Creating a world class Marine Protected Area system

Getting New South Wales back on track

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Written by

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Back cover image: Hawksbill turtle, Broughton Island © John Turnbull

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ACKNOWLEDGEMENT OF COUNTRY: The Australian Marine Conservation Society acknowledges the sea country management and custodianship by Aboriginal and Torres Strait Islander Traditional Owners of NSW, whose rich cultures, heritage values, enduring connections and shared efforts protect our oceans for future generations. We pay our respects to their Elders, both past, present and emerging leaders. We acknowledge that NSW was and always will be Aboriginal land and sea.

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Foreword

Valerie Taylor AM
Knight of the Order of the Golden Ark | Luminary ocean preservationist

I was first introduced to the marine world along the NSW coast in the late 1950s. It was a paradise of marine animals both large and very small.

I was invited to join the St. George spearfishing club where I eventually became the Australian Ladies Champion (something I am not proud of but will help explain the reason I am writing this foreword).

I was also seeing hundreds of beautiful dead fish lying on the grass at a spearfishing 'weigh in' that caused myself and my husband Ron Taylor (deceased) to walk away from the spearfishing. We were both still at the top of the game. We walked away champions knowing we would never engage in the blood sport of indiscriminate killing for fun again.

We became marine conservationists. Since then, I have been campaigning for greater protection of our marine environment. The present protection in NSW is totally inadequate. Reefs that were once a kaleidoscope of wonderful creatures are now compared to their former abundance almost devoid of fish life. Overfishing has taken a terrible toll.

It is only old time 'spearos' like myself who know the true extent of what our precious marine world has lost. I sometimes think I am the only diver left from the 1950s, the only one left to tell how rich it once was.

Being underwater filmmakers, Ron and myself, worked the NSW coast with our cameras, always looking for the rare, beautiful and exciting. There was not a reef or offshore island we did not visit several times a year. We could see the depletion of mainly fish and crayfish happening at a frightening pace.

Today, no young diver or snorkeler can ever know how magnificent the life around the NSW reefs and Islands used to be. Shelly Beach near Manly is perhaps one of the best examples of NSW marine life left, but even here, to my eye, there is a great deal missing.

Shallow reefs attached to headlands easily accessible to young snorkelers should be made educational no-take zones. We owe it to our country, our ocean, and our children.

I know it is important for young people to experience the excitement and wonder that greeted me when I first visited our then pristine reefs so long ago.

We need marine 'Totally Protected' sanctuary zones. Areas where reef fish can live and breed in safety. Even present-day marine parks along the NSW coast have their protections wound back and are sad barren places in my eyes, compared to their former richness I saw. Marine parks offer partial and total protection zones — we must do more to cherish the most valuable parts, the 'Totally' protected reefs, weeds, and kelp beds.

I have had success in having different marine animals protected, including the beautiful Grey Nurse Shark, a great money maker as a tourist attraction. It remains critically endangered due to fishing in their gutters where during the day they rest in groups waiting for darkness to go out hunting. This peaceful shark is the first in the world to be protected by law. It is important that all their habitats are totally protected. There is no sense protecting the tiger if you don't protect the jungle. The same applies to the liquid world we call the ocean. We all need a place to live, love and breed.

Executive Summary

NSW enjoys a biodiverse coastal marine environment which supports a unique mix of tropical and temperate species.

The NSW Government has an opportunity to better protect this biodiversity by correcting past neglect of the NSW Marine Protected Area (MPA) system and returning NSW to its world class reserve system. The report begins by setting out a strong science case for the importance and value of the NSW MPA network, then discusses flaws in NSW's MPA planning process and makes recommendations for the future.

In 2013 and 2019, the NSW Government downgraded 36 sanctuary zones (SZs) across the NSW MPA system. These downgrades set a dangerous precedent where best-practice and scientific input were not fully employed. We argue that restoration, retention, and expansion of SZs are critical — they are key to local maintenance of biodiversity and fish populations, and essential longshore pathway stops for fish dispersal.

This report will detail the evidence that SZs are key biodiversity safeguards and of additional benefit to adjacent fisheries (commercial and recreational), and so removing them is a threat to the NSW's marine environment. Apart from local value, SZs act as "stepping stones" for larval and adult longshore connectivity, so removals may disrupt this process. SZs have been conclusively shown to enhance biodiversity especially of fishes, particularly exploited fishes (which are often very important in food webs). SZs are also of social and economic value, including places where swimmers, divers, snorkelers, tourists visitors can enjoy a high quality marine environment.

We share key recommendations to assist government efforts to create a world class MPA reserve system. These will ensure marine parks (especially SZs) are well supported to give maximum biodiversity benefit, providing additional enhancement to recreational user value, including for fishing, tourism, and general nature appreciation. We recommend a process be in place to prevent non-scientific removal of SZs, as has happened previously, as well as supporting adequate enforcement and scientific performance-testing of their values.

Red scorpionfish, Jervis Bay © John Turnbull

The NSW story from a Founding Father of MPAs

One might say the history of the planning and establishment of a Comprehensive, Adequate and Representative (CAR) system of MPAs for NSW has been a long and chequered one. One of the main jurisdictional problems here has rested in the fact that historically NSW National Parks and Wildlife Service (NPWS) retained the primary responsibility for, and expertise in, the conservation of (mainly terrestrial) biodiversity throughout the state, while NSW State Fisheries (NSWSF, since incorporated into the Department of Primary Industries, DPI) had full responsibility for, and a highly developed expertise in, the conservation of all of the state's aquatic fauna and flora, (except for aquatic birds and mammals which remained the responsibility of the NPWS). "Fish", as defined under the previous NSW Fisheries and Oyster Farms Act 1935, thus comprised just about anything — other than birds and mammals — that lived, or "swam", in the state's waters. This jurisdictional problem delayed the initiation of any substantial work on an effective CAR MPA system.

During a short period in the early 1970s, both of the above government departments were located together in the same ministry, creating an opportunity for the relevant scientific and management officers of both departments, including myself in NSWSF as the Principal Research Scientist (Fish Ecology and Conservation) at the NSW Fisheries Research Institute, to successfully work together on a broad MPA endeavour.

This work was possible, thanks to our Environmental Studies team at NSWSF, which had previously begun to carry out surveys, including underwater diving surveys, of all of the "jewels in the crown" amongst the most highly regarded (e.g. by both divers and our fellow marine biologists) and other known high biodiversity marine sites throughout the entire NSW coastline. These surveys first resulted in the creation of a number of relatively small Aquatic Reserves by NSWSF over the following decade. (Due to jurisdictional difficulties, they couldn't be called Marine "Parks" at the time). These Aquatic Reserves were established at Julian Rocks (in Byron Bay; since incorporated into the Cape Byron Marine Park), Long Reef (on Sydney's Northern Beaches), North Harbour (near Manly), Towra Point (in Botany Bay), Shiprock (in Port Hacking) and Bushrangers Bay (near Shellharbour). During this time, survey and planning work was also carried out in preparation for the creation of a number of much more extensive MPAs, which were initially planned for the Solitary Islands, Jervis Bay and Lord Howe Island.

'1975' saw the First International Conference on Marine Parks and Reserves being held by the IUCN in Tokyo, which I attended, and which provided us with much technical information and impetus for a more extensive MPA system in NSW. The creation by the Australian Government of the Great Barrier Reef Marine Park, with an Authority to oversee and manage it (GBRMPA), also occurred in that year. It was clear a more extensive and comprehensive zoning system, similar to the GBRMP, was now necessary for larger MPAs that were now being planned for NSW.

A couple of decades later, the initial (1998) Interim (now "Integrated", version 4) Marine and Coastal Regionalisation of Australia by our Fish Ecology and Conservation group at the Fisheries Research Institute at Cronulla, inspired the ambition that at least one major Marine Park was needed in each of the six separate bioregions that had been identified for NSW waters. Since that time, as indicated in this report, such major MPAs have been declared and have become well-established in all of these identified NSW bioregions, except for the Hawkesbury Shelf (the area roughly between Newcastle and Wollongong, and including the entire coastline of the Sydney Metropolitan Area), and the Twofold Shelf (near Eden in the far south of the state).

The former (Hawkesbury Shelf) gap in this MPA system is clearly, though unsurprisingly, due to the political, but also logistical, difficulties in establishing highly protected MPAs (including especially "No-Take" SZs) in such a densely populated area of the state. This primarily political difficulty has most recently been emphasised by the so called "Amnesties", allowing fishing in SZs of the existing Marine Parks. They were granted by the previous state government, following political pressure by various narrow self-interest groups.

A working "triumvirate" between the recently created Marine Estate Management Authority (MEMA), DPI/Fisheries and DPE/National Parks to manage the NSW MPA system was originally in my opinion a potentially good idea, but, as pointed out in this report, its eventual approach to the overall MPA management problem (i.e. one based on threat and risk assessment, TARA, rather than CAR, see below) was both inappropriate and badly flawed, resulting in the retrogressive "Amnesties" as outlined above.

What has held up the process, has thus usually been the differences in political ideology and adversarial attitudes of the various governments and their ministers to the sometimes conflicting needs for both natural resource exploitation (here primarily fisheries harvest) and biodiversity conservation. As clearly emphasised in this report, however, this conflict need not exist since a balanced CAR system of MPAs can contribute to both of these objectives.

As they say — and as outlined in some detail in the following report — much of the rest is history, and it now becomes the task of the relatively new Labor Government in NSW to pick up the baton for MPAs.

Dr David Pollard
Research Associate with the Department of Ichthyology
at the Australian Museum in Sydney.

Introduction

The values of Australia's and NSW's coastal marine environment

Australia's ocean gems: Australia has one of the most biodiverse marine coasts globally and spans latitudes from cold temperate to tropical. Its "sea territory" is the 6th largest area among countries on earth and covers over 30 degrees of latitude, including tropical to cool temperate ecosystems.

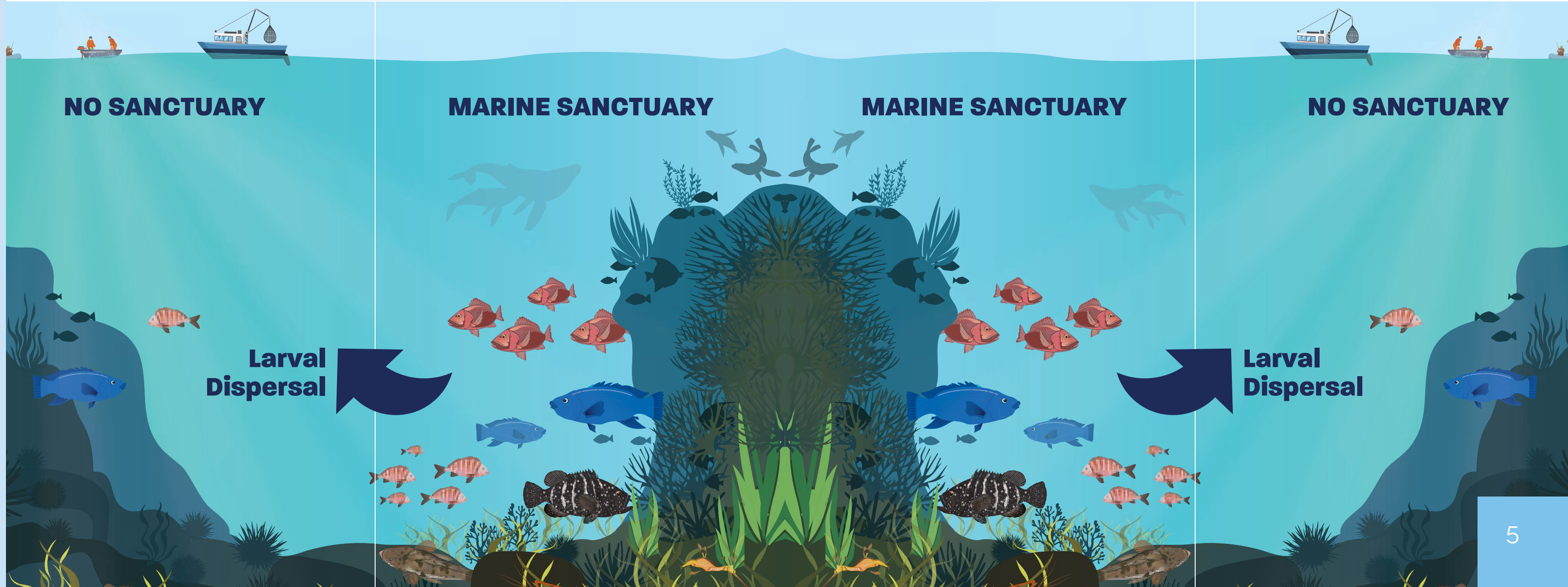
Our inshore areas include coastal estuaries, sandy beaches, rocky reefs, mangrove and mudflats, all within the three nautical mile band administered by the state. Deeper habitats, such as reefs, supporting sponges, kelps and sandy habitats extend out into Commonwealth-managed areas to 200 nautical miles. Each habitat has its unique biodiversity and forms a habitat mosaic/seascape with adjacent habitats, allowing movement of organisms between them.

NSW waters: The NSW marine environment covers 12 degrees of latitude and subtropical to warm temperate ecosystems. It encompasses the northern limits to the Great Southern Reef and the southern subequatorial zone, with a "transition zone" at around 30 degrees.

NSW's unique ocean landscape

<u>Latitudinal connectivity</u>*:* A key driver of biodiversity and physical ocean conditions (and management of our oceans), is the southward flowing East Australian Current (EAC). Coastal marine seascapes are impacted from roughly January to May each year by the south-flowing EAC (Creswell et al. 2016) bringing warmer waters and supporting north-south movement of larvae and propagules (Booth et al. 2007). Marine organisms usually have a dispersive phase, with the larval phase occurring after hatching from an egg. Larvae can drift and swim in the ocean for days to months before finding a new home on, for example, a coastal reef. Some fishes and other marine organisms, such as kelp, may disperse in this way for 10s of km to over 100 km, and this indicates the value of having a network of refuges (such as SZs), acting as "stepping stones" (e.g., Coleman et al. 2013). This spatial population connectivity means actions taken in one region or state can influence downstream populations (Figure 1), akin to terrestrial wildlife corridors.

Figure 1: Concept diagram illustrating that marine parks are spatially connected.



Threats to the NSW marine environment

Summary of threats

Threats to the NSW marine environment can be natural and anthropogenic, and either local and global in nature. TARA, NSW's Threat and Risk Assessment process, ranked threats (see below) to the NSW environment (including estuaries), to be discussed later, but key direct human-caused threats include:

- **Land-use:** vegetation clearing on land, foreshore development, estuary entrance modification, beach nourishing/grooming, stock grazing.
- **Fishing**: commercial, recreational, estuarine, offshore, various methods including handline, net haul, traps.
- **Shipping:** commercial shipping (freighters bulk carriers, smaller vessels such as ferries and charter boats), recreational boating (cruisers, yachts, fishing boats large and small).
- **Pollution:** stormwater and industrial runoff (urban areas: sewage effluent, industrial wastes, sediment), agricultural runoff (sediments, fertilisers).

What about climate change?

Over the last decades, the NSW coast has seen rapid changes of which many can be attributed to human-caused climate change. In particular, increased water temperature due to strengthening of the EAC, increased intensity of climate-related storms ("East Coast Lows"), rising sea levels, and change in freshwater flows to rivers have been documented. Management needs to adapt to the predicted changes (such as species range shifts, more intense storms, change in freshwater flows, and warmer winter waters) as well as climate synergisms with other threats, including river nutrient runoff, overfishing, and coastal development. A recent review of losses of marine biodiversity (Edgar et al. 2023) found continent-wide declines in reef biodiversity associated with ocean warming.

Blueys Head, Blueys Beach © James Sherwood

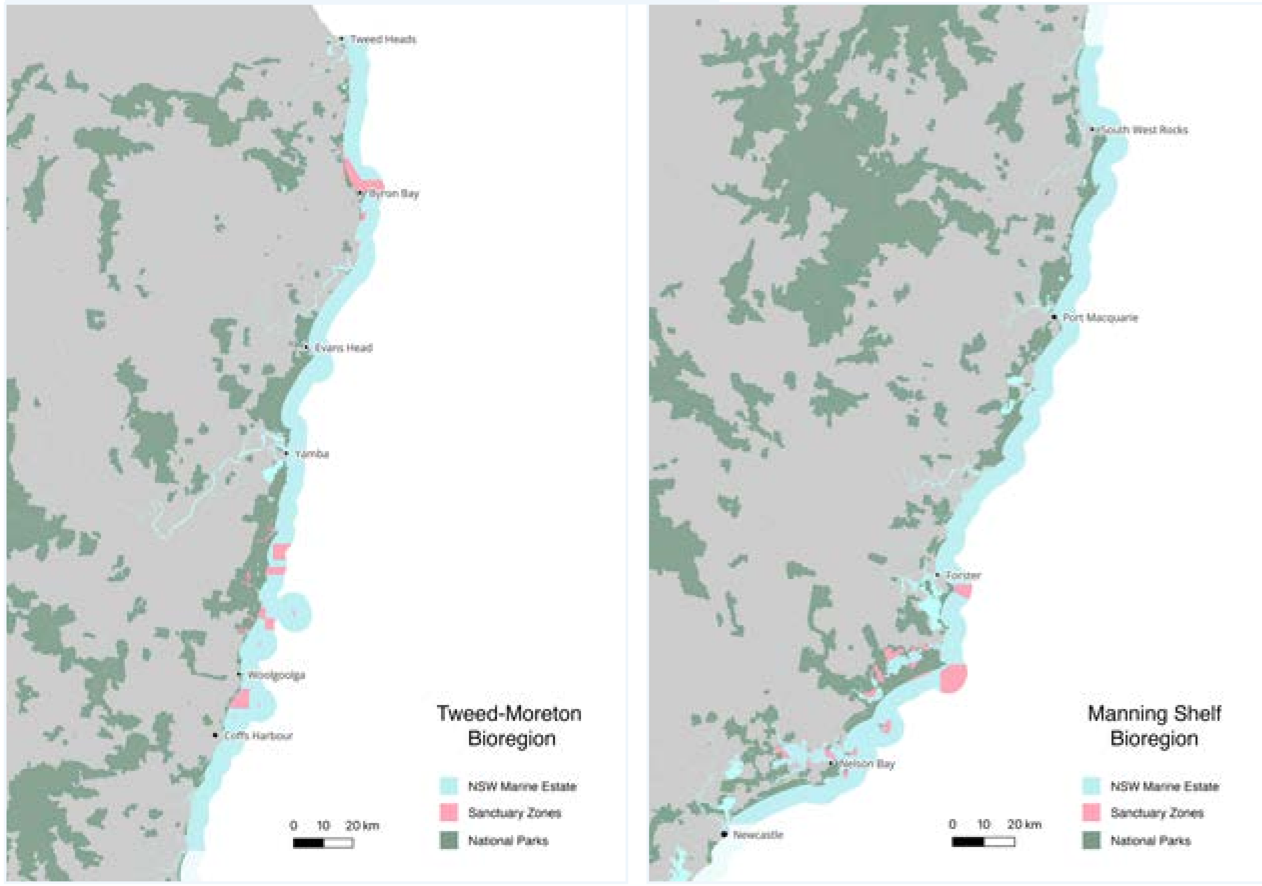
Marine bioregions, planning and MPAs

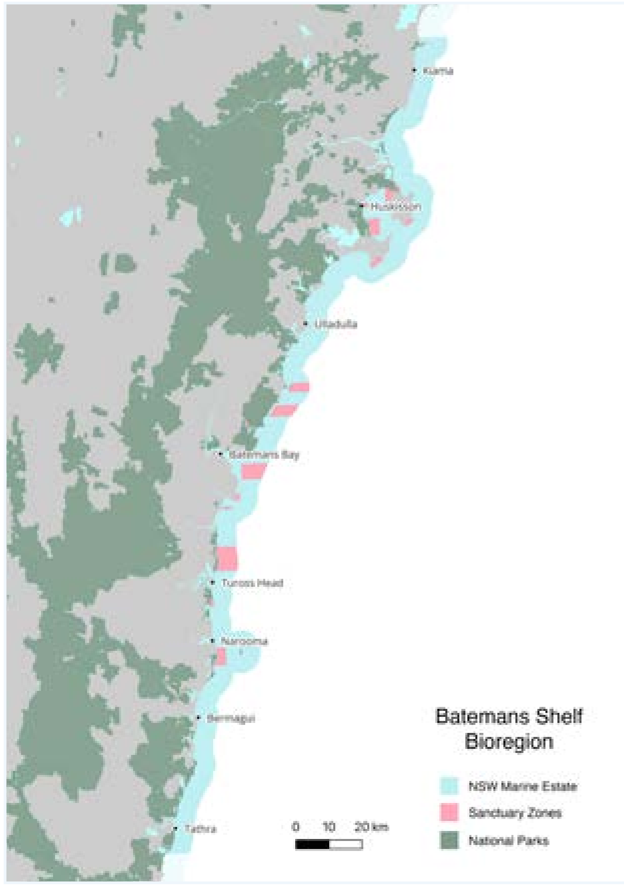
in NSW and Australia

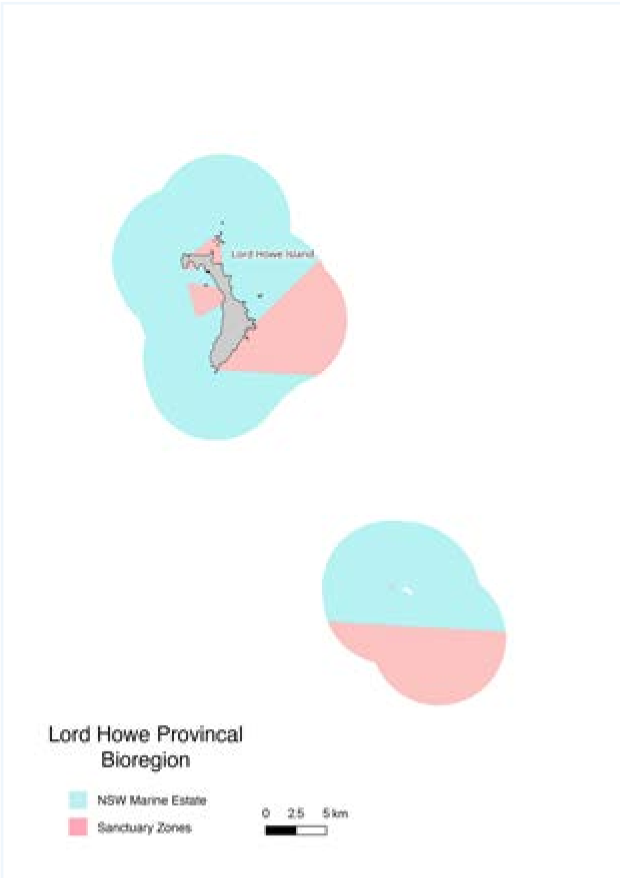
The Australian coastline has been divided into over 60 bioregions based on geographical features that proxy for ecosystems. Coastal and offshore areas are managed by relevant states (coast to three nautical miles) and the Commonwealth (generally beyond three nautical miles to the 200 nautical mile limit) agencies. In NSW, six bioregions cover our coast (see Figure 2):

- Tweed-Moreton Bioregion with Cape Byron Marine Park and Solitary Islands Marine Park (total MPA are 47% of coast, with 7% as SZ)
- Manning Shelf Bioregion with Port Stephens Great Lakes Marine Park (total MPA are 45% of coast, with 8% as SZ)
- Hawkesbury Shelf Bioregion: Sydney has no marine park, approximately 1.3% in Aquatic Reserve system, with 0.4% as SZ
- Batemans Shelf Bioregion with Jervis Bay and Batemans Marine Park (total MPA are 52% of coast, with 8% as SZ)
- Twofold Shelf Bioregion has NO MPA and 0% as SZ
- Lord Howe Province (total MPA is 100% of islands, with 28% as SZ)

Figure 2: SZ protection in NSW managed waters across each bioregion.



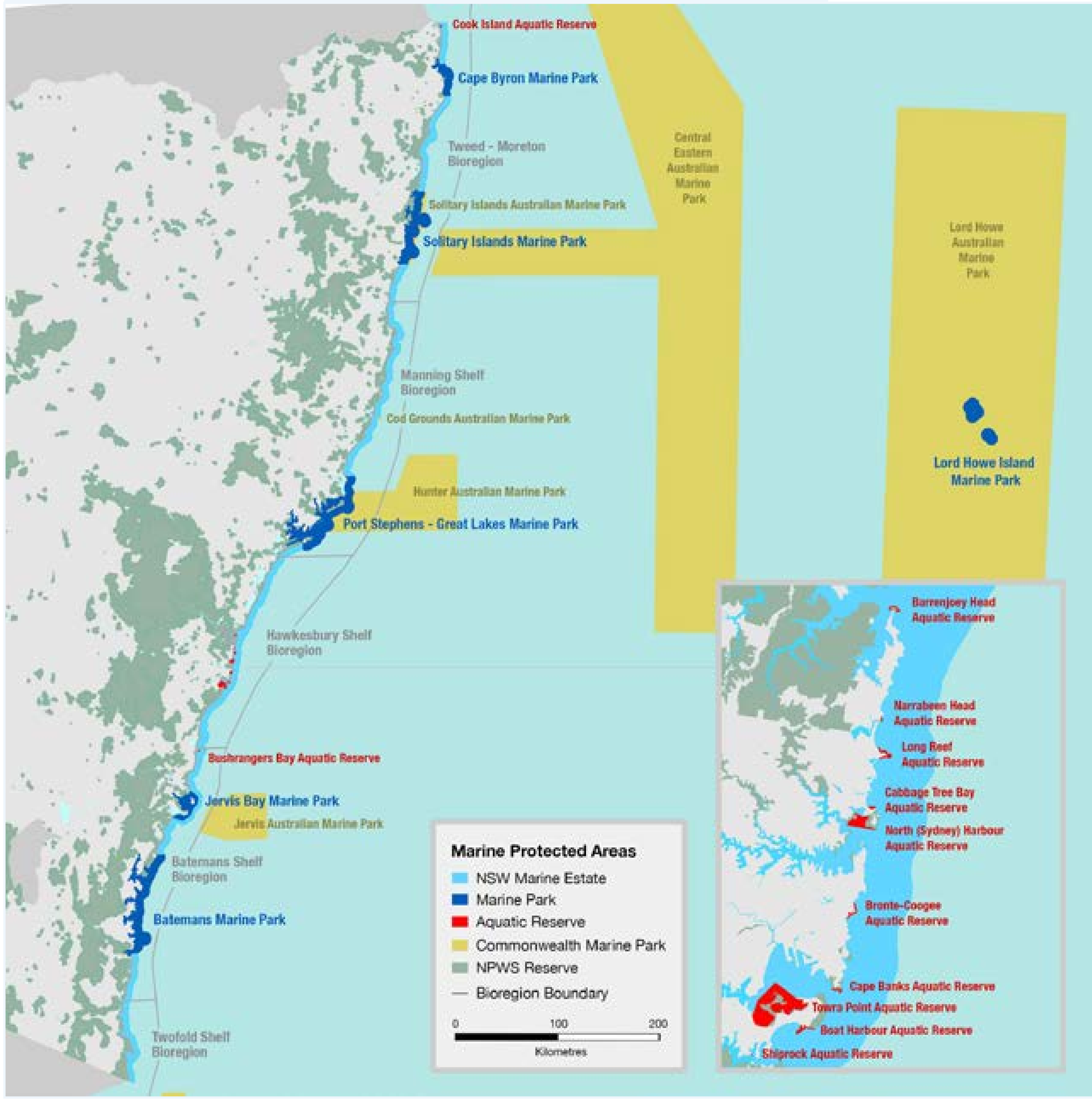




These are complemented by Commonwealth Marine Parks (no SZs) near Solitary Islands, Port Stephens Great Lakes and Jervis Marine Parks.

NSW Marine Parks and Aquatic Reserves [Figure 3] are multi-use zoned (compared with Victoria's smaller (no-take only) reserve system. Typically, there are two main zones — the SZ (no-take) zone, approximately 15-20% of the MPA network (IUCN Protected Area Category II) and the Habitat Protection zone (HPZs) which allows most forms of recreational fishing (around 75% of the MPA area, IUCN IV). Approximately 7.4% of the NSW marine environment is zoned as highly protected or no-take, equivalent to IUCN protected area category II National Park.

Figure 3: Map of NSW MPAs. Approximately 7.4% of the coastal waters are no-take, with less than 1% in the Hawkesbury Shelf Bioregion. Inset: Sydney region with existing Aquatic Reserves in Red.



The value of MPAs

Especially SZs (no-take)

Marine parks

Marine parks have been adopted worldwide as a key plank in any ocean biodiversity conservation plan. Their primary purpose has been to conserve biodiversity by excluding exploitative practices, such as fishing and mining. While marine parks are often legislated to reduce or prevent direct exploitative activities, they are also centres for marine protection in general, including combatting habitat disturbance and improving water quality, and act as resilient habitats in the face of climate change (Bates et al. 2019). Despite the social and economic value of MPAs, it is important to note the *Marine Estate Management Act 2014 (MEM Act)* states *"The primary purpose of a marine park is to conserve the biological diversity, and maintain ecosystem integrity and ecosystem function, of bioregions in the marine estate."*

In 2022, Australia ranked the 9th country globally for percentage levels of ocean area under high protection, with 9.6% no-take SZs, (Mpatlas.org, 2022). Therefore, global targets of 30% are way above the on-the-ground protected area network at this time.

SZs: gold class marine protection

Global research on the performance of marine no-take (SZ, IUCN I or II) zones has overwhelmingly demonstrated their benefits:

1. Higher biodiversity compared to adjacent less protected areas, such as HP zones.
2. Higher abundance particularly of exploited species (e.g. targeted fish, crabs, abalone, lobster).
3. Higher sizes/biomass particularly of exploited species.
4. Spillover of adults into adjacent exploited areas (see Figure 1).
5. Spillover of larvae into nearby exploited areas, leading to higher fish biomasses and fishing opportunities in adjacent areas (see Figure 1).
6. Being close to a natural state: outside SZs food webs are altered, mostly by removal of key species especially top predatory fishes.

Edgar et al. (2014) reviewed 87 MPAs worldwide including Australia, and showed that to be of maximum effectiveness, they must: include No-take zones, have effective Enforcement, be Old (in place for >10 years), be Large (>100 km^2) and be Isolated by deep water or sand (thus NEOLI). Only 10% of the MPAs in their analysis had four or five of the criteria.

The Australian situation: evidence for effectiveness of SZs

Key global research on the effectiveness of SZs (no-take areas) has been conducted in Australia, including NSW. Edgar et al. (2018) showed definitively that a substantial drop in marine fish stocks in Australia over the decade 2005 to 2015 occurred but not in SZs, and exploited species dropped but not non-targeted species, emphasising that direct fishing activity was the main cause. Harasti et al. (2018) demonstrated that snapper (one of the most popular recreational and commercial targets) were larger and more abundant in SZs (no-take areas) but that adjacent HP zones (line fishing allowed) had few benefits over open areas. A summary of key scientific papers and their findings is given in Appendix 1.

Spatial protection is embedded in standard fishery management, so SZs can be fisheries management tools. The Marine Estate Management Authority (MEMA) notes that marine parks:

- conserve biodiversity, ecosystem integrity and function, particularly by managing cumulative threats associated with reductions in abundances of species and trophic level
- Provide scientific reference sites
- Conserve bequests and intrinsic values
- Increase resilience to the impacts of climate change

These key points are well stated and highlight the primacy of marine conservation and its role in climate impacts of marine parks, which are not primarily to improve fishing performance outside MPAs. It should be emphasised that fisheries management that occurs outside SZs has conservation benefits. However, marine park management and fisheries management are very different: they have different objectives. Fisheries management aims to sustain fisheries to allow long-term stable catch rates by fishers, while marine park management seeks to enhance/maintain biodiversity. The divergence is clearly seen where, if fish stocks are at a fraction of their natural/historical abundance but the new low level is maintained, this is seen as a win for fisheries management, but clearly not so for maintenance of natural ecosystems and marine food web integrity (fishing removal of key predatory fishes).

Batemans Marine Park

450 km south of Sydney | Approx. 850km^2 | Est. 2006

Sanctuary Zones: 19%

Values: Rocky reefs, deep rocky reefs, key estuaries (eg Clyde river), key lagoons. Offshore Tollgate Island and world renowned Montague Island.

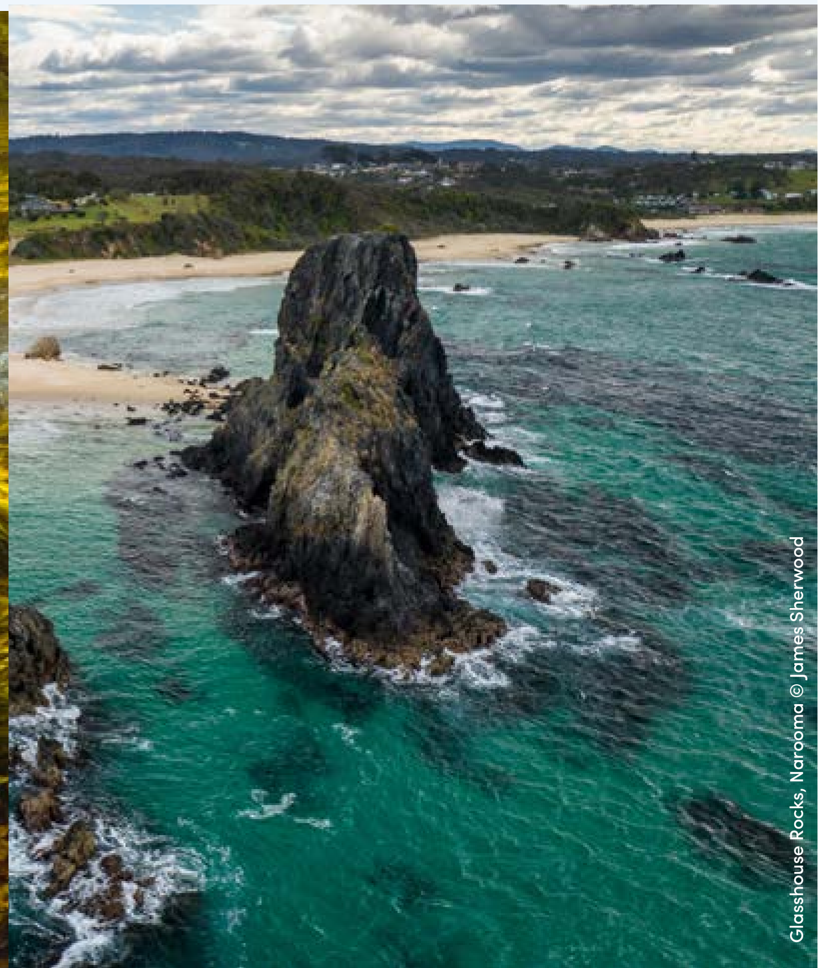
Evidence of effective Sanctuary Zones: Five years after the creation of the park research showed that fish abundance was 38% higher inside the marine sanctuaries than in partially protected areas (Kelaher et al. 2014), i.e., they found no benefits as measured by fish abundance from partially protected areas in the Bateman Marine Park.

After ten years, SZs displayed greater stability in species composition with 4-6 times the species commonly targeted by fishers compared with partially protected and unprotected areas (Pettersen et al. 2021).

Red morwong and abalone found to be more abundant inside of marine sanctuaries compared with partially protected areas (Coleman et al. 2013).

Risks: Amnesties (revoke SZ status). The 2013 government Amnesty removed significant areas of SZs to allow fishing without evidence, including at Montague Island. Currently, about 700 ha of former SZ allows fishing.

Australian fur seal, Montague Island © James Sherwood



Glasshouse Rocks, Narooma © James Sherwood

Number One Beach, Seal Rocks © James Sherwood

Looking Glass © Jim Dodd

Fly Point © Jim Dodd

Port Stephens - Great Lakes Marine Park

150 km north of Sydney | Approx. 980 km^2 | Est. 2005

Sanctuary Zones: 18%

Values: Key offshore islands, sandy beaches, subtropical coral beds, northern limits to weedy seadragon populations, Broughton Island habitats, key seabird nesting e.g. Gould's Petrel. The adjacent Hunter Commonwealth Marine Park offshore is 6257 square kilometres.

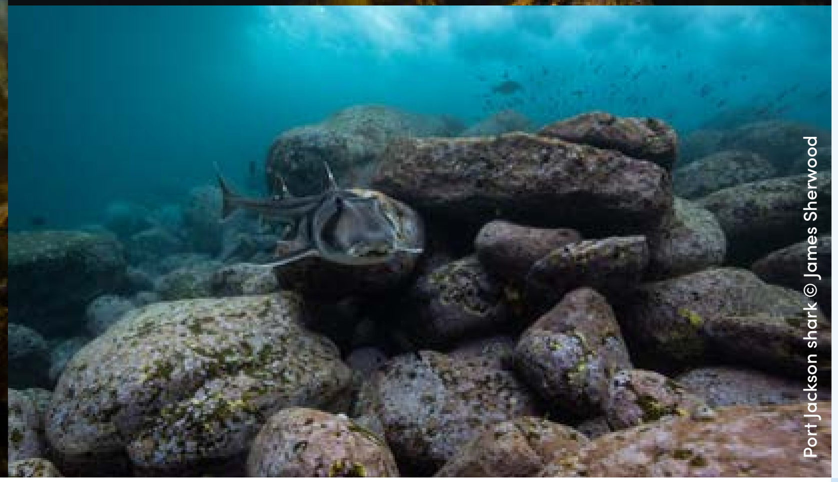
Evidence of effective Sanctuary Zones: After eight years of protection, snapper numbers and size increased inside of SZs with an almost three-fold increase in numbers at Broughton Island (Harasti et al. 2018).

Wrasse, scorpionfish, sea bream, leatherjacket and morwong also increased inside of SZs when compared with the fished areas outside (Harasti et al. 2017).

Risks: Amnesties (revoke Sanctuary status). The 2013 government Amnesty removed key sandy beach and rocky reef habitats SZs to allow fishing without evidence of likely impacts. Port Stephens estuary soft coral beds were decimated by sand movements.


Eastern blue groper © James Sherwood


Giant cuttlefish © James Sherwood


Port Jackson shark © James Sherwood

Cabbage Tree Bay Aquatic Reserve

Sydney | Approx. 20ha | Est. 2002

Sanctuary Zones: 100%

Values: Profuse fish and invertebrate life, sea cliffs, expanding subtropical coral beds.

Evidence of effective Sanctuary Zones: Cabbage Tree Bay, Manly, has shown even small marine sanctuaries are playing a critical role in the restoration of the marine environment by enhancing biomass and biodiversity at the local scale (Turnbull et al. 2018).

Beck et al. (2016) showed Cabbage Tree bay and Bushrangers Bay Aquatic Reserves had more key predators (up to 10 times) than paired fished areas nearby. Curley et al. (2013) found increased numbers of both red morwong and legal-size yellowfin bream where spearfishing is prohibited, relative to fished control sites.

Risks: As a small and very popular area in Sydney, issues such as boating (anchor damage, litter), nearby fishing (removal of fish, plastics pollution) need careful management. The volunteer group Friends of Cabbage Tree Bay are effective at education and enforcement.

Jervis Bay Marine Park

140km south of Sydney | Approx. 215 km² | Est. 1998

Sanctuary Zones: 20%

Values: Spans over 100km of coastline and adjacent oceanic, embayment and estuarine waters. About 15km away from the offshore Jervis Marine Park (Commonwealth waters) that covers approximately 2400km2 of the continental shelf.

Rocky reefs, deep rocky reefs, high sea cliffs, Bowen Island (penguin colonies) Indigenous areas (e.g. Wreck Bay). Bay supports extensive seagrass beds.

Evidence of effective Sanctuary Zones: *Cheilodactylus fuscus* (red morwong) had higher densities in no-take SZ's, (Barrett et al. 2009). Fishing discards attract rays *(Pini-Fitzsimmons et al. 2023).*

Risks: Large embayment susceptible to algal blooms (eg coccolith bloom bay-wide event), but generally well flushed.


Plantation Point, Jervis Bay © James Sherwood


Fiddler ray, Jervis Bay © John Turnbull


Eastern blue devil fish, Jervis Bay © John Turnbull

Solitary Islands Marine Park

500 km north of Sydney | Approx. 710km² | Est. 1998

Sanctuary Zones: 12%

Values: Profuse fish and invertebrate life, sea cliffs, significant hard coral cover and diversity", and sub-tropical – warm-temperate overlap zone.

Evidence of effective Sanctuary Zones: SZs had significantly larger animals and higher abundances when compared with partially protected (Habitat Protection Zones or HPZs). No difference between the partially protected areas (HPZs) and areas open to fishing (General Use Zones or GUZs). Fished species, such as snapper, grey morwong, pearl perch, and venus tuskfish were found to be consistently more abundant and larger in sanctuary areas after 14 years of protection (Malcolm et al. 2018).

Giant mud crabs were 2-3 times more abundant in the SZs compared with areas open to fishing in the park's estuaries (Butcher et al. 2014).

Risks: Our earliest established marine park, the SIMP, is a major diving tourism centre. It is a transition point of ocean subtropical to warm temperate zones, so it is very vulnerable to climate change shifts in condition, but also to agricultural runoff from coastal farms. In January 2011, parliament passed a zoning plan to boost marine protection to 20% — however, this was rescinded by parliament three months later with a change of government, (Hansard, 25 May 2011).


Schooling fish with diver, Solitary Islands © John Turnbull


Soft corals, Solitary Islands © John Turnbull


Flat Top Rock, Solitary Islands © James Sherwood

The TARA approach

Risks and benefits, does it link with CAR principles?

The previous government rebadged the NSW marine environment as the 'NSW Marine Estate', implying the state's marine environment is a resource to be utilised. Integral to current 'NSW Marine Estate' spatial planning is the TARA approach. The TARA model is largely based on what is often a highly subjective assessment of perceived threats and risks to marine parks, using information provided by stakeholders.

The MEMA advises the NSW Government on the management of the NSW marine estate. MEMA's functions under the MEM Act include undertaking threat and risk assessments, developing management strategies, promoting collaboration between public authorities and fostering consultation with the community. The NSW Marine Estate Threat and Risk Assessment Report Final Report, (2017, page 3) outlines the NSW Government approach to marine management as *"key outputs of the TARA process in the form of evidence-based risk levels for threats to the environment, social and economic benefits provided by the marine estate for the state."* This statement should have been qualified to note MPAs' primary role is biodiversity conservation.

The process of the TARA Framework for the NSW Marine Estate is (in order) to:

1. Identify key benefits and threats to those benefits that the Estate provides to the NSW community
2. Prioritise threats based on the risk (a combination of likelihood of a threat occurring and consequence of the threat) they pose to community wellbeing, so that management efforts can focus on the most important issues
3. Assess the adequacy of current management settings and alternative options for addressing priority threats
4. Implement the most cost-effective management settings that adequately address threats
5. Be accountable to the NSW community in terms of monitoring the effectiveness of management settings.

Threat and risk ranking is the focus of the second step in this five-step process, and as stated, this is focused on "community wellbeing" rather than biodiversity conservation.

A key element of the TARA process is the ranking of perceived threats. This critically involves the subjective categorisation of threats, then "expert opinion" (often without direct evidence) to rank these and prioritise action. The TARA for NSW Marine Estate (New South Wales Marine Estate Threat and Risk Assessment Report Final Report, 2017) recognised (ranked) threats as seen in Table 1.

Table 1: Ranked NSW Marine Estate Threats (using the TARA method) with fishing threat categories highlighted in yellow.

1.	Urban stormwater discharge
2.	Estuary entrance modifications
3.	Agricultural diffuse-source runoff
4.	Clearing riparian & adjacent habitat including wetland drainage
5.	Climate change (over the next 20 yrs)
6.	Modified freshwater flows
7.	Foreshore development
8.	Recreation & tourism boating & boating infrastructure
9.	Navigation & entrance management & modification, including harbour maintenance
10.	Sewage effluent & septic runoff
11.	Stock grazing of riparian & marine vegetation in estuaries
12.	Four-wheel driving
13.	Recreational fishing – boat-based line & trap fishing
14.	Passive recreational use – swimming, surfing & dog walking
15.	Recreational fishing – shorebased line & trap fishing
16.	Beach nourishment & grooming
17.	Commercial fishing – ocean trawl
18.	Commercial fishing – ocean trap & line
19.	Commercial fishing – estuary general
20.	Deliberate introduction of pests & weeds
21.	Shipping – small commercial vessels
22.	Oyster aquaculture
23.	Commercial fishing – ocean haul
24.	Recreational fishing – hand gathering
25.	Whale & dolphin watching

TARA shortcomings

Categorisation bias: Note in Table 1 above that “fishing” has been subdivided into seven categories which means each is ranked further down the list, whereas other categories, such as foreshore development, have not been divided further. In the case of foreshore development, it could have been divided further e.g. in private homes and commercial infrastructure categories. If the seven fishing activities were combined into one category (as is the case for other categories) it could be the Number One Risk to the NSW Marine Estate.

Ranking processes bias: Expert opinion must be carefully managed to avoid biases. Opinion, even of experts, is clearly inferior to actual evidence and so must not be preferred. And, even if opinion (not evidence) must be used, there are many better processes that can be employed (e.g., multicriteria analysis: Fowler et al. 2014). These analysis models detail how the expert opinion process needs to be carefully planned, including correct stakeholder identification, deployment of adequate ranking methodology, and how to best present biases in the absence of evidence, even if experts are used.

The State-wide TARA was informed by a series of matrices, guided by a series of background information reports developed by the MEMA agencies and external consultants to inform the assessment. For instance, the Marine Estate Expert Knowledge Panel (MEEKP) developed rankings as part of a one-day workshop undertaken on 26 May 2016, which appears inadequate given the complex background data and ranking recommendation inputs. Decision-making became centred on a comprehensive background report (NSW Marine Estate Threat and Risk Assessment Background Environmental Information, 2016), which provided the information on environmental assets and activities in the NSW Marine Estate to inform an assessment of TARA to these assets. This information was presented in the final TARA report (NSW Marine Estate Threat and Risk Assessment Report Final Report, 2017). The evidence outlined in these reports was also used as the basis to identify and assess the threats through a series of workshops with MEMA agencies, independent experts, and key stakeholders along the NSW coast.

Threat and Risk Assessment Framework for the NSW Marine Estate (2015) noted all of the evidence used in a TARA should be transparent so that it is clear what evidence was used to form a judgment about the threats and risks. This report shows further transparency over decision-making is required, as demonstrated by critical flaws in the application of TARA.

Case study on ranking processes bias: As an example, risk ratings in the NSW Marine Estate Threat and Risk Assessment Report Final Report (2017) placed Four Wheel Driving at #12, yet the background evidence (NSW Marine Estate Threat and Risk Assessment Background Environmental Information, 2016) noted that there is “is no specific information on the level of activity and level of associated stressors”. By contrast, (NSW Marine Estate Threat and Risk Assessment Background Environmental Information, 2016) provided evidence that Recreational Fishing – Shore (#15) and Commercial Fishing – Estuary General (#19) had significant impacts including bycatch, incidental catch of species of concern (protected shorebirds, grey nurse sharks), and caused associated marine debris (e.g. rise in Taronga Zoo treatment of animals suffering recreational fishing debris injuries).

The government’s own evidence shows there is no justification for the high ranking of 4WD above ‘all’ fishing activities, considering the limited area of use by 4WDs in the study. The New South Wales Marine Estate Threat and Risk Assessment Report Final Report (2017) lists a “summary of evidence” for 4WD impacts as:

“While most activities contributing to physical disturbance are more common in the Hawkesbury region, 4WD is more commonly allowed on the North Coast Beaches, and is limited within the Hawkesbury Region to one or two locations.”

And in Appendix C, *“Water pollution – physical disturbance, habitat impacts and toxicants likely to result in minor impacts, but under current management there is limited access to the nearshore area for four wheel drives in estuaries”.*

These statements show 4WD impact on the marine environment is more a localised threat. It is important the government releases any documentation, including evidence, that led to the decision to rank 4WD impact and other impacts above Fishing as an overall category, including, used by the NSW Marine Estate Threat and Risk Assessment Report Final Report (2017), given the above apparently erroneous rankings.

Bream and *Posidonia* seagrass © James van den Broek

The CAR (Comprehensive-Adequate-Representative) Approach

The "gold-standard" alternative is the CAR approach, which drives the planning process, on the premise that areas need to be set aside for Marine Parks, and within them no-take SZs, as advocated globally and in Australia. CAR posits spatial protection is required and then asks where best to place protection zones to fulfil the criteria:

- **Comprehensive(ness)** – an MPA network should include the full range of ecosystems recognised at an appropriate scale within and across each bioregion, i.e. the network should stretch across the entire marine environment of a state or territory.
- **Adequate(ness)** – an MPA network must contain sufficient levels of protection to ensure the ecological viability and integrity of populations, species, and communities.Current best-practice MPA design should ensure a minimum of 30% of the marine estate is protected within SZs.
- **Representative(ness)** – an MPA network must represent all habitats and ecosystems, including at a bioregional level. For this to be achieved in NSW, marine parks should be established for the Hawkesbury Shelf and Twofold Shelf bioregions. MPA network design should also represent all habitats on a local level e.g. this might include kelp forest, sandy shores, a grassy seabed, a coral reef, or a rocky shoreline.

Input data for CAR include seabed mapping, habitat/vegetation surveys, knowledge of hydrographic processes (e.g. currents). The CAR process is widely used in Australia.

Ultimately, the conservation values of MPAs need to be prioritised to ensure that biodiversity is protected in perpetuity. TARA should sit below this and inform decision making that applies to different stakeholder interests in the marine park.

Impacts of downgrades to MPAs

Australia has been a global focus for SZs delisting and downgrading (Albrech et al. 2021, see Figure 5,6). There are concerns the proposed Toondah Harbour development may lead to further downgrade issues in the Moreton Bay Marine Park in Queensland.

A devastating blow to marine conservation in NSW came in 2013 when the government announced key SZs would revert to HP zones, allowing fishing (aka "the Amnesty"). This was done without warning or empirical evidence, and the NSW government has clearly indicated that it used TARA, a resource model approach to planning, rather than using the recommended National Reserve System model of CAR (see above a critique of the TARA). In total, about 9% of NSW's former SZ network has been downgraded since 2011. The loss of high functioning SZs is about 330 times the area of the 20 hectare Cabbage Tree Bay Aquatic reserve in Sydney.

Solitary Islands Marine Park

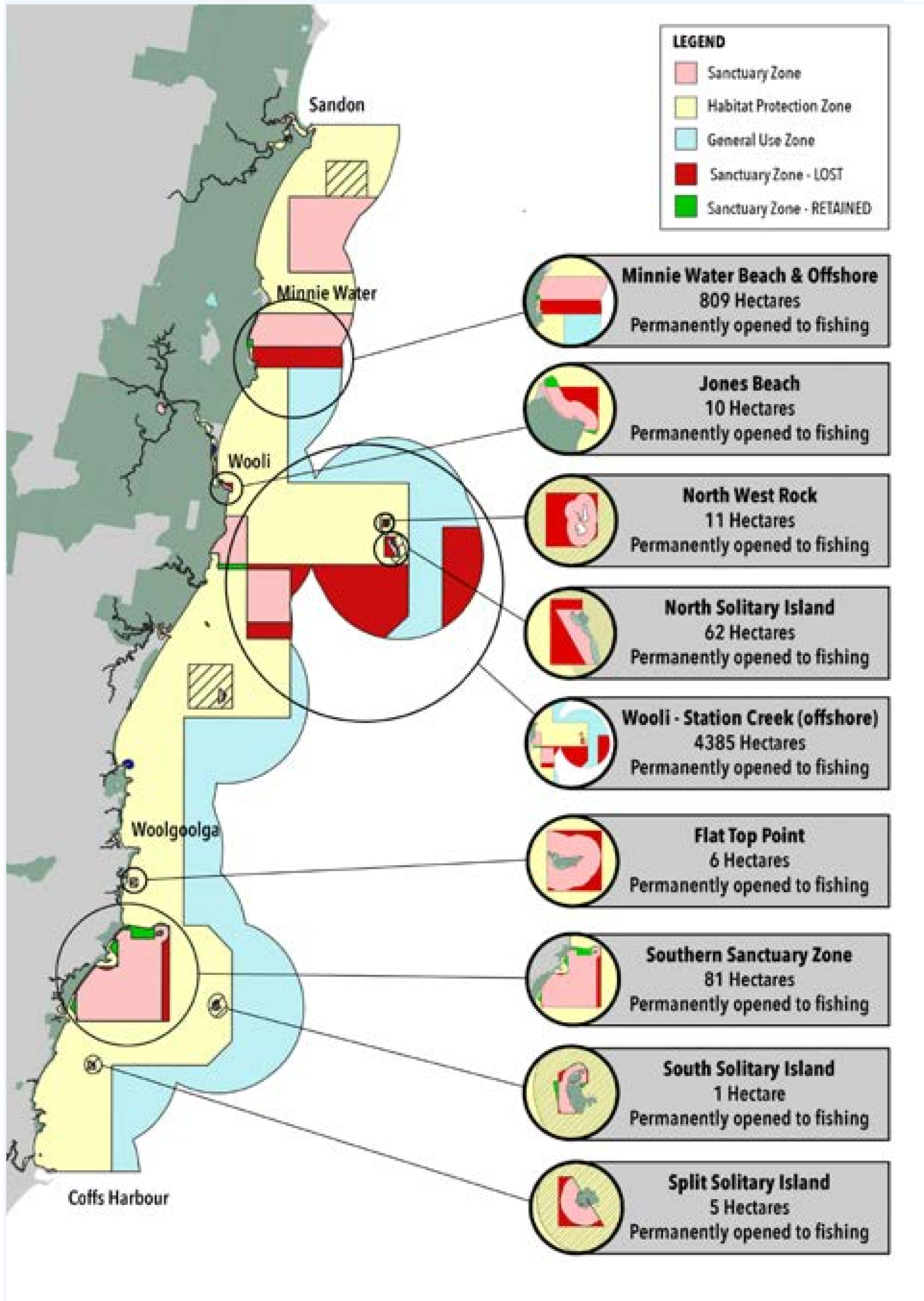
8% was upgraded to SZ and then wound back in the Solitary Island Marine Park in 2011, negatively impacting on improved CAR representation and connectivity (Figure 4). The initial zoning upgrades were supported by the Solitary Islands Marine Park zoning plan review report 2009, which found:

- The park provided inadequate SZs protection levels, with many groups calling for 20% to 50% of each habitat type.
- A lack of representation of habitat types in SZs, including in estuaries, deep and intermediate reefs, and island-fringing reefs.
- A lack of contiguous SZs to provide for habitat protection.

Examples of improvements in the initial 2011 plan included continuous protection for intermediate and deepwater zones (with offshore reef habitat not currently represented) and increased protection for the critically-endangered grey nurse shark at North Solitary Island.

Australian fur seals, Montague Island © John Turnbull

Figure 4. The 2011 Solitary Islands Marine Park rezoning was rescinded shortly after its implementation resulting in significant losses to the (pink) SZ network. SZ areas permanently lost (in red), and retained (in green) as a result of the O'Farrell Government's decision in 2011 to rescind the Solitary Islands Marine Park Management Plan.

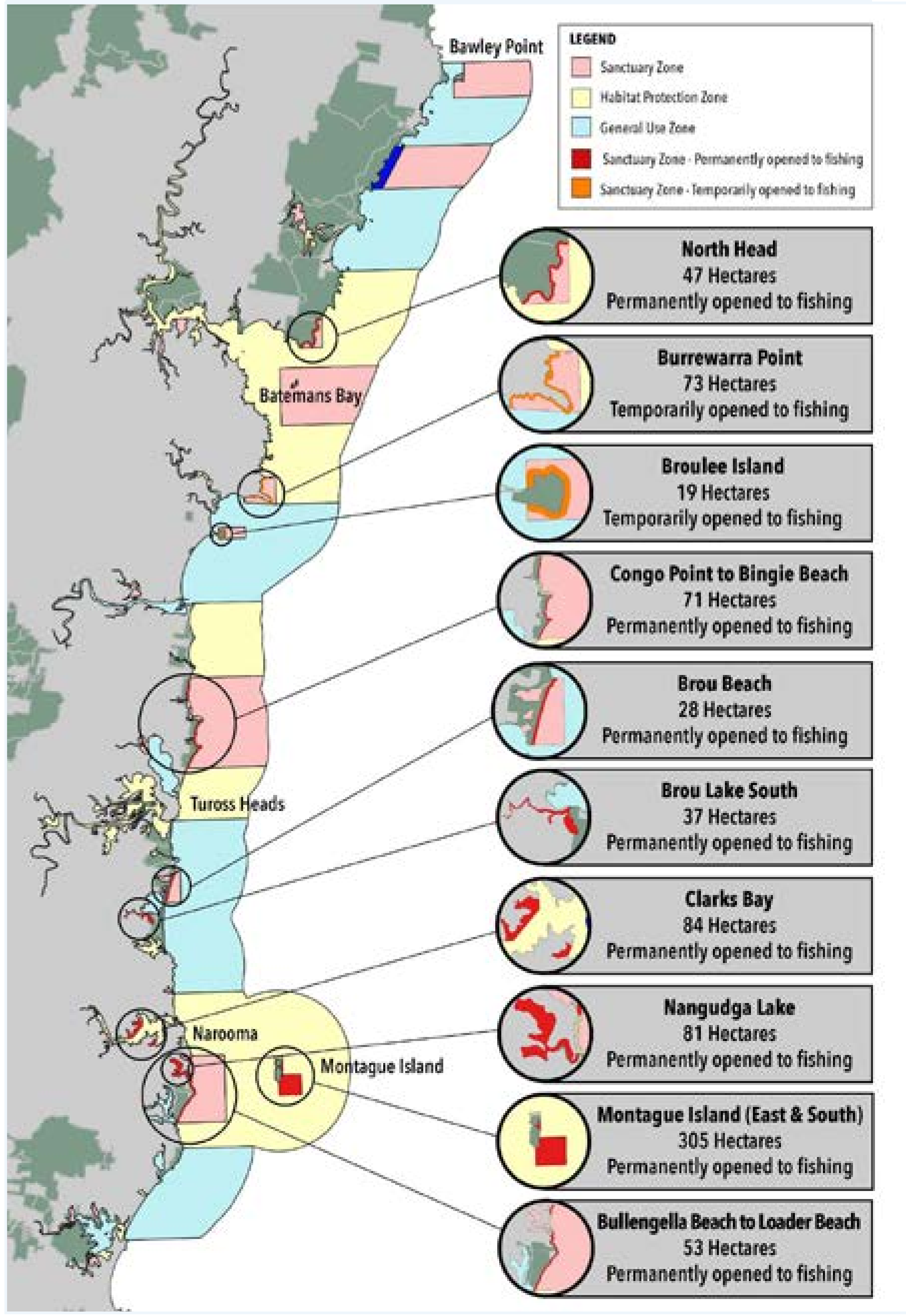


2013 & 2019 Amnesties

In 2013, the O'Farrell Government opened 30 marine sanctuaries to fishing (see Appendix 2). Seven of these sites were in the Bateman's Marine Park. Under pressure from the public, the government was forced to restore 20 of the lost SZs in NSW, but erosion of marine protection continued when in 2019 the NSW government opened six more SZs to fishing in the Batemans Marine Park (Figure 5).

Yellowtail scad ©James Sherwood

Figure 5. Map of the Batemans Marine Park indicating the extent of the downgrades since 2011. SZ areas temporarily lost (in orange) and permanently lost (in red) as a result of the O'Farrell Government's Amnesty and further rollbacks under the Berejiklian Government.



These sites included Brou Lake (South), Clarks Bay (Freshwater Bay), Forsters Bay, Montague Island, and Nangudga Lake. A total of 330 hectares of SZs were downgraded in 2013, reduced to 200 hectares in 2014 when some downgraded SZs were returned, but after more 2019 downgrades, over 700 hectares of Batemans Marine Park nearshore marine habitat has been downgraded. Habitats open to fishing in these Amnesties, including key rocky headlands, beach habitats, lagoons, and estuarine systems, plus slabs of the waters off Montague Island, a critical habitat of prolific fish life, the critically endangered grey nurse shark, and the 'vulnerable' EPBC-listed Australian and New Zealand seals.

Reversing protection of natural habitats can have devastating effects, including rapid depletion (see Harasti et al. 2019), more human litter, such as monofilament fishing line, and loss of biological connectivity. SZs act as important "baseline" ecosystem states for research into ecological change so downgrades can disrupt ongoing research which requires SZ stability over time to determine connectivity, including across the NSW marine environment as a whole. Sandy beaches, a target of Amnesties to date, harbour significant biodiversity and are corridors for fish migration, such as Australian salmon and whiting. Accessible rocky reefs, another habitat type that lost SZ protection, support a range of fish and invertebrate species. Equivalent to a marine protection downgrade, the delays in announcing a Sydney Marine Park over the last decade have prevented important no-take protection in Australia's busiest bioregion for recreational fishing and general human pressures.

Weedy seadragon, Jervis Bay © John Turnbull

Future planning

How to build a robust MPA network along the NSW coast

A process should be developed to ensure adequate marine protection in NSW, one that considers stakeholder views, but is strongly based on marine conservation (anchored in the CAR principles and at a large-scale to incorporate connectivity). This view is supported by the 2020 NSW's Marine Estate Knowledge Panel's technical paper, reviewing the biological and ecological sciences relevant to assessing NSW's MPA performance. The paper concludes *"the current network of NSW MPAs, with effective zoning restrictions, established on a bioregional basis and applying the CAR principles, provides a critical component of an integrated approach to the management of the NSW Marine Estate. This network of MPAs enables conservation outcomes that would not otherwise be possible with other management regimes or tools."* The process must provide outcomes immune to political interference and happen in a timely and transparent manner. Planning should be led and conducted by recognised MPA experts, rather than non-expert consultants. Importantly, the previous network of MPAs must be restored and protected for reasons of resilience and long-term status. The gains from these must not be eroded by political intervention (such in the 2013 and 2019 Amnesties). New processes and on-the-ground outcomes must be based on expanding on the original network, rather than a 'no net loss' approach. Legislative reform which includes clearly stating best-practice MPA management principles and planning processes should be considered. Below are some key aspects that need attention in revitalisation of the process:

Education and collaboration/cooperation

Better communication of the values of no-take areas to fishers and the wider community is essential. This includes communicating biology and biodiversity concepts and evidence for spillover and other phenomena, including communicating the excellent research already produced by government agencies on SZ values. Giakoumi et al. (2018) showed that comprehensive stakeholder engagement was key to MPA success, and Fowler et al. (2014) described a multicriteria analysis involving stakeholder engagement that generates a very robust decision where many alternatives exist.

Enforcement needs to be boosted

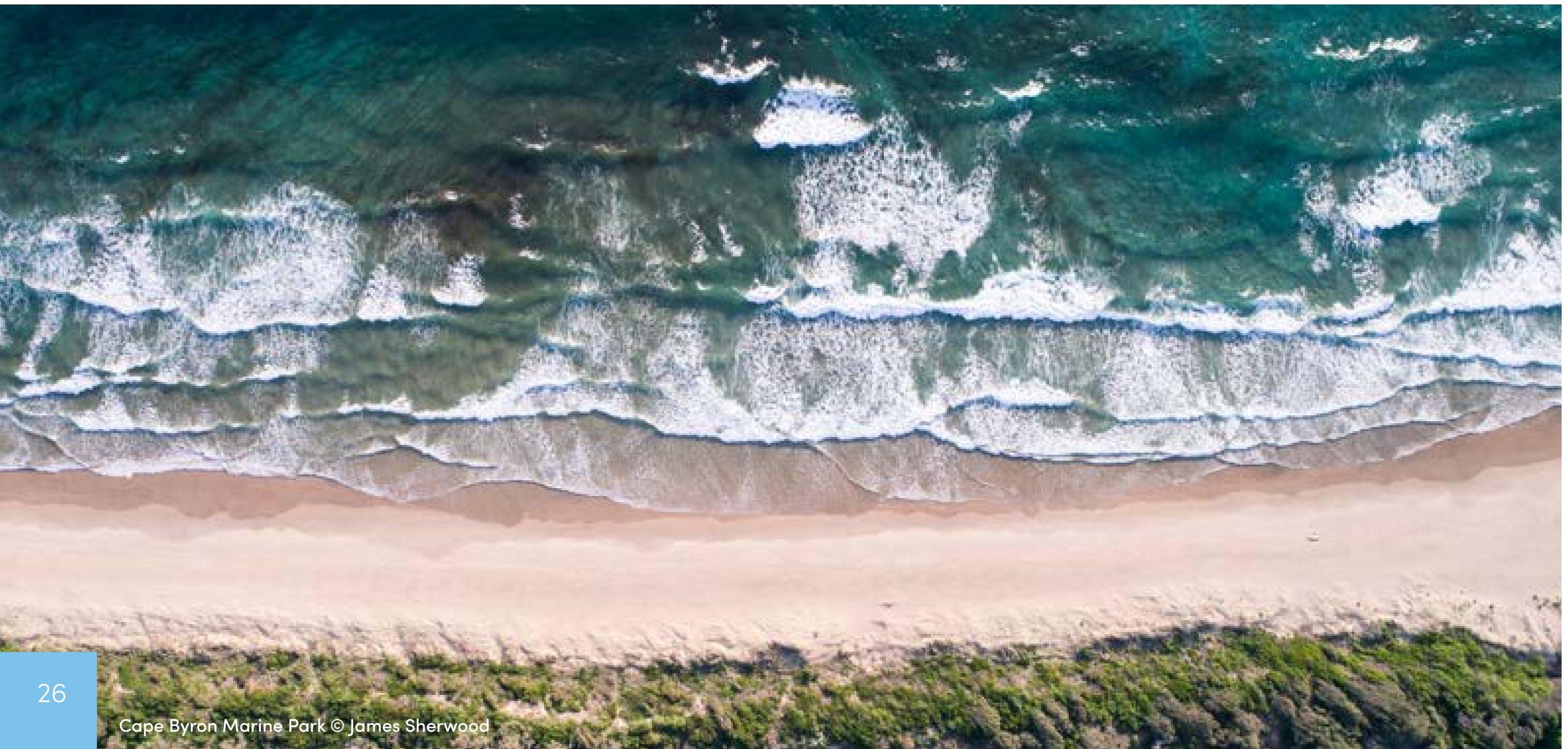
Reinforcing earlier-cited literature, Edgar et al. (2014) summarised the features of 87 MPAs as due to five key factors: No-take, well Enforced, Old (>10 years), large (>100 km2), and Isolated by deep water or sand. Some of the most successful MPAs have associated vigilance and enforcement. For example, at Maria Island Tasmania, there is a permanent ranger presence, while at Cabbage Tree Bay SZ in Sydney, the Friends of Cabbage Tree Bay (funded by the Northern Beaches Council) help to provide vigilance and education. Cabbage Tree Bay also is exceptional in its small size, yet very high biodiversity, perhaps a model for smaller well enforced local marine protection.

A 30 x 30 vision for NSW marine waters

Australia committed to the Global Biodiversity Framework, which includes a commitment to protect 30% of lands and seas by 2030, an important goal for future marine conservation and one which can support adjacent robust fisheries. Why 30%? Bohnsack et al. (2000) described the rationale for 30% area no-take. This combined reproductive theory and modelling of fisheries removals and connectivity of marine systems. At present, Australia's marine park network falls short, with Commonwealth waters about 10% no-take. State waters fare worse as follows: Victoria 5.3%, NSW 7.4%, WA 2%, SA 6%, Qld 4%, Tasmania 1.7%. While any marine management is useful, it is clear that to be fully effective areas must have "no-take" SZ status. Each coastal bioregion (six of which are in NSW) must have adequate (i.e. CAR standard) MPAs to ensure biodiversity coverage at an appropriate scale (i.e. NSW-wide) and maintain latitudinal connectivity of "safe havens" for species dispersal.

Fund key research and enforcement

Effectiveness of SZs for biodiversity enhancement plus for connectivity is of critical value, nuanced at the species level where data gaps exist, if we are to maximise SZ benefits to maximise biodiversity and connectivity. Government funding of this research is very poor, with best practice international examples including Palau's tourist environmental tax (Pristine Paradise Environmental Fee), which feeds into good research outcomes. In Australia, opportunities may include State Recreational Fishing Trust funds collected from annual license fees. At present, these are not well directed to research on marine conservation and marine parks, but this could change. Also, the rise of citizen marine science adds an opportunity. Ongoing long-term monitoring is critical to assessing positive and negative impacts given decades may elapse for no-take benefits to accrue. Given funding to researchers may be sporadic and limited, thus necessitating short-term outcomes, citizen science properly managed may be a key here. Advancing partnerships with Indigenous Rangers, including the Gamay Rangers (La Perouse Local Aboriginal Land Council, Sydney), is extremely valuable in this process, as Indigenous Australians have been caring for country for thousands of years. The Gamay Rangers use an effective model where they have been marrying traditional knowledge with modern-day ranger training and with linkages to scientists.



Cape Byron Marine Park © James Sherwood

Conclusion and recommendations

NSW is a documented world leader in biodiversity management and conservation research. NSW coastal waters harbour globally-significant marine biodiversity but are under present and future threat by exploitation (e.g. fishing), climate change and overdevelopment. The NSW marine protected area (MPA) network is well supported and valued by the overwhelming majority of NSW residents (2014 Galaxy Poll). The system has, however, suffered immensely under previous governments and aspects of oversight by Department of Primary Industries (DPI) – with significant reductions in marine park management, public relations and communications, research and compliance activities. These have included the removal of sanctuary protections and significant reductions of environmental protections of the MPA system. Ministerial decisions (e.g. removing protection without consultation) over the last decade have led the NSW Government to fall short of their statutory requirements for NSW marine parks (e.g. zoning reviews for Cape Byron, Solitary Islands, Lord Howe Island, Port Stephens Great-Lakes, Jervis Bay and Batemans Marine Parks), as well as non-delivery of required Marine Park Advisory Meetings for each marine park.

The science is clear. Significant levels of research have been done across the NSW MPA network using the National Representative System of MPAs guidelines and the CAR principles, indicating the strong conservation benefits of SZs across NSW. This research is in line with similar findings worldwide of the effects of no-take marine reserves. NSW already "punches above its weight" with key research findings, as demonstrated in this report (e.g. Appendix 1).

We recommend:

1. Relocating MPA administrative control into the Department of Environment (DPE). Shift administration of MPAs (including administration of the MEM Act), out of the DPI, placing all NSW protected area estate under the administrative control of the Department of Environment.
2. Restoring sanctuary zones (SZs) and building on the existing MPA network, rather than reducing, shifting, or trading zones.
   - Apply CAR best-practice principles for reserve system design, the National Reserve System guidelines and other international scientific standards, including the 30x30 target on a bioregional basis, and ensure connectivity.
   - Use a TARA as a tool that feeds into the design process, rather than making it the main focus of MPA design.
3. Establish MPAs in largely unprotected bioregions. This includes a Sydney Marine Park (Hawkesbury Shelf) and an Eden Marine Park (Twofold Shelf).
   - These MPAs should contain significant SZs to ensure connectivity and allow local biodiversity to flourish and not impede connectivity.
   - One option towards this is to convert all NSW Aquatic Reserves to fully no-take SZs.
4. MPAs, like their counterparts on land, are a conservation tool established to manage, protect and recover biodiversity and species, and should be applied as such and not be used as a fisheries and resource management tool.

- While spatial closures (e.g. SZs) are a proven fishery management tool, this should not be the primary reason for the establishment and maintenance of SZs. Fisheries management tools have different objectives, usually to enhance the profitability and sustainability of the fishery, which can be very different to the goal of preserving a natural ecosystem. Fisheries tools are based on current populations, not on the goal of restoring historical population levels. For example, a sustainable flathead fishery would see no decline in biomass in future, despite a high drawdown of stock in decades gone by (called the "shifting baseline" phenomenon, whereby high abundances of fish in decades past are forgotten and current abundances are based on too recent baselines).

5. Marine reserve planning should include experimentation with sanctuary design (but not by removing existing SZ no-take rules) to, for example, (a) evaluate fisheries benefits via design for larvae spill over, (b) to control urchins or to understand spatial connectivity (c) to measure resilience against poor water quality and climate change.
6. Ensure baseline surveys are conducted inside and outside sanctuary zones and that sites are monitored periodically to (a) better understand the effects of protection and (b) inform future management decisions. Comparative surveys to sites outside the marine park would also benefit our understanding of the value of SZs and habitat protection zones inside the marine park. Baseline surveys can also help with rigorous performance measures. They could help ensure we have some of the best managed marine protected areas in the world and to educate the public on the immense values of SZs.
7. Performance indicators should be developed to demonstrate that MPAs and SZs are working, with reference to global best-practice examples.
8. Capitalise on the opportunity to harness citizen power to expand research and enforcement capacity, as enforcement is highly inadequate due to too few personnel "on the water" and high quality citizen science data has been shown to expand research capacity.
9. The NSW Government has the opportunity to recast the draft Mainland Marine Park Management Plan using a CAR framework, with reforms in MPA management, focusing on valuing MPAs. While an overarching plan of management for all NSW MPAs (including marine parks and Aquatic Reserves) is advantageous, the management of each existing marine protected areas must be autonomous to a degree to allow local research links. A model for reform would be the Marine Park Act 1997, which was repealed for the MEM Act in 2014.

Julian Rocks © James Sherwood

Seahorse, Nelson Bay © John Turnbull

References

Albrecht, R., Cook, C.N., Andrews, O., Roberts, K.E., Taylor, M.F.J., Mascia, M.B. and Golden Kroner, R.E. (2021). Protected area downgrading, downsizing, and degazettement (PADDD) in marine protected areas. Marine Policy, 129, p.104437. doi:https://doi.org/10.1016/j.marpol.2021.104437.

Barrett, N.S., Buxton, C.D. and Edgar, G.J. (2009). Changes in invertebrate and macroalgal populations in Tasmanian marine reserves in the decade following protection. Journal of Experimental Marine Biology and Ecology, 370(1-2), pp.104–119. doi:https://doi.org/10.1016/j.jembe.2008.12.005.

Bates, A.E., Cooke, R.S.C., Duncan, M.I., Edgar, G.J., Bruno, J.F., Benedetti-Cecchi, L., Côté, I.M., Lefcheck, J.S., Costello, M.J., Barrett, N., Bird, T.J., Fenberg, P.B. and Stuart-Smith, R.D. (2019). Climate resilience in marine protected areas and the 'Protection Paradox'. Biological Conservation, 236, pp.305–314. doi:https://doi.org/10.1016/j.biocon.2019.05.005.

Beck, H.J., Feary, D.A., Fowler, A.M., Madin, E.M.P. and Booth, D.J. (2016). Temperate predators and seasonal water temperatures impact feeding of a range expanding tropical fish. Marine Biology, 163(4). doi:https://doi.org/10.1007/s00227-016-2844-8.

Bohnsack, J.A., Causey, B., Crosby, M.P., Griffis, R., Hixon, M.A., Hourigan, T., Koltes, K., Maragos, J.E., Simons, A. and Tilmant, J.T. (2000). A rationale for minimum 20-30% no-take protection. Proceedings 9th International Coral Reef Symposium, Bali, Indonesia 23-27.

Booth, D.J., Figueira, W.F., Gregson, M.A., Brown, L. and Beretta, G. (2007). Occurrence of tropical fishes in temperate southeastern Australia: Role of the East Australian Current. Estuarine, Coastal and Shelf Science, 72(1-2), pp.102–114. doi:https://doi.org/10.1016/j.ecss.2006.10.003.

Butcher, P., Boulton, A., Macbeth, W. and Malcolm, H. (2014). Long-term effects of marine park zoning on giant mud crab Scylla serrata populations in three Australian estuaries. Marine Ecology Progress Series, 508, pp.163–176. doi:https://doi.org/10.3354/meps10865.

Coleman, M.A., Feng, M., Roughan, M., Cetina-Heredia, P. and Connell, S.D. (2013). Temperate shelf water dispersal by Australian boundary currents: Implications for population connectivity. Limnology and Oceanography: Fluids and Environments, 3(1), pp.295–309. doi:https://doi.org/10.1215/21573689-2409306.

Coleman, M.A., Palmer-Brodie, A. and Kelaher, B.P. (2013). Conservation benefits of a network of marine reserves and partially protected areas. Biological Conservation, 167, pp.257–264. doi:https://doi.org/10.1016/j.biocon.2013.08.033.

Cresswell, G.R., Peterson, J.L. and Pender, L.F. (2017). The East Australian Current, upwellings and downwellings off eastern-most Australia in summer. Marine and Freshwater Research, [online] 68(7), p.1208. doi:https://doi.org/10.1071/mf16051.

Curley, B.G., Glasby, T.M., Curley, A.J., Creese, R.G. and Kingsford, M.J. (2013). Enhanced numbers of two temperate reef fishes in a small, partial-take marine protected area related to spearfisher exclusion. Biological Conservation, 167, pp.435–445. doi:https://doi.org/10.1016/j.biocon.2013.07.031.

Edgar, G.J., Stuart-Smith, R.D., Heather, F.J., Barrett, N.S., Turak, E., Sweatman, H., Emslie, M.J., Brock, D.J., Hicks, J., French, B., Baker, S.C., Howe, S.A., Jordan, A., Knott, N.A., Mooney, P., Cooper, A.T., Oh, E.S., Soler, G.A., Mellin, C. and Ling, S.D. (2023). Continent-wide declines in shallow reef life over a decade of ocean warming. Nature, [online] pp.1–8. doi:https://doi.org/10.1038/s41586-023-05833-y.

Edgar, G.J., Stuart-Smith, R.D., Willis, T.J., Kininmonth, S., Baker, S.C., Banks, S., Barrett, N.S., Becerro, M.A., Bernard, A.T.F., Berkhout, J., Buxton, C.D., Campbell, S.J., Cooper, A.T., Davey, M., Edgar, S.C., Försterra, G., Galván, D.E., Irigoyen, A.J., Kushner, D.J. and Moura, R. (2014). Global conservation outcomes depend on marine protected areas with five key features. Nature, [online] 506(7487), pp.216–220. doi:https://doi.org/10.1038/nature13022.

Edgar, G.J., Ward, T.J. and Stuart-Smith, R.D. (2018). Rapid declines across Australian fishery stocks indicate global sustainability targets will not be achieved without an expanded network of 'no-fishing' reserves. Aquatic Conservation: Marine and Freshwater Ecosystems, 28(6), pp.1337–1350. doi:https://doi.org/10.1002/aqc.2934.

Fowler, A.M., Macreadie, P.I., Jones, D.O.B. and Booth, D.J. (2014). A multi-criteria decision approach to decommissioning of offshore oil and gas infrastructure. Ocean & Coastal Management, 87, pp.20–29. doi:https://doi.org/10.1016/j.ocecoaman.2013.10.019.

Giakoumi, S., McGowan, J., Mills, M., Beger, M., Bustamante, R.H., Charles, A., Christie, P., Fox, M., Garcia-Borboroglu, P., Gelcich, S., Guidetti, P., Mackelworth, P., Maina, J.M., McCook, L., Micheli, F., Morgan, L.E., Mumby, P.J., Reyes, L.M., White, A. and Grorud-Colvert, K. (2018). Revisiting 'Success' and 'Failure' of Marine Protected Areas: A Conservation Scientist Perspective. Frontiers in Marine Science, [online] 5(223). doi:https://doi.org/10.3389/fmars.2018.00223.

Harasti, D., Davis, T.R., Mitchell, E., Lindfield, S. and Smith, S.D.A. (2017). A tale of two islands: Decadal changes in rocky reef fish assemblages following implementation of no-take marine protected areas in New South Wales, Australia. Regional Studies in Marine Science, 18, pp.229–236. doi:https://doi.org/10.1016/j.rsma.2017.10.011.

Harasti, D., Williams, J., Mitchell, E., Lindfield, S. and Jordan, A. (2018). Increase in Relative Abundance and Size of Snapper Chrysophrys auratus Within Partially-Protected and No-Take Areas in a Temperate Marine Protected Area. Frontiers in Marine Science, 5. doi:https://doi.org/10.3389/fmars.2018.00208.

Harasti, D., Davis, T.R., Jordan, A., Erskine, L. and Moltschaniwskyj, N. (2019). Illegal recreational fishing causes a decline in a fishery targeted species (Snapper: Chrysophrys auratus) within a remote no-take marine protected area. PLOS ONE, 14(1), p.e0209926. doi:https://doi.org/10.1371/journal.pone.0209926.

Kelaher, B.P., Coleman, M.A., Broad, A., Rees, M.J., Jordan, A. and Davis, A.R. (2014). Changes in Fish Assemblages following the Establishment of a Network of No-Take Marine Reserves and Partially-Protected Areas. PLoS ONE, 9(1), p.e85825. doi:https://doi.org/10.1371/journal.pone.0085825.

Malcolm, H.A., Williams, J., Schultz, A.L., Neilson, J., Johnstone, N., Knott, N.A., Harasti, D., Coleman, M.A. and Jordan, A. (2018). Targeted fishes are larger and more abundant in 'no-take' areas in a subtropical marine park. Estuarine, Coastal and Shelf Science, 212, pp.118–127. doi:https://doi.org/10.1016/j.ecss.2018.07.003.

Mpatlas.org. (2022). Available at: https://mpatlas.org/countries/list.

New South Wales Marine Estate Threat and Risk Assessment BACKGROUND ENVIRONMENTAL INFORMATION TARA background environmental report Published by NSW Department of Primary Industries NSW Marine Estate Threat and Risk Assessment -background environmental information. (2016). Available at: https://www.marine.nsw.gov.au/__data/assets/pdf_file/0006/1347954/NSW-Marine-Estate-Threat-and-Risk-Assessment-background-environmental-information-TARA-report.PDF [Accessed 22 Sep. 2023].

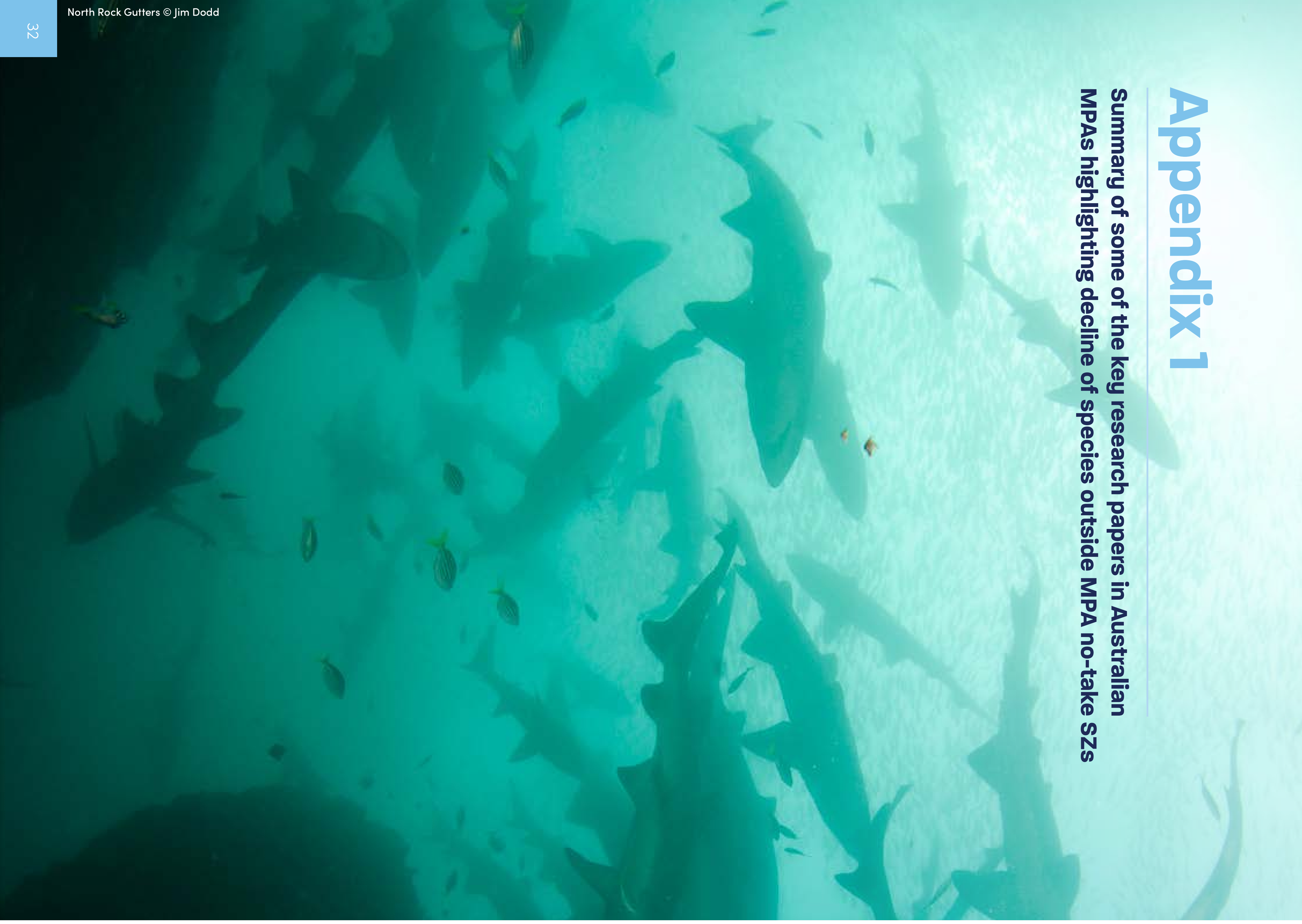
New South Wales Marine Estate Threat and Risk Assessment Report Final Report. (2017). Available at:https://www.marine.nsw.gov.au/__data/assets/pdf_file/0011/1352666/NSW-Marine-Estate-Threat-and-Risk-Assessment-Final-Report.pdf.

Pettersen, A.K., Marzinelli, E.M., Steinberg, P. and Coleman, M.A. (2021). The impact of marine protected areas on temporal stability of fish species diversity. Conservation Biology. doi:https://doi.org/10.1111/cobi.13815.

Pini-Fitzsimmons, J., Knott, N.A. and Brown, C. (2023). Recreational fishery discard practices influence use of tidal estuary by a large marine mesopredator. Marine and Freshwater Research. [online] doi:https://doi.org/10.1071/MF22146.

Threat and Risk Assessment Framework for the NSW Marine Estate. (2015). Marine Estate Management Authority. Available at: https://www.marine.nsw.gov.au/__data/assets/pdf_file/0003/1347735/NSW-marine-estate_threat-and-risk-assess-framework.PDF.

Turnbull, J.W., Shah Esmaeili, Y., Clark, G.F., Figueira, W.F., Johnston, E.L. and Ferrari, R. (2018). Key drivers of effectiveness in small marine protected areas. Biodiversity and Conservation, 27(9), pp.2217–2242. doi:https://doi.org/10.1007/s10531-018-1532-z.



North Rock Gutters © Jim Dodd

Appendix 1

Summary of some of the key research papers in Australian MPAs highlighting decline of species outside MPA no-take SZs

Location	Key Species	Relevant Findings	References
NEW SOUTH WALES			
NSW coast		Spearfisher direct impact on target species meant partial protection zones had some benefits	Curley et al. 2002
NSW coast	Eighteen 'no take' marine reserves and 14 partially protected, fished areas	Total fish abundance responded positively to protection, but only on shallow reefs. Comparing values of individual functional traits implied a return of larger bodied species of fish in protected areas and an increase in trophic level. The latter was significant on deeper reefs and was strongly correlated with age of protected area.	Coleman et al. 2015
Solitary Islands Marine Park		SZs in the marine park had significantly larger animals and higher abundances when compared with partially protected (HP zones). Critically, little significant difference was recorded between the partially protected areas (HP zones) and areas open to fishing (GUZs). Clearly indicating the value of the SZs. Four species targeted by fishers: snapper Chrysophrys auratus, grey morwong Nemadactylus douglasi, pearl perch Glaucosoma scapulare, and venus-tuskfish Choerodon venustus, were more abundant and larger in 'no take' zones overall and showed an increase through time in 'no take' relative to both types of fished area. In contrast, there was no distinct pattern of four bycatch species increasing in abundance in 'no-take' areas.	Malcolm et al. 2018
Solitary Islands Marine Park	Mud crabs	Crab numbers increased rapidly after zone closure and un-fished zones protected giant mud crabs from exploitation with catches two to three times greater than in fished zones.	Butcher et al. 2014
Port Stephens - Great Lakes Marine Park	Snapper	Snapper abundance increased threefold after eight years of no-take SZ, with more snapper than in areas open to fishing. Over 12 months of camera surveillance, a total of 108 recreational vessels were observed illegally fishing within the no-take area (avg 9.0 ± 0.9 per month). From 2011–2017, the abundance of C. auratus within the Seal Rocks no-take area significantly declined by 55%, whilst the abundance within the other fished areas and no-take areas did not significantly decline over the same period. Lengths of C. auratus in the Seal Rocks no-take area were significantly smaller in 2017 compared to 2013 which was driven by a decline in the number of legal sized fish over 30 cm. Based on mean number of illegal fishers per vessel recorded in the no-take area, and an allowable bag limit of 10 C. auratus per person, it is possible that more than 2,000 C. auratus are removed annually from this no-take area. There is a strong likelihood that illegal recreational fishing is causing a reduction on a fishery targeted species within a no-take MPA and measures need to be implemented to reduce the ongoing illegal fishing pressure.	Harasti et al. 2019
Sydney	Morwong, YF bream	NSW Aquatic Reserves, despite their small size, (especially enforced ones e.g. Cabbage Tree Bay in Sydney) had large benefits — larger and more of key fish species.	Turnbull et al. 2017

Location	Key Species	Relevant Findings	References
Jervis Bay	Key fished species	Luderick (G. tricuspidata) exhibited strong site fidelity on shallow subtidal reefs and was significantly larger and more abundant within marine reserves. Rock blackfish (G. elevata) was significantly more abundant in one of four marine reserves, although showed no difference in size between zones. Silver drummer (K. sydneyanus) was significantly larger in marine reserves, although not significantly more abundant.	Ferguson et al. 2016
Jervis Bay	40 fish species drawn from 24 families	A significant increase in Haletta semifasciata, a locally targeted fish species, in no-take marine reserves compared with fished areas. Fish assemblages in seagrass varied greatly amongst times and locations.	Kiggins et al. 2020
Solitary Islands Marine Park	Various fish taxa, flathead	The abundance of two fish taxa and low-mobility and sessile benthic macro-invertebrates, and the mean size of the commercially targeted bluespotted flathead Platycephalus caeruleopunctatus, were each significantly greater in the un-trawled HP.	Pryor et al. 2020
Shelly Beach, Sydney and Bushrangers Bay vs Palm Beach, Sydney and Bass Point	Yellowfin Bream, Sennet, Kingfish, tailor, flathead and others	Predatory fish species density 6-10 times higher in (very small) marine reserves compared to fished areas.	Beck et al. 2016
Batemans Marine Park	Morwong, abalone	There was a lot of variation among MPAs in effectiveness of no-take areas after five years. There were more abalone (Haliotis rubra) and red morwong (Cheilodactylus fuscus) in no-take zones vs partial protection zones (fishing allowed).	Coleman et al. 2013
Batemans Marine Park	Harvested fishes	The retention of harvested species was four to six times greater in MPAs compared with partially protected and unprotected areas, and the stabilising effects of protection were observable within four years of park implementation.	Pettersen et al. 2021
Batemans Marine Park		Fish abundances were 38% greater across the network of marine reserves compared to the partially protected areas, although not all individual reserves performed equally. Compliance actions were positively associated with marine reserve responses.	Kelaher et al. 2014
NSW coast	NSW coastal	SZs have higher abundance of targeted fish species compared with other areas within some marine parks. The total abundance of targeted species and abundances of some key fisheries species (e.g. pink snapper) were found to be higher in SZs. This suggests increased protection may be effective at improving these aspects of the fish assemblage.	McKinley et al. 2011
Port Stephens	Whites seahorse, octopus, flathead, scorpionfish, anglerfish	Seahorse (Hippocampus whitei) were more abundant at the control sites. Seahorse predators (three species of fish and two species of octopus) were more abundant within the no-take MPA sites.	Harasti et al. 2014

Location	Key Species	Relevant Findings	References
Gordons Bay aquatic reserve, Sydney		Enhanced numbers of two temperate reef fishes in a small, partial-take marine protected area related to spearfisher exclusion.	Curley et al. 2013
Port Stephens to Wollongong	YF Bream, luderick, red morwong, blue groper, crimson wrasse, rock cale	Flight response of six species was tested in and outside no take sanctuaries. Assemblage-wide effects of fishing on predator-avoidance behaviour and behavioural modification were seen. The two commonly targeted species had the greatest flight response in fished areas	Fowler et al. in press
NSW coastal	Key targeted and non targeted fish species	There were substantial increases in relative abundance of C. auratus in NTMR compared with fished zones through time (effect sizes >150%). The wider assemblage of targeted fish (excluding C. auratus) only showed relatively small effects of protection (~11%) with trends observed for site-attached wrasses (labrids) and planktivores (e.g., commercially fished Scorpis lineolata) that are recreationally and commercially harvested.	Knott et al. 2021
Other AUSTRALIA			
Australia coastal	Fished an unfished fish species	30% decline in stocks over 2005-2015 decade, in fished areas, but NOT in no-take SZs.	Edgar Stuart-Smith and Ward 2015
Australia coastal	Shallow reef areas	Widespread marine species declines over 20 years.	Edgar et al. 2023
Australia wide	73 fish species	A meta-analytical comparison of 73 fished species within 91 marine reserves found that, on average, marine reserves had 28% greater abundance and 53% greater biomass of fished species compared to adjacent areas open to fishing. However, benefits of protection were not observed across all reserves increased connectivity and depth improve the aforementioned marine reserve benefits marine reserves that are highly protected (no-take) and designed to optimise connectivity, size and depth range can provide an effective conservation strategy for fished species in temperate and tropical waters within an overarching marine biodiversity conservation framework.	Goetze et al. 2021
Great Barrier Reef		The short to medium-term (five to 30 years) ecological effects of the establishment of No Take Marine Reserves (NTMR) within the Great Barrier Reef Marine Park (GBRMP). The density, mean length, and biomass of principal fishery species, coral trout and snapper (Plectropomus spp., Lutjanus spp). There was no indication that the displacement and concentration of fishing effort reduced coral trout populations on fished reefs. A severe tropical cyclone impacted many survey reefs during the study, causing similar declines in coral cover and fish density on both NTMR and fished reefs. However, coral trout biomass declined only on fished reefs after the cyclone	Emslie et al. 2015

Location	Key Species	Relevant Findings	References
Great Barrier Reef Marine Park	Coral Trout Snapper	Larval spillover of coral trout and tropical snapper sustained fished areas near SZs.	Harrison et al. 2012,
Great Barrier Reef		The short to medium-term (five to 30 years) ecological effects of the establishment of NTMRs within the Great Barrier Reef Marine Park (GBRMP). The density, mean length, and biomass of principal fishery species, coral trout (Plectropomus spp., Variola spp). There was no indication that the displacement and concentration of fishing effort reduced coral trout populations on fished reefs. A severe tropical cyclone impacted many survey reefs during the study, causing similar declines in coral cover and fish density on both NTMR and fished reefs. However, coral trout biomass declined only on fished reefs after the cyclone.	Emslie et al. 2015
Moreton Bay QLD	Mud crabs	Within the Moreton Bay Marine Park, mud crabs (Scylla serrata) are higher in abundance and larger in average size within the no-take areas compared to outside. This pattern is consistent for several other targeted species within the marine park.	Pillans et al. 2003
Ningaloo Reef WA	Key fished species	Distance to the nearest boat ramp was found to be a strong predictor of fished species abundance, indicating that the effect of recreational fishing can be detected across the NMP-Commonwealth. This study suggests a clear footprint of recreational fishing across the Ningaloo Marine Park.	Ashton et al. 2022
Tasmania		At the Maria Island reserve in Tasmania, southern rock lobster (Jasus edwardsii) abundance increased by 250%, with increasing numbers of legal-sized lobsters being largely responsible for this increase. Lobsters within the reserve were significantly larger compared with fished sites.	Barrett et al. 2009
Tasmania		The Tinderbox Marine Reserve in Tasmania showed a 10-fold increase in the abundance of large fish and a doubling of species diversity of large fish in no-take areas compared to fished areas.	Barrett et al. 2007
Great Barrier Reef		Monitoring of the GBRMP has revealed a two-fold increase in both numbers and size of fish, in particular coral trout, red emperor and red throat emperor on many of the no-take reefs. The crown of thorns' frequency of outbreaks was found to be seven times higher on fished reefs compared to protected reefs. The exact reason for this is unclear, but it appears that the protection of fish and other animals has significantly helped this ecosystem return to a more balanced state.	McCook et al. 2010
Aldinga Reef Aquatic Reserve (South Australia)		Increase in abundance of fish greater than 45cm and increased biomass of fish inside the reserve compared to outside.	Edgar and Stuart-Smith, 2009
Palm Islands Qld		The no-take reserves around Palm Island and the Whitsunday Islands off Queensland were shown to contain 3.6 and 2.3 times respectively the abundance of coral trout compared to fished zones. The biomass of coral trout was approximately four times higher in protected areas. There were significantly higher numbers of legal sized coral trout within protected areas compared to fished areas.	Evans and Russ 2004

Location	Key Species	Relevant Findings	References
Houtman Abrolhos Islands reserves in Western Australia		Targeted fish species were larger inside the reserves than areas open to fishing. Targeted species on average were found to be 48mm larger inside MPAs than in areas open to fishing.	Watson et al. 2009
Moreton Bay	Fish- targeted and non-targeted	Existing estuarine reserves in the Moreton Bay Marine Park may represent locations of low habitat value to fishes and hence do not significantly increase the abundance of harvested fish species i.e. residual areas selected for reserves	Gilbey et al. 2017
Moreton Bay		Greater seascape connectivity inside reserves translates into better conservation outcomes (i.e. enhanced productivity and diversity). Water Quality benefits of MPAs.	Olds et al. 2015
Tasmania		Marine no-take areas give climate change resilience to invading fish species and urchins) i.e. MPAs are a buffer against exploitation effects.	Bates et al. 2017
Eastern Australia		Fishing debris: fishing-related items (and especially monofilament and braided fishing line) were most prevalent at the majority of sites outside MPAs.	Smith and Edgar 2014
Southern GBR	3 protection zones, no-take, partial (no spear) partial all	Predatory fish biomass greatest in no-take zones; spearfisher exclusion made a big difference, especially when well enforced.	Hall, Cameron and Kingsford, 2022
Great Barrier Reef	Reef sharks	An order of magnitude fewer sharks on fished reefs compared to no-entry management zones that encompass only 1% of reefs. Recommendation to expand "no entry zones" (Scientific Research, Orange Zones).	Robbins et al. 2006
Tasmania		Marine reserves in Tasmania protected from fishing transform over decades.	Edgar, Barrett and Stuart-Smith, 2009
Western Australia		Snapper Pagrus auratus (Sparidae) home range dynamics: acoustic tagging studies in a marine reserve illustrated refuge value of MPAs for this popular fished species	Parsons et al. 2003
13 estuaries in eastern Australian		Position and connectivity of SZs were critical in their effectiveness. Spatial context variables were consistently more important than habitat conditions in structuring fish abundance and diversity. Sites that were closer to smaller vegetated habitats (i.e. mangrove and seagrass) and key seascape features (i.e. estuary mouth and intertidal flats) typically supported diverse fish assemblages in high abundance.	Goodridge et al. 2022

Location	Key Species	Relevant Findings	References
Moreton Bay Marine Park	Target species: Snapper, tuskfish, red throat emperor, spangled emperor, sand crabs	Catch rates and the size of mud crabs and yellowfin bream were higher within the two old green zones compared to the new green zones (SZs) or open areas. However, sand crabs did not show any significant responses to zoning in any of the SZs surveyed. Catch rates and mean weight of snapper increased rapidly in the new SZs at St Helena Island. In the offshore areas of the marine park, the average biomass of the fishing target species: snapper, spangled emperor, red throat emperor, blackspot tuskfish, Maori rock cod and gold spot wrasse, all increased in the new SZs. In contrast, there was no significant change in the abundance of targeted aquarium species. Overall, there was evidence of a trend towards increased numbers and biomass of some targeted species within the new SZs within three years of their implementation. However, this is insufficient time to determine the full impacts of the zoning changes, particularly for long-lived species and further regular monitoring is required to make a comprehensive assessment.	Haywood et al. 2019
Ashmore Reef WA	Sharks esp. Carcharhinus amblyrhynchos	They surveyed shark assemblages at Ashmore Reef in Western Australia using baited remote underwater video stations in 2004 prior to enforcement of MPA status and then again in 2016 after eight years of strict enforcement. After 10 years of marine park status, they found an increase in the relative mean abundance of sharks Carcharhinus amblyrhynchos from 0.16 ± 0.06 individuals/hr-1 in 2004 to 0.74 ± 0.11 individuals/hr-1 in 2016, a change that was also accompanied by a shift in the assemblage of sharks to greater proportions of apex species (from 7.1% to 11.9%) and reef sharks (from 28.6% to 57.6%), and a decrease in the proportional abundance of lower trophic level species (from 64.3% to 30.5%).	Speed et al. 2018
Australian coastal marine protected areas		Increased connectivity and depth improved marine reserve benefits and that these factors should be considered to optimise such benefits over time.	Goetze et al. 2021
Australian shallow reefs		Continent-wide declines in shallow reef life over a decade of ocean warming.	Edgar et al. 2023

Peer reviewed published literature

Aston, C., Langlois, T., Fisher, R., Monk, J., Gibbons, B., Giraldo-Ospina, A., Lawrence, E., Keesing, J., Lebrec, U. and Babcock, R.C. (2022). Recreational Fishing Impacts in an Offshore and Deep-Water Marine Park: Examining Patterns in Fished Species Using Hybrid Frequentist Model Selection and Bayesian Inference. 9. [online] doi:https://doi.org/10.3389/fmars.2022.835096.

Barrett, N.S., Edgar, G.J., Buxton, C.D. and Haddon, M. (2007). Changes in fish assemblages following 10 years of protection in Tasmanian marine protected areas. Journal of Experimental Marine Biology and Ecology, 345(2), pp.141–157. doi:https://doi.org/10.1016/j.jembe.2007.02.007.

Barrett, N.S., Buxton, C.D. and Edgar, G.J. (2009). Changes in invertebrate and macroalgal populations in Tasmanian marine reserves in the decade following protection. Journal of Experimental Marine Biology and Ecology, 370(1-2), pp.104–119. doi:https://doi.org/10.1016/j.jembe.2008.12.005.

Bates, A.E., Stuart-Smith, R.D., Barrett, N.S. and Edgar, G.J. (2017). Biological interactions both facilitate and resist climate-related functional change in temperate reef communities. Proceedings of the Royal Society B: Biological Sciences, 284(1856), p.20170484. doi:https://doi.org/10.1098/rspb.2017.0484.

Beck, H.J., Feary, D.A., Fowler, A.M., Madin, E.M.P. and Booth, D.J. (2016). Temperate predators and seasonal water temperatures impact feeding of a range expanding tropical fish. Marine Biology, 163(4). doi:https://doi.org/10.1007/s00227-016-2844-8.

Butcher, P., Boulton, A., Macbeth, W. and Malcolm, H. (2014). Long-term effects of marine park zoning on giant mud crab Scylla serrata populations in three Australian estuaries. Marine Ecology Progress Series, 508, pp.163–176. doi:https://doi.org/10.3354/meps10865.

Coleman, M.A., Palmer-Brodie, A. and Kelaher, B.P. (2013). Conservation benefits of a network of marine reserves and partially protected areas. Biological Conservation, 167, pp.257–264. doi:https://doi.org/10.1016/j.biocon.2013.08.033.

Coleman, M.A., Bates, A.E., Stuart-Smith, R.D., Malcolm, H.A., Harasti, D., Jordan, A., Knott, N.A., Edgar, G.J. and Kelaher, B.P. (2015). Functional traits reveal early responses in marine reserves following protection from fishing. Diversity and Distributions, 21(8), pp.876–887. doi:https://doi.org/10.1111/ddi.12309.

Curley, B.G., Kingsford, M.J. and Gillanders, B.M. (2002). Spatial and habitat-related patterns of temperate reef fish assemblages: implications for the design of Marine Protected Areas. Marine and Freshwater Research, 53(8), p.1197. doi:https://doi.org/10.1071/mf01199.

Curley, B.G., Glasby, T.M., Curley, A.J., Creese, R.G. and Kingsford, M.J. (2013). Enhanced numbers of two temperate reef fishes in a small, partial-take marine protected area related to spearfisher exclusion. Biological Conservation, 167, pp.435–445. doi:https://doi.org/10.1016/j.biocon.2013.07.031.

Edgar, G. and Stuart-Smith, R. (2009). Ecological effects of marine protected areas on rocky reef communities—a continental-scale analysis. Marine Ecology Progress Series, 388, pp.51–62. doi:https://doi.org/10.3354/meps08149.

Edgar, G.J., Barrett, N.S. and Stuart-Smith, R.D. (2009). Exploited reefs protected from fishing transform over decades into conservation features otherwise absent from seascapes. Ecological Applications, 19(8), pp.1967–1974. doi:https://doi.org/10.1890/09-0610.1.

Edgar, G.J., Ward, T.J. and Stuart-Smith, R.D. (2018). Rapid declines across Australian fishery stocks indicate global sustainability targets will not be achieved without an expanded network of 'no-fishing' reserves. Aquatic Conservation: Marine and Freshwater Ecosystems, 28(6), pp.1337–1350. doi:https://doi.org/10.1002/aqc.2934.

Edgar, G.J., Stuart-Smith, R.D., Heather, F.J., Barrett, N.S., Turak, E., Sweatman, H., Emslie, M.J., Brock, D.J., Hicks, J., French, B., Baker, S.C., Howe, S.A., Jordan, A., Knott, N.A., Mooney, P., Cooper, A.T., Oh, E.S., Soler, G.A., Mellin, C. and Ling, S.D. (2023). Continent-wide declines in shallow reef life over a decade of ocean warming. Nature, [online] pp.1–8. doi:https://doi.org/10.1038/s41586-023-05833-y.

Emslie, Michael J., Logan, M., Williamson, David H., Ayling, Anthony M., MacNeil, M. Aaron, Ceccarelli, D., Cheal, Alistair J., Evans, Richard D., Johns, Kerryn A., Jonker, Michelle J., Miller, Ian R., Osborne, K., Russ, Garry R. and Sweatman, Hugh P.A. (2015). Expectations and Outcomes of Reserve Network Performance following Re-zoning of the Great Barrier Reef Marine Park. Current Biology, 25(8), pp.983–992. doi:https://doi.org/10.1016/j.cub.2015.01.073.

Evans, R.D. and Russ, G.R. (2004). Larger biomass of targeted reef fish in no-take marine reserves on the Great Barrier Reef, Australia. Aquatic Conservation: Marine and Freshwater Ecosystems, 14(5), pp.505–519. doi:https://doi.org/10.1002/aqc.631.

Ferguson, A.M., Harvey, E.S. and Knott, N.A. (2016). Herbivore abundance, site fidelity and grazing rates on temperate reefs inside and outside marine reserves. Journal of Experimental Marine Biology and Ecology, 478, pp.96–105. doi:https://doi.org/10.1016/j.jembe.2016.02.008.

Fowler, A.M., Macreadie, P.I., Jones, D.O.B. and Booth, D.J. (2014). A multi-criteria decision approach to decommissioning of offshore oil and gas infrastructure. Ocean & Coastal Management, 87, pp.20–29. doi:https://doi.org/10.1016/j.ocecoaman.2013.10.019.

Fowler, A.M., Feary D.A. and Booth D.J. (in press). Fishing affects the predator avoidance behaviour of both target and non-target reef fishes. Marine Biology

Gilby, B.L., Olds, A.D., Yabsley, N.A., Connolly, R.M., Maxwell, P.S. and Schlacher, T.A. (2017). Enhancing the performance of marine reserves in estuaries: Just add water. Biological Conservation, 210, pp.1–7. doi:https://doi.org/10.1016/j.biocon.2017.03.027.

Goetze, J.S., Wilson, S., Radford, B., Fisher, R., Langlois, T.J., Monk, J., Knott, N.A., Malcolm, H., Currey-Randall, L.M., Ierodiaconou, D., Harasti, D., Barrett, N., Babcock, R.C., Bosch, N.E., Brock, D., Claudet, J., Clough, J., Fairclough, D.V., Heupel, M.R. and Holmes, T.H. (2021). Increased connectivity and depth improve the effectiveness of marine reserves. Global Change Biology, 27(15), pp.3432–3447. doi:https://doi.org/10.1111/gcb.15635.

Goodridge, L.A., Henderson, C., Mosman, J.D., Olds, A.D., Borland, H.P. and Gilby, B.L. (2022). Seascape context matters more than habitat condition for fish assemblages in coastal ecosystems. Oikos, 2022(8). doi:https://doi.org/10.1111/oik.09337.

Hall, A., Cameron, D. and Kingsford, M. (2022). Prohibiting spearfishing boosts conservation outcomes for partially protected areas. Biological Conservation, 272, p.109662. doi:https://doi.org/10.1016/j.biocon.2022.109662.

Harasti, D., Martin-Smith, K. and Gladstone, W. (2014). Does a No-Take Marine Protected Area Benefit Seahorses? PLoS ONE, 9(8), p.e105462. doi:https://doi.org/10.1371/journal.pone.0105462.

Harasti, D., Williams, J., Mitchell, E., Lindfield, S. and Jordan, A. (2018). Increase in Relative Abundance and Size of Snapper Chrysophrys auratus Within Partially-Protected and No-Take Areas in a Temperate Marine Protected Area. Frontiers in Marine Science, 5. doi:https://doi.org/10.3389/fmars.2018.00208.

Harasti, D., Davis, T.R., Jordan, A., Erskine, L. and Moltschaniwskyj, N. (2019). Illegal recreational fishing causes a decline in a fishery targeted species (Snapper: Chrysophrys auratus) within a remote no-take marine protected area. PLOS ONE, 14(1), p.e0209926. doi:https://doi.org/10.1371/journal.pone.0209926.

Harrison, Hugo B., Williamson, David H., Evans, Richard D., Almany, Glenn R., Thorrold, Simon R., Russ, Garry R., Feldheim, Kevin A., van Herwerden, L., Planes, S., Srinivasan, M., Berumen, Michael L. and Jones, Geoffrey P. (2012). Larval Export from Marine Reserves and the Recruitment Benefit for Fish and Fisheries. Current Biology, 22(11), pp.1023–1028. doi:https://doi.org/10.1016/j.cub.2012.04.008.

Haywood M., Pillans R., Babcock R., Lawrence E., Darnell R., Burridge C., Dennis D., Donovan A., Cheers S., Pendrey R. and Dell Q. (2019). Protected: Changes in fish and crab abundance in response to the Moreton Bay Marine Park rezoning. In: Tibbetts IR, Rothlisberg PC, Neil DT, Homburg TA, Brewer DT, & Arthington AH (Eds). Moreton Bay Quandamooka & Catchment: Past, present, and future. The Moreton Bay Foundation. Brisbane, Australia. Available from: https://moretonbayfoundation.org/

Kelaher, B.P., Coleman, M.A., Broad, A., Rees, M.J., Jordan, A. and Davis, A.R. (2014). Changes in Fish Assemblages following the Establishment of a Network of No-Take Marine Reserves and Partially-Protected Areas. PLoS ONE, 9(1), p.e85825. doi:https://doi.org/10.1371/journal.pone.0085825.

Kiggins, R.S., Knott, N.A., New, T. and Davis, A.R. (2019). Fish assemblages in protected seagrass habitats: Assessing fish abundance and diversity in no-take marine reserves and fished areas. Aquaculture and Fisheries. doi:https://doi.org/10.1016/j.aaf.2019.10.004.

Knott, N.A., Williams, J., Harasti, D., Malcolm, H.A., Coleman, M.A., Kelaher, B.P., Rees, M.J., Schultz, A. and Jordan, A. (2021). A coherent, representative, and bioregional marine reserve network shows consistent change in rocky reef fish assemblages. Ecosphere, 12(4). doi:https://doi.org/10.1002/ecs2.3447.

Malcolm, H.A., Williams, J., Schultz, A.L., Neilson, J., Johnstone, N., Knott, N.A., Harasti, D., Coleman, M.A. and Jordan, A. (2018). Targeted fishes are larger and more abundant in 'no-take' areas in a subtropical marine park. Estuarine, Coastal and Shelf Science, 212, pp.118–127. doi:https://doi.org/10.1016/j.ecss.2018.07.003.

McCook, L.J., Ayling, T., Cappo, M., Choat, J.H., Evans, R.D., De Freitas, D.M., Heupel, M., Hughes, T.P., Jones, G.P., Mapstone, B., Marsh, H., Mills, M., Molloy, F.J., Pitcher, C.R., Pressey, R.L., Russ, G.R., Sutton, S., Sweatman, H., Tobin, R. and Wachenfeld, D.R. (2010). Adaptive management of the Great Barrier Reef: A globally significant demonstration of the benefits of networks of marine reserves. Proceedings of the National Academy of Sciences, 107(43), pp.18278–18285. doi:https://doi.org/10.1073/pnas.0909335107.

McKinley, A.C., Ryan, L., Coleman, M.A., Knott, N.A., Clark, G., Taylor, M.D. and Johnston, E.L. (2011). Putting marine sanctuaries into context: a comparison of estuary fish assemblages over multiple levels of protection and modification. Aquatic Conservation: Marine and Freshwater Ecosystems, 21(7), pp.636–648. doi:https://doi.org/10.1002/aqc.1223.

Olds, A.D., Connolly, R.M., Pitt, K.A., Pittman, S.J., Maxwell, P.S., Huijbers, C.M., Moore, B.R., Albert, S., Rissik, D., Babcock, R.C. and Schlacher, T.A. (2015). Quantifying the conservation value of seascape connectivity: a global synthesis. Global Ecology and Biogeography, 25(1), pp.3–15. doi:https://doi.org/10.1111/geb.12388.

Parsons, D., Babcock, R., Hankin, R., Willis, T., Aitken, J., O'Dor, R. and Jackson, G. (2003). Snapper Pagrus auratus (Sparidae) home range dynamics: acoustic tagging studies in a marine reserve. Marine Ecology Progress Series, 262, pp.253–265. doi:https://doi.org/10.3354/meps262253.

Pettersen, A.K., Marzinelli, E.M., Steinberg, P. and Coleman, M.A. (2021). The impact of marine protected areas on temporal stability of fish species diversity. Conservation Biology. doi:https://doi.org/10.1111/cobi.13815.

Pillans, S., Johnstone, R., Possingham, H., Pillans, R., Dews, G. and McPhail, Ian. (2003). Effectiveness of No-Take Marine Reserves in Subtropical Australia. In: Proceedings of the Fifth International Conference on Science and the Management of Protected Areas (eds Munro, N. W. P et al) University of Victoria, British Columbia, Pp 1-8.

Pryor, S.H., Schultz, A.L., Malcolm, H.A. and Smith, S.D.A. (2019). Partial protection disallowing trawling has conservation benefits in a subtropical marine park. Ocean & Coastal Management, [online] p.105027. doi:https://doi.org/10.1016/j.ocecoaman.2019.105027.

Robbins, W.D., Hisano, M., Connolly, S.R. and Choat, J.H. (2006). Ongoing Collapse of Coral-Reef Shark Populations. Current Biology, 16(23), pp.2314–2319. doi:https://doi.org/10.1016/j.cub.2006.09.044.

Smith, S.D.A. and Edgar, R.J. (2014). Documenting the Density of Subtidal Marine Debris across Multiple Marine and Coastal Habitats. PLoS ONE, 9(4), p.e94593. doi:https://doi.org/10.1371/journal.pone.0094593.

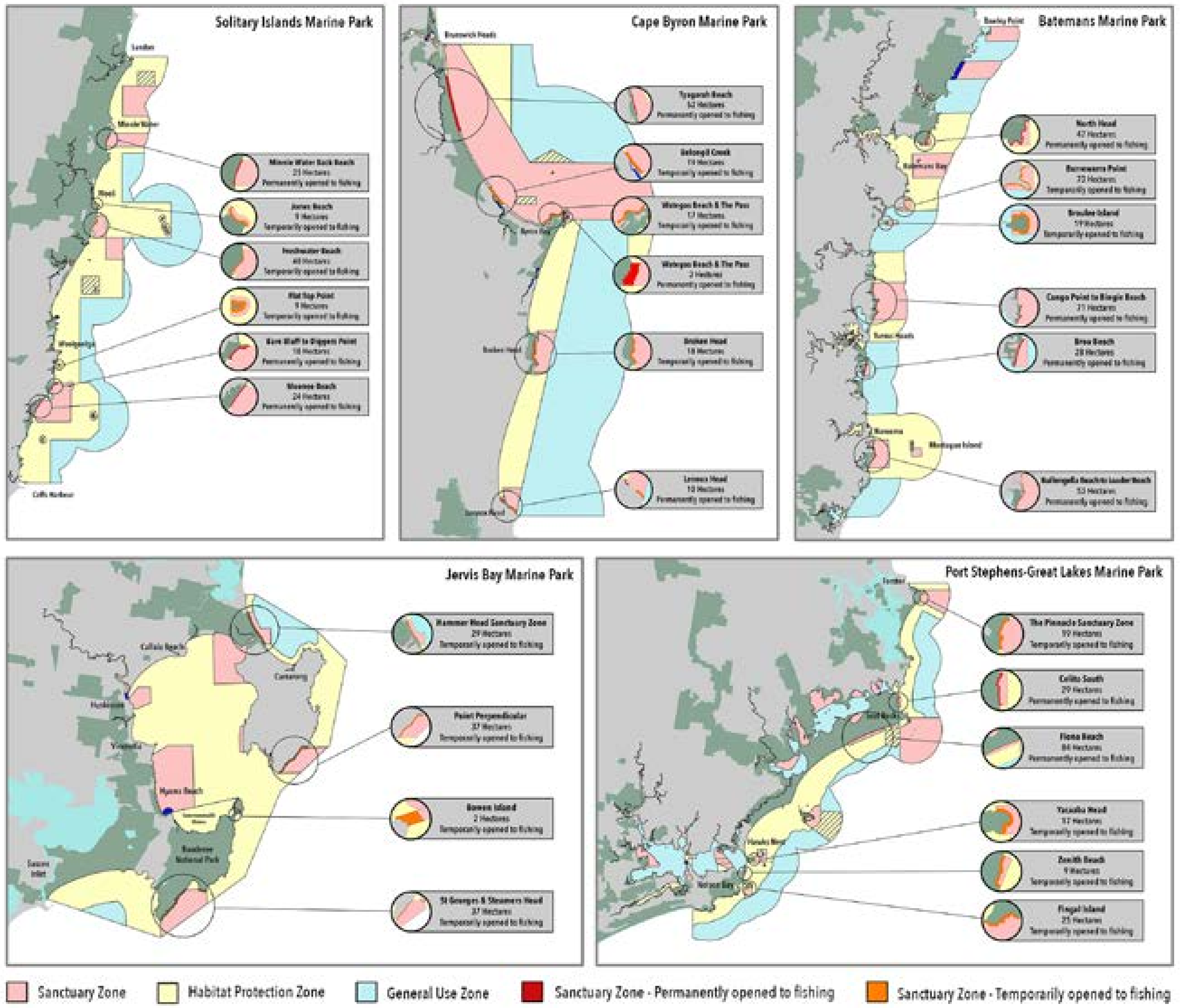
Speed, C.W., Cappo, M. and Meekan, M.G. (2018). Evidence for rapid recovery of shark populations within a coral reef marine protected area. Biological Conservation, 220, pp.308–319. doi:https://doi.org/10.1016/j.biocon.2018.01.010.

Turnbull, J.W., Shah Esmaeili, Y., Clark, G.F., Figueira, W.F., Johnston, E.L. and Ferrari, R. (2018). Key drivers of effectiveness in small marine protected areas. Biodiversity and Conservation, 27(9), pp.2217–2242. doi:https://doi.org/10.1007/s10531-018-1532-z.

Watson, D., Anderson, M., Kendrick, G., Nardi, K. and Harvey, E. (2009). Effects of protection from fishing on the lengths of targeted and non-targeted fish species at the Houtman Abrolhos Islands, Western Australia. Marine Ecology Progress Series, 384, pp.241–249. doi:https://doi.org/10.3354/meps08009.

Appendix 2

NSW Beaches and headlands that were permanently or temporarily opened to fishing as a result of "The Amnesty" in 2013.



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