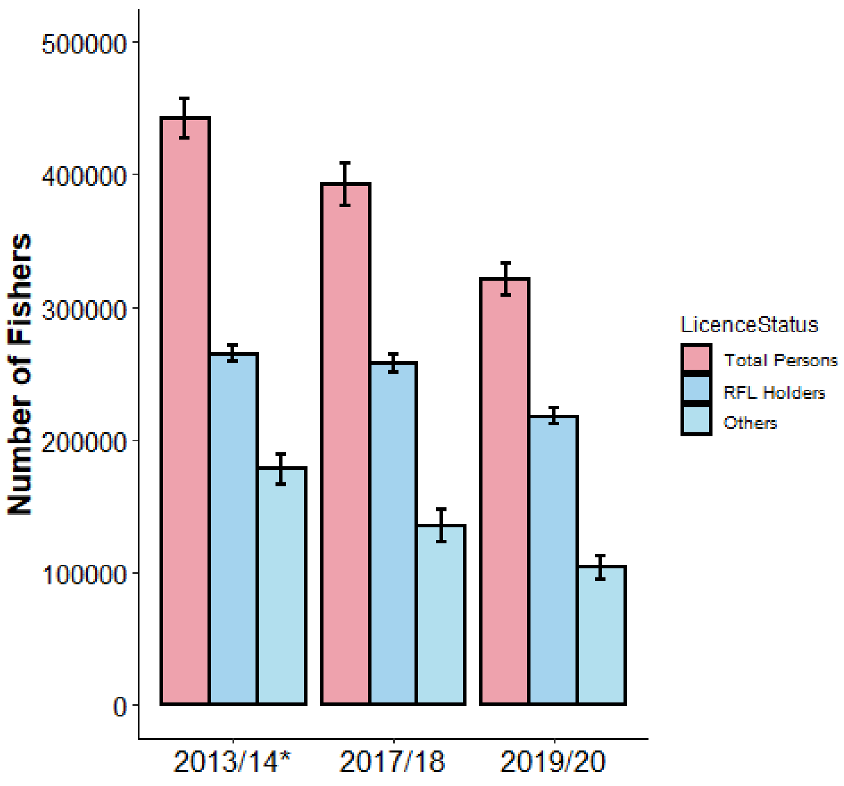

Figure 1. Participation by RFL household residents who fished within NSW through time (Murphy et al., 2022).

The sample size for the most recent (2019/2020) survey (1,990 recreational fishing licence (RFL) households) was similar to previous surveys, with 1,882 and 1,960 RFL households engaged in the 2013/14 and 2017/18 surveys, respectively. Response rates remained high (89.6% in 2013/14, 82.6% in 2017/18 and 80.8% for 2019/20) as did the proportions of eligible RFL households that completed the survey (92.0% in 2013/14, 95.8% in 2017/18 and 92.9% in 2019/20). This consistency in response and completion rates allows for robust comparisons to be made between surveys.

The number of active fishing licences decreased from 432,218 for the 2017/18 survey period to 430,223 for the 2019/20 survey period. The 2019/20 survey also showed a decline in fishing effort and catch compared with previous survey years. Overall, fishing effort (fisher-days) by RFL households during 2019/20 was lower than in 2017/18 (by ~23%) and lower compared to 2013/14 levels (by ~31%) (Figure 2, from Murphy et al., 2022). When considering these data, it is important to note that Queensland (QLD) residents were excluded in the 2013/14 RFL household survey (mainly due to sampling and cost constraints), but the subsequent surveys included QLD resident fishers. Therefore, results presented in this report for 2013/14 may underestimate RFL household fishing effort and catch for that year.

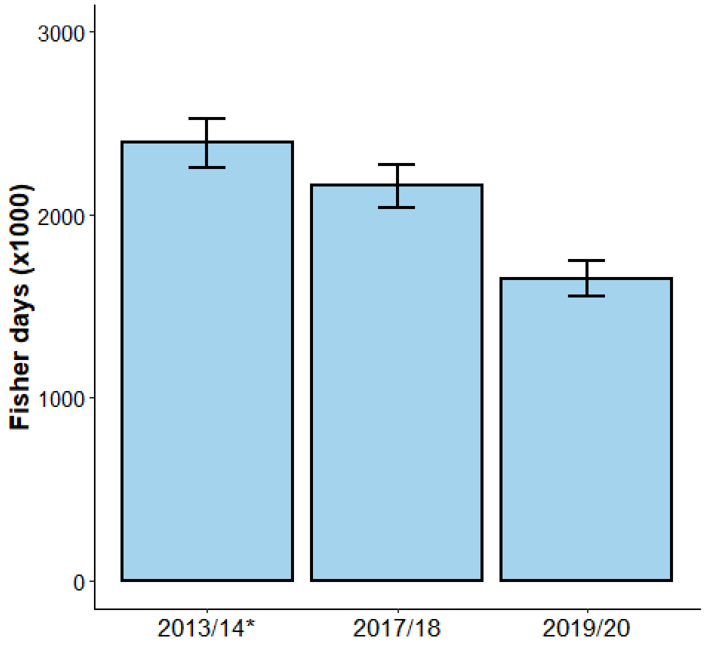

Figure 2. Total statewide fishing effort through time (Source: Murphy et al., 2022).

When interpreting differences in the NSW recreational fishery through time it is critical to consider causes of inter-annual variability. These include environmental influences, natural changes in abundance of target species, and socio-economic factors among survey years. The 2019/20 survey year encompassed a combination of extreme environmental and social factors that likely impacted on recreational fishing activities including drought, an extreme fire season followed by flooding and the COVID-19 pandemic.

2.4.2 Locations

Fisher days in RFL households totalled 1,237,696 for saltwater during the 2019/20 survey period (Murphy et al., 2022). While saltwater recreational fishing in NSW is geographically widespread, effort within regions is generally highly concentrated in locations that are relatively easy to access and that provide appropriate habitat for target species (Caddy and Carocci, 1999; Butcher, 2006; Smallwood et al., 2006; Ochwada-Doyle et al., 2014). Most marine recreational fishing occurs in estuaries, or coastal areas and embayments that provide protection from prevailing weather (although game fishing for large pelagic fish such as tuna (Scombridae) and marlin (Istiophoridae) occurs in more offshore waters). Such areas are more accessible than areas further from the coast (West et al., 2015). Recreational fishing can also be aggregated around artificial reefs and/or Fish Aggregating Devices (FADs) that aim to increase productivity and aggregate target species (Brickhill et al., 2005; Folpp and Lowry, 2006).

During the 2019/20 survey period (Murphy et al., 2022) fishers mostly fished in estuaries (66%), followed by oceanic waters (34%) (Figure 3, from Murphy et al., 2022). Murphy et al., (2022) found rates of participation were similar for shore-based and boat-based fishing, with 54% of fishers in RFL households doing some form of shore-based fishing during the survey period, and 46% participating in boat-based fishing events. By region there were estimated to be 472, 543 fisher days in the north coast, 499,378 fisher-days in the central coast and 265, 854 fisher-days in the south coast.

Shore-based recreational fishers use jetties, wharves and breakwaters in addition to the natural coastline. In NSW, the majority of shore-based effort occurs from natural shore areas (79%) as opposed to man-made structures (21%) (West et al., 2015). Boat-based fishing is done from vessels ranging in size from canoes/kayaks to large game-fishing boats. In NSW, the proportion of hire or charter boat effort was 8% of the total boat effort. The charter fishing boat fleet in NSW consists of many different sized vessels, which target and catch a great variety of fish species and can move from port to port in response to seasonal and tourist demand. Although the fleet is only a small proportion of the overall boat effort, charter boats can have many fishers aboard.

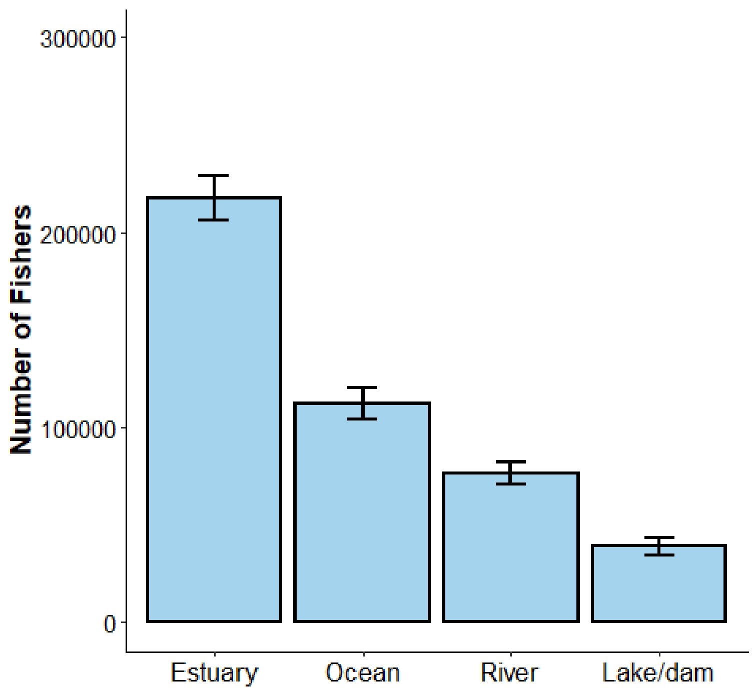

Figure 3. Participation by Waterbody for RFL households during 2019/20 (Source: Murphy et al., 2022).

Recreational fishing effort is also known to be concentrated at smaller scales within the broad categories above, and this can be explained in terms of ‘hotspots’ (locations where catches are known or perceived to be great) (Lynch, 2006) or because of ease of access (Caddi & Carocci, 1999). Fishing hotspots in NSW coastal waters are usually associated with reef habitat, or artificial reefs, but they may also occur in other areas such as creek mouths or deep-water areas near shore (Lynch, 2006). In Lynch’s study, which covered fishing effort in some 50 km of coast around Jervis Bay that included areas of open ocean, a large coastal embayment and estuaries, the most obvious hotspot for boat-based fishing was a deep-water trolling area very close to the shore and rocky shore-based fishers fished mostly in one location within the entire study area. Hotspots may also be specific to particular target species rather than simply being related to total catch (Lynch, 2006). In shore-based locations, hotspots may be associated with a coastal feature (such as a prominent headland or cape) or unusually deep water or currents that facilitate greater abundance of certain species. Accessibility is a stronger driver of shore-based recreational fishing than boat-based fishing. Access to much of the foreshore of estuaries or coastal fringes can be limited due to private property or unsuitable terrain. In NSW, most shore-based fishing in the coastal fringe occurs from ocean beaches rather than from rocky shores (West et al. 2015).

In another study of the distribution of recreational fishers at local scales, Griffin et al., (2021) also found boat and shore-based effort to be aggregated around hotspots in Sydney Harbour. Boat-based hotspots were located close to shore, near rocky reef and predominantly in the eastern parts of Sydney Harbour (i.e., closer to the ocean). Shore based fishing was far more dispersed across the harbour, but hotspots concentrated on wharves and jetties. Griffin et al., (2021) considered the drivers to distribution to be a mixture of environmental constraints, learnings (including from other fishers) and, for the more experienced fishers, knowledge of fish habitat and behaviour. Boat fishers showed more consistent patterns, with less effort when winds were over 30 km h^{-1}, in cold weather (less than 20◦C), or after more than 8 mm of rainfall. Tides also had strong effects on boat fisher intensity compared with shore based fishing intensity as did the proximity to nearby reef. The influence of environmental cues were less easily interpreted for shore-based fishing due to variable observations. Griffin et al., (2021) make the point that drivers of distributions in Sydney Harbour may not be applicable to other estuaries which may be more, or less, influenced by environmental or other factors.

Improvements in fishing gear, technology for finding fish, and the sharing of information may be increasing the efficiency of parts of the recreational fishery and allowing great access to some habitat types (Cooke et al., 2021). Technological advancements in boat based deep-water recreational fisheries are considered to have enhanced access and efficiency in Australia (Sumpton et al., 2013).

2.4.3 Catch of Key Species

Estuaries comprise the largest component of the saltwater recreational fishery in terms of fishing effort and it are a multi-gear and multi-species fishery. The key species caught include Yellowfin Bream, Dusky Flathead, Sand Whiting, Luderick, Tailor, Mulloway, Eastern King Prawns, Mud Crabs and Blue Swimmer Crabs and various baitfish.

Coastal waters include beaches, headlands and inshore ocean waters (within 3 nautical miles). Key target species in coastal waters include most of the estuarine species given above as well as more oceanic species such as Rock Blackfish, Silver Trevally, Australian Salmon, Snapper, Yellowtail Kingfish, Bluespotted Flathead, morwong and leatherjackets.

Key species in offshore waters include many of those species mentioned in the coastal fishery as well as several deep-water fish species such as Gemfish, Banded Rock Cod, Blue Eye Trevalla, Pink Ling and a number of pelagic gamefish species including several species of tuna, marlin and shark.

For some species, recreational harvest can be significant and exceed or equalled state commercial fisheries catches; while for other commercially targeted species, recreational catches can be minimal. For instance, the recreational harvest of Yellowtail Kingfish and Dusky Flathead was estimated to be greater than the commercial catch in New South Wales in 2019-20 (Murphy et al., 2022). These comparisons highlight the importance of recreational fisheries, for some species in particular, and the need to include recreational harvest in stock and ecological assessments.

Murphy et al. (2022) in their statewide survey provided estimates for recreational catch in NSW. They found that there were 128 species and species groupings caught during the 2019/20 survey period. Catch by waterbody and by platform was recorded as part of the survey, this provided some finer scale catch information for the assessment, however the breakdown of catch between coastal waters and offshore waters was not recorded.

Overall, the total statewide recreational catch of RFL households was estimated to be 7,849,661 individual organisms, with 4,121,144 being kept (53% of total catch) and the remaining 3,728,518 released (47% of total catch) by NSW RFL households during 2019/2021, compared to an estimated 8.9 million in 2017/18 and 11.6 million in 2013/14. Total statewide catch by Waterbody for RFL households during 2019/20 is shown in Figure 4.

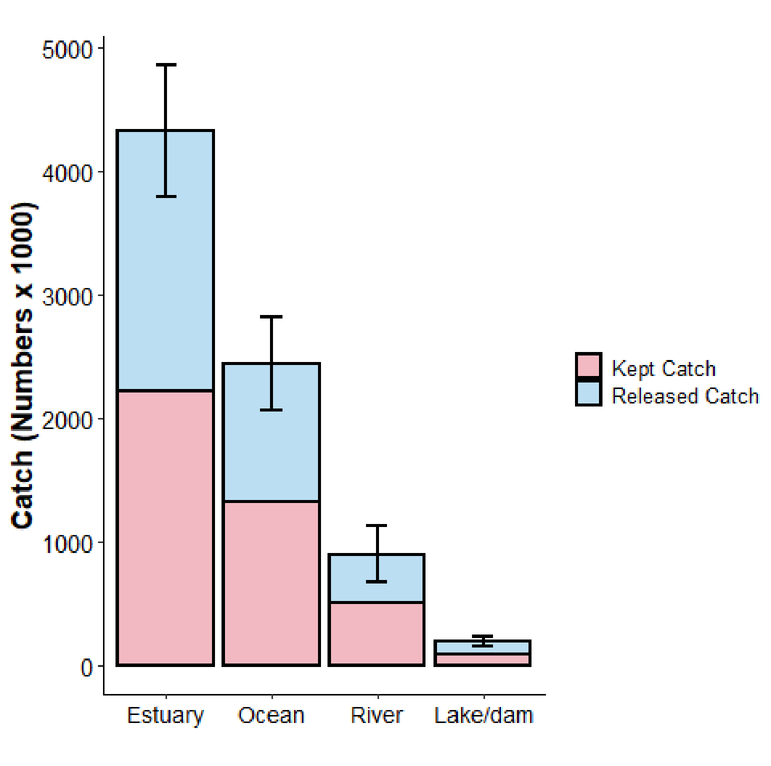

Figure 4. Total statewide catch by Waterbody for RFL households during 2019/20 (all species combined). (Source: murphy, et. al., 2022).

Some species showed higher catches in 2019/20 compared to 2017/18, such as Bream (14% higher), Snapper (5%), Sand Whiting (13%), and Silver Trevally (27%), whereas the catches of others were less, including Dusky Flathead (35% lower), Sand Flathead (43%), Grey Morwong (54%) and Mulloway (43%) (Murphy et al., 2022). Bream were the most common species/group caught (an estimated 1,098,534 individuals), followed by Dusky Flathead (572,822), Snapper (475,753), Sand Whiting (391,146) and Sand Flathead (370,182).

Overall, 47% of all species/groups caught were released (or discarded), with the highest rate of release (>75%) observed for saltwater species/groups such as Bream, Eastern Red Scorpionfish, Sergeant Baker, sharks and rays, and wrasse/gropers. Studies of release rates of gamefish in NSW including pelagic shark species and marlins also show high release rates – approximately 55% for the former (Heard, et al., 2016) and 88% for the latter (Lowry and Murphy, 2003).

The smaller crustacean species dominated the remainder of the total catch, including saltwater nippers (823,391 individuals), saltwater prawns (398,068). Blue Swimmer Crabs accounted for the majority of the larger saltwater crustaceans (69,116), followed by Mud Crabs (38,620) and Rock Lobsters (9,390).

The top five retained finfish species in each of the regions are listed in Table 1 and statewide data displayed in Figure 5. Regionally, ghost nippers comprised the most commonly retained species in the northern region. Prawns were the most commonly retained species in the southern region.

Table 1. Numerically dominant retained finfish species in each region (modified from Murphy et al., 2022).

Northern	Central	Southern
Bream	Bream	Dusky Flathead
Dusky Flathead	Snapper	Sand Flathead
Sand Whiting	Dusky Flathead	Bream
Snapper	Sand Whiting	Sand Whiting
Sand Flathead	Yellowtail Scad	Snapper

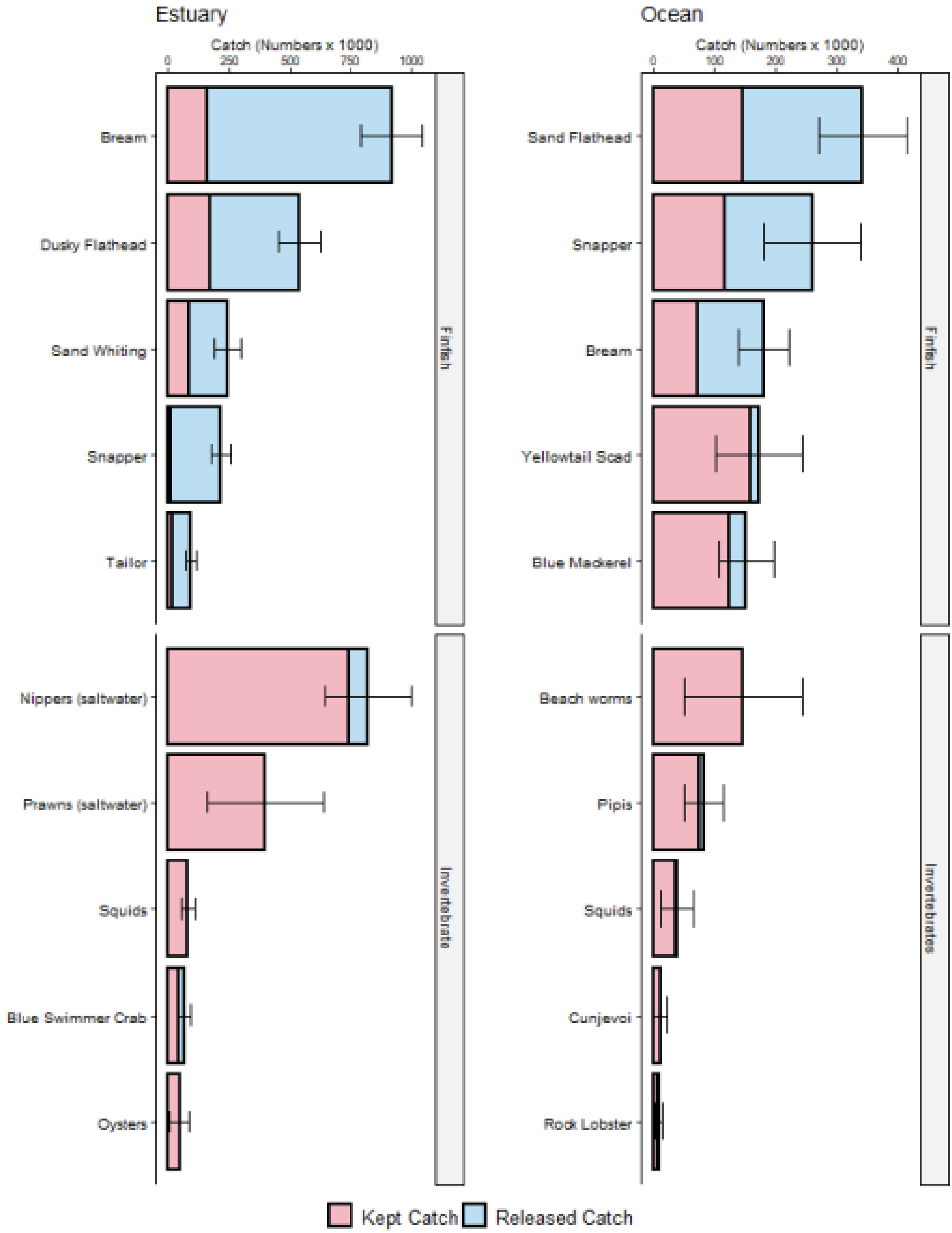

Figure 5. Total statewide catch of top finfish and invertebrate species/groups by Waterbody (saltwater) for RFL households during 2019/20 (Source: Murphy et al., 2022).

In 2019/20, total recreational harvest weights were estimated for 13 key species and compared with commercial fisheries data. Most of the total (recreational plus commercial) harvest weight was attributed to RFL households for two of the 13 species – 53% and 57% of the total harvest for Dusky Flathead and Yellowtail Kingfish, respectively were harvested by fishers within RFL households. Sand flathead and Mulloway caught by RFL households accounted for almost half the total catch (48% and 44% of harvest, respectively). Catches (by RFL households) of Australian Salmon and Luderick were substantially smaller than the commercial harvest (7% and 8%, respectively, of the overall total) (Figure 6, from Murphy et al., 2022).

It should be noted that harvest estimates for the recreational sector are confined to the harvest from RFL households only and do not include estimates from fisher households comprised exclusively of short-term and/or licence-exempt fishers, nor households which may have taken up a long-term licence after 31st March 2019 (just prior to and during the diary period). While the information provided in the recreational fishing survey represents the best available data, harvest number and weight estimates from RFL households are likely to underestimate the total recreational harvest.

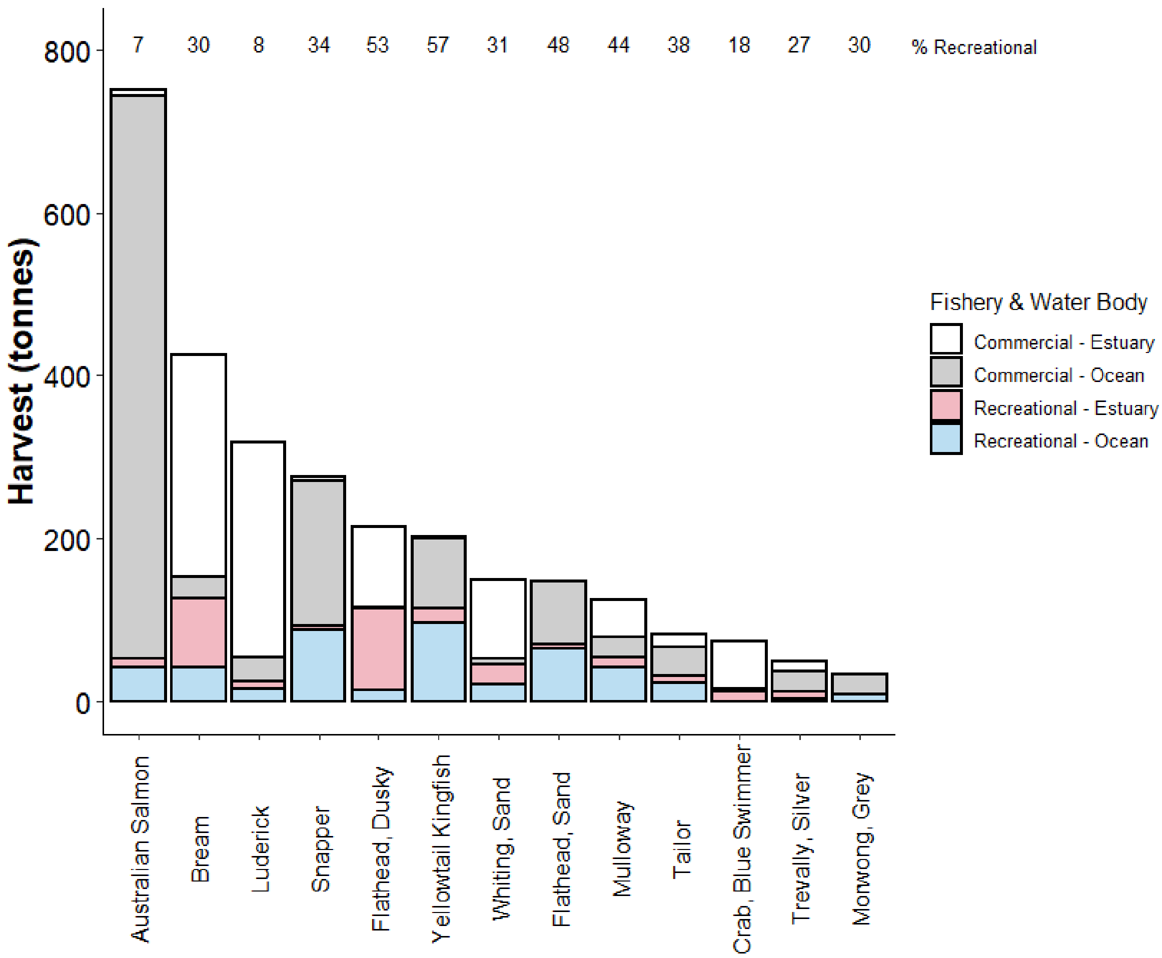

Figure 6. Estimates of harvest weights (tonnes) retained (kept) by RFL households alongside reported landings for the commercial fisheries sector during 2019/20 (Source: Murphy et al., 2022).

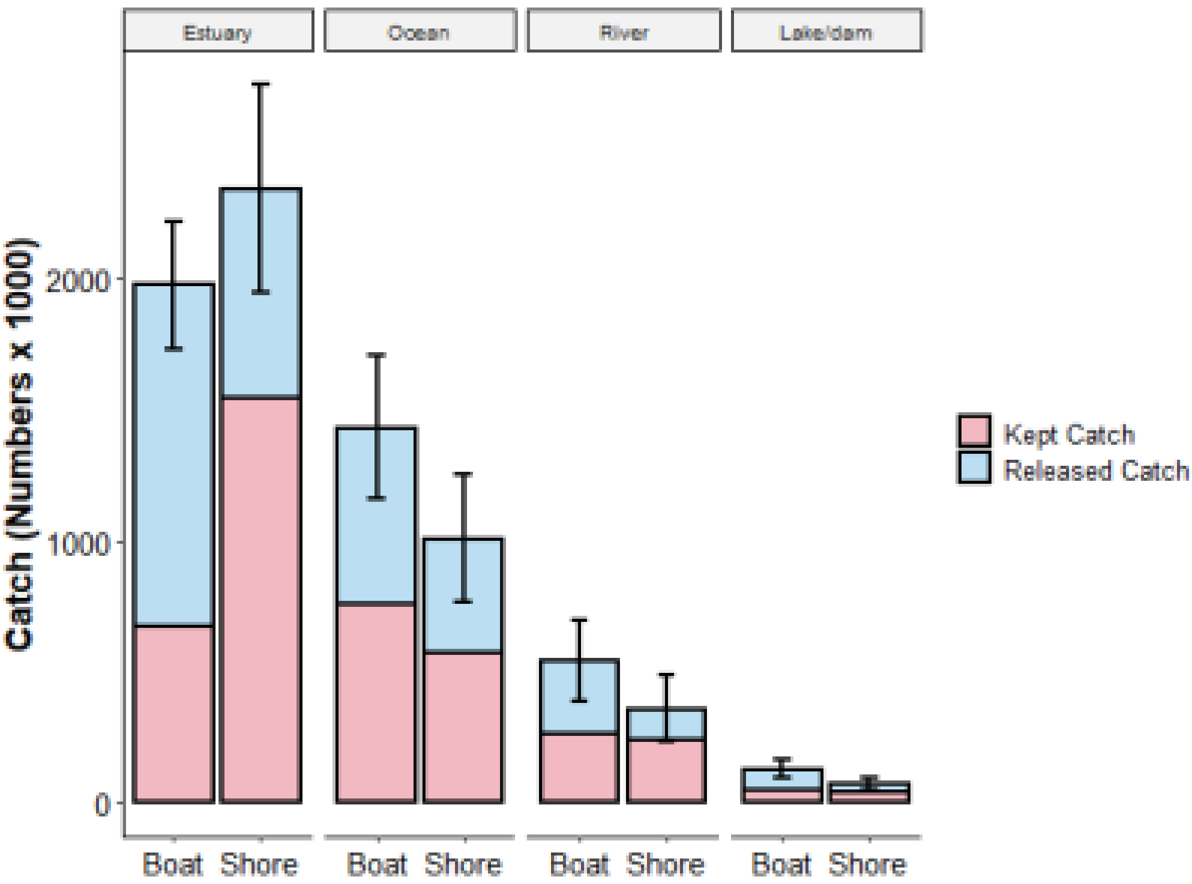

Figure 7. Total statewide catch by Platform and Waterbody for RFL households during 2019/20 (all species combined) (Source: Murphy et al., 2022).

Charter fishing catch is a subset of catch by boat based recreational fishers and is described in 2.3.4. The majority of charter fishing effort is in coastal waters and this has been the focus of recent studies (Gray and Kennelly, 2017; Hughes et al., 2021). As of 9/5/22, there were 139 charter boat licences in NSW with an active Estuarine Fishing endorsement.

It is a requirement of NSW charter fishing operators to submit monthly catch and effort information. Table 2 below provides catch logbook data from NSW charter boats operating with an estuary charter fishing endorsement and shows the top ten harvested species caught in the fishery.

Table 2. Top ten harvested species caught in the estuary charter fishery.

Species	2016	2017	2018	2019	2020	2021	Total
Ghost Nipper	1,976	1,481	1,611	8,490	454	5,843	19,855
Dusky Flathead	1,683	2,255	2,267	2,979	2,853	2,561	14,835
Yellowtail Scad	1,340	852	1,270	1,452	1,569	1,106	7,589
Yellowfin Bream	545	771	1,176	1,841	1,263	1,623	7,396
Southern Calamari	751	733	1,068	1,372	788	658	5,446
Trumpeter Whiting	183	566	590	1,114	1,204	186	3,843
Yellowtail Kingfish	517	624	603	564	508	431	3,303

Herring (other)	45	245	380	10	0	2,600	3,280
Tailor	372	552	409	326	307	442	2,414
Silver Trevally	217	572	392	489	198	173	2,078

As of 9/5/22, there were 157 charter boat licences in NSW with an active Near Shore Bottom and Sportfishing endorsement.

Statewide, the nearshore charter fleet harvested 151,378 individual organisms of 146 different species in 2017/18 with just 30 species comprising 95% of the total retained catch (Hughes et al., 2021).

More than half of the catch were made up of five key recreational fish species: Bluespotted Flathead (22.5%), Snapper (13.6%), Grey Morwong (9.1%), Blue Mackerel (5.2%) and 'other' Flathead (4.7%) (Hughes et al., 2021).

Released catch - of the 12,091 individual organisms observed caught (observer program), 4,125 (34%) were subsequently released.

Species with high release rates included Longspine Flathead (98%), Mado (92%), Halfbanded Seaperch (86%), Eastern Red Scorpionfish (68%) Yellowtail Kingfish (59%) and Snapper (53%).

Species with low release rates included Eastern Blackspot Pigfish (3%), Grey Morwong (4%), Ocean Jacket (9%), Yellowtail Scad (10%), Blue Mackerel (13%) and Bluespotted Flathead (17%).

Additional information on the NSW charter catch is also found in Gray and Kennelly (2017). They found that retained catch per client was highest in the southern region (mean 6.97 fish ± 0.56) followed by the central region (4.81 fish ± 0.50) and then the northern region (3.57 fish ± 0.25) (Table 3).

Table 3. Catch rate per client in the NSW charter fishery across the three coastal regions (modified from Gray and Kennelly, 2017).

	Region		
Species	Northern	Central	Southern
Snapper	1.20	0.21	0.69
Blue Spotted Flathead	0.76	0.25	0.38
Ocean Jacket	0.02	1.54	0.35
Redfish	-	0.65	0.78
Grey Morwong	0.11	0.51	1.00
Silver Sweep	0.08	0.03	0.71
Sergeant Baker	0.03	0.16	0.26
Blue Mackerel	0.04	0.26	0.65
Tiger Flathead	0.05	0.27	0.12
Ocean Perch	-	0.39	0.19
Eastern Red Scorpionfish	0.01	0.07	0.07

Mado	-	-	0.01
Red Pigfish	0.03	0.09	0.20
Southern Maori Wrasse	-	0.02	0.32
Yellowtail Scad	0.20	0.04	0.13

2.5 Management Arrangements and Monitoring

2.5.1 Bag and Size Limits, Gear and Area Restrictions

As discussed above, recreational fishing is an important source of fishing mortality to some species generally, and more specifically in areas where commercial fishing is prohibited (e.g., NSW Recreational Fishing Havens), it represents the only significant source of fishing mortality, apart from some limited catch taken by Aboriginal cultural fishing activities. Catch is managed in NSW through a mature regulatory framework and the application of a suite of management tools. These management tools are supported by research, monitoring, and compliance activities. Recreational fishing in NSW contributes to important research and monitoring activities and unless they are exempt, recreational fishers are required to pay a recreational fishing licence fee.

Overall Australia along with the United States score consistently high in terms of the status of their recreational fisheries policies and the perceptions of their implementation (Potts et al., 2020). Recreational fishing in NSW is managed under the *Fisheries Management Act 1994* and the *Fisheries Management (General) Regulation 2019*. Recreational fishing access in NSW is also influenced by zoning provisions under the NSW *Marine Estate Management Act 2014*. NSW Fisheries legislation includes the standard tools for recreational fisheries management that are described in McPhee (2008) including:

- Minimum size limits which are typically set at a size at which at least 50% of the species reaches sexual maturity to enable them to spawn at least once prior to being able to be retained.
- Maximum size limits which can limit the number of large fish of a species taken and be combined with minimum legal sizes to create a "slot limit".
- Bag and possession limits that limit numbers of fish species that may be taken. These bag and possession limits aim to cap an individual's catch and distribute it more equitably among recreational fishers.
- Limits on the number and dimensions of recreational fishing gear that can be used.
- Closed areas and seasons that prohibit the take of some or all species.
- Closed areas that prohibit the use of some or all recreational fishing gear.

NSW DPI Fisheries' Recreational Fisheries Monitoring Program (RFMP) provides key information biennially on recreational fishing participation, fishing effort and catch in NSW waters. The data acquired by the RFMP provides long-term trends in the recreational fishery and robust statewide estimates for the more common fishing activities and species caught (Murphy et al., 2022).

Charter fishing is managed with additional management controls compared with recreational fishing. The charter boat licensing scheme was implemented in 2000 following extensive industry-wide consultation. It was introduced to ensure the sustainable harvest of the resource by capping the total effort. The licence provides charter operators with a tradeable right which provides greater business certainty.

During the licence allocation process, operators satisfying the eligibility requirements were issued with a charter fishing boat licence. A total of 276 charter fishing boat licences were issued, with 30 of those licences being non-transferable. Four endorsement categories were also created and issued to operators satisfying the eligibility criteria. The endorsement categories are managed by species that may be permitted to be taken under each category, which are:

- Estuary,
- Nearshore Bottom and Sportfishing,
- Gamefishing, and
- Deep Sea Fishing.

Each charter fishing licence also contains a limit on the maximum number of passenger seats onboard the vessel. This restriction caps the total potential fishing effort in the fishery by preventing operators from upgrading to larger vessels under their licence.

It is a requirement of NSW charter fishing operators to submit monthly catch and effort information through the charter industry logbook program. This provides spatial and temporal data on retained catch and fishing effort and is used for monitoring the fishery.

The largest component of the charter fishery in terms of catch and effort is the fleet operating in nearshore marine waters. This fleet is more intensively monitored using a combination of the mandatory industry logbook reporting and an on-board scientific observer program as well. The observer program collects complementary data on the size composition of the catch, rates of discarding and post-release condition of discards, and collects client demographic information and interactions with threatened, endangered and protected species (Hughes et al., 2021).

2.5.2 Status of Stocks

The Status of Australian Fish Stock Reports are a series of assessments of the biological sustainability of a broad range of wild-caught fish stocks compared against a nationally agreed framework. The reports provide independent status assessments of 148 wild-caught Australian species and a consistent national reporting framework that was developed collaboratively by fisheries scientists from around Australia. The reports examine whether the abundance of fish and the level of harvest from the stock are sustainable.

To classify stocks into one of these categories, the current abundance and level of fishing pressure are compared with defined biological reference points. Each stock is then classified either as a sustainable stock, depleting stock, depleted stock, recovering stock, negligible stock, or undefined stock (See section 5.1).

2.5.3 New Management Approaches

Harvest strategies have become integral to fisheries management in Australia and are one of the main overarching tools for fisheries management planning (Dowling et al., 2008; McPhee, 2008; Smith et al., 2008, 2014). A harvest strategy sets out a decision framework necessary to achieve pre-determined biological and economic objectives in a fishery. They are generally considered to comprise three elements: (a) a monitoring strategy, (b) a method for assessing stock status, and (c) a decision process (McPhee, 2008). While initially designed for commercial fisheries only, NSW DPI are progressing their consideration and implementation in recreational fisheries (Fowler et al., 2022). This should further advance structured decision making associated with the management of NSW recreational fisheries and work to improve the performance of fisheries. All harvest strategies must ensure there is a high likelihood that biological objectives for the stocks will be achieved, particularly those to avoid a stock becoming classified as overfished or depleted, or to promote recovery to target levels. In practice, this means there should be a ‘high likelihood’ that a stock or management unit will not fall below its biological limit reference point and reduce risk from overfishing.

2.5.4 Fisheries Compliance and Illegal Fishing

NSW DPI is responsible for administering fisheries laws governing the fisheries resources of the state, which is implemented through the Fisheries Compliance Unit. This unit ensures compliance of existing rules by the recreational fishing sector. A team of Fisheries Officers patrol NSW waterways, detecting and preventing illegal fishing and damage to fish habitats. The patrols act as a significant deterrent to fishers from violating the law and detects many of those that do.

Although compliance rates cannot be directly used to understand the added impact of illegal recreational fishing, it can provide some insight. From 2012 to 2021, of 45,000 to 49,000 total contacts each year made by NSW Fisheries Officers, the rates of compliance ranged from 89.4% to 90.6% (Source: NSW DPI Compliance data). There are 100 Fisheries Officer roles across the state in 17 coastal and 9 inland locations. Compliance with fisheries legislation by NSW recreational fishers is relatively high (89.5 % in 2020- 2021 and this rate remains relatively stable: DPI pers. comm.) and helps to demonstrate that although some fishers do break the rules, most recreational fishers follow the rules. Fishery offences (marine and inland) indicated that for 2019-20, some 38% of offences relate to licence fee and access issues, 18% to fish sizes, 13% to illegal methods, 12% to excess fish and 11% to area-based offences (NSW DPI Compliance data) (See section 5).

3 Description of the Existing Environment

The community considers that the NSW Marine Estate’s most important assets are its natural beauty and its clean waters, supporting a variety of unique and abundant Australian marine life. In this report the existing environment is described so as to align with the three broad environmental asset groups detailed in the Marine Estate Management Strategy (2017):

<u>Clean waters/ water column</u> - This asset refers to the physio-chemical attributes of the water column itself – the water that is located between the seabed and the surface. The characteristics of marine waters are influenced by a suite of physio-chemical variables that interact and vary spatially and temporally at many different scales; this includes impacts from winds, sea conditions and currents, and river discharges from estuaries.

<u>Habitats and associated biota</u> – Habitat types are broken down into the key habitat components for each water type (estuarine, coastal or offshore). The assessment considers impacts to the various habitats and its typical habitat forming biota (sponges, bryozoans, ascidians (incl. feather stars), crinoids, tubeworms, barnacles, oysters etc.)

<u>Planktonic assemblages</u> - Planktonic organisms may have a limited ability to control their fine-scale distribution in the water column but are otherwise at the mercy of oceanic currents and water movements. Planktonic assemblages consist of phytoplankton and zooplankton that live within the water column. Many marine organisms such as corals, fish, crabs, lobsters and sea urchins, have a planktonic larval stage that is vital for the dispersal of the species. These are called meroplankton as they only spend part of their lifecycle as plankton. Organisms that remain in the plankton for their entire life cycle are called holoplankton. Plankton forms the basis of most marine food chains and is an important food source for many invertebrates, fish and some whale species. Planktonic assemblages vary across the habitats depending on several factors including nutrients, salinity, currents and temperature.

Fish assemblages - Assessment of the specific asset of fish assemblages considers all direct and indirect impacts on fish populations from the various threats and stressors. As this assessment is focused on recreational fishing, this is also where the main fishing-based impacts would be expected to be observed and allows for a clearer indication of the impacts of recreational catch on fish assemblages, targeted catch, bycatch species and indirect impacts to other species from the catch.

This report will use the same definition for fish as that given in the *Fisheries Management Act 1994* – "Fish means marine, estuarine, or freshwater fish or other aquatic animal life at any stage of their life history."

Fish assemblages refers to the variety and abundance of all fish species in a given waterbody. The habitat forming species that are included in the habitat assets are excluded from the fish assemblages asset e.g. sponges, bryozoans, ascidians etc.

Marine fish species of NSW are very diverse and often associated with certain habitat types. The habitat type is highly variable along the coastline. The climate changes from being more tropical in the far north of the state to the cooler temperate waters of the far south, this has the effect of more tropical species being found in the north compared to those in the south. The species behaviour also varies greatly from being highly cryptic and strongly associated with the habitat type they exist within, to being highly mobile pelagic species that regularly move along the coastline. The East Australian Current has a significant effect on the fish of NSW and results in many tropical species being washed down the coast during the warmer months. However, it is reported that many of these species do not survive the winter period.

Threatened and protected species [1] - In NSW, the responsibility for aquatic biodiversity management is divided between the NSW Department of Primary Industries (DPI) and the Environment, Energy and Science Group (EES). The NSW Department of Primary Industries is responsible for all species of fish and marine vegetation. "Fish" include bony fishes, sharks and rays, aquatic invertebrates such as worms, snails, mussels, corals, sponges, sea urchins, barnacles, crabs, crayfish, aquatic insects and prawns. Marine vegetation includes all seaweeds, seagrasses and marine algae. Other types of animals, including whales, dolphins, seals and waterbirds, and plants, including freshwater plants, are the responsibility of the Environment, Energy and Science Group (EES). A threatened species is a plant or animal that has been assessed and found at risk of extinction.

DPI administers the key pieces of legislation that identify and protect threatened fish and marine vegetation in NSW: *The Fisheries Management Act 1994* (FMA) and the *Fisheries Management (General) Regulation 2010*. EES administers the *Biodiversity Conservation Act 2016* (BCA) and its supporting regulations. In the NSW marine environment this Act covers marine mammals, marine reptiles, sea birds and wading birds.

At the Commonwealth level, the Department of Agriculture Water and Environment administers the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). This legislation provides a legal framework to protect and manage nationally and internationally important flora, fauna, ecological communities, and heritage places - defined in the EPBC Act as matters of national environmental significance. The Commonwealth marine environment (generally from 3 to 200 nautical miles from the coast) is listed as a Matter of National Environmental Significance (MNES).

The EPBC Act focuses Australian Government interests on the protection of matters of national environmental significance, with the states and territories having responsibility for matters of state and local significance. In order to determine if a species is eligible for listing as threatened in one of the categories under the EPBC Act, a rigorous scientific assessment of the species' threat status is undertaken. These assessments are undertaken by the Threatened Species Scientific Committee to determine if the item is eligible for listing against a set of criteria as set out in the guidelines for nominating and assessing threatened species and ecological communities.

Under all threatened species legislation, it is illegal to do anything that may result in killing, injuring, harming, taking, trading, keeping or moving a member of a listed protected species or threatened species or community unless a permit or approval has been issued. Species and communities of conservation importance include those species listed under State and Commonwealth legislation.

Under the FMA species may be listed as: vulnerable; endangered; critically endangered; or presumed extinct. Populations of species and ecological communities can also be listed as threatened and the processes that threaten species may be listed as key threatening processes. Habitat essential to the survival of endangered or critically endangered species, populations of a species or ecological communities can also be declared as critical habitat.

Under the FMA endangered populations are also listed but must meet certain criteria. The population must have undergone a very large reduction in abundance, distribution or genetic diversity and be affected by a threatening process. Populations of the seagrass Posidonia australis in Port Hacking, Botany Bay, Sydney Harbour, Pittwater, Brisbane Waters and Lake Macquarie are listed as endangered.

[1]The key threatened fish species or species groups (FMA) included in this risk assessment are:

- The Grey Nurse Shark (Critically Endangered)
- White Shark (Vulnerable)
- Black Rockcod (Vulnerable)
- Southern Bluefin Tuna (Endangered)
- Scalloped Hammerhead Shark (Endangered)
- Great Hammerhead Shark (Vulnerable)
- White's Seahorse (Endangered)
- Cauliflower Soft Coral (Endangered)
- Other Syngnathids (seahorse, pipefish, pipehorse, and seadragon)
- Solenostomids (ghostpipefish)
- Pegasids (seamoths).

Several other rare fish are also protected from fishing or collecting in the FMA as 'protected fish'. Examples include: Eastern Blue Devil Fish, Bluefish, Goldspotted Rockcod (Estuary Cod) and Herbst Nurse Shark. Although populations of these species may not be currently declining, they are protected to avoid becoming threatened in the future. Plant species that provide important fish habitat, such as mangroves, seagrasses and seaweeds, are also protected to maintain the health of aquatic communities and the productivity of fisheries.

The EPBC Act also includes many of the same threatened species listed in NSW (e.g., White Shark, Grey Nurse Shark) but also includes a number of other species which may be recorded in offshore waters but are not specifically listed within NSW legislation (e.g. Wandering Albatross). For threatened species under the EPBC Act as well as the categories of critically endangered, endangered, vulnerable and extinct in the wild a further category of "conservation dependent" is defined and applies only to fish. For a conservation dependent species, the species is the focus of a specific conservation program the cessation of which would result in the species becoming vulnerable, endangered or critically endangered.

Conservation dependent species of relevance to this assessment are Eastern Gemfish, Southern Bluefin Tuna, Blue Warehou, and Scalloped Hammerhead Shark.

As well as listing species that are threatened, the EBPC Act also lists “migratory” species, “marine” species and cetaceans. These listings are not mutually exclusive. Migratory species are those listed under various international legislation including the Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention), the Japan-Australia Migratory Bird Agreement (JAMBA), the China-Australia Migratory Bird Agreement and the Republic of Korea-Australia Migratory Bord Agreement. Marine species belong to taxa that the EBPC Act recognise as requiring protection to ensure their long-term conservation and additional consideration in development assessment. This includes sea snakes, sygnathids (pipefishes and pipehorses), sea birds and marine mammals (sirenians and pinnipeds). Cetaceans (whales, dolphins and porpoises) are all protected under the EPBC Act in the Australian Whale Sanctuary.

Under State and Commonwealth legislation, key threatening processes (KTPs) may also be designated. Under the FMA, key threatening processes are threatening processes that adversely affect threatened species populations or ecological communities, or could cause species, populations or ecological communities that are not threatened to become threatened. Hook and line fishing (including recreational fishing) in areas important for the survival of threatened fish species is listed under the Act as a key threatening process. In the marine environment this includes the Grey Nurse Shark and the Black Cod. The KTP includes catch and release, not just the ‘taking’ of fish.

3.1 Estuaries

An estuary is defined in the 2017 TARA as a semi-enclosed coastal body of water that:

- is connected to the sea, either permanently or periodically
- has a salinity that is different from the adjacent open ocean due to freshwater inputs or evaporation
- includes a characteristic biota
- extends upstream to the limit of influence by the sea, including tidal rise.

The above definition has been adapted from Whitfield and Elliott (2011), with the addition of a reference to evaporation and extent. Roper et al., (2011) recognised 184 estuaries along the NSW coast, although Williams et al., (1998) had previously identified more than 950 waterbodies with a connection to the NSW coast, most of which were small, ephemeral streams or springs. There is substantial geomorphic variation across NSW estuarine systems (Roy et al., 2001) (See Figure 8 below showing the major estuaries within NSW). For the purpose of this assessment, these additional habitats are defined as beach and mudflat, rocky shores, subtidal rocky reefs, and subtidal soft sediments.

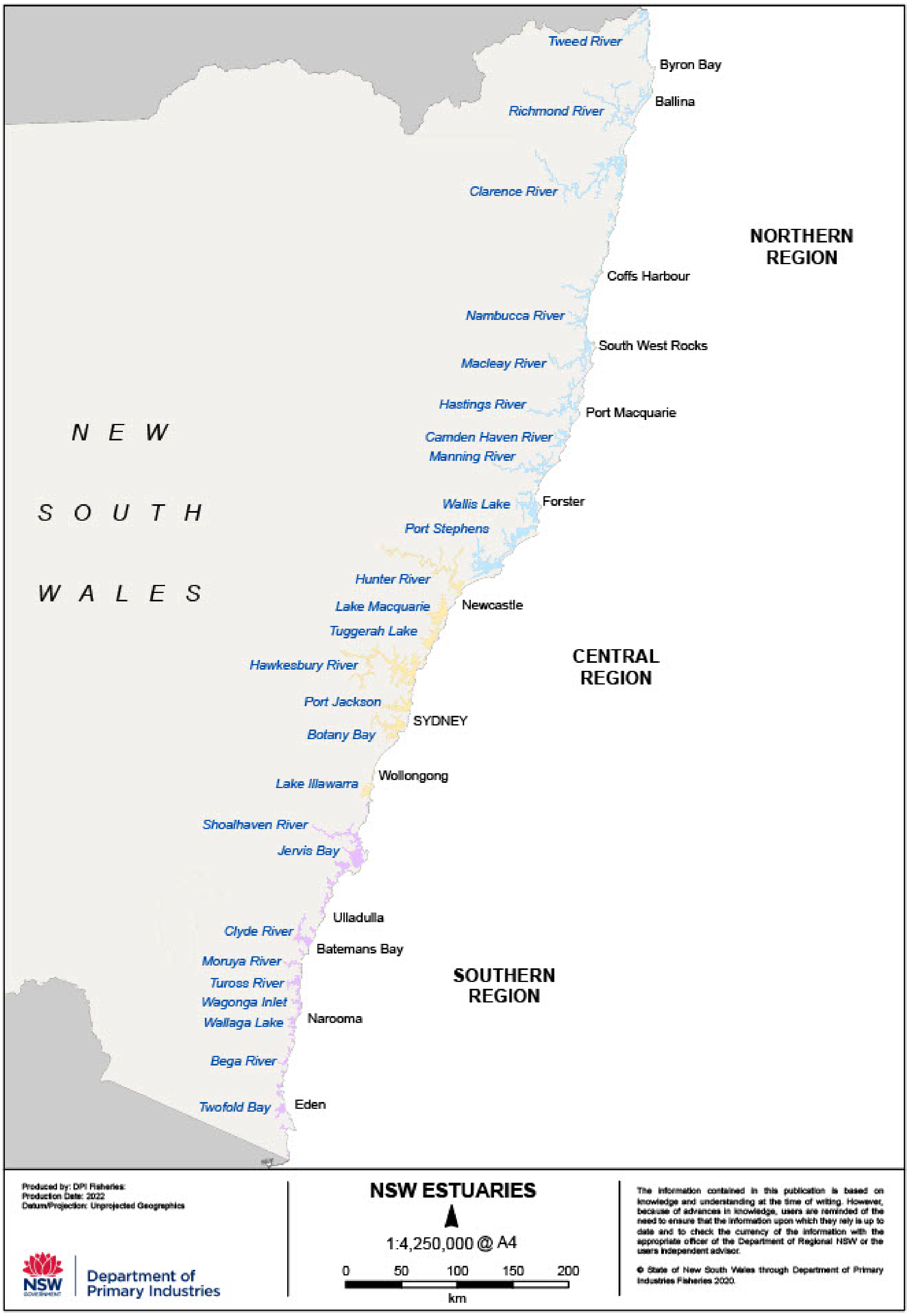

Figure 8. The New South Wales marine environment, showing the major estuaries.

3.1.1 Estuarine Waters

Estuarine waters are more variable in physio-chemical parameters than offshore waters and more greatly influenced by anthropogenic factors including catchment activities. Important water quality characteristics include turbidity, temperature, salinity, and nutrient levels. In estuarine areas these parameters are influenced by rainfall, seasons, tides, the geomorphology of the catchment and estuary as well as point and non-point source discharges (Roy et al., 2001; Scanes et al., 2007; Dunn et al., 2019) further detail is provided in the Marine Estate TARA Background Environmental Report (2017); section 5.6, page 55.

3.1.2 Estuarine Habitats

Table 4 provides a concise summary of habitat and biotic assemblages that was initially provided in the Marine Estate TARA Background Environmental Report (2017); section 5.7, pages 55-86.

Table 4. Summary of Estuarine Habitat Types and Associated Biota.

Estuarine Habitat	Associated Biota
Saltmarsh: Saltmarsh is an intertidal community of plants, such as sedges, rushes, reeds, grasses, succulent herbs and low shrubs that can tolerate high soil salinity and occasional inundation with saltwater.	Habitat for a variety of fish and invertebrates, including crabs, prawns, molluscs, worms, spiders and various other insects. Important for juveniles of many recreationally important fish species such as Yellowfin Bream, Sand Whiting, Mullet, Luderick and eels are commonly found in saltmarsh. Smaller fish species such as perchlets, glassfish, hardyheads, blue-eyes and gobies are also found there.
Mangroves: Mangroves are a group of trees and shrubs that can grow in marine, estuarine and, to a limited degree, fresh water. Mangroves are important nursery areas for fish and invertebrates.	Important habitat for many fish and invertebrate species. Larger invertebrates include larger snails and crabs such as the Mud Periwinkle, Mudwhelk and the Semaphore Crab. The sediment also holds a wide range of invertebrate species such as bivalves and polychaete worms. Many juvenile and adult fish species common, including Mullet, Yellowfin Bream, Sand Whiting, Luderick and Dusky Flathead.
Seagrasses: Seagrasses are a unique group of specialised marine plants that generally look like land grasses. Seagrasses occur in sheltered areas and shallow waters, growing in soft sediments such as sand or mud.	Habitat for a diverse range of flora and fauna, including algal epiphytes, crabs, shrimps, fish, sponges, syngnathiformes bryozoans, amphipods, polychaetes, gastropods and bivalves. Important habitat for juvenile fish species. Many fish species such as Bream, Luderick, Leatherjackets, Snapper and

	Sea Mullet live in seagrass habitats for part of their life cycle.
Beaches and mudflats: Beaches and mudflats occupy a dynamic position between sea and land and are often large areas within estuaries made up of a varying mixture of sand, silt and clay.	A wide range of invertebrate species occur above and below the surface of these soft substrates. This includes prawns, various bivalves, beach worms and crustaceans. Soldier Crab and Ghost Shrimp among most abundant macrofauna of sand and mud flats. Habitat for many species of fish such as Dusky Flathead, Sand Whiting and mullet species as well as a range of sharks and rays.
Shallow soft sediment: Soft-sediment habitats are dominated by muddy sediments, but commonly also contain sand, pebbles, and cobbles.	Macroinvertebrates such as brittle stars and dogwhelks are commonly recorded over unvegetated subtidal habitats. A range of polychaete worms, Ghost Shrimps, amphipods and molluscs are often found in shallow sandy substrate. An important habitat for many fish species such as Yellowfin Bream, Dusky Flathead, Leatherjackets, mullet species, Gurnard, sharks and rays, as well as various crab species such as the Mud Crab.
Rocky shores: Rocky shores are present in many NSW estuaries and are dominated by cobbles and boulders, providing a complex habitat structure for a diverse range of organisms	Various macroalgae inhabit rocky shores including leafy, low turf-forming species with a range of red, green and brown algae all recorded at this habitat type. Rocky-shore assemblages in estuaries are populated by a variety of gastropods (e.g. whelks, limpets and winkles), chitons and bivalves (e.g. oysters, mussels). Various crustacean species are common, particularly barnacles, crabs as well as starfish and sea urchins. A number of fish species are found in rock pools, including blennies, gobies and Toadfish as well as number of juvenile species such as Luderick and Mullet.
Subtidal reefs: Subtidal rocky reefs are composed of rocks (e.g. granite, limestone, basalt) which are always submerged, even at low tide. Rocky reefs are primarily found in drowned river valleys, and are less	Important habitat for a range of algae and invertebrates which create further habitat for various demersal and pelagic fish. Hundreds of different invertebrate species can be recorded on this habitat type, include a range of crustaceans, sea stars, polychaetes and molluscs. The fish and invertebrates include reef associated

common in barrier rivers, bays or some of the large lakes.	species as well as a range of transient species that move between reef systems. Target species for recreational fishers include Bream, Luderick, Mullet and Silver Trevally, all of which can be commonly found at this habitat type.

3.1.3 Estuarine Planktonic Assemblages

Estuarine plankton includes phytoplankton, holoplankton (e.g. copepods) and meroplankton such as the larvae of fish, molluscs, and crustaceans. Zooplankton in an estuary, are regulated by salinity, temperature, diel phase and tidal cycle (Trnski, 2001; Redden and Rukminasari, 2008). Predation by the Blue Jellyfish (*Catostylus mosaicus*) can also influence the structure of estuarine zooplankton assemblages (Pitt et al., 2008). In many estuaries there is a predictable seasonal succession of dominant copepod taxa (Jeffries, 1962). Phytoplankton assemblages will also vary with turbulence, turbidity, light and nutrients (Scott et al., 1979; Everett et al., 2007; Hitchcock et al., 2010; Shen et al, 2011). Because of the influence on salinity, temperature, mixing, nutrient delivery and residence time, the timing and magnitude of freshwater discharges play an important role in determining species composition (Rissik et al., 2009). See section 5.7.9 (pages 85 & 86) of the Marine Estate TARA Background Environmental Report (2017) for more information.

3.1.4 Estuarine Fish Assemblages

Estuaries are recognised as highly diverse and productive habitats and key nursery areas for many species see section 5.7.8 (pages 84 & 85) of the Marine Estate TARA Background Environmental Report (2017). Estuary fish assemblages in NSW are generally well studied. Recent work has included further additional information on;

- the nursery role of estuaries for commercially and recreational important species (Schilling et al., 2018).
- the influence of rainfall on reproduction and recruitment (Stewart et al., 2020; Hewitt et al., 2022).
- the structure of fish assemblages in relation to varying fishing pressure (Astles and McLeod, 2018; Gray, 2022a).
- the connectivity of estuarine fauna between estuaries and other habitats; (Russell et al., 2021; Gray 2022b; Swadling et al, 2022).
- food webs and trophic structures (Goddard et al., 2022; Jänes et al., 2021).

Typical key finfish species for recreational fishers in estuaries include species such as Yellowfin Bream, Dusky Flathead, Flounder, Sand Whiting, Luderick and Mullet. Several of these species are also caught in coastal waters. Invertebrates targeted by recreational fishers in estuaries include Blue Swimmer Crab, Mud Crab, School Prawns, Eastern King Prawn and Ghost Nippers.

3.1.5 Estuarine Threatened and Protected Species

Table 5 provides examples of key threatened and protected species found in estuarine waters in NSW. See section 5.8 (pages 86 to 92) of the Marine Estate TARA Background Environmental Report (2017) for more information. Many of these species are commonly encountered in coastal waters.

Table 5. Threatened and Protected Flora and Fauna that may occur in NSW Estuaries.

Threatened and Protected fish and marine vegetation (FMA & EPBC Act)	Threatened and Protected marine mammals, seabirds, shorebirds and reptiles (BCA & EPBC Act)
Threatened fish and shark species such as the critically endangered Grey Nurse Shark, White Shark and Black Rockcod may infrequently occur in estuaries. The key habitat for these species, however, is coastal water. Protected species that occur in NSW estuarine waters include estuary cod and the Queensland groper. Up to 31 syngnathids (seahorse, pipefish, pipehorse and seadragon) including the threatened White's Seahorse, four solenostomids (ghost pipefish) and two species of pegasids (seamoths) are present in NSW waters. Pipefish species are the most common group and are strongly associated with seagrass habitat in estuaries throughout NSW. Populations of the seagrass *Posidonia australis* in Port Hacking, Botany Bay, Sydney Harbour, Pittwater, Brisbane Waters and Lake Macquarie are listed as endangered in the FMA. Small populations of the threatened Cauliflower Soft Coral occur in Port Stephens.	Whale and seal species are more commonly found in coastal habitats, but occasional animals may enter more oceanic estuaries on rare occasions. Bottlenose Dolphins commonly occur in many NSW estuaries. 56 species of seabird from the Family Petrels, Albatrosses and Shearwaters are recorded from NSW. Many inhabit those zones between coastal waters and those off the continental shelf. Several species forage within the bays, estuaries and harbours. Many species of shorebirds use estuarine habitats for foraging and roosting. This includes Oystercatchers, Eastern curlew, Plovers, Sandpipers, and Herons. The Little Penguin is the smallest species of penguin and is encountered in NSW estuaries including in Sydney Harbour. Although five species of marine turtle may occur in NSW waters, Green Turtles and Loggerhead turtles are the two species most likely to occur in estuarine habitats. Other marine turtle species that may occur in NSW waters are the Hawksbill Turtle, Flatback Turtle and the Leatherback Turtle. Twelve sea snake species have been reported in NSW. They occur primarily in open coastal waters but may enter some large marine dominated estuaries such as Port Stephens.

3.2 Coastal

This component describes the habitats and associated biota that exist within the part of the continental shelf that is within the NSW coastal waters boundary and extends for 3 nm (the limit of state jurisdiction) offshore from either the mainland coast or the eastern coast of islands (e.g. Montague Island) (figure 9). Further detail is provided in the 2017 TARA Background Environmental Report; section 7.1 (pages 246 to 248).

Figure 9. The NSW marine environment showing the three regions used in this assessment and extent of coastal waters.

3.2.1 Coastal Waters

The water within coastal waters contains different pelagic habitats that are made up of a variable combination of depth, salinity, temperature, density, oceanic and inshore currents, and atmospheric conditions (e.g. wind).

The surface layers are more exposed and influenced by atmospheric forces, whilst the deeper water layers have less variation and a more constant temperature and salinity. The deeper layers of water are more strongly affected by oceanic currents, with the most influential for the NSW coast being the east Australian current (EAC) and its associated gyres, eddies and upwellings. Oceanic currents have a substantial influence on water characteristics (Ridgway and Dunn, 2003; Suthers et al., 2011; Huang and Wang, 2019). Further detail is provided in the Marine Estate TARA Background Environmental Report (2017) section 7.1 (pages 246 to 248).

3.2.2 Coastal Habitats

For detailed content see Habitats and Assemblages from the Marine Estate TARA Background Environmental Report (2017); section 7.2 (pages 248 to 263). Table 6 below provides a concise and simplified description of key habitat types, ecological features and assemblages specific to NSW coastal waters.

Table 6. Biota associated with the environmental assets (habitat types) in NSW coastal regions.

Environmental Asset	Associated Biota
Beaches: Ocean beaches are composed of intertidal and shallow subtidal components. In NSW they are wave-dominated, and are usually moderately sloping or steeply sloping, depending on the degree of exposure to waves and swell.	Nursey habitat for juvenile fish including Yellowfin Bream, Sand Whiting and Sea Mullet. A range of invertebrate species occur below sand surface dominated by crustaceans (e.g. ghost crabs), polychaetes (e.g. beach worms) and molluscs (e.g. pipis).
Shallow soft sediments: Mainly composed of sandy sediments but also commonly contain pebbles, cobbles and boulders. This habitat type is commonly recorded along NSW in the depth range 0-25m.	Many animals within the shallow soft-sediment habitat are animals living within the sediment, generally dominated by amphipods, bivalves and polychaete worms. Fish species include, eastern Australian Salmon, Yellowfin Bream, Flatheads, Leatherjackets, Luderick, Sea Mullet, Tailor, Sand Whiting and stingrays.
Deep soft sediments: Extensive habitat type generally dominated by sandy sediments but also commonly contain pebbles, cobbles and boulders.	Most of the animals within these habitats live within the substrate, although the habitat also commonly contains larger sessile organisms such as sponges, sea pens, ascidians, bryozoans, seawhips which increase the complexity of the habitat. A wide range of fish species recorded from this habitat type including Flatheads, Silver Trevally, Leather jackets and stingrays.
Rocky shores:	Crustacean species are common in this habitat type, particularly barnacles and

Local intertidal area of the coast that are dominated by rock. Commonly found adjacent to most rocky headlands. Rocky shores can consist of platforms, boulder fields and rock pools.	crabs, along with sea urchins, starfish and anemones. Gastropods (e.g. whelks), chitons and bivalves (e.g. oysters, mussels) are also abundant. Macroalgae such as kelp, sea lettuce and Neptune's necklace is common over this substrate type. Important habitat for many fish species found in rock pools, including blennies, gobies and Toadfish as well as number of juvenile species such as Luderick and Mullet.
Shallow rocky reefs (<25m deep): Rocky reef outcrops are adjacent to most headlands along much of the coast. Significant shallow-reef systems can also be found immediately offshore from some ocean beaches. There are some distinct regional differences in the extent and distribution of rocky reefs in NSW. The northern region is generally characterised by small, isolated, shallow reefs. The central region contains extensive areas of shallow reef system and a large proportion of the southern region contains shallow nearshore reef with continuous rocky coastline.	This habitat type contains a diverse range of plant, fish and invertebrate species. Macroalgae are important plant species that form key habitat over this substrate and provide habitat and shelter for invertebrates and fish. Kelp strands provide habitat for a range of sponges, bryozoans and ascidians. Several hundred species of invertebrates are found over this complex habitat type, including molluscs, polychaetes, and echinoderms, which form the dominant assemblages. Commonly targeted invertebrates include rock lobsters and abalone. Fish species commonly associated with this habitat include Snapper, Red morwong, Yellowfin Bream, Luderick, Rock Blackfish, Wobbegongs, Sweep, Eastern Blue Groper, Yellowtail Scad and many species of wrasse and leatherjackets. Many pelagic migratory species also regularly occur over shallow reefs, including Yellowtail Kingfish, Bonito and Silver Trevally.
Deep rocky reefs: Deep rocky reefs (those in depths >25 m) are commonly found in NSW coastal waters. They are generally continuous with shallow reefs adjacent to rocky headlands or offshore islands.	There is a gradual decrease in the presence of habitat forming organisms in water over 25 metres. There is reduction in the presence of kelp (and coral in the north) to a more sparse mosaic of algae and sponge species. In general, there is a higher diversity of invertebrates found in the shallower sections of reef. Deep rocky reefs contain a range of invertebrates including various molluscs (e.g. cowries), bryozoans, feather-duster worms, basketstars, seawhips and seastars, anemones, crabs, shrimps, and octopus. The fish composition is very diverse and

	includes species such as Snapper, Blue Morwong, Yellowtail Kingfish, Bullseyes, wrasses and leatherjackets.

3.2.3 Coastal Planktonic Assemblages

The dynamics of coastal phytoplankton and zooplankton assemblages are influenced by estuarine discharges, currents and upwellings which affect the diversity and abundance of the assemblages through changes in temperature, nutrients and other physiochemical factors (Hallegraeff and Reid, 1986; Kingsford and Suthers, 1994; Ajani et al., 2001). At least 280 species of phytoplankton occur in coastal waters offshore of Sydney (Hallegraeff and Reid, 1986). Plumes from estuaries may provide a significant cue to larvae in coastal waters that an estuary is nearby for recruitment (Kingsford and Suthers, 1994). Plankton is an important food source for fish species. On rocky reefs adjacent to Sydney, on average, 56% of the total fish biomass was ultimately supported by phytoplankton (Truong et al., 2017).

3.2.4 Coastal Fish Assemblages

Coastal fish assemblages are generally well studied although the amount of information available can vary between the different habitat types present with coastal reef habitat the most well studied.

Recent work involving aspects of coastal fish assemblages in NSW includes:

- analysis of habitat used by coastal reef fish at a landscape scale (Rees et al., 2018; Swadling et al., 2019); rock pool fish assemblages (Harasti et al., 2018)
- food webs and trophic structures (Goddard et al., 2022)
- aspects of the biology and ecology of individual fish species including Silver Trevally (Fowler et al., 2018), Yellowtail Scad (Dawson et al., 2020)
- larval ecology of reef associated fishes (Hawes et al., 2020)
- and climate induced changes (Fowler et al., 2018; Holland et al., 2020).

Examples of key finfish species for recreational fishers in coastal areas include Snapper, Bluespotted Flathead, Tailor, Australian Salmon and Yellowtail Kingfish, although important species such as Yellowfin Bream, Sand Whiting and Luderick are common in both estuarine and coastal habitats. Invertebrates targeted by recreational fishers include squid (and other cephalopods), Blacklip Abalone, Eastern Rock Lobster, Beach Worms and Pipis.

3.2.5 Coastal Threatened and Protected Species

Table 7 provides examples of key threatened, and protected species found in coastal waters in NSW.

Table 7. Threatened and Protected Flora and Fauna that may occur in NSW Coastal Waters.

Threatened and Protected fish and marine communities (FMA & EPBC Act)	**Threatened and Protected marine mammals, seabirds, shorebirds and reptiles (BCA & EPBC Act)**
Most threatened fish and shark species listed in the *FMA* occur in NSW coastal habitats, including the critically endangered Grey Nurse Shark, White Shark, Black Rockcod, Scalloped Hammerhead and Great Hammerhead.	Marine mammal species are generally widely distributed, with some being highly migratory. The Southern Right Whale, Blue Whale, Humpback Whale and Sperm Whale are all listed as threatened in NSW and occur in coastal waters. Bottlenose

Protected fish species such as the Ballina Angelfish, Bluefish, Elegant Wrasse, Queensland Groper and Eastern Blue Devil Fish inhabit coastal and offshore rocky reefs in NSW. All syngnathids (seahorse, pipefish, pipehorse and seadragon) are protected with up to 31 species recorded, with four solenostomids (ghost pipefish) and two species of pegasids (seamoths) present in NSW waters. Some pipefish species occur in coastal habitats. There are also two species additionally included in the EPBC Act that occur in NSW coastal waters: School Shark and Blue Warehou (conservation dependent).	Dolphins are also widely distributed through coastal waters. Australian Fur Seals and Long-nosed Fur Seals are the most commonly occurring pinniped species and are largely concentrated in southern NSW waters, they occur in coastal habitat. 56 species of seabird from the Family Petrels, Albatrosses and Shearwaters have been recorded in NSW. Many inhabit those zones between coastal waters and those off the continental shelf. Species of shorebird which occur in coastal habitat types include the Beach Stone-Curlew, Little Tern, Hooded Plover, Pied Oystercatcher, Broadbill Sandpiper and Great Knot. At least 17 species of marine reptiles have been recorded in open coastal waters of NSW. This includes five species of marine turtle; Loggerhead Turtle, Green Turtle, Hawksbill Turtle, Flatback Turtle and Leatherback Turtle. 12 sea snake species have been recorded in NSW waters. Most of the sea snakes occur primarily in open coastal waters, are seen very infrequently and are individuals that have strayed from their core tropical populations. The exception is the Yellow-bellied Sea Snake, considered abundant and is probably a long-term resident in the oceanic waters off the NSW coast.

3.3 Offshore

This component describes the key habitats, ecological features and associated biota that exist beyond the NSW coastal waters state boundary (broadly 3 nm offshore), within the waters of the continental shelf, out to the deep ocean environments at the edge of Australia's exclusive economic zone, 200 nm offshore (figure 10). This covers the full extent of NSW' recreational fishing jurisdiction.

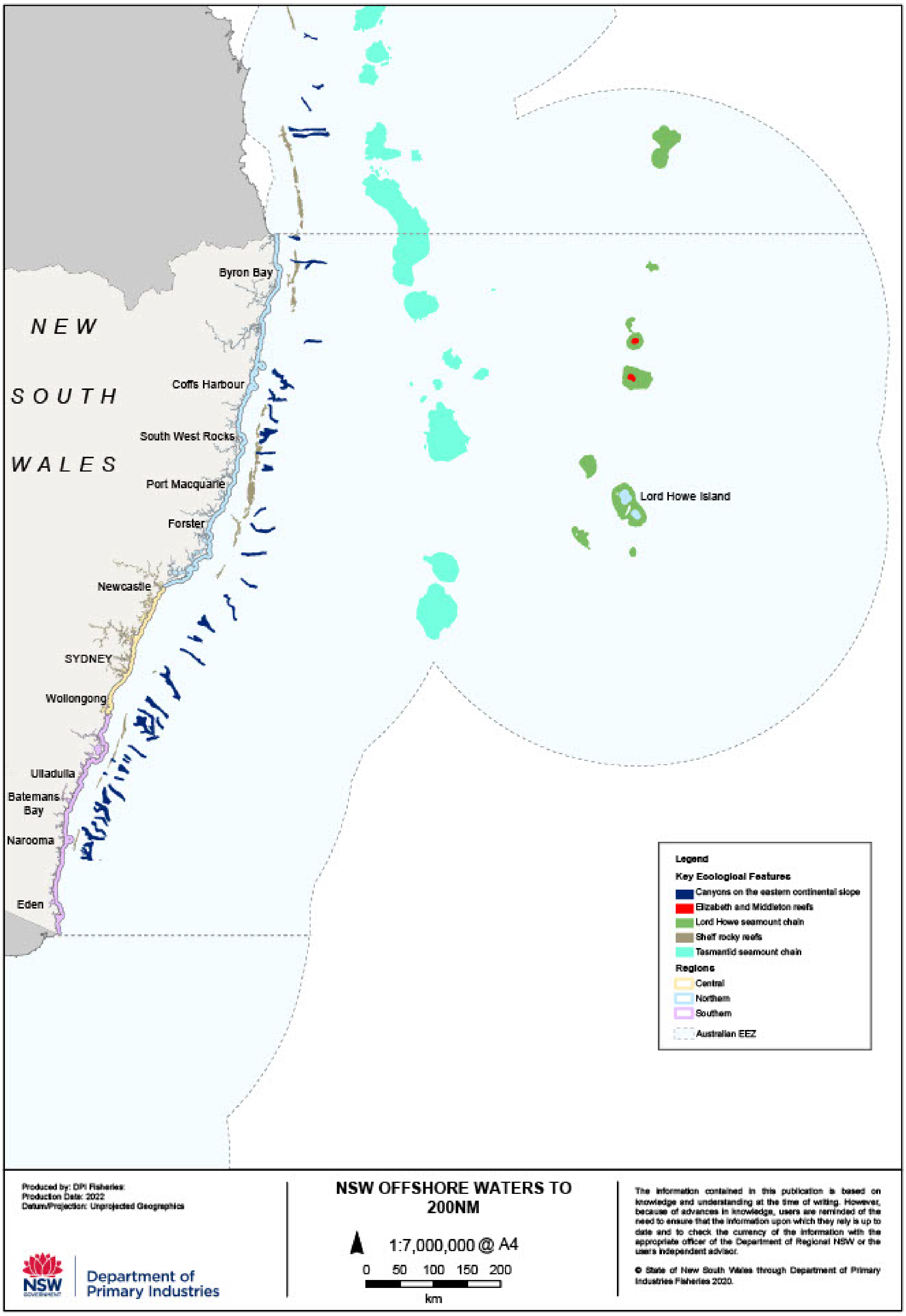

Figure 10. The NSW marine environment showing the extent of offshore waters.

3.3.1 Offshore Waters

This component refers to the water column itself – the water that is located between the seabed and the surface. The water within offshore waters, as with the coastal waters, contains different pelagic habitats that are made up of a variable combination of depth, salinity, temperature, density, oceanic and inshore currents, and atmospheric conditions (e.g. wind). The surface layers are more exposed and influenced by atmospheric forces, whilst the deeper water layers have less variation and a more constant temperature and salinity.

The deeper layers of water are more strongly affected by oceanic currents, and in offshore waters, the East Australian Current (EAC) and its associated gyres, eddies and upwellings has a substantial influence on water characteristics (Ridgway and Dunn, 2003; Suthers et al., 2011; Huang and Wang, 2019).

3.3.2 Offshore Habitats

Table 8 describes the key habitat types, ecological features and assemblages specific to NSW' offshore waters.

Table 8. Biota associated with the environmental assets (habitat types) in NSW offshore regions.

Offshore habitat	Associated Biota
Shelf reef: This sea-floor feature that consists of rocky outcrops and boulder substrates, shifts from being an algae dominated community to a benthic community dominated with attached invertebrates. This shift occurs at a depth of around 45m +.	Shelf reef habitats contain a diverse assemblage of bottom-dwelling fishes that show distinct patterns of association with shelf-reef habitats. The physical structure of the reefs (rugosity, slope and relief) is likely to have the greatest influence on the spatial distribution of fishes on rocky reefs (Williams et al., 2019). Shelf reef at depths of 45 m to several hundred metres are sea-floor communities below the photic zone that are dominated by attached invertebrates (including large sponges, gorgonians and soft corals) (Ingleton et al., 2020). These invertebrates create a complex habitat that supports a multitude of benthic animals such as crustaceans, molluscs, annelids and echinoderms and also provide refuge for juvenile fish species. The complexity of the sponges, species richness and density generally increases with depth. A diverse range of demersal fish are associated with this habitat type including species such as Jackass Morwong, Snapper, Pearl Perch, Silver Trevally, Yellowtail Kingfish and Butterfly Perch. There is gradual change of the species assemblages from temperate species to a greater proportion

	of tropical species to the north of the state and offshore towards the shelf edge. Shelf reefs are a significant focus for boat-based anglers and charter fishers who target a range of associated species depending on latitude with important species being Snapper, silver Trevally, and Yellowtail Kingfish.
Shelf Plain: The offshore region contains extensive areas of low relief which is dominated by sands and gravels.	While these habitats tend to have less species diversity than other habitat types that offer greater habitat relief and habitat diversity (at several scales). Species include populations of polychaete worms and isopods and largely consists of infauna, it can also contain larger sessile macrofauna (e.g., sponges, ascidians, byozoans & seawhips). Recreational line fishers target and catch several species of flathead on the continental plain including Bluespotted Flathead and Tiger Flathead. Other various species caught include Eastern School Whiting, Gummy Shark, Gurnard and Pink Ling. Spanner Crabs are targeted by recreational fishers using specific spanner crab nets in the northern region of NSW.
Continental Slope and Canyons **Continental slope:** This is the edge of the continental shelf that experiences a significant drop at a steep angle into the deep ocean. Canyons are a significant bathymetric feature of the continental slope. Canyon systems have a marked influence on the diversity and abundance of species, driven by the combined effects of steep and rugged topography, ocean currents, sea-floor types and nutrient availability. They significantly contribute to the overall habitat diversity of the sea floor, by providing hard surfaces in depth zones where soft sediment habitats prevail. **Canyons:**	Large benthic animals such as sponges and feather stars are abundant, with particularly high diversity found in the upper slope regions (150–700 m). Canyons also create localised changes in productivity in the water column above them, providing feeding opportunities for a range of benthic, demersal and pelagic species. There is also a significant increase in the productivity of the water column above which provides feeding opportunities for a range of recreationally important pelagic species such as Marlin, tuna, Broadbill Swordfish and various shark species. Canyons are an important habitat type for key deep-water demersal species such as Gemfish, Blue-eye Cod and Hapuka.

Sea-floor feature with steep and rugged topography found along the eastern continental slope. Canyons contribute significantly to overall habitat diversity and productivity. This is due to the combined effect of their topography and geology and creating localised currents. The upwellings created transport bottom waters towards the surface, bringing cold nutrient rich water to the surface which results in increasing the biological productivity of that area.	
Abyssal Plain: The abyssal seafloor occurs between ocean depths of 3000 and 6000 m they are essentially a network of plains and rolling hills punctured by seamounts, and subdivided by mid-ocean ridges, island arcs and ocean trenches. The abyssal seafloor is mostly covered by fine sediments (medium sands to clays). Hard substrates associated with manganese nodules and fault scarps occur in many parts of the abyss.	The biology of animals that inhabit the deep ocean basins remains one of the least well studied subjects in the biological sciences (Gage and Tyler, 1991). In deep sea benthic environments, assemblages have been described for bathyal, abyssal and hadal depth zones, and there are clear differences in communities inhabiting rocky substrate versus soft substrate habitats. Animals that commonly occur in or on abyssal sediments include molluscs, worms (nematodes, sipunculids, polychaetes, hemichordates and vestimentiferans) and echinoderms (holothuroids, asteroids, ophiuroids, echinoids, and crinoids) and crustaceans. Fish of the abyssal zone include the fishes of the family Ipnopidae, which includes the Abyssal Spiderfish, Tripodfish, Feeler Fish, and the Black Lizardfish. None of these fish species are recognised as species caught by the recreational fishery.
Seamounts: These consist of underwater volcanic mountains, plateaux and terraces. The NSW offshore area has a prominent seamount chain formed by underwater volcanic mountains, plateaux and terraces that runs north–south at approximately 155° E, extending into the Tasman Basin. At the deepest point of the chain, features rise to a depth of 1400–900 m below sea level. At the northernmost extent, features rise to a depth of 400–150 m below sea	Seamount chains provide enhanced productivity, resulting in aggregations of marine life and increased biodiversity. They are biological hotspots with high diversity of demersal and pelagic species. Feeding grounds and sites for reproduction for a number of oceanic species including billfish, tuna and various shark species. Both seamount chains cover deep water and rise up to depths of several hundred metres deep and break the surface to form islands in some areas. The seamounts contain a range of habitats

level, with some breaking the surface to form islands. There are two seamount chains present in NSW waters that run parallel to the coast; the Lord Howe and the Tasmantid seamount chain.	including deep sea sponge gardens to shallow water tropical coral reefs and are areas of high biodiversity and high species endemism. Key deep water recreational fishing species such as Blue Eye Trevalla, Hapuku and Bass Groper are available in seamount habitat. These species tend to be long lived and slow growing and hence low resilience to fishing pressure.

Shelf Reefs

Fish assemblages on NSW shelf reefs are relatively well studied, particularly at the Solitary Islands. At the Solitary Islands, reef fish assemblages differed significantly among the depth categories with three distinct assemblages on reefs <25 m, 25–50 m and >50 m and species richness also increased along a cross-shelf gradient (Malcolm et al., 2010; 2011). Tropical taxa were most prevalent, comprising 50% of the 254 species recorded. Australian endemics accounted for 23% of species, with east coast endemics (14%) predominating (Malcolm et al., 2010). Many sub-tropical and tropical reef associated species are expanding their ranges in NSW (Fowler et al., 2017; Booth et al., 2018).

Williams et al. (2019) assessed the structure of fish assemblages in two depth categories: shallow (20–40 m) and mesophotic (80–120 m) off Port Stephens. They found that there are significant differences in the fish assemblages between shallow and mesophotic reefs, primarily driven by Southern Maori Wrasse and Crimson Banded Wrasse only occurring on shallow reefs and schooling species of fish that were unique to each depth category: Mado on shallow reefs and Redfish on mesophotic reefs. At other locations in NSW, depth was also found to influence the overall structure of the fish assemblage, but landscape factors and factors related to habitat complexity were also important (Parsons et al., 2016).

Shelf reef species targeted by recreational fishers include Snapper, Grey Morwong, Yellowtail Kingfish, and Pearl Perch in the northern region. In NSW the biology and ecology of Snapper (e.g. Gillanders, 2002; Stewart, 2011; Harasti et al., 2015; Morgan et al., 2018) and Grey Morwong is well understood (Stewart and Hughes, 2009; Stewart et al., 2011). Pearl Perch are less well studied, but information is available on their age structure (Stewart et al., 2013).

Shelf Plain

The structure of fish assemblages on the shelf plain of NSW is known as a result of studies that have documented bycatch from commercial trawling operations. As an example, Kennelly et al. (1998) surveyed Eastern King Prawn trawl grounds offshore of Ballina, Yamba, Coffs Harbour and Port Stephens. Abundant taxa present include whiting, flathead, bugs/slipper lobsters and cuttlefish. In general, for most species and groups of species, they identified highly significant differences in species composition and abundances between locations, years and seasons (with these factors also frequently interacting). Gray and Otway (1994) provided species lists and assessment of fish assemblages in 30, 60 and 100 m offshore of the Sydney region and found that assemblages of fishes at 30 and 60 m depth were most like each other but consistently differed from those at 100 m depth.

Aspects of the biology and ecology of key fished species in shelf plain habitat are known. Age, growth and reproduction of whiting species from this habitat has been studied as well as depth distributions (Gray et al., 2014; 2017). For species of flathead on the shelf plain in NSW, there is an understanding of their movement dynamics, feeding ecology and niche differentiation, and their abundance in the presence and absence of commercial trawl fishing (Barnes et al., 2011; Fetterplace et al., 2016; Pryor et al., 2020). For bug/ slipper lobsters there have been studies that have assessed their age and growth, reproductive biology and diet (Stewart et al., 1998; Stewart and Kennelly, 1998; Courtney et al., 2001). There is also a diverse cephalopod fauna in this habitat type which has been assessed by Nottage et al. (2007) through examination of trawl catches, but relatively little specifically known about the biology and ecology of species present. Spanner Crabs are also known to be abundant on the shelf plain north of Coffs Harbour and the biology and ecology of this species is well studied (e.g. Kennelly, 1992; Kennelly et al., 1994; Chen et al., 1999).

Continental Slope and Canyons

The continental slope is the focus of Commonwealth commercial trawl fishing operations and several studies have examined aspects of the fish assemblages present. Walker and Gason (2007) provide an overview of the chondrichthyan fauna, while Graham et al., (2001) assessed historical changes in shark and ray abundance and identified significant declines in some species attributed to trawl fishing activities. Klaer (2004) provide detailed analysis of historical trawl fishing records of finfish distribution and abundance and the factors that may influence them. Koslow et al., (1994) surveyed the mid-slope (800–1200 m) demersal fish community off south-eastern Australia as a whole (including southern NSW) and found 37 families and 111 species of demersal fish were represented. Distinct assemblages of demersal fish were found at upper (500 m) and mid-slope (800–1200 m) depths.

The structure of fish assemblages associated with canyons and the factors that influence them are less well known in NSW but some of the sites sampled by McLean et al., (2015) using baited longlines and baited underwater video cameras included canyon habitat. From their work, however, the exact species composition of canyon habitat cannot be determined. Elsewhere in Australia, in Tasmania (Hill et al., 2014) and the Great Australian Bight (Currie et al., 2012; Williams et al., 2018) the fish assemblages on canyons have been assessed.

There are several deep-water demersal species that are caught by recreational fishing in continental shelf and canyon habitat including Ocean Perch, Blue Eye Trevalla, Hapuku and Bass Groper. Several of these species have been reasonably well studied because of their importance in commercial fisheries, but others are less so. The biology and ecology of Ocean Perch including their habitat use, age and growth and aspects of larval ecology (Withell and Wankowski, 1988; Furlani, 1997; Seiler et al., 2012) has been studied. For Blue Eye Trevalla the stock structure, age and growth and reproductively biology is understood (Robinson et al., 2008; Wakefield and Newman, 2008). Both Hapuku and Bass Groper are not well studied in NSW.

Seamounts

Seamount habitat is the focus of Commonwealth fishing operations and several studies have examined aspects of the fish assemblages present. Seamounts in Australia (and globally) are recognised as a high value habitat for fish and invertebrates (Clark et al., 2012). Most fish species that occur on seamounts also occur widely on continental shelf and slope habitat, but seamounts can be an important habitat for commercially valuable species which may form dense aggregations for spawning or feeding (Clark, 2001).

Abyssal Plain

Fish assemblages of the abyssal plain are generally poorly studied due to the practical challenges of studying them given the depths involved and their general lack of species of fisheries significance. O'Hara et al., (2020) provide some information for faunal of abyssal depths which highlighted the paucity of knowledge of invertebrates in particular with 58% of the collected fauna undescribed. From a biomass perspective, members of the Family Synaphobranchidae (basketwork eel) were important with seven species taken during their surveys and the Southern Cut-throat Eel (*Histiobranchus australis*), which attains a length of about 70 cm, present at almost all of the 2500 m collection sites from Tasmania to the Coral Sea, demonstrating its dominance in this environment. Other fish common at abyssal depths include: deep sea tripod fish (Family Iponidae), anglerfishes (Order Lophiiformes), grenadiers (Sub Family Macrourinae), and viperfish (Family Stomiidae). Very little is known about the biological and ecological factors that structure the abyssal fish assemblage.

3.3.3 Offshore Planktonic Assemblages

The diversity and abundance of plankton assemblages in offshore waters are strongly influenced by oceanic currents and upwellings (Smith and Suthers, 1999; Bax et al., 2001). Compared to coastal waters, discharges from estuaries have less of a direct influence on abundance and diversity in offshore waters. Cross-shelf advective processes can retain passively drifting ichthyoplankton within the shelf region and minimise longshore drift (Dempster et al., 1997; Smith & Suthers., 1999). On the continental shelf off Sydney, 70 families of ichthyoplankton were recorded with frequently encountered families being Myctophidae, Carangidae, Gonostomatidae, Pomacentridae, Gonorhynchidae, Berycidae and Serranidae (Dempster et al., 1997).

3.3.4 Offshore Fish Assemblages

Fish assemblages in NSW offshore waters are not as well studied compared to estuarine and coastal waters, but relevant information exists for a number of key components and aspects.

Despite coastal ecosystems containing well known trophic cascades, there remains uncertainty about the abiotic and biotic factors governing the occurrence and strength of recreational offshore fishing induced trophic cascades causing impacts to shelf reefs and other offshore environments (Eger & Baum., 2020).

Pelagic Fish Assemblages

The biology and ecology of many pelagic fish species is well studied in NSW including information on Yellowtail Kingfish, Blue Mackerel, tuna, billfishes and pelagic sharks. These are the principal pelagic species caught by recreational fishers in NSW. For Yellowtail Kingfish it is known that there is a single stock of fish in NSW (Miller et al., 2011), age and growth and reproductive biology is understood (Gillanders et al., 1999), and information on movement patterns is known (Gillanders et al., 2001). The reproductive biology and age and growth of Blue Mackerel is understood (Stewart and Ferrell, 2001; Neira and Keane, 2008; Rogers et al., 2009). Information on the reproductive biology and age and growth of movements of Southern Bluefin, Yellowfin Tuna and billfishes is available (Ortiz et al., 2003; Farley et al., 2007; Evans et al., 2008; Kopf et al., 2011).

The role of physical oceanographic factors in influencing the distribution and abundance of pelagic fish in NSW is established. Sea surface temperature (SST), sea level anomaly, SST frontal index, upwelling and eddy kinetic energy were significant environmental predictors for pelagic fish distributions (Young et al., 2011; Brodie et al., 2015). The association of juvenile pelagic fish such as Dolphinfish with floating objects such as clumps of algae is established (Dempster and Kingsford, 2004).

3.3.5 Offshore Threatened and Protected Species

The Temperate East Marine Plan provides an overview of taxa of conservation significance at the Commonwealth level in the Temperate Marine Region which includes much of the offshore region considered in this assessment. Species groups identified as conservation values in the Temperate East Marine Region are:

- bony fishes (10 species)
- cetaceans (9 species)
- marine reptiles (families Cheloniidae, Dermochelyidae, Hydrophiidae and Laticaudidae) (24 species)
- seabirds (34 species)
- sharks (6 species)

In addition to these species at the Commonwealth level, further species are protected under NSW legislation. Table 9 provides examples of key threatened and protected species found in offshore waters in NSW.

Table 9. Threatened and Protected Flora and Fauna that may occur in NSW Coastal Waters

Threatened and Protected fish and marine communities (FMA & EPBC Act)	**Threatened and Protected marine mammals, seabirds, shorebirds and reptiles (BCA & EPBC Act)**
Many threatened fish and shark species listed in the *FMA* occur in NSW offshore habitats, including the critically endangered Grey nurse Shark, White shark, Black Rockcod, Scalloped Hammerhead, and Great Hammerhead. Protected fish species such as the Ballina Angelfish, Elegant Wrasse, Eastern Blue Devil Fish and Herbst's Nurse Shark may inhabit offshore rocky reefs in NSW. Syngnathids (seahorse, pipefish, pipehorse and seadragon) are protected with up to 31 species recorded, with four solenostomids (ghost pipefish) and two species of pegasids (seamoths) present in NSW waters. Some pipefish species occur in estuarine and coastal habitats and may inhabit offshore waters. There are also several fish species additionally included in the EPBC Act that are occur in NSW offshore coastal waters: Eastern Gemfish, Orange Roughy, School Shark, Southern Bluefin Tuna, Harrison's Dogfish, Southern Dogfish and Blue Warehou (conservation dependent).	Cetaceans (whales, dolphins and porpoises) are all protected under the EPBC. All seals and sea lions occurring within Australian waters, including Australian Fur Seals and Long-nosed Fur Seals, are protected as listed marine species. Offshore areas may be used as foraging areas by Leatherback Turtles and other species including Green and Loggerhead Turtles may utilise offshore areas during part of their life cycle. All birds that occur in the region are protected under the EPBC Act as listed marine species. There are 41 species of seabird that are regularly present or occasionally occur in the region, 20 of these are listed as threatened and/or migratory e.g. Common Noddy, Flesh-footed Shearwater and Wandering Albatross. All sea snake species are protected as listed marine species.

4 The Environmental Assessment Process

4.1 Previous Assessments

In 2017, the Marine Estate Management Authority (MEMA) completed an evidence-based statewide threat and risk assessment for the NSW marine estate (2017 TARA) in accordance with AS/NZS ISO 31000:2009. The 2017 TARA assessed threats and risks to environmental assets as well as the social, cultural and economic benefits (community benefits).

Many activities can threaten the environmental, social and economic benefits of the marine environment. The 2017 TARA emphasised that it is important to understand the mechanism by which an activity can be a threat and included a wide range of activities that could potentially degrade an environmental asset, as well as the elements of the activities that potentially change the environmental assets (defined as stressors). Within the report there are many cases of different activities causing harm through similar stressors – for example, the activities of four-wheel driving, dog walking, surfing and recreational fishing can all create the stressor “wildlife disturbance” (to a greater or lesser degree) that could potentially have a negative impact on an environmental asset, such as foraging shorebirds, with the effect of changing their behaviour and reducing their health/ fitness.

Essentially, the 2017 TARA aimed to identify how various activities may affect environmental, social, cultural or economic benefits that accrue from the marine estate. A risk assessment process (in accordance with AS/NZS ISO 31000:2009) was embedded within the TARA process and was used to assess the risk of a threat to a benefit being realised. It also included a consideration of the magnitude of the potential consequences and the likelihood that those consequences will occur given current management controls (2017 TARA).

4.2 This Assessment

Recreational fishing is described as one of several potential threats to the marine estate categorised under "Marine resource use" within the 2017 TARA. This report builds on these earlier reports to provide a contemporary and more comprehensive assessment of the recreational fishery in NSW as a basis for improved management. The assessment presented here uses the 2017 TARA wherever possible and provides additional detail on the activities of recreational fishing in NSW. The same risk assessment process was used in this current assessment to assess the risk of a threat to a benefit being realised. Including a consideration of the magnitude of the potential consequences and the likelihood that those consequences will occur given current management controls.

The risk goals, objectives and definitions of consequence and likelihood that were used in the 2017 TARA were drafted by MEMA agencies with input from the Marine Estate Expert Knowledge Panel (MEEKP) and sets out the overall goals and objectives, consequence and likelihood definitions that were used in the 2017 TARA.

To reflect the triple bottom line nature of the assessment, specific goal statements, objective statements and consequence definitions were prepared for the environmental aspects of the 2017 TARA, with common likelihood definitions used.

The risk goals and objectives are consistent with the legislative objectives administered by MEMA agencies and the vision for NSW marine estate of a “healthy coast and sea, managed for the greatest well-being of the NSW community, now and into the future” (MEMA, 2015). See section 2 for detail on broader project objectives.

The risk matrix adopted for use in all assessments was taken from the document, 'Threat and Risk Assessment Framework for the NSW Marine Estate' (MEMA 2015a) and is reproduced in Table 10. Using this risk matrix, four 'risk levels' are possible – 'Minimal', 'Low', 'Moderate' or 'High'.

Table 10. Risk Levels Used in Assessments

LIKELIHOOD	LEVEL OF RISK				
ALMOST CERTAIN	MINIMAL	LOW	MODERATE	HIGH	HIGH
LIKELY	MINIMAL	LOW	MODERATE	HIGH	HIGH
POSSIBLE	MINIMAL	MINIMAL	LOW	MODERATE	HIGH
UNLIKELY	MINIMAL	MINIMAL	MINIMAL	LOW	MODERATE
RARE	MINIMAL	MINIMAL	MINIMAL	MINIMAL	LOW
CONSEQUENCE LEVEL	INSIGNIFICANT	MINOR	MODERATE	MAJOR	CATASTROPHIC

When new assessments were necessary, the same methodology or an equivalent process was followed throughout, and the same classifications used wherever possible. While the 2017 TARA focussed solely on NSW estuarine and coastal waters, this assessment included the new category of Commonwealth waters (i.e. offshore') occurring from three to 200 nautical miles from the territorial baseline, and which added a new suite of habitats, assemblages and associated biota to the assessment (see section 3.3).
This report does not aim to include all literature that examines impacts and details about the environmental assets identified, as the Marine Estate TARA Background Environmental Report (2017) contains much of this information already, however it does, where relevant, update this information.

Due to the 2017 TARA combining some aspects of recreational fishing activities (e.g. line and trap fishing) and also having not assessed the component stressors separately, risk scores by individual stressor from the previous assessment were unavailable for the updated assessment. These risk scores were evaluated and allocated based on the summarised evidence and information provided in the 2017 TARA report. Using the evidence tables from the 2017 TARA, risk for each of the stressors was allocated based on the previous overall risk scored for the activity and the text given within the cells summarising the evidence, along with the identified key stressors. Based on this content, the stressors were allocated the overall risk score given for the activity, or a reduced risk score if there was less/ little/ or no mention of the stressor in the evidence table.

In this assessment, all minimal and low risk scores were screened, and a relevant literature search undertaken to establish whether new evidence was available. Where new evidence was identified, the risk score was re-evaluated, and an assessment completed and summarised in the evidence tables. Where stressors were allocated moderate risk scores (or higher), due to the elevated risk score, the risk was re-evaluated, and an assessment completed in the same way.

4.3 Assessment Regions

This environmental assessment has been broken down into three regions in the context of the inshore saltwater fishery. This matches the regional division described in the Marine Estate

TARA Background Environmental Report (2017) and includes all estuarine and coastal waters (figure 7).

- The **northern region -** Queensland border to the southern end of Stockton Bight (Newcastle)
- The **central region** - Newcastle to Shellharbour
- The **southern region** - Shellharbour to the Victorian border.

The landward boundary includes coastal and estuarine waters to the limit of tidal influence.

Offshore waters include the habitat and biota that exist beyond the NSW coastal waters state boundary (broadly 3 nm offshore), within the waters of the continental shelf, out to the deep ocean environments at the edge of Australia's exclusive economic zone, 200 nm offshore (see section 3.3). The offshore assessment has not been regionalised because it shows much more latitudinal homogeneity in geomorphology, fauna and human pressures than coastlines and estuaries.

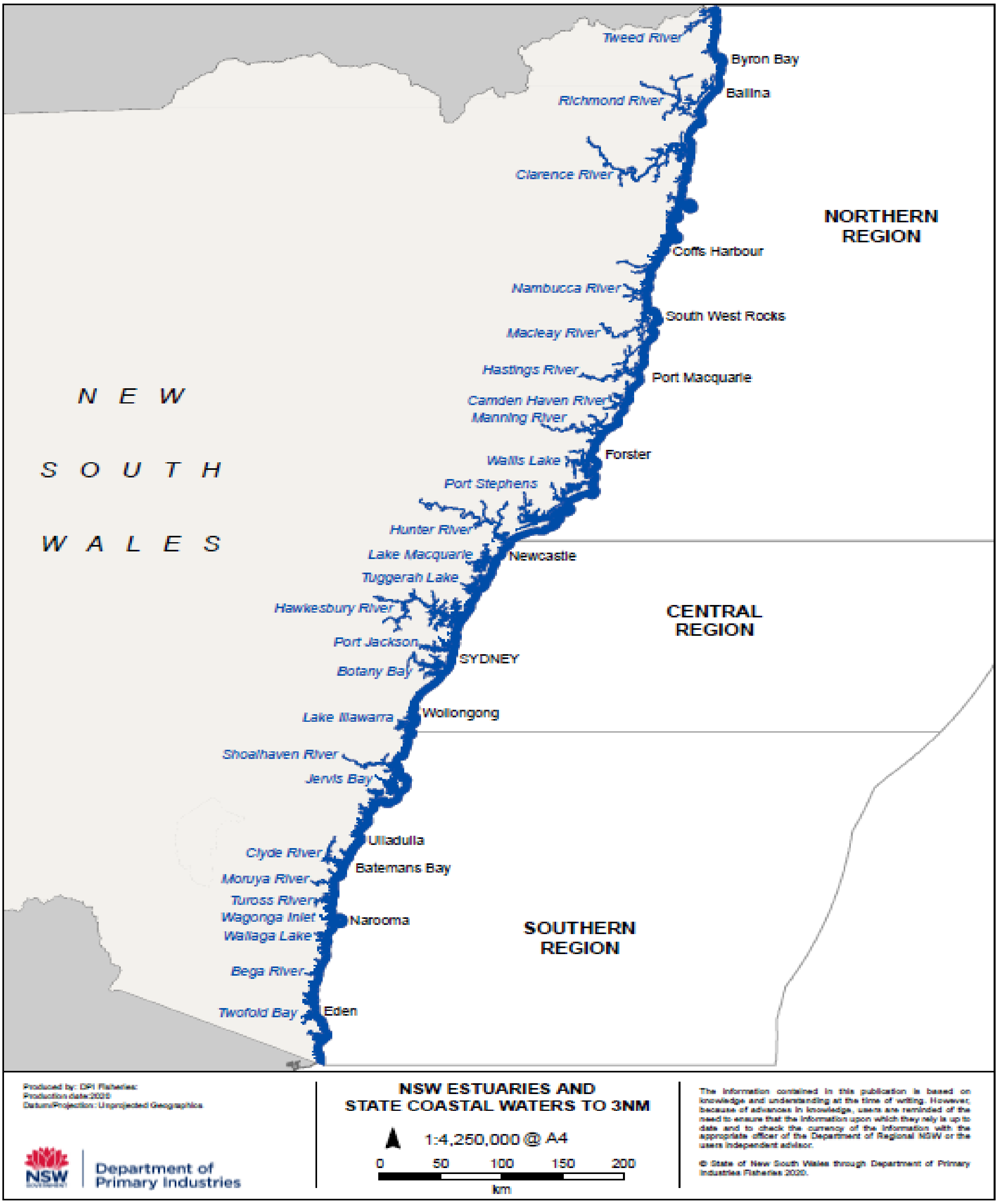

Figure 7. The NSW marine environment showing the three regions used in this assessment and extent of coastal waters.

4.4 Environmental Assets of the Marine Environment

The formal risk assessment process considered the following three assets that align with the Marine Estate Management Strategy's three broad environmental assets groups (see section 3 for a detailed description of each):

- Clean waters/ water column
- Habitats and associated biota

- Threatened and protected species.

Resilience of the ecosystem was also considered when assigning the appropriate consequence levels throughout the threat and risk assessment.

Additionally, to adequately assess the threats to the environmental assets, additional subdivision was applied, thus estuaries, coastal waters and offshore waters are considered separately, again to align with the regional division given in the Marine Estate Management Strategy (see section 4.3). Estuaries and coastal waters were subject to a full risk assessment process as part of the 2017 TARA. The offshore waters component has been considered separately, using a similar process to that undertaken for the estuaries and coastal components through the Marine Estate assessment project. This was not done originally as the focus of the Marine Estate project was to assess those waters that are within NSW state waters – those within three nautical miles from the coast or relevant island baseline.

4.5 Relationships between Recreational Fishing Activities and Stressors

Many activities can threaten the environmental, social and economic benefits of the marine estate. The 2017 TARA identifies that it is important to understand the mechanism by which an activity can be a threat. The 2017 TARA included a wide range of activities that could potentially degrade an environmental asset, as well as the elements of the activities that potentially change the environmental assets (defined as stressors).

There are many potential risks to various components of the marine environment posed by recreational fishing activity (Lewin et al., 2008; 2019). The Marine Estate TARA Background Environmental Report (2017) described stressors of specific relevance to recreational fishing activities. This information is updated below.

Categories of recreational fishing activity

Recreational fishing activities need to be separated to enable a thorough analysis of stressors. Within the 2017 TARA, recreational fishing was described as one of several threats categorised under "marine resource use" and the specific activities of recreational fishing that potentially threaten the benefits were broken down to a number of different fishing methods (activities). In this assessment, to enable a more thorough analysis of stressors, shore-based line and trap fishing were further separated into their components. In this assessment, charter fishing was considered with boat-based line fishing. Table 11 shows the differences between this assessment and 2017 TARA in terms of how activities were considered.

Table 11. Primary activity categories that may threaten environmental assets taken from the TARA (2017) and further classification of recreational fishing sub-categories for use in this report.

Categories considered in the 2017 statewide TARA			This assessment
Primary threat category	Activities that result in sources of threats	Specific activities assessed	Specific activities assessed
Marine resource use	Recreational fishing Charter fishing	Shore based line and trap fishing Boat based line and trap fishing Hand gathering Spearfishing Charter fishing	Shore based line fishing Shore based trap fishing Boat based line fishing Boat based trap fishing Hand gathering Spear fishing

5 Ecological stressors

The Marine Estate TARA Background Environmental Report (2017) listed ecological stressors that could threaten environmental assets. Given that recreational fishing activities do not create, nor contribute to, all the potential stressors, only those relevant to recreational fishing were considered here (see Table 11).

Table 11. Ecological stressors identified in the Marine Estate TARA Background Environmental Report (2017) that may result in threats to environmental assets and those that recreational fishing potentially contributes to.

Ecological stressors	Potential contribution from recreational fishing (Yes/No)
Reduction in abundances of species and trophic levels	**Yes**
Incidental bycatch	**Yes**
Incidental catch of species of conservation concern	**Yes**
Ghost fishing	**Yes**
Wildlife disturbance	**Yes**
Water pollution	**Yes**
Toxic contaminants	No
Nutrients and organic matter	No
Acid sulphate soils	No
Suspended sediments	No
Pathogens	No
Pests and disease	**Yes**
Sedimentation	No
Sediment contamination	No
Thermal pollution	No
Groundwater pollution	No
Bank erosion	No
Physical disturbance	**Yes**
Litter and marine debris (including microplastics)	**Yes**
Changes to tidal flow velocity and patterns	No
Changes to tidal prism	No
Climate change	**Yes**

Further, some of the relevant stressors from Table 11 were consolidated to simplify this assessment (see Table 12).

Table 12. Ecological stressors consolidated for this assessment.

Ecological stressors (as given in the 2017 statewide TARA background report)	Ecological stressors (consolidated for this assessment)
Reduction in abundances of species and trophic levels	Catch and bycatch
Incidental bycatch	
Incidental catch of species of conservation concern	
Ghost fishing	Marine debris and pollution
Litter and marine debris (including microplastics)	
Wildlife disturbance	Wildlife disturbance
Pests and disease	Pests and disease
Physical disturbance	Physical disturbance
Climate change	Climate change

Conceptually these stressors are not strictly independent. For example, interactions with threatened and protected species can be direct, via catch, or through wildlife disturbance. Wildlife disturbance and physical disturbance may also occur simultaneously in some instances.

The sections below include a summarised version of the stressors used in this assessment as well as updated additional relevant content that the activity of recreational fishing may create or contribute to. For further detail about stressors see the Marine Estate TARA Background Environmental Report (2017).

5.1 Catch and bycatch (direct and indirect effects)

This stressor can result in the reduction in abundance of individual species and potential ecosystem flow on impacts. As well as direct reductions in abundance from harvesting of fish species, harvesting impacts in marine environments are also reported to include reduced reproductive success and truncation of age and size structure of fish. This can then affect life history traits such as growth rates and size at maturity which reduces resilience at times of hardship (Lewin et al., 2008; 2019). These may be simple direct effects or more complex indirect effects.

- An example of a direct effect:
  - reductions in abundance of predator species when prey have been harvested
- Examples of indirect effects:
  - changes to benthic invertebrate communities through the removal of fish that feed on benthic invertebrates (e.g., Sand Whiting)
  - longer-term increases in the abundances of scavenger or predator species because of large numbers of trapped, dead, or injured animals being made available in regularly fished areas.
- Examples of trophic impacts include:
  - Impacts to food webs and species interactions by harvesting that may result in changes to predator/prey or herbivore/plant relationships (Lewin et al., 2008; Altieri et al., 2012).

5.1.1 Catch

For the numerically dominant species recorded in the 2019/20 catches by Murphy et al., (2022), their stock status as described in the 2016 and 2020 Status of Australian Fish Stocks (SAFS) reports is identified in Table 13. All species are classified in the SAFS reports as sustainably fished and there have been no changes in the stock status. These ten species are also caught by commercial fisheries in NSW.

Table 13. The Stock Status in 2016 and 2020 of the 10 numerically dominant finfish in the NSW recreational catch. Catch from Murphy et al., 2022.

Species	**Catch – 2019/20**	**SAFS 2016**	**SAFS 2020**
Bream	1,098,500 caught 68% released	Sustainable (Yellowfin)	Sustainable (Yellowfin)
Dusky Flathead	572,800 caught 68% released	Sustainable	Sustainable
Snapper	475,800 caught 73% released	Sustainable	Sustainable
Sand Whiting	391,100 caught 58% released	Sustainable	Sustainable
Sand Flathead	370,200 caught 57% released	Sustainable	Sustainable
Yellowtail Scad	203,900 caught 10% released	Sustainable	Sustainable
Tailor	191,500 caught 71% released	Sustainable	Sustainable
Blue Mackerel	173,000 caught 18% released	Sustainable	Sustainable
Eastern Red Scorpionfish	115,800 caught 91% released		
Yellowtail kingfish	82,000 caught 62% released	Sustainable	Sustainable

There are seven species caught (and often targeted) by recreational fishers in NSW that have populations classified as depleted under SAFS. The species are Mulloway, Silver Trevally, Pearl Perch, Grey Morwong, Gemfish, Redfish and Blue Warehou (listed in table 13). All these species are also caught in commercial fisheries managed in NSW state waters or Commonwealth waters adjacent to NSW. Except for Mulloway and possibly Pearl Perch, NSW recreational catches are less than NSW commercial catches. For Blue Warehou, commercial and recreational catches are both very small and it is a species rarely encountered by NSW recreational fishers as it is primarily distributed further south in waters off Victoria and Tasmania.

Table 13. Catch information on seven finfish species listed as depleted that may be caught by recreational fishers in NSW. Recreational catches from 2019/20 survey - Murphy et al. (2022) and commercial catches from Murphy et al. (2022), NSW commercial catch records and SAFs (2020).

Species	NSW Recreational Catch	NSW Commercial Catch	Region	Comment
Mulloway	55t (2019/20 Survey)	71t (Murphy et al 2022)	All	NSW DPI has made several management changes in 2013 and 2018, including reducing the recreational bag limit from five fish to one and increasing the minimum size limit from 45cm to 70cm to assist with stock recovery. Further consideration of changes to the management arrangements for the species are currently progressing. This is taking place in the form of the preparation of a harvest strategy for the species, which is tasked with promoting the stock recovery of the species.
Gemfish (Eastern)	Not quantified but considered to be low.	1.3t (2019/20 fiscal year) 70t in Commonwealth managed commercial fisheries (SAFs 2020)	All	Heavily depleted by targeted commercial trawling in state and Commonwealth fisheries. Inhabit deeper continental shelf and upper slope waters from 100 – 700 m but are concentrated in 350 – 450 m depths on the continental slope. Main source of fishing mortality is from the Commonwealth Southern and Eastern Scalefish and Shark fishery (SESSF). The stock is managed by AFMA under a rebuilding strategy with an incidental catch allowance of 100 t. The species was listed as conservation dependent under the EPBC Act. Anecdotal evidence, including photographs and reports on social media websites, indicates that Gemfish are targeted and captured by recreational anglers. However, surveys of recreational catch in New South Wales during 2013–14 (West et al., 2015), 2017–18 (Murphy et al., 2020) and 2019-20 (Murphy et al., 2022) detected no Gemfish captures. It is therefore concluded that recreational catch is negligible, relative to commercial catch.
Silver Trevally	13t (2019/20 Survey)	42t in NSW managed commercial fisheries. 36t (Murphy et al 2022). 21t in Commonwealth managed commercial fisheries (SAFs 2020)	All	Caught in estuaries, coastal areas, and offshore waters. Commercial catches reached approximately 1,400 t during the 1980s before declining to current levels.
Pearl Perch	Harvested catch estimated at 7,508 fish in 2019/20 (2019/20 Survey)	13.3 t (2019/20 fiscal year)	N	Inhabit coastal and continental shelf reefs in depths between 10-150 m). Spawning fish not generally found in NSW.

Redfish	Harvested catch estimated at 9,646 fish in 2019/20 (2019/20 Survey)	13.4 t (2019/20 fiscal year) 21t in Commonwealth managed commercial fisheries (SAFs 2020).	All	Redfish landings in the Commonwealth fisheries peaked in the late 1970s and early 1980s, with significant discards recorded on top of landed catch. Offshore species typically found in depths between 50 and 450 m.
Blue Warehou	Not quantified but considered to be low.	0.2 t (2019/20 fiscal year)	S	Coastal and offshore species found to depths of about 100 m. Main source of fishing mortality is from the Commonwealth Southern and Eastern Scalefish and Shark fishery (SESSF). The stock is managed by AFMA under a rebuilding strategy which prevents targeted capture of the species. The species was listed as conservation dependent under the EPBC Act. Not considered a species desired by recreational fishers in NSW and is rarely encountered. Recreational and Aboriginal catches of warehou species in New South Wales are unknown. Surveys of recreational and Aboriginal catches have either not specified catches of warehou species (West et al., 2015, Murphy et al., 2020 and Murphy et al., 2022) or reported them into a broader 'finfish - other' category (Henry and Lyle, 2003).
Grey Morwong	10t	24t (Murphy et al 2022). Approximately 20t in Commonwealth managed commercial fisheries (SAFs 2020).	All	Typically occurs in coastal waters to a depth of 100 m. Recreational harvest has declined from an estimated 156 t in 2001/02. Before that, commercial catches had also declined significantly during the 1990s. The species is not generally targeted by recreational fishers but is captured as bycatch when targeting snapper and other species. The New South Wales recreational harvest of Grey Morwong has also declined from an estimated 156 t in 2000–01 to 29 t in 2013–14 (West et al., 2015) to 22 t in 2017–18 (Murphy et al., 2020) to 10t in 2019-20 (Murphy et al., 2022) indicating that the availability of this species to recreational fishers has declined. These trends indicate that the Grey Morwong population was fished down substantially during the 1970s and 1980s and has not yet shown evidence of recovery. The above evidence indicates that the biomass of this part of the stock is likely to be depleted and that recruitment is likely to be impaired.

Most fish species harvested by recreational fishers are also harvested commercially. In the complete absence of recreational fishing, there would still be fishing mortality for most fish species from commercial fishing (and to a much lesser extent Aboriginal cultural fishing). Across the various species for 2019/20, estimates of the proportion of harvest from recreational fishing varied from 7.7% for Luderick to 56.6% for Yellowtail Kingfish (Table 14). Overall, recreational catch for 2017/18 was reported to only take 13-14% by weight of the total catch (Murphy et al., (2022).

Table 14. Table of estimated recreational and commercial catches for finfish species in NSW 2019-20 (Sources: Murphy et al., 2022)

Species/Group	Recreational catch (tonnes)	Commercial catch (tonnes)	Total harvest (tonnes)	Recreational catch (%)
Blue Swimmer Crab	13	61	74	17.5
Sand Flathead	72	77	149	48.1
Dusky Flathead	114	101	215	53.1
Australian Salmon	53	696	749	7.1
Grey Morwong	10	24	34	29.5
Luderick	24	293	318	7.7
Mulloway	55	71	126	43.7
Sand Whiting	46	104	150	30.8
Silver Trevally	13	36	50	27.1
Snapper	94	182	276	34.1
Tailor	32	52	84	38.1
Bream	127	299	426	29.9
Yellowtail Kingfish	114	88	202	56.6

5.1.2 Catch from Spearfishing

Global research indicates that spearfishing can significantly affect local densities, size, and depth distributions of targeted species (Godoy et al., 2010, Harmelin et al., 1995, Jouvenel and Pollard, 2001). There is little data on the current impact of spearfishing across NSW; however, given that the current level of activity only represents 2.8% of total saltwater recreational fishing effort, the impact of spearfishing in coastal NSW waters is expected to be relatively low.

Some insight into potential impacts has also been gained through spatial comparisons of Marine Protected Areas (MPAs) versus spearfished areas (Curley et al., 2013). Densities of legal-sized Red Morwong were 4.6 times greater in shallow water (<3.5 m) and 2.4 times greater in deeper water (4–12 m) within a 0.1 km^2 MPA closed to spearfishing for 12.5 years, than at fished locations. In the same study, densities of legal-sized, Yellowfin Bream were 2.3 times greater on shallow but not deeper areas of reef within the MPA.

Previous studies found that Red Morwong is a dominant part of the spearfishing catch (Schmeissing, 1997) and is rarely taken by anglers (Lincoln-Smith et al., 1989). The species is relatively easy to locate and spear due to its small home range, homing behaviour over distances up to 900 m, diver-neutral and docile behaviour, and tendency to aggregate in relatively shallow water (Lincoln-Smith et al., 1989, Lockett and Suthers, 1998; Lowry, 2003). In combination with its restricted geographical distribution and resultant sensitivity to climate change, these traits have led to it being described as a potentially vulnerable species (Syms, 2011). Similar effects have been demonstrated for Red Morwong in NSW MPAs (Coleman et al., 2013). Rapid recolonisation (within 2–4 months) by adult fish has been demonstrated after experimental removal of >70% of adult Red Morwong from aggregations (Lowry and Suthers, 2004). Despite this, recolonisation is likely to be influenced by the density of adjacent populations and connectivity of reef habitat.

In some competitions and locations, several spearfishing clubs dissuade their members from targeting sedentary species, such as Red Morwong. The prohibition of spearfishing using scuba gear also provides a depth refuge from spearfishing for some species (Lindfield et al., 2014). Spearfishers also require relatively clear water to be able fish effectively, which further limits spearfishing effort and success.

Spearfishing is regarded as one of the most selective forms of recreational fishing and catches a relatively small number of fish species but also has the capacity to target larger individuals in fish schools (Frisch et al., 2008; Sbragaglia et al., submitted). Spearfishing can also alter the behavioural responses of targeted species. For example, fishing pressure was found to be positively associated with a higher flight initiation distance of fishes in families that were primarily targeted by spear guns in Papua New Guinea (Feary et al., 2011; Januchowski-Hartley et al., 2012). There are no data on this potential impact in NSW.

5.1.3 Catch from Hand Gathering

Hand gathering can reduce harvested populations and indirectly change the structure of associated assemblages (Thompson et al., 2002). Despite limited quantitative data, concerns of extensive harvesting of intertidal organisms around Sydney led to the implementation of 14 intertidal protected areas (IPAs) by NSW Fisheries in July 1993. In 2002, six IPAs were replaced with aquatic reserves. These areas were selected based on length, biodiversity, geographic spread, educational values, research and community consultation. Nine IPAs remain in place: Bungan Head, Mona Vale Headland, Dee Why Headland, Shelly Beach Headland, Sydney Harbour, Bondi, Long Bay, Inscription Point and Cabbage Tree Point. There is also no harvest allowed in all marine park sanctuary zones.

Populations of the limpet *Cellana tramoserica,* which is subject to harvesting, were significantly larger in Bouddi Marine Extension than in unprotected areas (Alexander and Gladstone, 2013). One ecological effect of harvesting is serial depletion of populations. Sedentary species, such as oysters, mussels and species with high site fidelity are the most susceptible to this.

There are some anecdotal concerns about the impact of harvest of Beachworm populations. This includes localised depletions and declining levels of total catch, coupled with exploitation of broader areas to support harvest. The prey items of foraging shorebirds are directly targeted in hand gathering fisheries, which can limit access to food by displacement and competition (e.g. Beach Stone Curlews). The impact on shorebird species from bait collection has been identified as a high priority for research (Department of Environment, Climate Change and Water NSW, 2010). This is particularly the case on nesting beaches in northern NSW, where it is possible that the collection of Pipis reduces availability of prey species of Pied Oystercatcher.

5.1.4 Catch from Fishing Tournaments

Anecdotal reports received by DPI over the late 1990s and early 2000s indicated there was concern from the community over “catch and keep” fishing tournaments and harvesting of large fish by recreational fishers regarding the potential for localised depletion of resources and conflict over access. As a response to this concern NSW DPI instigated a Tournament Management Program to develop a code of practice for fishing events[1] and work with fishing competitions to achieve improved environmental performance over time. This program, along with a general shift in responsible fishing behaviour, resulted in a positive shift amongst fishing clubs and organised fishing events with the majority of competitions now having more conservative rules than required by legislation (such as operating with reduced bag limits or with more stringent size limits in place) with many operating best practice catch and release practices.

The more progressive fishing tournaments have been considered responsible for driving responsible fishing practices and best practice catch and release techniques more broadly across the wider fishing community and as such have largely had a positive influence on angler behaviour.

Spearfishing events have adapted in-line with changes to line fishing competitions to reduce the overall numbers of fish being brought in to be weighed for points and trophies.

Competition spearfishing has been predominantly boat based for many years. In recent years, a few boat based spearfishers have accessed offshore locations to target species such as Dolphinfish and tunas. Gledhill et al., (2014) reviewed 335 historical competition datasets from 50 sites in NSW dated from 1961 to 2011. The data sets were made available voluntarily by spearfishers, and represented more than 13,000 diver days, with 98,000 individual fish caught weighing around 108,000 kg. Approximately 150 species were represented in the overall catch. The data sets extend from near Coffs Harbour south to near Eden.

There is a long-standing tournament structure associated with the NSW game fishery. Catch and release (usually with tagging) is the most significant component of the fishery. Some harvest still exists, however, there are minimum weights in place that exceed legislated requirements and reduce the potential harvest of game fish species.

Monitoring of the NSW recreational game fishery began in the early 1994 and collates game fish tournament catch data using three data collection methods: tournament results; tournament scheduled radio reports of location and fishing activity; and post-fishing angling-party interviews. Table 15 provides some key results of NSW game fishing tournament monitoring program that have been extracted from Ghosn, 2020. The 2019 season included data from 25 events held between Port Macquarie and Eden.

Table 15. Catch and release rates for NSW game fishing tournaments in 2019 (Source: Ghosn, 2020)

Species	Total Caught (2019)	% Released (2019)	Mean Total Caught (1994-2019)	Mean % Released (1994-2019)
Black Marlin	170	96.5	266	92.7
Striped Marlin	214	96.3	355	91.0
Blue Marlin	86	73.3	95	70.1
Shortbill Spearfish	27	85.2	14	86.5

[1] www.dpi.nsw.gov.au/__data/assets/pdf_file/0008/603953/Code-of-practice-for-fishing-events-in-NSW.pdf

Mako Shark	88	80.7	110	68.7
Blue Shark	32	87.5	41	72.0
Tiger Shark	22	31.8	41	33.9
Hammerhead Shark	42	97.6	29	91.2
Whaler Shark	27	96.3	35	78.7
Albacore	5	80.0	135	83.7
Yellowfin Tuna	62	37.1	370	70.5
Striped Tuna	19	84.2	199	60.2
Mahi Mahi	237	86.9	354	81.6
Yellowtail Kingfish	18	100.0	70	92.7
Wahoo	7	14.3	12	51.1

5.1.5 Illegal Catch

In addition to legal harvest of fishes, illegal fishing can occur, which includes all fishing activities that do not comply with current fisheries regulations (e.g. exceeding bag limits, keeping undersize fish or protected species, using illegal gear and poaching from protected areas). Illegal fishing undermines the effectiveness of management and conservation efforts, and thus the ecological sustainability of the fishery.

Illegal fishing increases the overall fishing mortality from the marine environment, however, in most cases due to the scale of the illegal activity the impacts at a stock level are likely to be minimal. Although compliance rates cannot be directly used to understand the added impact illegal recreational fishing has, it can provide some insight (see section 2.5.4 Fisheries compliance and illegal fishing). Scientific monitoring and stock assessment of affected stocks will support the detection of population impacts from the overall fishing mortality and identify whether there is excessive fishing pressure and whether overfishing is occurring.

Compliance rates in recreational fisheries are generally high (Bova et al., 2017), Although, "hotspots" of non-compliance can arise (Haggarty et al., 2016; Harasti et al., 2019). Harasti et al. (2019) used surveillance cameras to survey no-take areas within the Port Stephens – Great Lakes Marine Park. During the study period, cameras picked up a number of vessels illegally fishing and the researchers suggest this is causing a decline in Snapper (*Chrysophrys auratus*) within no-take sites. New approaches to further enhance compliance rates in recreational fishing based on behavioural changes and social norms are being developed and trialled which have the potential to enhance traditional compliance activities (Bova et al., 2017; Mackay et al., 2018).

Overharvesting of small fishes within estuaries may influence adult stocks, because estuarine habitats are important nursery areas for many species. For example, most Snapper (89%) caught in the adult fishery in central NSW originated from local nursery estuaries, including Sydney Harbour, Hawkesbury Estuary, Botany Bay and Port Hacking (Gillanders, 2002). Non-compliance in Sydney Harbour occurs particularly during the warmer months. Non-compliance hotspots include mudflats around the harbour and the Parramatta River, and the intertidal protected areas, aquatic reserve or fishing closures (e.g. Port Jackson shellfish closure) (2017 TARA).

Illegal harvest is reported to be principally driven by social norms and compliance is through fear of enforcement penalties (Bergseth & Roscher, 2018; Read et al., 2015). Levels of illegal fishing activity vary spatially, with reduced compliance generally occurring in areas that are more accessible and attractive to offenders (Advani et al., 2015; Weekers & Zahnow, 2018), and in areas with ineffective enforcement (Agnew et al., 2009; Hønneland, 1999; Petrossian, 2015). Community support for regulation also plays a substantial role in compliance rates (Arias & Sutton, 2013).

5.1.6 Direct Catch Impacts

Since the 2017 TARA, there have been several studies that have assessed relevant aspects related to catch in addition to the recreational surveys described in Section 2. Numerically, Ghost Nippers represent the most important target for recreational hand gatherers and further recent information on the harvest is available. Chick (2020) synthesises available information on nippers and augments this with some manipulative experiments. Overall, Chick (2020) identified that the weight of evidence was sufficient to support an understanding that the biomass of Ghost Nippers is at a level sufficient to ensure that on average, future levels of recruitment are adequate and fishing mortality is at a level to avoid the stock being recruitment impaired. Chick (2020) found that Ghost Nipper harvesting was highly localised and there was annual variation in the standing stock of nippers.

Ochwada-Doyle et al., (2021) provided information on fine scale temporal and spatial variation in recreational catches in NSW that can inform additional management actions if necessary. Fowler et al., (2021) provided a detailed decision analysis tool for prioritising monitoring and assessment for fisheries of limited commercial value. Taylor and Suthers (2021) identify that in urban areas where recreational fishing is frequently the dominant or the only source of fishing mortality, it is focussed on predatory species, and this may have impacts on the trophic structure of fish assemblages in combination with other factors. However, this has not been assessed to date in NSW.

Further information has been collected for recreational fishing activities in offshore waters. Tracey et al., (2021) determined the national retained recreational catch of Southern Bluefin Tuna was approximately 263 tonnes, of which approximately 30 tonnes was taken from NSW. Lynch et al., (2020) collected information on recreational fishing in the Commonwealth Hunter Marine Park and identified Grey Morwong, Eastern Blue Spotted Flathead and Blue Mackerel were important retained species.

5.1.7 Indirect Catch Impacts

In addition to the direct impact of harvesting to the species being targeted, there can be additional impacts to other species within the food-web. These impacts are context specific and are often hard to quantify due to the complexity of food-webs. Flow on impacts to the structure of fish assemblage as a whole from fishing activities are known (e.g. Lozano-Montes et al., 2011; Farmer and Wilson, 2011; Mumby et al., 2012). Determining impacts generally involve comparing fully or partially protected fishing areas with those remaining open to relevant forms of fishing (e.g. Graham et al., 2003; Kelaher et al., 2014; Ferguson et al., 2016). Impacts can include changes to species diversity, species abundance (increases or decreases), average size and the trophic structure of the assemblage (Kelaher et al., 2014; Ferguson et al., 2016; Harasti et al., 2018; Cresswell et al., 2019). These studies generally do not allow determining what specific proportion of any impacts are associated with recreational as opposed to commercial or artisanal fishing. Knott et al., (2021) assessed structural aspects of the fish fauna in 72 rocky reef areas in NSW. While clear effects were evident for the key target species (Snapper), they found relative abundance of non-target or by-catch species generally did not differ among management zones across the bioregional network surveyed.

There are also the added dynamics of other threats possibly involved, which makes quantifying the impact specifically from recreational harvest hard to quantify. The impacts include marine wildlife and fishers competing for the same fish and invertebrate resources and also marine wildlife feeding on lower trophic levels that are the prey of harvested species. The removal of top predatory fish can also have significant indirect effects on marine ecosystems, influencing a range of ecological processes that might include predation, competition, and herbivory. This can be known as a trophic cascade. There are some international examples of how fishing, can result in trophic cascades, Perez-Matus et al., 2007 found higher fish biomass and an increase of kelp-associated sessile species were observed in the south pacific when a fishery in the south pacific was restricted. Anthropogenic removal of fish or invertebrate species preying on sea rchins has resulted in overgrazing of seagrass beds (Rose et al., 1999; Wallner-Hahn et al., 2015), which may ultimately contribute to the total loss of seagrass-associated ecosystem services (Eklöf et al., 2008). Although there are very few studies on changes in trophic cascades in marine ecosystems with a focus on recreational fishing, indirect impacts on lower trophic levels take longer and are more difficult to detect from predatory fish removal, compared to direct effects on target species. Effects are also not straightforward and are influenced by fish community composition, habitat structure, and environmental conditions (Lewin et al., 2019). Examples of these impacts are recognised, though those involving mammals, birds or reptiles (threatened and protected species) at a local scale are not yet reported.

Another indirect impact from catch is the addition of fish discards into the water. This often occurs near areas with fish cleaning facilities where fish waste enters the water rather than collected in waste bins/skips. A study near the Woollamia boat ramp in Jervis Bay, Australia, a site where local anglers have been incidentally provisioning food for Smooth Stingrays *Bathytoshia brevicaudata* through fish-cleaning activities for > 30 years is the first published study in Australian to show that discards from fish cleaning sites can cause stingray behaviour changes. In the study behavioural observations were used to assess stingray site use patterns, it was observed that residency patterns were altered, and stingrays also displayed anticipatory behaviour. Significantly more stingrays visited during provisioning than pre-provisioning in simulated provisioning trials at sites where stingrays are not normally provisioned. The study suggests the findings have implications with respect to accepted practices for discarded fish waste (Pini-Fitzsimmons et al. 2018).

5.1.8 Bycatch

Bycatch refers to the part of the catch that is 'taken incidentally in addition to the target species towards which fishing effort is directed' and occurs to some degree in most wild fisheries. As well as retained catch, recreational fishing can generate bycatch which may be retained as catch or may be released (otherwise known as discarded) – this is commonly referred to as incidental bycatch. Bycatch in recreational fisheries is highly dependent on habitats fished and methods used, with spearfishing, for example, having very low levels of bycatch compared to line fishing (Frisch et al., 2008).

In nets and traps, bycatch can be reduced by using different gear configurations such as mesh size and utilising escape gaps in traps, leading to less undersized fish/ invertebrates being caught. For example, in NSW the mesh size of recreational prawn nets has been optimised through legislation to reduce the catch of small prawns (Broadhurst et al., 2005). In line fishing, reducing unwanted bycatch is based more around gear choice combined with techniques such as using more targeted baits and lures and fishing in key habitat areas for the target fish. The focus in line fishing is minimising injury to caught fish and returning them back to the environment with minimal harm. This can be through gear choice (e.g., using circle hooks/ lures), and best practice handling (e.g., minimising air exposure, swift unhooking, using knotless mesh nets, wetting hands etc).

In recreational fishing, catch and release is the common response to the capture of unwanted species, protected species, fish of certain sizes or sexes, or where the angler is "sport fishing", where the fish are released after capture by choice (Cooke and Wilde, 2007). Sport fishing is generally increasing in popularity in Australia across a wide range of species from Yellowfin Bream, Dusky Flathead and Snapper through to shark and marlin species (where the vast majority are now released). Statewide, it was estimated that over 9.3 million fish and invertebrates were caught in 2017/18 with 49% of this catch released (Murphy et al., 2020). While research demonstrates that most fish recreationally caught and released survive the experience, impacts vary between species from causing no apparent long-term effects, through to chronic sublethal impacts, or direct mortality (See table 16) (Muoneke and Chlidress, 1994; Broadhurst et al., 2005; Butcher et al., 2006; Arlinghaus et al., 2007).

NSW DPI researchers summarised studies from 22 fresh and saltwater species in the NSW DPI Catch and Release Handbook 2013. Release survival of Blue Swimmer Crabs and Giant Mud Crabs was found to be 100% and was estimated to be 97 % for Eastern Rock Lobster. Survival rates for key estuarine and coastal species was also presented in this publication, often with a range given, based on various experiments that had been undertaken on that species – Dusky Flathead or example was given an estimated survival rate of 91 – 97% in the report. Other various studies included in the handbook estimated mortality at 4% for Sand Mullet (Broadhurst et al., 2011), 6% for Sand Whiting (Butcher et al., 2006) and 8% for Tailor (Broadhurst et al., 2012a). Mortality estimates for Snapper caught inshore was also low at 7.6% (Broadhurst et al., 2012b).). The mortality rate for Eastern Sea Garfish was the highest of all the species studies and was considerably greater than others at 49% (Butcher et al., 2010) due to handling related scale loss.

Table 16. Summarised of studies from 22 fresh and saltwater species in the NSW DPI Catch and Release Handbook (2013). www.dpi.nsw.gov.au/fishing/recreational/fishing-skills/catch-and-release

Species	Survival (%)	Key factors for fish mortality
Dusky Flathead	91-96	Poor handling and sub-optimal live well water quality
Luderick	99	Poor handling
Mulloway	73-81	Deep hooking and poor handling
Sand Whiting	93	Deep hooking
Silver Trevally	63-98	Excessive time in poorly designed live wells
Pearl Perch	91	Deep hooking
Snapper	67-92	Deep hooking and poor handling
Tailor	92	Deep hooking

Yellowfin Bream	72-97	Deep hooking
Yellowtail Kingfish	85	Deep hooking

Large offshore pelagic fish species are less comprehensively studied than inshore species, however there are several studies that suggest that catch and release survival is also high for these species. Meta-analysis conducted on existing data from 46 different tagging/tracking studies that measured the release mortality of billfish caught on commercial and recreational fishing gear provided an overall survival rate of 86%. These studies included data from 400 pop-up satellite archival tags and 64 acoustic (ultrasonic) tags involving most species of billfishes (Family *Istiophoridae*). The actual range of release mortality rates predicted by the meta-analysis with 95 percent confidence was 10.3 to 17.6%, providing a mean of approximately 14% of all billfish species considered together do not survive release (Musyl et al., 2014).

For Southern Bluefin Tuna in the oceanic pelagic environment of NSW, mortality rate was estimated at 17%. The reported post-release survival estimate should be considered conservative as the effects of processing, in particular drawing blood samples and attaching satellite tags are unknown and may have biased the results towards a higher mortality rate (Cooke and Schramm 2007). Except for hook type, no other factors tested were found to significantly influence the post-release survival rate. Fish caught on lures configured with treble hooks had a lower post-release survival rate than fish caught on either baited circle hooks or lures configured with J-hooks (Tracey et al., 2016).

Survival estimates for 30 Mako Sharks caught by anglers and released with satellite tags off the south-eastern coast of Australia were found to be high, with an overall survival rate of 90% (French et al., 2015). Hook choice was considered to have contributed to an increased likelihood of mortality, with circle hooks found to significantly reduce deep hooking – 83% caught on circle hooks were jaw hooked vs 20% caught on j-hooks. Effects of catch and release for other shark species found species specific differences in blood parameters and associated stress response. Tagging data using Smart Position or Temperature Transmitting (SPOT) satellite tags was used to assume survival rates with 100% Tiger Sharks reporting for at least four weeks after release, which was significantly higher than Bull (74.1%) and Great Hammerhead (53.6%) Sharks (Gallagher et al., 2014).

The most common and universal cause of release mortality across a wide range of fish species is associated with deep hooking fish and the injury caused by the hook position or removal of the hook. This occurs most often when using bait with standard j-hooks (Cooke and Suski, 2004). Circle hooks have been widely demonstrated to reduce the rate of deep hooking and thus increase survival of released fish. A meta-analysis on studies relating to circle hooks in recreationally caught fish showed that the mortality rates were consistently lower for circle hooks than J-style hooks. Circle hooks were found to hook fish more frequently in the jaw, and less frequently in the gut than conventional hook types (Cooke and Suski, 2004). An Australian study on Sand Flathead demonstrated the use of circle hooks resulted in significantly lower deep-hooking rates (1%) and hence mortality, compared with conventional hook types (4–9%) and, based on catch rates, were at least as effective as conventional hook patterns. Estimated survival rates for line-caught Sand Flathead were high, over 99% for circle hooks and between 94 and 97% for conventional hooks. (Lyle et al., 2007). A study on Yellowfin Bream also demonstrated lower deep hooking rates (10%) using circle hooks compared to using j-hooks (16%) (Broadhurst et al., 2019). Circle hooks were found to be equally effective in hooking and landing Striped Marlin and far less likely to cause serious bleeding or become lodged in areas other than the mouth. In total, 16 of 61 fish died (mortality rate of 26.2%), all within 5 days of release and injury was a clear predictor of mortality; 100% of fish that were bleeding from the gill cavity died, 63% of fish hooked deep died (Domeier et al., 2003).

Barotrauma can occur typically when fish are caught from water depths of 10 m or more. Injuries occur due to the changes in pressure which are collectively termed 'barotrauma'. The most common symptom being an inflated swim bladder which stops a released fish from swimming back to the depth it was caught from. Other more severe injuries can include the stomach being forced out of the mouth, or the intestines from the anus and gas bubbles in various organs. Other common causes of injury can come from handling, hook location and hook removal (Muoneke and Chlidress, 1994; Arlinghaus et al., 2007; Wilde and Sawynok, 2009; Broadhurst et al., 2012).

The different physiological response to barotrauma between species was highlighted during experiments using hyperbaric chambers. Delayed mortality in barotrauma-affected Mulloway, was observed (88%) from pressure simulated at 30 metre depths, even when successfully repressurised, and 0% for individuals at 10 metres (simulated pressure) (Hughes et al., 2019a). This contrasts results observed in a similar experiment on Snapper which had 0% mortality of individuals at 30 metre depths (simulation) if repressurised after 10 minutes (16% mortality for the group not repressurised). This highlights the differences in physiological resilience to barotrauma across species and demonstrates the potential effectiveness of utilising tools such as release weights to return fish to depth and naturally repressurise them.

Various approaches including handling guidelines (e.g., minimising air exposure, swift unhooking, using knotless mesh nets, wetting hands etc), gear configurations (such as the use of circle hooks/ lures) and the use of release weights for deepwater species to treat barotrauma affected fish can improve survival (Arlinghaus et al. 2007). These are all currently promoted by NSW DPI in advisory material in fishing guides, on the DPI webpage and also through educational and promotional fishing days where environmentally responsible gear such as circle hooks are given away to participants. See:
www.dpi.nsw.gov.au/fishing/recreational/fishing-skills/catch-and-release

Given spearfishers are able to see and identify their catch before unloading their spear, bycatch from spearfishing is expected to be very low compared to line fishing (Frisch et al., 2008). Some bycatch can occur when fish are speared but are discarded because they are undersized or have been misidentified. Injury and death can also occur when fish are wounded by the gear but escape. While there are no quantitative data on levels of discards by spearfishers in NSW, a study on the Great Barrier Reef found spearfishing produced far less bycatch than line fishers (discards consist of 1% of their catch) (Frisch et al. 2008).

5.1.9 Incidental Catch of Species and Communities of Conservation Importance

Threatened and protected species such as White Shark and Grey Nurse Shark, cetaceans, turtles, and seabirds often have migratory routes, feeding areas, and/or life cycles that bring them into areas where they are more likely to interact with some fishing methods. These species may get entangled in fishing gear, ingest hooks or otherwise become hooked in the mouth, gills, fins, feet, wings or other areas on the body. Depending on the species and the injury type, the result of these interactions varies considerably. The interaction may have minimal impact with no long-term repercussions. It may be sublethal, leading to disease and health impacts of varying duration. Or it may result in the death of the individual animal. By law, threatened and protected species must be released after accidental capture and reported to the relevant authority.

Interactions between NSW recreational line fishers and Grey Nurse Sharks are established (Robbins et al., 2013). The species is not deliberately targeted by recreational fishers. The Commonwealth Recovery Plan and the NSW Priority Action Statement (PAS) both identify the need to undertake risk assessments on different hook and line fishing methods. Since the 2017 TARA, a draft risk assessment for recreational shore fishing in NSW has been prepared and has identified demersal line fishing with bait in areas where Grey Nurse Sharks occur as the highest risk of all the various forms of fishing. This is supported by research conducted by Robbins et al. (2013) that demonstrated that large bottom-set fish baits elicited strong responses from grey nurse sharks, with smaller baits representing a significantly lower, yet appreciable response rate. The risk assessment also includes a Code of Conduct which builds on existing advice already in the public domain[2].

Current management strategies take research findings into consideration to minimise Grey Nurse Shark interactions with recreational fishing activities. It was shown that Grey Nurse Sharks are unlikely to interact with certain types of fishing gear such as artificial lures used while spinning, trolling and jigging. In addition, past dietary studies have shown that it is considered highly unlikely that Grey Nurse Sharks will interact with vegetable-based baits (Robbins et al., 2013). Fishing is prohibited in certain Grey Nurse Shark critical habitat sites (Julian Rocks, The Pinnacle, Big and Little Seal Rocks, Little Broughton Island, Tollgate Islands) and Line fishing using bait is prohibited at certain sites (Fish Rock, Green Island, Magic Point, The Steps, Manta Arch, South Solitary Island, Mermaid Reef, Montague Island (line fishing permitted 1 May – 31 October – no bait).

The Black Rockcod was historically caught by spearfishers and line fishers on shelf reefs in NSW and has been fully protected since 1983 (Malcolm et al., 2010). The Temperate East Marine Bioregional Plan identified the risk to Black Rockcod from recreational fishing was "of less concern" from extraction but "of concern" for bycatch. The geographic range of Black Rockcod in NSW was once widespread but is now largely contracted to suitable habitat in the northern region only with the Solitary Islands Marine Park being a key location, although some are found within the Port Stephens Marine Park (Harasti et al., 2010; Harasti and Malcolm, 2013). Individual fish may be incidentally caught and released by recreational line fishers on rare instances (Harasti and Malcolm, 2013). NSW DPI provide information material aimed at assisting recreational fishers identify the species and use handle and release practices that enhance the survival of a released fish. Fishing is not permitted to occur in some of the key habitat for the species in the Solitary Islands Marine Park.

While interactions between recreational fishing activities and marine turtles are well documented in Queensland from boat strike and entanglement (Hazel and Gyuris, 2006), these sources of injury and mortality are substantially lower than disease and buoyancy disorders linked to poor water quality (Flint et al., 2017). NSW has substantially lower densities of marine turtles and lacks high density nesting areas. However, Loggerhead Turtle and Green Turtles are recorded nesting in New South Wales most years and it is possible that marine turtles may be nesting further south in response to climate change impacts (Limpus, 2004; 2008; Pike, 2013). Leatherback Turtle nesting was also historically recorded (Tarvey, 1993).

Interactions between recreational fishing gear and marine turtles do occur in NSW and are not trivial in terms of their occurrence, particularly at the local level. There was a significant issue in Port Stephens between 2011-2015 where 16 turtles were recorded as drowned in crab gear. This resulted in a successful trial on new crab fishing arrangements which have significantly reduced interactions in this area recognised as important NSW turtle habitat. It is considered

[2] Protecting the grey nurse shark…a guide for recreational fishers and divers (nsw.gov.au)

that most interactions occur while the gear contains bait and is being fished (rather than from ghost fishing impacts). Crab gear, by its nature, is set and left before being retrieved and this often means it is left unattended for periods of time which may lead to increased incidental interactions by wildlife with the gear.

Line fishing has been reported to entangle and hook coastal, estuarine and shorebirds. Ferris and Ferris (2004) reported that recreational fishing using unattended lines was the primary cause of this interaction, initially, with local investigations revealing 53 unattended fishing lines trailing from wharves and jetties in the area. The wharves and jetties were privately owned by riverside residents. These areas are particularly favoured by pelicans and at the beginning of the study it was revealed that the single most significant cause of entanglement to pelicans was due to the practice of fishers leaving fishing lines unattended and, to a lesser extent, entanglement with discarded/ lost fishing line. They also reported that levels of Pelican entanglements dropped with increased community awareness from media campaigns during the study. Media awareness programmes had reduced the incidence of unattended lines, and discarded line was still evident on beaches and rock-walls during the closure to fishing. Given the level of shore and boat based recreational fishing activity that occurs on the open coast, there is likely to be continued interaction between fishing line methods and these species.

Seabird entanglements and ingestion of fishing gear are assumed to be mostly from discarded and lost fishing gear as it is considered that most fishers try to avoid direct interactions. If they do occur, attempts are made to untangle/ unhook an incidentally caught wildlife. There will be incidences where actively fished gear interacts with wildlife, but it is likely to be lower in frequency than from gear which is lost or discarded. An example of the rate of active fishing gear direct interactions/ bycatch with the line-based charter fishery is recorded by observers as a component of the RFMP survey. This study included 172 observer trips on-board 31 different charter fishing vessels operating out of 14 ports between Swansea and Narooma. Overall, 397 individual observations of seabirds were made counting a total of 3,183 seabirds in the vicinity of fishing vessels. Eleven direct interactions (where seabirds either primarily fed on discards or removed fish or bait from the hooks) and a single incidence of bycatch were recorded in over 630 h of observed fishing in the offshore charter fishery of NSW (1.74 and 0.16 per 100 h fishing, respectively); these rates were likely due to the active fishing methods used which allows fisher behaviour to minimize interactions. The only incidence of bycatch recorded was a Shearwater, which swallowed a baited hook, before being released alive after the line was cut.

Historically, spearfishing is thought to have contributed to the decline in numbers of Grey Nurse Sharks, Blue Groper and Black Rockcod in NSW (Young et al. 2014). Incidental spearing of threatened and protected species (e.g. Grey Nurse Sharks, Blue Groper and Black Rock Cod by non-compliant and inexperienced fishers has been occasionally observed along the coast of NSW (NSW DPI, compliance data). Usually, these events receive significant media attention, but the overall number of instances is expected to be low as a result of effective education and advisory campaigns.

Given the gear and methods used in the hand gathering fishery, there is negligible incidental catch of species of conservation importance.

5.2 Physical Disturbance

Physical disturbance is disturbance which directly alters or removes habitat. It can vary at spatial and temporal scales. In relation to recreational fishing, physical disturbances can include those associated with vessels or shore-based fishing.

In terms of shore-based fishing, trampling is a common source of disturbance (Hardiman and Burgin, 2010) while some harvest activities directly impact habitat (e.g. nipper harvesting) (Skilleter et al., 2005). Trampling in the intertidal zone is associated with a range of leisure activities and is not restricted to recreational fishing (Hardiman and Burgin, 2010). Physical disturbance of habitats can flow on to other components of the ecosystem including listed species of shorebirds (Zharikov and Skilleter, 2004; Skilleter et al., 2005; Minchinton and Fels, 2013; Schlacher et al., 2016; Mendez et al., 2019). While the impacts of trampling on habitats associated with recreational fishing activities has been the focus of additional empirical research overseas since the 2017 TARA (e.g. Simon et al., 2019; Garmendia et al., 2021), this research is not of direct relevance to the ranking of risks in NSW. However, in their review of recreational fishing impacts, Lewin et al. (2019) identified that the effects of trampling may be severe but locally confined, usually reversible, and comparably easy to manage on a local scale.

Physical disturbance from vessels can be associated with anchoring and mooring (Unsworth et al., 2017; Flynn et al., 2019; Broad et al., 2020) and from wash, turbulence and turbidity (Burgin and Hardiman, 2011). Consideration of the impacts from recreational boat anchoring and moorings has complexities. First, not all impacts are from boats undertaking recreational fishing. Even if boats that are attached to permanent moorings do undertake recreational fishing, it may not be the only or indeed primary activity that is undertaken. NSW DPI does not manage boating and moorings which is a matter for NSW Maritime. Although not quantified, in recent years since the 2017 TARA was published, the use of electric outboards and kayaks for estuarine and nearshore coastal fishing has likely continued to increase and these fishing platforms do not generally require anchoring while fishing.

There has been relevant additional research assessing the impacts of boat anchoring and moorings on habitats including seagrass and reefs in Australia and overseas (Unsworth et al., 2017; Glasby and West, 2018; Kelly et al., 2019; Flynn and Forrester, 2019; Broad et al., 2020). Much of this research is focussed on either commercial shipping or in coral reef environments. The former is not relevant to the consideration of recreational boating impacts as functional coral reef habitats in NSW are limited to parts of the Solitary Islands only. Commercial shipping (e.g., bulk carriers) anchor offshore and the large size of the anchors used are not comparable to those used by recreational fishers. Across all of NSW, it was estimated that currently leased moorings were causing losses of 129,884 m^2 of *Posidonia* and 93,940 m^2 of *Zostera* with this being considered an underestimate (Glasby and West, 2018). Scar size from moorings in both species of seagrass increased significantly with depth and boat length.

A follow-on impact from seagrass disturbance is an impact on the threatened White’s Seahorse. Habitats that are considered important habitat for the White’s Seahorse include sponge gardens, seagrass meadows and soft corals. In Port Stephens, over 90% of the soft coral and sponge habitats have declined at sites where the seahorse used to be abundant, mostly caused by the installation of boat moorings, boat anchors and smothering due to sand movement. A high priority action listed on the draft actions for ‘White's Seahorse Priorities Action Statement’ includes reducing the impact of public and private boat moorings on White’s Seahorse habitats.

The Cauliflower Soft Coral is a temperate soft coral species endemic to eastern Australia and listed as endangered under the *Fisheries Management Act 1994*. The largest remaining populations of the species are in Port Stephens in water approximately four to 11 metres in depth (Larkin et al., 2021a). The area of Cauliflower Soft Coral mapped in 2019 had declined by 67.5% compared to 2011 (Larkin et al., 2021a). The identified risks to the Cauliflower Soft Coral are anchor damage, sand inundation and marine debris from fishing (Poulos et al., 2013; Larkin et al., 2021a). Further unpublished information has suggested that the species is also susceptible to flooding[3]. There is scope for replanting Cauliflower Soft Coral in NSW (Larkin et al., 2021b).

5.3 Wildlife Disturbance

There are a range of activities that take place that can cause wildlife disturbance in the coastal zone (Hardiman and Burgin, 2010). Recreational fishing is a subset of the general disturbance to wildlife associated with leisure activities in the coastal zone. Disturbance from recreational fishing can come about from direct disturbance, such as noise, or indirect disturbance such as provisioning through discards or the use of burley.

Colonial seabirds, shorebirds, and waders can be affected by disturbance from fishing and general boating activity, and shore-based activities such as walking, four-wheel driving, and bait collecting. It is reported that the degree of impact from these disturbances is influenced by a number of factors such as: the number of people in the vicinity, the proximity of people to the birds, the species and the type and duration of activity they are undertaking (Hardiman and Burgin, 2010; Weston et al., 2014; Lethlean et al., 2017; Tablado and Jenni, 2017). The use of unmanned aerial vehicles (e.g. drones) is an emerging risk (Mulero-Pázmány et al., 2017; Weston et al., 2020). Excessive disturbance at beach-nesting sites, intertidal feeding grounds and high-tide roosts is reported as one of the five major threatening issues identified in relation to the conservation of waders at NSW wetlands (Smith, 1991). It has also been reported as a significant issue in other states (Schlacher et al., 2013; Weston et al., 2014).

Several studies have examined the issue of wildlife disturbance from human activity on rocky shores in the central region (Gladstone 2005; 2006, Gladstone and Sebastian 2009). The number of recreational fishers is lower than human disturbance from other recreational activities and their overall impact may be lower. However, recreational fishers can have an impact when they access remote sites adjacent to shorebird habitat or where they gather directly on foraging grounds, displacing the animals.

Disturbance of roosting or nesting seabirds and shorebirds by spearfishers accessing the water from land can disrupt nesting, increase risk of nest predation by other species, cause trampling or force migratory species into increased vigilance behaviour, which decreases feeding time (Blumstein et al. 2003). However, the overall number of spearfishers accessing the water from land is low. Excessive disturbance at beach-nesting sites, intertidal feeding grounds and high-tide roosts is reported as one of the five major threatening issues identified in relation to the conservation of wading birds in NSW wetlands (Smith 1991). In addition to spearfishing disturbance of roosting or nesting seabirds and shorebirds by hand gathering and by accessing the rocky shoreline from land can disrupt avifauna. Examples include birds moving away from the disturbances which can reduce foraging time, increase energy expenditure, and disrupt incubation leaving eggs exposed (Schlacher et al., 2013; 2016).

For shore-based activities several recent studies have examined wildlife disturbance on the NSW coast. These studies do not single out disturbance from recreational fishing, but rather consider it a subset of human disturbance in general. For example, Wooding (2019) assessed Sooty Oystercatchers in the Hunter region and determined that threats were in relation to human pressures, in general, and climate change. Totterman (2021) identified disturbance by recreational vehicles on beaches had clear impacts in northern NSW on the behaviour of Pied Oyster Catchers, however only between 5% and 16% of vehicles were associated with

[3] ww.scu.edu.au/engage/news/latest-news/2021/beautiful-rare-purple-cauliflower-coral-off-nsw-coast-may-be-extinct-within-10-years.php (accessed 9/12/21).

recreational fishing. This work on 4WD impacts builds on that which has been undertaken previously in NSW (e.g. Owner and Rohweder, 2003). 4WD access to beaches is not managed by NSW DPI.

Disturbances on marine wildlife from fishing activities include the effects of noise from fishing vessels, access to fishing sites, and the physical presence of fishers can also cause disturbance. Disturbance of dolphins is often associated with eco-tourism activities, and this has been the focus of additional research in NSW (e.g. New et al., 2020). Interactions that occur between fishing activities and marine wildlife include the effects of noise from fishing vessels, access to fishing sites, and the physical presence of fishers can also cause disturbance.

Cetaceans can vary in their response to vessel or boat noise - dolphins regularly actively approach boats to ride on bow waves and feed. However, it is reported that they can also avoid disturbance, especially if it is too lengthy, intrusive, or unpredictable. Examples of short-term responses of cetaceans to disturbance from vessel/boat activity or noise include spatial avoidance, increased dive time and swimming speed, changes in breathing patterns, group size and cohesion, and acoustic, foraging, socialising and resting behaviour (Lemon et al., 2006; Steckenreuter et al., 2011; Marley et al., 2017). All of these factors can potentially have negative cumulative impacts on individuals and populations. However, new information has suggested that the impact of these changes on individual fitness is complex and associated with characteristics specific to populations (New et al., 2020). Unlike cetacean tourism activities, boats engaged in recreational fishing do not actively pursue cetaceans and thus their pattern of disturbance is different and highly likely to be substantially less per vessel than one dedicated to dolphin or whale watching activities. In terms of acoustic disturbance from boating activities, dolphins have been demonstrated to adjust their communications based on ambient noise levels, although the impacts on individual fitness of this is unclear (van Ginkel et al., 2018).

In the NSW charter fishery, Hughes et al., (2021) recorded 3,635 individual animals across 28 species from 482 observations in the vicinity of fishing charter vessels. These were dominated by seabirds (88% of the total) and marine mammals (dolphins, whales, seals; 11%). Seabirds from seven families were observed with the most common being Shearwaters, Albatrosses and Gulls/Terns. However, only 33 direct interactions (involving 47 individuals) with the fishery were observed at a rate of 5.20 interactions per 100 h fishing. Of the 446 individual marine mammals observed in the vicinity of charter fishing vessels during the study period there were 21 direct interactions involving 30 individuals recorded at a rate of 3.31 interactions per 100 h fishing. All direct interactions recorded involved Seals (Otariidae) with 30 individuals observed primarily eating discards or depredating hooked fish. There were no recorded incidences of marine mammal bycatch observed (Hughes et al., 2021).

5.4 Marine Debris and Pollution

Marine debris, defined as discarded material present in the marine environment from anthropogenic sources, is comprised of a broad range of materials such as plastic, metal, wood and glass (Whiting, 1998). Marine debris can be considered in terms of volume and impacts on environmental assets. It enters the marine environment directly from land or from vessels via dumping, accidental loss or abandonment of fishing gear, or indirectly through storm water or rivers (Katsanevakis, 2008). Lost fishing gear such as traps and nets can continue to fish and catch both target and nontarget species leading to mortalities and this is called ghost fishing (Lively and Good, 2019). Most research to date on ghost fishing in Australia has focussed on commercial fishing gear (Wilcox et al., 2015; Hardesty et al., 2021).

The 2017 TARA, overseen by the Marine Estate Management Authority (MEMA), prioritised marine debris as a significant threat (MEMA, 2017). A marine debris threat and risk assessment (MDTARA., 2022) in NSW was subsequently undertaken as part of the Marine Estate Management Strategy and has recently been published. It has identified the following as high environmental risks:

- Microplastics
- Hard plastic fragments
- Plastic bag
- Plastic rope (and fragments)
- Fishing line
- Soft plastic remnants
- Fishing traps and pots
- Balloons
- Drinking packaging (plastic)
- Processed timber

Marine debris can directly impact animals through entanglement (Byard and Machado, 2019; Parton et al., 2019) or ingestion (Roman et al., 2019), and the Marine Debris TARA identified both these stressors as high risk in NSW. The Marine Debris TARA did not appear to differentiate between marine debris originating from commercial and recreational fishing activities. Spatially, fishing line was identified as a high risk in the southern region and a moderate risk in the central and northern region. Fishing “traps and pots” were identified as a high risk in the central region and a minimal risk in the northern and southern regions. Given the lower amount of line fishing effort in the southern region compared to the central and northern regions, it was uncertain from the Marine Debris TARA what the drivers were for this higher ranking there. Marine debris can also impact social values including the amenity and enjoyment of coastal areas and this was also assessed in the Marine Debris TARA with fishing line being the only fishing specific item identified as a high risk (MDTARA., 2022).

In terms of volume of marine debris, recreational fishing is only one of many sources, and it needs to be placed into the broader context. Nationally Tangaroa Blue’s Australian Marine Debris Database initiative identified fishing line to be a top 10 contributor to marine debris with 86,058 items being retrieved over the last two years (Tangaroa Blue., 2022). Within NSW, Smith et al. (2018) identified that on northern NSW beaches approximately half of the identifiable plastic bottles originated from passing merchant shipping. On the NSW central coast approximately 3.3% of plastic waste items were from recreational fishing[4]. An underwater based study conducted in NSW found fishing-related items (especially monofilament and braided fishing line) were prevalent at most sites (Smith & Edgar, 2014), this study also mentions the need for uniform and consistent data entry when recording items collected to improve data quality. Gacutan et al, (2022) analysed citizen science data from near shore sites, separating commercial and recreational items by size and scale and determined that 3% of items, in the temperate east zone, were from recreational fishing origin (Gacutan et al., 2022).

Watson et al. (2022) undertook a systematic review of recreational fishing marine debris. While their review identified several significant uncertainties, an important finding was that the marine debris from recreational fishing was highly concentrated at the local level in specific shallow estuarine and coastal areas, rocky ledges or uneven bathymetry. The Marine Debris TARA also identified that fishing ”traps and pots” were more concentrated at “hotspots”.

[4] Clean4ShoreAnnualReport0705v7 (stedwards.nsw.edu.au) (Accessed 15/12/21)

Watson et al. (2022) identified that it was not possible to quantify the volume of marine debris originating from recreational fishing. They also identified that local clean-ups of marine debris by angler groups could address the issue at local hotspots for recreational fishing. Dedicated fishing line recovery bins can also be effective at reducing discarding of fishing line and are well supported by anglers (Campbell, 2013).

When assessing impacts from marine debris more than just relative volumes needs to be considered as the potential for impacts (e.g., ghost fishing) on environmental assets differ based on the items present. An analysis of data from around Australia (Ceccarelli, 2009) found that discarded and active fishing gear is, by far, the largest cause of impacts on marine wildlife, and it exceeds other forms of plastic by an order of magnitude. The majority of ghost fishing incidents are in the northern waters of Australia, but northern New South Wales and the Sydney region has some of the highest reported number of incidents in Australia (Ceccarelli, 2009). This may reflect high rates of reporting in these areas by Taronga Zoo (See figure 13). However, separately, Thomson et al. (2020) identified for raptors in northern NSW and southern Queensland, the most significant source of injury was entanglement in fishing line. A recent study suggests that global estimates of marine debris may have been previously reported incorrectly and that a better understanding of the origin, the average proportion and uncertainty measure will allow for better implementation of management interventions (Richardson et al., 2021). Again, these considerations do not systematically differentiate between fishing gear lost by recreational or commercial fishers.

Fishers, both commercial and recreational, can lose their gear because of unfavourable weather conditions, bottom snags, mobile methods that inadvertently tow the gear or remove marker buoys, human error, vandalism, and gear failure (Laist 1997, Matsuoka et al. 2005). For example, in Queensland, it was estimated that a lost contemporary, collapsible trawl mesh pot will catch between 3 and 223 blue swimmer crabs per year after the bait has been exhausted (Campbell and Sumpton, 2009). The potential for ghost fishing varies for different fisheries and different gear types. Three pieces of information are needed to assess the potential impacts of ghost fishing:

- The quantity and type of gear lost
- The hazard-life of the gear (length of time that the gear is likely to continue fishing) (Jennings and Kaiser 1998, Laist 1997)
- The types of animals caught and their level of mortality.

One of the issues in determining the risk level of recreational fishing impact contributing to marine debris is that published research on wildlife entanglement tends not to discriminate between the types of marine debris that causes wildlife impact through entanglement or ingestion (Smith and Edgar, 2014). There are however several online databases where these wildlife incidences are recorded. Care does need to be taken when interpreting the results and attributing entanglements to recreational fishing gear due to commercial fishing gear and shark protection measures (shark nets) providing other sources of interaction. Some debris may also originate outside of NSW state waters. The following data sources were accessed for wildlife entanglement and ingestion data caused by recreational fishing gear:

- NPWS (National Parks & Wildlife Service) marine wildlife events database 'Elements' 2011-2021
- Data from Taronga wildlife hospital 2000- 2020 (data analysed independently and provided to DPI)
- The NSW Wildlife rehabilitation dashboard 2013-2020 (publicly accessible).

The Elements database is a reporting system for recording injured marine animals including whales, turtles, dolphins and seals. Reports include details of where the animal was found, what was wrong with the animal, what group was helping the animal and what is the status of the animal's health. Information is entered by NPWS or one of the four marine rescue and rehabilitation groups that have been working with NPWS to date (Dolphin Marine Conservation Park, Organization for the Rescue and Research of Cetaceans in Australia (ORRCA), SEA LIFE Sydney Aquarium and Sea World).

On review of the data provided from the Elements database, the total number of entanglements, potential caused by recreational fishing sourced gear, over the period 2011-2021, totalled 54, with most entanglements being of marine turtles (Figure 11). In the period considered, entanglements and ingestions were higher in 2011, 2012 and 2014 (Figure 12). All marine turtle entanglements recorded were from crabbing apparatus. All crab trap entanglements were assumed to be from a recreational fishing source; however, they could also be from commercial fishing. Ingestion of foreign material includes fishing hooks and line (again, which could potentially be from a commercial or recreational fishing source) and other objects not specifically recorded. The assumption was made for all fishing line and hooks to be of a recreational fishing source and other foreign object ingestion was excluded. The total numbers of ingestion records assumed to be from a recreational fishing source was eight over the period 2011-2021.

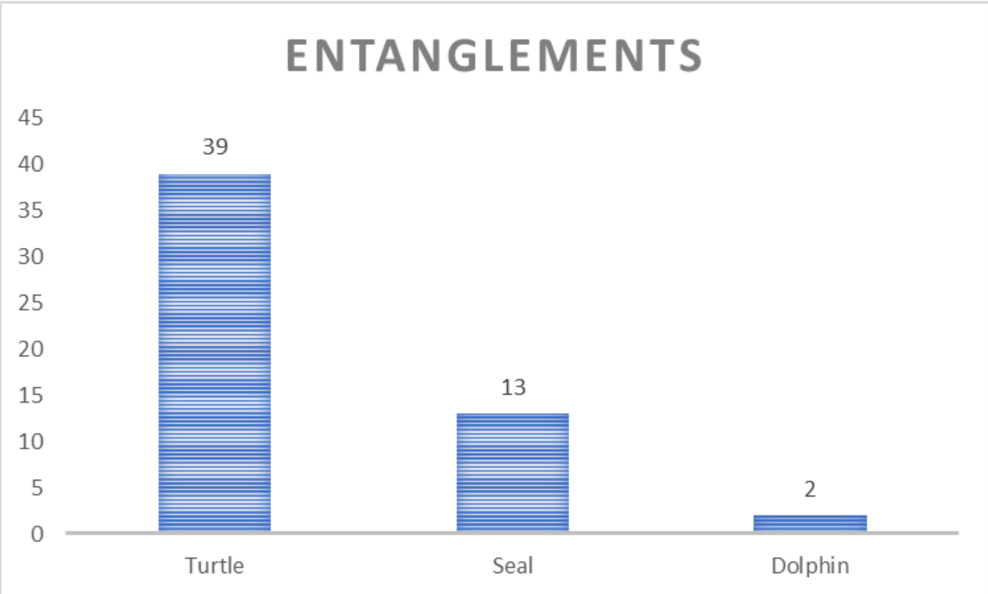

Figure 11. Total entanglements (54) from assumed recreational fishing gear across species over the entire reporting period 2011-2021 (National Parks and Wildlife Service (NPWS) Elements database).

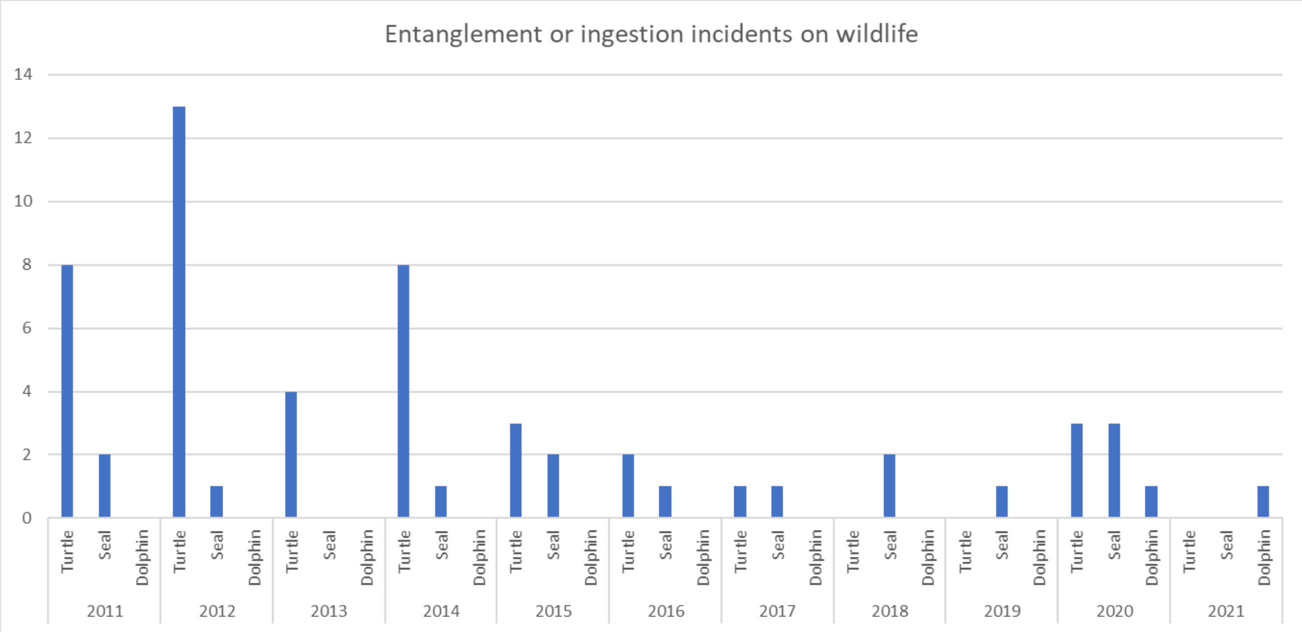

Figure 12. Trends in wildlife entanglements events and ingestion of foreign materials over the 2011 – 2021 period (National Parks and Wildlife Service (NPWS) Elements database).

A study by Papas 2021, combined internal data from Taronga wildlife hospital, Australian Registry of Wildlife Health records and Sydney Wildlife case records. The total combined dataset is 245 records from 2000-2020, with 192 birds (77%), 43 turtles (17%) and the rest (6%) made up of cetaceans, pinnipeds, lizards and "other". It was reported that the only data selected for analysis were records indicating injury to an animal as a result of 'recreational fishing' activities. This included embedded hooks, ingested fishing tackle, entanglement in fishing line and entrapment in fishing nets or crab traps. The study identified that the number of records increased over time (Figure 13). The data includes a broader mix of species, including many freshwater species as well as several terrestrial species.

Some caution needs to be taken in interpretation of these results in the current context. An analysis of the raw data demonstrated that there were likely to be multiple cases caused by commercial fishing operations, for example, many cases where fishing net was recorded, longline hook mentioned or several other instances of undetermined fishing source (recreational or commercial). It should also be considered that a proportion of the fishing line/hook injuries are likely to be from a commercial fishing source. The author also observed that the increasing trend of incidence of marine debris interaction could be related to an increase in awareness of the wildlife hospital, leading to increased presentations either by members of the public and veterinary practices.

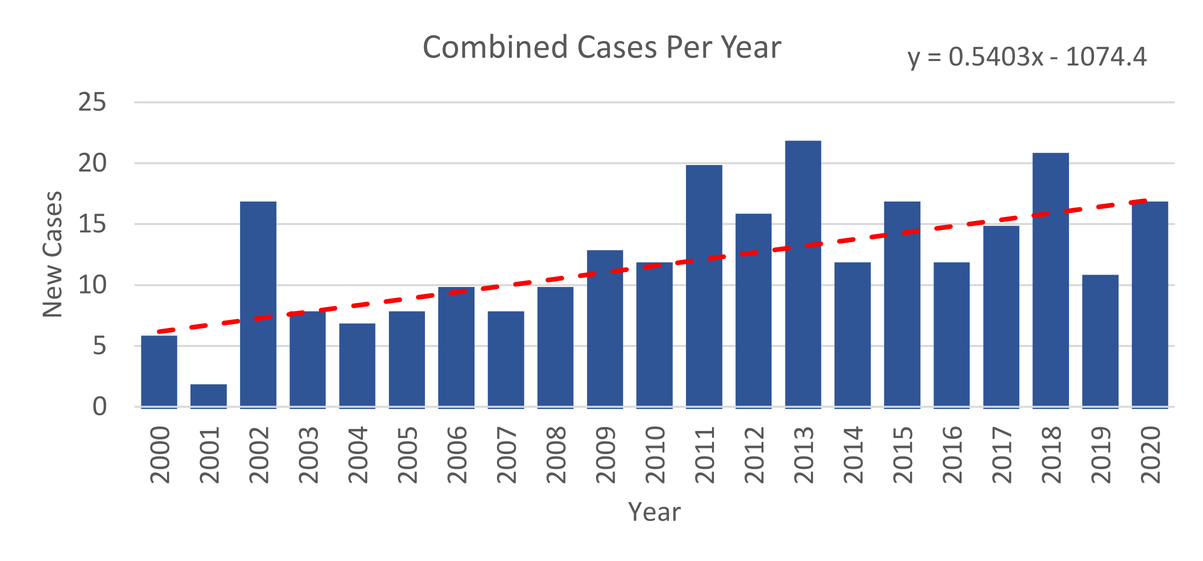

Figure 13. Trends in wildlife entanglements events and ingestion of foreign materials over the 2000 – 2020 period (Data from; Taronga wildlife hospital, Australian Registry of Wildlife Health records and Sydney Wildlife case records - From Papas, 2021).

The NSW Wildlife rehabilitation dashboard is a reporting system used by wildlife rehabilitation providers to record data throughout New South Wales. It can be used to explore trends for selected species, including threatened species. This database includes all types of wildlife. For the graphs displayed below, the data for birds only was selected and the reason for rescue; entanglement – marine debris (Figure 14). Verbal advice provided by NPWS suggested that all bird entanglements are caused by fishing line, however there are still issues with the ability to discriminate between commercial and recreational fishing line. As with all these data sources there is likely to be some cross over and duplication of records between databases.

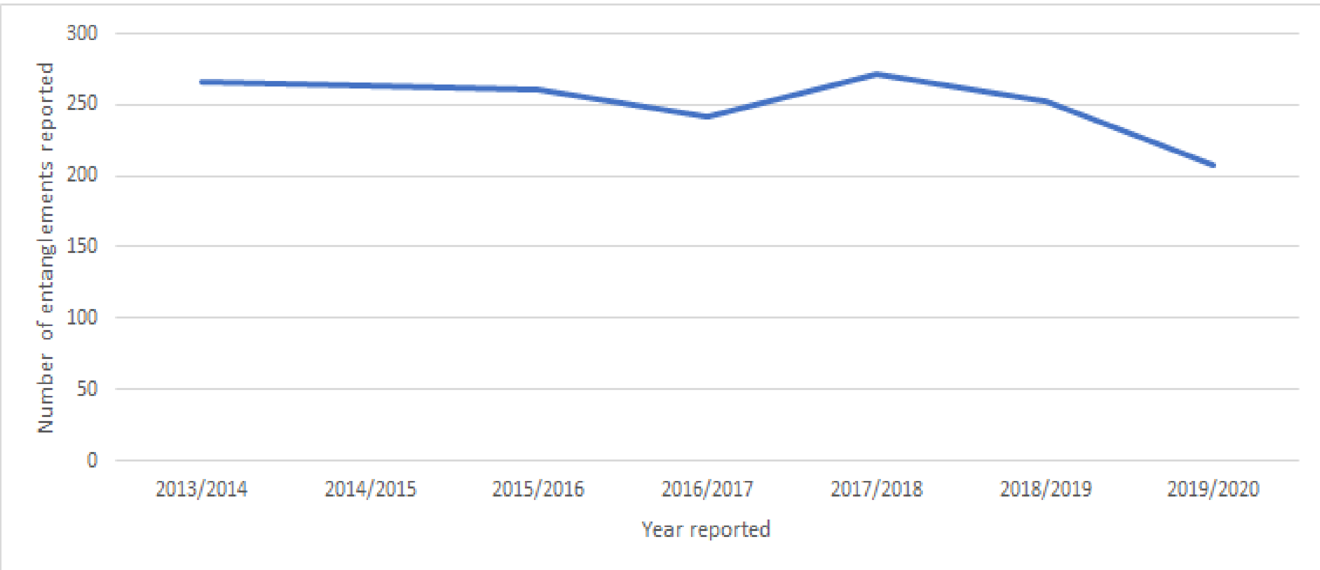

Figure 14. Bird entanglement numbers 2013 – 2020 (Data from the NSW Wildlife rehabilitation dashboard).

In terms of species impacted in the most recent reporting period, the Pelican was the most common with 93 occurrences, followed by the Silver Gull, with 63 (Figure 15). Efforts were made to eliminate records of non-recreational fishing gear, however due to the minimal level of detail required for data submissions this was not feasible. Thus, the data used is assuming all bird entanglements are caused by recreational fishing gear (fishing line), which again is highly unlikely, as commercial fishers may use the same gear in the NSW Ocean Trap and Line Fishery, and as such represents a worst-case scenario.

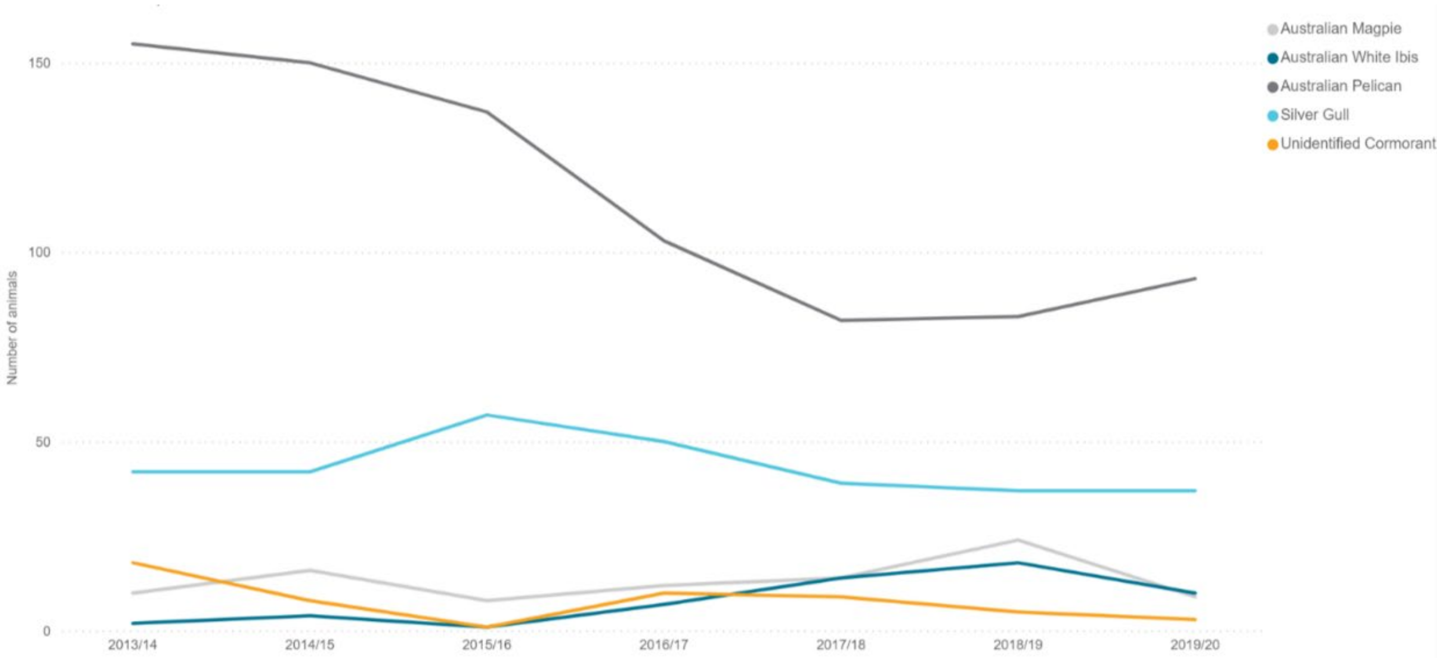

Figure 15. Bird entanglement by species (Data from NSW Wildlife rehabilitation dashboard).

The consideration of the three datasets highlights the important need to differentiate consistently between marine debris generated from recreational and commercial fishing activities. A uniform and clear process of obtaining and entering data would help ensure a thorough investigation into the source of fishing related marine debris. This would allow for a more robust analysis and attribution of the origin of debris and a clearer understanding of how recreational fishing is contributing to marine debris and wildlife incidences, thus improving specific management strategies (Smith and Edgar, 2014).

For ghost nets in northern Australia a detailed guide[5] is available to assist the local communities to identify the likely sources of material found which can assist with an evidence-based management response. Fishing stakeholders in NSW could be involved in the preparation of a similar guide to assist community members and agencies that are documenting marine debris, entanglements and ingestions with identifying the likely sources. A workshop with fishing stakeholders is planned to be held in the near future to better understand and manage marine debris from recreational fishing, including better identification of the source.

Several current considerations are relevant to differentiating marine debris from recreational and commercial fishing:

- Conventional fishing nets are more likely to be from commercial fishing practices. Recreational fishers predominantly fish with line (97%) and only a small number of

[5] Ghost Net ID Guide, Riki Gunn, Ghost Nets Australia. 2015. Accessed May. 12. 2022. Available: https://cdn.tierramar.com.au/wp-content/uploads/2022/06/16190242/Ghost-net-id-guide.pdf

recreational fishers use nets – less than 3% in freshwater/marine combined (Murphy et al., 2021). NSW regulations require all recreational fishing nets, other than crab gear, must be actively fished. The largest net that can be used is the hand hauled prawn net which can be up to 6 m in length and must be continuously and manually pulled through the water. This minimises the chance of this gear becoming marine debris.

- 'Netting' incidences may potentially be from crab nets, however the size of net panels from crab traps would be significantly smaller than conventional commercial fishing nets. Also crab traps are used in the NSW commercial fishery and could also potentially be responsible for several crab trap interactions.
- Monofilament and braided fishing line are used by both the recreational and commercial sector. Heavy monofilament leader with large hooks is more likely to be of commercial origins than thin (light) monofilament and small hooks. However, it is still hard to pinpoint the source definitively.
- Data completion is carried out by several organisations and volunteers with varied levels of experience, this can make it more challenging to ensure a uniform process of data capture, processing, and attribution of source of marine debris.

When considering microplastics in the aquatic environment and the prevalence within fish samples, Wootton et al., (2021) identified across all states in Australia, an average of 35.5% of fish samples had at least one piece of microplastic in their gastro-intestinal tract. Overall, the ingestion of microplastic was widespread across species, locations, diets and habitat niches of fish species investigated, but the average plastic ingestion was less than other similar global studies (Wooton et al., 2021).

In their study microplastics were dominated by fibres, with polyolefin being the dominant polymer group with more than 80% of plastic pieces from this source. Polyolefin is present in and likely from synthetic clothing or fishing equipment, however the specific source is not determined in this study. They identified that wastewater systems are likely to be contribute substantially to the load with grey water from the washing of clothes washing a likely significant source. Drawing on the work of Ziajahromi et al. (2017), Wootton et al. (2021) highlight that one wastewater treatment plant in Sydney discharges between 3.6 million and 460 million pieces of microplastic into the ocean daily most of which are fibres. Polyolefin is also commonly used to make fishing nets and rope, however it cannot be determined whether these fibres originated from recreational or commercial fishing but given that nets are more commonly used by commercial fishers, it is more likely that they arose from commercial fishing activities. Other studies have shown that microplastics can be up taken by planktonic organisms (e.g. Lin, 2016).

Specifically related to crabbing, Broadhurst and Millar (2017) identified how "witches hat crab nets" that target blue swimmer crabs and mud crabs can contribute to micro-debris through the loss of twine and proposed alternative configurations that can ameliorate this. Their work demonstrated that small changes to the design of the apparatus can have positive impacts on marine debris.

There are also potential impacts to the environment from lost lead weights, including ingestion by wildlife. This was reviewed by Grade et al (2019), however most of this research is associated with impacts to waterfowl in freshwater lakes internationally and as such the results are not directly transferable to marine recreational fishing in NSW. The potential impacts of lost lead weights on wildlife have not been assessed in NSW.

The primary source of marine debris associated with spearfishing is similar to that for general recreational and tourism. Loss of spearfishing equipment contributing to marine debris is minor. Lost/ discarded spearfishing is not capable of ghost fishing impacts. Spearfishers can use boats to access dive sites and can therefore contribute to boat-derived marine debris and pollution.

As with spearfishing, the primary source of marine debris associated with hand gathering methods is similar to that for general recreational and tourism. Based on the type of gear used and the fact that all the gear is only fished actively, little opportunity exists for the gear to be lost or discarded and result in any ghost fishing impacts.

Pollution

In addition to impacts from marine debris, there are three potential sources of pollution from boating activities: impacts on water quality from petroleum products, impacts on water quality from anti-foulants and air emissions. The *Marine Pollution Act 2012* (MPA) is NSW's key legislation for the regulation of marine pollution from vessels in NSW State waters. In March 2021, several changes to legislation occurred including the addition of recreational vessels and the coverage of all NSW State waters to be recognised under the MPA.

Motorboats are usually powered by either diesel or a petroleum and oil-based mixture, both of which are sometimes accidentally spilt into waterways when filling up tanks or servicing engines close to the water body. Both types of fuel emit exhaust fumes into or onto the water when the motorboat is underway. Research on the impacts of two stroke outboard engine emissions have generally focussed on freshwater environments (English et al., 1963; Surber, 1971; Brenniman et al., 1976) or on demonstrating toxicity levels in laboratory experiments (e.g., Mattos et al., 2010). The direct transferability of this research to NSW marine waters is limited. Pollutants and resuspended nutrients in marine (and estuarine) areas also have large volumes of water in which to disperse (compared to freshwater river systems) (Majamäki., (2019). Looking at the estuarine environment and using microcosm experiments, Nayar et al. (2004) found impacts from petroleum products on periphyton assemblages, however a substantial amount of the pollution detected was from port associated activities.

Antifoulants are chemical treatments used to remove growth (algae and sessile invertebrates) from boat hulls. Their use is necessary for boats permanently moored in marinas and anchorages, but not necessary for trailer boats which constitute the majority of boats used for recreational fishing in NSW. Historically, tri-butyl-tin (TBT) was widely used in NSW and elevated concentrations of the compound are frequently evident in marinas and commercial ports. Impacts on fauna including mortality of oyster spat and endocrine disruption in gastropods from TBT exposure are known (Roach and Wilson, 2009; Burgin and Hardiman, 2011). Sale and supply of antifoulants is regulated by the Australian Pesticides and Veterinary Medicines Authority (APVMA).

Airborne emissions from recreational boating can be emitted directly to the air or below the water surface and include:

- Volatile hydrocarbons (VOC) – evaporate quickly (60%) immediately (human health impacts)
- carbon monoxide (CO) – around 80% will be released into the atmosphere even if discharged underwater (petrol engines produce more), (human health impacts)
- Particulate matter – can be formed directly in combustion chamber (human health impacts)
- Nitrogen oxides – depleting ozone, attribute to acid rain
- Carbon dioxide (CO_2) – approximately 65% released to atmosphere, increases atmospheric CO_2 contributing to human induced climate change.

Advances in technology have improved engine performance to reduce emissions. The emissions of four-stroke engines into the water are less than two-stroke engines of equal power (Jüttner et al., 1995; Burgin and Hardiman, 2011). New outboard engines sold in Australia are four-stroke engines with two stroke engines no longer able to be sold.

The banning of toxic antifouling paints in many countries, including Australia, has gone a long way towards improving aquatic ecology (Whitfield and Becker, 2014).

5.5 Pests and Diseases

Marine pest and disease incursions can represent a risk to aquatic biodiversity and recreational fishing, however the risk associated with the activity of recreational fishing was not considered in the 2017 TARA. There are several vectors that allow the introduction and spread of pests and diseases in the marine environment including ballast water and biofouling associated with global shipping, marine aquaculture, deliberate release of aquarium animals, biofouling on and movements of coastal vessels, and the use of imported animals for bait (Hutchings, 2007; Morrisey et al., 2011; Knibb et al., 2018; Hayes et al., 2019). Table 17 details marine pests of relevance to NSW.

Marine pests can have severe ecological and economic impacts. For example, they can take over large areas of habitat to the detriment of native species. Some prey directly on native species or compete with them for food. Pest species can also cause considerable economic damage. Infestations of marine pests can impact on marine industries, such as aquaculture, commercial and recreational fishing and boating, tourism, and even international and domestic shipping. Some marine pests, such as toxic dinoflagellates, can threaten public health.

For recreational boating, biofouling occurs when aquatic organisms (including microorganisms, plants and animals) attach and grow on surfaces submerged in or exposed to the marine environment, including the hull and niche areas (for example, sea chests, rudders, propeller shaft, internal piping, anchor boxes, anchors, ropes, buckets) of boats. Vessels that have biofouling can unintentionally transport invasive plant and animal pest species within the marine environment. Biofouling on vessels can reduce fuel efficiency and speed and increase maintenance costs to vessel owners. In terms of recreational fishing, risk is not generally associated with pests being brought into the country, but rather their translocation once they have arrived.

The NSW Marine Pest Surveillance Plan (2022 – 2026) identifies several species to be included in 'passive surveillance' activities. These species have generally been identified or are known to be established in NSW and are included in the surveillance plan to engage with a range of stakeholders to monitor any spread. Due to their occurrence in NSW, there is an increased risk of translocation of these marine pests by recreational boat fishers (See Table 17). Recreational fishing is only one subset of recreational boating activities. Biofouling as a risk is only related to recreational boat fishing and possibly, in some circumstances, land-based trapping in gear that is not inspected or maintained.

Australia has a National System for the Prevention and Management of Marine Pest Incursions and the Commonwealth *Biosecurity Act 2015*, but states and territories have specific roles as well. NSW has its own *Biosecurity Act 2015* which identifies prohibited matters, outlines emergency responses and details biosecurity management actions. NSW DPI is involved in the implementation of the national *Marine Pest Plan 2019-2023* and the *NSW Marine Pest Surveillance Plan*. These plans aim to prevent the introduction and translocation of introduced marine species (by managing ballast water, biofouling and other vectors), strengthen the marine pest surveillance system at national and state levels (respectively) provide emergency preparedness and response capacity for outbreaks, support research and development and engage with marine pest stakeholders.

There are national guidelines established by the Marine Pest Sectoral Committee (MSPC, 2021) for managing biofouling of recreational boats that have been developed to assist recreational vessel owners and operators reduce the risk of spreading marine pests. These guidelines outline good maintenance techniques and recommend having effective antifouling (MPSC, 2009). As part of the Marine Pest Plan 2019-2023, NSW DPI is also implementing a passive surveillance program which is observer-initiated. For example, if a recreational fisher spots an unusual animal and reports it, or field researchers sampling for a scientific research project incidentally detect a recognised pest. Passive surveillance from marine industry sectors and the wider public can play an integral role in marine biosecurity. Furthermore, information and data sharing between stakeholders can lead to more complete surveillance of intelligence information. (MPP, 2022).

Table 17. Marine Pests that are identified as posing a risk to the NSW Marine Estate (Modified from The Marine Pest Surveillance Plan (Cardno, 2022)

Type of Organism	Common Name	Scientific Name	Comments
Bivalve mollusc	Asian clam	*Potamocorbula amurensis*	Not yet recorded in Australia.
Bivalve mollusc	Asian bag mussel	*Musculista senhousia*	Found in WA, SA, Vic and Tas. Not yet recorded from NSW.
Bivalve mollusc	Asian green mussel	*Perna viridis*	Not established in Australia but incursions have occurred in Qld that were successfully controlled. Not yet recorded from NSW.
Bivalve mollusc	Black striped mussel	*Mytilopsis sallei*	Not established in Australia but an incursion occurred in the NT that was successfully eradicated. Not yet recorded from NSW.
Bivalve mollusc	Pacific oyster	*Magellana gigas*	Deliberately introduced for marine aquaculture in WA, SA, Vic and Tas. Spread to NSW and cultivated in Port Stephens. Recognised by legislation as a noxious pest in NSW outside of Port Stephens.
Bivalve mollusc	*Soft shell clam	*Mya japonica*	Known from eastern Tasmania. Not yet recorded from NSW.
Gastropod mollusc	*NZ screwshell	*Maoricolpus roseus*	Known from Vic, Tas and NSW. In NSW it is known from Twofold Bay and the continental shelf from Merimbula to Bermagui. It is found in depths from 1 to 130 metres.
Gastropod mollusc	Rapa whelk	*Rapana venosa*	Not yet recorded in Australia.
Gastropod mollusc	Slipper limpet	*Crepidula fornicata*	Not yet recorded in Australia.
Finfish	*Yellowfin goby	*Acanthogobius flavimanus*	First detected in Australia in Botany Bay and Port Jackson in the early 1970s. Since that time, they have also been reported in the Hawkesbury and Hunter River estuaries. Its populations remain low in NSW (Middleton, 2006)

Finfish	*Japanese goby	*Tridentiger trigonocephalus*	Known from WA, Vic and NSW. Locations in NSW include Sydney Harbour and Port Kembla. Not a species that has any recreational fishing significance.
Algae	*Caulerpa	*Caulerpa taxifolia*	First found in NSW in 2000 and is known to have spread to a total of 14 NSW estuaries or lakes, from Lake Macquarie south to in the Wallagoot Lake.
Algae	Japanese seaweed	*Undaria pinnatifida*	Known from Tas and Vic. Not yet recorded from NSW.
Algae	*Red algae	*Grateloupia turuturu*	Recorded from Botany Bay (NSW).
Crustacean	Asian paddle crab	*Charybdis japonica*	One recorded from SA. Not yet recorded from NSW.
Crustacean	Asian shore crab	*Hemigrapsus sanguineus*	Detected in Vic in 2021. Not yet recorded from NSW.
Crustacean	Brush clawed shore crab	*5.5.1.1* Hemigrapsus takanoi	Not recorded in Australia
Crustacean	Chinese mitten crab	*Eriocheir sinensis*	Not recorded in Australia
Crustacean	*European shore crab	*Carcinus meanas*	Records of occurrence in many estuaries and lakes in the southern region.
Polychaete	*European fan worm	*Sabella spallanzanii*	Occurs in NSW (Twofold Bay and Botany Bay).
Ascidian	*Non-native sea squirt	*Botrylloides giganteum*	May have been Identified from Georges River (NSW).

Species marked with * are species identified as included in “passive surveillance activities” under the NSW Marine Pest Surveillance Plan (2022-2026).

Of the pest species listed in Table 17, the invasive algae *Caulerpa taxifolia* has been spread by recreational boating activities. *Caulerpa taxifolia* established itself in NSW in the early 2000s and has now spread to at least 14 estuaries. The algae can be inadvertently spread by water users, including recreational fishers, by transportation of fragments that remain viable for a period of days (West et al., 2009).

There are specific protocols in NSW under biosecurity legislation regarding the need for the public to promptly notify NSW DPI of an occurrence of a pest species or disease and guidelines to minimise the spread. In 2015 a DPI risk assessment regarding *Caulerpa taxifolia* in NSW identified the following:

- Management should focus on minimising spread from affected estuaries.
- Populations are known to increase and decrease without human intervention and in response to natural environmental fluctuations such as wading birds, water currents, wind, waves, and tides.
- Populations may disappear by natural means.

While there were initial concerns regarding the potential impacts of *Caulerpa taxifolia* on seagrass beds in NSW (Montefalcone et al., 2007), later information suggested that the risk was lower than initially thought. Glasby (2013) identified that there is no evidence that the species is driving the loss of native vegetation in NSW nor does it appear to be preventing the recovery of the native vegetation.

Disease causing organisms can also have severe impacts and surveillance and reporting for disease causing organisms is fundamentally important for early detection, demonstration of Australia's disease status and market access for agriculture products (including seafood). It also underpins many aquatic animal health management decisions on issues such as regional biosecurity, translocation and management of on-farm disease risks. Australia's aquatic animal disease surveillance and reporting system comprises components to:

- require domestic and international reporting of aquatic animal diseases
- coordinate national active and passive surveillance programs
- provide field and laboratory diagnostic resources.

State and territory biosecurity authorities report quarterly to the Department on the disease status of diseases listed on the National List of Reportable Aquatic Diseases. There is an identification guide for aquatic animal diseases in Australia[6].

Imported farmed prawns are known to carry a range of diseases including white spot syndrome virus (WSSV) (Knibb et al., 2018). A highly plausible pathway for the entry of WSSV into the marine environment of south-east Queensland was the use of imported infected prawns meant for human consumption for bait by recreational fishers (Knibb et al., 2018). White spot may have consequences for some species of recreational importance, as all decapod crustaceans (order Decapoda) are considered susceptible to infection, including prawns, lobsters and crabs from marine, brackish or freshwater environments. An epizootic of Australian Pilchards in the 1990s with approximately 70% mortality (Gaughan et al., 2008) was associated with the introduction of a herpes virus most likely introduced via tuna feed for aquaculture (Jones, 2000).

The National Policy Guidelines for Translocation of Domestic Bait and Berley breaks down the main risks of disease translocation through bait. In Australia, live finfish, crustaceans, molluscs, and annelids are used as bait. Live bait presents a higher exposure risk compared to other bait categories because the animals may escape or be released into the receiving waterway, remain alive, and expose aquatic animal populations to pathogens of concern over an extended period.

Crustacea are a popular source of bait and are known to harbour a range of viral, bacterial and other diseases (Diggles, 2011). Finfish and invertebrates are widely used as bait throughout Australia, where they are used on hooks as live, fresh dead or cut baits to attract a wide variety of predatory and scavenging species of fish. It also includes the regional movement of bait at a local scale by fishers collecting their own bait . The risk of pathogen survival (and in some cases multiplication) would appear to be higher in freshly dead whole bait than frozen bait (Goodwin et al cited in Diggles, 2011). As most fresh dead bait is collected by fishers for their own use, data on use patterns and volumes is limited and quantifying risks may involve higher uncertainties. However, transmission of viruses from frozen bait products to the wild can occur (Nunan et al, 1998).

Managing the risk includes ensuring that imported seafood products are adequately screened at the border for disease and promotion of educational and awareness approaches that reduce or eliminate the use of bait that has the potential to carry disease into the marine environment and other techniques that limit disease transfer.

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[6] Aquatic animal diseases significant to Australia: identification field guide 5th edition. Department of Agriculture, Water and the Environment. 2020. Accessed: May. 25th. 2022. Available: https://www.agriculture.gov.au/sites/default/files/documents/field-guide-5th-edition.pdf

5.6 Climate Change and Recreational Fishing

Climate change is a global phenomenon that is occurring in concert with the other environmental stressors of varying temporal and spatial scales. The recreational fishing focused stressors are described below (Fig 16). Assessment of climate change risk has not been included in the risk matrix due to a mismatch of the scale of the issue relative to the recreational fishing methods considered, environmental values and the complexity of the issue.

Recreational fishing can contribute to climate change through emissions and product consumption. Recreational fishing can also be impacted by climate change through changes in the distribution and abundance of target species and their habitats (e.g., Gillanders et al., 2011; Davis et al., 2020). However, the potential impacts are substantially more complicated due to the inter-relationship of many variables (Fig 16).

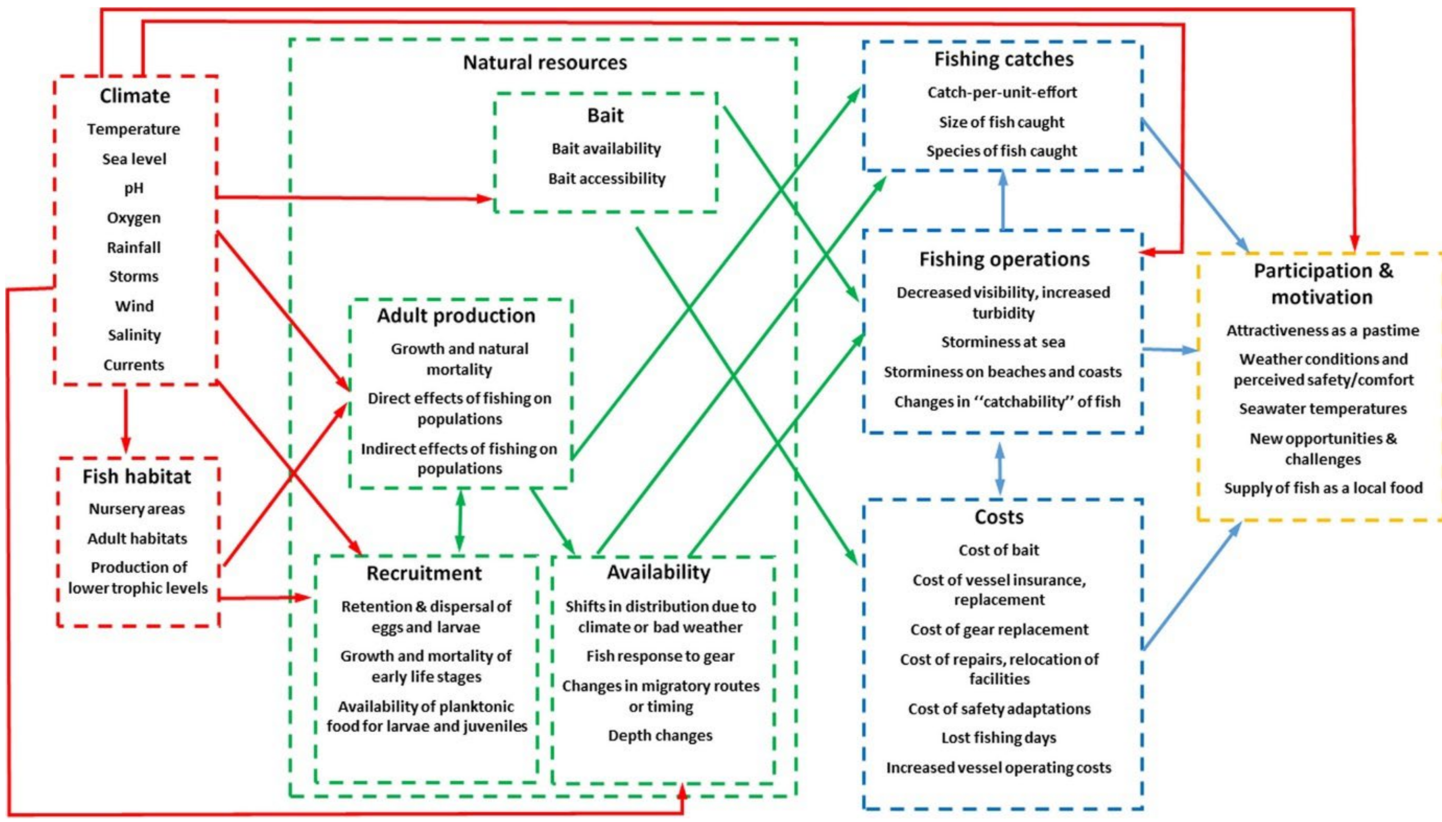

Figure 16. The pathways by which each aspect of marine recreational fishing can be affected by climate change, from the climate drivers, to changes in natural resources, catches, fishing operations, costs and fisher behaviour. (Source: Townhill et al., 2019).

Recreational fishing takes place in a global environment during a time when the impacts of climate change from industrial emissions are increasingly being recognised. Reduction of carbon emissions are required globally and the recreational fishing sector is expected to limit its carbon emissions as part of its public responsibility. Like the general public and tourists, recreational fishers contribute to the level of CO_2 in the atmosphere through car and boat travel generating a carbon footprint. Previous calculations undertaken for the Assessment of the Social and Economic Impacts of Recreational Fishing on Other User Groups in NSW (BMT 2021) identified that the contribution to the carbon footprint of NSW passenger vehicles by recreational fishing is less than 1% of all passenger vehicle kms annually, with 0.5% being a reasonable adjusted figure (40% of recreational trips kms, 60% other leisure, touring and marine recreation). In the absence of recreational fishing, other activities would be likely substituted. The emerging national trend towards less carbon emitting vehicles, electric cars and outboards should reduce the carbon emissions from vehicles and vessels in NSW in the coming decades with benefits to the environment accruing at a future date.

Impacts of climate change on recreational fisheries in Australia (including NSW) has been the focus of several studies. In Tasmania, 45 species of coastal predatory reef fish, representing 27 families (about 30% of the inshore fish families occurring in the region), exhibited major distributional shifts thought to be climate related (Last et al., 2011). Climate change impacts may also lead to local and regional increases or decreases in species abundance Creighton et al. (2013) assessed the potential for impacts on key recreational species nationally. For species relevant to recreational fishing in NSW, they identified the following:

- Although uncertainties exist, Dusky Flathead are likely to be resilient to climate impacts.
- A likely decrease in the range and abundance of Black Bream principally as a result in changes in rainfall patterns and availability of suitable habitat.
- A likely increase in the range and abundance of Mahi Mahi (as a result of increased oceanic water temperature for longer periods of the year.)
- A likely increase in the abundance and range of Yellowtail Kingfish, although these impacts are likely to occur in other Australian states (e.g. Victoria and Tasmania)[7].

Climate change will require various adaptation strategies from recreational fishers and the willingness and ability to implement such strategies is variable (van Putten et al., 2017). Fisheries management is also required to adapt to changing distributions of desired recreational target species (Frusher et al., 2014).

6 Key Knowledge Gaps

A multitude of interactions between recreational fishing and the environment of NSW are evident. Despite the evidence described above, the quantification of these impacts in NSW, and elsewhere, is limited due to the amount of scientific research that has been conducted in the specific contexts. There are some areas that need further attention to improve our knowledge on the scale of the impact and ultimately enable improved decision making regarding whether a targeted management response is required and what actions would be most beneficial.

The issue of degraded water quality in the immediate areas around cleaning stations utilised by recreational fishers is one area where there is currently limited evidence and has been raised as an area of concern. Currently only some anecdotal evidence exists regarding water quality impacts mostly associated with numbers of fish frames and carcasses seen in the water surrounding cleaning tales and associated social concerns regarding this raised during busy fishing periods. Further investigation of this issue could enable establishment of the scale of water quality impacts from cleaning stations and whether any additional management is required to minimise those impacts recorded.

There is a clear issue around the identification of sources of marine debris. Current beach litter protocols have some limitations with respect to collecting information that can be used to understand the sources of litter and identify appropriate management measures. An example

[7] Champion et al. (2018) identified that core oceanographic habitat for Yellowtail Kingfish from eastern Australia has shifted poleward at a rate of 94.4 km/decade in response to climate-driven changes in regional oceanography.

is the category “nets”, that does not differentiate between the types of fishing nets found, nor whether these are lost or discarded or likely from recreational or commercial fishing sources.

There are currently some online tools used for marine debris identification, including for ghost nets in the Northern Territory. With the large amounts of marine debris identification and reporting being conducted through citizen science, this is an area that protocols, and identification material could be developed when classifying marine debris fishing gear in NSW.

In relation to fauna and recreational fishing marine debris, there is an obvious risk involving fishing line across the entire coast of NSW. The risk is likely to vary spatially across the state, however as this study does not involve a detailed analysis of the spatial location and behaviours of the greatly varied species of wildlife vulnerable to entanglement or ingestion of fishing related debris, the risk is considered to be similar across all three regions as various species interactions occur across all of them. In most cases it is also not known whether the entanglements or ingestions have occurred from actively fished gear, passively set gear or from lost/ discarded gear. Even with this incomplete understanding of recreational fishers and marine debris contribution there is an obvious need for focussed management responses to address the specific risks it poses.

The identification of these knowledge gaps is integral to the process of risk assessment. The development of strategies to fill these knowledge gaps in the future will enable a better overall understanding of risk and enable consideration of practical and achievable management strategies to mitigate risk from recreational fishing impacts.

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Appendix 1 – Glossary of terms

TERM	DESCRIPTION
Activity	Something occurring in the marine environment. This may be a community benefit and/or a threat to an environmental asset, for example, Shore based line fishing, Boat based trapping.
Artificial Reef	Artificial reefs (ARs) are utilised world-wide to enhance fishing opportunities, by creating additional habitat for local aquatic organisms and fish. The NSW DPI artificial reef program builds artificial reefs to enhance recreational fishing. Innovative and state of the art reef designs are used to deflect currents to create eddies and upwellings to provide intricate habitats for a variety of fish species.
Consequence	The result of something happening, including a change in circumstances affecting objectives. It can be certain or uncertain and have positive or negative effects on objectives. A consequence can be expressed qualitatively or quantitatively.
Cumulative impact, threats or risks	The impact (positive or negative) resulting from the effects of one or more impacts, and the interactions between those impacts, added to other past, present and reasonably foreseeable future pressures.
Ecological	The relationship between organisms and their environment.
Effect	A deviation from the measured status. Effects can be positive or negative.
Environmental Asset	The natural attributes, components and living resources of the marine estate for example habitat (e.g. beaches or rocky shores) or threatened species.
Environmental benefit	Benefits derived by the community from an environmental asset.
Evidence	Relevant and credible information sources relating to threats and risks (environmental, social or economic) such as scientific research or reports, unpublished data/research or supporting background reports.
Impact	The outcome of the direct or indirect effect of activities and natural events on the assets or values of the environmental, social or economic components (i.e. pressure + response).
Key stressors	These are stressors that are responsible for impacts on environmental assets and related risks to community benefits e.g. an activity such as storm water discharge can adversely impact environmental assets through several key stressors, such as water pollution, marine debris and sediment contamination.
Key Threatening Process (KTP)	A threatening process is defined as a key threatening process if it threatens or may threaten the survival, abundance or evolutionary development of a native species or ecological community.
Likelihood	The chance of something happening.
Quality of Evidence	A rating of the quality of available evidence e.g. adequate, limited or inferred to convey the level of confidence in the knowledge and deal with uncertainty and/or absence of evidence.
Region	The section of NSW that the TARA has been applied to. The Northern region is from the Queensland border to Stockton, Central region from Stockton to Shellharbour and Southern region from Shellharbour to the Victorian border.
Stock Status	Within the Status of key Australian fish stocks reports, the term 'stock' is used generically in reference to three levels of stock status assessment—biological stocks, management units and populations assessed at the jurisdictional level.

Appendix 2 – Key Fish Species List

Common Name	Scientific Name	Common Name	Scientific Name
Abyssal Spiderfish	*Bathypterois longipes*	Cobia	*Rachycentron canadum*
Albacore	*Thunnus alalunga*	Cockles	*Aroida and Veneroida*
Angel Sharks	*Squatina Spp.*	Common Jack Mackerel	*Trachurus declivis*
Atlantic Salmon	*Salmo salar*	Common Silverbiddy	*Gerres subfasciatus*
Australian Anchovy	*Engraulis australis*	Crimson Banded Wrasse	*Notolabrus gymnogenis*
Australian Bass	*Macquaria novemaculeata*	Conjevoi	*Pyura stolonifera*
Australian Bonito	*Sarda australis*	Cuttlefish	*Sepia spp.*
Australian Sardine	*Sardinops sagax*	Dart	*Trachinotus spp.*
Australian Sawtail	*Prionurus microlepidotus*	Diamond Fish	*Monodactylus argenteus*
Banded Morwong	*Cheilodactylus spectabilis*	Dog Fish	*Squaliformes*
Banded Rockcod	*Epinephelus ergastularius*	Dusky Flathead	*Platycephalus fuscus*
Bass Groper	*Polyprion moeone*	Eastern Australian Salmon	*Arripis trutta*
Beachworms	*Onupidae*	Eastern Blue Devil Fish	*Paraplesiops bleekeri*
Bigeyes	*Priacanthidae*	Eastern Blue Groper	*Achoerodus viridis*
Bigeye Tuna	*Thunnus obesus*	Eastern King Prawn	*Melicertus plebejus*
Black Bream	*Acanthopagrus butcheri*	Eastern Pig Fish	*Bodianus unimaculatus*
Black Cod	*Epinephelus daemelii*	Eastern Red Scorpionfish	Scorpaena jacksoniensis
Blacklip Abalone	*Haliotis rubra*	Eastern Rock Lobster	Jasus verreauxi
Black Lizardfish	*Bathysauropsis gracilis*	Eastern Sea Garfish	Hyporhamphus australis
Blue Mackerel	*Scomber australasicus*	Eastern School Whiting	*Sillago flindersi*
Blue Shark	*Prionace glauca*	Estuary Perch	*Macquaria colonorum*
Blue Warehou	*Seriolella brama*	Feelerfish	*Bathypterois longifilis*
Bluefish	*Girella cyanea*	Flounders	*Pleuronectidae & Paralichthyidae*
Blue-eye Trevalla	*Hyperoglyphe antarctica*	Frigate Mackerel	*Auxis thazard*
Bluespotted Flathead	*Platycephalus caeruleopunctatus*	Gemfish	*Rexea solandri*
Boarfish	*Pentacerotidae*	Ghost nipper	*Trypaea australiensis*
Brown Tiger Prawn	*Penaeus esculentus*	Ghostsharks	*Chimaemriformes*
Bugs	*Ibacus spp.*	Giant Mud Crab	*Scylla serrata*
Butterfly Perch	*Caesioperca lepidoptera*	Eastern School Whiting	*Sillago flindersi*
Catfish	*Siluriformes*	Estuary Perch	*Macquaria colonorum*

Feelerfish	*Bathypterois longifilis*	Sea Mullet	*Mugil cephalus*
Flounders	*Pleuronectidae & Paralichthyidae*	Sergeant Baker	*Hime purpurissatus*
Frigate Mackerel	*Auxis thazard*	Shortbill Spearfish	*Tetrapturus angustirostris*
Gemfish	*Rexea solandri*	Silver Trevally	*Pseudocaranx georgianus*
Ghost nipper	*Trypaea australiensis*	Skipjack Tuna	*Katsuwonus pelamis*
Ghostsharks	*Chimaemriformes*	Snapper	*Chrysophrys auratus*
Giant Mud Crab	*Scylla serrata*	Spanish Mackerel	*Scomberomorus commerson*
Goatfish	*Mullidae*	Spotted Mackerel	*Scomberomorus munroi*
Goldspotted Rockcod	*Epinephelus coioides*	Southern Maori Wrasse	*Ophthalmolepis lineolata*
Goldspot Mullet	*Liza argentea*	Tailor	*Pomatomus saltatrix*
Gummy Shark	*Mustelus antarcticus*	Tiger Flathead	*Neoplatycephalus richardsoni*
Halfbanded Seaperch	*Hypoplectrodes maccullochi*	Tiger Shark	*Galeocerdo cuvier*
Hapuku	*Polyprion oxygeneios*	Tripodfish	*Bathypterois grallator*
Longspine Flathead	*Platycephalus grandispinis*	Yellowfin Bream	*Acanthopagrus australis*
Luderick	*Girella tricuspidata*	Yellowfin Tuna	*Thunnus albacares*
Mado	*Atypichthys strigatus*	Yellowtail Kingfish	*Seriola lalandi*
Mahi Mahi	*Coryphaena hippurus*	Yellowtail Scad	*Acanthopagrus australis*
Mako Shark	*Isurus oxyrinchus*		
Marlin (Black)	*Makaira indica*		
Marlin (Blue)	*Makaira mazara*		
Marlin (Striped)	*Tetrapturus audax*		
Morwong (Grey)	*Nemadactylus douglasii*		
Morwong (Jackass)	Nemadactylus macropterus		
Morwong (Red)	*Cheilodactylus (Morwong) fuscus*		
Mulloway	*Argyrosomus japonicus*		
Ocean Jacket	*Nelusetta ayraud*		
Pearl Perch	*Glaucosoma scapulare*		
Pink Ling	*Genypterus blacodes*		
Redfish	*Centroberyx affinis*		
Rock Blackfish	*Girella elevata*		
Sand Flathead	*Platycephalus bassensis*		
Sand Whiting	*Sillago ciliata*		