The effects of sediment on birds foraging in intertidal and nearshore habitats in Aotearoa New Zealand – A literature review and recommendations for future work

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The effects of sediment on birds foraging in intertidal and nearshore habitats in Aotearoa New Zealand

A literature review and recommendations for future work

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Caspian tern (taranui, *Hydroprogne caspia*) searching for prey. *Photo: Edin Whitehead*.

Cover image:

Background: Turbid waters surround Aotearoa New Zealand. NASA image courtesy Norman Kuring, Ocean Colour Team.

Inset top left: Karepiro Bay, Auckland. *Photo: Long Bay Okura Great Park Society*.

Inset right: Australasian gannet, white-fronted tern, wrybill. *Photos: Edin Whitehead*.

Executive summary

In Aotearoa New Zealand, sedimentation is the third highest scoring threat to coastal marine habitats and, until recently, the only one that could be impacted by activities governed by the Resource Management Act (RMA) 1991. The RMA defines the coastal environment as the foreshore, seabed, coastal water, and the air space above the water between the Mean High Water Spring (MHWS) mark to the outer limits of the territorial sea, an area of 167,650 km^2. The aim of this review is to outline the impacts of marine sedimentation on the foraging of coastal avian species throughout Aotearoa New Zealand and how these impacts have been addressed in the context of the RMA. New Zealand's coastal waters support an abundance of bird species, including 87 species of seabirds and 47 species of shorebirds, many of which are ranked as Threatened or At Risk in the New Zealand Threat Classification System. For those species of seabirds and shorebirds already in decline in New Zealand, any reductions in foraging efficiency caused by sedimentation could have profound effects on adult populations and subsequent recruitment.

Marine sedimentation is primarily caused by human activities on land and at sea. Activities on land that contribute to marine sedimentation include urban development, forestry and agriculture. At sea, destructive fishing practices, dredging, sediment dumping, and mining can create turbid water that reduces the foraging efficiency of many marine species. Sedimentation events can be cumulative, where sediment accumulates slowly over time, or catastrophic, where sediment is rapidly deposited, often following severe rainfall. The projected increase in the frequency and intensity of storm events with climate change may result in less recovery time between catastrophic sedimentation events, which can create less-resilient ecosystems. Both cumulative and catastrophic sedimentation events can negatively impact seabird and shorebird foraging, either directly or indirectly.

Literature detailing the direct impact of sedimentation on seabirds and shorebirds is scant. There is some information on how the turbidity caused by sedimentation can impact visual foraging seabirds such as terns, shags, and penguins. There are more literature sources detailing how sedimentation can indirectly impact seabirds and shorebirds through the effect it has on the marine food web. A key focus of the literature is how macroinvertebrates are impacted by catastrophic sedimentation events. From this, assumptions can be made of how shorebirds may be impacted through changes in the distribution, abundance and composition of their key prey source. Decreased light penetration, smothering of the seafloor, and a change in community composition caused by marine sedimentation are also discussed in the literature.

In Section 6 of this report, case studies highlight how the RMA and/or the New Zealand Coastal Policy Statement (2010) have been or can be used to avoid, remedy, and/or mitigate marine sedimentation impacts on seabirds and shorebirds. Information used in this section comes from primary literature and grey literature (including technical reports, theses, evidence, personal communication, news reports and personal observations). Case studies discuss actual or potential impacts of marine sedimentation caused by land use discharges, destructive fishing, mining, dredging and sediment disposal.

This review outlines how sedimentation can both directly and indirectly impact seabird and shorebird foraging. However, it mainly highlights how little we know about this important issue. Knowledge gaps are identified and research recommendations made. A prioritised approach is needed for further research relating to sedimentation impacts on seabirds and shorebirds, which will allow outstanding knowledge gaps to be addressed and inform future policy decisions and documents in New Zealand.

He Whakarāpopoto

I Aotearoa, ko te parakiwaitanga te tuatoru o ngā kaipatu i ngā nōhanga takutai moana, ā, tae atu ki tēnei wā, koinei anake te mea ka pāngia e ngā mahi kei raro i te mana o te Ture Whakahaere Rawa (RMA) 1991. Koia tēnei ko te whakamārama a te RMA mō te taiao takutai; ko te marae o Hinekirikiri, te kaupapa o te moana, te wai takutai me te hau takiwā kei runga o te wai kei waenganui o te Tai Nui Toharite puta atu ki te pae waho o te rohe moana, ā, hui katoa te takiwā 167,650km^2 tōna tapeke. Ko te whāinga o tēnei arotake he whakarārangi i ngā pānga o te parakiwaitanga moana ki te rapunga kai a ngā manu tai puta noa i Aotearoa, me te aha, ko te mahi whakatika a te RMA ki ēnei pānga. He maha ngā momo manu e tautokona ana e ngā wai takutai o Aotearoa, arā, e 87 ngā momo manu moana, e 47 ngā momo manu tai. Mo te maha o ngā momo manu moana, manu tai hoki kua heke kē nei i Aotearoa, ina heke tonu te kounga o te rapunga kai nā te parakiwaitanga, ka kino pea te pānga ki ngā taupori kātua me te tupuranga o ngā pīpī.

Ko te pūtake o te parakiwaitanga o te moana ka mātua takea mai i te mahi a te tangata ki te whenua me te moana. Ko ngā mahi kei runga whenua e whakaparakiwai ana i te moana ko ēnei; te whakawhanake tāone, te ngāherehere me te ahuwhenua. Ki te moana ia, nā ngā tikanga hao ika whakamōtī pēnei i te pūrere rou, te ruke para me te maina, ka paru haere te wai, ka wai ehuehu, ā, ka whakahekea te kounga o te rapunga kai a ngā tini momo o te moana. He mea whakapiki haere te putuputu o te parakiwai, arā, ka āta whakapiki haere i te takanga o te wā. Mānohi anō, ka tere te putuputu haere o te parakiwai, i te nuinga o te wā i muri mai o te ua tātā, kāti, kei te korokoro o te parata. Ko te whakapikinga o te auau me te kaha o ngā āwhā e whakapaetia ana, āpiti ki tēnā ko te panonitanga āhuarangi, ka iti iho pea te wā whakahaumanu i waenga i te takanga o ngā aituā parakiwaitanga. Nā tēnei ka ngoikore haere te aumangea o ngā pūnaha rauropi. Ka mutu, nā te parakiwaitanga auau me te aituā parakiwaitanga ka raru te rapunga kai a ngā manu moana me ngā manu tai, raru hāngai, raru huriāwhio rānei.

Tahitahi noa iho ngā tuhinga e āta whakamārama ana i te pānga tōtika o te parakiwaitanga ki ngā manu moana me ngā manu tai. Arā tonu ētahi kōrero mō te ehunga o te wai i te parakiwaitanga me tōna pānga ki ngā manu rapu kai ā-kanohi pēnei i te tara, i te kawau me te kororā. He nui ake ia ngā tuhinga taipitopito e whakaatu ana i te pānga parakiwaitanga kāore e hāngai ana ki ngā manu moana me ngā manu tai nā te kino ka pā ki te māwhaiwhai kame moana. Ko tētahi take matua mō ngā tuhinga ko te kite i te pānga o te parakiwaitanga aituā ki ngā tuaiwi-kore e noho ana ki te papa moana. Mai i tēnei ka āhei te hanga whakapae mō te pānga kino ki ngā manu tai mā ngā panonitanga ki te horanga, te rahinga me te hanganga o tā rātou tino kai. E matapakitia ana hoki ko te hekenga o te aho, te tāmitanga o te papa moana me te huringa o ngā kai rāroto, rārunga o te papa i te parakiwaitanga o te moana.

Kei te wāhanga 6 o tēnei pūrongo he kēhi rangahau e whakamira ana i te āheinga o te RMA, o te Kaupapa Here Tauākī Takutai rānei o Aotearoa (2010) ki te karo, ki te whakatika, ki te whakaheke rānei i te pānga o te parakiwaitanga moana ki ngā manu moana me ngā manu tai. E ahu mai ana te pārongo e kōrerotia nei i tēnei wāhanga i ngā tuhinga mātāmua, i ngā tuhinga umanga, arā, i ngā pūrongo hangarau, i ngā tuhinga whakapae ariā, i te taunakitanga, i ngā kōrero ā-waha, i ngā kawepūrongo me ngā kitenga ā-kanohi. E wānanga ana ngā rangahau i te pānga pū, i te pānga parakiwaitanga moana rānei e whakapaetia ana ka takea mai i ngā rukenga whenua, i ngā whakahaere kino o te hao ika, o te maina, o te pūrere rou me te ruke parakiwai.

E whakatakoto ana tēnei arotake i te pānga tōtika, huriāwhio hoki o te parakiwaitanga ki te rapunga kai a ngā manu moana me ngā manu tai. Heoi anō e mātua whakamira ana i tā tātou noho kuare ki tēnei take nui whakahira. Kua tautuhia ngā āputa o te mātauranga me te whakatakoto i ngā taunakitanga. Kua āta whakarārangitia te anga whakamua mō te rangahau e hāngai ana ki te pānga o te parakiwai ki ngā manu moana me ngā manu tai, ā, ko ngā pātai tārewa, ā taihoa ake ka uruparetia. Ka mutu, ka whakamōhio i ngā whakataunga kaupapa here me ngā tuhinga o te āpōpō mō Aotearoa.

Contents

White-fronted tern, inner Hauraki Gulf. *Photo: Edin Whitehead*

1. Introduction

Based on the rankings of MacDiarmid et al. (2012), marine sedimentation (primarily from land run-off) is the highest ranked marine pressure in New Zealand that can be mitigated under the Resource Management Act (RMA) 1991 and the New Zealand Coastal Policy Statement 2010 (Policy 22; DOC 2010).

The Department of Conservation (DOC) is coordinating and encouraging a national strategy for reducing sedimentation impacts in the marine environment according to national policies and legislation. DOC's 'Reducing Coastal Sediment Impacts Project' received funding to investigate sedimentation as a threat to marine habitats managed under the RMA (within the 12 nautical mile (NM) limit).

The aim of this project is to inform RMA processes (through regional policies, plans and consents) to promote the sustainable management of natural and physical resources by improving management of land-derived sediments and marine-based activities.

The 'Reducing Coastal Sediment Impacts Project' is directed at:

(a) Improving understanding of the role of sedimentation in adversely affecting the natural character of the coastal environment, and
(b) Improving understanding of how reducing sediment inputs can improve the condition of coastal marine vegetation and habitats.

One of the objectives of the 'Reducing Coastal Sediment Impacts Project' is to determine information needs and research priorities to promote improved processes and engagement under the RMA. One aspect of this is determining how human-induced cumulative or catastrophic sedimentation affects seabirds and shorebirds.

Therefore, this literature review outlines what is presently known about the impacts of marine sedimentation on the foraging of coastal avian species throughout Aotearoa New Zealand and how these impacts have been addressed in the context of the RMA.

The review has drawn on a range of literature including peer-reviewed scientific journal articles, 'grey' literature (including technical reports, council resource management plans, evidence, personal communications), theses, books and personal observations.

2. Statutory framework

2.1 The Resource Management Act (1991)

Marine sedimentation is the highest ranked marine pressure (MacDiarmid et al., 2012) that can be mitigated under the Resource Management Act (RMA) 1991, currently New Zealand's main piece of legislation promoting the sustainable management of natural and physical resources. The RMA gives direction to regional councils on how they should manage their resources, with Sections 5, 6 and 7 of the RMA being relevant to marine sedimentation.

Section 5(c) of the RMA discusses the sustainable management of resources while also addressing the need for 'avoiding, remedying, or mitigating any adverse effects of activities on the environment' (Ministry for the Environment, 2020).

Sections 6(a) and (c) discuss matters of national importance and are the sections most applicable to the impact of human-derived sedimentation on seabirds and shorebirds. They specifically state that: '(a) the protection of the coastal environment (among others) from inappropriate subdivision, use and development' and '(c) the protection of areas of significant indigenous vegetation and significant habitats of indigenous fauna' should be considered matters of national importance in the administration of the RMA.

Other matters that must be given regard to, while achieving the purpose of the RMA, are outlined in Sections 7(d) and (f), and the main matters applicable to this review are: '(d) the intrinsic values of ecosystems' and '(f) the maintenance and enhancement of the quality of the environment'.

It is important to note that the RMA defines biological diversity as 'the variability among living organisms, and the ecological complexes of which they are a part, including diversity within species, between species, and of ecosystems' (Ministry for the Environment, 2020), which provides an ecosystem-based approach to sustainability (Urlich, 2020).

Activities that are regulated by the RMA can fall into six categories, listed from the least to most restricted: Permitted, Controlled, Restricted Discretionary, Full Discretionary, Non-complying and Prohibited (Ministry for the Environment, 2020). Permitted activities do not require resource consent provided they comply with all relevant local rules, but activities in the middle four categories require resource consents. Prohibited activities cannot be issued resource consents.

In 2020, the RMA was reviewed by an independent panel in the 'New Directions for Resource Management in New Zealand' (Resource Management Review Panel, 2020). The review suggested that the RMA, with its many ad-hoc interventions and amendments added over the past 30 years, be repealed and replaced with a new, more cohesive legislation named the 'Natural and Built Environments Act (NBEA)' (Resource Management Review Panel, 2020). In February 2021, the Government announced that the RMA will be repealed and replaced by three new Acts: the 'Natural and Built Environments Act (NBA)', the 'Strategic Planning Act (SPA)' and the 'Climate Change Adaption Act (CAA)' (Parker, 2021). These Acts will aim to provide a greater focus on environmental outcomes and simplify regional resource management and development (Parker, 2021).

2.2 The New Zealand Coastal Policy Statement (2010)

The New Zealand Coastal Policy Statement 2010 (NZCPS 2010) is administered by DOC and sets out specific objectives and policies to achieve the purpose of the RMA concerning the coastal environment of New Zealand (Department of Conservation, 2010). The NZCPS 2010 supersedes the New Zealand Coastal Policy Statement 1994 (NZCPS 1994). Objective 1 of the NZCPS 2010 (Ecosystem Integrity), sets out the requirement to safeguard and sustain marine and intertidal ecosystems, including water quality and benthic habitat. Marine and intertidal ecosystems are those that might be significantly impacted by marine sedimentation, including water quality and the benthic environment.

Policy 11 of the NZCPS 2010, which concerns indigenous biological diversity, requires 'significant effects on biodiversity to be avoided, remedied or mitigated' (Department of Conservation, 2010). Policy 22 of the NZCPS 2010 address sedimentation in the coastal environment. Under

Policy 22, local authorities must: '(1) assess and monitor sedimentation levels and impacts on the coastal environment, (2) require that subdivision, use, or development will not result in a significant increase in sedimentation in the coastal marine area, or other coastal water, (3) control the impacts of vegetation removal on sedimentation including the impacts of harvesting plantation forestry, and (4) reduce sediment loadings in runoff and in stormwater systems through controls on land use activities' (Department of Conservation, 2010).

Integration of coastal management requires coordination and collaboration across administrative boundaries. Fig. 1 shows coastal management jurisdictions that are relevant for the RMA.

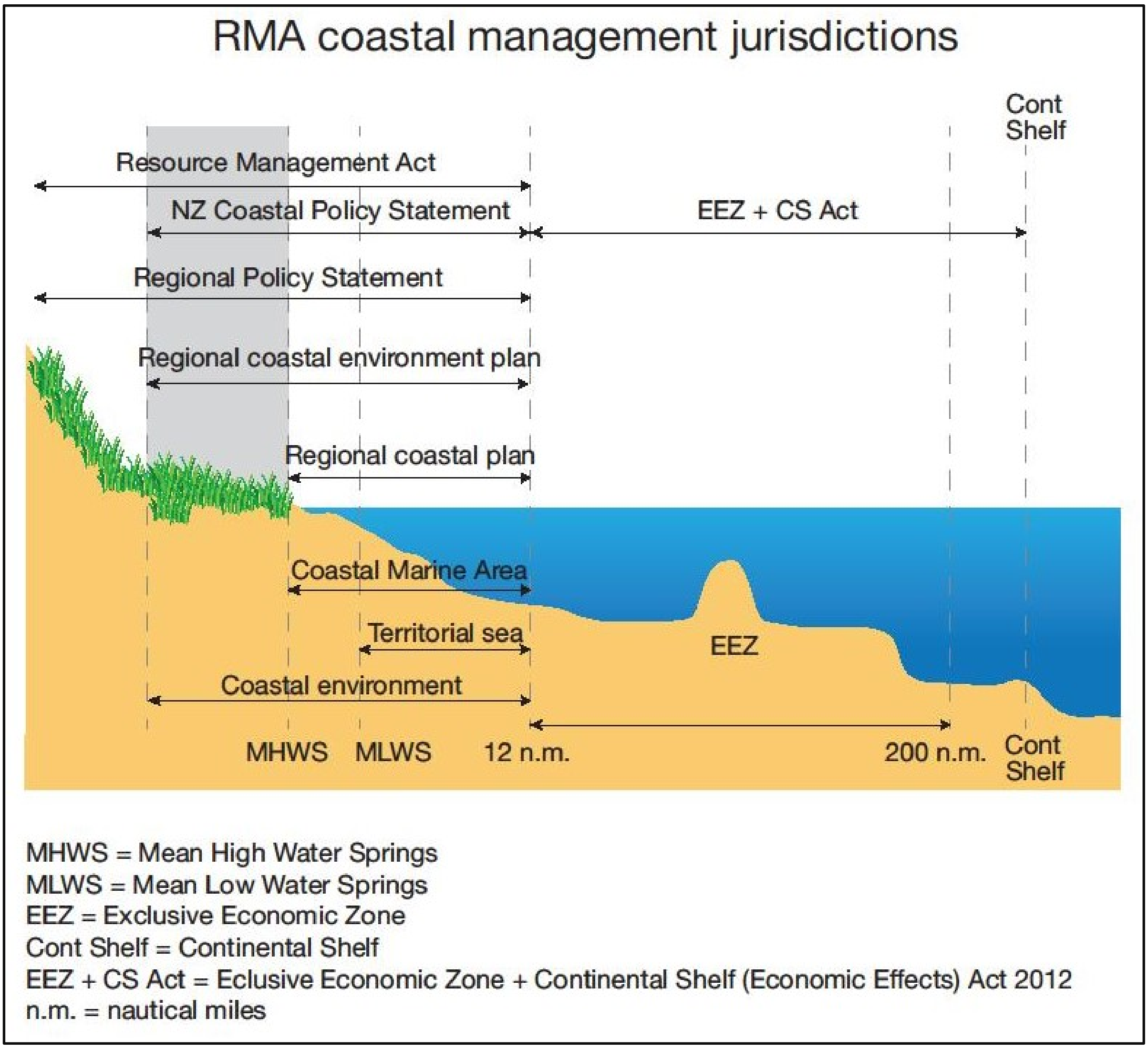

Figure 1. Statutory boundaries in coastal areas. *Image source: Department of Conservation https://www.doc.govt.nz/about-us/statutory-and-advisory-bodies/nz-conservation-authority/policies/coastal-management-principles/.*

2.3 Functions of Regional Councils under the RMA and NZCPS 2010

The RMA and NZCPS 2010 give direction to regional councils as to how they should manage their resources. Section 30 (1) (ga) of the RMA outlines that 'Every regional council shall have the following functions for the purpose of giving effect to the Act in its region: the establishment, implementation, and review of objectives, policies, and methods for maintaining indigenous biological diversity' (Ministry for the Environment, 2020). Therefore, the policies outlined under both the RMA and the NZCPS 2010 can be given effect to in regional policies, plans and consents to manage activities that contribute to marine sedimentation and their associated impacts on biological diversity.

3. New Zealand's coastal environment

The RMA defines the coastal environment as 'the foreshore, seabed, and coastal water, and the air space above the water between the Mean High Water Spring (MHWS) mark to the outer limits of the territorial sea' (12 NM from land) (Ministry for the Environment, 2020). It is this definition of the coastal environment in New Zealand, an area that totals 167,650 km^2, that is referred to throughout this report. The area between 12 NM and 200 NM is the Exclusive Economic Zone (EEZ), which is managed by the Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act 2012, rather than the RMA or NZCPS 2010 (Ministry for the Environment, 2018).

New Zealand's coastal waters are highly productive and support an abundance of marine mammals, fish, shellfish and birds. Two thirds of the coastline is hard, rocky shore and the remainder is soft sediment (Walrond, 2005). Distributed along the coastline are more than 400 estuaries – dynamic ecosystems where freshwater and saltwater merge (Ministry for the Environment, 2019). Coastlines are important for cultural, social and economic reasons and, as a result, many human settlements are located along New Zealand's coasts (Fig. 2). Most human activities in the marine environment are concentrated around the coast. These, combined with coastal development, place pressures on coastal environments (Teichert et al., 2016).

Figure 2. NZ fairy tern (tara iti, *Sternula nereis davisae*) at Waipu Estuary, Northland. *Photo: Edin Whitehead.*

3.1 Seabirds and shorebirds of Aotearoa New Zealand

Aotearoa New Zealand is an avian biodiversity hotspot with many endemic, native and migratory bird species found within the territorial sea and EEZ. New Zealand also has one of the highest proportions of threatened bird species globally, with 90% of seabirds and 80% of shorebirds ranked as threatened with, or at risk of, extinction (Ministry for the Environment & Statistics NZ, 2019). Birds that reside in the coastal environment face more threats than those in other habitat types (Miskelly et al., 2008). This is largely due to the human pressures placed on New Zealand's coastal ecosystems (Ministry for the Environment & Statistics NZ, 2019; Waikato Regional Council, 2013).

How New Zealand's coastal environments are utilised by seabirds and shorebirds varies among species. Some birds, such as shags and terns, spend their entire lives in the coastal environment, whereas others, such as albatrosses, spend most of their lives far from land, returning only to breed (Forest and Bird, 2014). As sedimentation primarily impacts coastal habitats, this review has considered only those species of seabirds that forage in coastal areas and has excluded species that forage further afield in pelagic areas. While this review focuses mainly on seabirds and shorebirds, other coastal foraging birds have also been included. Appendix 1 includes a list of seabirds, shorebirds and other bird species that forage in New Zealand's coastal environment.

3.1.1 Seabirds

Threats

Seabirds are the most threatened group of birds in the world (Croxall et al., 2012; Dias et al., 2019) with one-third of all seabirds categorised by the IUCN Red List of Threatened Species as Critically Endangered, Endangered or Vulnerable (BirdLife International, 2020). Globally, islands provide refuge for species that have been eliminated from mainland breeding sites through a range of land-based threats. In New Zealand, many seabird colonies are restricted to inaccessible coastlines or island refuges where land-based threats are less prevalent (Bellingham et al., 2010). Seabirds face a variety of threats both on land and at sea, from direct disturbance by humans and invasive predators at breeding sites, to being caught as fisheries bycatch, and the effects of marine pollution and climate change at sea (Dias et al., 2019; Whitehead et al., 2019).

Diversity and habitat

Aotearoa New Zealand is a seabird hotspot, with 87 species breeding throughout the country (Forest and Bird, 2014), which is approximately one-quarter of the global seabird species. Of those, approximately 37% are largely resident in New Zealand throughout the year, whereas the remainder migrate beyond New Zealand's EEZ outside of the breeding season (see tables in Appendix 1). Seabird orders found in New Zealand's coastal habitats include penguins (Spheniscidae), albatrosses (Diomedeidae), fulmars, petrels, prions and shearwaters (Procellariidae), storm petrels (Hydrobatidae), diving petrels (Pelecanoididae), tropicbirds (Phaethontidae), gannets and boobies (Sulidae), shags (Phalacrocoracidae), skuas (Stercorariidae), gulls (Laridae), and terns and noddies (Sternidae) (Gill et al., 2010; see tables in Appendix 1). This high seabird diversity is largely due to the productive oceans surrounding New Zealand and the lack of mammalian predators throughout much of its history (Taylor, 2000). New Zealand encompasses a range of different seabird habitats, from the subtropical Kermadec Islands where red-tailed tropicbirds (amokura, *Phaethon rubicauda*) are found, to the sub-

Antarctic, where several species of penguins and albatrosses form dense breeding colonies into their thousands (Fig. 3; Forest and Bird, 2014). So unique are the seabirds of New Zealand that almost half of the species breeding in New Zealand breed nowhere else in the world (Croxall et al., 2012).

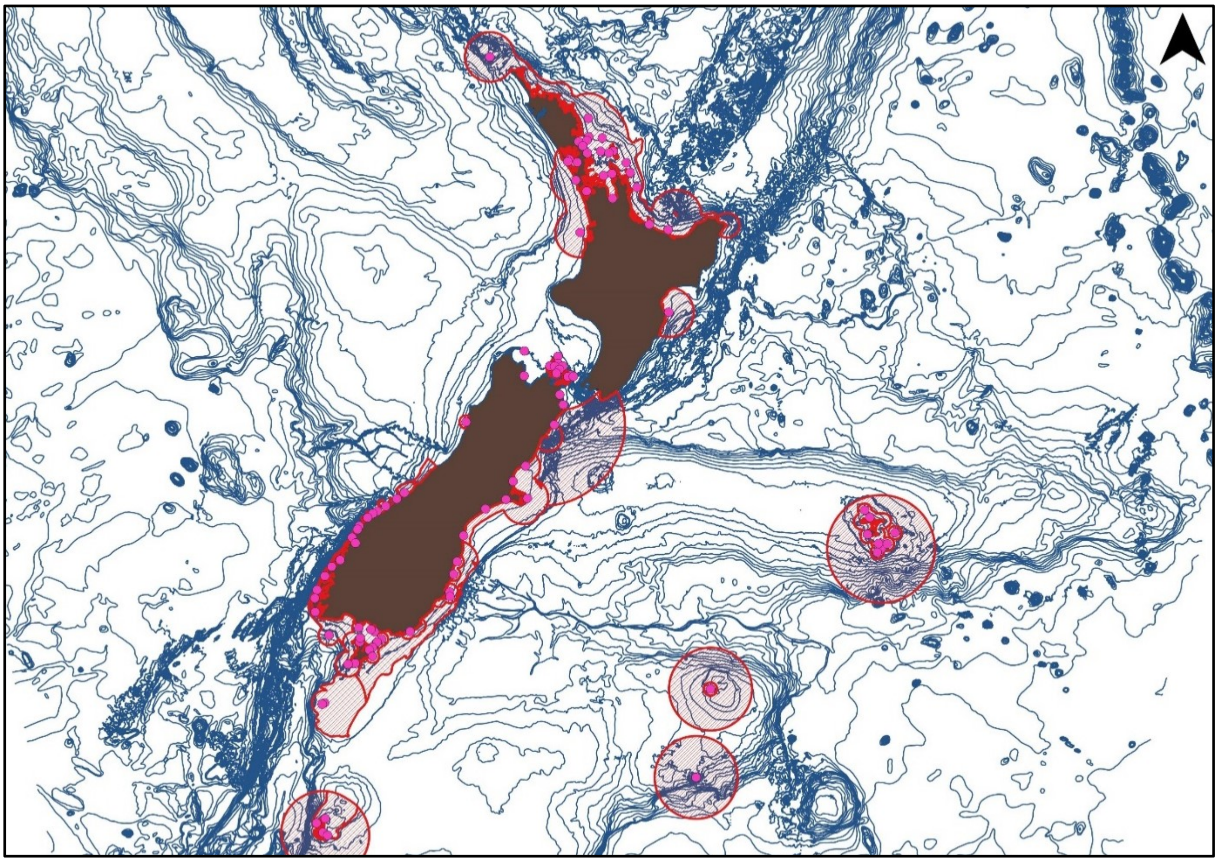

Figure 3. Confirmed Important Bird and Biodiversity Areas (IBA) for Aotearoa New Zealand seabirds and shorebirds (pink circles), and marine IBA (shaded polygons) for coastal and marine IBA based on colony locations and foraging areas (seaward extensions). Data source: http://datazone.birdlife.org/country/new-zealand/ibas.

Figure 4. White-fronted tern (tara, *Sterna striata*) dipping for krill at the fringes of a school of trevally (araara, *Pseudocaranx dentex*). *Photo: Edin Whitehead.*

Physiology and foraging

Seabirds, as their name implies, are species that spend at least part of their lives foraging exclusively at sea. They have a range of features that enable them to spend their lives at sea, including salt-excreting glands, webbed feet and waterproof plumage (Croxall, 1987). Different bill morphologies allow seabirds to target a range of different prey items such as fish, squid or krill. The prey items they target and the habitats in which they reside determine the foraging strategy employed by the different species (Figs 4–7).

Figure 5. Little black shag (*Phalacrocorax sulcirostris*) with prey. *Photo: Edin Whitehead.*

Figures 6 & 7. Examples of prey captures by hoiho (yellow-eyed penguin, *Megadyptes antipodes*) over different seafloor habitats. Upper image shows the capture of a juvenile tarakihi (*Nemadactylus macropterus*) over sandy bottom just off Golden Beach, Stewart Island/Rakiura. The lower image shows the capture of a blue cod (*Parapercis colias*) over bryozoan habitat off Saddle Point, Stewart Island/Rakiura. Note the size differences between the two prey items. *Images reproduced from Mattern & Ellenberg 2018*.

All seabirds are visual foragers to some degree and typically pursue prey in three different ways: surface feeding, pursuit diving, and plunge diving (Croxall, 1987). Pelagic feeders are those that forage in the water column by surface feeding, pursuit diving, shallow-plunge diving, or deep-plunge diving. For example, gulls feed along the water's surface by dipping their beaks into the water, whereas gannets, boobies, tropicbirds, terns and noddies plunge into the water to catch their prey. Gannets, like shags, are capable of pursuing prey underwater. Benthic feeders, such as yellow-eyed penguins (hoiho, *Megadyptes antipodes*) forage along the seafloor and, along with shags and some shearwaters, are also considered pursuit divers. While most coastal seabirds feed exclusively in the marine environment, others (such as shags and some terns) also exploit freshwater and estuarine environments.

Breeding and migration

All seabirds must return to land to breed. During the breeding season, seabirds are spatially restricted in their foraging (known as central place foraging (Orians & Pearson, 1979)), because they need to regularly return to their nest to relieve their partner or to feed their chicks (Fig. 8). This makes seabirds vulnerable to threats in the marine environment adjacent to breeding areas during the breeding season (Dias et al., 2019). Some seabirds from New Zealand have migratory phases where they range in much wider oceanic areas, while some will remain resident close to breeding sites when not breeding, but are not limited by having to commute back to a central place (i.e. their nest) when they do not have chicks.

Figure 8. Foveaux shag (*Leucocarbo stewartia*) colony, Rakiura/Stewart Island. *Photo: Edin Whitehead.*

3.1.2 Shorebirds

Diversity and habitat

Shorebirds, also known as waders, are members of the suborders Charadrii and Scolopaci. They forage in the intertidal zone between land and sea rather than in the water column, differentiating them from seabirds. Forty-seven shorebird species have been recorded in New

Zealand (see tables in Appendix 1). At least 13 of these are resident (defined as those that both breed and overwinter) in New Zealand, and the remainder are mostly long-distance migrants from the northern hemisphere that spend the austral summer in New Zealand to exploit seasonal food sources (Melville & Battley, 2006; Schuckard & Melville, 2013). Aotearoa New Zealand forms the southernmost extremity of the East Asian-Australasian Flyway, an important international migration route for many shorebird species between their northern hemisphere breeding and southern hemisphere grounds. Three of the migratory species that fly south to New Zealand each year – the bar-tailed godwit (kuaka, *Limosa lapponica*), lesser knot (huahou, *Calidris canutus*) and ruddy turnstone (*Arenaria interpres*) – occur in New Zealand in internationally important numbers (Melville & Battley, 2006), primarily at the Firth of Thames (Fig. 9), Manawatū Estuary and Farewell Spit (Battley et al., 2007; Dowding & Moore, 2006).

Shorebirds utilise the entire coastline but the species composition changes depending on the season and habitat. During winter, resident shorebirds – such as New Zealand dotterel (tūturiwhatu, *Charadrius obscurus*) and variable oystercatcher (tōrea pango, *Haematopus unicolor*) – occur in small numbers across the entire New Zealand coastline before they breed in spring, sometimes travelling inland to do so (Melville & Battley, 2006; Schuckard & Melville, 2013). During this time, flocks of migratory species start to arrive in New Zealand and are found mainly in certain large estuaries (Riegen & Sagar, 2020). Late-summer is the period where the highest number of shorebirds can be found on the coast of New Zealand, as both resident and migratory species are present (Schuckard & Melville, 2013).

Figure 9. Bar-tailed godwits (kuaka, *Limosa lapponica*) at Miranda, Firth of Thames. *Photo: Neil Fitzgerald.*

Physiology and foraging

Little is known about the diet and prey consumption of shorebirds in New Zealand (Battley et al., 2007; Wittington, 2015); therefore, this section also contains information from overseas examples. Shorebirds forage primarily on soft-sediment macroinvertebrates including bivalves, gastropods, crustaceans, polychaete, oligochaete and nemertean worms, echinoderms and cnidarians (reviewed in Battley et al., 2007). Different bill morphologies allow sympatric species (species that inhabit the same areas) to partition food resources by specialising in different macroinvertebrates at different sediment depths (Fig. 10; reviewed in Battley et al., 2007; Colwell, 2010; Jing et al., 2007).

Figure 10. New Zealand dotterel (tūturiwhatu, *Charadrius obscurus*) (left) and bar-tailed godwit (kuaka, *Limosa lapponica*) (right) feeding. Both photos taken at Waipu Estuary, Northland. *Photos: Edin Whitehead.*

Shorebirds employ several different foraging methods. The method varies according to the species, but it also depends on habitat, prey availability and season (reviewed in Mathot et al., 2018). Most shorebirds are visual predators, but some may also use tactile foraging (Colwell, 2010; Thomas et al., 2006; Wittington, 2015). For example, lesser knots and bar-tailed godwits can detect bivalves in wet sediments through special structures called Herbst corpuscles at the end of their bills (Colwell, 2010). However, shorebirds without these corpuscles can still search for macroinvertebrates by probing and sweeping their bill through sediments (Battley et al., 2007). Some species of shorebird forage nocturnally, using both visual and tactile foraging strategies (Colwell, 2010; Thomas et al., 2006). Visual foragers look for the faecal casts and ventilation holes of macroinvertebrates to indicate prey availability (Grant, 1984). Interestingly, some shorebird species can also graze on biofilm – collections of microorganisms that accumulate on the sediment surface – in addition to macroinvertebrate prey (reviewed in Mathot et al., 2018; Wittington, 2015). A study of wrybill (ngutuparore, *Anarhynchus frontalis*) foraging in the Firth of Thames revealed that the birds utilise both visual and tactile foraging methods (Wittington, 2015). Most of the prey items identified for wrybills in the Firth of Thames were small (<3 cm) polychaete worms (Fig. 11), but biofilm was identified as a moderate (35%) component of the diet.

Habitat choice varies among the species, but typically shorebirds will travel between local foraging and roosting sites daily, and return to breeding habitats on an annual basis, some over great distances (Waikato Regional Council, 2013). A preliminary tracking study found that some species have high local foraging site fidelity (e.g. godwits), whereas others (e.g. lesser knots) will disperse frequently between multiple foraging locations. Shorebirds typically prefer substrates with higher sand to mud ratio, but foraging substrate preferences differ among the species (Battley et al., 2007). Sediment penetrability can be an important factor influencing shorebird foraging habitat, as shown by short-billed dowitchers (*Limnodromus griseus*) in the USA that preferably forage on softer ripple crests than harder ripple troughs (Grant, 1984).

Figure 11. Wrybill (ngutuparore, *Anarhynchus frontalis*) with worm, Miranda, Firth of Thames. *Photo: Edin Whitehead*.

Threats

In New Zealand, while some endemic shorebird species appear to be increasing (e.g. variable oystercatcher) other species, particularly northern hemisphere migrants, are in serious decline (Riegen & Sagar, 2020). Nationwide shorebird counts by the Ornithological Society of New Zealand show that shorebird populations have declined on average 1.2% per year since 2005 (Riegen & Sagar, 2020). This is not an issue unique to New Zealand, as shorebird populations are in decline globally (reviewed in Schuckard & Melville, 2013). Some of these declines can be attributed to international pressures such as the loss of foraging habitat throughout the East Asian-Australasian Flyway, in particular the Yellow Sea (reviewed in Schuckard & Melville, 2013), whereas local threats include predation, habitat loss and degradation (e.g. sedimentation), and disturbance at both breeding and foraging habitats (Jackson et al., 2020; Melville & Battley, 2006). Therefore, maintaining and improving both breeding and foraging habitats in New Zealand is important for shorebird conservation (Jackson et al., 2020).

3.1.3 Other coastal birds

Several other avian species utilise the coastal environment in Aotearoa New Zealand. These include white-faced heron (matuku moana, *Egretta novaehollandiae*) (Fig. 12), white heron (kōtuku, *Ardea modesta*), reef heron (matuku, *Egretta sacra*), royal spoonbill (kōtuku ngutupapa, *Platalea regia*) (Fig. 13), several duck species, New Zealand (sacred) kingfisher (kōtare, *Todiramphus sanctus*) (Fig. 14), black swan (kakīānau, *Cygnus atratus*), and several wetland specialists including banded rail (mioweka, *Gallirallus philippensis*). A full list of species is given in Appendix 1. These species have been incorporated where applicable.

Figure 12. White-faced herons (matuku moana, *Egretta novaehollandiae*), Motuihe, inner Hauraki Gulf. *Photo: Edin Whitehead*.

Figure 13. A group of royal spoonbills (kōtuku ngutupapa, *Platalea regia*) feeding along a mangrove-fringed channel, Waitangi, Bay of Islands. *Photo: Edin Whitehead.*

Figure 14. New Zealand kingfisher (kōtare, *Todiramphus sanctus*) with prey, Whangateau Harbour. *Photo: Edin Whitehead.*

3.2 Cultural importance of seabirds and shorebirds

Tangata whenua have a special relationship with seabirds and shorebirds as many species are considered taonga (treasures). This relationship is recognised under the 'Treaty of Waitangi Act 1975', the 'Conservation Act 1987', and the 'Marine and Coastal Area (Takutai Moana) Act 2011', among others, and is reflected in species management plans with co-governance arrangements between DOC and iwi (Towns et al., 2018; Towns et al., 2012).

Kia Tūpato! Ka tangi a Tūkaiāia kei te moana, Ko Ngātiwai kei te moana e haere ana; Ka tangi a Tūkaiāia Kei tuawhenua, ko Ngātiwai kei tuawhenua e haere ana

Beware! When Tūkaiāia calls at sea, Ngātiwai are at sea; When Tūkaiāia calls inland, Ngātiwai are inland

Ngāti Wai Trust Board, Te Tūkaiaia: Te karanga o te iwi

Kei ha ra te pirīnga mo nga
mānu tipi one
Kā tere, kā tere, kā tere…

Where are the sanctuaries
for our birds?
Slipping away, slipping away,
slipping away…

Saana Waitai, Ngāti Kuri

4. Causes of marine sedimentation

4.1 Marine sedimentation

Marine sedimentation is a key ecological concern contributing to the degradation and sometimes complete loss of estuarine and coastal ecosystems (Halpern et al. 2007; Morrison et al. 2009). Sedimentation is considered the fifth most important threat to marine ecosystems globally, following increasing sea surface temperatures, demersal destructive fishing, coastal development, and point-source and non-point source pollution, and is thought to have the greatest functional impact on marine ecosystems (Halpern et al. 2007). Sediment from both land- and sea-based human activities can smother the seafloor and increase turbidity (water cloudiness) (Fig. 15) that can alter the structure and function of marine ecosystems with flow-on effects on marine top predators such as seabirds and shorebirds (Haney & Stone 1988; Thrush et al. 2004; Henkel 2006; Wenger et al. 2012; Kowalczyk et al. 2015). As noted above, in New Zealand, sedimentation is considered the third most important threat to marine habitats, and until recently (see Motiti fishing example in Case Study 6), was the only marine threat that could be mitigated by activities governed by the RMA (MacDiarmid et al. 2012).

Figure 15. Diver with arm buried in mud up to his elbow near Ponui Island, inner Hauraki Gulf. *Photo: Shaun Lee.*

Sediment deposition on the seafloor is a naturally occurring phenomenon caused by storms, volcanoes, fire and landslides, but anthropogenic activities have altered sediment accumulation rates (SAR) globally. While many human activities increase SAR, structures such as dams and weirs can decrease sediment flux into marine environments (Syvitski et al., 2005). In New Zealand, land clearance by Polynesian settlers caused little marine sedimentation (Swales et al., 2012) because existing root networks maintained soil structure (Wilmshurst, 1997). However, the widespread deforestation for agriculture and the associated erosion of soils following European settlement significantly increased marine sedimentation and SAR in parts of the country, with sedimentation rates now 10–20 times higher than in pre-European times (Gomez et al., 2007; Swales et al., 2012; Thrush et al., 2004; Wilmshurst, 1997). Marine sedimentation as a result of land-use changes has been recognised as a significant threat to New Zealand's coastal environments since the 1990s (Hewitt & McCartain, 2017).

Human activities both on land and at sea can contribute to marine sedimentation. On land, activities such as urban development, agriculture, forestry, mining and land reclamation can all contribute to sediment deposition in waterways, which often drain to the sea (Jackson et al., 2020; Ministry for the Environment, 2019; Walling, 2006) (Fig. 16). It is important to note here that land-derived sedimentation can be caused by activities throughout the catchment and transported considerable distances by rivers, not just by activities adjacent to the coast (Walling 2006; (Ministry for the Environment, 2019; Walling, 2006). In fact, more than one-third of rivers in New Zealand have excessive turbidity according to the Australian and New Zealand Guidelines (ANZG) for water quality (Ministry for the Environment, 2019).

Figure 16. Sediment plume at Long Bay-Okura. *Photo: Geoff Reid*.

It is when sediments arrive in marine environments at higher quantities than ecosystems can process that they become a pollutant (Ministry for the Environment, 2019). Provisions in regional plans and resource consents can help to control sediment-causing activities on land and therefore reduce marine sedimentation. However, while point source sediment discharges are more obvious and easy to regulate, non-point source discharges can be more difficult to address (Ministry for the Environment, 2019). It is easy to distinguish land-derived (terrigenous) sediment from marine sediment by its yellow-orange colour (caused by iron-rich soil minerals; (Thrush et al., 2013) and sediment-laden river plumes can be seen entering the marine environment following heavy rain.

Estuaries can receive nutrients, pollutants and sediments from entire catchments before they enter the ocean. Historically, New Zealand estuaries were dominated by sandy sediments and accumulated sediments at a rate of <1 mm per year (Robertson & Stevens, 2012). However, since 1840, urban development, agriculture and forestry within catchments have contributed to sedimentation in many estuaries throughout New Zealand and now more than half of all estuaries have turbidity levels above the ANZG threshold (Ministry for the Environment, 2019; Parliamentary Commissioner for the Environment, 2020).

At-sea activities such as dredging, dumping, sand mining and demersal destructive fishing can resuspend benthic sediments, which can cause turbidity (Halpern et al., 2007; Løkkeborg, 2004; Trathan et al., 2015). There are 37 ports and harbours in Aotearoa New Zealand, more than half (56%) of which are dredged (sediment excavated and dumped outside the harbour) to enable large vessels to dock. Dredging primarily occurs in commercial centres such as Whangarei, Auckland, Tauranga, Napier, Taranaki, Wellington, Picton, Christchurch and Otago. Dredging (weighted nets pulled across the sea floor) is also a commonly utilised fishing method in the coastal environment. From 2008 to 2012, 48% (112,423 km^2) of New Zealand's coastal environments (<250 m depth) were trawled or dredged, primarily by shellfish fisheries (Statistics NZ, 2016). Seabed mining is a relatively new industry in New Zealand, but one that contributes considerably to the country's marine economy. From 2007 to 2017, mineral extraction contributed between 0.4% and 1.2% to New Zealand's Gross Domestic Product (GDP – the measure of goods and services produced by a country; (Statistics NZ, 2019). This is more than the combined value of the shipping, fisheries and aquaculture industries (Statistics NZ, 2019). Given the financial benefits of seabed mining and technological advances in mining technology, the practice is likely to increase in the coming years (Environment Guide, 2018).

4.2 Sedimentation events

Sedimentation events typically fall into two categories: cumulative or catastrophic, both of which can alter the structure and function of coastal ecosystems. Cumulative sedimentation is where sediment is deposited gradually over time, for example, by a river transporting terrigenous sediment into an estuary; whereas catastrophic sedimentation is often caused by heavy rainfall that transports pulses of terrigenous sediment to the marine environment (Hicks, 1994; Hicks et al., 2000). The addition of only a few millimetres of sediment is enough to cause an ecosystem to reach a tipping point which may then take a long time to recover (Lohrer et al., 2006b). Tipping points occur when ecosystems can no longer cope with environmental change and shift from one state to another, often a less productive state (Lenton, 2013).

Climate change will alter sediment flux into the marine environment (Walling, 2006), and areas with a predicted increase in rainfall are likely to receive higher sediment loading in waterways during significant rainfall/storm events. The projected increase in the frequency and intensity of storm events with climate change may result in less recovery time between catastrophic sedimentation events, which can create less resilient ecosystems (Ministry for the Environment, 2019). Wind and waves associated with storms can also re-suspend sediments from the seafloor, causing turbidity of the water column.

5. How does marine sedimentation impact bird foraging in intertidal and nearshore habitats?

Section overview:

- This section explores both the direct impact that sedimentation can have on New Zealand’s seabirds and shorebirds and how they may be indirectly impacted by changes to marine ecosystems and food webs.
- Due to the limited amount of literature on the topic, this section draws from international examples of sedimentation impacts in coastal marine environments, as well as freshwater environments.
- The limited amount of literature available also means that how New Zealand’s seabirds and shorebirds are impacted by sedimentation has been generalised or assumed based on current knowledge of their habitat use, foraging strategies and prey species, using known impacts from international examples. Information gaps are clearly identified.

5.1 Direct impact of marine sedimentation on seabirds

Most seabirds and shorebirds are visual foragers to some degree (Colwell, 2010; Croxall, 1987; Schreiber & Burger, 2001) and their feeding efficiencies decline with increased turbidity caused by marine sedimentation (Cyrus, 1991; Haney & Stone, 1988; Henkel, 2006; Holbech et al., 2018; Kowalczyk et al., 2015). In healthy ecosystems, terrestrial sediments and nutrients can enrich marine ecosystems and can create important foraging grounds for coastal birds where they flow to the sea (e.g. estuaries, river mouths). However, excessive sediment loading from human activities on land and at sea can cause unfavourable foraging conditions, for example, by increasing turbidity and smothering the seafloor.

5.1.1 Effects of sedimentation on plunge-divers

The literature on the effects of sedimentation on plunge-diving birds and their foraging ecology indicates that plunge-divers do not exclusively forage in clear water; however, the source of sediment observed in these studies is not clearly delineated as being human-derived. One of the first examples of turbidity impacts on seabird foraging was a study by Ainley (1977), who found that deep-plunge-diving seabirds such as gannets (*Morus* spp.) and boobies (*Sula* spp.) were more common in clear surface water than in turbid water. Ainley (1977) suggested this was due to the birds’ greater ability to detect their prey in clear water. Other studies have found that shallow-plunge-diving seabirds such as terns were as common in turbid waters as in clear water (Hunt Jr & Schneider, 1987), suggesting that turbidity may have a lesser impact on shallow-diving birds. For example, Haney and Stone (1988) found that of 12 species of shallow-plunge-diving seabirds off the coast of the southeastern United States, only one of the tropicbird species (*Paethon lepturus*) was significantly more common in clear water, while five species were significantly more common in turbid waters. They also found that as turbidity decreased, so too did the number of foraging individuals. However, this may be a case of an ecosystem enriched by terrestrial nutrients rather than degraded by excessive human-derived sediment loads.

Turbidity can impact the prey capture behaviour employed by visual foragers. For example, kingfishers have been observed making shallower dives in turbid freshwater than in clearer water (Holbech et al., 2018). A temporary or permanent change in bird foraging behaviour caused by increased turbidity may alter prey capture rates, which can have flow-on effects on the populations of birds. For example, a decrease in prey capture rates could lead to nutritional stress. Nutritional stress, or starvation, may cause birds to allocate energy reserves to survival rather than reproduction, causing populations to decline.

It is thought that increased turbidity may alter the predator-prey relationship between visual foraging birds and their prey. Some plunge-diving seabirds such as terns may forage more frequently in turbid environments, because turbidity can concentrate small fish closer to the water's surface (Baptist & Leopold, 2010; Cyrus, 1991; Holbech et al., 2018; Russell et al., 2014; Safina et al., 1988; Shealer & Burger, 1995). For example, common terns (*Sterna hirundo*) were found at greater densities in more turbid water in both the United States and in coastal waters of southeast Ghana (Holbech et al., 2018; Safina et al., 1988). However, the prey capture rate of Damara terns (*Sterna balaenarum*) was higher in less-turbid water in two bays in Namibia (Braby et al., 2011). There may be a turbidity threshold beyond which tern foraging strategies become ineffective, however, as evidenced by three species of terns in a west African estuary that had less foraging success in extremely turbid water (<0.5 m secchi depth) compared with less-turbid water (Brenninkmeijer et al., 2002).

5.1.2 Effects of sedimentation on pursuit-diving seabirds

Some literature directly links increased turbidity to the foraging ability of pursuit-diving seabirds such as shags and penguins, and some local examples are included in this section.

Suspended sediments in the water column, which increase turbidity, have been cited as a factor inhibiting foraging for at least three species of penguins: little penguins (kororā, *Eudyptula minor*), yellow-eyed penguins and African penguins (*Spheniscus demersus*). Kowalczyk et al. (2015) found that little penguins fitted with Global Positioning Sytem (GPS) trackers avoided foraging in the areas with the highest turbidity but instead preferentially foraged in less-turbid water. The authors suggested that a turbidity threshold exists beyond which the ability for penguins to detect and capture prey is less efficient.

It can be difficult to determine how anthropogenic activities at sea impact mobile marine species such as seabirds. One study tracked little penguins from St Kilda, Australia, and found that they spent 30% of their time foraging in the vicinity of shipping channels (Preston et al., 2008). The authors suggested that the planned dredging of Port Melbourne in 2008–09 would adversely impact little penguins and their main prey, anchovies (*Engraulis australis*), primarily due to the turbidity and associated decrease in foraging efficiency for both the penguins and the anchovies (Preston et al., 2008). It is unclear whether sedimentation from the harbour dredging did influence the foraging habits of little penguins in 2008–09; however, little penguins from St Kilda were found to have higher levels of arsenic, mercury and lead in their blood compared with penguins from nearby Phillip Island (Victoria University, 2015). Pollutants bind to sediments (Charry et al., 2018) and it was suggested the pollutants may have been resuspended with sediment during the dredging project (Victoria University, 2015).

Little penguins, as central place foragers, have a restricted foraging range during the breeding season and nest success relies on birds finding sufficient prey near their colony (Agnew et al., 2015; Hoskins et al., 2008). Anecdotal evidence suggests that sedimentation from the Hutt River in Wellington Harbour has had an adverse effect on the little penguin population at Matiu/Somes

Island (Cook, 2021). Reduced foraging efficiency of adult penguins caused by land-derived sediment may have caused the starvation of 82 little penguin chicks over one breeding season (Cook, 2021). This loss is concerning for a species already ranked as At Risk – Declining under the New Zealand Threat Classification System (Robertson et al. 2017).

Sedimentation is also considered a threat to the Nationally-Endangered yellow-eyed penguin (Department of Conservation, 2019; Mattern & Ellenberg, 2016; Webster, 2021). A recent literature review by Webster (2018) discusses deforestation, agriculture, urban development and harbour dredging and sediment disposal as some of the causes of marine sedimentation in the Otago region. Highlighted in the review was a catastrophic sedimentation event that occurred in 2018. Sediment transported down the Clutha and Taieri Rivers (Fig. 17) created sediment plumes up to 30 km offshore, which was the suggested cause of a yellow-eyed penguin starvation event that year (Webster, 2021). The impact of sedimentation on yellow-eyed penguins is discussed further in Section 6, Case study 4.

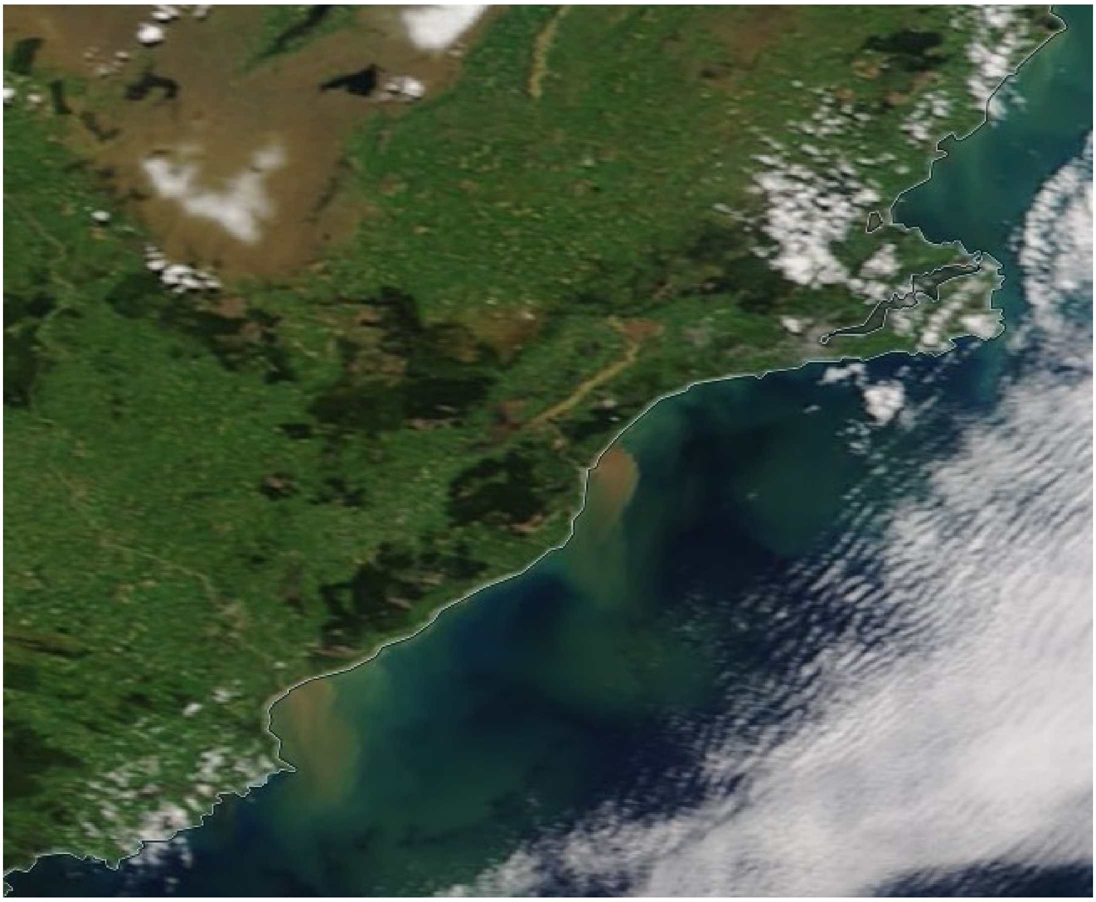

Figure 17. Sediment plumes from Clutha and Taieri Rivers. *Image source: NASA Worldview* https://worldview.earthdata.nasa.gov/.

Similar to penguins, the foraging efficiency of shags appears to be impacted by turbidity caused by sedimentation. For example, in a North American study, Brandt's Cormorants (*Phalacrocorax penicillatus*) were found more often in clearer water, and less often in turbid water (<5 m Secchi depth) (Henkel, 2006). Two studies of great cormorants/black shags (*Phalacrocorax carbo*) found their visual detection rates were hindered by turbidity (Hao, 2008), even at low turbidity levels

(Strod et al., 2008). Conversely, Grémillet et al. (2012) argue that the foraging efficiency of great cormorants is not affected by water turbidity, as population increases were higher in turbid lakes than clear lakes, thus correlating foraging efficiency to prey availability. In New Zealand, the foraging ability of the Nationally Endangered king shag (kawau, *Phalacrocorax carunculatus*) is anecdotally impacted by the sedimentation caused by both land- and sea-based activities such as forestry, agriculture and aquaculture (Environment Court of New Zealand, 2016; Schuckard et al., 2018; Schuckard et al., 2015). This impact of sedimentation on king shag foraging is discussed further in Section 6, Case study 2.

Some species of pursuit-diving seabirds are better suited to foraging in more turbid waters than others. For example, marbled murrelets (*Brachyramphus marmoratus*) occurred in significantly less turbid water than Kittlitz's murrelets (*Brachyramphus brevirostri*) despite occurring within the same habitat ranges (Day et al., 2003), which may be an example of niche partitioning between the species. Common diving petrels (*Pelecanoides urinatrix*) fill a similar ecological niche to murrelets in New Zealand waters (Thoresen, 1969), and may be impacted by turbidity caused by marine sedimentation.

5.2 Direct impact of marine sedimentation on shorebirds

Few examples exist of how sedimentation directly impacts shorebird foraging. Most of the examples relevant to shorebirds are of the indirect impacts that sedimentation has on the marine food web, which are discussed in Section 6.3, or on the heavy metals (Charry et al., 2018) and microplastics (Zhang et al., 2019) bound to sediments and how this impacts shorebirds, although these issues are beyond the scope of this review.

Wrybills preferentially forage in wet, muddy sediment in the Firth of Thames (Wittington, 2015), adopting a scything foraging method using their curved bills (authors' pers. obs.) (Fig. 18), in contrast to their feeding in gravelly riverbeds at their breeding grounds in the South Island. Their foraging in the Firth of Thames suggests that sedimentation caused by anthropogenic activities in the catchment may benefit foraging, although negative consequences of sedimentation are noted in the next section.

Another study looked at how the physical characteristics of estuaries were correlated to the diversity and abundance of shorebirds in estuaries in the North Island of New Zealand. While the size of the estuary was the most important variable influencing the abundance and diversity of shorebirds, the study found some evidence that shorebird abundance and diversity was influenced by catchment runoff (Whelan et al., 2003). Both Hill et al. (1993) and Whelan et al. (2003) found a negative relationship between catchment runoff and the abundance and diversity of shorebirds in some estuaries in the UK and New Zealand. This indicates that more shorebirds of different species may preferentially forage in estuaries with less runoff from land, which likely includes terrigenous sediment.

Figure 18. Wrybill (ngutuparore, *Anarhynchus frontalis*) feeding with its head tilted allowing its bill to scythe through the sediments and muddy water. *Photo: Edin Whitehead*.

5.3 Ecosystem and food web impacts of marine sedimentation

Marine sedimentation can impact marine top predators such as seabirds and shorebirds indirectly by altering the marine ecosystem processes and food webs that they or their prey rely on. At a base level, suspended sediment can decrease the light levels needed for photosynthesis, which can alter the primary productivity of coastal ecosystems (Kuo & Lin, 2010; Verspecht & Pattiaratchi, 2010). Moreover, sediment deposition can smother the seafloor, which can decrease habitat complexity and cause anoxic conditions where dissolved oxygen is depleted by the overgrowth or change in bacterial diversity (Lohrer et al., 2004; Norkko et al., 2002; Thrush et al., 2004). Another concern is that sediments can transport pollutants and microplastics to the marine environment, which can bioaccumulate in the prey of seabirds and shorebirds (Charry et al., 2018; Zhang et al., 2019), although this aspect is not a focus of this review. There is some literature documenting how human-derived sedimentation in the coastal environment can impact species in the lower- and mid-trophic levels, such as seagrass, bivalves and fish (Lohrer et al., 2004; Lohrer et al., 2006b; Lunt & Smee, 2014; Norkko et al., 2002; Norkko et al., 2010; Ohata et al., 2014; Wenger et al., 2012), which are discussed in this section.

5.3.1 Effects of sedimentation on macroinvertebrates

Changes in the quality, quantity and distribution of macroinvertebrates are some ways that sedimentation can indirectly impact shorebirds in New Zealand. Sediments can clog the filters of filter-feeding macroinvertebrates, resulting in reduced body condition and growth rates or, often, direct mortality (Lohrer et al., 2006a; Lohrer et al., 2004; Lohrer et al., 2006b; Norkko et al., 2010). This impact is illustrated in a series of simulated catastrophic sedimentation events in northern New Zealand. The first study found that 100 mm of terrigenous sediment deposited during a simulated catastrophic event smothered and killed all macrofauna and remained visible on the seafloor for 1 month (Lohrer et al., 2006a; Lohrer et al., 2006b; Norkko et al., 2002). Macroinvertebrate recolonisation of the study plot was slow following this event. Even in smaller amounts, sediment deposition had negative impacts, as 7 mm and 10 mm of terrigenous sediment significantly altered the macroinvertebrate community structure toward species more tolerant of disturbance (Lohrer et al., 2004; Lohrer et al., 2006b). A shift in the community composition of macroinvertebrates and the impact this can have on shorebird populations is discussed further below. It is because of the impacts of sedimentation on macroinvertebrates, which are the main prey of shorebirds, that sediment-impacted areas are likely to support fewer shorebirds (Jackson et al., 2020).

Filter-feeding shellfish play an important role in stabilising and removing sediment from the marine environment, which improves water quality, decreases turbidity, and creates habitat for other species. The Ministry for the Environment (2019) stated in a recent report that 500 km^2 of mussel beds from the Firth of Thames have been lost due to human harvesting. This quantity could reportedly filter the entire Firth of Thames in 1 day, whereas filtration by the current shellfish biomass takes approximately 2 years (Ministry for the Environment, 2019). This shows how shellfish harvesting can decrease the sediment filtration capacity of many coastal ecosystems in New Zealand. Together with increased land-based sediment input, a feedback loop exists where more sediment is being put into the marine environment and fewer filter feeders are available to filter the sediment from the water (Hauraki Gulf Forum, 2020; Ministry for the Environment, 2019). Consequently, there are likely to be complex feedback loops between anthropogenic sedimentation, processes and biomass removal from nearshore waters.

5.3.2 Effects of sedimentation on fishes

Sedimentation impacts on fish communities, a key prey group of many coastal seabirds, are not that well known; therefore, this section draws information from both freshwater and marine environments. Sedimentation and associated turbidity have been linked to changes in reproduction, behaviour and body condition in some fishes. For example, turbidity was shown to be the cause for the reduced body condition, slower growth and increased mortality in damselfish *Acanthochromis polyacanthus* (Wenger et al., 2012). In controlled aquarium experiments, damselfish took longer to find food and consumed less food in more turbid environments. Additionally, individuals that were exposed to high and medium sediment loads grew at less than half the rate of those in the control group. Mortality rates for the different treatments were 50% in the high-sediment treatment, <10% for the medium treatment and no mortality in the control treatment. Turbidity has been shown to alter the behaviour in three species of schooling marine fish in an experiment by Ohata et al. (2014). They found that ayu (*Plecoglossus altivelis*) and Japanese anchovy (*Engraulis japonicus*), species which typically live in turbid water, formed tighter schools in more turbid environments, whereas yellowtail (*Seriola quinqueradiata*) dispersed more at higher turbidity levels.

Other studies have shown how turbidity can facilitate fish species foraging by non-visual methods. For example, predation rates by visually foraging jack mackerel (*Trachurus japonicus*) on Japanese anchovy larvae decreased with increased turbidity, whereas the predation rate was equal for all experimental turbidity treatments on the tactile-foraging moon jellyfish (*Aurelia aurita*). In an estuarine system in Texas, USA, fish abundance was higher in low-turbidity environments, whereas the opposite applied to crabs (Lunt & Smee, 2014). This is likely because fish are usually visual predators that rely on visual cues to forage, whereas crabs can detect prey through non-visual chemo- and mechanosensory cues (Lunt & Smee, 2014). These examples show how sedimentation can alter the quality, quantity and distribution of fishes, and the potential impact such changes could have on the foraging ability of piscivorous seabirds and shorebirds.

5.3.3 Effects of sedimentation on community composition

Terrestrial sediment deposits in estuarine and marine coastal environments can force a shift toward more sediment-tolerant species such as bivalves and crustaceans, and can cause the local extinction of sediment-sensitive species such as polychaete worms and fishes (Lohrer et al., 2006b; Lunt & Smee, 2014). For example, estuaries and harbours are typically muddier and more turbid due to regular tidal inundation than other coastal environments, which are sandier or rocky. As such, macroinvertebrates living within these sheltered environments appear to be more tolerant of higher turbidity and sediment deposition, whereas outside harbours and estuaries taxa are generally more biologically diverse and more sensitive to terrigenous sediment (Lohrer et al., 2006a; Lohrer et al., 2006b).

If sensitive prey species are excluded from coastal environments by marine sedimentation, marine top predators such as seabirds and shorebirds that prey on those species may also be displaced. Several examples are provided by Mathot et al. (2018) that highlight how shorebird populations have decreased or been displaced by anthropogenic causes of macroinvertebrate decline. The first example explains how the population of lesser knots in Delaware Bay, USA, declined considerably following the harvest of horseshoe crabs, as lesser knots forage on the energy-rich eggs of horseshoe crabs when migrating. Another example is the decline of mollusc-foraging shorebirds and an increase in shorebird species that forage on polychaete worms in areas of the UK where shellfish fisheries increased (Mathot et al., 2018).

A sediment-driven change in community composition can also be observed in marine flora. For example, mangroves (manawa, *Avicennia marina*) have expanded in many areas in the northern North Island of New Zealand following human settlement due to increased sediment loadings (Department of Conservation, 2018), in some areas by up to 130% (Booth, 2020) (Fig.19). However, this is not always the case, as early survey charts highlight. For example, in the Kaipara Harbour, comparing an 1852 chart surveyed by the officers of *HMS Pandora* with recent hydrographic charts shows mangroves have declined through direct removal and draining of coastal lands (Fig. 20).

Figure 19. Mangrove (manawa, *Avicennia marina*) seedlings and pneumatophores, Whangateau Harbour. *Photo: Edin Whitehead*.

Figure 20. Detail from the chart of the Kaipara Harbour surveyed by Captain Drury and the officers of HMS *Pandora* in 1852 (left), and detail of the recent chart NZ 4265 (right). Source: https://data.linz.govt.nz/layer/51295-chart-nz-4265-kaipara-harbour/.

Areas of mangroves are shown in both charts. On the recent chart these are shown as small circular tree symbols.

Mangroves can have both positive and negative impacts on coastal bird populations. Regenerating mangroves can exclude shorebirds by displacing important foraging and roosting habitats such as saltmarsh, seagrass and sand/shell banks (Booth, 2020; Ellis et al., 2004), which can alter the distribution or abundance of shorebirds (Melville & Battley, 2006). Additionally, mangroves can trap sediment (Fig. 21), which can dry out and facilitate the movement of introduced cats and other pest mammals, key predators of shorebirds, into shorebird roost sites (Battley et al., 2007).

Conversely, mangroves can benefit coastal birds by the habitat they create and the ecosystem services they provide. For example, mangroves provide important foraging, dispersal and breeding habitat for some threatened coastal birds including New Zealand fairy tern (tara iti, *Sternula nereis davisae*), white heron, Australasian bittern (matuku, *Botaurus poiciloptilus*), Caspian tern (taranui, *Hydroprogne caspia*), pied shag (karuhiruhi, *Phalacrocorax varius varius*), banded rail, North Island fernbird (mātātā, *Bowdleria punctata*), South Island pied oystercatcher (tōrea, *Haematopus finschi*), pied stilt (poaka, *Himantopus himantopus*) and the bar-tailed godwit (Bell & Blayney, 2017; Department of Conservation, 2018). Additionally, mangroves can provide habitat for juvenile fishes and harbour an abundance of macroinvertebrates (Dencer-Brown et al., 2020), all prey items of coastal birds. Mangroves can also trap sediment, decreasing turbidity in coastal environments, which can facilitate increased foraging by some shorebird species (Department of Conservation, 2018; Ministry for the Environment & Statistics NZ, 2019). Mangroves and the contentious issue of their removal are discussed in Case Studies 5 & 6.

Figure 21. Mangrove fringed channels that trap sediment in Whangateau Harbour. *Photo: Edin Whitehead*.

Land-derived sediment can increase the abundance and distribution of cordgrass (*Spartina* spp.), which can reduce the foraging and roosting habitat for shorebirds on tidal flats (Jackson et al., 2021). The introduced cordgrass, a genus native to North America and Europe, converts tidal flats into dry land by trapping sediment (Jackson et al., 2021). In parts of China where cordgrass is present, the macroinvertebrate community shifted toward a community dominated by large crustacea as smaller bivalves and gastropods are excluded by the dense cordgrass roots (Jackson et al., 2021). This highlights how the altered macroinvertebrate community composition caused by cordgrass may exclude shorebird species that specialise in smaller prey. Three species of shorebirds are known to be impacted by invasions of cordgrass on the east coast of China – the Critically Endangered spoon-billed sandpiper (*Calidris pygmaea*), Endangered Nordmann's greenshank (*Tringa guttifer*) and eastern curlew (*Numenius madagascariensis*) (Jackson et al., 2021). Similarly, the diversity and abundance of macroinvertebrates were 50–60% higher in tidal flats without cordgrass than in cordgrass marshes in Australia (Cutajar et al., 2012), which indicates there may be a general decrease in shorebird numbers where cordgrass is present due to the impact it has on their prey source. It is thought that cordgrass may reduce the foraging opportunities for eastern curlews, eastern great egret (*Ardea alba modesta*), and royal spoonbills in internationally important wetlands in Australia (Cutajar et al., 2012).

Cordgrass was first introduced to New Zealand between 1913 and 1916 to convert wetlands and tidal flats into farmland (Hayward et al., 2008). It is known to exclude native coastal plants *Sarcocornia* and *Zostera* (seagrass) that facilitate shorebird foraging and it can reduce the habitat available for shorebird foraging and roosting by hardening intertidal flats (Hayward et al., 2008) (Fig. 22). In New Zealand, cordgrass has been shown to accumulate sediment at a rate of 3–15 mm per year (reviewed in Hayward et al., 2008). Now considered an invasive species, herbicides are used to control cordgrass in some coastal areas in New Zealand.

Figure 22. Cordgrass (*Spartina* spp.) growing in mats. Image source: http://pestplants.aucklandcouncil.govt.nz/plant-search/Spaspp

5.4 Overview of impacts of marine sedimentation

There is very little literature documenting the effects of marine sedimentation on seabirds and shorebirds. In general, sedimentation degrades the coastal habitat upon which seabirds and shorebirds rely. From the examples discussed above, we know that marine sedimentation can impact seabirds and shorebirds both directly and indirectly. The primary direct impact mentioned in the literature was the impact of increased turbidity on the visual acuity of foraging seabirds such as shags, terns and penguins. Examples are used from Africa, the USA, Australia and New Zealand to document these known effects. Little literature has been found documenting a direct effect on shorebird foraging, and this remains a key knowledge gap. Many studies can be used to infer the impact marine sedimentation may have on seabirds and shorebird foraging by the documented effect that sedimentation has on ecosystem processes and marine food webs. The examples discussed in this section included the impact of marine sedimentation on community composition, primary productivity, macroinvertebrates and fishes, and how changes to these trophic links might influence the distribution and abundance of seabirds and shorebirds. It is important to note that sedimentation impacts migratory seabirds and shorebirds on both an international and local scale, whereas birds resident in New Zealand are affected by local marine sedimentation year-round.

6. Avoid, remedy, and/or mitigate adverse sedimentation impacts on seabirds and shorebirds through activities governed by the RMA

This section uses case studies to highlight how the RMA and/or NZCPS 2010 have been or can be used to avoid, remedy, and/or mitigate marine sedimentation impacts on seabirds and shorebirds. However, there are few examples of management responses to marine sedimentation within the context of the RMA. Therefore, most of the case studies show how the RMA and/or NZCPS 2010 have been referenced in the Courts to appeal specific resource management plans or resource consents. Information used in this section comes from primary literature and 'grey' literature, including technical reports, theses, evidence, news reports and personal communications.

These case studies outline sedimentation caused by land-use discharges (case studies 1, 2, 3 & 4), mangrove removal (case studies 5 & 6), destructive fishing (case study 6), sand mining (case study 7), dredging and sediment disposal (case study 8) and describe the actual or suggested management responses to avoid, remedy and/or mitigate marine sedimentation.

Case study 1 – Okura Estuary urban development

The Long Bay-Okura Marine Reserve (LBOMR) was formed in 1995 and protects a stretch of coastline on the east coast just north of Auckland City. The marine reserve has been identified as a Significant Marine Ecological Area (SEA-M) in the Auckland Unitary Plan and it supports a range of marine species, including seabirds and shorebirds. Of the 25 seabirds and shorebird species that have been recorded in the marine reserve, 72% are listed as Threatened or At-Risk (under the NZTCS) (Environment Court of New Zealand, 2017a). Studies of the macroinvertebrates present in the adjacent Okura Estuary in the 1990s showed a diverse assemblage that included species sensitive to sedimentation, indicating a healthy estuarine ecosystem at the time (Auckland Unitary Plan Independent Hearings Panel, 2015).

In 2015, developer Okura Holdings Limited (OHL) sought resource consent to build 1000 houses next to the Okura Estuary. For the high-density housing development to occur, the Auckland Council would have had to shift the urban-rural boundary under the Unitary Plan. The Auckland Council rejected the development bid by OHL in 2017, partly based on the impact the development would have on the coastal birds in the Okura Estuary and the LBOMR (Neilson, 2020). Okura Holding Limited appealed the decision in the Environment Court in 2017 and was opposed by the Auckland Council, a local community group 'The Long Bay Okura Great Park Society' and the environmental group Forest & Bird. The local community in particular argued that the development would increase sediment deposition and turbidity in the estuary and adjoining marine reserve, as this had occurred previously (Environment Court of New Zealand, 2017b).

Expert evidence provided to the Environment Court outlined the impact the development would have on coastal birds and highlighted increased sedimentation and consequent mangrove spread as a result of urban development (Environment Court of New Zealand, 2017a). Both Policies 7 & 11 of the NZCPS 2010 were cited in regards to the issue (Auckland Unitary Plan Independent Hearings Panel, 2015; Environment Court of New Zealand, 2017b). Respondents suggested that macroinvertebrates, a key food resource for shorebirds, would be negatively impacted by sedimentation caused by the development (Auckland Unitary Plan Independent Hearings Panel, 2015). This was evidenced by annual estuary monitoring data from 2000 in Okura Estuary. Of the eight Auckland estuaries monitored, Okura had the most trends associated with increased sedimentation (Hewitt & Carter, 2020). In general, the monitoring data showed that sedimentation had increased in the Okura Estuary since 2000 and the macrofaunal community has changed toward species more tolerant of increased terrestrial sediment content (Hewitt & Carter, 2020; Hewitt & McCartain, 2017). It was suggested that increased sedimentation was caused by land-use changes such as urban development in the catchment. In 2018, the Environment Court subsequently rejected the appeal by OHL for the development to go ahead; in part based on the significant adverse effects the development would have on birdlife in the Okura Estuary (Environment Court of New Zealand, 2018).

In April 2018, a shellfish mortality event occurred in the Okura Estuary where 'hundreds and thousands of dead shellfish, mainly cockles (*Austrovenus stutchburyi*), littered the coastline' (Townend, pers. comm., March 18th, 2021; Fig. 23).

Figure 23. Dead cockles (*Austrovenus stutchburyi*) at Karepiro Bay at the mouth of the Okura Estuary, Hauraki Gulf, likely caused by sedimentation, April 2018. *Photo: Pete Townend.*

It was suggested that the mortality event was caused by heavy rainfall washing sediments from existing housing developments further inland into the estuary (Townend, pers. comm., March 18th, 2021). A comparison of the density of cockles (sized >15 mm) between April 2016, 2017 and 2018 found a 50% decrease in individuals at two of the sampled sites (Hewitt & Carter, 2020). Another site showed a more gradual decrease in cockle abundance, with average densities dropping from 34 cockles per core in April 2016, to 17 cockles in April 2018. Sites with initial low cockle densities showed no change and one site showed an increase in cockle abundance. Following the Environment Court decision, OHL escalated its appeal to the High Court in 2018. However, in 2019, the appeal was dropped and the development project ceased (High Court of New Zealand, 2019; Neilson, 2020).

Key points

- Okura Holdings Limited (OHL) wanted to build high-density housing next to the ecologically significant Okura Estuary and Long Bay-Okura Marine Reserve north of Auckland City.
- The development was opposed by local residents, Forest & Bird and the Auckland Council in part because of the impact the sediment associated with the development would have on the local biodiversity, including seabirds and shorebirds and their food sources.
- Policies 7 & 11 of the NZCPS 2010 were cited in Court regarding the issue of sedimentation caused by the development.
- The Environment Court rejected the appeal by OHL for the development to go ahead, in part based on the significant adverse effects the development would have on birdlife in the Okura Estuary.
- In 2019, OHL escalated its appeal to the High Court but later dropped the appeal and the development ceased.

Case study 2 – Forestry in the Marlborough Sounds and its impact on king shags

Both land-based and marine activities contribute to marine sedimentation in the Marlborough Sounds (the Sounds). Marine sedimentation is particularly concerning in the Sounds for the impact it likely has on the king shag, a visual-foraging seabird endemic to the Sounds. King shags are ranked as Nationally Endangered under the NZTCS and had a population of 634 individuals in 2018, a 24% decrease from 2015 (Schuckard et al., 2018; Schuckard et al., 2015). Potential threats to king shags include commercial fishing using dredging or bottom trawling methods and the impacts of adjacent land use on the marine environment, such as sedimentation from agriculture and forestry, all of which may directly impact their prey (benthic fish) and affect the shags' ability to detect their prey (Bull; Environment Court of New Zealand, 2016; Fahey & Coker, 1992; Kaspar et al., 1985; McClellan, 2018). Only forestry-derived sedimentation is discussed in this case study.

Sediment cores show how marine sedimentation has increased 10 times over historical rates, which are in line with altered land-use in the Marlborough region (Marlborough District Council, 2021). Forestry covers 17,400 ha in the Sounds and is a permitted activity in most of the region, even though much of the landscape is steep and prone to erosion (Urlich, 2015). Terrestrial sediment is loosened during forest harvesting and can be transported into waterways during periods of heavy rain, eventually making its way into the marine environment. In 2015, the Marlborough District Council (MDC) received a report of damage to a significant marine ecological site from forestry-derived sedimentation, which led the MDC to commission a literature review of the causes and consequences of adverse effects from forestry activities in the Sounds (Urlich, 2015). The review suggested ways to minimise forestry-derived sedimentation into the Sounds, which are outlined below.

The MDC manages resources in the region through the policies outlined in the Marlborough Sounds Resource Management Plan 2003, which was updated in 2015 and is now the proposed Marlborough Environmental Plan (MEP) (Marlborough District Council, 2015). In 2020, the MEP was appealed in the Environment Court by several organisations and individuals on the basis that it does not meet Objective 1 of the NZCPS 2010 – Ecosystem Integrity, which sets out the requirement to safeguard and sustain marine and intertidal ecosystems, including water quality and benthic habitat. It has been suggested that the current regulations on forest harvesting and associated earthworks under the RMA have failed to mitigate fine sediment deposition in the Sounds and, as such, catastrophic sedimentation events have seen some intertidal species disappear completely from local estuarine ecosystems, and areas of sand and shell substrate have been converted to mud (Urlich, 2015). At the time of writing this report, mediation was underway between the MDC and the appellants regarding amendments to the proposed MEP, some specific to addressing the issue of sedimentation in the Marlborough Sounds.

Policy 22 of the NZCPS 2010 requires sedimentation from plantation forestry harvesting to be controlled, a policy that is relevant to the Sounds. Several options have been suggested to reduce marine sedimentation to help to maintain the indigenous biodiversity of the Sounds (such as king shags) – a requirement of the MDC under the RMA. Examples given to the MDC in the literature review to minimise sediment from the forestry industry include: replanting setbacks (buffer zones where forestry activities do not occur) from the shoreline and along some streams to retain sediment; retiring and implementing buffer zones on steep (30°) erosion-prone slopes; dense and rapid replanting following harvest, to limit the period most vulnerable to erosion, and enhanced earthworks requirements to stabilise land (Urlich, 2015). It is yet to be seen whether these suggestions have been incorporated into the final MEP.

Key points

- Sedimentation from aquaculture, agriculture and forestry can threaten the foraging efficiency of king shags by increasing water turbidity.
- In response to a catastrophic sedimentation event, a literature review was commissioned by the MDC in 2015 and suggested several ways to reduce marine sedimentation specifically from forestry, which may alleviate the apparent impacts on king shag foraging. It is yet to be seen whether these recommendations are incorporated into the final MEP.
- The proposed MEP has been subject to multiple appeals to the Environment Court because it has been argued that it did not adequately address key issues surrounding sedimentation, as required by the RMA and NZCPS 2010. At the time of writing this report, mediation was underway between the MDC and the appellants regarding amendments to the proposed MEP, some specific to addressing the issue of sedimentation in the Marlborough Sounds.

Case study 3 – Sedimentation in the southern Firth of Thames and its impact on shorebirds

The Firth of Thames / Tikapa Moana-o-Hauraki (the Firth) is a deep embayment at the southern end of the Hauraki Gulf/Tīkapa Moana in northeastern New Zealand. While sedimentation is recognised as a key issue throughout the Hauraki Gulf (Hauraki Gulf Forum, 2020), this case study specifically discusses sedimentation in the Firth. The Firth is an internationally important habitat for shorebirds and was listed as a wetland of international importance under the Ramsar Convention in January 1990 (Battley et al., 2007). The habitat degradation caused by sedimentation is adversely impacting the shorebirds that forage in the intertidal zones of the southern Firth.

The Firth is ranked as one of New Zealand's three most important areas for shorebirds and annually hosts approximately 35,000 shorebirds, 11,000 of which migrate to its shores from as far away as Alaska and Siberia (Battley et al., 2007; Brownell et al., 2008). International migrant species that utilise the Firth include bar-tailed godwits, lesser knots and eastern curlews, whereas local shorebird species include pied oystercatcher, variable oystercatcher, wrybill and New Zealand dotterel (Battley et al., 2007; Brownell et al., 2008). The area also provides important habitat for non-shorebird species including shags, waterfowl, herons, gulls and terns (Battley et al., 2007). Seventy-four species, many rare or uncommon, have been recorded in the Firth (Department of Conservation, 2018). Habitat changes, in part caused by sedimentation, have altered the distribution and abundance of shorebird species in the Firth (Melville & Battley, 2006).

The southern Firth historically possessed a productive and diverse benthic environment dominated by polychaete worms, shellfish, crabs and shrimp, whereas now the area is characterised by a dense layer of fine terrestrial sediment, turbid water and a depauperate macroinvertebrate community (Battley et al., 2007). Seagrass habitat is sparse, whereas both mangroves and cordgrass have increased considerably in the Firth and exclude shorebirds from some high-tide roost sites and foraging grounds (Battley et al., 2007; Department of Conservation, 2018; Melville & Battley, 2006; Swales et al., 2016). Since the 1960s, more than 11 km^2 of intertidal flats has changed to mangrove habitat in the southern Firth (reviewed in Swales et al., 2016). These ecosystem changes suggest that the southern Firth may provide a less desirable foraging habitat for shorebirds than it did historically. Conversely, mangroves in the southern Firth provide breeding and foraging habitat for some threatened coastal birds such as the Nationally Critical Australasian bittern, At Risk – Declining banded rail, fernbird, and spotless crake (pūweto, *Zapornia tabuensis)* in addition to roosting habitat for shags and herons (Department of Conservation, 2018).

Sedimentation in the southern Firth is a result of both historic and contemporary sediment inputs (Brownell et al., 2008) from the surrounding 3600 km^2 Hauraki Catchment that drains via the Waihou and Piako rivers. During pre-European times, sediments accumulated in the southern Firth at a rate of <1 mm/year, whereas contemporary sediment accumulation rates (SAR) are now 5.5 mm/year (Swales et al., 2016). Sediments have accumulated at a higher rate in the southern Firth than in any other monitored North Island estuary (Swales et al., 2016; Waikato Regional Council, 2015). Sediment inputs from mining, deforestation and subsequent erosion in the catchment more than a century ago contribute to almost half of the marine sedimentation (Hauraki Gulf Forum, 2020; Swales et al., 2016). These 'legacy' sediments, combined with more recent sediment inputs from forestry and agriculture, appear to be contributing to the rapid sedimentation and associated ecosystem change occurring in the southern Firth (Swales et al., 2016; Waikato Regional Council, 2015).

Three-quarters of the contemporary sediment input into the Firth is thought to come from land use activities and the remaining quarter from natural erosion (Hill, 2011). High sediment input is exacerbated by the fact that wind and tidal currents retain sediment in the Firth (reviewed in Battley et al., 2007) rather than allowing for sediment dispersal. Given the high SAR in the southern Firth, the surrounding catchments require resource management policies that reduce the input of sediment into the Firth to limit the adverse effects of sedimentation on shorebirds in the region (Hill, 2011).

The Waikato Regional Council aim to reduce the amount of sediment entering the Firth of Thames by utilising an integrated approach to catchment management as exemplified by the Waihou Piako Zone Plan (the Plan). The Plan was developed in 2017, by Waikato Regional Council and other stakeholders, in part to protect and enhance the Firth for the migratory shorebirds that utilise the area (Waikato Regional Council, 2017). The Plan is informed by the legislative requirements of the RMA 1991, national policy directive of the NZCPS 2010 and regional and local policies of the Waikato Regional Plan 2007 and Hauraki Gulf Marine Park Act 2000 (Waikato Regional Council, 2017). Retiring steep, erosion- or flood-prone land, excluding stock from waterways, riparian planting and wetland restoration and creation are some of the implementation actions outlined in the Plan to reduce the amount of sediment entering the Firth via the Waihou and Piako rivers (Waikato Regional Council, 2017). Given the recent implementation of the Plan, it is yet to be seen whether the measures to reduce sediment from the Waihou Piako catchment from entering the Firth have been successful.

Key points

- The Southern Firth of Thames is an internationally important habitat for shorebirds.
- Sedimentation in the southern Firth is a result of both historic and contemporary sediment inputs from the surrounding catchment and is causing ecosystem changes that degrade the foraging habitat for shorebirds.
- The Waikato Regional Council aims to reduce the amount of sediment entering the Firth by utilising an integrated approach to catchment management as exemplified by the Waihou Piako Zone Plan.
- Retiring steep land and erosion- or flood-prone land, excluding stock from waterways, riparian planting and wetland creation and restoration are some of the implementation actions outlined in the Plan to reduce the amount of sediment entering the Firth via the Waihou and Piako rivers.
- It is yet to be seen whether the measures to reduce sediment from the Waihou Piako catchment from entering the Firth have been successful.

Case study 4 – Regional and District Plans in Otago and yellow-eyed penguin foraging

Marine sedimentation has been listed as a threat that may impact on the foraging ability of the Nationally Endangered yellow-eyed penguin (Te Rūnanga o Ngāi Tahu et al., 2019; Webster, 2018). Yellow-eyed penguins are found on the southeast coast of the South Island, Stewart Island/Rakiura, and the subantarctic Auckland Islands/Motu Maha and Campbell Island/Motu Ihupuku. On the mainland, yellow-eyed penguins breed in four distinct breeding regions: the Catlins, Otago Peninsula, North Otago and Banks Peninsula, and had a mainland population of only 177 breeding pairs in 2020 (Department of Conservation, 2020). Other indigenous biodiversity in the region considered in regional planning documents includes little penguins, royal albatross (toroa, *Diomedea sanfordi*), New Zealand fur seals (kekeno, *Arctocephalus forsteri*), New Zealand sea lions (whakahao, *Phocarctos hookeri*) and 'significant communities of wading birds' (Otago Regional Council, 2012). This section specifically discusses marine sedimentation impacts on the yellow-eyed penguins in the Otago region and how coastal birds are considered in the regional planning documents: Coast for Otago 2012 (the Coastal Plan), Water for Otago 2020 (the Water Plan) and in the Clutha District Plan 1998 (the CDP).

The Water and Coastal Plans consider sedimentation as a cross-boundary issue that requires integrated management to avoid, remedy or mitigate (Otago Regional Council, 2012, 2020). Each of the regional plans have policies in place to specifically address sedimentation in the region, and in doing so, the plans give effect to both the RMA and the NZCPS 2010. The policy most relevant to the impacts of sedimentation on seabirds and shorebirds is Policy 6.4.3 of the Coastal Plan. It states that 'Priority will be given to avoiding any adverse effect on the habitat of, and movement of any marine mammal or bird between the coastal marine area and any coastal protection area, or any of the following areas specified in Schedule 3.1 of this Plan, which are above the line of mean high water springs, and the coastal marine area' because these are areas of importance to yellow-eyed penguin and blue penguin foraging (Otago Regional Council, 2012). As such, any resource consent application in the Otago Region must state whether the proposed location of the activity is adjacent to any area identified as having 'bird conservation values' as specified in the Coastal Plan (Otago Regional Council, 2012).

How the Water and Coastal Plans are implemented on a local scale is exemplified by the Clutha District Plan (CDP). Section 4.2 of the CDP is relevant to the Clutha Coastal Resource Area (CRA), the strip of land 500 m landward of the Mean Highwater Springs (MHWS) mark. The area seaward of this boundary is defined as the Coastal Marine Area (CMA) and is administered by the Otago Regional Council. Several of the issues affecting the CRA identified in the CDP were related to land use and developments that degrade indigenous flora and wildlife habitats. In addition, issues relating to the turbidity of estuarine and coastal water, including activities that might increase sedimentation such as the clearance of native vegetation, exotic forest harvesting, residential and excavation activities were identified in the CDP. Specifically, the CDP mentions that activities or processes that take place in the CRA can 'adversely affect areas in the CMA particularly in matters of water quality, emission of noise, marine mammal and bird habitat, natural coastal processes and the effects on natural character' (Clutha District Council, 1998). Because of the issues identified regarding sedimentation, the CDP includes several rules to give effect to the NZCPS 2010 (the Plan was updated considering the new version of the NZCPS) to avoid, remedy or mitigate any adverse effects of sedimentation on areas of indigenous fauna habitat, such as those used by yellow-eyed penguins, and in estuaries, wetlands, waterbodies and sand dunes (Clutha District Council, 1998). As such, the clearance, modification or destruction of indigenous vegetation, wetlands or sand dunes, forestry activities, and land excavation are considered discretionary activities within the Clutha CRA, and the erection of buildings and structures is a controlled activity. Other rules stated in the CDP to reduce sedimentation in the Rural Resource Area include maintenance of thick riparian vegetation to filter sediment and stabilise banks, revegetating bare areas on hillslopes exceeding 30°, and management of earthworks.

Despite the resource management policies put in place by the Otago Regional Council to limit the effect of land-derived sedimentation on local species (such as yellow-eyed penguins), a major flood event in November 2018 caused large amounts of sediment to be transported down the Clutha and Taieri Rivers. Sediment plumes extended 30 km offshore and overlapped with yellow-eyed penguin foraging habitat during the breeding season (Webster, pers. comm., February 19th, 2021). Flooding coincided with a significant starvation event for yellow-eyed penguin adults and their chicks. It was suggested that the penguins, as visual foragers, found it difficult to find prey in highly turbid water caused by the floods (Department of Conservation, 2019; Webster, pers. comm., February 19th, 2021) . It is important to note that yellow-eyed penguins preferentially forage along the seafloor and are unable to readily change foraging location when visibility is reduced by turbidity. However, in this instance, they may change foraging strategy and forage higher in the water column, as has been observed when visibility was reduced by an algal bloom (Mattern & Ellenberg, 2016).

Key points

- Sedimentation causing increased turbidity has been identified as a threat to yellow-eyed penguins with the potential to cause acute starvation.
- The Water and Coastal Plans for the Otago Region consider sedimentation as a cross-boundary issue that requires integrated management to avoid, remedy or mitigate.
- The Clutha District Plan aims to avoid sedimentation in the marine environment by implementing specific rules around vegetation clearance and land excavation.
- Despite the regional regulations on specific land-uses that may contribute to increased marine sedimentation, severe rainfall events have caused catastrophic sedimentation events in the Otago region that have been reportedly linked to starvation events in the local yellow-eyed penguin population.

Case study 5 – New Zealand fairy terns and mangrove removal

New Zealand fairy terns (NZFT) are New Zealand’s rarest breeding bird (Hansen, 2006) and are ranked nationally as Threatened – Nationally Critical under the NZTCS (Robertson et al., 2017) and internationally as Vulnerable (BirdLife International, 2018). Less than 40 individuals were observed during a 2008 population count across their four known breeding sites: Pakiri river mouth and Papakanui Spit in the Auckland region and Waipu and Mangawhai Spits in Northland (Baird et al., 2013). New Zealand fairy terns are visual foragers that detect and capture prey in the top 5–8 cm of the water column (Ismar et al., 2014). It was suggested that the high water clarity in the Mangawhai Harbour may facilitate greater prey detection by NZFT and may be the reason that it hosts the country’s largest NZFT colony (Ismar et al., 2014).

Mangrove removal is a contentious topic in Northland, Auckland and Bay of Plenty, as evidenced by the high level of submissions on the ‘Mangrove provisions’ section of the Draft Regional Plan for Northland – August 2016 (the Plan). Many people believe mangroves are an unsightly nuisance and allowing their spread is unreasonable, whereas others understand that they play an important ecological role and think it is crucial to protect them (De Luca, 2015).

The initial draft version of the Plan permitted the removal of mangrove seedlings (<60 cm high) within mapped Significant Bird Areas outside of the birds’ breeding season (1 September to 31 January) when bird foraging ranges are typically restricted by nest location. The Royal Forest and Bird Protection Society of New Zealand (Forest & Bird) appealed the Plan under Schedule 1 of the RMA before the Environment Court, citing the mangrove removal provisions as a particular concern for NZFT. Forest & Bird highlighted that NZFT have been observed foraging for prey along mangrove-lined rivers and channels in the Kaipara Harbour and at Mangawhai (Baird et al., 2013; Ismar et al., 2014) and that mangroves were, therefore, critical to supporting breeding NZFT (Environment Court of New Zealand, 2020a). Forest & Bird suggested that mangrove removal and harbour dredging in the Mangawhai Harbour will likely negatively impact NZFT foraging by mobilising sediment, which would compromise the birds’ ability to detect prey (Environment Court of New Zealand, 2020a).

Northland Regional Council responded to Forest & Bird’s appeal by extending the temporal restriction on mangrove seedling removal to between 1 September and 28 February, during which the activity is prohibited in Significant Bird Areas (Northland Regional Council, 2020). In addition to mangrove removal outside of the breeding season, the Plan also mentions that certain land disturbance activities (earthworks, cultivation, vegetation clearance) should implement erosion and sediment control measures to minimise erosion and the discharge of sediment to water which, although not explicitly stated in the Plan, would also reduce the impact of sediment and its associated increased turbidity on NZFT foraging in the region.

It has been suggested that the disturbance and modification of the harbour and resuspension of sediment caused by the mechanical removal of mangroves at Mangawhai in 2015 has adversely affected the population of NZFT. This was exemplified by the time NZFT spent foraging to provision their chicks, which more than doubled in the two breeding seasons following mangrove removal (Independent Hearing Panel appointed by the Northland Regional Council, 2020). Additionally, fewer eggs were laid following mangrove removal (Williams, 2019). This is a concern, as any reduction in foraging efficiency or breeding effort is likely to negatively impact the population of this rarest breeding bird in New Zealand. Moreover, mangrove removal was thought to facilitate greater human disturbance of NZFT in the Mangawhai Harbour by improving access to previously inaccessible areas of the coast (Independent Hearing Panel appointed by the Northland Regional Council, 2020).

Key points

- NZFT are known to forage in mangrove-lined rivers and harbours; thus, removing mangroves may cause sedimentation, which might negatively impact NZFT foraging by increasing turbidity.
- The Draft Regional Plan for Northland, which included provisions for mangrove removal as a permitted activity, was appealed by Forest & Bird based on the potential impact such mangrove removal and subsequent turbidity could have on NZFT foraging.

- The management response by Northland Regional Council was to extend the temporal restriction on mangrove removal to prevent any adverse effects on NZFT foraging during the breeding season.
- Following mechanical mangrove removal in 2015, NZFT reportedly spent more time foraging, laid fewer eggs and were subject to more human disturbance than in previous years.

Case study 6 – Coastal birds in the Motiti Natural Environment Management Area

In 2015, the Bay of Plenty Regional Council (BOPRC) announced its draft Regional Coastal Environmental Plan (the Plan), which included the waters surrounding Motiti Island, the Tokau reefs including the Astrolabe reef/Ōtāiti, all of which form part of the wider Motiti Natural Environment Management Area/Motiti Rohemoana (MNEMA) (Bay of Plenty Regional Council, 2019). The Plan was appealed at the Environment Court by the Motiti Rohe Moana Trust, in part because it did not reflect the cultural importance of the MNEMA or adequately protect the indigenous biodiversity and ecosystems of the MNEMA, as required by the NZCPS 2010. The MNEMA supports a variety of coastal birds, listed here according to their threat classification status (NZTCS): Threatened – Nationally Critical black-billed gull (tarāpuka, *Larus bulleri*) and Australasian bittern, Threatened – Nationally Vulnerable wrybill, At Risk – Declining little penguin, red-billed gull (tarāpunga, *Larus novaehollandiae*) and white-fronted tern (tara, *Sterna striata*), At Risk – Recovering New Zealand dotterel, brown teal (pāteke, *Anas chlorotis*), pied shag and little shearwater (*Puffinus assimilis*), At Risk – Relict fluttering shearwater (pakahā, *Puffinus gavia*), fairy prion (tītī wainui, *Pachyptila turtur*) and white-faced storm petrel (takahikare-moana, *Pelagodroma marina*) and At Risk – Naturally Uncommon Buller's shearwater (rako, *Puffinus bulleri*) (Environment Court of New Zealand, 2017c; Robertson et al., 2017).

Sedimentation was mentioned throughout the Motiti Rohe Moana Trust appeal presented to the Environment Court as a known issue in the MNEMA marine environment. One issue identified by the Motiti Rohe Moana Trust was that increased sedimentation, primarily from land-based sources but also by disturbance, deposition and extraction in the marine environment, was contributing to the loss of biodiversity values and a decrease in water quality in the MNEMA (Environment Court of New Zealand 2020b). Examples of the impact caused by sedimentation included the possible loss of kelp forests, shellfish beds, subtidal sponge gardens and other habitats important for fish, kaimoana (seafood) and coastal birds. Additionally, sedimentation was said to favour mangrove growth in the region.

The proposed Plan proposed no method to control destructive fishing practices, despite the degradation of the Coastal Marine Environment (CMA) caused by such fishing methods (Gepp & Wright 2018), which was a key reason why the Plan was appealed by the Motiti Rohe Moana Trust. Fishing methods that damage the benthic environment (such as dredging and bottom trawling) resuspend sediment, causing water to become turbid (Turner et al. 1999). The turbidity caused by these fishing practices can impact the ability of visual foraging seabirds and shorebirds to detect prey and would likely have negatively impacted the visually foraging seabirds and shorebirds in the MNEMA, although this was not explicitly stated as a reason to prohibit fishing in Court documents. The Environment Court ruled that the Plan should prohibit fishing within three main areas of the MNEMA and impose 'controls within the balance of the MNEMA in particular concerning fishing methods that may damage the benthic environment or where they impact particularly on seabirds or other marine mammals' (Environment Court of New Zealand 2020b).

The Environment Court ruled that the BOPRC could only restrict fishing practices in coastal waters if it was 'strictly necessary' to maintain indigenous biodiversity, as a perceived overlap occurred between the two statutes that control fishing activities in the coastal marine environment, the Fisheries Act 1996 (the FA) and the RMA. An objective of the RMA is to maintain indigenous biodiversity 'and the ecological complexes of which biodiversity is part' (MfE 2020), whereas the FA is focused on the sustainable utilisation of fisheries (MPI 2020). However, the FA omits any reference to the link between organisms, ecological functions and habitats, and therefore lacks an ecosystem-based approach to sustainability (Urlich 2020). The BOPRC appealed this decision in the Court of Appeal, which had to evaluate the statutory relationship between the FA and the RMA and determine the 'strict necessity' of a fishing control in a coastal area.

The Court of Appeal ruled in 2019 that the FA and RMA are complementary, which meant that regional councils can control fishing activities under Section 30(1)(ga) of the RMA to maintain indigenous biodiversity and fisheries resources, provided they do not do so to manage those resources for *Fisheries Act 1996* purposes (New Zealand Court of Appeal 2019). This is the first example of how the RMA can be used by regional councils to inform the control of fishing as a function and for the purpose of protecting biodiversity, such as seabirds and shorebirds, in the coastal marine environment. 'The damage, destruction or removal of flora and fauna, including by fishing, over specific areas within a wider Motiti Natural Environment Management Area (MNEMA) is now prohibited' (Environment Court of New Zealand 2018; Gepp & Wright 2018), which will likely reduce the impact of marine sedimentation caused by destructive fishing practices on seabirds and shorebirds in the MNEMA.

Several policies were included in the proposed Plan to address the issue of land-based sediment input. For example, Policy WQ 4 addresses sediment input into the coastal environment by promoting the use of catchment-based solutions to prevent or mitigate sedimentation in preference to the use of methods to reverse the effects of sedimentation, such as mangrove removal and dredging (Bay of Plenty Regional Council 2019). The methods suggested in the proposed Plan to mitigate the adverse effects of sediment-contributing activities included: maintenance and planting of vegetation, erosion protection works, and fencing in the same general locality (Bay of Plenty Regional Council 2019).

The Bay of Plenty Regional Council (2019) state in the Plan that the removal of mangrove seedlings in the MNEMA should be permitted in areas that have been identified as bird roosting or nesting sites outside of the bird roosting and nesting seasons (1 September to 31 January). The dates differ from those used by Northland Regional Council (Case Study 5) to accommodate the New Zealand Fairy Tern breeding season. This rule consequently allows for the discharge of sediment to the coastal marine area during mangrove removal, so by adding a temporal restriction to the activity, the sedimentation caused during mangrove removal will have less impact on seabirds and shorebird foraging during the breeding seasons.

Key points

- It was suggested that the Bay of Plenty Regional Coastal Environmental Plan did not adequately address the NZCPS, BOP Regional Policy Statement (RPS) and the impacts of activities in the CMA, including the effects of fishing, despite the awareness that these practices can have adverse effects on indigenous biodiversity.
- The plan was appealed by the Motiti Rohe Moana Trust for failing to protect natural and cultural landscapes, in addition to indigenous biodiversity as required by the BOPRC under the RMA and NZCPS 2010. This was escalated to the Court of Appeal by the BOPRC and then the crown to determine whether the RMA or FA takes precedence in coastal waters.
- The Court of Appeal ruled that the BOPRC can control activities (including fishing) in the coastal area for the purposes of protected values with the RMA, NZCPS and RPS as a means of protecting indigenous biodiversity.
- Along with the decrease in sedimentation caused by destructive fishing, which is now prohibited, the plan also promotes catchment-based solutions to prevent or mitigate sediment runoff and increasing sedimentation, and has similar mangrove removal temporal rules to Northland Regional Council.
- This is a good example of a Matauranga Māori approach to marine conservation.

Case study 7 – Sand mining at the South Taranaki Bight

Sand mining off the South Taranaki Bight will cause a sediment plume that has the potential to negatively impact on seabirds foraging in the region. A report by Thompson (2015) suggests that the South Taranaki Bight may be utilised by 52 species of seabirds, including 20 coastal species (5x shags, 1x penguin, 1x gannet, 2x skua, 3x gulls, 7x terns and 1x noddy) in addition to 32 pelagic species (7x albatross, 1x giant petrel, 8x shearwaters, 9x petrels, 6x prions, 1x storm petrel). While all of these species have been observed in the region, detailed, systematic and quantitative information on the at sea distribution of virtually all species is lacking (Thompson, 2015). Taranaki's only seabird breeding colonies of significance are the Nga Motu/Sugar Loaf Islands near New Plymouth (Department of Conservation, 2021), but there are a number of estuarine sites of significant value to coastal bird species. These sites include the Waikirikiri Lagoon and the Whanganui, Whangaehu, Turakina, Manawatu and Rangitikei river estuaries (Thompson, 2015). There are major seabird colonies in the Marlborough and Nelson regions, and the South Taranaki Bight has been identified as a globally Important Bird Area (marine IBA) for seabird foraging and the passage of species through Cook Strait (Forest & Bird 2014).

The South Taranaki bight contains iron sand, which is of interest to mining companies such as Trans-Tasman Resources Limited (TTRL), who have applied for two resource consents since 2013. The first application was made to the Environment Protection Authority (EPA) in 2013 for consent to mine iron sand in a 66 km^2 area off the South Taranaki Bight (Environment Foundation, 2018). The project involves excavating 50 million tonnes of sand each year, extracting the iron and returning 90% of the sand to the seabed (Trans-Tasman Resources, 2020). Mining would occur in the Exclusive Economic Zone (out to 200 NM) and would therefore be governed by the EEZ Act, the Exclusive Economic Zone and Continental Shelf (Environmental Effects – Discharge and Dumping) Regulations 2015. However, the environmental impact from offshore mining, such as marine sedimentation, can impact the Coastal Marine Environment (CMA), 12 NM seaward of the

Mean Highwater Springs (MHWS) mark, which is governed by the RMA and NZCPS 2010. Therefore, this case study will focus on the impact that sand mining would have on the CMA.

An Environmental Assessment report was prepared by TTRL to support their resource consent application, which considered the impact of sedimentation on seabirds in the region. The report detailed how sediment would reduce light penetration that would decrease primary productivity in the South Taranaki Bight by 10% (reviewed in Environment Foundation, 2018) and would impact the marine food web on which seabirds rely. Additionally, the report stated that complete mortality of benthic fauna would occur in the mined area and the benthic environment outside of the mined area 'would be subjected to sedimentation and reduced light levels as a result of the sediment plume' (reviewed in Environment Foundation, 2018). The report also stated that the effects of mining activities on fish, a key prey group of seabirds, would include a loss of food sources, habitat and spawning grounds, and the displacement of species (reviewed in Environment Foundation, 2018). The report acknowledged that the sediment created by iron sand mining would have an impact on seabirds in the region, primarily that it would impact on visual foragers and effects on the food web, including habitat loss and the loss of foraging areas (reviewed in Environment Foundation, 2018). However, the Decision-Making Committee (DMC) of the Environmental Protection Agency (EPA) could not conclude as to the importance of the South Taranaki Bight for seabirds and therefore the significance of the potential effects, as required as part of the resource consent process (reviewed in Environment Foundation, 2018).

The DMC declined the resource application by TTRL in 2015 because the environmental objectives suggested in the Trans-Tasman Resources adaptive management approach were too general and non-specific, and because there was no option to start the mining operation in a small and localised way before scaling up, during which environmental impacts could have been addressed at an early stage (Environment Foundation, 2018). Another application was lodged by the TTRL in 2016 that included sediment plume modelling. The majority of the DMC felt the new application met the environmental requirements and approved the application in 2017 for 35 years.

In 2017, the consent was appealed in the High Court by many parties including iwi, commercial fisheries and environmental groups. Most appeals were general in nature and focussed on how the CMA would be impacted by the sediment plume, with several appeals stating that the resource consent was contrary to the precautionary principle provisions in the RMA and NZCPS 2010 (reviewed in High Court of New Zealand, 2018). Ngāti Ruanui, mana whenua of the area, opposed the consent on the grounds that mining would 'significantly impact the ability of tangata whenua to exercise kaitiakitanga over their rohe and marine resources and will in their view adversely affect the mauri of the marine environment' (reviewed in Environment Foundation, 2018).

The consent conditions regarding seabirds included: 'a) There shall be no adverse effects at a population level of seabird species that utilise the South Taranaki Bight that are classified under the New Zealand Threat Classification System as 'Nationally Endangered', 'Nationally Critical' or 'Nationally Vulnerable' or classified as 'Endangered' or 'Vulnerable' in the International Union for the Conservation of Nature Red List; and b) adverse effects on seabirds, including but not limited to effects arising from iii) The effect of sediment in the water column on diving birds that forage visually shall be mitigated, and where practicable avoided' (High Court of New Zealand, 2018).

The appeals specific to seabirds argued that the EPA granted resource consent with no systematic or quantitative surveys of seabirds in the region while at the same time acknowledging that sediment would impact on their foraging abilities (High Court of New Zealand, 2017). Supplementary evidence provided by seabird scientist Dr John Cockrem stated that the sediment plume derived from mining activities would negatively impact the foraging ability of little penguins, fairy prions and other seabirds in the region and that the proposed 'Seabirds Effects Mitigation and Management Plan' created by the TTRL could not achieve its stated goal of ensuring that there were no adverse effects at a population level (Environmental Protection Authority, 2017).

The 2017 EPA decision was quashed in 2018 by the High Court and referred back to the EPA for reconsideration. One of the suggestions by the High Court was that Condition 66 provided for TTRL to prepare a Seabird Effects Mitigation and Management Plan (SEMMP) to set out how compliance with condition 9 would be achieved, including setting out indicators of adverse effects at a population level of seabird species that utilise the STB. The SEMMP is required to be submitted to the EPA for certification that the requirements of the condition have been met. Trans-Tasman Resources Limited are yet to receive resource consent to mine iron sand within the STB.

Key points

- Trans-Tasman Resources Limited (TTRL) twice applied for resource consent to mine iron sand off the South Taranaki Bight, the most recent application was in 2015.
- Modelling of the sediment created by sand mining showed the sediment plume would extend into the Coastal Marine Area, which could impact the foraging abilities of the 20 coastal foraging seabirds in the region.
- The consent application was appealed in the High Court by iwi, commercial fisheries and environmental groups. Several of the appeals cited the precautionary principle provisions in the RMA and NZCPS 2010 concerning the impact of mining-derived sedimentation on marine ecosystems.
- Trans-Tasman Resources Limited are yet to receive resource consent to mine iron sand off the STB.

Case study 8 – Dredging of Port Otago and its impact on coastal birds

In 2010, Port Otago Limited (POL) applied for resource consent for 'Project Next Generation', a project to deepen and widen the harbour entrance to allow larger and a greater number of vessels to visit Port Chalmers. Dredging, sediment disposal and the construction of a wharf extension were among the activities covered by the resource consent applications (Port Otago Limited, 2010). The dredging would see a total of 7.2 million m^3 of sediment removed from the harbour, consisting of sands (62%), silts (34%), clays (3%) and rock (1%) (Port Otago Limited, 2010). Dredged material would be deposited at four sites – Aramoana Spit, Heyward Point and Shelly Beach near the harbour entrance and site 'A0' located 6.3 km northeast of Taiaroa Head (Fig. 24) (Port Otago Limited, 2010).

Figure 24. Proposed disposal site A0 (Port Otago drawing No. 11142). *Image source: Port Otago Limited, 2010* https://www.orc.govt.nz/media/3232/port-otago-project-next-generation-application-for-channel-works-va275956.pdf.

Port Otago Limited supplied an Assessment of Ecological Effects (AEE) to support their application. Thirty-four species of seabirds that utilise the Otago coastal waters were listed in the AEE that may be impacted by the dredging and sediment disposal (reviewed in Port Otago Limited, 2010). The Otago Harbour coastal waters support a variety of coastal birds, listed here according to their threat classification (NZTCS): Threatened – Nationally Critical black-billed gull, Threatened – Nationally Endangered black-fronted tern (tarapirohe, *Chlidonias albostriatus*) and yellow-eyed penguin, Threatened – Nationally Vulnerable grey-headed mollymawk (*Thalassarche chrysostoma*), banded dotterel (tūturiwhatu, *Charadrius bicinctus*), Caspian tern, Hutton's shearwater (*Puffinus huttoni*) and flesh-footed shearwater, At Risk – Declining white-fronted tern, red-billed gull, sooty shearwater (tītī, *Puffinus griseus*), little penguin, South Island pied oystercatcher and erect-crested penguin (*Eudyptes sclateri*), At Risk – Recovering Otago (Stewart Island) shag (kawau, *Leucocarbo chalconotus*) and At Risk – Naturally Uncommon northern royal albatross (toroa, *Diomedea sanfordi*) (reviewed in Port Otago Limited, 2010). The AEE listed settlement of sediments in intertidal areas, increased turbidity levels and removal of roosting sites as the potential effects of dredging on birds of the Otago Harbour but discerned that the effects would be low impact and short-lived (Port Otago Limited, 2010).

The resource consent application was publicly notified and received 198 submissions and, of those, 17 mentioned the impact the dredging and sediment disposal would have on coastal birds in the region (Otago Regional Council, 2011). Submissions related to seabirds and shorebirds highlighted the lack of knowledge of how the project would impact the foraging abilities of seabirds and shorebirds in the region, many of whom are listed as threatened. Several submissions suggested the resource consent application failed to give effect to sections 5 – 'avoiding, remedying, or mitigating any adverse effects of activities on the environment', 6(c) – 'the protection of areas of significant indigenous vegetation and significant habitats of indigenous fauna' and 7(d) 'the intrinsic values of ecosystems' of the RMA (Otago Regional Council, 2011).

In 2011, Otago Regional Council and the Minister of Conservation granted the resource consent, provided POL meet several conditions. The conditions specific to seabirds and shorebirds were collaboratively developed by DOC and POL. The conditions were that the dredging and sediment disposal: 'a) avoids sensitive sites at sensitive times of the year; b) avoids interaction with seabirds and marine mammals; c) requires baseline and ongoing monitoring to determine the physical and biological effects of disposal at site A0, and d) requires the establishment and service of a technical group that will receive and assess monitoring information and advice on ways to minimise the effects of the activities' (Otago Regional Council, 2011). The point of some of the resource consent conditions was that the technical group would be able to voice their concerns to the Otago Regional Council if there were significant issues of non-compliance and/or unacceptable impacts from dredging activities (McKinlay, pers. comm., June 1st, 2021). These conditions ensured that 'Project Next Generation' gave effect to sections 6(c) and 7(d) of the RMA.

It is relevant to note for this Case Study that the original resource consent application by POL included a dredge being transported to New Zealand that could complete the capital works in 180 days. However, this was not required, as a local dredge was able to complete the work over a longer timeframe but with less disruption (McKinlay, pers. comm., June 1st, 2021). Additionally, the full extent of the dredging works included in the application did not take place due to a technical issue with the larger vessels that were intended originally to visit the port (McKinlay, pers. comm., June 1st, 2021).

Key points

- Port Otago Limited (POL) applied for resource consent for 'Project Next Generation', a project to deepen and widen the Port Chalmers Harbour entrance.
- 7.2 million m^3 of sediment would be removed from the harbour and disposed of at four sites, three at the harbour entrance and one offshore.
- The Assessment of Ecological Effects (AEE) suggested that the dredging and sediment disposal would have a negligible impact on seabirds and shorebirds that forage in the Otago Harbour.
- 198 submissions were made on the resource consent application, a number of them opposed the application on the basis that sedimentation would negatively impact the foraging abilities of seabirds and shorebirds in the region, especially threatened species.
- The consent was granted with four conditions that give effect to sections 6(c) and 7(d) of the RMA to reduce the impact of sedimentation on seabirds and shorebirds in the region.

7. Knowledge gaps summarised

This review highlights the sparsity of information on the impact of marine sedimentation on seabirds and shorebirds in Aotearoa New Zealand and globally. The key knowledge gaps identified by this review are:

- Direct links between catastrophic sedimentation events and their impacts on seabird and shorebird foraging are poorly documented. The impact of catastrophic sedimentation events during the breeding and non-breeding seasons are anecdotally recorded but poorly documented or modelled in New Zealand.

- Little information exists in the literature on how the rates of sedimentation in New Zealand's coastal waters will shift in line with future climate change projections.
- The effect of turbidity is not well studied in coastal or marine environments in New Zealand or internationally, even though rates of sedimentation from human-derived activities are increasing in many coastal areas worldwide.
- How sedimentation has altered the foraging grounds available to shorebirds through, for example, the expansion of mangroves or cordgrass, is not well documented.
- Seabird diet and foraging preferences for coastal habitats in New Zealand are largely not well known.
- Shorebird diet and foraging preferences, including the substrate characteristics and macroinvertebrate species composition, are not well known in New Zealand.
- How sedimentation impacts trophic links in New Zealand's coastal ecosystems is not well known. There is some literature on the impact of sedimentation on macroinvertebrates in New Zealand, but there is no information on the impact sedimentation has on marine fishes, a key prey for many seabirds in New Zealand, and little information globally.
- The effectiveness of current policy initiatives and tools to address sedimentation needs to be assessed and best practise developed.

8. Research recommendations

Further research on the impacts of sedimentation on seabirds and shorebirds is required. Investigating aspects where information is presently incomplete or lacking needs to be prioritised so that future policy decisions and documents in New Zealand can be properly informed.

Priorities for further research include:

Sediment sources and movement

- Investigating the direct and indirect impacts of sedimentation from sand and other mineral mining on seabird and shorebird foraging.
- Investigating the direct and indirect impacts of dredge dumping (e.g. Whangārei, Waitematā and Otago Harbours) on the diet, productivity and survival of key seabird species.
- Developing models that could predict 'tipping points' for key seabird and shorebird species after catastrophic sedimentation events to enable conservation managers to prepare appropriate responses.
- Modelling cumulative and catastrophic sedimentation events in line with climate change projections and how these might impact on seabird and shorebird foraging.
- Assessing how the inputs from storm events and sediment plume events, and outflows from forestry operations, agricultural land and urban development alter the diet of seabirds and shorebirds.

Sedimentation impacts on ecosystems and seabird and shorebird prey

- Review substrate characteristics and invertebrate species composition at key shorebird feeding areas throughout New Zealand (identified as Important Bird Areas and Significant Bird Areas (Forest and Bird, 2016)). Then determine and map any changes in species diversity and composition at a subset of key sites as a sediment impact monitoring tool. Combine this with predictive modelling to determine shorebird diet changes if prey composition might change with sedimentation impacts.
- Investigate the direct and indirect impacts of mangroves on the availability of feeding habitat for coastal birds in New Zealand and changes in areas where mangroves have been removed (e.g. Mangawhai, Whangamata, Tauranga Harbour).
- Carry out a comprehensive national review of the direct and indirect impacts of sedimentation on shorebird foraging in large estuaries in New Zealand that have been identified as areas that support tens of thousands of shorebirds.
- Investigate the impact of sedimentation on marine fishes to determine the flow-on effect this may have on piscivorous seabirds.

Sedimentation impacts on seabird and shorebird foraging

- Investigate the direct and indirect impacts of sedimentation on seabird foraging, especially for threatened species with specialised foraging strategies, such as yellow-eyed penguins/hoiho and king shags/kawau, or other indicator species. This could include the cumulative impacts of sedimentation and other stressors (e.g. increased sea surface temperature, fishing activities) in the marine environment.
- Monitor other key species, including representatives of the full range of foraging types (i.e. visual benthic foragers (shags, penguins), visual pelagic foragers (terns, gannets, little penguins), surface-feeding, shallow and deep plunge divers). Nationally common and easily observed species such as white-fronted tern, Australasian gannet, pied shag, and little penguin should be monitored. Monitoring must cover both normal conditions and catastrophic events, particularly storm or flood events that result in sediment plumes in harbours, estuaries, and coastal waters; and include productivity (breeding success) and survival in relation to these events.
- Monitoring studies could also include modelling of previous catastrophic sedimentation events in relation to survival and productivity of seabird species, one-off tracking studies in areas of known sedimentation impacts to determine how seabirds forage during sedimentation events, or other novel tracking studies (e.g. bird-borne cameras – see Mattern & Ellenberg 2018).

A number of these recommendations could be developed as MSc or PhD projects that help to fill basic ecological knowledge gaps of seabird and shorebird foraging in Aotearoa New Zealand. Examples include diet and foraging studies of seabird and shorebird species, monitoring the breeding success of seabird and shorebird populations in relation to sedimentation events or examining the impact of sedimentation on marine fishes that are consumed by key seabird and shorebird species.

9. Conclusions

Aotearoa New Zealand is an avian biodiversity hotspot with many endemic, native and migratory bird species found within the highly productive coastal environment. New Zealand also has one of the highest proportions of threatened bird species globally where 90% of seabirds and 80% of shorebirds are threatened with, or at risk of, extinction. Birds that reside in the coastal environment face more threats than those in other habitat types because of human-related pressures (such as marine sedimentation and coastal development) in coastal ecosystems. In New Zealand, marine sedimentation is the third highest scoring threat to coastal marine habitats and the only one, until recently, that can be impacted by activities governed by the RMA (MacDiarmid et al., 2012). This review outlines the impacts of marine sedimentation on the foraging of coastal avian species throughout Aotearoa New Zealand and how these impacts have been addressed in the context of the RMA.

There is very little literature documenting the effects of marine sedimentation on seabirds and shorebirds. In general, the literature outlines how sedimentation degrades the coastal habitat on which seabirds and shorebirds rely. The examples discussed throughout this review have revealed that marine sedimentation can impact seabirds and shorebirds both directly and indirectly. The primary direct impact mentioned in the literature was the impact of increased turbidity on the visual acuity of foraging seabirds such as shags, terns and penguins. Little literature has been found documenting a direct effect on shorebird foraging, and this remains a key knowledge gap. Many studies can be used to infer the impact marine sedimentation may have on seabirds and shorebird foraging by the documented effect that sedimentation has on ecosystem processes and marine food webs.

There are few examples of a management response to marine sedimentation in New Zealand within the context of the RMA. The case studies highlighted in this review mention seabirds and shorebirds, for example, within resource management plans, and discuss the need to reduce sedimentation, but often lack a direct connection between the two. Mostly, the impact that sedimentation can have on seabirds and shorebird foraging is mentioned only in court appeals by conservation groups, local community groups and iwi appealing a resource management plan or consent. These appeals usually suggest that regional councils are perceived to be not fulfilling their statutory requirements to protect indigenous biodiversity and ecosystems under the RMA and/or NZCPS 2010.

A number of knowledge gaps are identified, and research recommendations made relating to sedimentation impacts on seabirds and shorebirds, which will allow outstanding questions to be answered, and will inform future policy decisions and documents in New Zealand. Several of the research recommendations could be developed as MSc or PhD projects that help to fill basic ecological knowledge gaps of seabird and shorebird foraging in Aotearoa New Zealand.

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Aotearoa New Zealand’s rarest bird, the New Zealand fairy tern (tara iti, *Sternula nereis davisae*), Waipu Estuary, Northland. *Photo: Edin Whitehead*.

Appendices

1 SEABIRDS OF AOTEAROA NEW ZEALAND

Table 1. Seabird taxa (species and subspecies) resident (breeding and/or overwintering) in Aotearoa New Zealand, including the Kermadec, Chatham and New Zealand Subantarctic Islands. Both the New Zealand Threat Classification System (NZTCS) categories and global conservation status (IUCN Red List, viewed 5 August 2020) are listed for each species. The NZTCS complements the IUCN Red List but is 'focussed at the national level and provides a more sensitive classification for taxa with naturally restricted distributions and small numbers as a result of insular rarity' (Townsend et al., 2008). The conservation categories (NZTCS) and statuses (NZTCS, IUCN) for each system, ranked from most to least threatened are: **NZTCS** - Extinct, Threatened – Nationally Critical, Nationally Endangered, Nationally Vulnerable, At Risk – Declining, Recovering, Relict, Naturally Uncommon, Not Threatened; **IUCN** – Extinct (EX), Extinct in the Wild (EW), Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT), Least Concern (LC), Data Deficient (DD), Not Evaluated (NE).

Preferred Common Name	Māori Name(s)	Name and Authority	NZTCS Category	NZTCS Status	IUCN Status
Yellow-eyed penguin	Hoiho, tarakaka	*Megadyptes antipodes* Hombron & Jacquinot, 1841	Threatened	Nationally Endangered	EN
Eastern rockhopper penguin		*Eudyptes filholi* Hutton, 1879	Threatened	Nationally Vulnerable	VU
Fiordland crested penguin	Tawaki, pokotiwha	*Eudyptes pachyrhynchus* G.R. Gray, 1845	Threatened	Nationally Vulnerable	VU
Snares crested penguin		*Eudyptes robustus* Oliver, 1953	At Risk	Naturally Uncommon	VU
Erect-crested penguin		*Eudyptes sclateri* Buller, 1888	At Risk	Declining	EN
New Zealand little penguin	Kororā	*Eudyptula minor* Mathews, 1911	At Risk	Declining	LC
Australian little penguin	Kororā	*Eudyptula novaehollandiae* (Stephens, 1826)	At Risk	Recovering	LC
Antipodean wandering albatross	Toroa	*Diomedea antipodensis antipodensis* Robertson & Warham, 1992	Threatened	Nationally Critical	EN

Preferred Common Name	Māori Name(s)	Name and Authority	NZTCS Category	NZTCS Status	IUCN Status
Gibson's wandering albatross	Toroa	*Diomedea antipodensis gibsoni* Robertson & Warham 1992	Threatened	Nationally Critical	EN
Southern royal albatross	Toroa	*Diomedea epomophora epomophora* Lesson, 1825	At Risk	Naturally Uncommon	VU
Northern royal albatross	Toroa	*Diomedea sanfordi* Murphy, 1917	At Risk	Naturally Uncommon	EN
Southern Buller's albatross	Toroa	*Thalassarche bulleri* Rothschild, 1888	At Risk	Naturally Uncommon	NT
Northern Buller's albatross	Toroa	*Thalassarche bulleri platei* Rothschild, 1888	At Risk	Naturally Uncommon	NT
Grey-headed albatross		*Thalassarche chrysostoma* J.R. Forster, 1785	Threatened	Nationally Vulnerable	EN
Campbell albatross		*Thalassarche impavida* Mathews, 1912	Threatened	Nationally Vulnerable	VU
Black-browed albatross	Toroa	*Thalassarche melanophris* (Temminck, 1828)	Non-resident Native	Coloniser	LC
Chatham Island albatross	Toroa	*Thalassarche eremita* Murphy, 1930	At Risk	Naturally Uncommon	VU
Salvin's albatross	Toroa	*Thalassarche salvini* (Rothschild, 1893)	Threatened	Nationally Critical	VU
New Zealand white-capped albatross	Toroa	*Thalassarche steadi* Robertson & Nunn, 1938	At Risk	Declining	NT
Light-mantled sooty albatross	Toroa pango, toroa, toroa-a-ruru koputu	*Phoebetria palpebrata* (Forster, 1785)	At Risk	Declining	NT

Preferred Common Name	**Māori Name(s)**	**Name and Authority**	**NZTCS Category**	**NZTCS Status**	**IUCN Status**
Northern giant petrel	Pāngurunguru	*Macronectes halli* Mathews, 1912	At Risk	Recovering	LC
Fulmar prion		*Pachyptila crassirostris crassirostris* Mathews, 1912	At Risk	Naturally Uncommon	LC
Chatham fulmar prion		*Pachyptila crassirostris pyramidalis* Fleming, 1939	At Risk	Naturally Uncommon	LC
Antarctic prion	Totorore	*Pachyptila desolata* Gmelin, 1789	At Risk	Naturally Uncommon	LC
Fairy prion	Tītī wainui	*Pachyptila turtur* (Kuhl, 1820)	At Risk	Relict	LC
Broad-billed prion	Pararā	*Pachyptila vittata* Forster, G, 1777	At Risk	Relict	LC
Snares Cape petrel		*Daption capense australe* Mathews, 1913	At Risk	Naturally Uncommon	LC
Grey petrel	Kuia	*Procellaria cinerea* Gmelin, 1789	At Risk	Naturally Uncommon	NT
Black petrel	Takoketai, tāiko	*Procellaria parkinsoni* G.R. Gray, 1862	Threatened	Nationally Vulnerable	VU
Westland petrel	Tāiko	*Procellaria westlandica* Falla, 1946	At Risk	Naturally Uncommon	EN
White-chinned petrel		*Procellaria aequinoctialis* Linnaeus, 1758	Not Threatened	Not Threatened	VU
Chatham petrel	Ranguru	*Pterodroma axillaris* (Salvin, 1893)	Threatened	Nationally Vulnerable	VU

Preferred Common Name	**Māori Name(s)**	**Name and Authority**	**NZTCS Category**	**NZTCS Status**	**IUCN Status**
White-naped petrel		*Pterodroma cervicalis* (Salvin, 1891)	At Risk	Relict	VU
Cook's petrel	Tītī	*Pterodroma cookii* (G.R. Gray, 1843)	At Risk	Relict	VU
Mottled petrel	Korure, tītī	*Pterodroma inexpectata* (J.R. Forster, 1844)	At Risk	Relict	NT
White-headed petrel		*Pterodroma lessonii* (Garnot, 1826)	Not Threatened	Not Threatened	LC
Grey-faced petrel	Ōi, tītī	*Pterodroma macroptera gouldi* Hutton, 1869	Not Threatened	Not Threatened	LC
Chatham Island tāiko	Tāiko	*Pterodroma magentae* Giglioli & Salvadori, 1869	Threatened	Nationally Critical	CR
Soft-plumaged petrel		*Pterodroma mollis* (Gould, 1844)	At Risk	Naturally Uncommon	LC
Kermadec petrel		*Pterodroma neglecta neglecta* Schlegel, 1863	Threatened	Nationally Endangered	LC
Black-winged petrel	Tītī	*Pterodroma nigripennis* Rothschild, 1893	Not Threatened	Not Threatened	LC
Pycroft's petrel	Tītī	*Pterodroma pycrofti* Falla, 1933	At Risk	Recovering	VU
North Island little shearwater		*Puffinus assimilis haurakiensis* Fleming & Serventy, 1943	At Risk	Recovering	LC
Kermadec little shearwater		*Puffinus assimilis kermadecensis* Murphy, 1927	At Risk	Recovering	LC
Subantarctic little shearwater		*Puffinus elegans* Giglioli & Salvadori, 1869	At Risk	Naturally Uncommon	LC

Preferred Common Name	Māori Name(s)	Name and Authority	NZTCS Category	NZTCS Status	IUCN Status
Buller's shearwater	Rako	*Puffinus bulleri* Salvin, 1888	At Risk	Naturally Uncommon	VU
Flesh-footed shearwater	Toanui, tuanui	*Puffinus carneipes* Gould, 1844	Threatened	Nationally Vulnerable	NT
Fluttering shearwater	Pakahā	*Puffinus gavia* Forster, 1844	At Risk	Relict	LC
Sooty shearwater	tītī	*Puffinus griseus* Gmelin, 1789	At Risk	Declining	NT
Hutton's shearwater		*Puffinus huttoni* Mathews, 1912	Threatened	Nationally Vulnerable	EN
Wedge-tailed shearwater		*Puffinus pacificus pacificus* Gmelin, 1789	At Risk	Relict	LC
White-bellied storm petrel		*Fregetta grallaria grallaria* Vieillot, 1818	Threatened	Nationally Endangered	LC
New Zealand storm petrel		*Fregetta maoriana* Mathews, 1932	Threatened	Nationally Vulnerable	CR
Black-bellied storm petrel		*Fregetta tropica* Gould, 1844	Not Threatened	Not Threatened	LC
Grey-backed storm petrel		*Garrodia nereis* Gould, 1841	At Risk	Relict	LC
New Zealand white-faced storm petrel	Takahikare-moana, takahikare	*Pelagodroma marina maoriana* Mathews, 1912	At Risk	Relict	LC
Kermadec storm petrel		*Pelagodroma marina albiclunis* Murphy & Irving, 1951	Threatened	Nationally Critical	LC
Leach's storm petrel		*Oceanodroma leucorhoa* Vieillot, 1818	Non-resident Native	Coloniser	LC

Preferred Common Name	Māori Name(s)	Name and Authority	NZTCS Category	NZTCS Status	IUCN Status
Northern diving petrel	Kuaka	*Pelecanoides urinatrix urinatrix* Gmelin 1789	At Risk	Relict	LC
Southern diving petrel	Kuaka	*Pelecanoides urinatrix chathamensis* Murphy & Harper 1916	At Risk	Relict	LC
Subantarctic diving petrel		*Pelecanoides urinatrix exsul* Salvin, 1896	At Risk	Relict	LC
Whenua Hou diving petrel	Kuaka	*Pelecanoides whenuahouensis* Fischer, 2019	Threatened	Nationally Critical	CR
Red-tailed tropicbird	Amokura, tawake,	*Phaethon rubricauda* Boddaert, 1783	At Risk	Recovering	LC
Australasian gannet	Tākapu, tākupu	*Morus serrator* G.R. Gray, 1843	Not Threatened	Not Threatened	LC
Masked booby		*Sula dactylatra tasmani* Lesson, 1831	Threatened	Nationally Endangered	
Black shag	Kawau, tuawhenua	*Phalacrocorax carbo novaehollandiae* Stephens, 1826	At Risk	Naturally Uncommon	LC
Little shag	Kawau paka	*Phalacrocorax melanoleucos brevirostris* Gould, 1837	Not Threatened	Not Threatened	LC
Little black shag	Kawau tūi	*Phalacrocorax sulcirostris* Brandt, 1837	At Risk	Naturally Uncommon	LC
Pied shag	Kāruhiruhi, kawau	*Phalacrocorax varius varius* Gmelin, 1789	At Risk	Recovering	LC
Auckland Island shag		*Leucocarbo colensoi* Buller, 1888	Threatened	Nationally Vulnerable	VU

Preferred Common Name	Māori Name(s)	Name and Authority	NZTCS Category	NZTCS Status	IUCN Status
Campbell Island shag		*Leucocarbo campbelli* Filhol, 1878	At Risk	Naturally Uncommon	VU
Otago shag	Kawau	*Leucocarbo chalconotus* Gray, 1845	At Risk	Recovering	VU
King shag	Kawau	*Leucocarbo carunculatus* Gmelin, 1789	Threatened	Nationally Endangered	VU
Chatham Island shag		*Leucocarbo onslowi* Forbes, 1893	Threatened	Nationally Critical	CR
Bounty Island shag		*Leucocarbo ranfurlyi* Ogilvie-Grant, 1901	At Risk	Naturally Uncommon	VU
Foveaux shag		*Leucocarbo stewarti* Ogilvie-Grant, 1898	Threatened	Nationally Vulnerable	VU
Pitt Island shag		*Stictocarbo featherstoni* Buller, 1873	Threatened	Nationally Critical	EN
Spotted shag	Parekareka, kawau tikitiki, pāteketeke	*Stictocarbo punctatus punctatus* Sparrman, 1786	Not Threatened	Not Threatened	LC
Brown skua	Hākoakoa	*Catharacta antarctica lonnbergi* Mathews, 1912	At Risk	Naturally Uncommon	LC
Black-billed gull	Tarāpuka	*Larus bulleri* Hutton, 1871	Threatened	Nationally Critical	EN
Southern black-backed gull	Karoro	*Larus dominicanus dominicanus* Lichtenstein, 1823	Not Threatened	Not Threatened	LC
Red-billed gull	Tarāpunga	*Larus novaehollandiae scopulinus* Forster, 1843	At Risk	Declining	LC

Preferred Common Name	Māori Name(s)	Name and Authority	NZTCS Category	NZTCS Status	IUCN Status
Caspian tern	Taranui	*Hydroprogne caspia* Pallas, 1770	Threatened	Nationally Vulnerable	LC
Sooty tern		*Onychoprion fuscata serratus* Linnaeus, 1766	At Risk	Recovering	LC
Common noddy		*Anous stolidus pileatus* Scopoli, 1786	Non-resident Native	Coloniser	LC
White-capped noddy		*Anous tenuirostris minutus* Boie, 1844	At Risk	Naturally Uncommon	LC
Pacific white tern		*Gygis alba candida* Gmelin, 1789	Threatened	Nationally Critical	LC
Black-fronted tern	Tarapirohe, tarapiroe	*Chlidonias albostriatus* Gray, 1845	Threatened	Nationally Endangered	EN
White-fronted tern	Tara	*Sterna striata* Gmelin, 1789	Threatened	Nationally Vulnerable	NT
Antarctic tern		*Sterna vittata bethunei* Travers, 1896	At Risk	Recovering	LC
New Zealand fairy tern	Tara iti	*Sternula nereis davisae* Mathews & Iredale, 1913	Threatened	Nationally Critical	VU
Grey ternlet		*Procelsterna cerulea albivitta* Bonaparte, 1856	At Risk	Naturally Uncommon	LC

2 SHOREBIRDS OF AOTEAROA NEW ZEALAND

Table 2. Shorebird taxa (species and subspecies) resident (breeding and/or overwintering) in Aotearoa New Zealand, including the Kermadec, Chatham and New Zealand Subantarctic Islands. Both the New Zealand Threat Classification System (NZTCS) categories and global conservation status (IUCN Red List, viewed 28 January 2021) are listed for each species. The NZTCS complements the IUCN Red List but is 'focussed at the national level and provides a more sensitive classification for taxa with naturally restricted distributions and small numbers as a result of insular rarity' (Townsend et al., 2008). The conservation categories (NZTCS) and statuses (NZTCS, IUCN) for each system, ranked from most to least threatened are: **NZTCS** - Extinct, Threatened – Nationally Critical, Nationally Endangered, Nationally Vulnerable, At Risk – Declining, Recovering, Relict, Naturally Uncommon, Not Threatened; **IUCN** – Extinct (EX), Extinct in the Wild (EW), Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT), Least Concern (LC), Data Deficient (DD), Not Evaluated (NE).

Preferred Common Name	Māori Name(s)	Name and Authority	NZTCS Category	NZTCS Status	IUCN Status
Chatham Island snipe		*Coenocorypha pusilla* Buller, 1869	Threatened	Nationally Vulnerable	VU
Snares Island snipe	Tutukiwi	*Coenocorypha huegeli* Tristram, 1893	At Risk	Naturally Uncommon	NT
Subantarctic snipe		*Coenocorypha aucklandica* Gray, 1845	At Risk	Naturally Uncommon	NT
Lesser knot	Huahou	*Calidris canutus* Linnaeus, 1758	Threatened	Nationally Vulnerable	NT
Sanderling		*Calidris alba* Pallas, 1764	Non-resident Native	Vagrant	LC
Eastern curlew		*Numenius madagascariensis* Linnaeus, 1766	Non-resident Native	Vagrant	EN
Curlew sandpiper		*Calidris ferruginea* Pontoppidan, 1763	Non-resident Native	Vagrant	NT
Sharp-tailed sandpiper		*Calidris acuminata* Horsfield, 1821	Non-resident Native	Migrant	LC
Pectoral sandpiper		*Calidris melanotos* Vieillot, 1819	Non-resident Native	Vagrant	LC

Preferred Common Name	Māori Name(s)	Name and Authority	NZTCS Category	NZTCS Status	IUCN Status
Red-necked stint		*Calidris ruficollis* Pallas, 1776	Non-resident Native	Migrant	NT
Whimbrel		*Numenius phaeopus* Linnaeus, 1758	Non-resident Native	Migrant	LC
Bar-tailed godwit	Kuaka	*Limosa lapponica* Linnaeus, 1758	At Risk	Declining	NT
Black-tailed godwit		*Limosa limosa* Linnaeus, 1758	Non-resident Native	Vagrant	NT
Hudsonian godwit		*Limosa haemastica* Linnaeus, 1758	Non-resident Native	Vagrant	LC
Grey-tailed tattler		*Tringa brevipes* Vieillot, 1816	Non-resident Native	Vagrant	NT
Wandering tattler		*Tringa incana* Gmelin, 1789	Non-resident Native	Vagrant	LC
Ruddy turnstone		*Arenaria interpres* Linnaeus, 1758	Non-resident Native	Migrant	LC
Variable oystercatcher	Tōrea pango, Tōrea tai, Tōrea	*Haematopus unicolor* Forster, 1844	At Risk	Recovering	LC
South Island pied oystercatcher	Tōrea	*Haematopus finschi* Martens, 1897	At Risk	Declining	LC
Chatham Island oystercatcher	Tōrea tai	*Haematopus chathamensis* Hartert, 1927	Threatened	Nationally Critical	EN
Pied stilt	Poaka	*Himantopus himantopus* Linnaeus, 1758	Not Threatened	Not Threatened	LC

Preferred Common Name	Māori Name(s)	Name and Authority	NZTCS Category	NZTCS Status	IUCN Status
Black stilt	Kākí	*Himantopus novaezelandiae* Gould, 1841	Threatened	Nationally Critical	CR
Pacific golden plover	Kuriri	*Pluvialis fulva* Gmelin, 1789	Non-resident Native	Migrant	LC
Grey plover		*Pluvialis squatarola* Linnaeus, 1758	Non-resident Native	Vagrant	LC
New Zealand dotterel	Tūturiwhatu, tuturiwhatu pukunui, rako	*Charadrius obscurus* Gmelin, 1789	At Risk	Recovering	CR
Greater sand plover		*Charadrius leschenaulti* Lesson, 1826	Non-resident Native	Vagrant	LC
Lesser sand plover		*Charadrius mongolus* Pallas, 1776	Non-resident Native	Vagrant	LC
Banded dotterel	Tūturiwhatu, pohowera	*Charadrius bicinctus* Jardine & Selby, 1827	Threatened	Nationally Vulnerable	NT
Wrybill	Ngutuparore, Ngutu pare	*Anarhynchus frontalis* Quoy & Gaimard, 1830	Threatened	Nationally Vulnerable	VU
Black-fronted dotterel		*Elseyornis melanops* Vieillot, 1818	At Risk	Naturally Uncommon	LC
Shore plover	Tūturuatu	*Thinornis novaeseelandiae* Gmelin, 1789	Threatened	Nationally Critical	EN
Spur-winged plover		*Vanellus miles* Boddaert, 1783	Not Threatened	Not Threatened	LC

3. OTHER BIRDS THAT UTILISE COASTAL AREAS

Table 3. Other coastal birds (species and subspecies) resident (breeding and/or overwintering) in Aotearoa New Zealand, including the Kermadec, Chatham and New Zealand Subantarctic Islands. Both the New Zealand Threat Classification System (NZTCS) and global conservation status (IUCN Red List, viewed 28 January 2021) are listed for each species. The NZTCS complements the IUCN Red List but is 'focussed at the national level and provides a more sensitive classification for taxa with naturally restricted distributions and small numbers as a result of insular rarity' (Townsend et al., 2008). The conservation statuses for each system (NZTCS, IUCN), ranked from most to least threatened are: **NZTCS** - Extinct, Threatened – Nationally Critical, Nationally Endangered, Nationally Vulnerable, At Risk – Declining, Recovering, Relict, Naturally Uncommon, Not Threatened; **IUCN** – Extinct (EX), Extinct in the Wild (EW), Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT), Least Concern (LC), Data Deficient (DD), Not Evaluated (NE).

Preferred Common Name	Māori Name(s)	Name and Authority	NZTCS Category	NZTCS Status	IUCN Status
White heron	Kōtuku	*Ardea modesta* Gray, 1831	Threatened	Nationally Critical	LC
Cattle egret		*Ardea ibis* Linnaeus, 1758	Non-resident Native	Migrant	LC
Plumed egret		*Ardena intermedia plumifera* Wagler, 1829	Non-resident Native	Vagrant	LC
White-faced heron	Matuku moana, matuku	*Egretta novaehollandiae* Latham, 1790	Not Threatened	Not threatened	LC
Little egret		*Egretta garzetta* Linaeus, 1766	Non-resident Native	Vagrant	LC
Reef heron	Matuku moana	*Egretta sacra* Gmelin, 1789	Threatened	Nationally Endangered	LC
Nankeen night heron		*Nycticorax caledonicus* Gmelin, 1789	Non-resident Native	Coloniser	LC
Royal spoonbill	Kōtuku ngutupapa	*Platalea regia* Gould, 1838	At Risk	Naturally uncommon	LC
Sacred kingfisher	Kōtare	*Todiramphus sanctus* Vigors & Horsfield, 1827	Not Threatened	Not threatened	LC

Preferred Common Name	Māori Name(s)	Name and Authority	NZTCS Category	NZTCS Status	IUCN Status
Brown teal	Pāteke	*Anas chlorotis* Gray, 1845	At Risk	Recovering	NT
Grey teal	Tētē moroiti, tētē	*Anas gracilis* Buller, 1869	Not Threatened	Not Threatened	LC
Auckland Island teal		*Anas aucklandica* Grey, 1849	Threatened	Nationally Vulnerable	VU
Campbell Island teal		*Anas nesiotis* Fleming, 1935	Threatened	Nationally Vulnerable	VU
Black swan	Kakīānau	*Cygnus atratus* Latham, 1790	Not Threatened	Not threatened	LC
Banded rail	Mioweka, konini, mohu pererū	*Gallirallus philippensis* Linnaeus, 1766	At Risk	Declining	LC
Fernbird	Mātātā, koroātito	*Bowdleria punctata* Quoy & Gaimard, 1830	At Risk	Declining	LC
Australasian bittern	Matuku hūrepo	*Botaurus poiciloptilus* Wagler, 1827	Threatened	Nationally Critical	EN
Spotless crake	Pūweto	*Zapornia tabuensis* Gmelin, 1789	At Risk	Declining	LC

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Mangrove (manawa, *Avicennia marina*) seedlings and pneumatophores, Whangateau Harbour. Photo: Edin Whitehead.