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Marine biodiversity stocktake of the Waikato region 2015

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Prepared by:
Sietse Bouma

For:
Waikato Regional Council
Private Bag 3038
Waikato Mail Centre
HAMILTON 3240

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Peer reviewed by:
Hilke Giles | Date November 2016

Approved for release by:
Dominique Noiton | Date December 2016

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1 Introduction

1.1 Background

The coastal marine area is valued for its ecosystems and biodiversity and for a range of uses including recreation and commercial opportunities. In particular, estuaries and harbours are highly visible and valued features of the coastal landscape. They link freshwater and marine environments and as such provide a range of ecological services, including export of detritus, nutrients and sediment to the coastal zone, providing nursery habitats for fish and crustaceans and roosting areas for marine and coastal birds. Estuaries are preferred sites for human settlement and provide opportunities for recreation, including boating, swimming, windsurfing, fishing and kayaking. Gathering seafood is of particular importance to tangata whenua and numerous archaeological, historical and cultural sites are located in and around estuaries.

Waikato Regional Council recognises that the coastal marine area is largely public space that supports a wide range of public and private uses that may result in conflict. Waikato Regional Council has to make decisions on how and where activities may be established or be carried out. This decision making takes into consideration biodiversity values, interests, uses, costs and benefits from development and effects of activities.

Waikato Regional Council recognises that good decision-making is underpinned by good scientific information. Particularly important, in relation to marine biodiversity, is information on species and/or habitats present, and their vulnerability/sensitivity to activities and uses. This includes vulnerable life stages of species and the sensitivity of species or habitats to specific pressures. This report focussed on collating this type of information.

1.2 Policy context

Policy 11 of the New Zealand Coastal Policy Statement (NZCPS[1]) and policy 11.4 of the Proposed Waikato Regional Policy Statement (proposed RPS[2]) provide specific guidance on the protection of indigenous coastal and marine biodiversity in the Waikato region (see textboxes below).

To implement these policies, specific information is needed on species and habitats within the Waikato region's CMA that are covered by these policies, and additionally, the vulnerable life stages of indigenous species and the sensitivity of species and habitats to specific pressures. This report aims at contributing to that information.

NZCPS policy 11: Indigenous biological diversity (biodiversity)
To protect indigenous biological diversity in the coastal environment:
(a) avoid adverse effects of activities on:
- (i) indigenous taxa that are listed as threatened or at risk in the New Zealand Threat Classification System lists;
- (ii) taxa that are listed by the International Union for Conservation of Nature and Natural Resources as threatened;
- (iii) indigenous ecosystems and vegetation types that are threatened in the coastal environment, or are naturally rare;
- (iv) habitats of indigenous species where the species are at the limit of their natural range, or are naturally rare;
- (v) areas containing nationally significant examples of indigenous community types;

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[1] http://www.doc.govt.nz/about-us/science-publications/conservation-publications/marine-and-coastal/new-zealand-coastal-policy-statement/new-zealand-coastal-policy-statement-2010/
[2] http://www.waikatoregion.govt.nz/Council/Policy-and-plans/Regional-Policy-Statement/

(vi) areas set aside for full or partial protection of indigenous biological diversity under other legislation;

(b) avoid significant adverse effects and avoid, remedy or mitigate other adverse effects of activities on:

(i) areas of predominantly indigenous vegetation in the coastal environment;

(ii) habitats in the coastal environment that are important during the vulnerable life stages of indigenous species;

(iii) indigenous ecosystems and habitats that are only found in the coastal environment and are particularly vulnerable to modification, including estuaries, lagoons, coastal wetlands, dune-lands, intertidal zones, rocky reef systems, eelgrass and saltmarsh;

(iv) habitats of indigenous species in the coastal environment that are important for recreational, commercial, traditional or cultural purposes;

(v) habitats, including areas and routes, important to migratory species;

(vi) ecological corridors, and areas important for linking or maintaining biological values identified under this policy.

Proposed Waikato Regional Policy Statement, policy 11.4: Safeguard coastal/marine ecosystems

Protect indigenous biodiversity in the coastal environment by:

a) avoiding adverse effects on:

i) indigenous taxa listed as 'Threatened' or 'At Risk' in the New Zealand Threat Classification System lists or taxa listed as threatened by the International Union of Nature and Natural Resources;

ii) habitats of indigenous species where the species are listed as Threatened or At Risk, are at the limit of their natural range, or are naturally rare; and

iii) areas containing nationally significant examples of indigenous community types;

b) maintaining or enhancing:

i) areas used by marine mammals and wading/coastal birds including breeding, feeding, roosting and haul-out sites (areas where marine mammals come ashore);

ii) whitebait spawning areas and shellfish beds;

iii) habitats, corridors and routes important for preserving the abundance and diversity of indigenous and migratory species;

iv) indigenous habitats and ecosystems that are unique to the coastal environment and vulnerable to modification and the impacts of climate change, including estuaries, lagoons, coastal wetlands, dune-lands, rocky reef systems, seagrass and saltmarsh;

v) habitats of indigenous species that are important for recreational, commercial, traditional or cultural purposes.

1.3 Project scope

This report covers different ecological groups (benthic communities, estuarine and coastal vegetation, fish, birds and marine mammals) and four subtidal biogenic habitats that are known to be of specific importance for these ecological groups (rhodolith beds, shellfish beds, seagrass beds and sponge gardens). For each ecological group the different sections start with an inventory of completed surveys and information on the presence of particular species and/or habitats. Where relevant distinctions are made between the West Coast and East Coast (Coromandel Peninsula) of the Waikato region's Coastal Marine Area (CMA) as well as between harbours/estuaries, the subtidal offshore marine environment and offshore islands. The sections subsequently provide information on vulnerable life stages of species and the sensitivity of species and/or habitats to specific pressures. For each of the subtidal biogenic habitats a general description is provided followed by information on their known distribution in the Waikato CMA, their importance for biodiversity and pressures on these habitats.

The vulnerability or sensitivity of species and habitats depend on many different factors, including anthropogenic and non-anthropogenic stressors. In this report the terms vulnerability and sensitivity are not defined and may be used interchangeably. In relation to anthropogenic stressors it is important to consider the scale and duration of an activity, the current state of the environment, the time of the year, tides and currents, and the presence of other stressors (cumulative effects). The vulnerability can also change during different life stages. Shellfish for example can be particularly vulnerable to sedimentation during their spawning season or juvenile life stages, but may become more vulnerable to commercial and recreational harvesting when they reach a certain size such as the minimum harvestable size.

This report did not aim to identify all vulnerable life stages and/or all (sensitivities to) pressures. Instead, it extracts information on vulnerable life stages contained in the material reviewed. For example, for benthic communities information has been collected on the spawning season of the most dominant benthic species in the Waikato region's CMA and the sensitivity of benthic species to sedimentation; for fish on life history characteristics of the most targeted species in the Hauraki Gulf, the timing of diadromous fish migrations for spawning, and the sensitivity of fish to underwater noise and sedimentation; for birds on the breeding season of threatened or at risk species in the Waikato region's CMA, the sensitivity of birds to disturbance by different human activities (e.g. disturbance or initial flight response distances), and specifically the sensitivity of wetland birds to habitat loss (e.g. mangrove removal); and for marine mammals on the reproduction of the most encountered species within the Waikato region's CMA, the sensitivity of marine mammals to underwater noise, disturbance by human activities, and specifically the sensitivity of large whales to ship strike.

This report can be used to underpin and prioritize future Waikato Regional Council science projects, to support resource consent processes (e.g. by identifying potential adverse effects of activities and provide information to help develop effective resource consent conditions and monitoring programmes), and to support policy and planning decision-making by identifying areas with high coastal and marine biodiversity values.

1.4 Information sources

Most of the information presented in this report was collated from information already held by Waikato Regional Council or accessible through the public domain. Examples include:

- Technical reports commissioned or prepared by Waikato Regional Council (www.waikatoregion.govt.nz/Services/Publications/Technical-Reports).
- Information available on the Internet (e.g. open access scientific publications, consultancy reports, student theses, online databases)[3].
- Information related to biodiversity and biosecurity collected as part of the Sea Change – Tai Timu Tai Pari project, a partnership led by mana whenua and central and local government working on creating a marine spatial plan for the Hauraki Gulf (www.seachange.org.nz).
- Unpublished reports and documents made available by experts and Waikato Regional Council. For example, an unpublished report on available biological data for Areas of Significant Conservation Value (ASCVs) in the Waikato region's CMA prepared by the Department of Conservation in 2007 (Bouma 2007). This report presented available biological information collected during an extensive literature review focusing on resources containing area-specific information on different benthic communities, estuarine and coastal vegetation, fish, birds and marine mammals.
- Resources contained in the Waikato Coastal Database (www.waikatocoastaldatabase.org.nz).

In addition to these resources, experts in different ecological groups were contacted to provide feedback on and input into this report. Face-to-face conversations were held with Dr. Carolyn Lundquist (National Institute of Water and Atmospheric Research (NIWA)); provided feedback on and input into entire report with focus on benthos), Megan Graeme (Natural Solutions Marine and Terrestrial Ecologists Limited; provided feedback on and input for estuarine and coastal vegetation), Dr. Mark Morrison (NIWA; provided feedback on and input for fish and biogenic habitats), Christopher Paul Gaskin (Kiwi Wildlife/Natural Lines Consultancy; provided feedback on and input for seabirds), Graham Don (Bioresearches Group Limited; provided feedback on and input for shorebirds), Kristina Hillock (Department of

[3] This was used as the main resource to identify examples of overseas studies related to specific pressures covered in this report.

Conservation; provided general feedback) and Sydney Harris (MSc. student University of Auckland; provided feedback on and input for underwater noise). Dr. Craig Bradford (University of Auckland) and Dr. Paul Franklin (NIWA) provided information related to respectively underwater noise and the sensitivity of freshwater fish to sedimentation/turbidity by email.

Efforts were put into providing an overview of available information that is as complete as possible. However, due to the complexity of this area of science and the large amount of information held outside the public domain it is not expected that all available information is included in this report.

1.5 Maps

Many data sets collected as part of inventories and surveys have not been captured as GIS datasets or are not readily available to Waikato Regional Council. However, three types of maps could be created for this report displaying valuable data sets:

1. Intertidal habitats in 14 different estuaries and harbours around the Coromandel Peninsula

   In 2013, Waikato Regional Council commissioned the National Institute of Water and Atmospheric Research (NIWA) to map intertidal habitats in Tairua Harbour, Otahu estuary, Whangamata Harbour, Wharekawa Harbour, Purangi estuary, Whitianga Harbour, Whangapoua Harbour, Kennedy Bay, Waikawau Bay, Port Charles, Colville Bay, Coromandel Harbour, Te Kouma Harbour and Manaia Harbour (Needham et al. 2013).

2. Estuarine vegetation in estuaries and harbours on the west coast of the Waikato region and around the Coromandel Peninsula

   Surveys have been carried out in most of the Waikato region's harbours and estuaries since 1997 by Natural Solutions (commissioned by Waikato Regional Council), and some have been surveyed multiple times to determine changes in community types over time. Vegetation types within the CMA were mapped and included the spatial cover of mangroves, seagrass, saltmarsh and estuarine weeds.

3. Priority 1 and 2 areas to coastal an estuarine birds on the east coast of the Waikato region (plus additional information)

   In 2013, Waikato Regional Council commissioned DM Consultants to identify sites of importance to coastal and estuarine birds on the east coast of the Waikato region's CMA. Based on criteria on significance provided in the Ramsar Convention and the Proposed Waikato Regional Policy Statement, Dowding assigned sites to four broad priorities. Priority 1 and 2 sites were mapped (Dowding 2013; Waikato Regional Council GIS-layer "Hauraki Gulf Marine Spatial Plan Locations"). For Tairua Harbour and Whangamata Harbour additional information provided by Bioresearches was added.

   The maps are presented in three appendices to this report.

1.6 Accessibility of information

Where the information presented in this report was available online links to the relevant reports or websites were provided in the reference list (chapter 10).

Most data presented in the maps displayed in the appendices can be requested from Waikato Regional Council via the Waikato Regional Council Data Catalogue (www.waikatoregion.govt.nz/Services/data-catalogue).

1.7 Structure of this report

Chapters 2 to 6 of this report contain information on the following ecological groups:

- Benthic communicates (Chapter 2)
- Estuarine and coastal vegetation (Chapter 3)
- Fish (Chapter 4)
- Birds (Chapter 5)
- Marine mammals (Chapter 6)

Chapter 7 provides information on subtidal biogenic habitats.

Chapter 8 contains a brief discussion focussed on how the information provided in this report can be used and how people can contribute.

Chapter 9 acknowledges people who contributed to this report.

Chapter 10 is a reference list that provides links to any information available online.

2 Benthic communities

2.1 Protected, threatened or at risk species

All hydrocorals (family *Stylasteridae*, includes the red corals), black corals (order *Antipatharia*), gorgonians (order *Gorgonacea*) and stony corals (order *Scleractinia*) are protected under the Wildlife Act (1953). Some stony corals, notably *Flabellum spp*. and the small colonial cup coral *Culicia rubeola*, are common on shallow coastal reefs throughout the Hauraki Gulf, whereas the occurrence and distribution of the larger, habitat-forming deep water species is poorly known in the Hauraki Gulf (Sea Change project - Roundtable Biodiversity & Biosecurity). Black corals and gorgonians are common on some deep (>40 m depth) reefs off northeast Great Barrier Island and are likely to occur in similar habitats throughout the outer Gulf (Sea Change project - Roundtable Biodiversity & Biosecurity). More information on the distribution of protected corals in New Zealand waters can be found in Baird et al. (2013)[4].

2.2 Inventories and surveys

2.2.1 Coromandel harbours and estuaries

Benthic communities

Benthic surveys or monitoring programmes have been carried out in intertidal areas of most of the estuaries and harbours around the Coromandel Peninsula (see Table 1). However, no reports were identified describing benthic communities in the subtidal channels of these estuaries/harbours.

Table 1. Benthic surveys and monitoring programmes in Coromandel estuaries and harbours.

Harbour/estuary	Benthic survey	References
Firth of Thames	Waikato Regional Council Regional Estuary Benthic Monitoring Programme since 2001 (5 sites, 26 indicator species)	Needham et al. 2014; Felsing et al. 2006
	Keeley 2001: 10 transects between Kaiaua and Tararu (all species)	Brownell. 2004
Manaia Harbour	NIWA 2000: mud to sand transition zones	Thrush et al. 2003
	Auckland University 1992: the effects of mussel farming on the benthic environment	De Jong 1994
Coromandel Harbour	Assessment of effects of a proposed marina in 1991 & 1998	Coffey 1991 & KMA Ltd. 1998
	Assessment of potential effects of forestry activity on the ecology of intertidal habitats in 1993	Thrush et al. 1993
	Assessment of a proposed jetty at Hannaford's Point in 1991	Coffey 1992a
	Assessment of biological and selected chemical effects relating to proposed channel improvements at Furley's Creek in 1992	Coffey 1992c

[4] Predictive models were used to predict the likely distribution of coral groups throughout the New Zealand Exclusive Economic Zone, according to a set of 10 environmental variables. Sources of information used were from research sampling (58%) and from commercial fishing effort where observers had been present (42%).

Colville Bay	Auckland University 1996: bird counts and benthic communities	Forbes 1997
Whangapoua Harbour	Ministry of Primary Industries 2002, 2005, 2010 & 2015: intertidal shellfish surveys[5]	Berkenbusch 2015 (in progress); Pawley 2012; Pawley & Ford 2006; Walshe & Akroyd 2006; Walshe & Akroyd 2002
	NIWA 2003: benthic communities and terrestrial sediment deposits	Cummings et al. 2003
	NIWA 2002: benthic communities and seagrass beds	Van Houte-Howes et al. 2004
	NIWA 1993-2006: forestry impacts	Halliday et al. 2006 Craggs et al. 2001 Morrisey et al. 1999
	Benthic survey to assess potential effects of a proposed redevelopment of the area in the vicinity of the Whangapoua Harbour boat ramp[6]	Graeme June 2001 & July 2001
	Preliminary physical assessment of Whangapoua estuary and environment 1990	Donald 1990
	Baseline macro-biota survey carried out in Whangapoua Harbour in January/February 1985	Miller 1987
Whitianga Harbour	Since 2008: Hauraki Gulf community shellfish monitoring program (supported by Waikato Regional Council)	Auckland Council 2012
	Ministry of Primary Industries 2012: intertidal shellfish surveys[3]	Pawley & Smith 2014
	NIWA 2000: mud to sand transition zones	Thrush et al. 2003
	Impact assessments (e.g. marina and canal development)	Larcombe et al. 1998; Coffey 1995, 1993; Don 1986; Penny 1990
	Auckland University 1987: pipi ecology	Creese 1988
	MAF 1984: baseline macro-biota survey	Miller 1987
Tairua Harbour	Ministry of Primary Industries 1999, 2000, 2001, 2002, 2005, 2010 and 2014: intertidal shellfish surveys[3]	Berkenbusch 2015 (in progress); Pawley 2012; Pawley & Ford 2006; Walshe & Akroyd 2003, 2002; Akroyd et al. 2001, 2000; Morrison & Browne 1999
	Waikato Regional Council 2010: shellfish and benthic habitat mapping	Felsing & Giles 2011

[5] These surveys are not harbour wide surveys, but focus on specific cockle and pipi beds such as those that are most targeted by recreational fishermen. GIS layers of the surveyed beds can be requested through RDM.sharedRDM@mpi.govt.nz (personal comment Richard Ford).

[6] Information collected during this survey included data on epi-fauna, infauna, birds and fish.

	Bioresearches 1993-1996: benthic surveys to assess impacts of the Pauanui Canal development	Bioresearches 1996a, 1995, 1994, 1993a,b,c,d,e,f,g
	Waikato Regional Council 1994: intertidal benthic survey	White 1996
	Auckland University 1984: baseline survey	Bridgewater & Foster 1984
Wharekawa Harbour	Bioresearches 1997-2011: annual monitoring programme for the Tairua Forest Ohio Block Operations Consent	Bioresearches 1997-2011
	Waikato Regional Council 2010: cockles, pipis, wedge shells	Graeme & Giles 2010
	Since 2010: Hauraki Gulf community shellfish monitoring program (supported by Waikato Regional Council)	Auckland Council 2012; Grant & Hay 2003
	NIWA 2002: benthic communities and seagrass beds	Van Houte-Howes et al. 2004
	NIWA 2000: mud to sand transition zones	Thrush et al. 2003
	DOC 1994: biological assessment	Bagshaw 1994
Whangamata Harbour	Ministry of Primary Industries 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2006, 2010 & 2015: intertidal shellfish surveys[3]	Berkenbusch 2015 (in progress); Pawley 2012; Pawley & Ford 2006; Walshe et al. 2005; Akroyd 2003, 2002; Akroyd et al. 2001, 2000; Morrison et al. 1999; Morrison & Browne 1999
	NIWA 2013 & 2014: effects of mangrove removal on sediment and macro-faunal communities (baseline, 3 months and 12 months after removal)	Bulmer & Lundquist 2014 & 2013
	NIWA 2002: benthic communities and seagrass beds	Van Houte-Howes et al. 2004
	Auckland University 1984: baseline survey	Bridgewater & Foster 1984
Otahu estuary	Waikato Regional Council 2009: shellfish and benthic mapping	Singleton et al. 2013

Benthic habitats

Studies that focused on mapping benthic habitats (without specifically quantifying the presence of species) in harbours and estuaries around the Coromandel Peninsula include:

- In 2013, Waikato Regional Council commissioned NIWA to map intertidal habitats that provide ecosystem goods and services. The study included 14 different estuaries/harbours around the Coromandel Peninsula, including Tairua Harbour, Otahu River, Whangamata Harbour, Wharekawa Harbour, Purangi River, Whitianga Harbour, Whangapoua Harbour, Kennedy Bay, Waikawau Bay, Port Charles, Colville Bay, Coromandel Harbour, Te Kouma Harbour and Manaia Harbour (Needham et al. 2013, Needham et al. 2014).

  Three different habitats were defined by the characteristics/dominance of the flora: seagrass, mangroves and pneumatophores (the aerial roots of mangroves). Twelve different habitats were defined by characteristics/dominance of the fauna: cockles, pipis, cockles and pipis, wedge shells, oysters, crustacean burrows, crabs and cockles, tubeworms and cockles, snails (*Amphibola*), 'low density deposit feeders', 'mounds and pits' and 'low fauna'.

A detailed description of these habitat types and maps showing the presence of these habitats in each of these estuaries/harbours were reproduced by Waikato Regional Council (based on Needham et al. 2013; see also paragraph 1.5) and are presented in appendix 1.

- In March/April 2002 the Department of Conservation (DOC) commissioned NIWA to carry out a broad scale seafloor habitat assessment and a broad scale soft sediment habitat assessment of the Firth of Thames using acoustic mapping with associated video and grab sample ground-truthing (Morrison et al. 2002a & 2003). Video and grab samples showed that epi-faunal assemblages were sparse and patchily distributed across the Firth of Thames. One area with horse mussel beds and one area with green-lipped mussels (low and patchy densities) were identified and beds of sand dollars were found along the western shore of the Firth of Thames. Sponges and anemones were present at a small number of sites in low densities.

- (Historic) surveys to assess the presence of mussel beds in the Firth of Thames. The Firth of Thames once supported extensive green-lipped mussel (*Perna canaliculus*) beds. Reid (1969) listed the main areas as Rangitoto Channel, Islington Bay, Tamaki Strait, Ponui Island, Ponui-Thames, Orere Point-New Brighton, and New Brighton to Thames, but mentioned that mussel beds occurred along the entire Coromandel Coast from Te Puru to Colville. Hardly any of these beds are left (<1%), likely as a result of a combination of overfishing and sedimentation (McLeod et al. 2011). Locations where some mussel beds are still present are on the north-western side of the Firth of Thames at Waimangu Point (presentation Darren Parsons 2014).

  The Revive our Gulf project (www.reviveourgulf.org.nz) aims at restoring mussel reefs in the Hauraki Gulf. As part of this project seven tonnes of green-lipped mussels were deposited in trial plots off eastern Waiheke Island in December 2013 and another 63 tonnes in September 2014[7]. In November 2014 the Bay of Plenty Polytechnic carried out a drop cam survey of the Matariki Rocks on the eastern side of the Firth of Thames (just south of Manaia Harbour) to assess the suitability of habitat for re-seeding of green-lipped mussels in that area. This study concluded that the area from the shoreline to approximately 8 m depth and areas deeper than 14 m depth were unsuitable, because of the presence of respectively boulder banks with mixed *Carpophyllum* and *Ecklonia* forest, and coarse sediment with sponge covered cobbles (Guccione 2014). A reasonable flat plateau gradually increasing from 8 m to 14 m depth was identified as a suitable area for mussel seeding (Guccione 2014).

2.2.2 West coast river mouths and harbours

River mouths

Three river mouths along the west coast of the Waikato region were identified as an Area of Significant Conservation Value (ASCV) in the Waikato Regional Coastal Plan 2005: Port Waikato, Marokopa estuary and the Mokau river mouth. Intertidal shellfish surveys focusing on cockle and pipi beds (commissioned by the Ministry of Primary Industries) have been carried out in Marokopa estuary in 2005 (Walshe & Akroyd 2006) and 2010 (Pawley 2012). No reports were identified that describe benthic communities at Port Waikato or the Mokau river mouth[8].

[7] Other areas where measures have been undertaken to restore mussel beds in the Hauraki Gulf are Okahu Bay and Meola Reef (www.reviveourgulf.org.nz).

[8] In 1991 Coffey & Williams contributed to a description of biological resources in estuarine and shallow subtidal habitats south of the Mokau River to Tongaporutu.

Harbours

There are three harbours along the west coast: Raglan Harbour, Aotea Harbour and Kawhia Harbour. Intertidal shellfish surveys focusing on cockle and pipi beds (commissioned by the Ministry of Primary Industries) have been carried out in Raglan Harbour in 1999 (Akroyd et al. 2000), 2000 (Akroyd et al. 2001), 2002 (Walshe & Akroyd 2003), 2003 (Walshe & Akroyd 2004), 2009 (Pawley 2011) & 2013 (Pawley & Smith 2014) and in Aotea Harbour in 2005 (Walshe & Akroyd 2006), 2009 & 2010 (Pawley 2011) & February 2015 (Berkenbusch in progress).
In 2008, the Department of Conservation (DOC) mapped the distribution and abundance of cockles and wedge shells in intertidal areas of Kawhia and Aotea Harbours and recorded the presence and abundance of other macrofauna (e.g. pipis and mud snails) and habitat types (e.g. seagrass) (Hillock et al. 2011).

Waikato Regional Council has five permanent monitoring sites within Raglan Harbour that were established in 2001 for the Regional Estuary Monitoring Program (Environment Waikato 2010). The number of monitoring sites was reduced to four in 2009. At each site, benthic samples are taken biannually. The samples are analysed for sediment properties and the presence or absence of 26 indicator taxa are identified. The results from April 2001 to April 2011 were analysed and published in Needham et al. 2014.

No information was found related to benthic communities in the subtidal channels of the harbours on the west coast of the Waikato region's CMA.

2.2.3 Offshore marine environment

Soft sediment benthic communities

The distribution of estuarine and marine habitats in the Hauraki Gulf, defined according to the Marine Protected Areas Policy Guidelines, were mapped as part of the Sea Change project and included soft sediment habitats. A map showing these different habitats in the Waikato region's offshore marine environment extracted from this dataset and created using the Sea Sketch tool (www.seasketch.org) is shown in Figure 1.

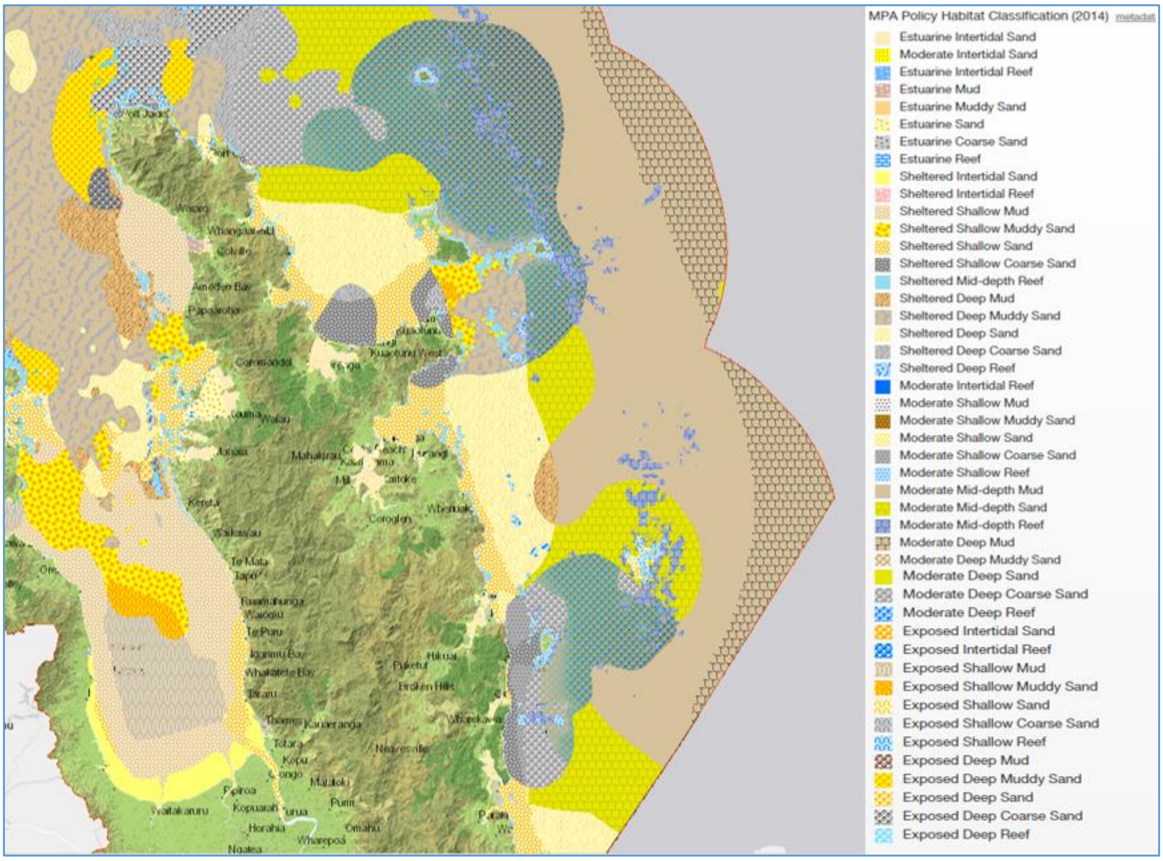

Figure 1. **Estuarine and marine habitats in the Hauraki Gulf (defined according to the Marine Protected Areas Policy Guidelines) (www.seasketch.org).**

Very limited information is available on benthic communities living in soft sediments in Waikato's offshore marine environment either for the west coast[9] or for the Coromandel Peninsula. Some information on the presence of scallop beds, horse mussels, dog cockles, rhodolith beds and sponge gardens is presented in chapter 7 of this report.

Other species that may be common in Waikato's offshore marine environment include the morning star *Tawera spissa*, Ostrich foot shells *Struthiolaria spp.* and heart urchins *Echinocardium spp.*. Dense beds of morning star shells were reported outside a bay of Slipper island in 5-6.4 m water depth (Schwarz et al. 2004), but no surveys were identified that focused on mapping the distribution of these species in the Waikato region's offshore marine environment.

Specific information on soft sediment benthic communities within the Te Whanganui-a-Hei marine reserve in 2002 was presented in Langlois et al. (2006).

Side scan sonar and single/multi-beam echo sounders have been used to map several areas in the Waikato region's CMA such as the Firth of Thames (Morrison et al. 2002a & 2003; see paragraph 2.2.1), Whitianga Harbour (e.g. Reeve 2008) and the Te-Whanganui-a-Hei marine reserve (see below).

Rocky reef benthic communities

Intertidal and subtidal rocky reef substrate in the Hauraki Gulf Marine Park were mapped as part of the Sea Change project (www.seachange.org.nz). A map showing rocky reefs around the Coromandel Peninsula, extracted from this dataset and created using the Sea Sketch tool (www.seasketch.org) is shown in Figure 2.

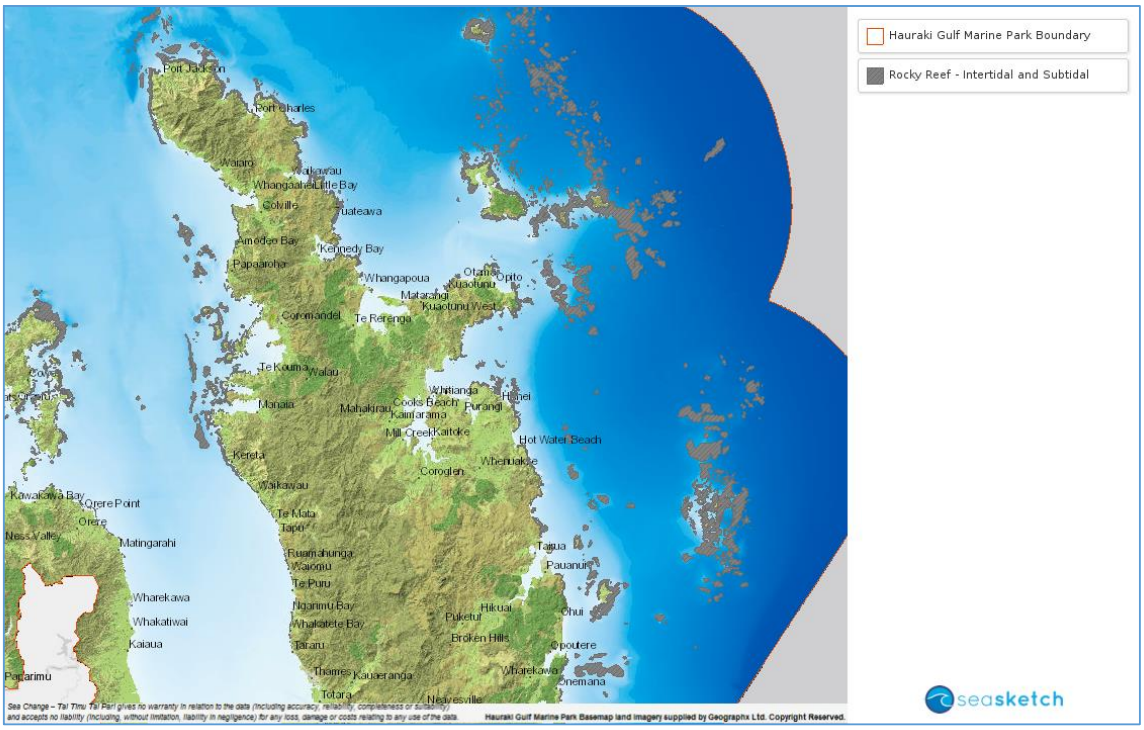

Figure 2. **Rocky reefs around the Coromandel peninsula (www.seasketch.org).**

[9] Several benthic surveys have been carried out on the west coast as part of the Trans-Tasman Resources Ltd. South Taranaki Bight offshore iron sand project (e.g. Beaumont et al. 2013; Anderson et al. 2013; MacDiarmid et al. 2011). However, this area is outside the Waikato region's CMA and may not be comparable to environmental conditions and habitats present on the west coast of the Waikato region.

Systematic, long term surveys of rocky reef benthic communities are limited to the Te Whanganui-a-Hei marine reserve. Lobsters have been monitored since 1996 by Coastal & Aquatic Systems Ltd. (Kelly 1996, 1997, 1999, 2000, 2001a, 2002, 2003; Haggitt & Kelly, 2004, Haggitt & Mead 2006, 2009b) and rocky reef benthic communities during a two-year study in 1999-2000 (Shears 2000), and monitoring surveys in 2006 and 2009 (Haggitt & Mead 2006; Haggitt & Mead 2009b).

In 2001 a habitat map of the reserve was produced by the Earth Sciences Department of the University of Waikato (unpublished report), and to ground-truth this map a habitat survey was carried by NIWA in 2004 (Hewitt et al. 2004). The area directly south of the marine reserve was mapped by the University of Waikato in 2006 (unpublished data DOC Waikato Conservancy).
Site specific surveys of rocky reef benthic communities within the Waikato region's CMA include:

- Macro-invertebrates on rocky reefs at Fantail Bay, Cape Colville from Port Jackson to Sandy Bay, Te Anaputa Point near Wharekawa Harbour, Great Mercury Island and Flat Island were surveyed between May 2002 and February 2003 as part of a Hauraki Gulf wide survey of 38 rocky reefs (Smith et al. 2004). The information was used for the development of a regional scale marine environment classification for the Hauraki Gulf. General site descriptions and fish and macro-invertebrate consumers found at these sites are presented in respectively appendix I and appendix III of Smith et al. 2004.

- A survey identifying intertidal and shallow subtidal biota in four different bays on Cuvier Island (Landing Bay, Picnic Bay, Northwest Bay and Scott's Monument) carried out by a group of 12 members of the Conchology Section of the Auckland War Memorial Museum in April 2003 (Hayward & Morley 2003).

- In 1976 members of the Auckland University Field Club visited Great Mercury Island. Benthic communities west of Great Mercury Island were described by Grace & Grace (1976) and the intertidal life on rocky shores by Staveley Parker (1976).

- A survey of rocky reef fauna at two sites off red Mercury Island (Rolypoly Bay and Mokomoko Rock) in 1972 (Grace 1972).

- Results of a subtidal survey of Whitianga Rock carried out by students of the Bay of Plenty Polytechnic in 1992 (Davies et al. 1992).

- A preliminary intertidal and subtidal survey carried out at 14 sites around Slipper Island by students from the Bay of Plenty Polytechnic, Tauranga in 1996 (Reid & Wills 1996).

- A survey of benthic communities west of Slipper Island carried out in 1974 (Grace & Whitten 1974).

- A survey of intertidal rocky reefs on Ruamahua-iti and Middle Island (Aldermen Islands) carried out in 1973 (Saies 1973).

- A subtidal survey in the area between Long Point and The Pinnacles carried out by students of the Whitianga outpost of the Bay of Plenty Polytechnic in July 1991 (Cook et al. 1991).

- A subtidal survey (recording fish and other marine life present) at different sites along the coastline between Stony Bay and the Sugar Loaf Rocks carried out in 1975 (Donoghue 1975). Dive sites included the Sugar Loaf Rocks, a site 100 m northwest of the entrance of Stony Bay, the northern headland of Shag Bay, The Pinnacles and the northern corner of Poley's Bay.

2.3 Vulnerable life stages

The vulnerability of benthic communities or species depend on many different factors, and may change during different life stages. Shellfish for example can be particularly vulnerable/sensitive to sedimentation during their spawning season or juvenile life stages, but may become more vulnerable to commercial and recreational harvesting when they reach their minimum harvestable size. In Table 2 information is presented on the main spawning seasons of dominant benthic species in intertidal areas of the Waikato region's CMA. However, it should be noted that the exact timing of spawning may vary between locations and depend on different environmental factors (e.g. Booth 1983).

Table 2. Spawning seasons of dominant benthic species in intertidal areas of the Waikato region's CMA.

Benthic species	Spawning season	References
Cockles	Spawning: summer and autumn Settling: 2–3 weeks later	Grant & Hay 2003
Pipis	Spawning: spring and summer Settling: 2–3 weeks later	Grant & Hay 2003
Wedge shells	Spawning: spring to autumn Settling: 2–3 weeks later	Taylor 1998 Grant & Hay 2003
Oysters	January to March	www.aquaculture.org.nz
Tunnelling mud crab	Eggs August to May	www.seafriends.org.nz
Mud snail (*Amphibola*)	No specific information found	No specific reference found

In the offshore marine environment horse mussels spawn throughout the year, but mainly in the summer (Booth 1983). Scallops have two main spawning events around October and mid-January (Morrison 1999; Williams & Babcock 2004 in De Jong 2013). No specific information was found on the spawning season of morning stars, dog cockles, heart urchins or Ostrich foot snails.

2.4 Sensitivity to specific pressures

Sedimentation from land is one of the main threats to benthic communities and habitats. In order to assess potential effects of sedimentation caused by both natural processes (e.g. erosion) and human activities in catchments (e.g. forestry, coastal development) information was collected on sedimentation in the Waikato region's CMA, the sensitivity of soft sediment benthic communities to fine sediments and increasing mud contents, and the sensitivity of rocky reef communities to terrestrial sediment runoff. The results are summarized in the following paragraphs.

2.4.1 Sedimentation in the Waikato region

In 2014 Hadfield et al. carried out a pilot modelling study of sediment transport and deposition in the Hauraki Gulf (Hadfield et al. draft 2014). Twenty freshwater rivers with the largest annual sediment load were included in the model (run for a two year period), and the transport of fresh water (i.e. a proxy for suspended sediment) in the model was validated by comparison of time-series of simulated temperature and salinity with measurements at the NIWA Firth of Thames mooring. An output of the model is shown in Figure 3, and indicates that suspended sediment concentrations are highest in the very south of the Firth of Thames.

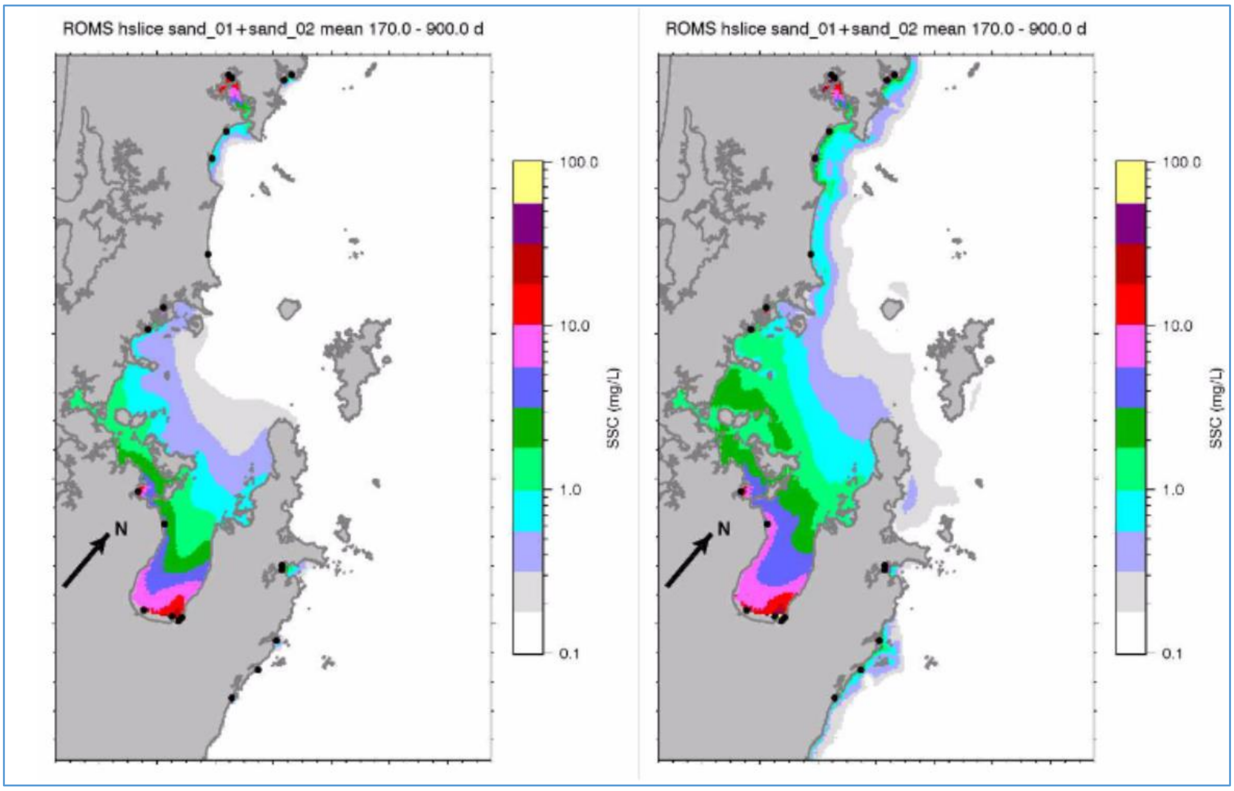

Figure 3. **Time-mean surface (left) and bottom (right) suspended sediment concentration (*SSC*) from the Hauraki Gulf model (Hadfield et al. draft 2014).**

In 2015 Green & Zeldis described the current state of knowledge related to the Firth of Thames water quality and ecosystem health (report commissioned by Waikato Regional Council and Dairy New Zealand) which included knowledge related to sedimentation rates.

In 2008 Jones compiled available information on coastal sedimentation in the Waikato region's CMA. The report used case studies on five harbours and their catchments to discuss the state of knowledge on sources, delivery and effects of sedimentation providing information on for example pre- and post-European sedimentation rates, sediment yields (the amount of sediment travelling in suspension in streams) and sediment deposition (the amount of sediment deposited in the estuaries). The harbours included were Whangamata Harbour, Wharekawa Harbour, Whangapoua Harbour, Tairua Harbour and Whitianga harbours.

In 2004 Mead & Moores described estuarine sedimentation processes and methodologies that can be employed to evaluate rates of sedimentation and presented available information on sedimentation rates and calculations of the sediment yield of estuaries/harbours within the Waikato region both on the west coast and around the Coromandel Peninsula.

Information and references related to sedimentation rates, yields, depositions and sources for different harbours and estuaries were extracted from the studies mentioned above and are summarised in Table 3.

Table 3. Sedimentation in harbours/estuaries in the Waikato region's CMA.

Harbour/estuary	Sedimentation rates/yields/depositions	References
Raglan Harbour	Pre-Polynesian (5000-2000 years BP): largely infilled during this time as the existing river valley was drowned during sea level rise.	Mead & Moores 2004
	The harbour wide average was 0.3-0.5 mm/year over the last 8,000-6,500 years.	Swales et al. 2005
Kawhia Harbour	In 1986 less than 1 mm/year.	Curtis 1996 in Turner & Riddle 2001 in Mead & Moores 2004
Firth of Thames	Information on sedimentation rates using various datasets.	Green & Zeldis 2015
	Mid-1950s-2008: approximately 20 mm/year.	Swales et al. 2008
	Pre-Polynesian settlement: 0.09-0.010 mm/year; after Polynesian settlement: 0.13-0.38 mm/year; after European settlement: 0.5-1.5 mm/year.	Hume & Dahm 1992
Coromandel Harbour	Pre-Polynesian settlement: 0.02-0.94 mm/year; Polynesian settlement: 0.07-0.57 mm/year; after European settlement: 0.82-11.7 mm/year.	Hume & Dahm 1992 in Mead & Moores 2004
Whangapoua Harbour	Before human settlement 0.03-0.08 mm/year; after Polynesian settlement 0.12-0.13 mm/year; after European settlement: 0.9-1.5 mm/year.	Hume & Dahm 1992 in Jones 2008; information on sediment sources in Roddy 2007 and Gibbs 2006
	58.8 tonnes/km^2/year (Hicks and Shankar model) to 140 tonnes/km^2/year (SedRate extrapolation from measurements taken in Opitonui River).	Jones 2008
Whitianga Harbour	Before 1950s as high as 30 mm/year; post 1950s to present 4.9-9.6 mm/year.	Reeve 2008
	36 tonnes/km^2/year (SedRate extrapolation from measurements taken in Waiwawa River) to 69.3 tonnes/km^2/year (Hicks and Shankar model).	Jones 2008
Tairua Harbour	1933-1984: 2-22 mm/year with an average of 6 mm/year	Hume and Gibb 1987 in Jones 2008; information on sediment from forestry operations in West 2006
	80.7 tonnes/km^2/year (estimated from the NIWA sediment model by Hicks and Shankar) to 150 tonnes/km^2/year (SedRate extrapolation from hydrological and suspended sediment data collected in Tairua River).	Jones 2008
Wharekawa Harbour	Before European settlement 0.1 mm/year; after European settlement (1980-1945) 3.6-7.2 mm/year; 1945 to present 5-8 mm/year, but near the river mouth up to 20 mm/year.	Swales & Hume 1995 in Jones 2008; information on sediment sources in Gibbs & Bremner 2007
	60 tonnes/km^2/year (SedRate extrapolation from measurements taken in Wharekawa River) to 183 - 252 tonnes/km^2/year (NIWA sediment core study).	Jones 2008

Whangamata Harbour	Before human settlement 0.1 mm/year; after Polynesian settlement 0.3 mm/year; after European settlement 11-15 mm/year.	Sheffield et al. 1995 in Jones 2008
	Before human settlement 0.10-0.18 mm/year; 1940 to present 5 mm/year; 664 tonnes/km^2/year.	Swales & Hume 1994 in Jones 2008
	98 tonnes/km^2/year (Hicks and Shankar model) to 664 tonnes/km^2/year (NIWA sediment core study).	Jones 2008

2.4.2 Sensitivity of soft sediment benthic communities to fine sediments

Robertson (2013; student thesis Victoria University) determined the sensitivity of macro-invertebrates to fine sediments using data supplied by New Zealand Regional Councils. These data covered sampling efforts carried out in 25 different estuaries around New Zealand over the last 10 years[10]. The main results of this study are presented in the Table 4.

Between 1999 and 2004 NIWA carried out various studies in North Island estuaries to assess effects of sedimentation on macro-faunal communities. The sensitivity of specific macro-benthic taxa to increasing silt/clay content determined from these studies are provided in Gibbs & Hewitt (2004) and are shown in Table 5.

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[10] This dissertation refers to several other studies on the sensitivity of macro-invertebrates to sedimentation including Mannino & Montagna 1997; Rakocinski et al. 1997; Peeters et al. 2000; Norkko et al. 2002b; Ellis et al. 2002; Thrush et al. 2004; Lohrer et al. 2004b; Sakamaki & Nishimura 2009; Jones et al. 2011; Wehkamp & Fischer 2012.

Table 4. Optimum and distribution sediment mud content ranges and mud sensitivity ratings for 42 macro-invertebrate taxa from 25 estuaries around New Zealand (Robertson 2013).

Table 8. Optimum and distribution sediment mud content ranges and final mud-sensitivity ratings for 42 macroinvertebrate taxa from 25 NZ estuaries. Optimum range = the % mud range over which taxa exhibit their highest abundances. Distribution range = the range of the mud concentration where at least one individual occurs. For final sensitivity ratings, 1 = highly sensitive; 2 = sensitive; 3 = widely tolerant; 4 = slightly positive response; 5 = highly positive response. Notably, as most taxa were intolerant of mud content beyond ~30 %, those which exhibited optimum ranges beyond ~30 % were considered highly tolerant of elevated mud concentrations. Maximum density models and raw presence only values were used to extract values for taxa optimum and distribution ranges, respectively.

Taxa	Optimum mud range (%)	Distribution mud range (%)	Final sensitivity rating
Tanaid sp.	0.1 - 6.1	0.1 - 35	1
Perrierina turneri	0.9 - 6.9	0.9 - 34.4	1
Orbinia papillosa	0.1 - 14	0.1 - 41.2	1
Colurostylis lemurum	0.8 - 11.6	0.8 - 58	1
Microspio maori	1.2 - 7.5	0.7 - 56	1
Cumacea	1.6 - 10.2	0.5 - 53	1
Scoloplos cylindrifer	2 - 16.1	0.1 - 39.3	1
Haminoea zelandiae	2.5 - 12.3	0.1 - 31	1
Aonides sp.	2.6 - 10.1	0.6 - 45.6	1
Ostracoda	3 - 15.9	2 - 43.0	1
Sabellidae	3.5 - 10	1.7 - 36.5	1
Maldanidae	5 - 13.2	5.7 - 47.8	1
Terebellidae	12 - 18.0	1 - 18.0	2
Austrominius modestus	0.1 - 11.4	0.1 - 70.1	2
Aglaophamus sp.	0.9 - 24.5	0.7 - 60.9	2
Notoacmea helmsi	1 - 19.5	0.1 - 71.5	2
Boccardia syrtis	1 - 22.4	0.8 - 76.5	2
Cyclomactra ovata	1 - 26.1	0.8 - 60.4	2
Macomona liliana	1 - 38.6	0.1 - 75.4	2
Paphies australis	1 - 39.8	0.1 - 75.7	2
Prionospio sp.	2.9 - 38	0.1 - 73.1	2
Anthozoa sp. 1	6.8 - 22.5	7.9 - 51.7	2
Austrovenus stutchburyi	6.8 - 44.9	0.1 - 80	2
Zeacumantus lutulentus	7 - 17.1	6.5 - 46	2
Edwardsia sp.	7 - 33.3	0.1 - 71.1	2
Tenagomysis sp. 1	8.1 - 21.1	2.8 - 62	2
Nucula sp.	8.8 - 25.1	1 - 55.1	2
Amphipoda sp.	8.9 - 37.5	0.4 - 73.4	2
Nereidae	14 - 59.5	0.9 - 77.6	3
Anthopleura aureoradiata	23.8 - 43.8	0.1 - 55	3
Nemertea	0.1 - 61.3	0.1 - 75.4	3
Amphibola crenata	1 - 53.1	0.1 - 78.5	3
Potamopyrgus sp.	4.1 - 35.4	0.5 - 92	3
Cominella glandiformis	5 - 75.0	0.1 - 75.7	3
Amphipoda sp. 2	50.5 - 60.9	0.1 - 65.9	4
Paracorophium excavatum	12.6 - 54.8	0.1 - 92	4
Scolecolepides sp.	15.1 - 75.5	0.5 - 92	4
Capitella sp.	20.7 - 55.3	0.1 - 92	4
Helice crassa	38.9 - 70	0.1 - 90	5
Amphipoda sp. 1	43.3 - 82	0.1 - 92	5
Macrophthalmus hirtipes	44.1 - 68.5	0.1 – 90	5
Exosphaeroma sp.	84.8 - 92	1 - 92.0	5

Table 5. Sensitivity of macro-benthic taxa to increasing silt/clay content in North Island estuaries. (Gibbs & Hewitt 2004; table adapted from Norkko et al. 2001).

Table 3. Sensitivity of macrobenthic taxa to increasing silt/clay content of the sediment using density gradients. Optimum range = the percent silt/clay were taxa exhibit their highest abundances. Distrib. range = total range of occurrence over different silt/clay concentrations. Curve fit = r2 and p-values for non-linear (exp) or linear (linear) curve fits. Na = not applicable. SS = highly sensitive; S = sensitive, I = no response; P = slightly positive response; PP = highly positive response.

Taxa	Faunal group	Optimum range (%)	Distrib range (%)	Curve fit	Sensitivity
Aonides oxycephala	Polychaete	0 - 5	0 - 5	0.997 (exp); p<0.0001	SS
Travisia olens	Polychaete	0 - 5	0 - 5	Na	SS
Paphies australis	Bivalve	0 - 5	0 - 5	Na	SS
?Waitangi sp. aff. *W. chelatus*	Amphipod	0 - 5	0 - 5	Na	SS
Notoacmea helmsii	Gastropod	0 - 5	0 -10	0.974 (exp); p<0.0001	SS
Cominella glandiformis	Gastropod	5 - 10	0 - 10	Na	SS
Anthopleura aureoradiata	Anemone	5 - 10	0 - 15	Na	SS
Diloma subrostrata	Gastropod	5 - 10	0 - 15	Na	SS
Macomona liliana	Bivalve	0 - 5	0 - 40	Na	S
Orbinia papillosa	Polychaete	5 - 10	0 - 40	Na	S
Colurostylis lemurum	Cumacean	0 - 5	0 - 60	0.812 (exp); p=0.0005	S
Boccardia syrtis	Polychaete	10 - 15	0 - 50	0.360 (exp); p=0.0547	S
Nucula harvigiana	Bivalve	0 - 5	0 - 60	0.780 (exp); p<0.0001	S
Scoloplos cylindrifer	Polychaete	0 - 5	0 - 60	Na	S
Austrovenus stutchburyi	Bivalve	5 - 10	0 - 60	0.784 (exp); p=0.001	S
Syllid	Polychaete	25 - 30	0 - 40	Na	S
Waipirophoxus waipiro	Amphipod	0 - 5	0 - 70	0.684 (exp); p=0.0006	S
Macroclymenella stewartensis	Polychaete	10 - 15	0 - 60	Na	S
Paracalliope ?novizealandiae	Amphipod	35 - 40	0 - 50	Na	S
Goniada emerita	Polychaete	50 - 55	0 - 60	Na	S
Cirratulid	Polychaete	10 - 15	5 - 70	Na	S
Aricidea sp.	Polychaete	35 - 40	0 - 70	Na	S
Arthritica bifurca	Bivalve	55 - 60	5 - 70	Na	S
Cossura sp.	Polychaete	20 - 25	5 - 65	Na	S
Musculista senhousia	Bivalve	55 - 60	0 - 60	Na	S
Tanaid	Crustacean	10 - 15	0 - 100	0.240 (exp); p=0.2880	S
Glycerid	Polychaete	10 - 15	0 - 95	0.205 (exp); p=0.2252	I
Heteromastus filiformis	Polychaete	10 - 15	0 - 95	Na	I
Aquilaspio aucklandica	Polychaete	65 - 70	0 - 95	Na	I
Nemertina	Nemertean	55 - 60	0 - 95	Na	I
Macropthalmus hirtipes	Crab	45 - 50	0 - 95	Na	I
Lumbrinereid	Polychaete	30 - 35	0 - 65	0.344 (linear)	P
Theora lubrica	Bivalve	45 - 50	5 - 65	0.242 (linear)	P
Nereid	Polychaete	55 - 60	0 - 100	Na	P
Oligocheate	Oligochaeta	95 - 100	0 - 100	Na	PP
Scolecolepides sp.	Polychaete	25 - 30	0 - 100	Na	PP
Helice crassa	Crab	95 - 100	5 - 100	0.676 (exp); p=0.0006	PP
Paracorophium excavatum	Amphipod	95 - 100	40 - 100	0.791 (exp); p=0.0008	PP

Effects of suspended sediments on specific suspension – and non-suspension feeders

Part of the NIWA studies was to assess the sensitivity and effects of suspended sediments on the condition and feeding of suspension feeders (horse mussels, cockles, pipis, and scallops) and non-suspension feeders (wedge shells, heart urchins, the gastropod *Zeacumantus lutulentus* and the polychaete *Boccardia syrtis*). The results were presented in Gibbs & Hewitt (2004) and are briefly summarised below.

Suspension feeders

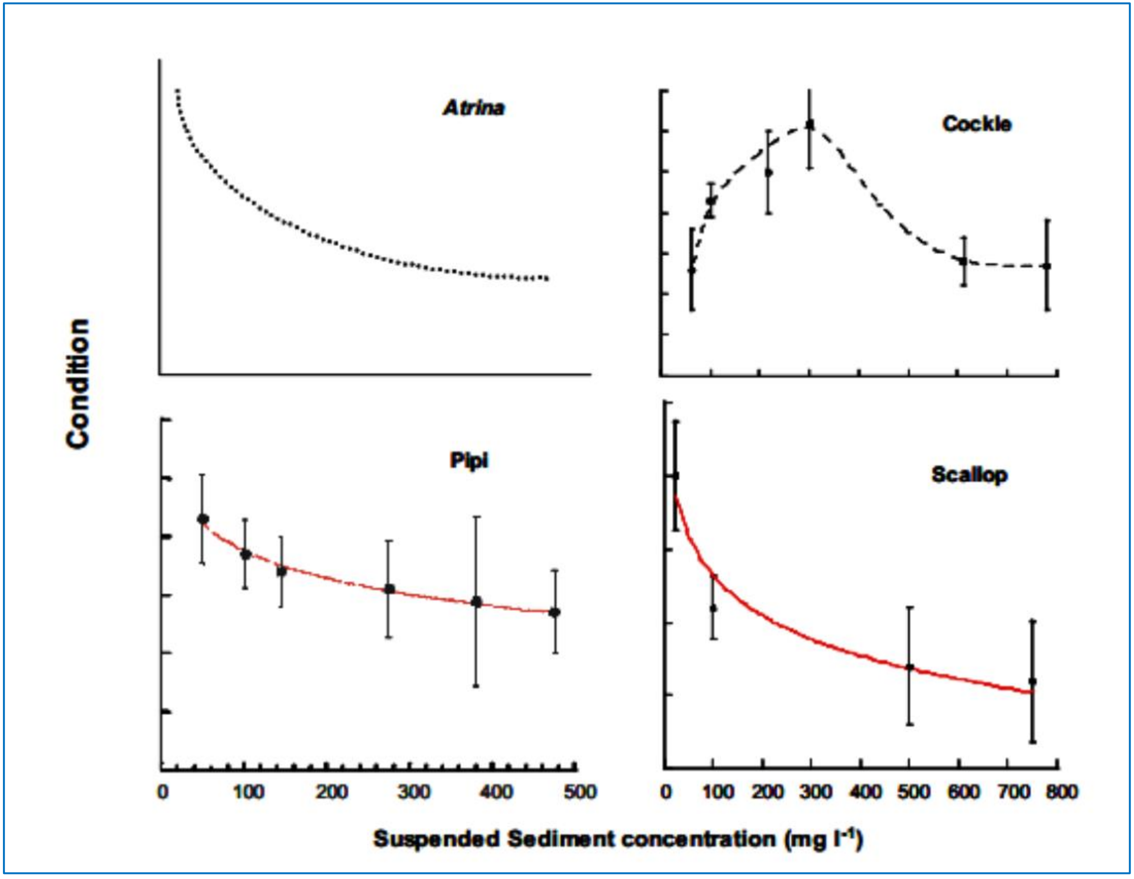

Figure 4. Change in the condition of four suspension feeding bivalves relative to increasing concentrations of terrigenous suspended sediment (Gibbs & Hewitt 2004).

- *Horse mussels*
  Hewitt & Pilditch (2004) found that horse mussels were sensitive to suspended sediments and exhibited high rejection of filtered particles (mostly 75 – 100 %), but high organic absorption efficiencies (0.9 – 1) at all suspended sediment levels. Although the studies showed variable site-specific feeding responses of horse mussels to suspended sediment concentrations, the results consistently indicate that horse mussels experience increasing stress to increasing suspended sediment concentrations.

- *Cockles, pipis and scallops*
  Adult cockles, pipis, and scallops all exhibited the ability to continue feeding in high levels of suspended sediment over the short-term (< 1 week) but their condition was adversely affected by high suspended sediment concentrations occurring for long time periods[11]. Cockles had difficulties coping with suspended sediment concentrations higher than 400 mg per litre over long periods. For scallops, variation in clearance rates suggested that suspended sediment concentrations higher than 100 mg per litre affected their ability to process the particles (Nicholls et al. 2003; Figure 4). The type of suspended sediment was also important, for example, suspended terrigenous sediment affected cockles more than re-suspended marine sediment.

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[11] In 2006 Norkko et al. (2006) studied effects of increased sedimentation on the physiology of cockles and pipis. They found no significant differences in RNA content (indirect measure of short-term growth over the short term in response to either increased suspended sediment concentrations (laboratory experiment, 14 days) or deposition of thin layers of terrigenous clay (field experiment, 10 days), but over the longer term changes in both suspended material and deposition affected the two bivalve species (transplant and field experiments, 3–5 months).

Non-suspension feeders

- *Wedge shells*
  The wedge shell *Macomona liliana* a common inhabitant of soft sediments was adversely affected at suspended sediments concentrations above 300 mg per litre after 9 days. After 14 days of exposure to the highest suspended sediment concentrations (750 mg per litre), most of the wedge shells had died or were lying exposed on the surface of the sediment.

- *Heart urchins*
  The heart urchin *Echinocardium australe* was adversely affected after 3 days at suspended solids concentrations above 80 mg per litre. Burial times and death rates in *Echinocardium australe* increased with increasing exposure to suspended sediment. While it is unlikely that deaths occurred directly from the suspended sediments, sub-lethally stressed animals remaining on the sediment surface are more vulnerable to predators (Lohrer et al. 2003).

- *The gastropod Zeacumantus lutulentus*
  The herbivorous gastropod *Zeacumantus lutulentus* showed no direct effects to increasing suspended solids. However, if the reduction in light associated with increased suspended solids reduced primary production by benthic microphytes, this should reduce the available food supply to *Zeacumantus lutulentus*.

- *The polychaete Boccardia syrtis*
  The deposit-feeding polychaete *Boccardia syrtis* was adversely affected at suspended solids concentrations above 80 mg per litre after 9 days. Feeding rates for *Boccardia* decreased over time, with the largest decreases occurring in treatments with the highest suspended sediment concentrations (750 mg per litre). Nicholls et al. (2000) found that *Boccardia* were also highly sensitive to terrigenous sediment deposition.

Conceptual model linking sediment accumulation rates to macro-faunal communities

Based on the sedimentation studies mentioned above, NIWA presented a conceptual model to predict likely changes in macro-faunal communities to increasing sediment accumulation rates (Figure 5; Lundquist et al. 2003).

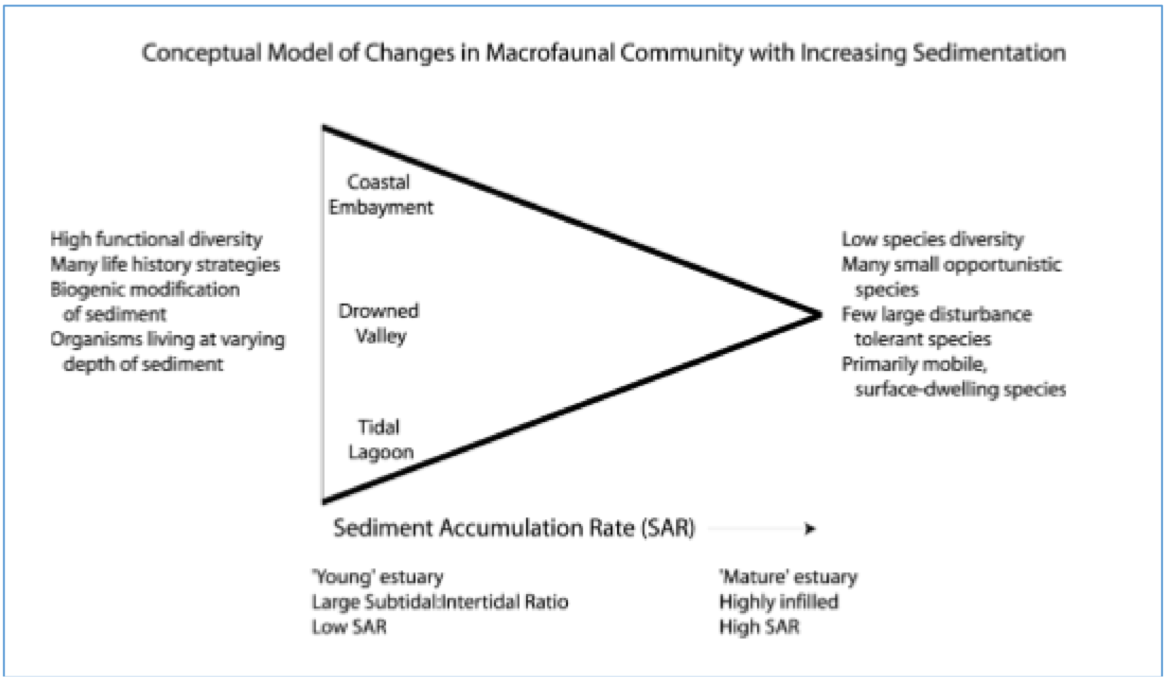

Figure 5. Conceptual model of macro-benthic community structure as sediment deposition increases, ranging from 'young' estuaries with low SAR to 'mature', highly infilled estuaries with high SAR (Lundquist et al. 2003).

General guidelines to assess impacts of sedimentation on soft sediment benthic communities

Based on the NIWA studies mentioned above Gibbs & Hewitt (2004) produced the following general guidelines to assess likely impacts of sedimentation on benthic communities:

- The thicker the layer of mud, the more animals will be killed and the longer recovery will take. This will affect both the number of species and the number of animals within each species – some species are more sensitive than others.

- If mud is washed down a stream to a tributary estuary or embayment results in a mud layer greater than 2 cm for more than 5 days, all resident animals except mobile crabs and shrimps will be killed due to lack of oxygen.

- Mud thickness of around 5 mm for more than 10 days will reduce the number of animals and number of species, changing assemblage structure.

- Frequent deposition of mud, less than 5 mm, may still have long-term impacts that can change animal communities.

2.4.3 Sensitivity of rocky reef communities to sediment runoff

Examples of New Zealand studies focusing on the sensitivity of rocky reef communities to terrestrial sediment runoff include:

- Schwarz et al. (2006) studied the effects of terrestrial runoff on the biodiversity of rocky reefs focusing on how terrestrial sediment inputs affect filter feeding invertebrates, planktonic larvae of paua and kina, productivity and relative abundance of kelp, understorey algae and associated epi-fauna. Field studies were conducted at four sites on a gradient between the Whitianga Harbour mouth and Hahei and, for larval studies, in Wellington Harbour. This study showed terrestrial sediment had both indirect (via water clarity) and direct (via sediment effects on filter feeders) effects. A lower water clarity reduced the photosynthetic potential of *Ecklonia radiata* suggesting the production of all primary producers is also reduced. In the laboratory, sponges, green-lipped mussels, and rock oysters all showed signs of physiological stress through altered feeding rate responses to elevated suspended sediment concentration. Experiments on larval paua and kina (conducted in Wellington using suspended sediment concentrations ranging from 0.03677 g per litre (ambient at mouth of Hutt River at the time of experiment) to 0.07354 g per litre) increased cumulative mortality at larval competency by up to 49% for paua, and up to 27% for kina. For paua, early acute exposure was highly deleterious, resulting in greatly increased larval mortality that was manifested in subsequent stages. Kina exposed to sediments early in development showed some capacity to recover, and those exposed later in development had cumulative mortality more similar to larvae that were chronically exposed to sediments in high concentrations.

- Philips & Shima (2006) studied effects of suspended sediments on larval survival and settlement of New Zealand urchins (*Evechinus chloroticus*) and abalone (*Haliotis iris*). The mortality rates of larvae of both sea urchins and abalone increased with increasing sediment concentrations, but the mortality rates of larvae of sea urchins decreased with age, while older larvae of abalone continued to incur high losses when exposed to sediments. For urchins, this effect was immediate and coincided only with exposure to sediments, whereas elevated mortality rates persisted well after the removal of sediments for abalone.

- Steger (2006) studied the impact of terrestrial-derived sedimentation on temperate rocky reef communities in the Te Whanganui-a Hei marine reserve.

3 Estuarine and coastal vegetation

3.1 Protected, threatened or at risk species

De Lange et al. (2012) described the status of New Zealand indigenous vascular plants. Threatened and at risk species present within the Waikato region are listed in appendix 6 of the Conservation Management Strategy for the Waikato Region 2014-2024 (DOC 2014)[12].

3.2 Inventories and surveys

3.2.1 Estuarine vegetation

Estuarine vegetation surveys have been carried out in most of the Waikato region's harbours and estuaries since 1997, and some have been surveyed multiple times to determine changes in community types over time (Table 6). Vegetation types within the CMA were mapped and included the spatial cover of mangroves, seagrass, saltmarsh and estuarine weeds (e.g. spartina and saltwater paspalum).

In total 59 different community types were distinguished during all the different surveys. To produce overview maps for this report different community types were grouped together to show the presence/absence of mangroves, seagrass beds, saltmarsh and estuarine weeds mixed with - or without any other vegetation types. The maps are shown in appendix 2 of this report.

Table 6. Estuarine vegetation surveys in the Waikato region's harbours/estuaries

Harbours/estuaries	References
Kawhia harbour	Graeme 2005/42, 2014/16 (data 2012)
Aotea Harbour	Graeme 2005/43, 2014/26 (data 2012)
Raglan Harbour	Graeme 2005/44, 2012/35
Port Waikato	Graeme 2005/41, 2014/25 (data 2011)
Firth of Thames	Graeme 2006/40; Swales et al. 2008 (mangrove expansion 1950-2008)
Manaia Harbour	Graeme 1998b, 2008/44; Turner & Riddle 2001 (mangrove expansion 1971-1995)
Te Kouma Harbour	Graeme 1998b, 2013/40; Turner & Riddle (mangrove expansion 1971-1995)
Coromandel Harbour	Graeme 1998a, 2013/40
Colville Bay	Graeme 2013/06
Waikawau Bay and Estuary	Graeme 2013/39
Kennedy Bay	Graeme 2014/27 (data 2012)
Whangapoua Harbour	Graeme 2013/38 (data 2010); harbour catchment and management plan being developed in 2015
Otama estuary	Graeme 2010/29
Whitianga Harbour	Graeme 1999, 2009/15

[12] Seagrass (*Zostera muelleri*) was not listed in this appendix and an article published in 2011 describing an extinction risk assessment of the world's seagrass species assigned New Zealand's only seagrass species, *Zostera muelleri*, to the IUCN Red List category of 'Least Concern' (Short et al. 2011). However, due to a large estimated decline in its area of occupancy this species is classified as 'At Risk' in the New Zealand Threat Classification list (De Lange et al. 2012; Matheson et al. 2011).

Purangi Estuary	Graeme 2014/28 (data 2012)
Tairua Harbour	Graeme 1998a, 2008/52: Wildland consultants 2012 (mangrove removal consent); O'Donnell 2011 (mangrove expansion, harbour and catchment management plan)
Wharekawa Harbour	Graeme 1997, 2008/40; O'Donnell 2009 (mangrove expansion, harbour and catchment management plan)
Whangamata Harbour	Graeme 1997, 2007/25; Beaufill draft 2007 (mangrove expansion, harbour and catchment management plan); Basheer 2007 (mangrove expansion since 1944); Wildland consultants 2011 (mangrove removal consent)
Otahu Estuary	Graeme 1997, 2007/25; Turner & Riddle 2001 (mangrove expansion between 1983 and 1996)

In 2014 Waikato Regional Council commissioned Natural Solutions – Marine and Terrestrial ecologists Ltd. to review the estuarine vegetation monitoring programme. Findings presented in Graeme & Beard (2015) included:

- Kawhia and Aotea harbours are characterised by extensive seagrass communities, Raglan Harbour by rushland and mangrove communities and Port Waikato is characterised by weed communities.

- There are relatively extensive seagrass beds in some Coromandel Peninsula estuaries including Coromandel, Tairua, Whangamata, Whangapoua and Wharekawa. However, these are dwarfed by the huge seagrass beds found in Kawhia and Aotea harbours. For example, the total area of seagrass beds in Kawhia Harbour alone is 842 ha, which is far more than all the seagrass beds of the Coromandel Peninsula harbours combined (593 ha).

- Rushland is a predominant vegetation community in Colville Bay, Kennedy Bay, Otahu, Otama and Waikawau estuaries. It is also the predominant vegetation community in Raglan Harbour.

- Mangroves are an uncommon vegetation community on the west coast except in sheltered eastern arms of Raglan. Mangroves are the predominant vegetation community in the southern Firth of Thames, Manaia, Purangi, Te Kouma, Whangamata, Whangapoua, and Whitianga estuaries.

- Spartina and saltwater paspalum are two invasive exotic species that are threatening the health and integrity of Waikato estuaries.

With respect to trends in intertidal vegetation types the report stated that direct comparison between different surveys is difficult, because mapping techniques evolved since 1989 from delineating community boundaries on hard copy aerial maps out in the field to mapping community boundaries on to digital aerials while in the field, with the ability to zoom in and out to help clarify features. However, general trends noted included:

- The area of seagrass has stayed the same or increased slightly seaward.

- Mangroves have expanded seaward except where mangrove removal has been undertaken (i.e. Wharekawa and Whangamata).

- Saltmarsh has shown a decrease, some of which may be due to better mapping techniques but also an expansion of saltwater paspalum into sea meadow, rushland and saltmarsh ribbonwood communities.

- Spartina has decreased significantly in coverage due to the control programme undertaken by the Department of Conservation.

- Saltwater paspalum is showing an increasing trend in coverage.

3.2.2 Coastal vegetation

Priority ecosystems on public conservation lands and waters in the Waikato region

Areas identified by the Department of Conservation as priority ecosystems on public conservation lands and waters in the Waikato region are presented in appendix 4 of the Conservation Management Strategy for the Waikato region (DOC 2014) and includes several coastal areas and offshore islands (see Table 7)[13].

Table 7. Coastal areas and offshore islands identified by DOC as priority ecosystems on public conservation lands and waters in the Waikato region (extracted from DOC 2014, appendix 4).

Ecosystem unit	Predominant ecosystems habitat types included within the unit	Administrative status
Alderman Islands	Pōhutukawa (*Metrosideros excelsa*), pūriri (*Vitex lucens*), karaka (*Corynocarpus laevigatus*) broadleaved forest	Nature Reserve/Wildlife Sanctuary
Aotea Harbour Dunes	Spinifex (*Spinifex spp*.), pīngao (*Demoschoenus spiralis*) grassland/sedgeland Oioi (*Apodasmia similis*), knobby clubrush (*Ficinia nodosa*) sedgeland Mānuka (*Leptospermum scoparium*) or kānuka (*Kunzea ericoides*) scrub	Scientific Reserve[14]
Cuvier Island	Pōhutukawa, pūriri, karaka broadleaved forest Pōhutukawa treeland/rockland Bare rock	Nature Reserve
Horseshoe Bay	Pōhutukawa, pūriri, karaka broadleaved forest	Conservation Park / Recreation Reserve/Scenic Reserve
Hot Water Beach	Spinifex, pīngao grassland/sedgeland Oioi, knobby clubrush sedgeland	Recreation Reserve
Mercury Islands	Pōhutukawa, pūriri, karaka broadleaved forest	Scenic Reserve/ Nature Reserve/Wildlife Sanctuary
Otama beach	Spinifex, pīngao grassland/sedgeland Flaxland	Recreation Reserve
Waikawau beach	Spinifex, pīngao grassland/sedgeland Oioi, knobby clubrush sedgeland	Recreation Reserve

Sand dunes

Hilton et al. (2000) carried out an inventory of New Zealand's active dune lands and compared maps of active dune lands from the 1950s, 1970s, 1980s (derived from published topographic

[13] Sites were identified using its Natural Heritage prioritising processes in September 2013. Sites on private land were not included and the list does not necessarily include all nationally significant ecosystems present in the Waikato region. The list is subject to change as priorities are refined and revised—new sites may be added and others removed (DOC 2014).

[14] In 2012 DOC commissioned Wildland consultants to carry out a comprehensive assessment of the flora of the Te Tuhi I Oioroa Aotea Heads Scientific Reserve.

maps and other historic sources) and 1990s (derived from the most recent aerial photographs held by local authorities). The report summarised that there have only been two major surveys of New Zealand's active and stabilized dune lands: the New Zealand dune and beach vegetation inventory (Patridge 1992; field surveys carried out between 1984 and 1988) and the Protected Natural Areas (PNA) Program surveys (Coromandel Peninsula: Humphreys & Taylor 1990; field surveys carried out between 1987 and 1989).

The national sand dune and beach vegetation inventory identified 23 national priority sites for conservation including Waikawau beach, Otama Beach and Hot Water Beach in the Waikato region (Hilton 2000). Other information extracted from this survey presented in an unpublished DOC report on biological data for identified ASCVs (Bouma 2007) included information for Port Waikato, Marokopa river mouth, Raglan Harbour and Kawhia Harbour on the west coast; and Wharekawa harbour, Whangamata Harbour, Opito Bay, and Cape Colville (Port Jackson to Sandy Bay) on the Coromandel Peninsula.

Information extracted from the PNA Program surveys for several identified ASCVs around the Coromandel Peninsula were presented in the unpublished DOC report by Bouma (2007) and included information for Manaia Harbour, Whangapoua Harbour, Whitianga Harbour, Wharekawa Harbour and Opoutere Sandspit, Otahu estuary, Fantail Bay, Opito Bay and Otama beach, Cape Colville: Port Jackson to Sandy Bay and Waikawau Bay.

3.2.3 Vegetation on offshore islands

Several offshore islands have been identified by the Department of Conservation as priority ecosystems on public conservation lands and waters in the Waikato region: the Alderman Islands, Cuvier Island and the Mercury Islands (Table 7; DOC 2014).

References for vegetation surveys on the Waikato region's offshore islands extracted from Bouma (unpublished DOC report 2007) are shown in Table 8.

Table 8. References vegetation on the Waikato region's offshore islands (extracted from Bouma 2007).

Offshore island	References
Gannet Island	De Lange 1994
Cuvier Island	Brandon 2006 (draft); Towns & Stevens 1997; De Lange 1993; Beever et al. 1969
Mercury Islands & Ohinau islands	Great Mercury Island (Wright 1976; Esler 1977)
	Red Mercury Island (Towns & Stevens 1997; Lynch et al. 1972)
	Stanley Island (Taylor & Lovegrove 1997; Towns & Stevens 1997)
	Double Island (Atkinson unpublished report 1992)
	Korapuki Island (Hicks et al. 1975; Atkinson unpublished data 1962, 1987 and 1989)
	Middle Island (Atkinson 1964; Cameron 1990)
	Green Island (Atkinson, 1964)
	Flat Island, Black Rocks and the stack 200m west of Green Island (Taylor et al. 1990)
Slipper Island Group	Wright 1974; Court 1974; Hayward & Hayward 1974
Alderman Islands	Taylor et al. 1994; Court et al. 1973; Thorpe & Stanway unpublished data 1992

3.3 Sensitivity to specific pressures

Threats to estuarine vegetation types in the different harbours and estuaries in the Waikato region have been identified as part of the estuarine vegetation surveys (see Table 6) and include (in no particular order):

- Estuarine weeds (e.g. spartina and saltwater paspalum) and coastal edge weeds;

- Sediment runoff from land (from both natural processes and human activities such as forestry);

- Developments (e.g. subdivisions, roading) around edges of harbours/estuaries;

- Stock access to the coastal environment and unfenced streams in catchments;

- Degradation of freshwater wetlands around harbours/estuaries (e.g. drainage, pollution).

- Sea level rise.

- Dumping of rubbish in the coastal environment;

- Clearance of mangroves;

These threats were also discussed in the review of the estuarine vegetation project (Graeme & Beard 2015), which included recommendations to address these threats.

The following paragraphs provide further information on the sensitivity of estuarine vegetation to two of these threats: climate change and the invasive weed saltwater paspalum.

3.3.1 Sensitivity of estuarine vegetation to climate change

Climate change in the Waikato region
Li et al. (2010) provided an assessment of the key climate change impacts on the Waikato region in terms of projected changes by 2020, 2050 and 2100. They used the following eight climatic indices: mean temperature change, mean precipitation change, extreme precipitation change, peak streamflow change, potential evapotranspiration deficit (PED), temperature-humidity index (THI), growing degree days (GDD), and sea level rise. Results related to mean temperature and mean precipitation changes, sea level rise and peak flows are briefly summarised below and indicate:

- An increase of the mean annual temperature of 1.2°C by 2050 and 2.18°C in 2100. The average summer temperature shows the highest seasonal change: 1.29°C by 2050 and up to 2.45°C by 2100;

- A highly variable mean annual precipitation change ranging from -4.58 mm to +7.19 mm in 2050 and from -7.3 mm to +16.91 mm in 2100;

- A sea level rise for the Coromandel area between 8.54 cm and 15.31 cm by 2020, and up to 43.84 - 96.03cm by 2100[15];

- An increase in peak stream flows in rivers such as the Kauaeranga and Waihou Rivers. The average recurrence intervals (ARIs) for peak stream flows are expected to decrease meaning these peak flows occur more frequently.

For medium to long term coastal planning purposes the report recommended to use a base value sea level rise of 0.5 m relative to the 1980-1999 average together with an assessment of the potential consequences from a range of possible higher sea level rises (at least 0.8 m relative to 1980-1999 average). For planning and decision timeframes beyond the year 2100 it was recommended to allow for a sea level rise of 10 mm per year beyond 2100.

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[15] The assessment for the Waikato region did not take into account the local variations in vertical land movements, which could modify the sea level rise values for specific locations (Li et al. 2010).

Potential impacts of sea level rise on estuarine vegetation in Coromandel Harbour[16]

In 2006 Graeme & Dahm assessed potential impacts of sea level rise and surrounding land use on estuarine vegetation in Coromandel Harbour (Graeme & Dahm 2007). The study used sea level scenarios of 0.2 m and 0.5 m for respectively the next 50 and 100 years, and also assessed consequences of a 0.88 m sea level rise projection as a worst- case scenario projection. Based on available information on sedimentation rates in Coromandel Harbour (see Table 3), the authors assumed that sedimentation rates in Coromandel Harbour are too low to significantly counterbalance sea level rise.

The investigation established a close relationship between bed level and the various estuarine vegetation communities, with the vegetation communities generally only occurring in defined bed level ranges. It concluded that estuarine vegetation communities would generally tend to move landward with seagrass unlikely to be reduced in area and mangroves possibly slightly reduced in area. In areas where landward topography rises steeply, significant loss of rushland/sea meadow communities was predicted, but this loss may be balanced by increased areas of rushland/sea meadow communities in areas where adjacent topography is low-lying and landward expansion is not constrained by development or other human activities. Some estuarine vegetation communities in Coromandel Harbour, such as rush and sedgeland, appeared to be critically dependant on shelter provided by chenier ridges that are common in this harbour. Overall, the results of the study suggested that protection of both low-lying areas and chenier complexes are critical to the protection of Coromandel Harbour estuarine vegetation communities in the face of sea level rise (Graeme & Dahm 2007).

3.3.2 Vulnerability of estuarine vegetation to the invasion of saltwater paspalum

Spatial abundance in the Waikato region's estuaries and harbours

In 2014 Graeme & Kendal prepared a report summarising the most up to date information related to saltwater paspalum in the Waikato Region and providing recommendations for management and control strategies. The biology and weed characteristics of saltwater paspalum in New Zealand were reviewed previously by Graeme & Kendal (2001). The spatial abundance of saltwater paspalum in surveyed Waikato harbours and estuaries is presented in Figure 6. The spatial distribution is shown on the estuarine vegetation (weed) maps in appendix 2 of this report.

[16] The predicted climate change effects can also have impacts on other ecological groups. For example, increased mean annual precipitation and increased peak stream flows may increase sedimentation rates in estuaries and harbours that may directly affect benthic communities and (diadromous) fish and indirectly impact on birds (via the food chain). Increased temperatures may have impacts on life history traits of species (e.g. spawning season, survival, growth), and sea level rise may change the availability of suitable conditions/space for the establishment of benthic communities or estuarine vegetation which in turn can effect birds.

Table 1: Saltwater paspalum spatial abundance data for surveyed Waikato estuaries

Estuary	First survey date	Saltwater Paspalum (ha)	Second survey date	Saltwater Paspalum (ha) *	Intertidal Area (ha) **	Intertidal Area (%)
Kawhia	2005	0.42	2012	0.8	5318	0.02
Aotea	2005	0.78	2012	2.31	2433	0.09
Raglan	2004	3.22	2012	5.45	2461	0.22
Port Waikato	2004	3.8	2011	4.75	116	4.09
Southern Firth	2006	0.11			7366	0.00
Manaia	1998	0.52	2008	0.17	431	0.04
Te Kouma	1998	0.05	2009	0.02	71	0.03
Coromandel	1998	0.59	2009	0.54	677	0.08
Colville Bay	2012	0.93			161	0.58
Waikawau	2008	6.95			35	19.86
Kennedy Bay	2012	7.07			49	14.43
Whangapoua	2010	6.52			1258	0.52
Otama	2010	3.89			19	20.47
Whitianga	1999	11.07	2009	10.31	1242	0.83
Purangi	2012	0.72			118	0.61
Tairua	1998	23.14	2008	22.24	528	4.21
Wharekawa	1997	15.84	2008	19.47	226	8.62
Whangamata	1997	0.02	2007	0.96	408	0.24
Otahu	1997	2.69	2007	6.87	68	10.10

* Note earlier field surveys were undertaken using larger mapping scales and non-digitised techniques often resulting in the over-estimation of small populations such as saltwater paspalum

** The intertidal area of each estuary is based on draft data from Gibberd et al (2014) that is yet to be finalised and may change slightly.

Figure 6. Spatial abundance of saltwater paspalum in surveyed Waikato harbours and estuaries (Graeme & Kendal 2014).

Prioritisation of areas for control of saltwater paspalum

Saltwater paspalum threatens estuarine vegetation because it can climb over vegetation and form dense beds, easily smothering sea meadow, saltmarsh ribbonwood, rushland and even short mangrove communities (Graeme & Kendal 2014). At the upstream saltwater limit, saltwater paspalum grows amongst freshwater riparian vegetation and often meets its freshwater invasive relative, Mercer grass (*Paspalum distichum*) (Graeme 2014). Field observations suggest that saltwater paspalum generally excludes burrowing fauna, reduces access to bird feeding and roosting sites, alters fish spawning and feeding grounds, and alters estuarine hydrology by accumulating sediments (Graeme & Kendal 2014).

Graeme& Kendal (2014) prioritised areas for saltwater paspalum control based on the ecological value of the site, the degree of saltwater paspalum infestation, and the site's vulnerability to invasion. Factors used to assess the site's vulnerability included:

- Stock access/feral pigs or goats. Their disturbance directly damages the vegetation communities and increases their vulnerability to weed invasion and persistence, and also exacerbates the spread of saltwater paspalum by breaking off fragments which can then float away to infest new sites.

- Drainage. Disturbance of native estuarine vegetation communities caused by drainage works enhances the ability of saltwater paspalum to invade and establish in an area.

- Infilling/bunding. If estuarine vegetation is in an undisturbed state then it is more resilient and less likely to be invaded and dominated by saltwater paspalum.

- Tracking/other vegetation removal. Damage to native vegetation communities caused by vehicle tracks or paths and/or the removal of mangroves makes a site more disturbed and therefore more vulnerable for invasion by saltwater paspalum.

Based on the ecological assessment Aotea Harbour, Southern Firth of Thames, Colville Bay / Te Kouma estuary and Otahu estuary were identified as the highest ecological priority areas for saltwater paspalum control. It was also recommended to try and control the weed in harbours and estuaries where it is still in its early pioneer stage (<1 ha) such as Kawhia Harbour, Southern Firth of Thames, Manaia Harbour, Te Kouma Harbour, Coromandel Harbour, Colville Bay, Purangi estuary and Whangamata Harbour.

An overview of important sites within all Waikato harbours and estuaries for saltwater paspalum control was provided in Table 4 of Graeme & Kendal 2014.

4 Fish

4.1 Protected, threatened or at risk species

Several fish species occurring in the Hauraki Gulf are protected in New Zealand waters under the Wildlife Act (1953). These include spotted black grouper, giant grouper, great white shark, basking shark, whale shark, giant manta ray and spine tailed devil ray (Sea Change, Roundtable Biodiversity & Biosecurity; Francis & Lyon, 2012). Deepwater nurse shark, smalltooth sandtiger and oceanic whitetip shark are also protected under the Wildlife Act 1953 and may occur in offshore parts of the Gulf, but have yet to be formally recorded from it (Sea Change, Roundtable Biodiversity & Biosecurity). Records of the presence of some of these species in the Waikato region's coastal and marine environment are rare, but do exist (e.g. manta rays at the Alderman Islands and great white sharks along the Waikato region's west coast and in the Hauraki Gulf).

Whitebait, bullies, eels, smelt, torrentfish and lamprey occur in the catchments of the Hauraki Gulf and most of them are listed as threatened or at risk in New Zealand Threat Classification lists (Goodman et al. 2013; DOC 2014). They need both freshwater and marine to complete their life cycle (diadromous species) and are important for recreational and cultural fisheries.

4.2 Inventories and surveys

4.2.1 Demersal fishes Hauraki Gulf

Fish species

NIWA estimated the importance of different parts of the Hauraki Gulf Marine Park for the conservation of demersal fishes using the predicted distributions of 56 species of fish caught in research bottom trawls[17]. The results are available on the website of the Sea Change project (www.seasketch.org), and are shown in Figure 7.

The distributions of these species were predicted by statistically modelling the relationship between the occurrence and abundance of each species in a trawl and a variety of data describing the physical marine environment at the site and the characteristics of the research vessel and the trawl (Leathwick et al. 2006, 2008). Reef fishes, rare species and freshwater fishes found in estuaries were excluded from the dataset and no information on spawning and nursery areas was included in the analysis.

Fish habitats

Several habitats in the subtidal marine environment have been identified as important habitats for fish, including subtidal seagrass beds, shellfish beds (e.g. horse mussels, scallops), rhodolith beds, sponge gardens, kelpforests, bryozoans and reef forming tubeworms (e.g. Morrison et al. 2014; MacDiarmid et al. 2013; Morrison et al. 2009; Morrison et al. 2008). Information on the presence of these habitats in the Waikato region's CMA and their importance to fish is provided in chapter 8 of this report.

Fish species often have different habitat preferences depending on their life stage. Compton et al. (2012) used boosted regression trees to describe ontogenetic habitat associations of snapper across the inner Hauraki Gulf. These models identified that juvenile snapper were most frequently associated with low orbital velocities and slow tidal current speeds, as well as biogenic sedimentary structures. In contrast larger snapper were associated with faster tidal currents and faster orbital velocities. Juvenile and adult snapper were spatially separated:

[17] Using data from Kendrick & Francis 2002 who determined species assemblages in the Hauraki Gulf (and the factors affecting them) from abundance data collected from 1,381 trawl tows by two research vessels during 1964–1997.

juveniles occurred in waters close to shore, whereas larger snapper occurred mainly in the channels between the islands and waters around the islands.

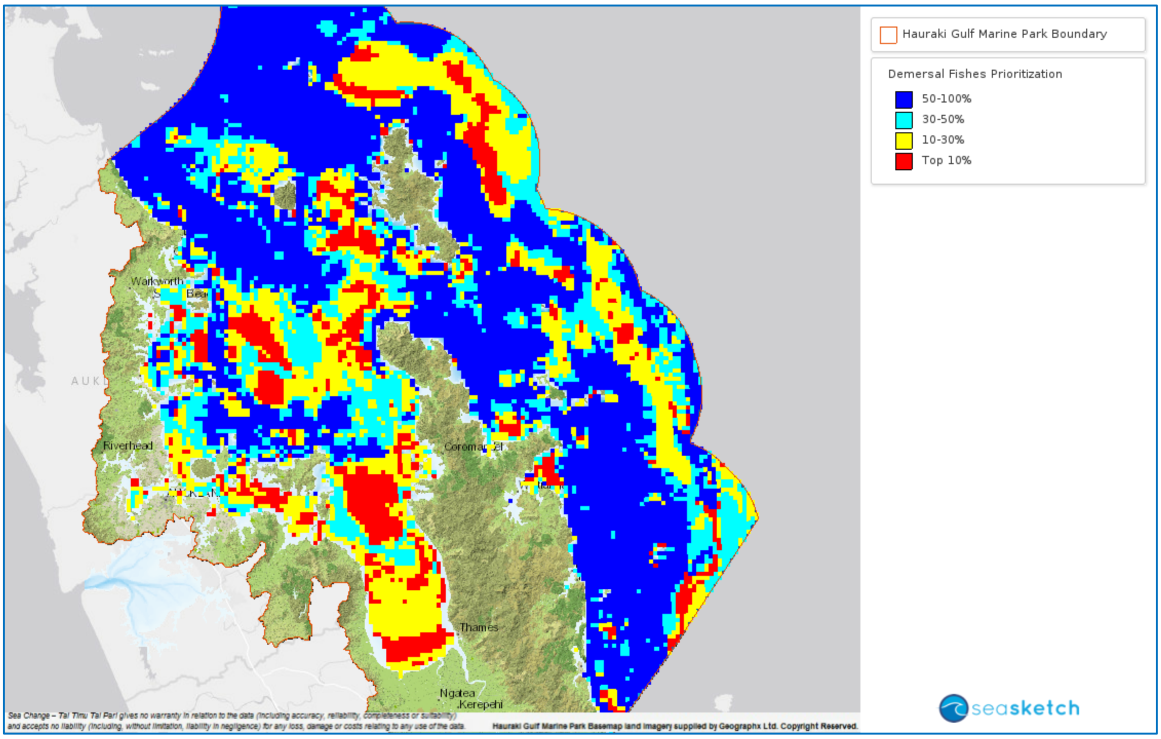

Figure 7. The importance of different parts of the Hauraki Gulf Marine Park for the conservation of demersal fishes. The top 10% shows the top 10% of cells with the highest conservation value (www.seasketch.org).

4.2.2 Shallow rocky reef fishes Hauraki Gulf

Smith et al. (2013) analysed fish data collected during 467 dives around New Zealand together with environmental, geographic and dive specific variables to predict the distribution and relative abundance of 72 fish species on shallow subtidal reefs around New Zealand. The results are available on the website of the Sea Change project (www.seasketch.org), and are shown in Figure 8.

Between May 2002 and February 2003 a survey of 38 rocky reefs throughout the Hauraki Gulf (at approximately 15 m depth) was carried out as part of the development of a regional scale marine environment classification for the Hauraki Gulf (Smith et al. 2004). This survey covered epi-faunal communities, cryptic benthic fishes, mobile invertebrate consumers larger than 50 mm (e.g. gastropods, echinoderms and crustaceans) and small invertebrate consumers (e.g. small gastropods and hermit crabs). Rocky reefs at Fantail Bay, Cape Colville from Port Jackson to Sandy Bay, Te Anaputa Point near Wharekawa Harbour, Cuvier Island, Great Mercury Island and Flat Island were included in this survey. General site descriptions and lists of fish and macro-invertebrate consumers identified during the surveys were presented in respectively appendix I and appendix III of Smith et al. (2004).

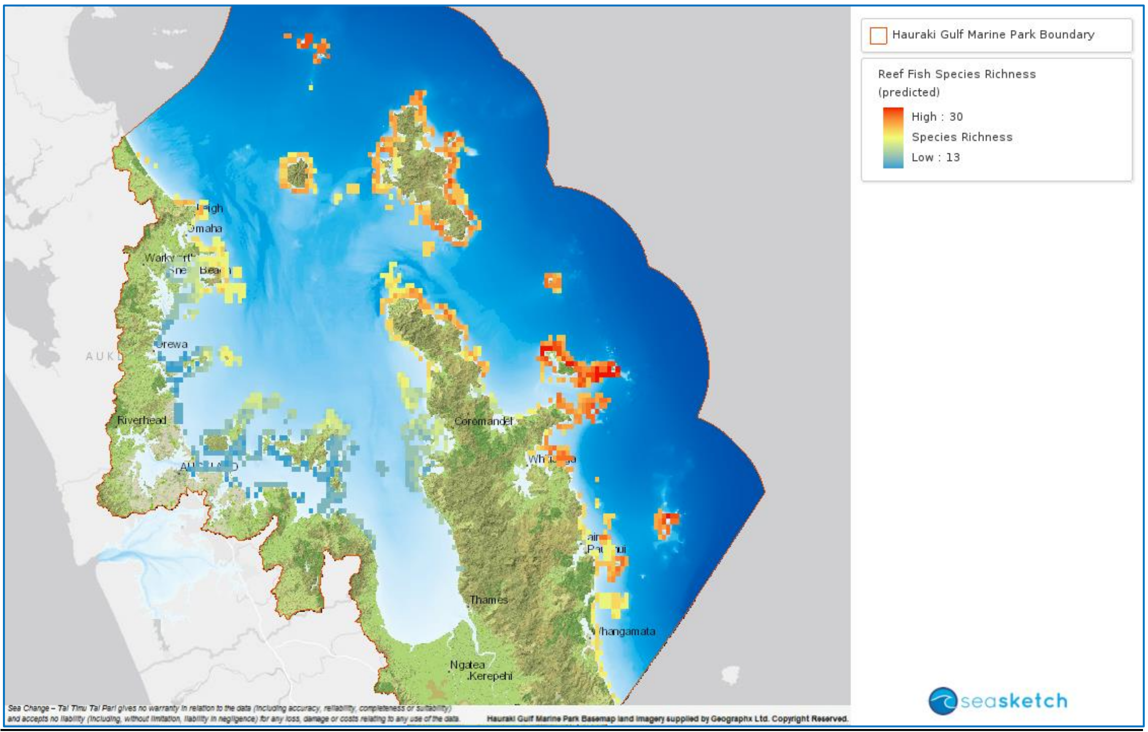

Figure 8. **Predicted species richness of reef fishes on shallow rocky reefs (less than 50m depth) in the Hauraki Gulf Marine Park (www.seasketch.org).**

4.2.3 Fish in the Waikato region's harbours and estuaries

Fish species

Fish surveys have been carried out in most of the estuaries and harbours around the Coromandel Peninsula and along the West Coast of the Waikato region's CMA (see Table 9)[18]. However, no reports were identified that describe trends in fish communities (e.g. distribution, abundances etc.) in any of the harbours or estuaries over time.

Table 9. **Fish surveys in estuaries and harbours in the Waikato region's CMA.**

Estuary/harbour	Brief description available information	References
Port Waikato	Beach seine tows carried out by NIWA in 2001: 8 species caught; low diversity, but whitebait and smelt were abundant.	Francis & Morrison unpublished data in Lundquist et al. 2004
Marokopa estuary	No specific surveys found for this area, but the area was known as a popular fishing spot for kahawai and whitebait. Flounder and eels are important for local Maori.	Abrahamson 1990
Mokau estuary	A report on fish and fisheries values in the Mokau and Awakino Rivers identified 15 marine species in the Mokau estuary.	Hanchet & Hayes 1989
Raglan Harbour	Beach seine tows carried out by NIWA in 2001: 15 species caught; notable species included yellow-eyed mullet, grey mullet, eels, stingrays, kahawai, flounder, snapper, trevally and dogfish.	Unpublished data used in Francis et al. 2005

[18] Results of several of these surveys were used by NIWA in 2011 to develop models to predict patterns of richness, occurrence and abundance of 12 small fish species in New Zealand estuaries (in total data from 69 estuaries were used; Francis et al. 2011). The authors concluded that the use of these models was limited for decision making purposes.

	A general description of the ecological values of this harbour stated that giant kokopu was found in streams around Raglan harbour.	Ritchie 1990
Aotea Harbour	Beach seine tows carried out by NIWA in 2001: 14 species caught; most common species included anchovy, flounder and yellow-eyed mullet.	Francis & Morrison unpublished data in Lundquist et al. 2004
Kawhia Harbour	Beach seine tows carried out by NIWA between January and April 2006 in seagrass beds to assess the role of seagrass as an ecosystem fuel.	Morrison et al. 2014[19]
	Beach seine tows carried out by NIWA in 2001: 12 species caught; most common species included anchovy, flounder and yellow-eyed mullet.	Francis & Morrison unpublished data in Lundquist et al. 2004
	A general description of this harbour reported the presence of snapper, gurnard, trevally and kahawai in this harbour.	Ritchie 1990
Firth of Thames	Beach seine tows carried out by NIWA in 2001: 7 species caught, low diversity, but high abundances of flounder, sole and yellow-eyed mullet.	Francis & Morrison unpublished data in Lundquist et al. 2004
	MPI Hauraki Gulf fisheries surveys 1982-2000: common coastal fish species caught; most dominant were snapper, jack mackerel, John Dory, red gurnard, sand flounder and yellow-belly flounder.	Morrison et al. 2002b
	MPI Trawl surveys 1960-1980: 26 species caught including eels, flounder, snapper, kahawai, pilchard, yellow-eyed mullet, aharu, grey mullet, and sharks and in the Waihou and Piako rivers whitebait.	Brownell et al., 2004
Manaia Harbour	Beach seine tows carried out by NIWA in 2003: 11 species caught.	Unpublished data used in Francis et al. 2005
	Auckland University 1992: yellow-eyed mullet, grey mullet, kahawai, flounder, spotty, parore, snapper, kingfish and eagle ray recorded in this harbour.	De Jong 1994
	DOC Coastal Resource Inventory 1990: was an important area for long-finned eels and short-jawed kokopu.	Abrahamson 1990
Coromandel Harbour	Beach seine tows carried out by NIWA in 2001: 13 species caught, most common were speckled sole, sand flounder, yellow- eyed mullet and anchovy.	Francis & Morrison unpublished data in Lundquist et al. 2004
Colville Bay	No data found	
Whangapoua Harbour	120 sites were sampled by NIWA in ?	Personal comment Mark Morrison February 2015
	Beach seine tows carried out by NIWA in 2001: 14 species caught; the abundance of juvenile snapper was 5-10 times higher than in Whitianga, Tairua and Whangamata harbours.	Francis & Morrison unpublished data in Lundquist et al. 2004
Whitianga Harbour	Beach seine tows carried out by NIWA in 2001: 16 species caught; most common were gobies and estuarine triplefins, but also notable were yellow-eyed	Francis & Morrison unpublished data in Lundquist et al. 2004

[19] In-faunal and epi-faunal invertebrates inside and outside seagrass meadows were also sampled.

	mullet and flounder.	
	Baseline report Whitianga marina 1993: 21 species recorded during the survey and another 15 species expected to be present.	Coffey 1993
Purangi estuary	No data found	
Tairua Harbour	Beach seine tows carried out by NIWA between January and April 2006 in seagrass beds to assess the role of seagrass as an ecosystem fuel.	Morrison et al. 2014[15]
	Beach seine tows carried out by NIWA in 2001: 12 species caught; high numbers of parore compared to Whitianga, Whangamata and Whangapoua harbours.	Francis & Morrison unpublished data in Lundquist et al. 2004
	Auckland University 1984: Species recorded during a baseline survey included yellow-bellied flounder, sand flounder, yellow-eyed mullet, koheru, parore, spotty and large numbers of juvenile flatfish and gobies, snapper, kahawai and trevally.	Bridgewater & Foster 1984
Wharekawa Harbour	No data found	
Whangamata Harbour	Beach seine tows carried out by NIWA in 2001: 14 species caught; high numbers of sand gobies and yellow-eyed mullet.	Francis & Morrison unpublished data in Lundquist et al. 2004
	Auckland University 1984: Species recorded during a baseline survey included snapper, kahawai, trevally, parore, yellow-eyed mullet, koheru, sand flounder and eagle rays.	Bridgewater & Foster 1984
Otahu estuary	No data found	

Fish habitats

Mangroves

A review of knowledge on mangroves prepared in 2007 (Morrisey et al. 2007) concluded that the temperate mangrove forests of northern New Zealand support high abundances of small fishes, but that species diversity is low compared to other estuarine habitats, with most of the small fish assemblage dominated by juveniles of the ubiquitous yellow-eyed mullet, as well as juvenile grey mullet in the west coast estuaries. Based on the consistent and widespread numbers of short-finned eels and parore in mangroves, and their low abundance in many alternative habitats, they suggested that mangroves can probably be viewed as "effective juvenile habitat" for these two species, and that mangroves on the west coast can probably be classified as nursery habitats for grey mullet. Sand and yellow-belly flounder were caught at most sites, but in low numbers relative to their high and widespread abundance over bare mud and sand habitats in the wider estuarine environment.

Seagrass

A sampling programme carried out in seagrass meadows across New Zealand between January and April 2006[20] revealed that seagrass meadows in northern New Zealand are important juvenile fish nurseries, particularly for species such as snapper and trevally (Morrison et al. 2014). However, the results showed that the value of a given habitat type is contextual, being affected by factors such as biogeography and local setting, as well as habitat quality (e.g.

[20] Nine locations across New Zealand (North and South Island) were sampled including Tairua Harbour and Kawhia Harbour in the Waikato Region (see Table 9). For each site a seagrass area and a bare area were selected and sampled.

seagrass blade height and density, water depth, and patchiness)[21]. Other species that have regularly been reported in seagrass meadows include parore, garfish/piper, and spotties (Morrison et al. 2009; Morrison & Francis 2002; Francis et al. 2005; Schwarz et al. 2006a).

Experiments with artificial seagrass structures in Whangapoua Harbour showed that juvenile snapper are attracted to seagrass beds and that increasing blade densities were associated with increasing fish densities (although the patterns of response varied across species) and species diversity (unpublished data in Morrison et al. 2014).

4.2.4 Shallow rocky reef fishes in the Waikato region

Offshore islands on the eastern side of the Coromandel Peninsula

Data used by Smith et al. (2013) to predict species richness of reef fishes on shallow (less than 50m depth) rocky reefs in the Hauraki Gulf Marine Park (Figure 8) included data collected during dives on rocky reefs around most the offshore islands on the eastern side of the Coromandel Peninsula. These data indicate a high species richness of reef fishes around offshore islands compared to most other areas around the Coromandel Peninsula.

Information on fish using specific habitats around offshore islands (such as the subtidal seagrass beds at Great Mercury Island and Slipper Island) is provided in chapter 7. Older references related to the presence of fish species around offshore islands in the Waikato region's CMA (mainly checklists) are included in table 10.

Table 10. References related to the presence of fish around offshore islands in the Waikato region's CMA (extracted from Bouma 2007, unpublished DOC report).

Estuary/harbour	Fish survey	References
Cuvier Island	Auckland University Field Club: checklist	Smith et al. 2013; Smith et al. 2004; Housley et al. 1981
Great Mercury Island	Rocky reef survey 2002-2003; checklist	Smith et al. 2013; Smith et al. 2004; Grace 1976
Red Mercury Island	checklist	Smith et al. 2013; Grace 1972
Little Ohena	Rocky reef survey 2002-2003	Smith et al. 2013; Smith et al. 2004
Slipper Island	Students BOP Polytecnic 1997	Smith et al. 2013; Reid & Wills 1996; Dawbin & Mulgrew 1997
Rabbit Island	checklist	Smith et al. 2013; Reid & Wills 1996; Dawbin & Mulgrew 1997; Grace 1974
Watchman Rock	Students BOP Polytechnic 1996	Smith et al. 2013; Reid & Wills 1996; Dawbin & Mulgrew 1997
Alderman Islands	checklist	Smith et al. 2013; Grace 1973

[21] More specific info: Lowe M.L. 2013. Factors affecting the habitat usage of estuarine juvenile fish in northern New Zealand. Unpublished PhD thesis, University of Auckland. 276 pages.

Te Whanganui-a-Hei marine reserve

The only long-term dataset that allows assessing trends of shallow rocky reef fish is the dataset from the fish monitoring programme carried out in the Te Whanganui-a-Hei marine reserve. Since the establishment of the marine reserve in 1992, fish surveys have been carried out every two years since 1997 by Auckland University (e.g. Willis et al. 1997, 2000, 2003a; Taylor et al. 2003, 2004, 2006) and by Ecoast since 2010.

Massey University (Albany campus) also carries out annual fish surveys in the Hahei area (with transects within and outside the marine reserve) and has a long term dataset for this area.

4.2.5 Diadromous fishes in the Waikato region

Records of whitebait species (5 species), common smelt, bullies (4 species), eels (2 species) and lamprey in the catchments of the Hauraki Gulf extracted from the Freshwater Fish Database[22] are shown in Figure 9 (Franklin 2014).

These figures show that records for these species exist for many areas on the Coromandel Peninsula. However, no reports were identified that provide information on the abundances, distributions or trends of these species in the Waikato region's CMA (e.g. use of harbours and estuaries).

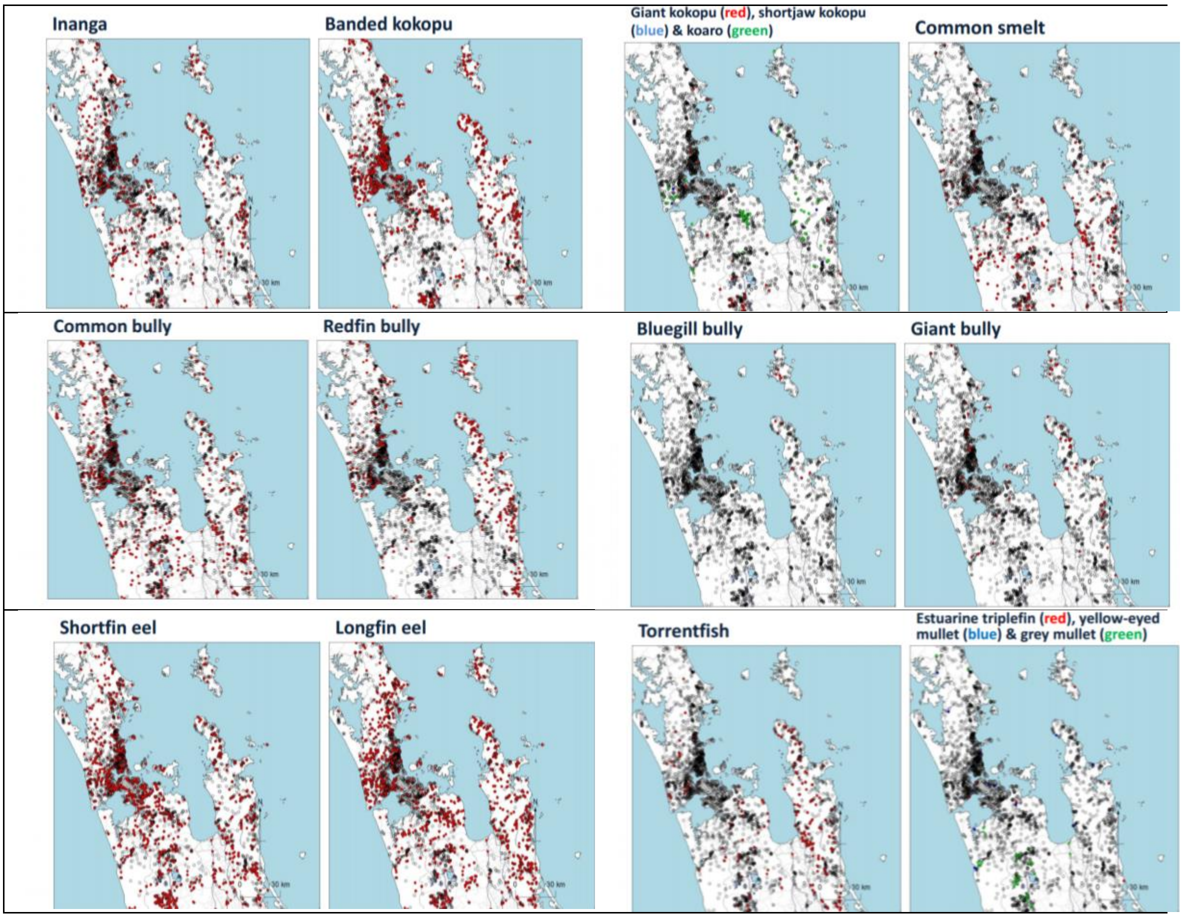

Figure 9. Records of diadromous fish species in catchments of the Hauraki Gulf (Franklin 2014; Freshwater Fish Database).

[22] www.niwa.co.nz/our-services/online-services/freshwater-fish-database.

4.3 Vulnerable life stages

4.3.1 Coastal and marine fish species

Morrison et al. (2014) reviewed the life history information of 38 coastal and marine finfish species that have some component of their life cycle in coastal waters in terms of spawning, oceanic transport, nursery habitats, adult habitats, adult migrations and movements, and population connectivity and stock structure. Information on species distributions and movement dynamics for the most targeted species in the Hauraki Gulf[23] was extracted from Morrison et al. 2014 and is presented in Table 11.

Hurst et al. (2000) summarised information on important areas for spawning, pupping, egg-laying, and juveniles of 35 important fish species which occur in under 200 m depth. The overall conclusions from the study were that most areas around New Zealand in less than 200 m depth are important for either spawning or juveniles of one or more coastal species; that some of these areas are also important for juveniles of deeper spawning species (e.g., hake and ling); and, conversely, that some "coastal" species extend into depths over 200 m, either as juveniles, or to spawn (e.g. red cod, giant stargazer).

O'Driscoll et al. (2003) summarised information on important areas for spawning, pupping, and egg-laying, and for juveniles of 32 important deep water fish species (occurring from 200 m to 1,500 m depth), 4 pelagic fish species, 45 invertebrate species or species groups, and 5 seaweeds. The overall conclusion from this study was that all areas around New Zealand, from the coast to 1500 m, are important for either spawning or juveniles of one or more fish or invertebrate species. Evaluation of the relative "significance" of different areas was difficult because of varied levels of sampling coverage, species identification, and data collection.

[23] Commercial fisheries catch approximately 75 different finfish species in the Hauraki Gulf, but the 15 most targeted finfish species are snapper, jack mackerel, pilchard, John Dory, gurnard, kahawai, flatfish, tarakihi, trevally, yellow-bellied flounder, leatherjacket, rig, barracouta, grey mullet and parore (Hauraki Gulf Forum 2011). The main finfish species caught in the Hauraki Gulf by recreational fishermen are snapper, kingfish, kahawai, trevally, gurnard, tarakihi and John Dory (Hauraki Gulf Forum 2010).

Table 11. Summaries of species distributions and movement dynamics of the most targeted finfish species in the Hauraki Gulf (information extracted from Table 6 in Morrison et al. 2014).

Species	Area and habitats	Ontogenetic shifts	Evidence of spawning migrations	Evidence of migration / partial migration / behavioural morphs?	Stocks/populations	Key references
Barracouta	Around New Zealand; nursery areas include Tasman and Golden Bays, Canterbury Bight and Pegasus Bay. Depth range 50–450 m.	Limited information, but adults have a wider distribution than juveniles.	Spawning aggregations occur around the country, which are targeted by fishers. Extensive movements between feeding and spawning grounds, tag returns up to 500 n.m.	No information available.	At least three separate barracouta spawning stocks: east coast North and South Islands; west coast South Island; and Chatham Islands.	Hurst & Bagley (1989), Langley & Bentley (2002)
Grey mullet	Generally restricted to more northern temperate waters, with the main fisheries being in the upper half of the North Island. Usually in depths of 1–10 m.	Juvenile grey mullet occur in almost all of northern New Zealand's estuaries, and the species is thought to be estuarine dependent in New Zealand.	Grey mullet movements are poorly understood in New Zealand, but tag returns show movements along surf beaches from one estuary to another.	It is suspected that there is considerable fine spatial structuring in New Zealand grey mullet populations and that migratory dynamics are diverse within populations, including resident and migratory morphs.	There are no studies from New Zealand of how grey mullet populations are structured, and currently the species is managed as one single stock (GMU 1).	Hutton (1872), Hore (1988), Chang et al. (2004a, b), Paulin & Paul (2006), Morrisey et al. (2007)
Jack mackerel	Around the country, more common in the north. Found between 30 and 300 m deep.	The distributions of 0+, 1+, and all juveniles combined are consistent with known spawning areas.	Spawning is suggested to occur throughout the species range.	No information available.	Not known.	Jones (1990), Kailola et al. (1993)
John Dory	Three Kings to Foveaux Straight and around Chatham Islands out to 200 m; most common in less than 50 m.	Juveniles widespread and most abundant in 50–100 m water depth.	Danish seiners target small aggregations in the Hauraki Gulf seasonally, but it is not known if these are related to spawning. Very little is known about John dory movement. Adults move out into deeper water in the Hauraki Gulf in summer, with a shallower inshore distribution in winter	No information available.	Not known. It seems likely that localized populations exist; maintained by feeding, spawning and juvenile nursery habitats on a relatively local scale, with some evidence that biogenic habitat areas may be important in the juvenile stage.	Hore (1982, 1985), Langley (1994), Hanchet et al. (2001), Morrison et al. (2001b)
Kahawai	Around the country, but more common around the North Island and on the east coast of the South Island. Found in waters up to 200m.	Juveniles are found in estuaries and along coastal beaches.	The spawning habitat of kahawai is unknown but is thought to be associated with the seabed in deeper offshore waters (i.e. 60–100 m).	No information, but tagging data shows both resident and more mobile fish, with distances moved ranging up to 743 n.m.	Unkown.	Wood et al. (1990), Jones et al. (1992), Griggs et al. (1998), Hartill & Walsh (2005)
Kingfish	Widely distributed around the North Island and the northern half of the South Island, generally in depths of less than 150 m.	Juvenile kingfish and their habitats are very poorly known in New Zealand. Small fish of less than 300 mm in length are thought to associate and drift with flotsam and drift seaweed far offshore, for around one year.	Anecdotal evidence suggests that kingfish spawn across a range of settings, from estuaries out to deep water.	No information available. Tagging work shows most fish to be resident at the scale of tens of kilometres; large movements are also reported of up to 410 n.m. around New Zealand, as well as large movements to Australia, along with recaptures from Lord Howe Island and Wanganella Banks.	Although kingfish are capable of moving very large distances, indications from tagging are that most adult kingfish stay within localised areas in New Zealand.	Walsh et al. (2003), Holdsworth & Saul (2011)

Species	Area and habitats	Ontogenetic shifts	Evidence of spawning migrations	Evidence of migration / partial migration / behavioural morphs?	Stocks/populations	Key references
Leatherjacket	Found around most of the country, especially in association with rocky reef habitats, more common in the north. Found in depths of 40–60 m.	Juvenile leatherjackets recruit into the heads of *Ecklonia radiata* kelp plants on rocky reef habitats. It appears that the kelp heads are the principal settlement and initial growth habitats for this species.	Leatherjackets spawn around nest sites prepared and guarded by the male of the species in spring and summer.	No information available.	Unknown.	Poynter (1980)
Red Gurnard	Around the country from 10–200 m.	Research trawl records show that 0+ and 1+ red gurnard (10–20 cm) are caught around much of the coast of the North Island in depths less than 100 m. High catches in Golden and Tasman Bays are thought to be evidence of a nursery which supplies the west coast of the South Island, where catches are dominated by older fish.	Elder's (1976) Hauraki Gulf study indicates that red gurnard make seasonal migrations associated with ontogeny and reproductive maturity, with fish moving into deeper water as they get older, and on a seasonal basis to spawn.	No information available.	Separate stocks are thought to exist, but their definitions are not clear.	Elder (1976)
Rig	Around the country. Most common in shelf waters 100–200 m.	Young are either born in estuaries or large coastal harbours, or they make their way into these places after being born in nearby coastal waters.	Rig aggregate annually in spring and summer in shallow coastal waters to breed. Rig are highly mobile, undergoing seasonal inshore– offshore migrations, presumably relating to their reproductive cycle.	Large scale movements have been shown by tagging, with some fish moving up to 1159 km, and more than 50% fish having moved more than 50 km.	Several stocks are suggested. SPO 1 (Raglan through to East Cape), SPO 8 (Raglan to Wellington), SPO 2 (East Cape to Wellington), SPO 7 (South Island north and west coasts excluding Fiordland), and SPO 3 (South Island east coast, Southland and Fiordland).	Graham (1956), Francis (1988), Paul (2000), Francis (2010), Francis et al. (2012)
Snapper	Most abundant in the northern half of the North Island, but occurs throughout the west coast of North Island, east coast North Island to Hawkes Bay, as well as in Tasman, and Golden Bays, and the Marlborough Sounds in the South Island. Most commonly found in waters less than 70 m deep.	Juveniles more common inshore and structured estuarine habitats seem to be important for immediate post settlement stage snapper. Juveniles probably leave estuaries/harbours after about 3–5 months and gradually disperse into deeper coastal waters as they get older.	There are a number of spawning aggregation sites throughout the area that snapper occupy. While not all snapper necessarily move to these aggregations for spawning, most snapper appear to undertake seasonal and potentially long distance movements to contribute to these aggregations (as evidenced by seasonal patterns in tagging and abundance).	Snapper movement is complex with tagging indicating a continuum of movement behaviour from highly residential (hundreds of metres) to highly mobile (hundreds of kilometres) present within the snapper stock. Movements seem to be influenced by seasonal spawning aggregations as well as habitat and location (inshore and reef habitats being more residential). Furthermore, snapper appear to be able to change their movement behaviour from mobile to residential, but potentially not in the other direction.	Multiple separate stocks are likely to exist: west coast North Island, east coast North Island, Hawkes Bay and South Island.	Cassie (1956), Paul (1976), Crossland (1977a, 1982), Kingett & Choat (1981), Drummond & Mace (1984), Gilbert & McKenzie (1999), Morrison et al. (2009), Parsons et al. (2009, 2011)
Tarakihi	All around New Zealand down to 400	Vooren (1975) concluded that	Movement in adult populations has	No information available.	Large-scale movements	Graham (1939b,

Species	Area and habitats	Ontogenetic shifts	Evidence of spawning migrations	Evidence of migration / partial migration / behavioural morphs?	Stocks/populations	Key references
	m.	tarakihi nurseries were mostly some way offshore (10–30 km) in depths of 20–100 m and in a number of areas, also noted the presence of biogenic habitat. However, they also appear common on shallow rocky reefs along the lower east North Island and top of the South Island.	received limited attention. Annala (1987) reported tagging studies carried out in various locations; while first year returns showed limited movement, fish at liberty for longer indicated more extensive migrations of over 300 km. Spawning migrations or 'runs' are well known to commercial fishers.		during both larval and adult phases and lack of genetic isolation suggest that tarakihi around New Zealand are a single stock	1956), Vooren (1972, 1975), Robertson (1978), Jordan (2001), Langley & Starr (2012)
Trevally	Common around the North Island and the north-west of the South Island, mainly less than 100 m depth.	Juveniles are found in estuaries and harbours, and on some shallow water rocky reef systems, with an association with structure, e.g. subtidal seagrass, horse mussel beds, generally in higher current areas. Pelagic phase associates with drift algae.	Tagging data indicates some fish movement into shallow waters in spring, followed by a movement back into deeper waters in summer.	Tagging data shows relatively limited movement, with more than 50% of fish moving less than 18.5 km; but with long distance movements up to 246 km. Adult trevally show both pelagic and demersal distribution patterns, and can form large schools in the water column and on the surface. Tagging suggests that these patterns reflect different seasonal behaviours of the same stock.	Stock structure is poorly understood; but several discrete stocks are likely.	James (1984), Horn (1986), Walsh et al. (2010)
Yellow-bellied flounder	Estuaries, embayments and shallow coastal regions (to a depth of 50 m) around the country.	Juveniles appear to be exclusively limited to sheltered harbours and estuaries and have been found in many estuaries around New Zealand.	Yellow belly flounder adults move offshore to spawn between winter and spring, followed by a movement back onshore.	No information available.	No information available.	Tunbridge (1966a), Colman (1973, 1974, 1976), Francis et al. (2005, 2011)

4.3.2 Diadromous fish species

Spawning inanga and eels

Inanga (the main whitebait species in the Waikato region) spawn in estuaries between March and June laying eggs in riparian vegetation at spring high tide (Franklin 2014). Males fertilise the eggs after which the eggs are exposed for a number of weeks remaining moist among the vegetation. When the next spring tide reaches the eggs, the larvae hatch and the falling tide carries them out to sea, where the hatchlings spend the winter feeding on small crustaceans. In spring (generally between July and November) juveniles migrate upstream to live in freshwater habitats (NIWA 2010).

Currently there are no known spawning sites in catchments around the Hauraki Gulf (Franklin 2014) [24].

Known spawning sites of inanga in the Waikato River estuary and delta on the west coast of the Waikato region were presented in Jones & Hamilton (2014). They developed a hydrodynamic model of the Waikato River delta to aid with the assessment of whitebait spawning habitat, and to help inform restoration plans for the area (Figure 10).

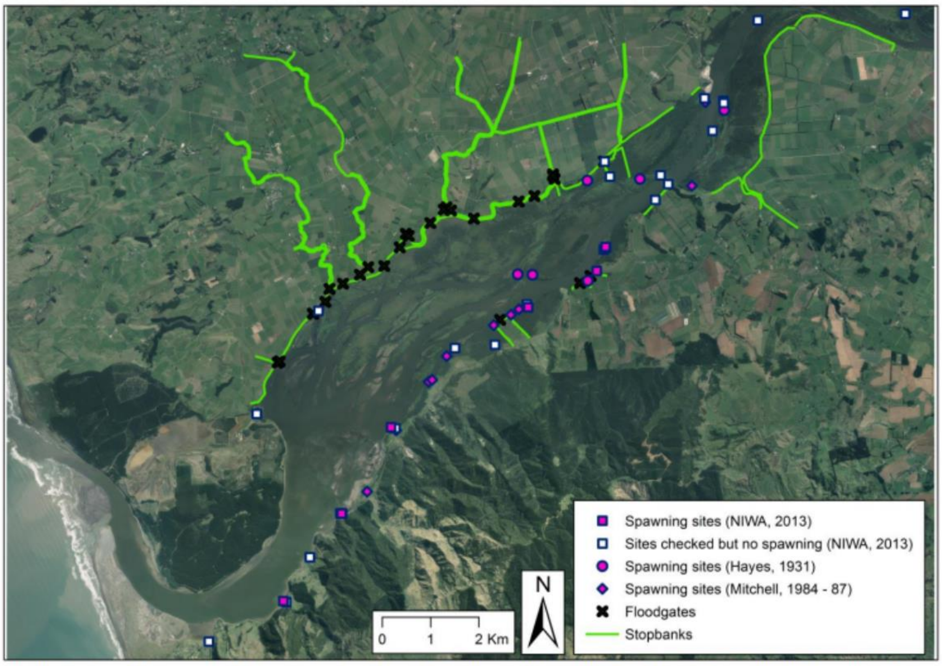

Figure 22: Stopbanks, floodgates and known whitebait spawning sites (historical and current) in the Waikato River estuary and delta. Location of spawning sites in 2013 provided by Cindy Baker and Paul Franklin (NIWA), and historical sites from Mitchell (1990).

Figure 10. Known spawning sites in the Waikato River estuary and delta (Jones & Hamilton 2014).

Eels spawn in the sea possibly near Tonga/Fiji (Franklin 2014). Glass eels migrate into estuaries between July and November (with migration peaks during August to October) and may stay for some time in estuaries before migrating into freshwater as elvers (November-March). They rear to adulthood in freshwater (& estuaries) and when ready for spawning, male short-finned eels migrate to sea in February/March and male long-finned eels in April. The females of each species migrate shortly after the males (www.teara.govt.nz; Franklin 2014).

[24] Auckland Council has a project to try and locate spawning locations. Waikato Regional Council failed to identify any in the Waihou River in a recent survey (Franklin 2014).

Timing of freshwater fish migrations and spawning

In 2007 Waikato Regional Council published the Freshwater Fish Migration (Hamer 2007; Figure 11) and Spawning Calendar (Hamer 2007; Figure 12). The migration calendar shows the peak and range periods for migration activity, conservation status, migration direction, life stage at time of migration, and instream works restrictions period relating to indigenous fish habitat waterways under Waikato Regional Council's regional plan. The spawning calendar shows the peak and range periods of spawning activity, conservation status, spawning habitat and instream works restriction period relating to trout habitat waterways.

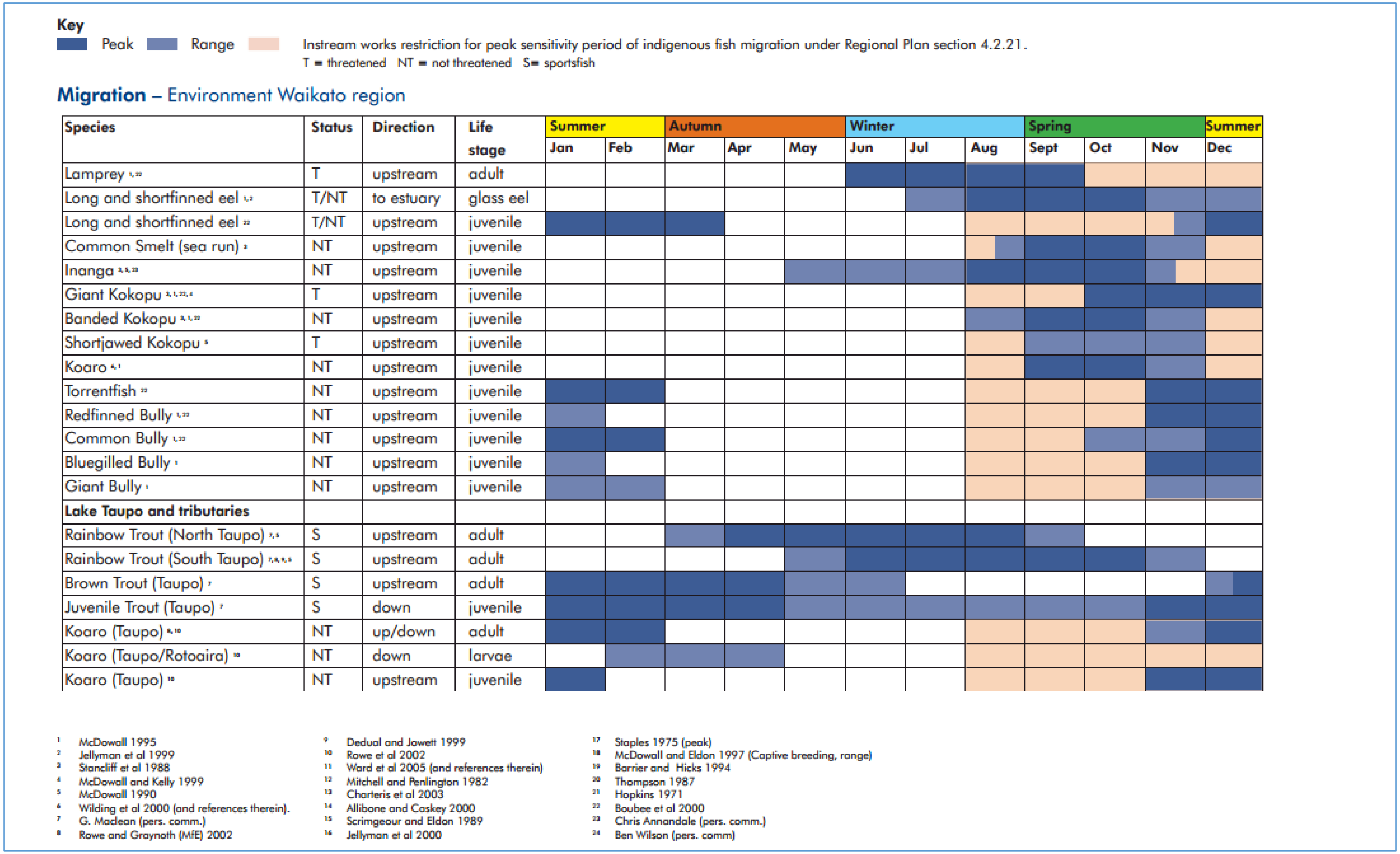

Figure 11. **Fish migration calendar for the Waikato Region (Hamer 2007).**

Key

Peak ■ Range ■ Instream works restriction for peak sensitivity period of trout spawning under Regional Plan section 4.2.21.

T = threatened
NT = not threatened
S = sportsfish

Spawning Habits – Environment Waikato region

Species	Status	Spawning habitat	Jan (Summer)	Feb (Summer)	Mar (Autumn)	Apr (Autumn)	May (Autumn)	Jun (Winter)	Jul (Winter)	Aug (Winter)	Sept (Spring)	Oct (Spring)	Nov (Spring)	Dec (Summer)
Lamprey	T	upper catchment (unconfirmed)									Range	Range	Range	Range
Longfinned eel	T	Pacific ocean												
Shortfinned eel	NT	Pacific ocean												
Common Smelt (sea run)	NT	sand banks of rivers	Range	Range	Peak	Peak	Peak	Range	Range					Range
Inanga	NT	tidal esturary edge vegetation		Range	Peak	Peak	Peak	Range	Range					
Giant Kokopu	T	mid-low reaches (unconfirmed)				Range	Range	Peak	Peak	Peak				
Banded Kokopu	NT	stream margins at flood among vegetation and debris				Range	Peak	Peak						
Shortjawed Kokopu	T	stream bank rocks, debris and vegetation during flood					Peak	Peak						
Koaro	NT	cobbles at stream edge				Peak	Peak	Peak/Range						
Torrentfish	NT	lowland rivers/estuaries	Peak	Peak	Peak	Peak	Range				Range	Range	Range	Range
Redfinned Bully	NT	flowing water under rocks							Range	Range	Range	Range	Range	
Common Bully	NT	under firm flat surfaces	Range	Range								Range	Range	Range
Bluegilled Bully	NT	similar to other bullies	Range	Range							Range	Range	Range	Range
Giant Bully	NT	estuaries (unconfirmed)	Range	Range										Range
Cran's Bully	NT	under large rocks	Range	Range								Range	Range	Range
Upland Bully	NT	under large flat rocks	Range	Range								Peak	Peak	Peak
Black Mudfish	T	wetlands				Range	Range	Range	Range	Range/Peak	Peak/Range	Range		
Dwarf Galaxias	T	small stones instreams									Peak	Peak	Peak	Peak
Rainbow Trout (Waikato)	S	gravel bed in flowing water					Range	Peak	Peak	Peak	Peak			
Brown Trout (Waikato)	S	gravel bed in flowing water					Peak	Peak	Peak	Restriction	Restriction			
Lake Taupo and tributaries														
Rainbow Trout (North Taupo)	S	gravel bed in flowing water	Range	Range	Range	Range	Range	Range	Range	Peak	Peak	Range	Range	Range
Rainbow Trout (South Taupo)	S	gravel bed in flowing water					Restriction	Range	Range	Peak	Peak	Peak	Range	
Brown Trout (Taupo)	S	gravel bed in flowing water					Peak	Peak	Peak	Restriction	Restriction			
Common Smelt	NT	sandy lakeshore/slow flowing streams	Peak	Peak	Peak						Range	Peak	Peak	Peak
Koaro (Taupo)	NT	cobbles at stream edge	Peak	Peak										Peak
Common Bully	NT	hard substrates	Range	Range							Range	Range	Range	Range

1 McDowall 1995
2 Jellyman et al 1999
3 Stancliff et al 1988
4 McDowall and Kelly 1999
5 McDowall 1990
6 Wilding et al 2000 (and references therein).
7 G. Maclean (pers. comm.)
8 Rowe and Graynoth (MfE) 2002
9 Dedual and Jowett 1999
10 Rowe et al 2002
11 Ward et al 2005 (and references therein)
12 Mitchell and Penlington 1982
13 Charteris et al 2003
14 Allibone and Caskey 2000
15 Scrimgeour and Eldon 1989
16 Jellyman et al 2000
17 Staples 1975 (peak)
18 McDowall and Eldon 1997 (Captive breeding, range)
19 Barrier and Hicks 1994
20 Thompson 1987
21 Hopkins 1971
22 Boubee et al 2000
23 Chris Annandale (pers. comm.)
24 Ben Wilson (pers. comm)

Figure 12. Fish spawning calendar for the Waikato Region (Hamer 2007).

4.4 Sensitivity to specific pressures

4.4.1 Sensitivity to underwater noise

New Zealand studies

Many human activities in Waikato region's CMA create underwater noise that may have impacts on marine organisms such as fish. Knowledge about these effects in New Zealand waters is very limited. Only two completed studies related to fish were identified at this stage:

1. An investigation of the hearing thresholds of four age classes of hapuka (*Polyprion oxygeneios*) from larvae to juvenile stages (Caiger et al. 2013); and

2. A study investigating the hearing specialisation of the New Zealand bigeye (*Pempheris adspersa*) (Radford et al. 2013).

However, interest in this topic is growing and the Institute of Marine Science and The University of Auckland currently have two projects underway investigating the effects of noise on marine life. The first project investigates the relationship between marine biodiversity and acoustic diversity (Sydney Harris, MSc student) and the second project aims at creating an underwater sound map of the Hauraki Gulf (Rosalyn Putland, PhD candidate)[25].

Overseas studies

Quantification of underwater noise and identification of potential effects of underwater noise on marine life (especially fish and marine mammals) has received a lot more attention in Europe, where underwater noise was identified in the European Marine Strategy Framework Directive (MSFD) as one of the 13 descriptors to assess the progress towards reaching the 'Good Environmental Status' of marine waters. Examples of overseas studies related to the vulnerability of marine life to underwater noise include:

- A summary of available information on fish audiograms[26] by an environmental consultancy in the UK in 2004 (Nedwell et al. 2004). Fish with specialist hearing structures (e.g. prootic auditory bullae in herring and sprat) were classified as 'high' sensitivity, non-specialists with a swimbladder (e.g. cod, eels, mackerel) as 'medium' sensitivity and non-specialists with no swimbladder (e.g. plaice) as 'low' sensitivity (Nedwell et al. 2004; Figure 13).

- An extensive scientific synthesis on the impact of underwater noise on marine and coastal biodiversity and habitats by the United Nations Environment Programme (UNEP) in 2012 (UNEP 2012). The synthesis included information on natural[27] and anthropogenic[28] noise sources and levels, the potential impacts on marine organisms (marine mammals, fish, turtles and invertebrates), and mitigation and management options.

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25 E.g. www.radionz.co.nz/national/programmes/ourchangingworld/audio/201751866/underwater-soundscape-of-the-hauraki-gulf

26 And also marine mammal audiograms (see chapter 6).

27 E.g. wind, waves, currents, ice, and marine animals.

28 E.g. marine construction and industrial activities (pile driving, cable laying, dredging, and drilling), various types and sizes of vessels (supply boats, crew boats, fishing vessels, small craft and boats), seismic explorations and research sound (e.g. topography studies).

Table 2.1 shows a summary of the fish species, showing different levels of specialisation. Those fish with specialist structures have been classified as 'high' sensitivity, non-specialists with a swimbladder are 'medium' sensitivity and non-specialists with no swimbladders are termed 'low' sensitivity.

Table 2.1. Summary to show specialisation levels of a variety of fish species.

Species	Common name	Family	Swimbladder connection	Sensitivity
Anguilla anguilla	European eel	Anguillidae	None[1]	Medium
Clupea harengus	Herring	Clupeoidea	Prootic auditory bullae[2]	High
Cottus scorpius	Sculpin	Cottidae	No swimbladder[1]	Low
Gadus morhua	Cod	Gadidae	None[1]	Medium
Limanda limanda	Dab	Pleuronectidae	No swimbladder[1]	Low
Melanogrammus aeglefinus	Haddock	Gadidae	None[1]	Medium
Merluccius merluccius	European hake	Merluccidae	None[1]	Medium
Pleuronectes platessa	Plaice	Pleuronectidae	No swimbladder[3]	Low
Raja clavata	Thornback skate	Rajidae	No swimbladder[1]	Low
Scomber scomber	Atlantic mackerel	Scombridae	None[1]	Medium
Sprattus sprattus	Sprat	Clupeoidea	Prootic auditory bullae[2]	High

[1] Popper & Fay (1993), [2] Blaxter *et al*. (1981), [3] Turnpenny & Nedwell (1994).

Figure 13. Hearing specialisation in fish (Nedwell et al. 2004)

4.4.2 Sensitivity to sedimentation

Information on sedimentation in the Waikato region's CMA is presented in paragraph 2.4.

Sensitivity of estuarine and marine fish species

There is very little research on the direct effects of suspended sediments on estuarine and marine fish species, but effects can include fish gill clogging, reduced finfish foraging abilities (e.g. juvenile snapper), and modification or loss of important nursery habitats (Morrison et al. 2009).

Morrison et al. (2009) summarised potential direct effects of suspended sediments on marine fish using freshwater fish examples as a surrogate for marine species in combination with a limited number of studies on marine fish. They summarised that:
'effects of suspended sediment concentrations on fish are dependent upon synergistic factors including duration of exposure, frequency, magnitude, temperature, and other environmental variables, with responses varying greatly between species and developmental stages. The effects of these responses can ultimately compromise fish health, reproduction, year class strength, and distribution of adult populations.'

Sensitivity of diadromous fish species to turbidity levels

NIWA developed a Decision Support System (DSS) to set maximum turbidity levels for riverine fish, distinguishing between peak flow conditions (based on research results reported in Rowe et al. 2002) and base flow conditions[29] (Figure 14). The DSS was based on seven years' research, but NIWA stated that there are still many gaps in the understanding of effects of increased turbidity levels on fish. In particular, knowledge of the long-term implications of increased turbidity on the habitats and foods of fish and effects on rare fish species is limited.

[29] www.niwa.co.nz/freshwater/management-tools/sediment-tools/setting-maximum-turbidity-levels-for-riverine-fish-dss

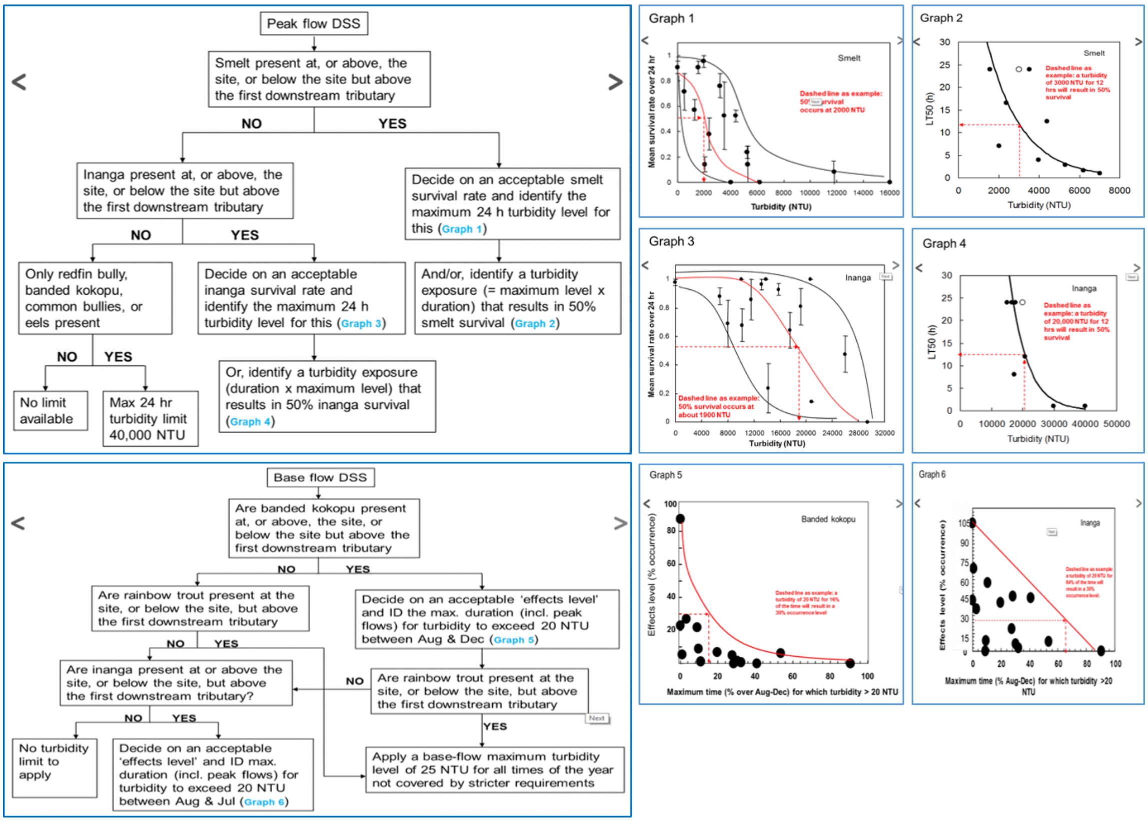

Figure 14. **Decision Support System to set maximum turbidity levels for riverine fish distinguishing between peak flow - and base flow conditions (www.niwa.co.nz).**

5 Birds

5.1 Protected, threatened or at risk species

All threatened and/or at risk bird species in New Zealand are listed in Robertson et al. 2012. Threatened or at risk bird species present within the Waikato region are listed in appendix 6 of the Conservation Management Strategy for the Waikato region operative since September 2014[30].

5.2 Inventories and surveys

Three groups of birds can be distinguished using the Waikato region's CMA: seabirds, shorebirds and birds using coastal wetlands.

(Gaskin 2014): 'Seabirds breed on land, but they get their food from the sea, where they spend most of their lives. They are essentially marine creatures and possess unique physiological and morphological adaptations for life at sea. They can be highly mobile. Their foraging takes them across jurisdictional boundaries. Some of our local species are resident in our waters throughout the year; others migrate away for months following breeding, journeys that can be ocean-wide.'

(Dowding 2013): 'Shorebirds is a term most commonly used to describe the 'typical' waders – members of the sub-orders *Charadrii* and *Scolopaci*. Shorebirds can broadly be classed into those species that are resident (i.e. they breed within the region and do not generally move out of it at any time of year), and those that are migratory (i.e. they breed elsewhere, and move into the region to spend their non-breeding season).'

[30] Threatened or at risk coastal and estuarine bird species on the east coast of the Waikato region are also listed in Dowding 2013.

Wetland birds are birds that occupy palustrine, lacustrine and riverine swamps, marshes, bogs and fens (Johnson & Gerbeaux 2004 in O'Donnell et al. 2014).

5.2.1 Seabirds

5.2.1.1 New Zealand seabirds

New Zealand has great seabird diversity with 85 breeding species of which 36 are endemic species (42%) breeding nowhere else in the world (Gaskin & Rayner 2013). Of the 359 seabird species worldwide, approximately one quarter breed in New Zealand and 10% are endemic to New Zealand breeding grounds, making the country a world centre of seabird diversity (Gaskin & Rayner 2013).

New Zealand network of Important Bird Areas (IBAs)

Important Bird Areas (IBAs) are the sites needed to ensure the survival of viable populations of most of the world's bird species. They are recognised as internationally important for bird conservation and known to support key bird species and other biodiversity. The IBA programme is run by an international conservation organisation (Birdlife International) and is implemented nationally by BirdLife Partners (in New Zealand Forest & Bird). IBA sites are identified by local experts applying international agreed criteria for terrestrial and marine areas.

In New Zealand the initial focus has been on identifying IBA sites for seabirds (Forest & Bird 2014; Figure 15). However, the presence of other bird species (land, shore and water birds) was also taken into account, and many of the seabird IBAs identified to date include such species as trigger species. To date the IBA programme in New Zealand identified:

1. Ninety-seven IBA sites on land, including offshore islands, principally colony sites, but also including major roosts and non-breeding congregatory sites.

2. Forty-four sites on inland rivers (for inland breeding gulls and terns) and in coastal areas such as harbours, estuaries and lagoons;

3. Twenty-six seaward extensions for foraging of limited range species and coastal and continental shelf areas

4. Forty-three areas for pelagic seabirds.
   Identified IBA sites on land or offshore islands within the Waikato region's CMA are:
   - Firth of Thames (NZ020)
   - Cuvier Island (NZ023)
   - Mercury Islands (NZ024)
   - Aldermen Islands (NZ025)
   - Gannet Island (NZ029)

Site descriptions for the identified IBAs for seabirds are being prepared and are expected to be available mid 2015 (Chris Gaskin personal comment January 2015). IBAs for other species groups (land, shore and water birds) will need to be identified to complete New Zealand's IBA network (Gaskin 2014).

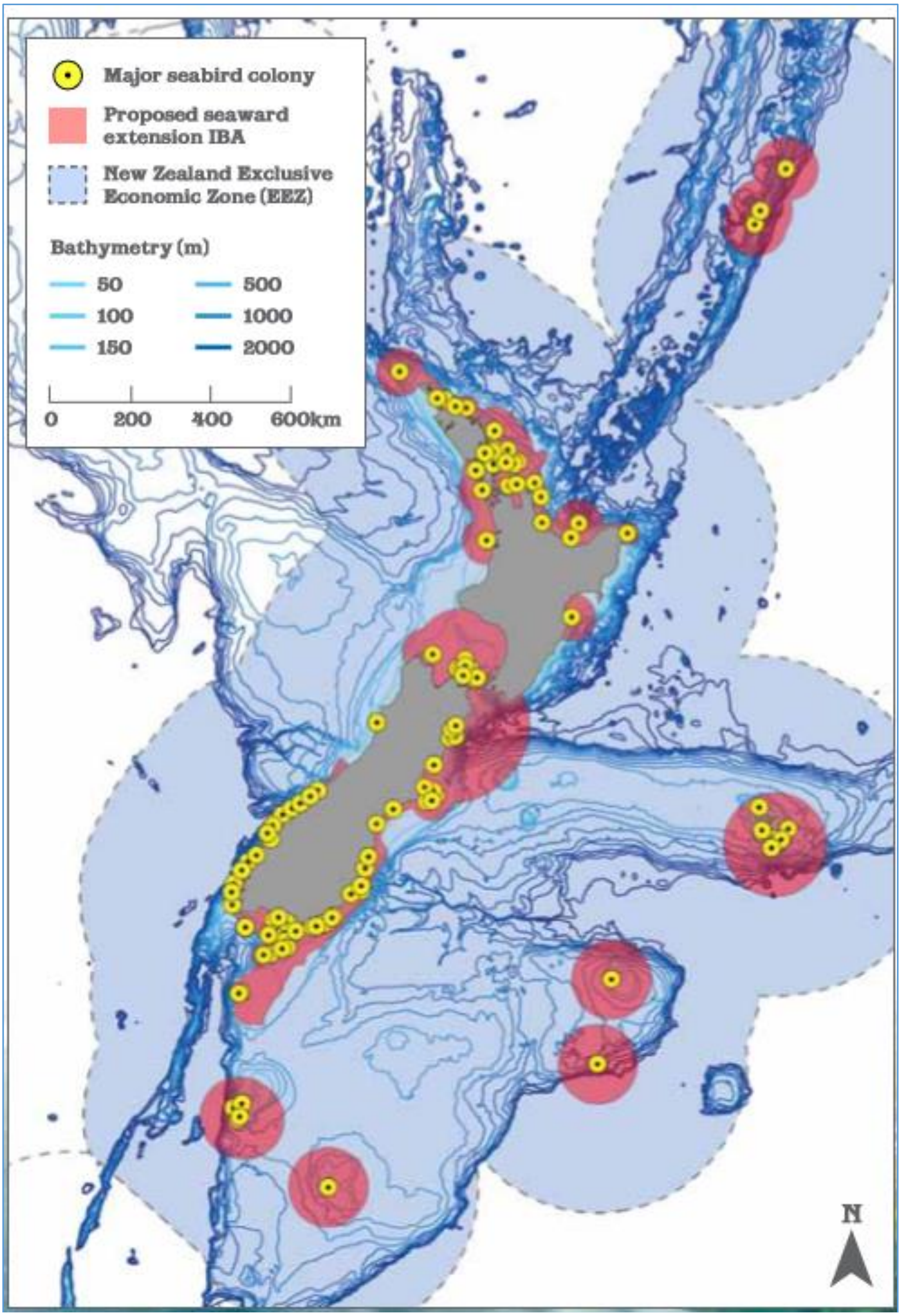

Figure 15. Major seabird colonies and proposed seaward extension IBA (Forest & Bird 2014).

5.2.1.2 Seabirds of the Hauraki Gulf

Over 70 species of seabird, approximately 20% of the world's seabird species (total 359 species), have been seen within the wider Hauraki Gulf Region (Gaskin & Rayner 2013). On a New Zealand scale the seabird diversity of the greater Hauraki Gulf region (26 breeding species, 4 regional endemics) ranks very highly compared to other New Zealand locations that have great international prominence as seabird sites (Gaskin & Rayner 2013). For example, the Kermadec Islands (a nature reserve of the highest conservation protection) supports only 14 breeding species (2 regional endemics; Gaskin 2011), the Chatham Islands supports 28 breeding species (5 regional endemics; Aikman and Miskelly 2004) and the Snares Islands 17 breeding species (2 regionally endemics; Miskelly et al. 2001).

In 2013 Gaskin & Rayner presented a strategic plan for seabirds in the wider Hauraki Gulf Region which included an overview of current knowledge regarding twenty-seven seabird species breeding in the Hauraki Gulf region, including their breeding habitat and recommendations to protect seabird species and enhance the understanding of them and their habitat. The described taxa include 14 petrels and shearwaters, 1 penguin, 1 gannet, 5 cormorants (shags), 3 gulls and 3 terns. 16 described species (59%) are endemic to New Zealand, and Buller's shearwaters, New Zealand fairy tern, Pycroft's petrel and black petrel breed nowhere else in New Zealand or the world. Distribution maps of known breeding sites of these species within the wider Hauraki Gulf were presented as part of the individual species profiles. The New Zealand storm petrel was discovered breeding on Hauturu/Little Barrier Island in February 2013, the only known breeding site for this species.

In 2013, Waikato Regional Council commissioned Gaskin & Miller to create "seabird layers" for the Hauraki Gulf Marine Spatial Plan. Predictive species distributions and species richness maps[31] were produced by modelling at-sea survey data (collected between 2006 and 2013) in combination with a number of physical and environmental variables that are either known, or suspected, to be correlated with seabird distribution and abundance (Miller & Gaskin 2013, unpublished). The 19 species included were: Buller's Shearwater, Flesh-footed Shearwater, Fluttering Shearwater, Little Shearwater, Fairy Prion, Black Petrel, Cook's Petrel, Pycroft's Petrel, Black-winged Petrel, Grey-faced Petrel, White-faced Storm Petrel, NZ Storm Petrel, Common Diving Petrel, Little Penguin, Australasian Gannet, Pied Shag, Southern Black-backed Gull, Red-billed Gull, White-fronted Tern (Gaskin & Miller 2013)(www.seasketch.org). A map showing the predicted total seabird species richness and the seabird species richness at breeding sites in the Hauraki Gulf is presented in Figure 16.

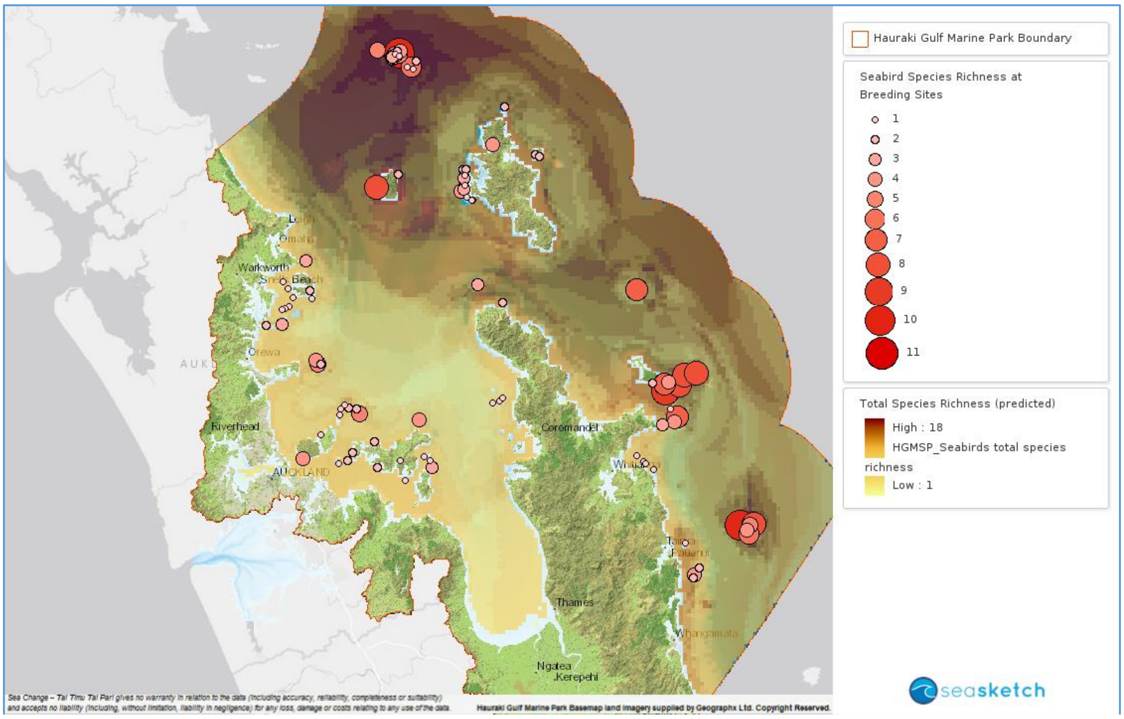

Figure 16. Predicted total seabird species richness and seabird species richness at breeding sites in the Hauraki Gulf (www.seasketch.org).

[31] Seabird presence and population estimate data were from C.P. Gaskin (unpublished data), R. Buxton (2013b), D.R. Towns (unpublished data) and supplemented by peer reviewed and grey literature. There are 417 seabird presence records on the islands and rock stacks within the wider Hauraki Gulf region (www.seasketch.org).

5.2.1.3 Seabirds using offshore islands in the Waikato region

References related to birds using offshore islands on the eastern side of the Coromandel Peninsula are shown in Table 12.

Table 12. Information for birds using offshore islands on the eastern side of the Coromandel (Bouma 2007; Unpublished DOC report).

Estuary/harbour	Bird survey	References
Gannet Island	Coastal Resource Inventory	Abrahamson 1990
	Counts Australasian Gannets as part of NZ fur seal surveys	Bouma 2007; Bouma et al. 2008
Cuvier Island	Observations Dowding	Personal comment Dowding 2007 in Bouma 2007
	Students Victoria University 2005: proposal NZ World Heritage Site	Hughes et al. 2005
	Observations Auckland University Field Club	Bellingham al. 1981
Great Mercury Island	Otago University: conservation potential of the Mercury Islands	Smuts-Kennedy 1998
	Birds of Great Mercury Island	Grace 1976
Red Mercury Island	Otago University: conservation potential of the Mercury Islands	Smuts-Kennedy 1998
	Students Victoria University 2005: proposal NZ World Heritage Site	Hughes et al. 2005
Stanley Island	Otago University: conservation potential of the Mercury Islands	Smuts-Kennedy 1998
	Observations 1967	Thoreson 1967
Double Island	Otago University: conservation potential of the Mercury Islands	Smuts-Kennedy 1998
	Eradication program 1992	McFadden 1992
Korapuki Island	Otago University: conservation potential of the Mercury Islands	Smuts-Kennedy 1998
	Restoration plan Korapuki Island	Towns & Atkinson 2004
	Eradication program 1991	McFadden &Towns 1991
	Ecological description island 1975	Hicks 1975
Green Island	Otago University: conservation potential of the Mercury Islands	Smuts-Kennedy 1998
	Birds with emphasis on diving petrels	Thoresen & Thomson 1991
Ohinau Islands	Ecological survey 1990	Taylor et al. 1990
Slipper Island	Checklist	Douglas & Gubb 1974
	Observations Dowding	Personal comment Dowding 2007 in Bouma 2007
Alderman Islands	Ecological survey 1994	Taylor et al. 1994

5.2.2 Shorebirds

5.2.2.1 Sites of importance to shorebirds in the Hauraki Gulf

As part of the Sea Change project a GIS layer was produced showing areas in the Hauraki Gulf that are known to contain important shorebird and wading bird roosting, breeding and feeding habitats. The results are presented in Figure 17. Areas in the Auckland Region were derived from Ornithological Society of New Zealand bird surveys and identify areas of importance for wading birds, New Zealand dotterel and New Zealand fairy tern (only known breeding area for this species in the Hauraki Gulf is Pakiri Beach)(www.seasketch.org).

Sites of importance around the Coromandel Peninsula were identified by Dowding (2013) (see next paragraph). More detailed maps of areas of importance to shorebirds in the Waikato region were produced by Waikato Regional Council (Waikato Regional Council GIS-layer "Hauraki Gulf Marine Spatial Plan Locations") and are presented in appendix 3.

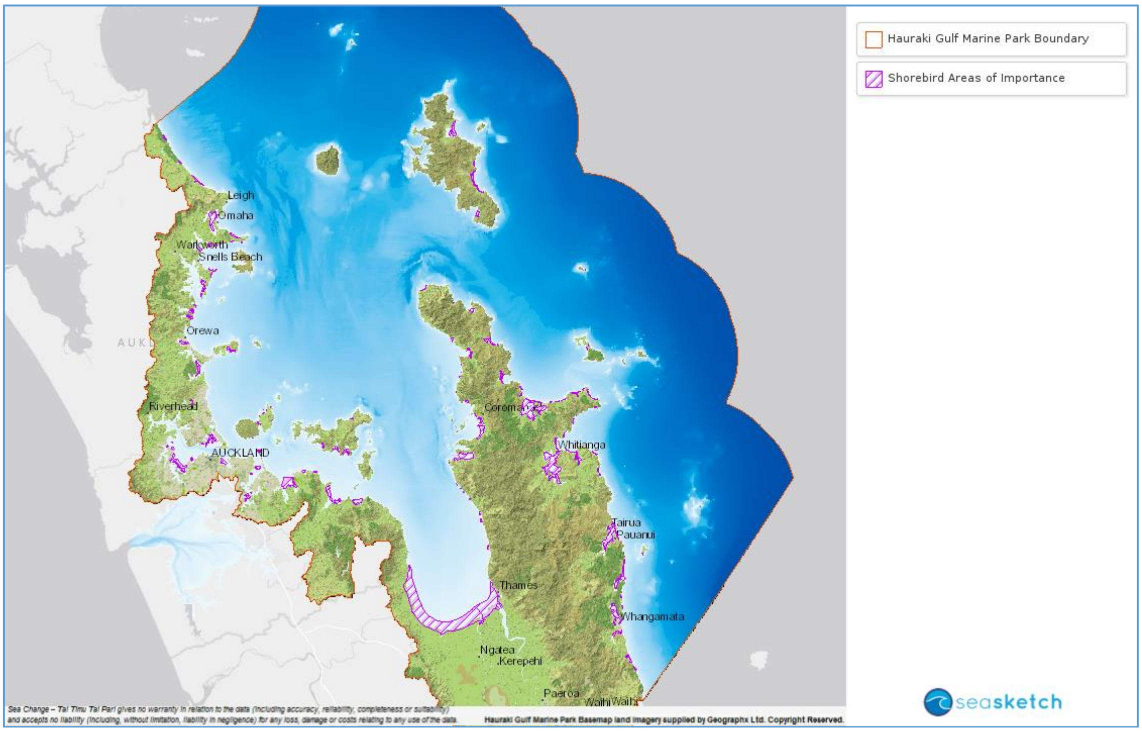

Figure 17. Areas in the Hauraki Gulf that are of importance to shorebirds (www.seasketch.org).

5.2.2.2 Sites of importance for shorebirds on the east coast of the Waikato region

Dowding (2013) identified sites of importance to coastal and estuarine birds on the east coast of the Waikato region (report commissioned by Waikato Regional Council). Based on criteria on significance provided in the Ramsar Convention and the Proposed Waikato Regional Policy Statement, sites were assigned to one of the following four broad priorities:

- Priority 1: The site regularly holds 1% of the global population of one or more species or subspecies that were classified as Threatened under the New Zealand Threat Classification System List for 2012 (Robertson et al. 2013).
- Priority 2: The site regularly holds one or more Threatened or At Risk species or subspecies, or values are insufficiently known but type of habitat, older data, or other factors suggest that this is probable.
- Priority 3: The values of the site for coastal birds are not presently considered high; Threatened or At Risk shorebird or wetland bird taxa are not currently known to be present.
- Priority 4: Where shorebird/wetland bird values of a site are unknown, it is classified as Priority 4 (Insufficient Data).

The following data sources were used to identify areas of importance:

- Unpublished results of a national census of northern New Zealand dotterels in 2011 (NNZD census 2011), with an update for some sites in 2012 (Susan Bryant personal comment). The 2011 census resulted in a population estimate of 2100-2200 individuals, including an estimated 900 breeding pairs. 1% levels for this taxon were therefore set at 9 pairs or more at breeding sites, and 21 adult individuals or more at roosting, flocking, or feeding sites;

- Data on northern New Zealand dotterels contained in Dowding (2006);

- Unpublished sightings and counts of shorebirds made in the Firth of Thames and on Coromandel Peninsula between 2005 and 2012, and retrieved from the Ornithological Society's shorebird database. This dataset contained 1136 individual counts, 974 of them from the Firth of Thames and 162 from sites on Coromandel Peninsula;

- Two reports on shorebirds in the Firth of Thames (Battley & Brownell 2007, Dowding 2008a);

- Information from papers in the Ornithological Society's journal Notornis;

- Species records from a series of estuarine vegetation surveys undertaken by Meg Graeme and published by Environment Waikato;

- Records from the Department of Conservation's bittern database;

- Records from a Department of Conservation waterbird database under construction, listing records of crakes, rails, and fernbird;

- An unpublished report by Bouma (2007)[32] listing the biological values of ASCVs in the Waikato region. Some older information from this report was used where more recent data do not exist;

- A report on habitat networks of New Zealand shorebirds (Dowding & Moore 2006);

- Sightings and counts recorded at Birding-NZ.net;

- Personal communications from individuals;

- Unpublished counts, observations, and reports by Dowding.

References for the 36 areas of importance for shorebirds are presented in table 13. These references were mainly extracted from Dowding 2013, who prepared individual 'site inventories' containing information on the importance of the sites for birds, threats, information gaps and references, but also includes other references (in bold).

[32] This report made reference to reports and data sources related to resource consent applications such as Whitianga Waterways, Whitianga marina, Tairua marina, Tairua Forest Ohio Block Operations, Whangamata marina and mangrove clearances at Whangamata, but did not summarise the actual information.

Table 13. **References for the 36 areas of importance for shorebirds identified by Dowding 2013 (maps of priority 1 and 2 areas are presented in appendix 3).**

Harbours/estuaries	Priority	References
Firth of Thames (Kaiaua to Waihou river)	1	Veitch & Habraken (1999); Dowding & Moore (2006); Battley & Brownell (2007); Dowding (2008a); unpublished OSNZ shorebird database; NNZD census 2011; DOC banded rail database.
Firth of Thames (Waihou river to Tararu)	1	Battley & Moore (2004); A. Habraken (pers. comm.), unpublished OSNZ shorebird database.
Coast north of Thames (Te Puru to Matariki Bay)	2	NNZD census 2011.
Manaia Harbour	2	Graeme (2008); NNZD censuses 2004 and 2011; **McCarthy 2006; Graeme 1998b; Abrahamson 1990**
Te Kouma Harbour/Peninsula	4	NNZD censuses 2004, 2011.
Coromandel Harbour	1	P. Stewart (pers. comm); unpublished OSNZ shorebird database; NNZD census 2011; Birding-NZ.net; **Dowding 2006; Abrahamson 1990**
Koputauaki Bay to Tukituki Bay	2	NNZD census 2011; Birding-NZ.net.
Colville Bay	1	Graeme (2013); Dowding (2006); NNZD census 2011; Birding-NZ.net; unpublished OSNZ shorebird database; DOC fernbird database; **Forbes 1997; Abrahamson 1990**
Waiaro Bay	2	NNZD census 2011
Port Jackson to Fletcher Bay	2	NNZD census 2011; **McCarthy 2006; Abrahamson 1990**
Stony Bay	2	NNZD census 2011; **McCarthy 2006**
Port Charles	2	NNZD census 2011; Birding-NZ.net.
Waikawau Bay (including estuary) and Little Bay	1	NNZD census **2004**, 2011; Moehau Environment Group (2010); **Dowding 2006**; **Abrahamson 1990**
Kennedy Bay	2	NNZD census 2011
Whangapoua Harbour (including Whangapoua beach and Matarangi spit)	1	Dowding (2006); Dowding & Moore (2006); NNZD census 2011; DOC bittern and fernbird databases; Birding-NZ.net; **Graeme June & July 2001; Abrahamson 1990**
Gray's beach-Kuaotuna beach	2	NNZD census 2011
Kuaotuna Peninsula (including Otama Beach and Opito Bay)	1	NNZD census 2011; DOC bittern database; **McCarthy 2006; Abrahamson 1990**
Ohinau Island group	3	Chappell 2008; **Taylor et al. 1990**
Matapaua Bay to Whauwhao beach	2	NNZD census 2011
Mercury Island Group and Cuvier Island	2	**<u>Cuvier Island</u>: Hughes et al. 2005; Bellingham et al. 1981; <u>Great Mercury Island</u>: Grace 1976; Smuts-Kennedy 1998; <u>Red Mercury Island</u>: Hughes et al. 2005; Smuts-Kennedy 1998; <u>Stanley Island</u>: Smuts-Kennedy 1998; Thoreson 1967; <u>Double Island</u>: Smuts-Kennedy 1998; McFadden 1991; <u>Korapuki Island</u>: Towns & Atkinson 2004; Smuts-Kennedy 1998; McFadden &Towns 1991; Hicks et al.**

		1975; <u>**Green Island**</u>**: Thoreson & Thomson 1991; Thoreson 1967**
Wharekaho	2	Unpublished data Dowding, unpublished OSNZ shorebird database, NNZD census 2011.
Whitianga Harbour	2	NNZD census 2011, Graeme (2009), DOC bittern and fernbird databases; **Graeme 1999; Abrahamson 1990.**
Cook's beach, Purangi estuary, Cathedral Cove and Hahei beach	2	NNZD census 2011, W. Hare (pers. comm.); **Humphreys & Taylor 1990; Coffey & Grace 1990; Abrahamson 1990.**
Hot water beach	2	**Abrahamson 1990**
Alderman Islands	3	**Taylor et al. 1994**
Tairua Harbour (including Tairua Ocean Beach, Pauanui Beach and Spit, and Pauanui Waterways)	1	NNZD census 2011; DOC banded rail database; **Dowding 2006;** Larcombe 2005; Dowding 2005; Pierce 2005; **Pierce & Owen 2004; Bioresearches 1996a, 1995, 1994, 1993a,b,c,d,e,f,g; Abrahamson 1990**
Slipper Island	2	NNZD census 2011; **Douglas & Gubb 1974**
Ohui	2	Dowding 2012; Dowding 2003
Wharekawa Harbour and Opoutere sandspit	1	DOC bittern and banded rail databases; Dowding 2012; NNZD census 2011; **Bioresearches 2011, 2010, 2009, 2008, 2007, 2006**; Dowding 2006; **Bioresearches 2005, 2004, 2003, 2002, 2001, 1999, 1998, 1997; Graeme 1997**; **Bagshaw 1994**; **Abrahamson 1990**; **Parrish 1981**
Onemana	2	NNZD census 2011
Tokakahakaha (beach south of Onemana)	2	Unpublished data Dowding, NNZD census 2011
Whangamata Harbour	1	Unpublished data Dowding, Rayner 2011; **McCarthy 2006**; **Pierce & Owen 2004**; **Bioresearches since 2003-ongoing**; **Dowding 1997**
Otahu Estuary	2	Unpublished data Dowding; NNZD census 2011; **McCarthy 2006; Abrahamson 1990**
Clark Island Group	3	**Abrahamson 1990**
Whiritoa beach	2	Unpublished data Dowding, NNZD census 2011
Mataora Bay	2	Unpublished data Dowding, NNZD census 2011

5.2.2.3 Shorebirds using the West Coast of the Waikato region

Dowding (2010; internal migrants and resident shorebirds) and Battley (2009, 2010; internal and external migrants) collected information on shorebirds using the Waikato region's west coast as part of data for the Taharoa wind farm and Hauauru Ma Raki wind farm resource consent applications. The presented information showed significant numbers of resident and migrating shorebirds using the west coast of the Waikato region:

<u>Resident shorebirds</u>

- Up to 70 variable oystercatchers wintering at Port Waikato in 2009;
- Estimated population of 22 New Zealand dotterels between Port Waikato and Taharoa;
- Breeding colony of Caspian terns at Port Waikato in 1995 (232 birds with nests and chicks in 1995);
- Large numbers of white-fronted terns seen at Kaawa beach, but significance of area unclear.

Migrating shorebirds

- West Coast is part of the migration route of South Island Pied Oystercatchers. Northward migration begins in December with peaks through January and early February and fewer birds in March. Southward migration starts in mid-June with peaks in July and August;

- Kawhia Harbour is one of the most important wintering sites for black stilts, one of the world's most threatened shorebird species. Records suggest that this species migrates along the West Coast;

- Approximately 10,000 pied stilts use the west coast as a migration route to breeding areas in harbours from Kawhia to Parengarenga;

- Approximately 6,000 banded dotterels use the West Coast as a migration route;

- Approximately 5,000 wrybills migrate along the West Coast (95% of the global population).

In 2007, Bouma (unpublished DOC report) collected information and references related to birds using ASCVs along the west coast of the Waikato region including Port Waikato, Marokopa estuary and River mouth, Mokau River mouth, Kawhia Harbour, Aotea Harbour and Raglan Harbour and provided very short summaries of the available data. For these areas the report presented specific information on sightings/records of species classified by Hitchmough et al. (2005) as nationally critical, nationally endangered, nationally vulnerable, serious decline, gradual decline, sparse and range restricted extracted from "Classified Summarised Notes" (CSN)[33] from 1 July 1999 to 30 June 2003 (Parrish, 2001, 2002, 2003, 2006). Other references for information on birds using these areas on the west coast of the Waikato Region's CMA identified in the Bouma 2007 report include:

- Information from the Coastal Resource Inventory carried out by the Department of Conservation (Abrahamson 1990);

- A review commissioned by DOC in 2004 collating information on the important regions, habitats and sites used by seven endemic shorebird species in New Zealand: New Zealand pied oystercatcher, variable oystercatcher, pied stilt, black stilt, New Zealand dotterel, banded dotterel and wrybill. For each taxon its status, range and numbers are outlined and important breeding and non-breeding sites described (Dowding & Moore, 2006). This review included data from bird counts carried out at Port Waikato by the Ornithological Society of New Zealand (OSNZ).

- Site descriptions in the directory of wetlands in New Zealand (Cromarty & Scott 1996). This directory describes 73 wetlands and wetland complexes that meet the criteria for international importance. The lower Waikato River and estuary were identified as such a wetland in this report;

- Notes from estuarine vegetation surveys carried out in Aotea Harbour (Graeme 2005/43), Kawhia Harbour (Graeme 2005/42), Raglan Harbour (Graeme 2005/44) and Port Waikato (Graeme 2005/41);

[33] Classified Summarised Notes (CSN) are annual lists of counts and sightings of birds, arranged by species published in Notornis. The purpose of CSN is to record the results of bird census counts, anecdotal observations of behaviour and to improve the understanding of bird distributions in New Zealand. In general those observations that do not add to knowledge of bird distribution as shown in "The Atlas of bird distribution in New Zealand", are ignored in the CSN.

- The Maniapoto State of Environment Report describing natural features of Marokopa estuary and Mokau River mouth (Maniapoto Maori Trust Board, 2002).

5.2.3 Wetland birds

O'Donnell et al. (2014) provided a list of 30 indigenous bird species that characteristically feed, breed or shelter in freshwater wetlands in New Zealand. The list includes 18 species listed in Miskelly et al 2008 as threatened or at risk. Largely restricted to these wetlands are Australasian bittern, brown teal, marsh crake, spotless crake, North Island fernbird and banded rail (all classified as threatened or at risk)[34].

Specific surveys to determine the abundance and distribution of coastal wetland birds within the Waikato region's CMA appear to be limited to resource consent applications for the removal of mangroves in Whangamata Harbour (Rayner 2011; Wildlands 2011, Wildlands 2013) and Tairua harbour (Wildlands 2012) and have mainly focussed on banded rails (see also 5.5.3)[35]. Records for these species presented in the 'Atlas of the bird distribution in New Zealand 1999-2004' (Robertson et al. 2007) are shown in Figure 18.

Figure 18. Distribution of six bird species that are largely restricted to wetlands (Robertson et al. 2007).

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[34] Although freshwater wetlands, they may border estuaries or harbours in the Waikato region's CMA.

[35] Recently protocols for the inventory and monitoring of populations of the Australasian bittern have been developed by the Department of Conservation (O'Donnell & Williams 2015). Draft protocols for monitoring fernbirds, spotless crake and marsh crake were developed by the Department of Conservation in 2009 (O'Donnell 2009b, 2009c, 2009d).

5.3 Vulnerable life stages

The breeding season and migration movements can be regarded as vulnerable life stages of birds. Information on the breeding season, breeding habitats and foraging habitats and movements provided in the individual seabird profiles of the 27 species breeding in the wider Hauraki Gulf Region presented in Gaskin & Rayner (2013) are summarized in Table 14. The breeding season of coastal and estuarine bird species listed as threatened or at risk within Waikato region's CMA (including shorebirds and freshwater/wetland species) are presented in Table 15. Maps showing the known breeding sites of these species within the Waikato region's CMA are shown in chapter 9 of Gaskin & Rayner (section 3 Inner Hauraki Gulf, Firth of Thames and western Coromandel; and section 4 Eastern Coromandel to Whangamata Harbour).

Table 14. Breeding season, breeding habitat, foraging habitats and movements of 27 seabird species breeding in the wider Hauraki Gulf Region (information extracted from Gaskin & Rayner 2013).

Bird species (NZ conservation status)	Breeding season	Breeding habitat	Foraging habitat and movements
Northern blue penguin (at risk, declining)	July - Feb, 1-2 eggs laid Aug-Oct, hatching Sept-Nov after c. 36 days, fledging Nov-Jan after c. 54 days.	Rock and natural crevices, burrows and under thick vegetation.	Sedentary, coastal waters close to breeding sites.
Black petrel[36] (nationally vulnerable)	October-July, 1 egg laid Nov-Dec, incubation c. 57 days, chicks hatch end Jan-Feb, chicks fledge April-July after c. 107 days.	Breed colonially in forested habitat, nesting in underground burrows.	Offshore foraging habitats, shelf break and pelagic waters. Migrates to eastern Pacific off South America during winter non-breeding period.
Grey faced petrel (not threatened)	April- December, 1 egg laid June-July, hatching Aug-Sept after c. 55 days, chicks fledge Dec-Jan after c. 118 days.	Breed colonially in forested and or scrub habitats on islands, islets and some mainland headland sites, nesting in underground burrows.	Offshore in deep sub-tropical and temperate waters of Tasman Sea and Pacific Ocean. Roams widely (Australia to central South Pacific) within subtropical and temperate waters during non-breeding.
Black winged petrel[32] (not threatened)	October-May, 1 egg laid Dec-Jan, hatching Feb-Mar and fledging May-June.	Burrow nesting in scrub or open habitats.	Pelagic foraging to in Tasman Sea and South Pacific Ocean during breeding as far south as Subtropical Convergence. Migrates to Equatorial and North Pacific Ocean.
Cook's petrel[32] (relict)	Sept-April, 1 egg laid mid-November, incubation 46-50 days, chick rearing approximately 87 days.	Burrow nesting in forest predominantly between 300 – 700 m on Little Barrier Island.	Pelagic foraging in Tasman Sea and Pacific Ocean during breeding. Migrates to North Pacific Ocean during New Zealand winter.
Pycroft's petrel (vulnerable, recovering)	October-April, 1 egg laid Nov-Dec, hatching Jan after c. 47 days, fledging March-April after c. 80 days.	Burrow nesting in forest and or scrub habitats.	Pelagic foraging in Pacific Ocean during breeding with concentration off east coast of North Island. Migrates to central tropical Pacific during New Zealand winter.
Fairy prion[32] (relict)	Aug-Jan, 1 egg laid October, chicks fledge in Jan.	Breed colonially, nesting in underground burrows and rock crevices on offshore islands.	Essentially unknown.
Buller's shearwater[32] (naturally uncommon)	October-May, 1 egg laid Nov-Dec, incubation c. 51 days,chicks fledge in April-May after c. 90 days.	Breed colonially in forested habitat, nesting in underground burrows.	Offshore foraging habitats, shelf break and pelagic waters. Migrates to eastern Pacific off South America during winter non-breeding period.

[36] Not known to breed in the Waikato region's CMA.

Flesh-footed shearwater (nationally vulnerable)	Sept-May, 1 egg laid Dec, incubation c. 53 days, chicks fledge April-May after c. 92 days.	Breed colonially in forested and or open habitats, nesting in underground burrows.	Offshore pelagic foraging habitats during breeding season. Migrates to North Pacific Ocean winter non-breeding period.
Sooty shearwater (declining)	Sept-May, 1 egg laid Nov-Dec, eggs hatch Jan after c. 53 days, chicks fledge April-May after c. 97 days.	Breed colonially in forested and or scrub or open habitats, nesting in underground burrows.	Offshore foraging within region and to Sub Antarctic waters. Migration to North Pacific Ocean during winter non-breeding period.
Fluttering shearwater (relict)	July-Feb, 1 egg laid Sept-Oct, eggs hatch Oct-Nov and chicks fledge Jan-Feb.	Breed colonially in forested and or scrub or open habitats, nesting in underground burrows and under boulders.	Common inshore species but also offshore foraging. Post breeding, most birds remain in local waters. At least partial migration to eastern Australian seabird during winter nonbreeding period.
North Island little shearwater (vulnerable, recovering)	May-Dec, 1 egg laid June-July, incubation 52-58 days, chicks fledge Nov-Dec after 70-75 days.	Breed colonially in low scrub to forest habitats, nesting in underground burrows or natural crevices.	Offshore foraging but poorly known. Migrates to south-east Pacific Ocean in non-breeding season.
White faced storm petrel (relict)	Aug - Feb, 1 egg laid October-November, chick fledge Jan-March.	Breed colonially, nesting in underground burrows, rock crevices and or under dense mats of vegetation.	Forages offshore breeding and migrates to eastern tropical Pacific during austral winter. Poorly known.
New Zealand storm petrel[32] (critical)	Commencing late Dec-Jan, poorly known.	Not known.	Present WHGR from late September to early June on current data; possibly disperses to Coral Sea. Poorly known.
Common diving petrel (not threatened)	March -Jan, 1 egg laid Jul-Oct, incubation c. 53 days, chicks fledge Nov-Jan after c. 52 days.	Breed colonially, nesting in underground burrows or on surfaces under dense vegetation.	Inshore and offshore foraging habitats near breeding colonies. Migrates south during summer non-breeding period.
Australasian Gannets (not threatened)	July -April, 1 egg laid August-December, chicks fledge March-April.	Breed colonially on open rock stacks, islands and coastal headlands building a raised pedestal nest from guano and seaweed.	Migratory. Breeding populations feed throughout inshore and offshore waters. Migrates to east coast of Australia during winter.
Pied shag (nationally vulnerable)	Colonies active all year, laying July-Oct and Jan-March, fledging after 43-53-60 days.	Colonies commonly positioned in trees overhanging sea > 10 m above water. Nest a large platform of sticks and seaweed.	Sedentary, inshore waters, solitary but occasionally form feeding flocks when prey abundant.
Spotted shag (not threatened)	Variable, laying in March, Aug and Dec.	Rocky coastlines, cliffs and islets near open ocean.	Mainly deep water up to 15 km from shore.

Little shag[32] (not threatened)	Eggs laid Aug-Feb.	Trees overhanging freshwater and estuaries, ledges on river gorges or sea cliffs.	Sheltered coastal waters, estuaries, harbours and rivers and lakes. Disperse widely following breeding.
Black shag[32] (naturally uncommon)	Eggs laid June-October, incubation in 27-31 days and fledging in 7 weeks.	Trees overhanging fresh and or coastal waters, coastal or river cliffs.	Sheltered coastal waters, estuaries, harbours and rivers and lakes. Disperse widely following breeding.
Little black shag[32] (naturally uncommon)	Eggs laid Aug-Feb.	Trees overhanging freshwater and estuaries, ledges on river gorges or sea cliffs.	Sheltered coastal waters, estuaries harbours and rivers and lakes. Disperse widely following breeding.
Southern black-backed gull[32] (not threatened)	September-March, 1 -2-3-5 eggs laid Oct-Nov, incubation 23- 27-30 days and fledging at c. 50 days old.	Nest in colonies, or as individual pairs, on dunes, sandspits/shellbanks, boulderbanks, rocky islets and city buildings.	Consider sedentary with local movements.
Red-billed gull (nationally vulnerable)	Oct-Feb, 1-2-5 eggs laid Oct-Dec, incubation 24-25-27 days, chick rearing c. 37 days.	Sandspits, boulderbanks, shellbanks, gravel beaches, rocky headlands, islets and offshore islands.	Poorly documented.
Black-billed gull (nationally critical)	Sept-March, 1-2-4 eggs laid Sept-Dec, incubation 20-24 days and fledging at c. 26 days old.	Nest on in colonies on coastal sandspits, boulderbanks or shellbanks.	Poorly known.
New Zealand fairy tern[32] (nationally critical)	November-February, 1-2 eggs laid mid-November, incubation 23-25 days, chick rearing 22-23 days.	Nests on low lying sand-spit, beach and dune habitats.	Non-migratory with inshore coastal foraging during breeding. Kaipara Harbour an important overwintering habitat, also for non-breeding birds and failed breeders.
Caspian tern[32] (nationally vulnerable)	Sept-March, 1-3 eggs laid Sept-Dec, incubation 26-28 days and fledging at 33-38 days old.	Nest on low lying sand spit, beach and/or dune habitats, and occasionally on inner Gulf islands.	Inshore, estuarine foraging during breeding. Movements focused within productive harbours during non-breeding period.
White-fronted tern (at risk declining)	Sep-Feb, 1-2 eggs laid mid-Oct-Jan, incubation c. 24 days, chick rearing 29-35 days.	Nests on low lying sand-spit, beaches, rocky islets, rock stacks and offshore islands.	Primarily inshore, harbour and estuarine foraging for surface shoaling fish. Non-breeding movements unknown.

Table 15. Breeding season of coastal and estuarine bird species listed as threatened or at risk within the Waikato region's CMA (information extracted from nzbirdsonline.org.nz)

Bird species (NZ conservation status)	Breeding season
Eastern bar-tailed godwit (at risk, declining)	May–August (Alaska); migration: staggered through March
Variable oystercatcher (at risk, recovering)	October–March
South island pied oystercatcher (at risk, declining)	Spring–summer
Pied stilt (at risk, declining)	Lowland areas June–July, inland birds August–October
Black stilt (threatened, nationally critical)	August–December
Northern NZ dotterel (threatened, nationally vulnerable)	August–February
Banded dotterel (threatened, nationally vulnerable)	August–November
Wrybill (threatened, nationally vulnerable)	September–October, second clutches to January
Brown teal (at risk, recovering)	Most months except late autumn, mostly July–September
Reef heron (threatened, nationally endangered)	September–December
Australasian bittern (threatened, nationally endangered)	August–December
Banded rail (at risk, declining)	Spring–summer
North island fernbird (at risk, declining)	August–March

5.4 Sensitivity to specific pressures

Gaskin (2014) and Gaskin & Rayner (2013) identified several threats to seabirds in the wider Hauraki Gulf Region including (in no specific order):

- Introduced predators including cats, rats, pigs, mustelids and hedgehogs;
- Habitat modification and urban development/subdivisions;
- Marine litter, pollution and oil spills;
- Interaction with fisheries[37];
- Human disturbance caused by different activities;
- Fire.

The vulnerability of seabirds to these threats depend on different factors, but species specific information on for example breeding seasons, breeding habitats and foraging habitats and movements can assist in assessing the vulnerability to specific pressures.

[37] In 2013 a National Action Plan for Seabirds (NPOA-Seabirds 2013) developed by the Department of Conservation and the Ministry of Primary Industries set out a long- term strategic approach to reduce the incidental by-catch of seabirds in New Zealand fisheries zones or by New Zealand flagged vessels in high seas fisheries.

A substantial number of actual and potential threats to shorebirds in the coastal zone have been identified (see for example Dowding 2008a). In the short term, predation and disturbance have the greatest impact on resident species. In the longer term, habitat loss and degradation are threats to both resident and migratory species (Dowding 2013).
Threats to wetland birds in the coastal marine area include habitat loss, predation, invasive species, overexploitation and climate change (O'Donnell et al. 2014 and references therein).

5.4.1 Sensitivity of birds to human disturbance

Disturbance distances can depend on many different factors such as type of activity (e.g. boating, walking (with dogs), flying) frequency of disturbance (e.g. habituation) and time of the year (e.g. breeding season). Several overseas studies have focussed on determining disturbance distances or initial flight response distances of birds resulting from different activities, and have subsequently used these distances to identify buffer zones around foraging and breeding birds to manage disturbance. Examples include:

- A review of flight-initiation distances of 250 Australian bird species (Weston et al. 2012; includes wetland species).

- A review of disturbance distances of 26 priority bird species that breed in Scotland based on existing studies and an expert opinion survey (Ruddock & Whitfield 2007).

- A two year study to develop buffer zones to protect foraging and loafing water birds from disturbance by personal watercraft in Florida. Thirty-nine bird species were exposed to the rapid approach of a personal watercraft and an outboard powered boat to determine the flushing distances to these two watercraft. Considerable variation in the flush distances existed among individuals within the same species and between species with minimum and maximum flush distances ranging from 5 m to 159 m and average flush distances from 17.64 to 57.92 m (Rodgers & Schwikert 2002).

- An assessment of the disturbance of various shorebird species by pedestrians and recreational and commercial shellfish harvesters at a key stop over site at Monomoy National Wildlife Refuge, Massachusetts, USA (Koch & Paton 2014). They approached 11 species of shorebirds to quantify flight-initiation distances (FID). The results showed that species and age affected FID. Based on adult FID they developed species-specific buffer-zones for 11 species varying from 61-186 m.

- Guidelines for managing visitation seabird breeding islands in the Great Barrier Reef Marine Park based on the vulnerability of breeding seabirds to different human activities (e.g. tourism, recreation, boating, fishing, navigational aids and meteorological stations, defence activities, aircraft and research activities)(Claridge 1997). For each of these human activities known impacts are described together with possible control/mitigation measures. Examples of control measures that specify specific buffer zones include:
    - the establishment of a boat-free zone for a distance of 200 m from high water mark around the island (if small) or from high water mark where colonies occur close to shore (if larger);

    - defence activities should only occur at a distance of greater than 300 m from any surface-nesting seabirds and outside the colony area of burrow-nesting seabirds;

    - standardise controls on aircraft so that there is no overflight of seabird breeding islands at less than 1,500 feet and no lateral approach closer than one kilometre. Where seaplanes are permitted to operate in the vicinity of breeding seabirds they are not permitted to take off or land within 300 m of the island.

5.4.2 Sensitivity of wetland birds to habitat loss and predation

Sensitivity to habitat loss

All six wetland species largely restricted to wetlands and classified as threatened or at risk (e.g. Australasian bittern, brown teal, marsh crake, spotless crake, North Island fernbird and banded rail) can be affected by habitat loss. However, of particular concern in the Waikato region's CMA are potential effects of mangrove removal on banded rail[38].

Bellingham (2013) provided information on banded rails on the New Zealand birds online website (nzbirdsonline.org.nz/species/banded-rail) covering for example their distribution and habitats, behaviour and ecology, breeding, food and threats. The information refers to several studies on banded rails including a study on foraging distances and habitat preference of banded rail in the Ohiwa Harbour (Botha 2010) and studies on the habitat use and distribution of banded rails in the Nelson and Malborough regions (Elliott 1987; Elliott 1989). Some information extracted from these information sources includes:

- Banded rail were once common throughout New Zealand, but their distribution in the North Island is now confined to Northland, Auckland, Waikato and Bay of Plenty Regions.

- This endemic New Zealand subspecies is currently classified as 'at risk – declining', with a qualifier of 'data poor' to indicate that the classification is based on limited information.

- In the North Island banded rail use both saltmarsh, mangroves and rush-covered freshwater wetlands as their preferred habitat.

- Banded rails consume snails, crabs, insects, worms and spiders, but also feed on dead fish, seeds and fruit when available. The study in Ohiwa Harbour revealed that banded rail foraged within 6 m of saltmarsh where saltmarsh adjoins open mudflats (and an average of only 1 m away from rushes), but up to 280 m from saltmarsh where this movement occurs under the cover of mangroves.

- Banded rail breed in spring and summer, constructing a rough platform of rush and reed fragments, usually in jointed rush thickets between 10 cm and 50 cm above ground or water.

Saltmarsh habitat has been lost throughout New Zealand considerably reducing habitat available to banded rail. In contrast mangroves have expanded in many North Island estuaries and may have enhanced foraging habitat available to banded rail (Waikato Regional Council memo #3021027). In the Waikato region's CMA saltmarsh habitat around Coromandel harbours has also been lost and mangrove habitat increased. Please refer to the maps in appendix 2 and chapter 3 of this report for specific information on trends in saltmarsh and mangrove communities in estuaries and harbours in the Waikato region's CMA.

Mangrove clearances have been carried out in several harbours around the Coromandel Harbour including Wharekawa Harbour, Whangamata Harbour and Tairua Harbour. Specific banded rail surveys were carried in Whangamata Harbour (Wildlands 2011, 2013) and Tairua Harbour (Wildlands 2012) to be able to assess potential effects of mangrove removal on this species. However, these surveys were limited and did not provide conclusive information on the total numbers and/or distribution of this species in both harbours and did not quantify potential effects. The reports recognised the removal of mangroves as a threat to banded rails and recommended to accompany the removal of mangroves with restoration measures that improve the habitat for banded rails (e.g. restoring saltmarsh and terrestrial margins of the harbours), and to retain ecological corridors and connectivity.

[38] Effects of mangrove removal on sediment characteristics and benthic communities after removal of mangroves at twenty sites in the Auckland region are described in Lundquist et al. 2014.

Waikato Regional Council and Wildlands identified several specific research topics to better understand the impact of mangrove removal on banded rail (Waikato Regional Council memo #3021027) including investigations of:

- bird behaviour (quantifying movement and feeding patterns, particularly in saltmarsh and mangrove habitats);
- territory sizes and carrying capacity of habitats;
- movements of banded rails after removal of mangroves (maybe using radio-tracking of birds);
- the role of predation in population dynamics;
- lag effects/long term effects on banded rail following mangrove removal;

Sensitivity of wetland birds to predation

O'Donnell et al. (2014) reviewed impacts of introduced mammalian predators on indigenous birds of freshwater wetlands in New Zealand and identified a wide range of predators on wetland birds. Most frequent predators were cats, but dogs, stoats, rats, and ferrets were also common predators. Australasian bittern, brown teal, spotless crake, and marsh crake appeared to be particularly vulnerable to predation. The authors predicted that banded rail and North Island fernbird would be more resilient because of shorter attendance at nests and higher fecundity.

6 Marine mammals

6.1 Protected, threatened or at risk species

All marine mammals are protected under the Marine Mammal Protection Act (1972).

Marine mammals listed as threatened or at risk in the New Zealand treat classification systems lists within the Waikato region's CMA include Bryde's whales (nationally critical), Maui's dolphin (nationally critical), bottlenose dolphins (nationally endangered) and southern right whales (nationally endangered)(Baker et al. 2010).

6.2 Inventories and surveys

6.2.1 Marine mammals in New Zealand waters

Berkenbusch et al. (2013) provided an overview of available information on the distribution, population status (i.e., the population size and population trends, both globally and in New Zealand waters), age at first reproduction, maximum growth rate, breeding locations and seasonality, and longevity of 35 marine mammals species inhabiting New Zealand waters.

6.2.2 Marine mammals in the Hauraki Gulf

The following summary extracted from the Sea Change project (Biodiversity & Biosecurity Roundtable report) provides a brief description of the presence of marine mammals in the Hauraki Gulf:

"The cetacean fauna of the region is relatively diverse and includes southern right whale, humpback whale, blue whale, Bryde's whale, sei whale, minke whale, common dolphin, striped dolphins (*Stenella coeruleoalba*), bottlenose dolphin, killer whale, false killer whales, long-finned pilot whale and a variety of beaked whales (Baker 1983; Visser 2000; Baker & Madon 2002; Constantine 2002; O'Callaghan & Baker 2002; Stockin et al. 2008; Visser et al. 2010; Wiseman et al. 2011; Zaeschmar et al. 2012). Resident species are Bryde's whale, common dolphin, bottlenose dolphin and killer whale. Bryde's whales are concentrated in inner Hauraki Gulf, with smaller clusters of sightings off Cape Brett, Cape Karikari and in the vicinity of Parengarenga Canyon (Baker & Madon 2002; O'Callaghan & Baker 2002; Wiseman et al. 2011). Common dolphins are widespread[39], but there is some evidence that Hauraki Gulf provides important foraging and nursery habitat for this species (Stockin et al. 2013). Genetic evidence shows there is little or no connectivity between the Northeast North Island and other coastal bottlenose dolphin populations, but population structure within Northeast North Island is unclear (Tezanos-Pinto 2009; Tezanos-Pinto et al. 2013). There is evidence of movement of bottlenose dolphins between the Hauraki Gulf, Bay of Islands and elsewhere in Northland, as well as changing habitat use in the Bay of Islands (Constantine 2002; Berghan et al. 2008; Tezanos-Pinto 2009; Tezanos-Pinto et al. 2013). The significance of the region to endangered southern right whales is unknown. Recent sightings of right whales in Hauraki Gulf have involved mother-calf pairs suggesting the species may have once used the Hauraki Gulf as a nursery habitat. Humpback whales migrate through the region apparently without feeding. However, dwarf minke and blue whales have both been observed feeding on euphausiid swams in the Hauraki Gulf (Gaskin 1968; Dawbin 1988; Garrigue et al. 2010; Torres et al. 2013; Clinton Duffy personal observation). Long-finned pilot whales, false killer whales and beaked whales are most frequently encountered over the outer shelf and upper slope, probably

[39] Sightings data collected in the Hauraki Gulf between February 2002 and January 2005 during 506 boat-based surveys covering all months of the year showed that large groups of common dolphins are regularly seen in the Hauraki Gulf and that larger aggregations were most frequent during the austral winter when nutrient upwelling typically leads to increased prey availability within the region (Stockin et al. 2008).

reflecting the importance of squids in their diet. Long-finned pilot whales can be particularly abundant in this habitat and sometimes form mixed pods with large bottlenose dolphins. Groups of New Zealand fur seals are sometimes encountered along the shelf break (Clinton Duffy personal observation)."

6.2.3 Marine mammals in the Firth of Thames

Du Fresne (2008) evaluated potential impacts of marine finfish farming on marine mammals in the Firth of Thames. This report describes the status, distribution, life history and behaviour of marine mammal species that are most likely encountered in the Firth of Thames. These species are: short-beaked common dolphins (*Delphinus delphis*), bottlenose dolphins (*Tursiops truncates*), killer whales (*Orcinus orca*), Bryde's whales (*Balaenoptera edeni/brydei*), and various species of beaked whales. The report also describes other marine mammals that are known to occur in the Hauraki Gulf including humpback whales (*Megaptera novaeangliae*), southern right whale (*Eubalena australis*), pilot whales (*Globicephala* sp.), and minke whales (*Balaenoptera acutorostrata/bonaerensis*).

6.2.4 Common dolphins eastern side of the Coromandel Peninsula

Large groups of common dolphins were regularly reported on the eastern side of the Coromandel Peninsula during a three-year study of resident common dolphins in the Mercury Bay area off Whitianga[40] (Neumann & Orams 2005). The group size ranged between 2 and 400 animals with an average of 32 dolphins per group. 408 individual common dolphins were identified based on unique photographs. Dolphins were found at a mean distance of 11.2 km from shore in spring (October–November), 15.2 km from shore in summer (December–February) and 16.4 km from shore in autumn (March–April) (Neumann & Orams 2005).

6.2.5 Marine mammals west coast of the Waikato region

The Maui's dolphin (*Cephalorhynchus hectori maui*) is the rarest dolphin in the world, with an estimated population size between 48 and 69 (Department of Conservation). They only occur along the west coast of the North Island between Dargaville and New Plymouth. Aerial and boat surveys are carried out regularly to determine the abundance and distribution of Maui's dolphins. During summer (October to March) they are mostly seen within one nautical mile of the coast.

In 2003, a bibliography for Hector's and Maui's dolphins was published (Martinez & Slooten 2003) and this was updated in 2012 (Du Fresne et al. 2012). Since July 2003, 39 peer-reviewed publications, 11 graduate theses (seven PhD and four MSc candidates) and 26 reports (published and unpublished) were produced (Du Fresne et al. 2012).

Three haul out colonies of New Zealand fur seals (*Arctocephalus forsteri*) are known along the west coast of the Waikato region: Gannet Island, Albatross Point and Tirua Point. Several surveys have been carried out to determine the number of seals present at these sites, with the oldest record for Gannet Island dating back to 1958. An aerial survey carried out on 22 January 2007 revealed that at least four pups were born on Gannet Island, making this the most northern breeding location in New Zealand (Bouma et al. 2008).

Records in Berkenbusch et al. (2013) show that many other marine mammal species can be encountered along the west coast of the Waikato region.

[40] This study consisted of 166 trips carried out between 1998 and 2001, excluding the winter months May to September (Neumann & Orams 2005).

6.3 Vulnerability life stages

Marine mammals are vulnerable during all life stages because of their low reproductive rate. Information on the reproduction of the four resident species in the Hauraki Gulf, New Zealand fur seals and Maui's dolphins is presented in Table 16.

Table 16. Reproduction of the most encountered marine mammal species in the Waikato region's CMA.

Species	Reproduction	References
Bryde's whales	Bryde's whale produce one calf during their life span most likely in late winter to early spring, either in NZ waters or the nearby Pacific Ocean. The gestation period is approximately 11 months.	Baker & Madon 2007 in Du Fresne 2008 Kato 2002 in Du Fresne 2008
Common dolphins	Short-beaked dolphins have a calving interval between 1 to 3 years during their 25 year life span.	Jefferson et al. 2008 in Du Fresne 2008
Bottlenose dolphins	The annual birth rate of bottlenose dolphins varies between 5 to 8% and calving peaks occur during summer. The gestation period is approximately 1 year and weaning generally between 3 to 6 years (can be up to 9).	Constantine 2002 and Boisseau 2003 in Du Fresne 2008
Killer whales	Killer whales can produce 5 to 6 calves during their life span with an average reproductive cycle of 5 years. The gestation period is between 15 to 18 months and weaning between 1 and 2 years.	Ford 2002 in Du Fresne 2008
Maui's dolphins	Maui's dolphins can produce 4 calves during their 20 years life span with a calving interval between 2 and 4 years.	wwf.panda.org www.doc.govt.nz
New Zealand fur seals	Females are philopatric and are sexually mature at 4–6 years, whereas males mature at 5–9 years. Pups are generally born between November and February.	Baird 2011

6.4 Sensitivity to specific pressures

6.4.1 Sensitivity to underwater noise

New Zealand studies

As part of a report for the Department of Conservation on the impacts of marine mammal watching in the Bay of Islands (Constantine & Baker 1997), research was conducted on the acoustic impact of vessels on bottlenose and common dolphins (Helweg 1995). This research aimed to assess noise levels from three swim-with-dolphin vessels: *Tutunui*, a 14 m jet propelled diesel engine catamaran; *Discovery I* and *Discovery II*, two 6.6 m aluminium hulled vessels, one propelled by two 90 hp outboard engines and the other by a single 175 hp engine. All three vessels had a peak frequency of sound below the highest sound detectable by both species of dolphins.

The study found no detectable changes in the acoustic behaviour of common dolphins with the presence of swim-with-dolphins vessels. For bottlenose dolphins only three acoustic recording were made. On two occasions, a high intensity burst-pulse sound known as a 'ratchet' was recorded, once when a vessel started its engine, and once when swimmers entered the water. This sound has been recorded in situations where there are high levels of stress, and it has been suggested that this may be a sound associated with alarm or 'anger' (see references in Helwig 1995).

Overseas studies

Examples of overseas studies that provide information on the hearing ranges and sensitivity of marine mammals to underwater noise include:

- A summary of available information on fish and marine mammal audiograms by an environmental consultancy in the UK in 2004 (Nedwell et al. 2004; see also paragraph 4.5).

- A drafted guidance for assessing the effects of anthropogenic sound on marine mammals prepared by the National Oceanic and Atmospheric Administration (NOAA) in December 2013 (NOAA 2013). Specifically, it identified the received levels, or thresholds, above which individual marine mammals were predicted to experience changes in their hearing sensitivity (either temporary or permanent) for all underwater anthropogenic sound sources. Information on the functional hearing ranges of marine mammals and a summary of temporary and permanent threshold shifts (based on 26 peer-reviewed studies) extracted from this guidance document is shown in Figures 19 and 20.

- An extensive scientific synthesis on the impact of underwater noise on marine and coastal biodiversity and habitats by the United Nations Environment Programme (UNEP) in 2012 (UNEP 2012). The synthesis included information on natural[41] and anthropogenic[42] noise sources and levels, the potential impacts on marine organisms (marine mammals, fish, turtles and invertebrates), and mitigation and management options (see also paragraph 4.5).

Table 1: Marine mammal functional hearing groups.

Functional Hearing Group	Functional Hearing Range*
Low-frequency (LF) cetaceans+ (baleen whales)	7 Hz to 30 kHz
Mid-frequency (MF) cetaceans (dolphins, toothed whales, beaked whales, bottlenose whales)	150 Hz to 160 kHz
High-frequency (HF) cetaceans (true porpoises, *Kogia*, river dolphins, cephalorhynchid, *Lagenorhynchus cruciger* and *L. australis*)	200 Hz to 180 kHz
Phocid pinnipeds (true seals)	75 Hz to 100 kHz
Otariid pinnipeds (sea lions and fur seals)	100 Hz to 40 kHz

* Represents frequency band of hearing for entire group as a composite (i.e., all species within the group), where individual species' hearing ranges are typically not as broad.

\+ Estimated hearing range for low-frequency cetaceans is based on behavioral studies, recorded vocalizations, and inner ear morphology measurements. No direct measurements of hearing ability have been successfully completed.

Figure 19. Marine mammal functional hearing groups (NOAA draft 2013).

[41] E.g. wind, waves, currents, ice, and marine animals.

[42] E.g. marine construction and industrial activities (pile driving, cable laying, dredging, and drilling), various types and sizes of vessels (supply boats, crew boats, fishing vessels, small craft and boats), seismic explorations and research sound (e.g. topography studies).

Table 6:	a. Summary of TTS and PTS onset dual acoustic threshold levels. b. Other factors for considerations based on frequency and duration of exposure.

a. Numeric Level*+

	PTS Onset (Received Level)		TTS Onset (Received Level)	
Hearing Group	**Impulsive**	**Non-impulsive**	**Impulsive**	**Non-impulsive**
Low-Frequency (LF) Cetaceans	*Cell 1* 230 dB_{peak} & 187 dB SEL_{cum}	*Cell 2* 230 dB_{peak} & 198 dB SEL_{cum}	*Cell 11* 224 dB_{peak} & 172 dB SEL_{cum}	*Cell 12* 224 dB_{peak} & 178 dB SEL_{cum}
Mid-Frequency (MF) Cetaceans	*Cell 3* 230 dB_{peak} & 187 dB SEL_{cum}	*Cell 4* 230 dB_{peak} & 198 dB SEL_{cum}	*Cell 13* 224 dB_{peak} & 172 dB SEL_{cum}	*Cell 14* 224 dB_{peak} & 178 dB SEL_{cum}
High-Frequency (HF) Cetaceans	*Cell 5* 201 dB_{peak} & 161 dB SEL_{cum}	*Cell 6* 201 dB_{peak} & 180 dB SEL_{cum}	*Cell 15* 195 dB_{peak} & 146 dB SEL_{cum}	*Cell 16* 195 dB_{peak} & 160 dB SEL_{cum}
Phocid Pinnipeds (Underwater)	*Cell 7* 235 dB_{peak} & 192 dB SEL_{cum}	*Cell 8* 235 dB_{peak} & 197 dB SEL_{cum}	*Cell 17* 229 dB_{peak} & 177 dB SEL_{cum}	*Cell 18* 229 dB_{peak} & 183 dB SEL_{cum}
Otariid Pinnipeds (Underwater)	*Cell 9* 235 dB_{peak} & 215 dB SEL_{cum}	*Cell 10* 235 dB_{peak} & 220 dB SEL_{cum}	*Cell 19* 229 dB_{peak} & 200 dB SEL_{cum}	*Cell 20* 229 dB_{peak} & 206 dB SEL_{cum}

* Dual acoustic threshold levels: Use whichever level [dB_{peak} or dB SEL_{cum}] exceeded first. All SEL_{cum} acoustic threshold levels (re: 1 μPa^2-s) are weighted. Note that acoustic threshold levels for impulsive or non-impulsive sources are based on characteristics at the source and not the receiver.

+ The SEL_{cum} could be exceeded in multitude of ways (i.e., varying exposure levels and durations). It is valuable for applicants, if possible, to indicate under what conditions these acoustic threshold levels will be exceeded.

<u>Additional Detail Regarding Data Used to Derive Acoustic Threshold Levels:</u>

Cells 1 through 10: Acoustic threshold level (peak and SEL_{cum}) based on an extrapolation, using related data (when available), rather than direct measurements. All PTS onset acoustic threshold levels are extrapolations based on terrestrial and limited marine mammal growth rate data.

Cell 11: Direct measurements of TTS onset do not exist. Mid-frequency cetaceans are used as surrogates for peak and SEL_{cum} acoustic threshold levels.

Cell 12: Direct measurements of TTS onset do not exist. Mid-frequency cetaceans are used as surrogates for peak and SEL_{cum} acoustic threshold levels.

Cell 13: Peak pressure and SEL_{cum} acoustic threshold levels are based on data from a beluga exposed to a seismic watergun (Finneran et al. 2002).

Cell 14: Peak pressure is based on data from a beluga exposed to a seismic watergun (Finneran et al. 2002). The SEL_{cum} level is based on data from bottlenose dolphins (n=6) exposed to either octave-band noise or tones (Schlundt et al. 2000; Mooney et al. 2009a; Finneran et al. 2010a; Finneran and Schlundt 2010). For bottlenose dolphins: median = 178 dB SEL_{cum}, 1st quartile = 175.5 dB SEL_{cum}, 3rd quartile = 181.6 dB SEL_{cum}. Median level also supported by beluga data (Schlundt et al. 2000).

Cell 15: Peak pressure and SEL_{cum} acoustic threshold levels are based on data from a harbor porpoise exposed to airgun shots (Lucke et al. 2009).

Cell 16: Peak pressure level is based on data from a harbor porpoise exposed to airgun shots (Lucke et al. 2009). The SEL_{cum} is based on data from a harbor porpoise exposed to octave-band noise (Kastelein et al. 2012b).

Cell 17: Direct measurements of TTS onset for this type of sound source do not exist. The SEL_{cum} and peak pressure acoustic threshold level are based on an extrapolation from methodology derived from Southall et al. 2007.

Cell 18: Peak pressure level is based on an extrapolation from methodology derived from Southall et al. 2007, since no direct measurements exist. The SEL_{cum} is based on data from a harbor seal (n=1) exposed to octave-band noise (Kastak et al. 2005).

Cell 19: Direct measurements of TTS onset for this type of sound source do not exist. The SEL_{cum} is based on an extrapolation from methodology derived from Southall et al. 2007. Phocid extrapolation is used as a surrogate for the peak pressure level, since extrapolation produces unrealistic results.

Cell 20: The SEL_{cum} is based on data from a California sea lion (n=1) exposed to octave-band noise (Kastak et al. 2005). Phocid extrapolation is used as a surrogate for the peak pressure level, since extrapolation produces unrealistic results.

Figure 20. Temporary and Permanent Threshold shifts for marine mammals (NOAA draft 2013).

Guidelines to minimise acoustic disturbance

In New Zealand, the Department of Conservation developed the 'Code of Conduct for Minimising Acoustic Disturbance to Marine Mammals from Seismic Survey Operations'. This most recent code of conduct was published in November 2013 and was based on the voluntary 'Guidelines for Minimising Acoustic Disturbance to Marine Mammals from Seismic Survey' and earlier versions of the Code of Conduct published in respectively 2006 and 2012.

In April 2014 the International Maritime Organization (IMO) adopted voluntary guidelines to reduce underwater noise from commercial ships to address adverse effects on marine life (IMO 2014). These guidelines provide general guidance for reducing cavitation and machinery noise, and for vessel-quieting operations and maintenance, but does not set noise output standards or prescribe methods of noise reduction.

6.4.2 Sensitivity to human disturbance

New Zealand studies

In 1999 Constantine reviewed effects of tourism on marine mammals in New Zealand providing an overview of available research projects in New Zealand (Constantine 1999)[43].

North Island studies focusing on the disturbance of marine mammals by human activities have mainly focused on impacts of dolphin watching and 'swim with the dolphin' tours organised in the Bay of Islands (e.g. Constantine et al. 2002; Constantine et al. 2003), responses of seals to vessels and 'swim with seals' tourism activities in the Bay of Plenty (Cowling et al. 2013, 204) and the risk of ship strike to Bryde's whales in the Hauraki Gulf (see paragraph 3.4.3).

Several New Zealand studies have documented responses of seals to human activities[44], including:

- Cowling et al. (2014) documented responses of New Zealand fur seals to vessels in the Bay of Plenty at a recently established breeding colony. The responses varied with month, time of the day, duration of vessels exposure, and the distance of the vessel. Age and sex of the seals, and the number of seals present also influenced fur seal response. Fur seals became disturbed when vessels approached to 10-20 m distance. A precautionary minimum approach distance of 50 m was suggested.

- Cowling et al. (2013) assessed the impacts and sustainability of the swimming with New Zealand fur seal tourism industry in the Bay of Plenty between December 2011 and March 2012. The behaviour of seals in the water (interaction, neutral and avoidance) was monitored at 1 minute intervals, during 16 seal-swim events. Seals mostly ignored the swimmers (54% of records), but some interacted with swimmers (41%). Seals rarely avoided swimmers (5%). The results suggest that the monitored activities had minimal impacts on seals in the water.

- Between 1999 and 2001 effects of tourism activities on New Zealand fur seals at Abel Tasman National Park, the Kaikoura coastline and Whakamoa, Banks Peninsula were studied by approaching seals on land, by kayak, and by motorboat. Based on the results minimum approach distances of 30 m for land approaches, 20 m for kayak approaches and 30 m for boat approaches were recommended (Boren et al. 2002).

Study Waikato region

One study was found focusing on the disturbance of marine mammals by human activities in the Waikato region. From 1998 to 2001 the behaviour and ecology of common dolphins and the impact of tourism in the Mercury Bay area on the eastern side of the Coromandel Peninsula was investigated (Neuman & Orams 2005). This study concluded that boat traffic altered the behaviour of some dolphin groups, especially those containing few individuals.

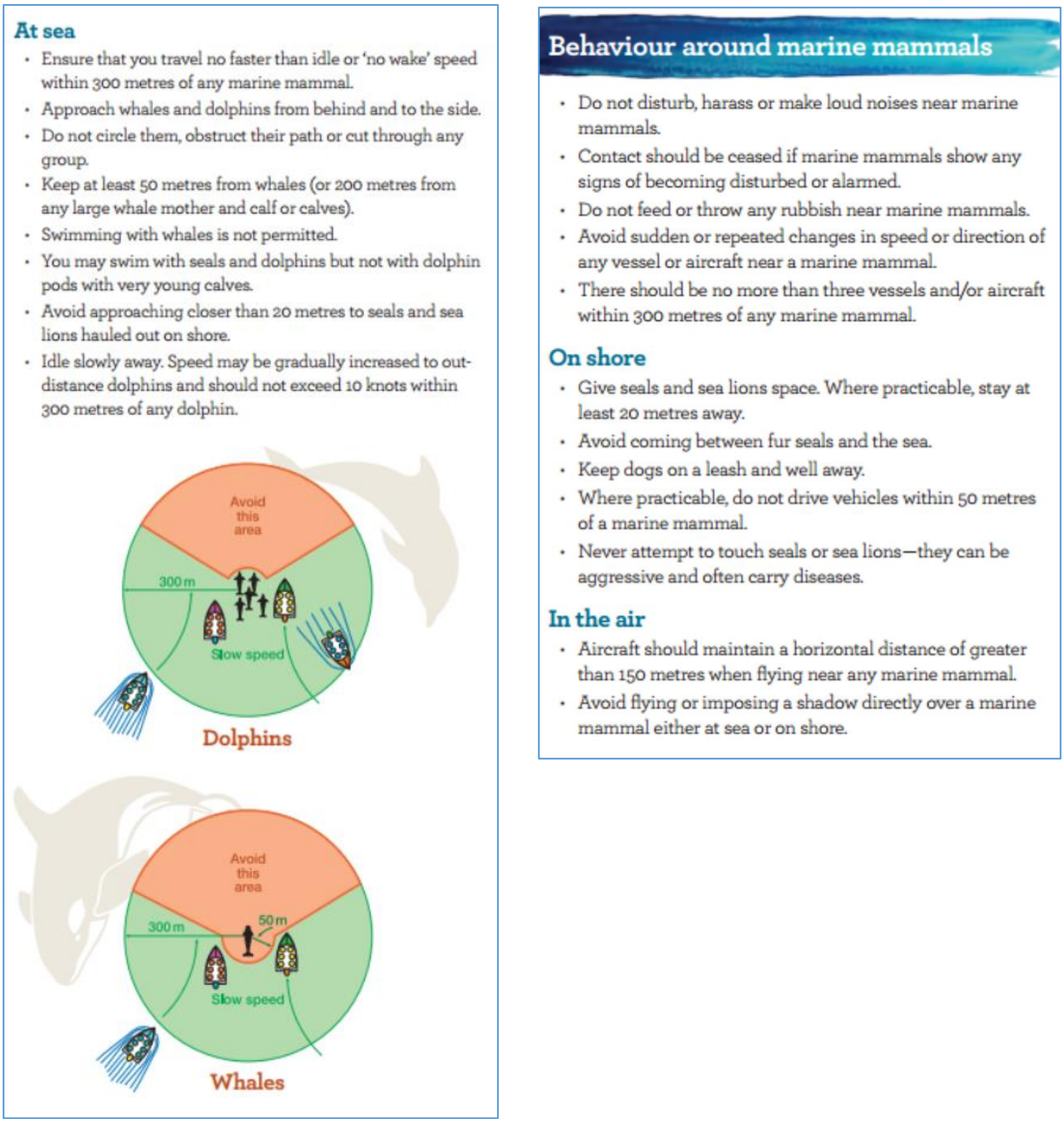
[43] Most of the research projects mentioned in that report were carried out in the South Island.

[44] A global review on the disturbance of seal haul outs by different human activities was published by Wilson (2014).

However, low-level commercial tourism appeared to have little impact on the dolphins. Few attempts at swimming with common dolphins resulted in a sustained interaction.

Guidelines to minimise disturbance of human activities

Worldwide many different regulations and guidelines have been developed to minimise impacts of human activities on marine mammals. These regulations generally describe approach distances (a distance beyond which a vessel or person may not / should not approach a marine mammal) and provide guidelines about behaviour around marine mammals. In New Zealand such guidelines are provided by the Marine Mammals Protection Regulations (1992). A summary of these guidelines is provided in the brochure 'Sharing our coasts with marine mammals' (Department of Conservation 2014; Figure 21).



At sea

- Ensure that you travel no faster than idle or 'no wake' speed within 300 metres of any marine mammal.
- Approach whales and dolphins from behind and to the side.
- Do not circle them, obstruct their path or cut through any group.
- Keep at least 50 metres from whales (or 200 metres from any large whale mother and calf or calves).
- Swimming with whales is not permitted.
- You may swim with seals and dolphins but not with dolphin pods with very young calves.
- Avoid approaching closer than 20 metres to seals and sea lions hauled out on shore.
- Idle slowly away. Speed may be gradually increased to out-distance dolphins and should not exceed 10 knots within 300 metres of any dolphin.

Behaviour around marine mammals

- Do not disturb, harass or make loud noises near marine mammals.
- Contact should be ceased if marine mammals show any signs of becoming disturbed or alarmed.
- Do not feed or throw any rubbish near marine mammals.
- Avoid sudden or repeated changes in speed or direction of any vessel or aircraft near a marine mammal.
- There should be no more than three vessels and/or aircraft within 300 metres of any marine mammal.

On shore

- Give seals and sea lions space. Where practicable, stay at least 20 metres away.
- Avoid coming between fur seals and the sea.
- Keep dogs on a leash and well away.
- Where practicable, do not drive vehicles within 50 metres of a marine mammal.
- Never attempt to touch seals or sea lions—they can be aggressive and often carry diseases.

In the air

- Aircraft should maintain a horizontal distance of greater than 150 metres when flying near any marine mammal.
- Avoid flying or imposing a shadow directly over a marine mammal either at sea or on shore.

Figure 21. Approach distances and behaviour around marine mammals (Department of Conservation 2014).

6.4.3 Sensitivity of large whales to ship strike

Around fifty Bryde's whales are estimated to live year-round within the Hauraki Gulf, one of the few resident populations of this species in the world. Another additional 159 Bryde's whales are estimated to be transient in the Hauraki Gulf. The distribution of sightings of this species between 1970 and 2013 (extracted from Berkenbusch et al. 2013) shows that they can be encountered anywhere in the Hauraki Gulf (Figure 22).

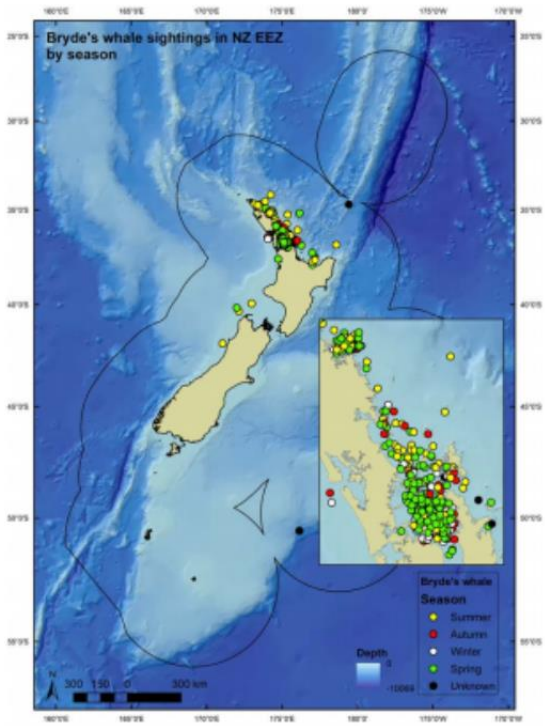


Figure 22. Distribution of Bryde's whale sightings in New Zealand waters between 1970 and 2013 (Berkenbusch et al. 2013). Reported sightings are from a variety of sources and need to be considered indicative only, as identifications may not be correct.

This nationally critically threatened species spends most of its time about six metres below the surface in areas where ships with drafts of up to 12 m are traversing to and from ports making them very vulnerable to ship strike (Constantine et al. 2012). Since 1996, the carcasses of 43 Bryde's whales have been found, with vessel collision accounting for 84% (n = 16) of the events for which a mortality cause could be assigned (Wiley et al 2014).

Based on a study of the movements and subsurface behaviour of Bryde's whales in the Hauraki Gulf using tags Constantine et al. (2012) provided suggestions to minimise ship collisions. Reducing the ship speed to a maximum of 10 knots was identified as the most feasible method for reducing vessel strikes.

Wiley et al. (2014) analysed individual vessel transits (vessels >70 m) in the Hauraki Gulf and the potential industry impact of speed reduction measures for reducing Bryde's whale mortality from ship strike. The study concluded that 44% (n=253) of the transits would increase by 15 minutes or less and 64% (n=365) of the transits by less than 1-hour. Transit times for 28% (n= 158) of the trips would increase by over 1-hour and 1% (n=6) would have a transit time increase by over 2-hours. Transit times would be increased most for ships in the passenger and cargo categories (mean increase = ~50 and 40 minutes, respectively) and least for ships in the "other" and tanker categories (mean increases of ~ 5 and 6 minutes, respectively).

Riekkola (2013) used large vessel tracks from Automatic Identification System (AIS) data (logs of all commercial shipping paths) and locations of Bryde's whale sightings to describe whale and vessel distribution in the Hauraki Gulf and to assess whether re-routing vessel traffic could be an effective means of mitigating vessel-strikes. Re-routing shipping appeared not to be a viable mitigation option.

In September 2013, the Port of Auckland published the Hauraki Gulf Transit Protocol for Commercial Shipping, which provides guidelines to minimise the risk of colliding with a whale (Port of Auckland September 2013). This voluntary Protocol included:

- a recommended approach to the Ports of Auckland;
- a recommendation to slow down to a maximum speed of 10 knots;
- a requirement to keep watch when transiting through the Hauraki Gulf posting whale lookouts during daylight hours, and slow down and/ or change course to keep as far from the whales as possible if a whale is sighted forward of the beam;
- A recommendation to immediately report all whale sightings to the Ports of Auckland Harbour Control.

A recent scientific study carried out by Ocean Life Survey showed the potential of thermal imaging technology to prevent ships hitting whales in the Hauraki Gulf. The study proved that the heat put out by Bryde's whales could be used to spot them at distances that would allow commercial vessels to avoid collisions (www.stuff.co.nz; 13 April 2015).

7 Subtidal biogenic habitats

Morrison et al. (2014) defined biogenic habitats as:
a) those living species that form emergent three-dimensional structure, that separate areas in which they occur from surrounding lower vertical dimension seafloor habitats; and

b) non-living structure generated by living organisms, such as infaunal tubes and burrows.

Examples of these habitats include mangroves, seagrass beds, shellfish beds (e.g. horse mussels, scallops, and oysters), kelp forests, sponge gardens, rhodolith beds, sea pen fields, bryozoan fields, brachiopod beds, deep-see hydrothermal vents, methane or cold seeps, stony coral thickets or reefs, and calcareous tubeworms (MacDiarmid et al. 2013; Morrison et al. 2009; Morrison et al. 2014).

The functions provided by these habitats are diverse and include elevation of biodiversity, benthic-pelagic coupling, sediment baffling, protection from erosion, nutrient recycling, the provision of shelter and food for a wide range of other organisms, and over longer time scales the creation of geological features (Morrison et al. 2014). They can also increase fisheries production for a range of species through the provision of shelter from predation, feeding grounds, and spawning and nursery habitats (Morrison et al. 2009).

Several research and monitoring programmes have focused on mapping and assessing the importance of biogenic habitats in intertidal areas[45], but information on the presence of subtidal biogenic habitats in the offshore marine environment and in subtidal channels of harbours and knowledge on their ecosystem functions is very limited.

As part of the Sea Change project a map was produced showing the predicted variation in potential delivery of biogenic habitats as an ecosystem service across the Hauraki Gulf (Figure 23). The map was produced by adapting and applying the ecosystem principles approach described in Townsend & Thrush (2010), and using best available physical/chemical datasets to generate Ecosystem Principle Scores ranging from 0-1 at a resolution of every 200 m^2 across the entire Hauraki Gulf. Map scores were divided into three categories referring to areas of high, medium and low service delivery.

This map indicates several areas in the Waikato region that have a predicted high potential for the delivery of biogenic habitats such as the area north of the Coromandel Peninsula and the area around the offshore islands on the eastern side of the Coromandel Peninsula.

The following paragraphs provide more specific information on the known distribution and (expected) biodiversity values of four specific subtidal biogenic habitats in the Waikato region's CMA: rhodolith beds, subtidal shellfish beds, subtidal seagrass and sponge gardens.

[45] E.g. Shellfish surveys carried out by MPI and various community groups (see paragraph 2.1.), assessments of the expansion of mangroves in various harbour and the ecological functions they provide (e.g. Morrisey et al. 2007).

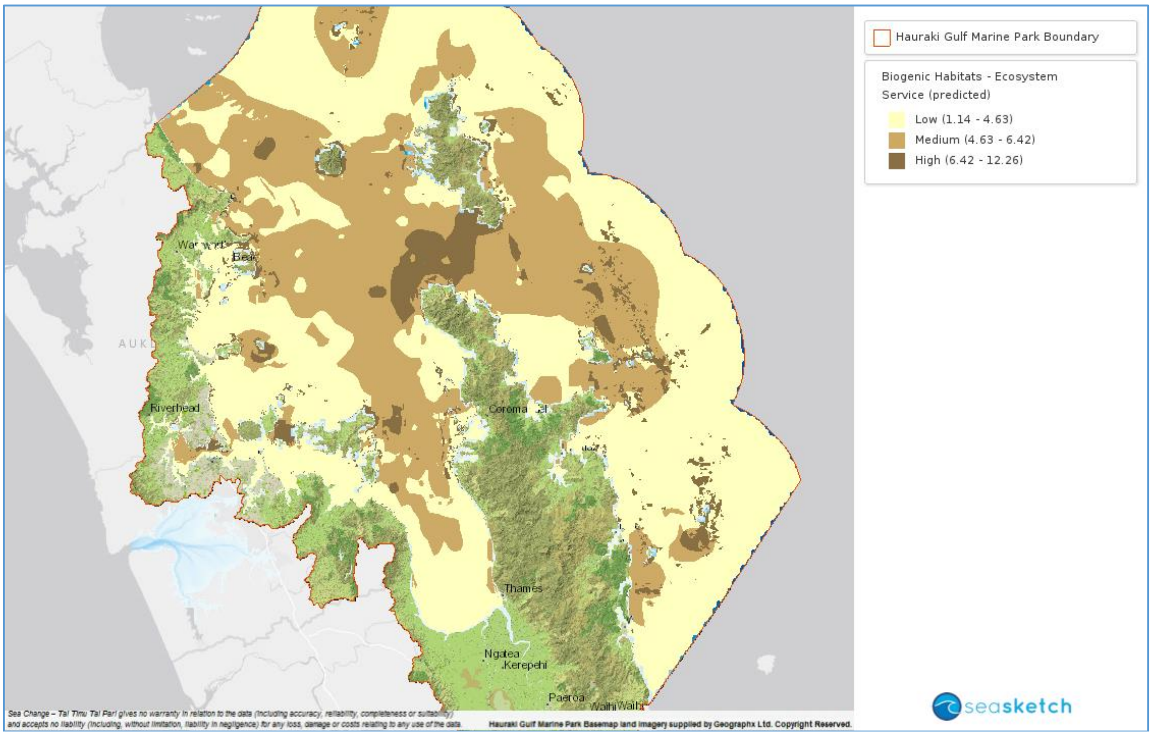


Figure 23. **Predicted variation in potential delivery of biogenic habitats as an ecosystem service across the Hauraki Gulf (www.seasketch.org).**

7.1 Rhodolith beds

7.1.1 General description

Rhodoliths are free-living non-geniculate coralline algae. They are not attached to any fixed surface and are able to be rolled on the sea floor by the action of water motion and currents (Farr et al. 2009). Rhodoliths are found in subtidal areas where there are no reefs, but rather coarse sand, gravel or shell debris, often in areas with strong currents and relatively clear water conditions (Farr et al. 2009). It is likely they also occur in New Zealand's Exclusive Economic Zone at locations characterised by strong currents within the photic zone (to depths of 200 m, depending on water clarity), particularly around the margins of reefs or elevated banks (MacDiarmid et al. 2013).

In New Zealand, at least four species have been identified: *Sporolithon durum, Lithothamnion crispatum, Lithothamnion proliferum*, and *Lithophyllum sp*. (Figure 24; Farr et al. 2009)[46].

[46] Fertile rhodoliths of both *S. durum* and *L. crispatum* are commonly found in New Zealand. The other two species are known from very few specimens and further work is required before their distribution in the New Zealand region is fully understood (Farr et al. 2009).

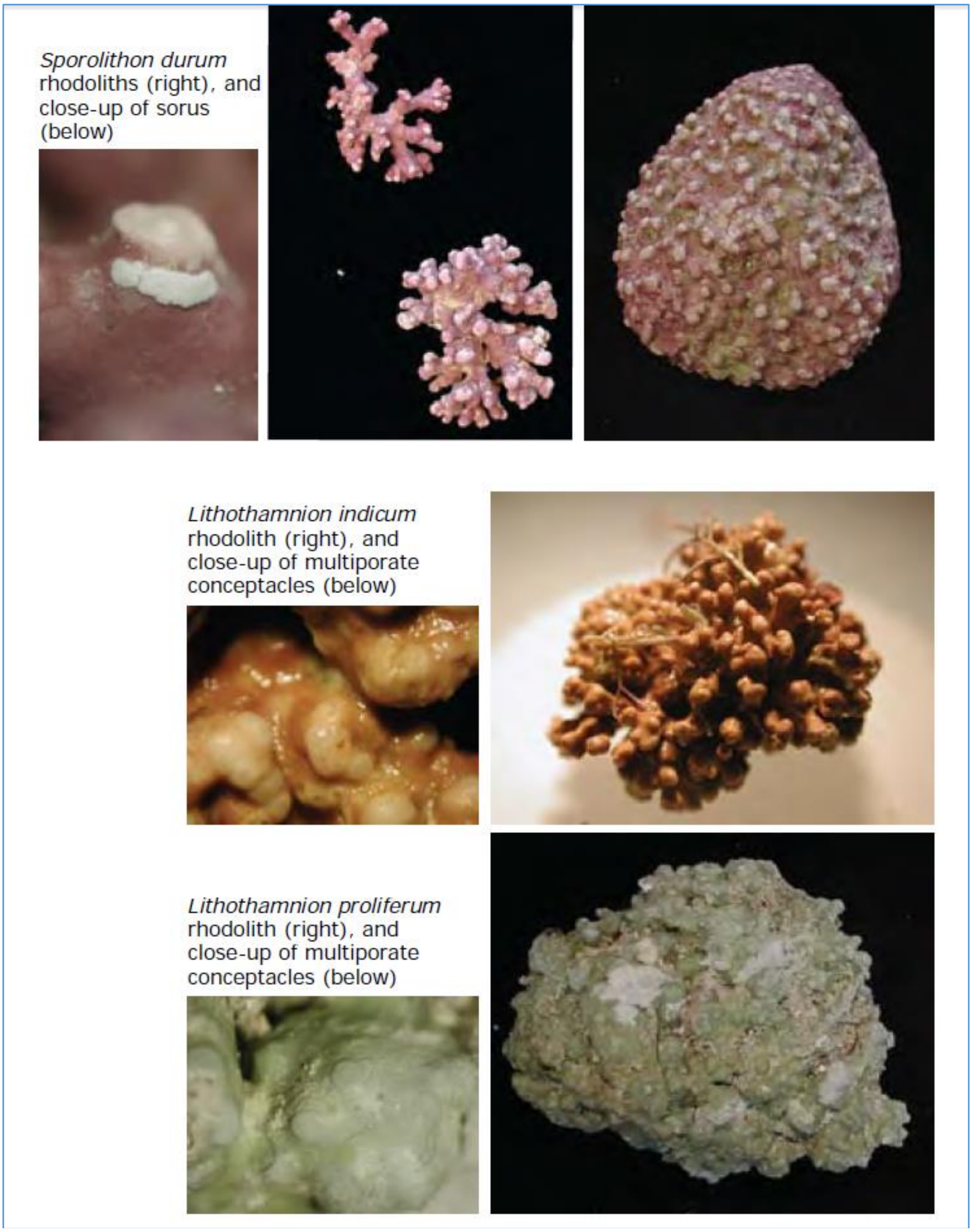


Figure 24. Rhodoliths found in New Zealand (Farr et al. 2009).

7.1.2 Known distribution

Known locations of rhodolith beds in northern New Zealand

Very little information exists about the location, extent or ecosystem functioning of rhodolith beds in New Zealand (MacDiarmid et al. 2013; Nelson et al. 2012). Known coastal locations in northern New Zealand are described by Nelson et al. (2012; Table 17) and shown in Farr et al. (2009) (Figure 25).

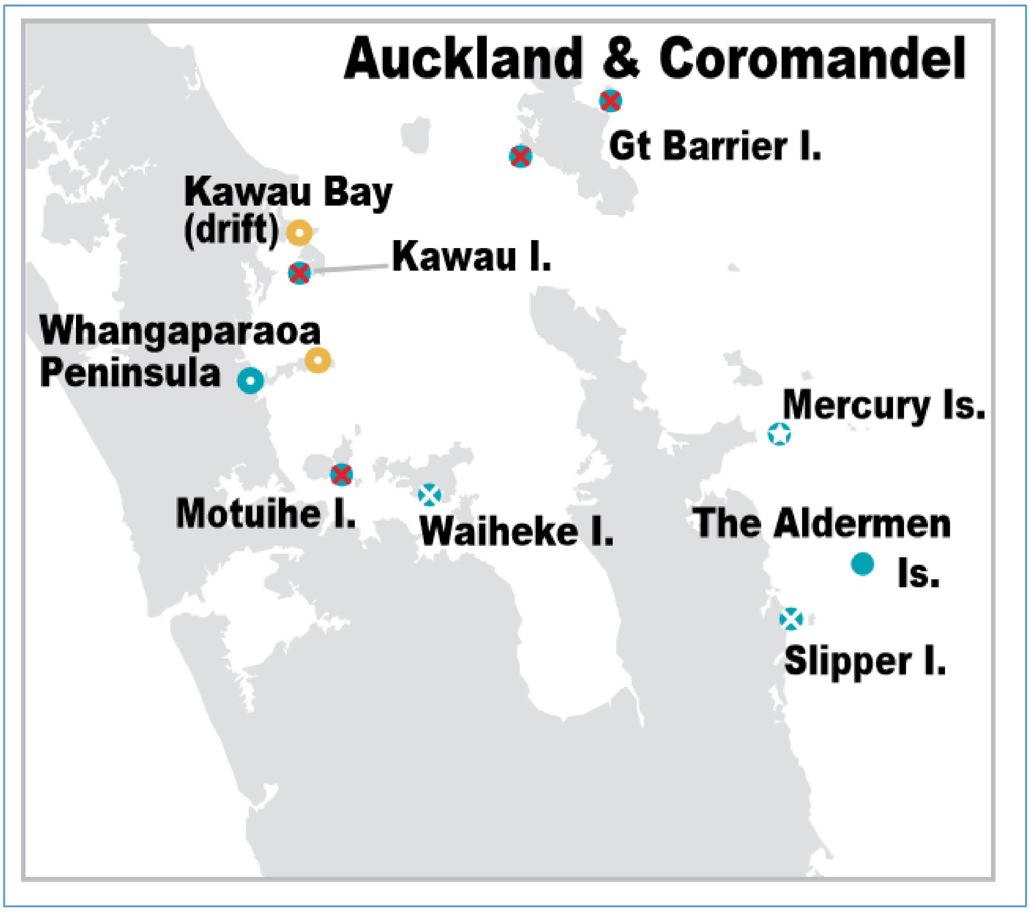


Figure 25. **Known locations of rhodolith beds in northern New Zealand (Farr et al. 2009).**

Known locations of rhodolith beds in the Waikato region

Known rhodolith bed locations in the Waikato region include the area west of Great Mercury Island (Grace & Grace 1976), an area south of Flat Island (Ohinau Island Group; Cinton Duffy personal comment in Lundquist et al. 2004), the Alderman Islands (Farr et al. 2009; Figure 25), and Slipper Island (Farr et al. 2009; Figure 25).

7.1.3 Importance for biodiversity

Internationally, rhodolith beds have been identified as critically important biodiversity hotspots, harbouring high diversity and abundance of marine animals and algae in comparison with surrounding habitats (Steller et al. 2003). They have also been identified as important nursery areas for commercial species such as scallops, crabs and fish, and are home to high densities of broodstock bivalves (Nelson 2009).

Very few studies on rhodolith beds have been carried out in New Zealand (Farr et al. 2009; Nelson et al. 2012). To date, the only extensive study in New Zealand on the ecology of subtidal rhodolith beds (two species: *Lithothamnion crispatum* and *Sporolithon durum*) was carried out at Kahuwhera Bay and Te Miko Reef (Bay of Islands) in February and September 2010. The biodiversity of these beds was investigated by sampling invertebrates (epifauna, infauna, cryptofauna), macro-algae and fishes (Nelson et al. 2012).

The results showed that:

- a number of undescribed taxa were discovered as well as new records for the New Zealand region, and range extensions of species known elsewhere;
- more than double the number of invertebrate taxa were present in the rhodolith beds than found outside the beds;

- both rhodolith beds harboured high diversity of associated macro-algae and invertebrates, but with markedly different species composition.

Descriptions of several other rhodolith beds in northern New Zealand also indicate the presence of diverse benthic communities in rhodolith beds (Table 17).

Table 17. Description of known rhodolith beds in northern New Zealand (Nelson et al. 2012).

Location	Biodiversity values
Cavalli Passage (off Matauri Bay, Northland) (Grace & Hayward 1980)	Rhodoliths at 5–10 m depth associated with bivalve *Tawera spissa*. Rhodoliths provided attachment surfaces for bryozoa, serpulid polychaetes and small algae, as well as grazers such as chitons, limpets and a variety of epifauna such as amphipods, crabs, isopods, ophiuroids and gastropods. The position of the rhodolith beds coincided with the highest diversity recorded in the survey area.
Tutukaka Coast (Brook et al. 1981)	Algae encrusting dead cockle shells in areas of fine muddy sand. Additionally, a *Corallina- Maoricolpus-Notomithrax-* association, with Corallina turf, encrusting non-geniculate corallines and the presence of poorly developed rhodoliths in some areas at depths of 1–7 m in gravelly muddy sand, associated with a diverse epi- and infauna.
Rakitu Island (East of Great Barrier Island) (Hayward et al. 1982)	Gravelly substrate that included various algae (*Caulerpa, Codium, 'Lithothamnion', Zonaria*), chitons, polychaetes and bryozoa associated with pebbles and large shells, in pebbly to coarse sandy pebble gravel at 12–18 m depth. They also recorded rhodoliths from the "gravelly substrate" association and a *Selenaria squamosal*-association, although made no specific comment on their association with other taxa.
West of Great Barrier Island (Hayward et al. 1986)	A very distinctive rhodolith- holothurian *Cucumaria-Glycymeris laticostata-* (now *Tucetona laticostata*) association, in depths of 10–15 m in high energy situations in coarse sediment that was characterised by a rich subsidiary epifauna. Rhodoliths were also found in smaller numbers associated with a *Corbula zelandica* and *Venericardia purpurata* sub-association.
Great Mercury Island (Eastern Coromandel) (Grace & Grace 1976)	Rhodoliths occurring in coarse sand to shell gravel at 4–15 m depth, in a channel with strong currents. They were found to be associated with the abundant *Tawera spissa* and *Venericardia purpurata* community.
Whangaparaoa Peninsula (Basso et al. 2009)	Rhodoliths in low intertidal and upper subtidal zones. Site dominated by the species *Sporolithon durum* although with rare *Lithophyllum sp*. rhodoliths also present. Large sizes (10–97 mm, mean 38.7 mm) and high densities.
Hauraki Gulf (Dewas & O'Shea 2012)	Benthic invertebrate assemblages associated with the rhodoliths were found to have higher taxon richness and abundance when compared to gravel substrates.

7.1.4 Pressures on rhodolith beds

Recent international studies have shown that rhodolith beds, which are fragile and slow growing (0.05 mm to 2 mm per year), are at risk from the impacts of a range of human activities. Such activities include physical disruption (trawling, dredging, anchoring; Hall-Spencer & Moore 2000), reduction in water quality (offshore dumping; e.g. Wilson et al. 2004; Riul et al. 2008), alterations to water movement (e.g. marine engineering), and aquaculture installations (e.g. shellfish rafts and lines, fish cages; Hall-Spencer et al. 2003, 2006).

Being calcified algae, rhodoliths are also recognized as being vulnerable to the impacts of climate change, in particular the effects of ocean acidification and rising sea temperatures (Nelson et al. 2012). Nelson et al. (2012) found that both species were vulnerable to the impacts of increasing temperature and decreasing pH.

Impacts of fragmentation on individuals and on beds may be critical in terms of biodiversity and abundance associated with rhodolith beds because the diversity and abundance of organisms supported by a rhodolith significantly increase with complexity (branching density) and the space available (thallus volume; Steller et al. 2003).

7.2 Subtidal shellfish beds

The list of bed-forming species that may be encountered in the New Zealand EEZ is long (MacDiarmid et al. 2013). Common examples include suspension feeding species such as horse mussels, scallops (e.g. *Pecten novaezelandiae*, *Zygochlamys delicata*) and dredge oysters (*Ostrea chiliensis*), but there are numerous other examples, such as *Dosinia anus* (venus shell/ringed Dosinia) and *Dosinia subrosea* (silky *Dosinia*), *Spisula aequilatera* (triangle shell), *Mactra discors* and *Mactra murchisoni* (trough shells) and *Bassina yatei* (frilled venus shell), all of which generally occur at depths shallower than 20 m (MacDiarmid et al. 2013). Deeper bed-forming bivalves include geoducs (*Panopea zelandica* and *P. smithae*), *Tucetona laticostata* (large dog cockles), dredge oysters and queen scallops (*Z. delicatula*) (MacDiarmid et al. 2013).

This paragraph provides information on the known distribution of horse mussel beds, dog cockle beds and scallop beds in the Waikato region and their role in supporting biodiversity values.

7.2.1 Horse mussels

7.2.1.1 General description

The fs.fish.govt.nz website provides the following general description for horse mussels:

"The horse mussel (*Atrina zelandica*; Figure 26) is a widespread endemic bivalve that lives mainly on muddy-sand substrates in the lowest inter-tidal and sub-tidal shallows of mainly sheltered waters. They are also found in deeper waters (to 70 m) off open coasts. The horse mussel is a flattened, emergent, filter-feeding mollusc, particularly conspicuous because of its size and abundance. Although more usually 260−300 mm long (110−120 mm wide) it can reach 400 mm in length and is New Zealand's largest bivalve. Horse mussels often live in groups, forming patches of up to 10 m^2 or more.

Horse mussels may spawn throughout much of the year, but their primary spawning period likely occurs during summer. There is no information on the size or age at which breeding begins. A pelagic larva is free-swimming for several days or weeks, but nothing is known of its primary settlement locations, which may not necessarily be within the adult beds. Recruitment events can be sporadic and short-lived.

There is little published information on age, growth and mortality for horse mussels. It appears that they grow rapidly for at least the first 2−4 years. Shells about 120 mm long in a northern bed increased about 40 mm per year until 166 mm, after which growth slowed dramatically. Large shells are at least 5 years and possibly up to 15 years old."

Figure 26. Horse mussel bed (niwa.co.nz).

7.2.1.2 Known distribution

Horse mussels are found all around New Zealand, but there are no inventories or systematic maps of their distribution (Morrison et al. 2014).

Areas in the Waikato region where horse mussel have been reported include:

- A horse mussel bed in the vicinity of Fantail Bay (Thrush et al. 1998);
- Large dense horse mussel beds were observed offshore of Whangapoua Harbour: past 3 mile bank at 27-35 m depth (M. Cryer personal comment in Lundquist et al. 2004; surveys for a possible horse mussel fishery between Kennedy Bay and Kuaotuna at depths of 16-25 m (Allan et al. 1984));
- Sparse horse mussels in shallower zones of Huruhuri Bay (Great Mercury Island) covered by coralline and fleshy brown algae (Schwartz et al. 2004);
- Sparse horse mussels in the area near Matariki Rocks on the eastern side of the Firth of Thames (just south of Manaia Harbour) (Guccione 2014).

By-catch data collected during a scallop survey in 2012 (Williams 2013) presented in the 2014 Hauraki Gulf State of Environment report also indicate the presence of horse mussels in the Waikato region: north of the Kuaotuna Peninsula and northwest of the Coromandel Peninsula (Figure 27).

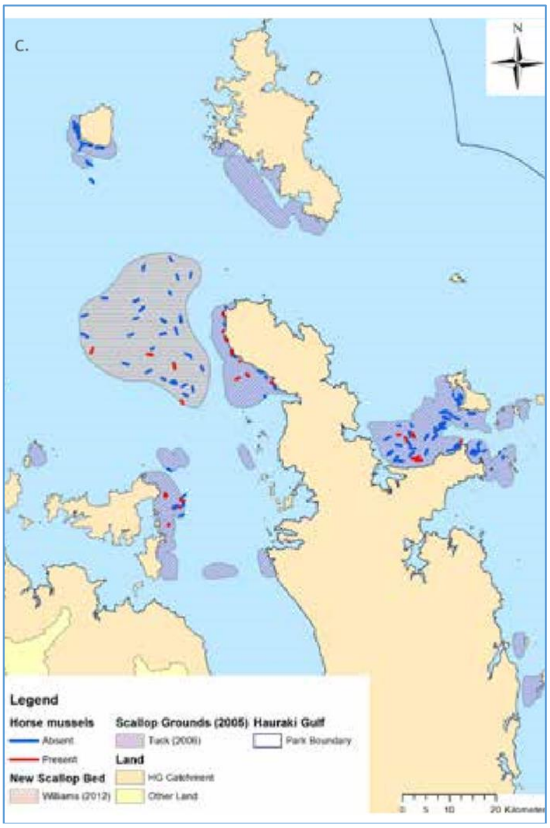


Figure 27. The presence/absence of horse mussels obtained during scallop surveys in the Hauraki Gulf (Hauraki Gulf Forum 2014; original data from Williams 2013).

7.2.1.3 Importance for biodiversity

Morrison et al. (2014) described the value and ecosystem functions of horse mussel beds as follows:

"Horse mussels remove large volumes of plankton and suspended sediments out of the water column, and at high densities, produce large amounts of faeces and pseudo faeces, which impact on the surrounding seafloor and biological assemblages (Cummings et al. 2001, Ellis et al. 2002). Their presence also alters fine scale boundary layer water flows (Nikora et al. 2002), mesoscale hydrodynamic interactions (Green et al. 1998), and community interactions (Keough 1984, Cummings et al. 1998, 2001).

Horse mussel beds often support diverse species assemblages of sponges, macro-algae, bryozoans, filter feeding bivalves, and soft corals, and mobile species such as sea cucumbers, hermit crabs, and small benthic fishes depending on environmental setting (e.g. Hay 1990b; Ellis et al. 2002; Usmar 2010 in Morrison et al. 2014). Northern New Zealand horse mussel beds also provide a nursery function for juvenile snapper and trevally, as well as supporting other small fishes such as triplefins (e.g. Morrison & Carbines 2006; Jones et al. 2010; Usmar 2010; Lowe 2013 in Morrison et al. 2014).

Usmar (2010) deployed artificial horse mussel patches in Mahurangi Harbour, both with and without artificial epifauna, as well as controls, and found highest snapper numbers (30–50 mm) to be associated with the horse mussels with epifauna. Mean densities were about 40–120 (± 30) snapper per 100 m^2, compared to adjacent area densities of 4.7 (± 3) per 100 m^2 (as sampled by beam trawling) a 10–30 fold difference, attributable to the artificial horse mussel structures. Other associated species included triple-fins, juvenile spotties (*N. celidotus*), goatfish (*U. lineatus*), and the invasive bridled goby (*Arenigobius bifrenatus*) (Usmar 2010)."

Morrison et al. (2009) also suspect that horse mussels may provide an important nursery habitat role for other harvested fish species, such as tarahiki and blue cod. Blue cod may recruit to biogenic habitats (including horse mussels) adjacent to rocky reefs, and then move with increasing size onto the reefs. Juvenile forms (about 3–5 cm) have been seen off Goat Island Bay, Leigh Marine Reserve, in association with horse mussels and sponges (Morrison personal observation in Morrison et al. 2009).

7.2.1.4 Pressures on horse mussel beds

Horse mussels are highly sensitive to increased sedimentation loads (see paragraph 2.4.2). They are also very vulnerable to damage caused by seafloor disturbing activities such as trawling, dredging, and potentially anchoring.

7.2.2 Dog cockles

7.2.2.1 General description

Dog cockles can form extensive beds and are probably common around New Zealand (Morrison et al. 2014)[47]. But despite the size, local abundance and extensive distribution almost nothing is known about its biology and longevity (Dewas 2008). They are known from shallow water to 73 m depth occurring partly buried in coarse sand and gravel (Powell 1979 in Dewas 2008).

7.2.2.2 Known distribution

By-catch data collected during a scallop survey in 2012 (Williams 2013) presented in the 2014 Hauraki Gulf State of Environment report indicate various locations in the Hauraki Gulf where dog cockles are present including the area north(east) of the Kuaotuna Peninsula, and the area northwest of the top of the Coromandel Peninsula (Figure 28).

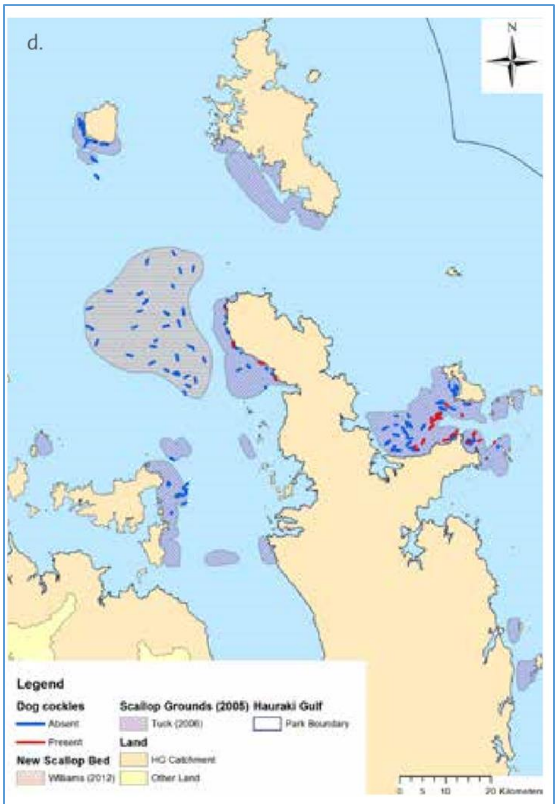


Figure 28. The presence/absence of dog-cockles obtained during scallop surveys in the Hauraki Gulf (Hauraki Gulf Forum 2014; original data from Williams 2013).

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[47]Being recorded from Cape Reinga to North Cape, Northland (Mimiwhangata), Greater Omaha Bay, Kawau Bay, Noises Islands and Tarakihi Island (inner Hauraki Gulf), the inner South Taranaki Bight, Tasman and Golden bays, Marlborough Sounds, Foveaux Strait, of the Manukau Harbour entrance, Hawkes Bay, Wanganui, Cape Farewell, Tasman Bay, Cape Palliser, Timaru, Oamuru, near Bligh Sound, and off the entrance to Doubtful Sound, Chalky Island (Morrison et al. 2014 and references therein).

7.2.2.3 Importance for biodiversity

Morrison et al. (2014) described the value and ecosystem functions of infaunal bivalves including dog cockles as follows:

"Infaunal bivalves such as dog cockles may provide various functions including benthic-pelagic coupling, nutrient transfer, phytoplankton abundance regulation, carbon sequestration, and food provision. There is no evidence that they directly provide shelter for fish, aside from some small cryptic forms (e.g. cling-fish). Dewas & O'Shea (2012) quantified dog cockle shell beds ("large post-mortem deposits") around Otara Island (Noises Islands, inner Hauraki Gulf), as well as shell grit and rock gravel. Invertebrate diversities and densities were consistently higher in the dead shell beds over time. 351 species were recorded, of which 30% were found only in dead shell habitat, compared to 10.5% being in the shell and rock gravel habitats."

7.2.2.4 Pressures on dog cockle beds

Little information is available, beyond the knowledge that direct and indirect fishing effects, and land-based impacts (Morrison et al. 2009) are important threats to many in-faunal bivalves, depending on species and environmental context (Morrison et al. 2014).

7.2.3 Scallop beds

7.2.3.1 General description

The fs.fish.govt.nz website provides the following general description for scallops:

"Scallops (*Pecten novaezelandiae*) are found in a variety of coastal habitats, but particularly in semi-enclosed areas where circulating currents are thought to retain larvae. After the planktonic larval phase and a relatively mobile phase as very small juveniles, scallops are largely sessile and move actively mainly in response to predators. They may, however, be moved considerable distances by currents and storms and are sometimes thrown up in large numbers on beaches.

Scallops are functional hermaphrodites, and become sexually mature at a size of about 70 mm shell length. They are extremely fecund and may spawn several times each year. The very high fecundity of this species, and likely variability in mortality of larvae and precruits, lead in great variability in annual recruitment. This, combined with variable mortality and growth rate of adults, leads to scallop populations being highly variable from one year to the next."

7.2.3.2 Known distribution

The known distribution of scallop beds in the Hauraki Gulf is shown in Figure 29 (Hauraki Gulf Forum 2014). In the Waikato region they mainly occur in the Colville area (Northwest of the Coromandel Peninsula) and in the area north of the Kuaotuna Peninsula and east towards the Mercury Islands, but smaller beds have also been reported just south of Manaia Harbour on the western side of the Coromandel Peninsula and areas around islands of the Slipper Island Group and the Alderman Islands on the eastern side of the Coromandel Peninsula.

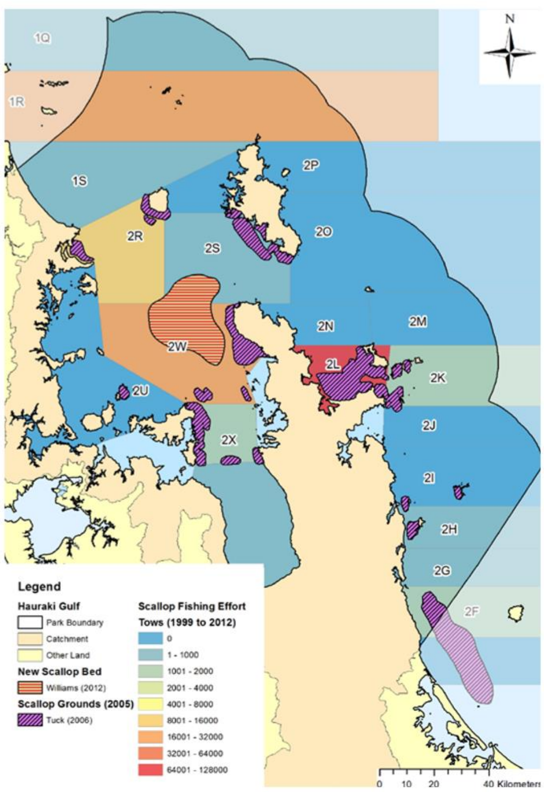

Figure 6-9: Total number of scallop tows in fishing reporting areas between 1999 and 2012. Also shown are the areas where commercial scallop dredging is prohibited; commercial scallop beds identified in Tuck *et al.* (2006); and, the approximate extent of the recently discovered, deep water scallop bed in Areas 2W and 2S *(based on Williams 2012)*.

Figure 29. Known scallop beds and scallop fishing efforts in the Hauraki Gulf (Hauraki Gulf State of the Environment report 2014).

7.2.3.3 Importance for biodiversity

Little is known about the ecological values or ecosystem services of scallop beds, but they can be expected to be similar to other shellfish beds (e.g. providing structural complexity influencing water flow conditions, shelter for predators, settlement habitats, feeding habitats, and maybe nursery habitats).

7.2.3.4 Pressures on scallop beds

The main pressure to scallop populations is from commercial fishing and recreational take. Additionally, scallops have been shown to be sensitive to suspended sediment concentrations under laboratory conditions (Morrison et al. 2009 and references therein; see also paragraph 2.4.2).

7.3 Subtidal seagrass

7.3.1 General description

Subtidal seagrasses grow best in clear water. An examination of the depth limit of seagrass communities distributed worldwide showed that seagrasses may extend from mean sea level down to 90 m, but are generally confined to depths of less than 20 m, or approximately 11% of surface irradiance (Duarte 1991).

7.3.2 Known distribution

Permanently submerged seagrass has been reported at a small number of locations in New Zealand, predominantly on offshore islands such as the Bay of Islands, Slipper Island, the Cavalli islands and Great Mercury Island (Rowden et al. 2012; Schwartz et al. 2006 and references therein), but also in subtidal channels of harbours such as Kaipara Harbour and Whangapoua harbour (Morrison et al. 2009).

Known locations of subtidal seagrass beds within the Waikato region are Hurihuri Bay (Great Mercury Island; Figure 30), South Bay (Slipper Island; Figure 30), and Whangapoua Harbour (Graeme 2013/38).

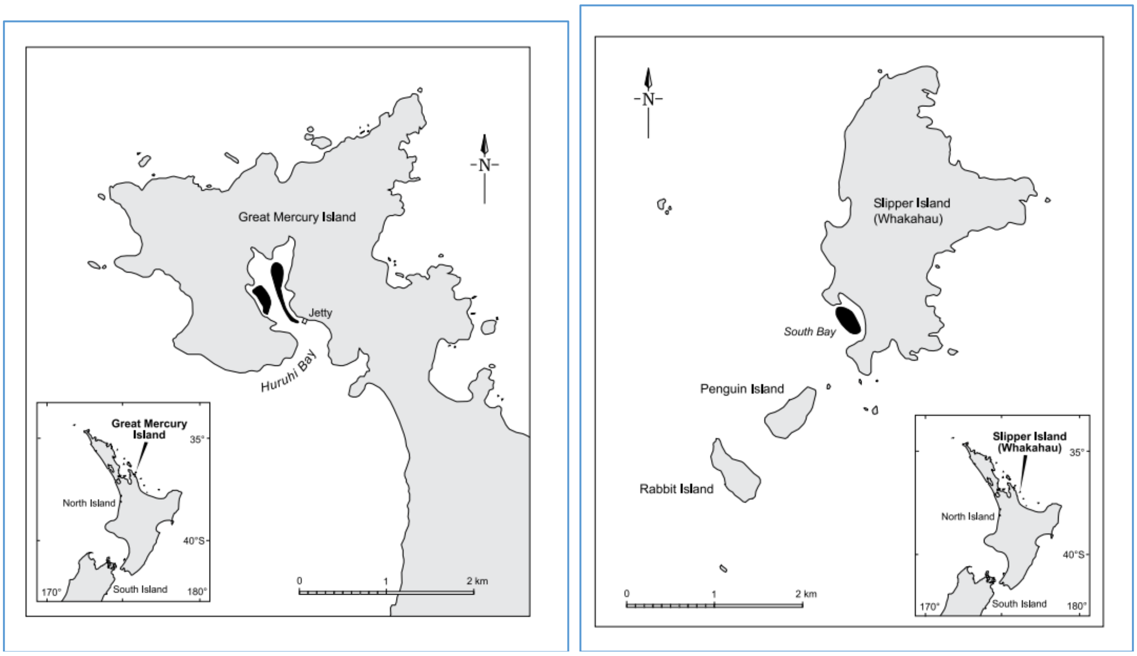

Figure 30. Subtidal seagrass beds at Great Mercury Island and Slipper Island (Schwartz et al. 2006).

The beds at Great Mercury Island and Slipper Island have been surveyed in the 1970's and 2004 (Schwartz et al. 2006). The seagrass bed in South Bay (Slipper Island) is permanently submerged, grows to 4–5 m below chart datum, and covered an area of approximately 0.03 km^2 in 2004 (Schwartz et al. 2006). In 1973, seagrasses were reported to occur throughout South Bay from low tide level to a depth of about 5 m indicating that the extent of the seagrass bed in 2004 was reduced to around 65% of that in 1973 (Schwartz et al. 2006).

In 2004, the seagrass bed at Hurihuri Bay, Great Mercury Island, consisted of an intertidal component and a subtidal fringe extending out to about 1 m below chart datum and covered an area of 0.07 km^2 (Schwartz et al. 2006). A map of Hurihuri Bay dating back to 1975 showed that seagrasses occupied the whole bay and extended out to the 5 m depth contour, indicating that the extent of these beds had declined substantially since 1975 (Schwartz et al. 2006).
Water clarity measurements at Slipper Island and Great Mercury Island carried out in May 2004 were equivalent to 36% and 80% of surface irradiance, respectively (Schwartz et al. 2006).

No specific surveys have been carried out to assess the distribution of subtidal seagrass beds in Whangapoua Harbour. Morrison et al. (2009) reported that aerial photographs from 1945 indicated that seagrass meadows covered much of the subtidal channel areas of Whangapoua Harbour, and Graeme (2013/38), who carried out a vegetation survey in Whangapoua Harbour in 2010, reported the presence of small areas of subtidal seagrass in this harbour, particularly up the Mapauriki arm.

7.3.3 Importance for biodiversity

Seagrass beds perform a variety of functions in estuarine and coastal ecosystems, including primary production, the trapping and stabilisation of bottom sediment, nutrient cycling, and the provision of habitat (Schwartz et al. 2006).

Morrison et al. (2014) assessed the function of seagrass meadows as biodiversity and productivity hotspots by sampling intertidal and subtidal seagrass beds at nine locations across New Zealand (North and South Island). They summarised that:

- Subtidal seagrass meadows in northern New Zealand are important juvenile fish nurseries, particularly for species such as snapper and trevally. However, the results showed that the value of a given habitat type is contextual, being affected by factors such as biogeography and local setting, as well as habitat quality (e.g. seagrass blade height and density, water depth, and patchiness)[48]."

- The role of seagrass habitat on the composition of faunal invertebrate communities (both in-faunal and epi-faunal) is complex and highly variable spatially. The presence of seagrass does not always equate to higher abundance, species richness or secondary production when compared to local bare or sand habitats. In terms of secondary production derived from seagrass compared to bare habitats, no consistent latitudinal trends were apparent for associated invertebrate communities. Subtidal seagrass sites were not identified as having higher secondary production values when compared to their intertidal seagrass counterparts, in contrast to its fish nursery values (north of Cook Strait).

Subtidal seagrass beds at Great Mercury Island and Slipper Island

In 2004 the seagrass bed in Hurihuri Bay (Great Mercury Island) supported high abundances of sand gobies, juvenile yellow-eyed mullet and snapper along with low abundances of other species. The juvenile snapper densities were especially notable, being one of the highest densities ever recorded over seagrass or any other habitat in New Zealand (Schwartz et al. 2004).

The macro-invertebrate abundance and diversity in the seagrass bed in South Bay (Slipper Island) was higher than at other sites around the Coromandel Peninsula. Twice as many taxa and more than three times the number of individuals were found within the South Bay seagrasses compared to bare adjacent sediments and compared to samples from the subtidal seagrasses at Great Mercury Island (Schwartz et al. 2004). The seagrass bed in South Bay was also associated with reasonable densities of snapper, trevally and kahawai (Morrison, unpublished data in Lundquist et al. 2004). Additionally, dive surveys in June 2004 identified reasonable numbers of goatfish and spotties and high densities of pipefish (Clinton Duffy personal comment in Lundquist et al. 2004). Night dives showed that the South Bay seagrass bed provides sleeping grounds for a number of fish species not encountered during the day, including adult red mullet and northern bastard red cod (Schwartz et al. 2006).

7.3.4 Pressures on subtidal seagrass

A reduction in water clarity might be expected to reduce the ability of the submerged segrass beds to persist (Schwarz et al. 2004). Seafloor disturbing activities can also negatively impact on subtidal seagrass beds.

7.4 Sponge gardens

7.4.1 General description

Morrison et al. 2014 described the value and function of sponges for fisheries as follows:

"Sponges occur around New Zealand, and are a central component of many rocky reef assemblages, especially below depths at which large algae are able to grow. They also occur across a range of soft sediment systems, where sufficient hard surfaces are available for initial attachment. The term 'garden' is used for situations where sponges grow in sufficient abundance and extent to form the dominant cover. In shallow north-eastern New Zealand, this

[48] More specific info: Lowe M.L. 2013. Factors affecting the habitat usage of estuarine juvenile fish in northern New Zealand. Unpublished PhD thesis, University of Auckland. 276 p.

is often on flat reef basements covered by a thin layer of coarse sediment, as well as on more topographically complex reef. Comparatively well studied examples include the “Sponge Garden” off Goat Island, Cape Rodney to Cape Okakari Marine Reserve, and Spirits Bay at the top of Northland.”

7.4.2 Known distribution

Kelly (2005) identified the dominant New Zealand sponge biodiversity hotspot to be in the northern New Zealand region that includes Three Kings, North Cape, Spirits Bay and Pandora and Wanganella Banks.

MacDiarmid (2013) provided examples of known sponge gardens in New Zealand’s EEZ including one example in the Waikato region: “Thames Estuary, Hauraki Gulf biogenic horse mussel habitat, 20–35 m: described as an example of a sponge garden with low species diversity, high morphological diversity, low to medium density, medium percentage cover, non-uniform and clumped distribution.”

A variety of different species of sponges and ascidians were identified using video footage collected during one dive (44 minutes; maximum depth 19 m) at the Alderman Islands in 2007 (Figure 31) (Sietse Bouma personal observations).

Figure 31. Sponges and ascidians Alderman Islands (Sietse Bouma 2007; one dive 44 minutes, maximum depth 19 m).

7.4.3 Importance for biodiversity

Sponge gardens have been reported to possibly provide nursery functions for juvenile snapper on north-eastern New Zealand reef environments (Battershill 1987 in Morrison et al. 2009). Work on soft sediment systems in the inner Hauraki Gulf has shown strong relationships between the abundance of snapper (especially juveniles) and the presence of biogenic seafloor structure, including sponge species such as the yellow finger sponge *Callyspongia ramosa* (Morrison et al. 2008).

7.4.4 Pressures on sponge gardens

Seafloor disturbing activities are probably the main threat to sponge gardens, but sponges can also be vulnerable to environmental factors such as sedimentation. Work by Lohrer et al. (2006b) found for example that the sponge *Aaptos spp*., a circular species found on rocky reefs, showed declines in condition relative to controls after experimental exposure to fine sediment deposits for three weeks, with water filtering rates also declining by about 40%.

8 Discussion

Use of presented inventories, surveys and references

This report provided an overview of available information for different ecological groups and habitats in the Waikato region's CMA at different scales (e.g. Hauraki Gulf, specific estuaries and/or harbours) and time periods. The references and information presented provide a basis to assess the (historic) presence of particular species and habitats in the Waikato region's CMA and can also be used to identify knowledge gaps in the availability of data. The data may also be useful to assess trends over time, but when doing this, different methods, observers, efforts and purposes of the various surveys and inventories need to be taken into account.

For example, the MPI shellfish surveys carried out in various Coromandel harbours and estuaries do not intend to map all cockle and pipi beds within an estuary or harbour, but focus on collecting detailed information (e.g. abundances and size distributions) for a number of selected shellfish beds at fixed locations. In contrast, the NIWA benthic habitat surveys carried out in thirteen Coromandel harbours and estuaries in 2013 focused on mapping all cockle and pipi beds, but did not collect any detailed information on abundances or sizes. The results of these studies may therefore not be directly comparable to each other, but may complement each other depending on the use of the dataset.

New survey techniques and monitoring tools are continuously being developed. Since the development of GIS units and field computers maps have become much more accurate, sophisticated new seafloor mapping technologies have allowed for the production of high resolution 3D maps of the seafloor, high resolution aerial photographs can now be used to map shallow habitats in estuaries and harbours, and thermal imaging techniques are being developed to monitor marine mammals. Results of these new techniques may not necessarily be directly comparable with previous surveys and inventories. However, they may provide opportunities to fill in knowledge gaps and carry out surveys and inventories more cost efficiently.

Use of information on vulnerable life stages and sensitivity to specific pressures

This project did not follow specific definitions or criteria for 'vulnerability' and 'sensitivity'. Instead, it focussed on aspects of vulnerability and sensitivity that would be relevant in a real-life scenario such as a resource consent process. As a consequence, this document does not cover all 'vulnerable life stages' or 'existing pressures/threats' to different species or habitats, but provides quantitative information that may assist the assessment of potential effects of human activities on particular species and habitats and that may help to identify possible resource consent conditions. An illustration how information in this report can be used for resource consent applications is provided in the text box below.

Illustration of how information provided in this report can be used

Assessment of impacts of sediment on benthic communities and (diadromous) fish in a Coromandel harbour.

What species are present?

- Available surveys and inventories: benthic communities (paragraph 2.2.1); fish in Coromandel harbours (paragraph 4.2.3); diadromous fish records (paragraph 4.2.5).

How vulnerable are these species to sediment during different times of the year?

- Vulnerable life stages of benthic species (spawning season; paragraph 2.3);
- Vulnerable life stages of coastal and marine fish species (spawning season; paragraph 4.3.1) and diadromous fish (spawning season and migration movements; paragraph 4.3.2).
- Sensitivity of benthic species to sedimentation (paragraph 2.4);
- Sensitivity of coastal and marine fish species and diadromous fish species to sedimentation (paragraph 4.4.2).

Update of information

Efforts were put into providing a complete as possible overview of available information, but it is not expected that all available information is included in this report and new information will become available in the future. Waikato Regional Council will endeavour to maintain an updated reference list and appreciates receiving information on new reports or datasets via email to info@waikatoregion.govt.nz.

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