MARINE ESTATE MANAGEMENT AUTHORITY

An audit of trained river entrances, armoured harbours and groynes and their multi-use and eco-features in NSW

Summary Report

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Cover image: Montage of multi-use and eco-engineering features used in NSW coastal infrastructure

Cover photo sources: Patrick Dwyer, Lea Mamo Google Earth, Ron Main and Adrian Toovey

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Why do an audit?

This is the first comprehensive audit of the 134 breakwater structures—large coastal structures that train river entrances, armour harbours and manage sand along the NSW coastline.

The audit is a first-pass assessment of these structures, their multi-use and eco-features, and their impacts on the environment. It has given us baseline information we need to better manage the structures. Multi-use features are built elements, such as a crest surface that provides access for pedestrians, and outcomes that enable uses and values additional to the structure's primary purpose. Eco-features are built elements or design outcomes that achieve an environmental benefit.

Completing an audit of these structures and features is important because estuary entrance modification—primarily caused by training river entrances and installing breakwaters—was identified as the second highest threat to the environmental assets in the NSW marine estate by the Threat and Risk Assessment undertaken by the Marine Estate Management Authority (MEMA) (Fletcher and Fisk 2017).

The community's access, use and enjoyment of nearshore and offshore marine environments is also important. This audit documents how some structures have features that improve access or add to social, cultural, economic and environmental values. The audit also identifies structures that could be suitable for adding multi-use and eco-features during maintenance or upgrade works to maximise delivery of social, cultural, economic and environmental values.

The audit was prepared as part of Initiative 2 in the Marine Estate Management Strategy (MEMS) (NSW Government 2018). The initiative focuses on delivering healthy coastal habitats with sustainable use and development. Together with a literature review (Mamo et al 2021) and the development of guidance notes (Dwyer and Dengate 2021), the audit fulfils the delivery of Action 2.1.2 outlined in the MEMS.

These resources are tools to assist in adopting a more integrated approach to maximise value and minimise unwanted impacts when undertaking future works to maintain and retrofit priority coastal infrastructure.

The complete audit includes an Audit Summary Report (this document) and three illustrated volumes:

- Volume I Breakwater Audit MEMA North Region
- Volume II Breakwater Audit MEMA Central Region
- Volume III Breakwater Audit MEMA South Region.

The three MEMA regions and the structures that were audited are mapped in Figure 1.

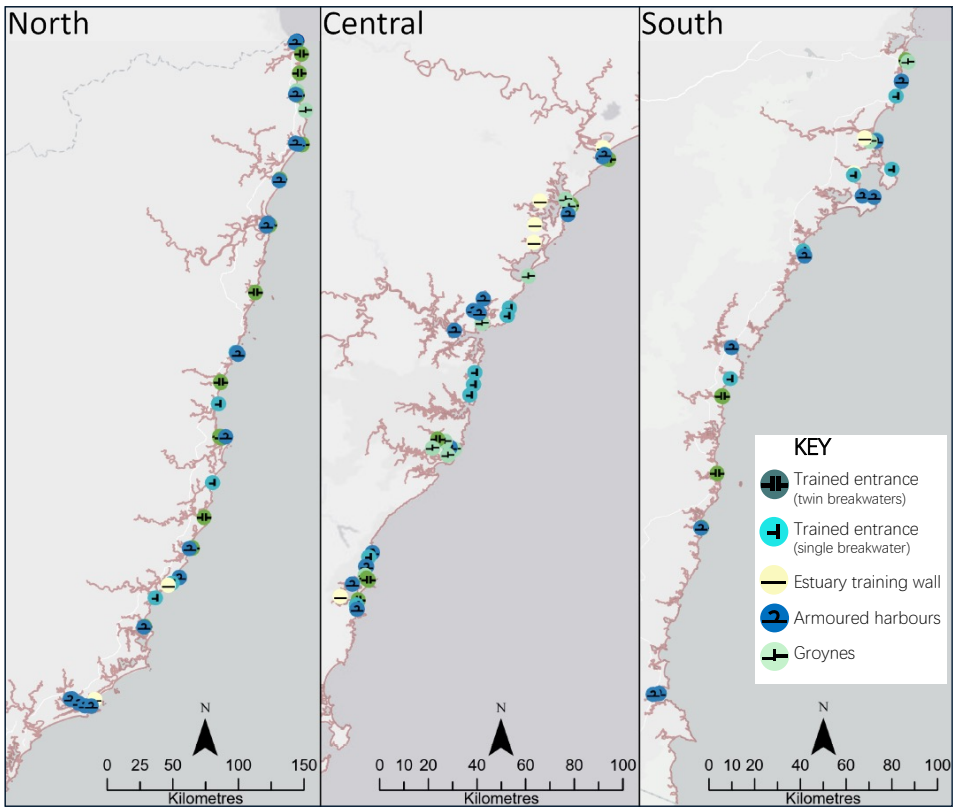


Figure 1: Marine Estate Management regions showing breakwater structures—trained river entrances, armoured harbours and groynes along the NSW coastline that were assessed in this audit.

Maps prepared by Alex Wray-Barnes and Emma Wilkie

Main findings

This audit of trained river entrances, armoured harbours and groynes and their multi-use and eco-features identified 134 structures along the NSW coastline. This total includes:

- 43 trained, or partially trained, estuary entrances
- 30 estuarine harbours
- 9 ocean harbours
- 13 groyne fields, eight of which are in estuaries.

Cumulatively, these structures total about 45 kilometres of breakwater and 72 kilometres of training wall and groyne infrastructure.

Most of the large coastal infrastructure is owned by the NSW Government, through either the Maritime Infrastructure Delivery Office or Crown Lands. Major port infrastructure at Newcastle, Sydney Harbour, Botany Bay, Port Kembla and Eden is managed by the Port Authority of New South Wales, NSW Ports, Port of Newcastle, and private port terminal operators. Several structures are owned by local government; ownership of some structures has not been able to be determined.

Unambiguous ownership arrangements are critical for sound management of existing structures. Many structures were built more than a century ago. They have become more vulnerable to damage from an increasing intensity and frequency of storms and sea level rise associated with climate change. They are also vulnerable to structural decline associated with ageing.

The audit found that many breakwaters have values and uses beyond their primary purpose. A key outcome from this audit was the identification of structures that could be suitable for adding multi-use and eco-features during structure maintenance or upgrade works. Table 1 summarises the first-pass assessment and shows priorities for investigation set after consultation with sector experts.

Detailed descriptions of all 134 structures are in the accompanying volumes.

Table 1: Summary of first-pass audit findings listing a subset of all the 134 structures that were audited, showing only those 77 structures where additional multi-use and eco-features could be considered

Structure	MULTI-USE AND ECO-FEATURES TO CONSIDER									
	Walking surface	Improve vista	Install CoastSnap photo point	Subtidal habitat			Refuge areas	Osprey tower	Fish Habitat Enhancement	
				Fishing platforms & seating	Emergency safety stairs	Netted swimming enclosure			Submerged habitat	Adjacent habitats
Tweed N	Maintain				Yes	Possible			Yes	
Tweed S	Maintain		Priority	Yes	Yes	Possible		Possible	Yes	Yes
Tweed Jack Evans harbour					Yes	Possible		Possible	Yes	
Cudgen N	Maintain		Priority		Yes	Possible				
Cudgen S	Maintain		Priority		Yes			Possible		
Mooball N							Examine and assess primary purpose			
Mooball S							Examine and assess primary purpose			
Brunswick N	Maintain		Priority		Yes		Maintain	Possible	Yes	Yes
Brunswick S	Maintain		Priority	Yes	Yes	Possible		Possible	Yes	Yes
Byron Main Beach groyne			Priority		Yes					
Richmond N	Maintain			Yes	Yes				Yes	Yes
Richmond S	Maintain		Priority		Yes			Possible	Yes	Yes
Evans N	Maintain		Priority		Yes		Maintain		Yes	
Evans S	Maintain				Yes				Yes	
Clarence N	Maintain				Yes		Maintain	Possible	Yes	Yes
Clarence S	Maintain			Yes	Yes			Possible	Yes	Yes
Iluka harbour					Yes				Yes	Yes
Yamba harbour				Yes	Yes				Yes	Yes
Wooli N	Maintain		Priority		Yes					Yes
Wooli S							Maintain	Possible		Yes
Coffs Harbour N	Maintain		Priority		Yes				Existing	
Coffs Harbour E	Maintain	Yes	Priority	Yes	Yes				Yes	
Bellinger N								Possible	Yes	Yes
Bellinger S							Maintain		Yes	Yes
Nambucca N	Maintain			Yes	Yes			Possible	Yes	Yes
Macleay N					Yes			Possible	Yes	Yes
Macleay S	Maintain			Yes	Yes			Possible	Yes	Yes
South West Rocks Creek N&S					Yes (N&S)					
Killick Creek					Existing					
Hastings N					Yes	Possible		Possible	Yes	
Hastings S	Maintain			Yes	Existing				Yes	

Structure	MULTI-USE AND ECO-FEATURES TO CONSIDER									
				Subtidal habitat					Fish Habitat Enhancement	
	Walking surface	Improve vista	Install CoastSnap photo point	Fishing platforms & seating	Emergency safety stairs	Netted swimming enclosure	Refuge areas	Osprey tower	Submerged habitat	Adjacent habitats
Camden Haven N	Maintain		Priority		Yes			Possible	Yes	Yes
Camden Haven S			Priority		Yes	Possible		Possible	Yes	Yes
Camden Haven harbour						Existing				
Manning N	Maintain			Yes	Yes		Maintain	Possible	Yes	Yes
Manning S training wall							Maintain			Yes
Wallis Lake N	Maintain		Priority	Maintain	Yes	Existing		Possible		
Wallis Lake S	Maintain		Priority		Yes					
Forster harbour	Maintain									
Port Stephens Hawkes Nest Moira Street										Yes
Port Stephens Soldiers Point harbour									Yes	
Port Stephens Corlette harbour	Maintain			Yes	Yes				Yes	
Nelson Bay d'Albora Marina	Maintain			Yes	Yes				Yes	
Hunter N	Maintain			Maintain	Existing	Possible			Yes	Yes
Hunter S	Maintain				Yes				Yes	
Kooragang Island training wall							Maintain			Yes
Lake Macquarie N	Maintain		Existing		Yes			Possible	Yes	Yes
Lake Macquarie S					Yes		Maintain			
Mawsons							Examine and assess primary purpose			
Gosford harbour	Maintain								Yes	
Botany Bay Molineux Point									Yes	
Cooks N	Upgrade			Yes	Yes					
Cooks S	Upgrade			Yes	Yes					
Botany Bay Lady Robinsons						Possible				
Botany Bay Silver Beach						Existing				
Wollongong N	Upgrade	Yes		Yes	Yes				Yes	
MM Groyne				Yes						
Port Kembla N	Maintain			Yes	Yes					
Port Kembla S	Maintain	Yes		Yes	Yes					
Lake Illawarra						Existing				
Lake Illawarra Berkeley harbour							Maintain			
Barrack Point			Priority							

Structure	MULTI-USE AND ECO-FEATURES TO CONSIDER									
				Subtidal habitat					Fish Habitat Enhancement	
	Walking surface	Improve vista	Install CoastSnap photo point	Fishing platforms & seating	Emergency safety stairs	Netted swimming enclosure	Refuge areas	Osprey tower	Submerged habitat	Adjacent habitats
Shell Cove N&S				Yes (N&S)	Yes (N&S)				Yes (N&S)	
Kiama harbour N&S	Maintain			Yes (N&S)						
Werri Lagoon							Examine and assess primary purpose			
Crookhaven N					Yes		Maintain	Possible		
Crookhaven boat ramp breakwater	Maintain			Maintain						
Crookhaven Greenwell Point	Maintain			Maintain						Yes
Currambene Ck Myola					Yes					Yes
Captains Point						Existing				
Murrays Beach	Maintain			Yes	Yes				Yes	
Ulladulla N	Maintain			Yes						
Batemans Bay S	Maintain		Priority	Yes	Yes				Yes	Yes
Moruya N	Maintain		Priority		Yes			Possible	Yes	Yes
Moruya S							Maintain		Yes	Yes
Wagonga Inlet N	Maintain		Priority		Yes	Existing		Possible	Yes	Yes
Wagonga Inlet S	Maintain				Yes				Yes	Yes
Bermagui N	Maintain		Priority		Yes	Possible			Yes	Yes
Bermagui S	Maintain				Yes	Existing				
Eden shipping terminal	Upgrade				Yes					
Eden Quarantine Bay	Upgrade				Yes					
Total for more detailed assessment and potential installation or upgrading	5	3	20	25	53	10	NA	22	43	32
Total existing to maintain	42	NA	1	4	3	7	12	NA	NA	NA

Note: N = North; S = South; Where applicable includes Shell Cove N&S currently under construction

Categorisation of structure type

Audited structures were categorised as either river training walls, armoured harbours, or sand trapping groynes. The criteria used are described below. Cataloguing in this way can be ambiguous as many structures have features, or achieve outcomes, that match multiple categories. For this audit, category assignment was informed by the intended purpose when the structure was built, if this information was available. Importantly, the audit has adopted an inclusive approach, listing built structures that were installed to manage or control estuary entrances, create harbours or manage sand regardless of the success of the eventual outcome. A key reason for the inclusive approach is that, even though a structure may not have fulfilled its intended purpose, the structure may have since been repurposed, or it may be having unintended impacts on other values.

Trained river entrances and connecting estuarine training walls

The audit identified 43 trained, or partially trained, estuary entrances. Fully trained entrances such as the Tweed, Richmond and Clarence Rivers are readily identifiable. They have large and prominent breakwaters that extend offshore. Partially trained estuaries with a single prominent breakwater wall, such as at the entrance of the Nambucca River, are also easily identified.

Estuaries such as Killick Creek and Narrabeen Lagoon were included as trained or partially trained due to the training effect of historical reclamation works at the estuary entrance. The audit also included estuaries where entrance training interventions are less apparent, such as the placement of boulders along part of the entrance channel at Cockrone Lagoon or the historical placement of ballast rock to improve the entrance of the Tomaga River at Mossy Point. Also included in the trained or partially entrance category are installations of buried geotextile sandbags to control some estuary entrances (for example, Racecourse Creek at Old Bar and Blackwater Creek at Mollymook).

Some entrance breakwater structures form a continuous structure with estuary training walls. Distinguishing a boundary between the breakwater and training wall is difficult. In some estuaries, the boundary may be defined with the presence of a wave-trap beach. The breakwater terminates on one side of the beach and an estuarine training wall continues further upstream on the other side of the wave-trap beach (Figure 2).

Figure 2: The boundary between breakwater (1) and estuarine training wall (2) is defined where the design incorporates a wave-trap beach (3).

Figure 3: The boundary between breakwater (1) and estuarine training wall (2) is not apparent in some estuaries. This audit uses the location of the hind dune (3) as a boundary as it generally aligns with focus of eco and multi-use features being ocean or estuary focused.

For some estuaries the breakwater has an impermeable core, while the estuarine training wall does not. In this audit, where a clear termination of the breakwater was not evident, breakwater distance was measured to the approximate location of the hind dune (Figure 3). This approach causes some inconsistence with the 100+ year old NSW Public Works records of breakwater and training wall lengths due to changes that have occurred to the foreshore and estuaries since estuaries were trained, such as the progradation of beaches. However, the hind dune or wave-trap beach boundary is suitable for distinguishing the focus of eco and multi-use features being ocean or estuary focused.

Armoured harbours

Armoured harbours are installed to create or enhance a sheltered and suitable location for mooring, berth or launching boats. The audit identified 39 harbours; nine are ocean harbours. Several estuarine harbours were created by leaving gaps in estuarine training walls (for example, Jack Evans Boat Harbour in the Tweed estuary, the Batemans Bay marina in the Clyde River, and the Hereford Street and Griffith Avenue harbours created on the northern side of the Hunter River). Other structures categorised as armoured harbours were initially used as both shelter and wharf structures. An example is the heritage-listed Woy Woy Railway Wharf Breakwater, which also looks somewhat like a groyne because it is perpendicular to the shore.

Sand trapping groynes

Groynes are usually installed perpendicularly to the shore to trap longshore sediments and stabilise the foreshore. Multiple groynes are installed in some places. In this audit, 13 groyne fields were identified, seven of which are in estuaries. Groynes differ from training structures as they are generally installed to manage sand along the foreshore rather than flows at estuary entrances and other waterway outlets. Many groynes do not have an impermeable core. A solid impermeable core is generally required to install a crest surface that provides access for most pedestrians.

Structures not audited

The audit did not assess rock armouring of riverbanks to manage erosion, works primarily associated with armouring bridge abutments, or relatively small-scale reclamation works.

Multiple values and uses

Multi-use features are built elements and outcomes that enable uses and values additional to the structure's primary purpose, such as a breakwater or an estuary training wall with a crest surface that also provides access for pedestrians.

Improved navigation for boating activities is the primary purpose for some of NSW's breakwater infrastructure, and 16 of the trained entrances and one ocean harbour have Coastal Bar Webcams for boating safety. Some estuary entrances have been trained for water quality and estuary management, management of ocean beach sand or flood mitigation. For entrance training works constructed for reasons other than boating, there are often no objective data on whether the structure fulfilled its intended purpose. The primary purpose of other structures when they were first constructed is no longer relevant. For a small set of structures, this audit was unable to determine a purpose for construction.

Many breakwaters have a range of values beyond their primary purpose. Breakwater infrastructure in NSW has resulted the stabilisation of shifting sand, resulting in an additional 3.2 kilometres of ocean beach (forming 11 beaches) and an extra 3.3 kilometres of estuarine beach (forming 19 estuarine beaches).

Eight structures are widely believed to have consistently improved surfing conditions, namely: Duranbah, North Wall Ballina, South Wall Ballina, Iluka Wall, Gallows Coffs Harbour, North Wall Port Macquarie, Tuncurry Breakwater, Newcastle breakwater.

At five locations—Richmond River north, Bellinger River south, Nambucca River, Lake Macquarie north and Wagonga Inlet south—the breakwater design creates rock enclosed swimming areas called sea lidos.

At another seven sites, the breakwater design enabled the installation of netted swimming enclosures at Camden Haven harbour, Wallis Lake north, Botany Bay Silver Beach, Lake Illawarra estuary training wall south, Captains Point Jervis Bay, Wagonga Inlet north, Bermagui River south.

Ten other sites with similar designs, which create 'wave-trap' beaches, may also be suitable for installing enclosed swimming areas: Tweed north, south and Jack Evans Boat Harbour, Cudgen Creek north, Brunswick River south, Hastings River north, Camden Haven south, Hunter River north, Botany Bay Lady Robinsons Beach, Bermagui River north.

Along the NSW coast, 15 structures were designed in a way that enabled reclamation and the creation of 1093 hectares of commercial land.

Walking and sightseeing along breakwaters is a very popular activity. The majority of structures (112 of the 134) are within at least 200 metres of a public car park. Many structures (72) are either part of popular public walkways or have walkways next to them. Some 70 structures have a crest surface that provides access to many people. Nineteen structures, most of which are government-owned, have a smooth concrete crest surface finish that is fully accessible to everyone, including those who use wheelchairs and accessibility scooters.

The following sections describe some of the opportunities to add value to breakwater infrastructure in NSW.

Accessible crest surfaces

Most breakwater structures maximise access opportunities, especially the structures owned by the NSW Government. Access provides recreational opportunities for the community, and it is often required for maintenance of the breakwater by heavy equipment. Improving the crest surface is critical to increasing opportunity for other multiple uses.

The audit identified 19 structures with crest surfaces that have smooth and safe walking surfaces that are 'accessible for all' (Figure 4). Maintaining an 'accessible for all' surface maximises the opportunity for other social and cultural values to be fulfilled at these structures. These values could be improved at the nine structures where the crest surface was 'rubble and not a walking surface' or 'a difficult walking surface'.

For example, upgrading the crest surface of the northern breakwater at Wollongong Harbour to be 'accessible for all' would increase its use and value to the community, especially as it is close to a popular Wollongong Central Business District coastal walk known as The Blue Mile. Likewise, upgrading the crest surface of the twin breakwaters that train the Cooks River in Sydney where its modified entrance reaches Botany Bay would improve opportunities for walking, fishing and plane watching in that very popular location. Installing fishing platforms would also maximise fishing opportunities in the Botany Bay Recreational Fishing Haven.

Rubble crest surface, not a walking surface

A difficult walking surface, accessible to some

Safe walking standard, occasionally difficult walking surface, accessible to most

Smooth, safe walking surface, accessible to all

Figure 4: The four categories of breakwater crest surface identified in this audit.

Improving vista from breakwater structures

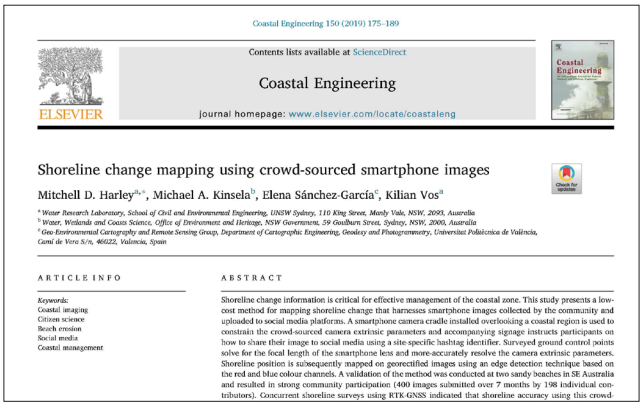
Many breakwaters are used to observe whales, birds, surfing and boating. The view from the end of a breakwater also provides a unique perspective back towards the coast. It is a perspective that Aboriginal people had when using these now submerged lands over 10,000 years ago. The audit identified several structures owned by the NSW Government (including Tweed estuary north, Richmond estuary north, Coffs Harbour northern breakwater and Camden Haven estuary north) where previous upgrade design works incorporated gradual elevation of the crest walkway surface to maximise sightseeing opportunities and improve pedestrian safety through visibility of approaching waves. This approach was pioneered by the NSW Government at the northern breakwater of the Richmond River Ballina. It is becoming standard practice.

The audit identified three structures where views could be improved by raising the walkway surface to enable people to safely see beyond the crest armour rock. Two of these structures, the eastern breakwater at Coffs Harbour (Figure 5) and the north wall at Wollongong Harbour, are owned by the NSW Government.

Installing CoastSnap photo points

Photo points are a tool for documenting morphodynamic change in the coastal environment by creating a library of photographic records taken from a fixed point over time. The NSW State Government's CoastSnap initiative, developed in collaboration with the UNSW Water Research Laboratory, engages the community in monitoring beaches to understand how different beaches respond to storm events and longer-term environmental drivers such as changes in climate, sea level and wave action (Harley et al. 2019; Rogers et al. 2020). The initiative involves installing a fixed cradle for a phone-camera with instructions and some information about coastal erosion information. Visitors can add their image to crowd-sourced images for analysis (Figure 6).

Figure 5: The eastern breakwater at Coffs Harbour is a site with opportunities to improve the view.



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Shoreline change mapping using crowd-sourced smartphone images

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ABSTRACT

Shoreline change information is critical for effective management of the coastal zone. This study presents a low-cost method for mapping shoreline change that harnesses smartphone images collected by the community and uploaded to social media platforms. A smartphone camera cradle installed overlooking a coastal region is used to constrain the crowd-sourced camera extrinsic parameters and accompanying signage instructs participants on how to share their image to social media using a site-specific hashtag identifier. Surveyed ground control points solve for the focal length of the smartphone lens and more-accurately resolve the camera extrinsic parameters. Shoreline position is subsequently mapped on georectified images using an edge detection technique based on the red and blue colour channels. A validation of the method was conducted at two sandy beaches in SE Australia and resulted in strong community participation (400 images submitted over 7 months by 198 individual contributors). Concurrent shoreline surveys using RTK-GNSS indicated that shoreline accuracy using this crowd-

Figure 6: The methodology of the CoastSnap program is outlined in a scientific paper (left). A CoastSnap photo point has been installed on the northern breakwater at Lake Macquarie providing an opportunity for visitors to contribute crowd-sourced images that are analysed to track shoreline change (right).

Source: Michael Kinsela

The breakwater sites recommended for the installation of a CoastSnap photo point were identified by the CoastSnap program manager Dr Michael Kinsela of the NSW Government Department of Planning Industry and Environment. Breakwaters are considered ideal locations to install CoastSnap photo points because many of the trained inlets disrupt longshore sand transport. Photo points can be installed on both north and south breakwaters. A disadvantage is the relatively low elevation of some breakwater structures. Table 1 includes 20 new sites that are considered suitable for CoastSnap photo points—these are where monitoring coastal erosion is important and there are no other suitable vantage points.

Recreational fishing platforms and seating opportunities

Recreational fishing platforms have been built on five breakwater structures. Of the 134 structures identified in this audit, 36 are in recreational fishing havens—these are places where commercial fishing effort has been removed to maximise recreational fishing opportunities. DPI Fisheries' Recreational Fishing Unit was consulted to identify breakwater locations where recreational fishing opportunities could be improved. In this first-pass assessment, 25 structures were identified as being appropriate for more detailed investigation of suitability for recreational fishing platforms. Consideration included:

- access to nearby populations
- knowledge about the seasonality of fishing related tourism
- suitability of the location for productive fishing
- the popularity of the existing structure for fishers.

Sixteen of the structures listed in Table 1 with potential to add recreational fishing facilities are owned and managed by the NSW Government; three are managed by NSW Ports. Seven of the locations where fishing platforms were recommended are in recreational fishing havens. Installing fishing platforms on the twin breakwaters where the Cooks River enters Botany Bay would improve recreational fishing opportunities in the Botany Bay Recreational Fishing Haven.

Emergency safety stairs

The existing network of breakwater structures and their adjacent waters are used by many groups. Emergency access stairs provide a way for rescuers to focus their efforts when someone finds themselves in trouble in the adjacent waterway.

Large metal stairs (Figure 7) that rise over the breakwater or training wall were developed in south east Queensland. It was a response to a fatal incident at the Southport Seaway on the Gold Coast in 2013, where removing the person suffering a medical emergency from the water up the breakwater was challenging. Informal emergency access points can also be created with careful placement and positioning of large flat rocks to form a 'rock stairway' during the replacement of breakwater armour rock. Figures 7 and 8 show metal and rock stairway safety access points incorporated into training wall and breakwater structures at Southport, Ballina and Stockton.

The rock emergency safety stairs shown in Figures 9 and 10 are on the Hastings River southern breakwater at Port Macquarie. Breakwater engineers report that these stairs were installed during breakwater maintenance works in response to a request by members of the Port Macquarie State Emergency Service after an incident: someone who had been swept down the river was not able to be reached from the breakwater. Fortunately, the person was able to be rescued by boat.

This audit identifies 53 structures where the installation of emergency safety stairs could be investigated. To maximise opportunities for emergency response, safety stairs could be located on northern and southern structures at multiple point along an estuary's training wall and breakwater network breakwaters. They could be co-located with life-saving buoys known as 'angel rings' by recreational fishers. A series of standard conceptual designs for safety stairs in a range of different settings and work method statements for installation could also be developed to increase adoption.

Figure 7: Metal safety stairs at the Southport Seaway in south east Queensland. These stairs are also used by many other breakwater users such as scuba divers and surfers. *Source: Gold Coast Dive Adventures*

Figure 8: Examples of safety stairs already incorporated into some NSW breakwater and training wall infrastructure.

Figure 9: Top view of the rock safety stairs in the Hastings River southern breakwater at Port Macquarie.

Figure 10: Side view of the rock safety stairs in the Hastings River southern breakwater at Port Macquarie.

Snorkelling and scuba diving

Some breakwaters can be suitable locations for snorkelling or scuba shore dives. The Coffs Harbour northern breakwater has been identified as a possible site for an underwater dive trail; the breakwater at Stockton on the Hunter River has opportunities to explore the shipwreck of the Adolphe. There is a strong and growing interest for shore-based snorkel and scuba diving opportunities within NSW.

Heritage values

Almost half of the breakwater structures in NSW were built more than 100 years ago. Thirty-one structures have been listed on registers for their heritage value or because there is a shipwreck in the immediate vicinity of the structure. Some structures are used as heritage trails. Examples include the Richmond River northern wall at Ballina, the breakwater at Nambucca Heads, and the northern wall of the Hunter River. A more widely applied

network of heritage trails and points of interest associated with breakwater structures could become part of a coastwide breakwater trail and the subject of QR-code or app-based tourism technology.

Many trained river entrances have shipwrecks that are important for our cultural heritage. Exact locations are known for only a small number of the many ships recorded as being shipwrecked on NSW coastal bars. Shipwreck heritage is managed under the *Commonwealth Underwater Cultural Heritage Act 2018*, which commenced on 1 July 2019 and replaces the *Historic Shipwrecks Act 1976*.

Consideration of the presence of underwater cultural heritage is required during maintenance and new works because the new Act requires:

> *All shipwrecks and their associated artefacts that have been underwater for 75 years remain protected and this level of protection will now be extended to sunken aircraft. Shipwrecks and aircraft that have been underwater less than 75 years, and other types of underwater cultural heritage, can be protected through individual declaration based on an assessment of heritage significance. (DAWE, 2019)*

As breakwaters project out onto the coastal seabed, they could serve a role as observatories looking into the past from both physical (geological) and human perspectives. Pairing visualisations of continental shelf landscapes during lower sea levels (and during sea level change) with local Aboriginal storytelling could capture people's imaginations and help them to connect with both geological time and (environmental change) and the Dreamtime.

Aboriginal cultures

Throughout coastal NSW, Aboriginal people have a special connection to Sea Country, which they have held for thousands of years. All of the large coastal infrastructure in NSW is located on Aboriginal land and Sea Country. Most of the existing breakwaters are located on, or very close to, important Aboriginal cultural heritage sites. In some cases, infrastructure and altered tidal movement has created erosion that has obstructed or covered these sites and may in the future disturb or uncover others. Many other structures are located on lands where Native Title claims have been initiated or determined. Some structures are adjacent to lands that are owned and managed by Local Aboriginal Land Councils. For some structures, the rocks that have been used to create breakwaters were sourced from sites that are also of importance to Aboriginal people.

The *Native Title Act 1993* (NT Act) gives recognition, by Australian law, of Aboriginal and Torres Strait Island People's traditional rights and interests in land and waters held under traditional law and custom. The NT Act protects native title rights by proscribing procedures (which can also be set out in an Indigenous Land Use Agreement) which must be complied with before a 'future act' can be validly done: this is any act that is inconsistent with the continued existence, enjoyment or exercise of native title. Any proposed development should consider the procedural requirements under the NT Act before commencement.

The involvement of Aboriginal people in effective land and Sea Country management protects Aboriginal cultural values. Meaningful engagement with relevant Aboriginal communities in the construction of coastal infrastructure, such as breakwaters, should be undertaken as a priority. This collaboration allows the cultural importance and traditional knowledge of an area to be included in the decisions around construction. It complements the process of informing changes that recognise and maintain Aboriginal peoples' connection to Sea Country. In addition, where there is opportunity for the participation of Aboriginal people to work On Country, this should also be considered.

Environmental impacts and values

Training the entrance of an estuary can substantially change the hydrology and hydrodynamics of a waterway (Mamo et al. 2021). This audit found documented evidence that there had been blasting of rock shelves at 14 of the 43 trained estuaries in NSW during training works. It is likely that the removal of rock shelves at river entrances would have increased the changes in tidal amplitude in the estuary.

Four abandoned breakwater structures are progressively deteriorating and still causing environmental and social impacts. Several other structures that were built have never fulfilled their intended purpose and have not been maintained. For some other structures installed for estuary management improvements to water quality, coastal management or flood mitigation, there has been no assessment to determine whether the structure is fulfilling is intended purposes or if it is causing unintended impacts.

In waterway areas identified as marine protected areas, there are 27 breakwater structures, of which 14 are owned and managed by the NSW Government. In NSW, there are six marine parks that extend across about 345,100 hectares (or 35% of the NSW marine estate). In all instances, the construction of the structures predates the declaration of the area as marine parks. Marine parks are managed with special legislative protection to conserve values and manage threats. In these areas, additional efforts should be made to prioritise reducing existing impacts from breakwaters and add environmental values. While consistent with this primary purpose, the objectives of marine park management support the provision of the multi-use opportunities that enable access and appreciation of the marine park.

Environmental values

Some breakwater structures in NSW add environmental value. Eco-features are built elements or design outcomes that achieve an environmental benefit. This audit is a first-pass assessment to identify sites where more detailed investigations could find the best set of eco-engineering designs to increase environmental values.

Wildlife refuge areas

The audit found 12 remote structures that have full or partial rubble crests that limit access and create habitat refuge areas. Three of the breakwaters owned by the NSW Government, including the Clarence northern breakwater (Figure 11), met the competing demands of access and habitat refuge. They provided partial access along the length of the long and remote structures.

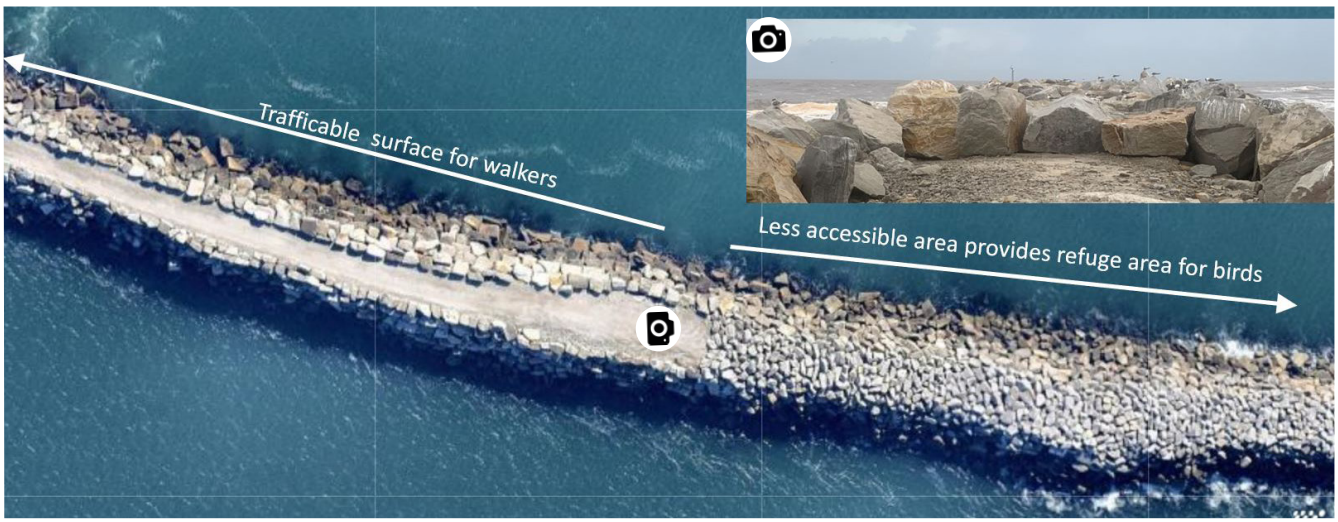

Figure 11: The Clarence northern breakwater has a habitat refuge for its last 250 metres.

Osprey towers

Ospreys are an endangered bird species in NSW. They are known to nest on marine infrastructure such as navigation markers (Thomson et al. 2019). Asset managers report that two pairs of ospreys successfully reared young on the Tweed Sand Bypass jetty. Discussion with experts from National Parks and Wildlife Service during the preparation of this audit found the coastal lands adjacent to breakwater were often good sites for osprey towers subject to:

- towers being located beyond a 200-metre buffer to areas that would be used in future breakwater maintenance work
- new towers being located at least 1 kilometre from known existing osprey nesting sites.

This audit's first-pass assessment found that Crown land adjacent to 22 breakwater locations could be investigated in more detail for their potential to have osprey towers installed. New towers could be installed when machinery is on-site for breakwater maintenance. They could also be installed by other asset managers such as energy authorities. Their aim may be to build new towers when it was necessary to relocate ospreys that have established nests in infrastructure incompatible with ongoing use by the birds. Proposals for new towers or other infrastructure on Crown land requires the osprey tower have certain and ongoing ownership, an asset management framework, and an authorisation for the occupation of Crown land under the *Crown Land Management Act 2016*. Organising these administrative tasks can take some time and may be most efficiently undertaken as a single project for all government-owned breakwaters where osprey towers have been recommended. This would enable the subsequent installation of towers to occur progressively as maintenance and upgrades occur without risk of delay in approvals.

Submerged habitat complexity

Increasing below-surface habitat complexity could be investigated for 43 structures. Techniques for maximising below-surface habitat complexity are outlined in the literature review by Mamo et al. (2021) and conceptual guidelines developed by Dwyer and Dengate (2021). Site-specific investigations will determine the type of habitat complexity to be installed. In Jack Evans Boat Harbour in the Tweed estuary, for instance, installation of seahorse hotels may improve habitat opportunities for the threatened Whites Seahorse. The installation of rock scree and a convoluted toe was suitable technique to maximise habitat for the critically endangered marine alga *Nereia lophocladia* during upgrades at the Coffs Harbour northern breakwater (Mamo et al. 2018).

Training wall design and modifications to enhance adjacent key fish habitats

Preliminary investigations identified 32 structures with designs and training wall layouts that may be able to be modified to increase opportunities for key fish habitat values for seagrass, oyster reefs, mangroves or saltmarsh in nearby backwaters. Marine Vegetation Management Strategies being developed for priority estuaries have identified some existing estuary training wall locations as opportunities for maximising future mangrove and saltmarsh communities in the backwaters created by the existing training wall network. Likewise, recent investigations into current and future potential oyster reefs have identified rubble areas next to breakwater and training wall areas as potentially ideal locations.

Minor modifications might involve improving flushing through a half-tide wall, or managing the elevation of a mosaic of backwater areas landward of the training wall to levels most suitable for the listed key fish habitat types. Such sites (Figure 12) may be suitable for the beneficial use of sediment dredged when maintaining navigation channels. The use of sediments may be a way to assist some intertidal marine vegetation build ground surface elevation and remain in the appropriate tidal window as sea levels rise.

Figure 12: Existing vegetation in the backwater behind the Macleay River southern training wall.

Ownership and management of structures

Ownership and management of some structures has not been able to be determined in this audit. The NSW Government (via the Maritime Infrastructure Delivery Office) manages most of the structures related to entrance channel infrastructure and regional harbours. NSW Ports manages structures at Port Kembla and Eden. Unambiguous ownership arrangements are critical to sound management, including a regime of contemporary asset management for existing structures.

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