Marsden Point Refinery: **A Resource Consent Application to Renew 20 Resource Consents from the Northland Regional Council**

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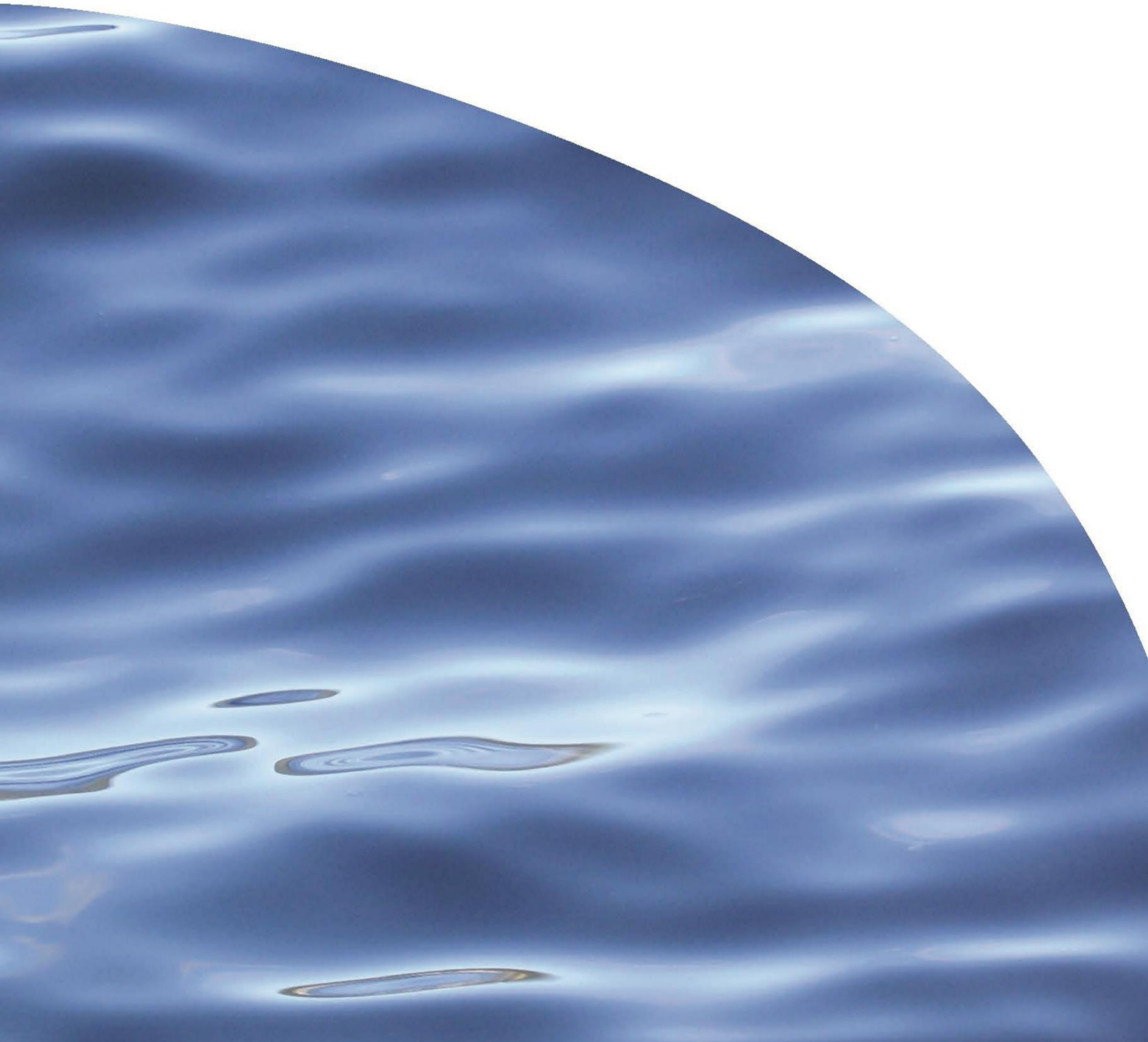
REFINING NEW ZEALAND LTD. MARSDEN POINT REFINERY RE-CONSENTING: MARINE MAMMAL ASSESSMENT OF EFFECTS



REFINING NEW ZEALAND LTD MARSDEN POINT REFINERY RE-CONSENTING: MARINE MAMMAL ASSESSMENT OF EFFECTS

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EXECUTIVE SUMMARY

Refining New Zealand (RNZ) owns and operates New Zealand's only oil refinery, based at Marsden Point at the entrance to Whangarei Harbour. RNZ is seeking to renew a number of its current resource consents regarding discharges (to air, water and land) and associated activities. Given most marine mammals' susceptibility to bioaccumulation and biomagnification of marine contaminants, often associated with coastal discharges, RNZ contracted the Cawthron Institute (Cawthron) to consider the potential effects of renewing their consents to discharge treated stormwater and wastewater, uncontaminated seawater and maintenance discharges on local and visiting marine mammal species.

The marine mammals most likely to be affected by the proposed project are those species that frequent the Whangarei Harbour and Bream Bay regions throughout the year or on a semi-regular basis. These species include bottlenose and common dolphins, orca, and Bryde's whales. Several other species are also considered due to various life history dynamics and / or are of special concern to local iwi Tangata Whenua o Whangarei Te Rerenga Paraoa. However, there is no evidence indicating that any of these species have home ranges or foraging habitats restricted solely to Whangarei Harbour and nearby Bream Bay waters. Based on current knowledge, the proposal area is not considered ecologically more significant in terms of feeding, resting or breeding habitats for any species relative to other regions along the north-eastern coastline of the North Island.

Marine mammals' long-life spans and coastal tendencies make them more susceptible to the bioaccumulation of contaminants within their thick blubber layers due to the lipophilic (fat soluble) and persistent nature of several chemicals. Moreover, marine mammals generally occupy a high trophic position in the food chain that makes them potentially vulnerable to biomagnification. Key factors that influence the extent of any potential effects from discharge contaminants on marine mammals include the type and amount of contaminants present, how an animal is exposed, the individual's or species' susceptibility to the contaminant as well as their baseline health at the time of exposure.

Predicting the possible impacts of marine discharges on New Zealand marine mammal species from a single source is complex and, at this point in time, must be based mainly on the quality and type of discharges and the species' expected exposure risk. Any overall risk from the combined discharges is expected to be low for those marine mammal species with the highest potential sensitivities and risk of exposure: individual bottlenose or common dolphin or orca, and possibly a Bryde's, humpback or southern right whale. Exposure to any discharge contaminants would most likely occur via the food chain (through prey species). However, the species known to occur in these waters are generalist feeders, potentially ranging and foraging throughout the entire Northland coastline (and beyond). The lack of any marine mammal residing within Whangarei Harbour or the wider Bream Bay area year-round means the likelihood of an individual animal foraging on prey, or swimming through waters exposed to the discharge would be very low. Based on the various data collected for the discharge and receiving environment and hydrodynamic modelling results, any potential

effects on marine mammals from the renewal proposal are considered negligible and no further mitigation is warranted.

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1. INTRODUCTION

1.1. Description of proposal

Refining New Zealand (RNZ) owns and operates New Zealand's only oil refinery based at Marsden Point at the entrance to Whangarei Harbour – Whangarei Te Rerenga Parāoa (Figure 1). The refinery was commissioned in 1964 and is the country's only oil refinery and the leading supplier of refined petroleum products to the New Zealand market.

RNZ is seeking to renew a number of its current resource consents regarding discharges (air, water and land), abstraction, coastal occupation and maintenance / repair activities; most of which will expire in 2022. Discharges to the marine environment currently include treated wastewater, groundwater and stormwater flows via a submarine diffuser attached to the refinery jetty and into the lower Whangarei Harbour near the entrance. In addition, there is a bypass diffuser and spillway from the stormwater basin for use in extreme rainfall events (Figure 1). A complete description of these discharges and their pathway through the refinery can be found in section 3 of the application (Kemble 2019).

Given the potential susceptibility of marine mammals to bioaccumulation and biomagnification of contaminants, concerns are often raised in association with coastal discharges. RNZ has contracted the Cawthron Institute (Cawthron) to consider the potential effects of renewing their consents to discharge treated stormwater and wastewater, uncontaminated seawater and maintenance discharges on local and visiting marine mammal species.

1.2. Assessment scope

RNZ contracted Cawthron to outline and assess any potential effects on marine mammals from the proposed reconsenting of current discharge services. This report includes:

- a summary description of the existing environment in terms of those marine mammal species identified as being the most susceptible to any effects of the proposed activities in Whangarei Harbour and the wider Bream Bay ecosystem
- a literature review of the potential associated effects of marine discharge with relevance to marine mammals and any potentially relevant guidelines
- categorisation of the overall risk of any resulting effects in terms of scale, duration / persistence, likelihood and possible consequences based on the findings of other relevant reports (e.g. water quality, hydrodynamics, ecology)
- recommendations for avoidance, remediation and mitigation options based on the final risk assessment of effects, if necessary.

Figure 1. Aerial view of the extent (shown in yellow) of Refining New Zealand's Marsden Point refinery sited at the Whangarei Harbour entrance. Inset: Locations of the refinery's three possible marine discharge points.

2. DESCRIPTION OF EXISTING ENVIRONMENT[1]

2.1. General approach

When considering the potential implications of marine developments on marine mammals, the appropriate scale of consideration is not just the area of the proposal but also the spatial scales relevant to the marine mammal species involved. For most marine mammals, normal home ranges can vary between hundreds to thousands of kilometres. For instance, while southern right whales may be considered only seasonal migrants to Bream Bay waters, this stretch of water may represent an important corridor that mother whales use to safely reach Northland nursery grounds during their winter migration. As a result, the importance of Whangarei Harbour and associated Bream Bay waters needs to be considered in the context of species' regional and New Zealand-wide distributions.

To date, several university research programmes have been undertaken on marine mammal species along the northeast coast of the North Island. Since the mid-1990s, these studies have mainly been concentrated to the north (Bay of Islands) and south (within the Hauraki Gulf) of the proposal area (see specific study details in Appendix 1). However, no marine mammal studies have focused on Whangarei Harbour and / or the Bream Bay region. In the absence of any long-term and spatially explicit baseline research on marine mammals in Whangarei Harbour or Bream Bay, species information and sighting data were collated from ongoing research throughout the central-eastern coastal region (i.e. Massey University-Albany, University of Auckland, Orca Research Trust). In addition, opportunistic sightings reported to Department of Conservation (DOC) (including the public, tourism vessels, seismic surveys, etc.) and strandings (previously collated through Te Papa National Museum and now DOC) were reviewed.

Without adequate population information (e.g. growth trends, total abundance etc.), the potential risks to marine mammal species associated with various anthropogenic activities must be assessed based on the species' life-history dynamics (e.g. species-specific sensitivities, conservation listing, life span, main prey sources) summarised from New Zealand and international data sources[2]. Collectively, this information is used to determine what is currently known about any relevant species' occurrence, behaviour, and distribution within the area of interest and to evaluate those species most likely to be affected by the proposed project.

[1] Note that this section is largely a summary and update of the Clement & Elvines (2015) report on marine mammals near Whangarei Harbour for RNZ.

[2] Peer-reviewed journals, New Zealand Threat Classification System - NZTCS, National Aquatic Biodiversity Information System – NABIS (www.nabis.govt.nz/), International Union for Conservation of Nature (IUCN) Red List of Threatened Species (https://www.iucnredlist.org/)

2.2. General site description

Whangarei Heads is also known as 'Whangarei Te Rerenga Parāoa', which means 'Whangarei, the gathering place of whales'. While this reference is also thought to be a metaphor for the gathering place of chiefs[4], the significance of whale migrations past this region is supported by the number of whaling stations found to the north near Whangamumu and along the entire eastern coastline of the North Island during the late 1800s and early 1900s (Dawbin 1956).

Out of the more than 50 species of cetaceans (whales, dolphins and porpoises) and pinnipeds (seals and sea lions) known to live or migrate through New Zealand waters, at least 27 cetacean and two pinniped species have been sighted or stranded along the north-eastern coastline of the North Island. Figure 2 highlights the various marine mammal species recorded from the north-eastern coastal regions between the Bay of Islands to the north and the entrance to the Hauraki Gulf and Great Barrier Island to the south. It is important to note again that a large majority of these sightings are collected opportunistically rather than systematically. Consequently, the number of sightings in these figures do not necessarily represent unique animals (i.e. the same animal may be reported by multiple members of public or on two separate days). As effort is not considered with opportunistic data, favourite fishing spots and tour boat tracks are likely to be over-represented, especially during periods of more favourable conditions (e.g. summer, daylight). Most sightings were recorded around the Bay of Islands and Hauraki Gulf regions (Figure 2), most likely a reflection of the marine tour companies operating within these vicinities that offer marine mammal tours and swims and report their sightings to DOC.

For this assessment, less importance is placed on the location of sightings with more emphasis on the presence and timing of an identified species in the lower Northland region. The more common species are listed in Table 1 and divided into three general categories that describe the current knowledge about their distribution patterns within Bream Bay and nearby waters. Species' information is likely to change as more systematic research becomes available, particularly for uncommon species:

- *Resident* — a species that lives (remains and feeds and / or breeds) within Bream Bay or nearby waters either permanently (year-round) or seasonally.
- *Migrant* — a species that periodically travels through part(s) of Bream Bay but remains only for temporary time periods that may be seasonally predictable.
- *Visitor* — a species that visits Northland or nearby waters intermittently. Depending on Bream Bay's proximity to the species' normal distribution range, visits may occur seasonally, infrequently or rarely.

[3] Further discussion of this reference can be found in Patuharakeke Te Iwi Trust Board's (PTB) cultural effects assessment (PTB 2020).
[4] A history of Ngati Wai – First of Four Instalments by Morore Piripi (http://teaohou.natlib.govt.nz/journals/teaohou/image/Mao37TeA/Mao37TeA018.html).

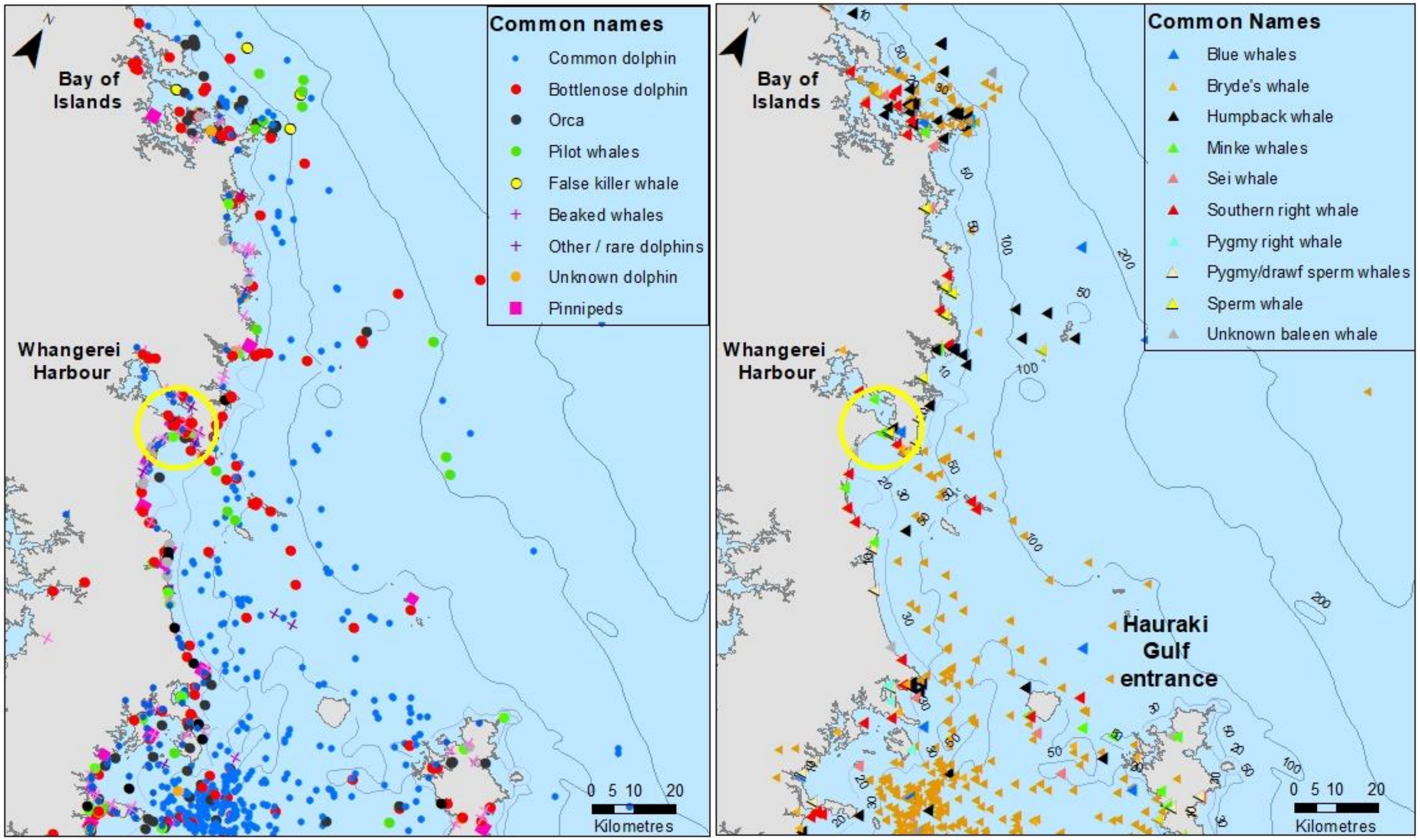

Figure 2. The distribution of Department of Conservation (DOC) reported sightings (1978–2018) and strandings (1869–2018) between Bay of Islands and the northern entrance of the Hauraki Gulf. Toothed whales and dolphins plus pinnipeds (seals) are shown in the left image and migrating whale species in the right image. The yellow circles indicate the extent of the area in which modelled dilution scenarios for the proposal discharge sites are being considered.

Table 1. The residency patterns of the more common marine mammal species to frequent Whangarei and nearby waters. Species' conservation threat status is listed for the New Zealand system (NZTCS – Baker et al. 2019) and internationally (IUCN system, ver 3.1). Modified from Clement and Elvines (2015).

Common name	Species name	NZ Threat Classification System	IUCN Listing	Residency category in Northland	Patterns of Seasonality (relative to proposal area)
Bottlenose dolphin	*Tursiops truncatus*	Nationally Endangered	Data Deficient	Seasonal to Year-Round Resident	Resident sub-population to north in Bay of Islands that ranges between Doubtless Bay, Great Barrier Island and Tauranga. Occasional visits to Whangarei / Bream Bay perhaps more over summer months. Generalist feeders. Currently in decline.
Common dolphin	*Delphinus delphis (including D. capensis)*	Not Threatened	Least Concern	Seasonal to Year-Round Resident	Common throughout north-eastern waters year-round. Feed on schooling or more pelagic fish species. Generally observed in waters deeper off Whangarei / Bream Bay with occasional inshore sighting.
NZ fur seal	*Arctocephalus forsteri*	Not Threatened	Least Concern	Seasonal to Year-Round Resident	Present year-round with multiple haul-out sites and breeding colonies in the Hauraki Gulf and regular sightings off the Hen & Chickens Islands and Bay of Islands. More susceptible to human effects in breeding colonies. Feed mainly over shelf waters.
Leopard seal	*Hydrurga leptonyx*	Naturally uncommon	Least Concern	Seasonal to Semi-Resident	Solitary animals occasionally observed within Whangarei Harbour (e.g. Marsden Cove Marina) as well as various haul-out sites and marinas between Auckland and Northland
Orca (killer whale)	*Orcinus orca*	Nationally Critical	Data Deficient	Seasonal to Semi-Resident	Frequent north-eastern waters year-round, more common in late winter / early spring. Forage in harbours, estuaries and coastal areas on rays, fish and other marine mammal species. Overseas populations noted for heavy pollutant loads due to high trophic level.
Bryde's whale	*Balaenoptera edeni brydei*	Nationally Critical	Data Deficient	Seasonal to Semi-Resident	Most commonly observed whale species in north-eastern waters year-round. Feed on small schooling fish and sometimes krill. Regularly move through Bream Bay travelling between Bay of Islands and Hauraki Gulf.
Pilot whales	*Globicephala melas, G. macrohynchus*	Not Threatened to Data Deficient	Data Deficient	Offshore Semi-Resident	While a more offshore species, inshore sightings occur mainly over summer months. Forages off shelf waters. Known for frequent and mass strandings in Bream Bay and surrounding waters.
Southern right whale	*Eubalaena australis*	At Risk - Recovering	Least Concern	Seasonal Migrant	Frequent more inshore, shallow regions of Northland during seasonal migration periods, particularly with new-born calves. Once present, they can remain in the Northland region for several days to weeks. Most often seen between August and November.
Humpback whale	*Megaptera novaeangliae*	Migrant	Endangered	Seasonal Migrant	Pass by Whangarei / Bream Bay on both north and south migrations but more prevalent and closer to shore on southern return migration when with calves (mainly Oct to late Dec).
Sperm whale	*Physeter macrocephalus*	Not threatened	Vulnerable	Offshore Visitor	Increased sightings along the north-eastern coasts, mainly over summer and autumn months.

2.3. Species of interest

Several of the species highlighted in Table 1 and Figure 2 are known to be year-round or seasonal residents of the coastal regions surrounding Whangarei Harbour and Bream Bay areas. The more common species occurring along the Whangarei coastline, and therefore those most likely to be affected by the proposed project, include bottlenose dolphins, common dolphins, orca, and Bryde's whale (Clement & Elvines 2015). A summary of these and other species reported from the general area is provided in Appendix 2.

Other species of interest include those that may be less frequent visitors but are more vulnerable to anthropogenic (human-made) impacts due to their current conservation status (e.g. southern right whales are 'at risk–recovering') or species-specific sensitivities (e.g. mass stranding tendencies of pilot whales). Given the reference to whales in the harbour's name by Tangata Whenua of Whangarei Te Rerenga Parāoa, several additional species are considered (e.g. PTB 2020; Table 1 and Appendix 1).

When considering potential implications of coastal developments on local marine mammal populations, the importance of Whangarei waters needs to be placed in the context of the species' regional and New Zealand-wide distribution. Our review is based on the available species data, and in reference to the following:

- Section 6(c) of the Resource Management Act 1991 (RMA) [5]
- Policy 11 of the New Zealand Coastal Policy Statement (NZCPS)
- Policy 4.4.1 of the Regional Policy Statement for Northland
- Method 9.2.5.2 of Northland's Regional Coastal Plan (RCP)[6]
- the relevant maps and provisions in the proposed Regional Plan for Northland (pNRP, see in particular Appendix 3).

Against this context, there is no evidence indicating that any of these species have home ranges restricted *solely* to Whangarei Harbour and nearby Bream Bay waters. While several whale species have their regular migration routes through this region, the harbour is not considered to be an ecologically important migration corridor as most animals generally pass by the area further offshore. Hence, based on current knowledge, the proposal area is not considered ecologically more significant in terms of feeding, resting or breeding habitats for any species relative to other regions along the north-eastern coastline.

[5] Section 6(c) - the protection of areas of significant indigenous vegetation and significant habitats of indigenous fauna.

[6] Appendix 9 - The Council has used the following criteria to determine those areas of important conservation value identified in the Plan as Marine 1 Management Areas. 5 – Marine Mammals and Birds Area including or near any: (a) marine mammal breeding or haul-out site.

As highlighted in Table 1, these waters also periodically support threatened species, such as Bryde's whales, bottlenose dolphins, orca and southern right whales. These species are relevant in regard to Policy 11(a) of the NZCPS, which refers to avoiding adverse effects on nationally and / or internationally recognised threatened species.

3. POTENTIAL EFFECTS OF CONTAMINANTS ON MARINE MAMMALS

Marine mammals are often referred to as 'marine sentinel organisms' or barometers for current ocean health issues (e.g. Bonde et al. 2004; Jessup et al. 2004; Wells et al. 2004; Bossart 2011). For Patuharakeke, regular visits by whales, in particular, to Whangarei are viewed as "obvious indicators" of both ecological and cultural health and wellbeing (PTB 2020). With long life spans, high trophic level diets and coastal residency, marine mammals are vulnerable to the bioaccumulation of anthropogenic contaminants. Measurable amounts of chemical pollutants have now been found in virtually every species of marine mammal world-wide (Kraus & Rolland 2007).

The lipophilic (fat soluble) and persistent nature of some chemicals make marine mammals particularly vulnerable to bioaccumulation within their thick blubber layers (lipid-rich, collagen fibre-laced), as well as biomagnification due to their generally higher trophic level in the food chain (Woodley et al. 1991; Weisbrod et al. 2000). Trace elements (e.g. heavy or toxic metals) are also known to accumulate in marine mammals' protein-rich tissues, such as the liver and muscle. Once contaminants are retained within an animal, they are not easily eliminated except during pregnancy and lactation, during which some contaminants can be passed to the offspring (Tanabe et al. 1994).

A comprehensive review of pollutant concentrations across Southern Hemisphere marine mammals found that coastal species in higher trophic levels (fish-eating) and with smaller bodies tend to have greater concentrations of most pollutants (Evans 2003). As a result, local marine mammals are often considered when assessing the potential effects of various discharges and / or contaminants on marine ecosystem health (Bonde et al. 2004). Key factors that influence the severity of potential effects from discharge contaminants on marine mammals include:

- types of contaminants
- pathways of exposure
- susceptibility
- baseline health.

3.1. Types of contaminants

The focus on contaminants of concern for marine mammals has shifted over the decades from heavy metals to more legacy pollutants[7], many of which are known for

[7] Legacy pollutants are generally persistent contaminants that have been left in the environment by sources that are no longer discharging them. As they are very hard to break down and often are not soluble in water, they remain long after the source disappears.

their endocrine disrupting potential. Endocrine disrupting chemicals (EDCs), known to affect reproductive and / or immune functions, include synthetic organic chemicals used in past industry and agriculture (e.g. organochlorine pesticides – OCPs), and currently used for plasticisers and detergents (e.g. alkylphenols; Fossi & Marsili 2003). The most well-studied organochlorine endocrine disruptors are organochlorine pesticides (e.g. DDT) and polychlorinated biphenyls (PCBs – dioxins and furans) used previously as coolants and lubricants for electrical equipment.

Oil leaks, spills and indirect discharges are also a major concern for marine wildlife. However, the chemicals of concern for marine mammals are not the aromatics, despite their toxicity. The high volatility of aromatics means they are found in large concentrations only immediately after a spill and generally disperse quickly. Instead, the less volatile polycyclic aromatic hydrocarbons (PAHs) are more persistent contaminants with a wide range of adverse effects, including endocrine disruption (Godard-Codding & Collier 2018).

More recently, emerging organic contaminants (EOCs) have become a global focus of concern as little is known about their fate or effects on the environment. These chemicals are found in pharmaceuticals and personal care products (PPCPs), such as soaps and detergents, and ultimately end up in wastewater systems. More information on both EDCs and EOCs can be found in Appendix 4.

3.2. Pathways of exposure

The three main routes of contaminant exposure in cetaceans, as in most animals, are respiratory, dermal, and oral (Godard-Codding & Collier 2018). Contaminants within the water column can be absorbed or actively taken up by organisms via the gills, skin, buccal cavity, gastrointestinal tract or through lesions and lacerations in the skin or, in the case of marine mammals, breathed into the lungs while at the surface. Some chemical and biological pollutants can concentrate in sea-surface microlayers (appearing as slicks) and / or bind to floating debris that can be directly ingested by coastal marine mammal species (Kraus & Rolland 2007). Due to the aggregating effect of coastal currents and frontal zones, baleen whales may swim through and feed directly on several pollutants. For other species that feed on fish, exposure to chemical contaminants may occur via the food chain or indirectly via the skin if they are in close proximity to areas influenced by high levels of industry or agriculture (WHO 2002). Alternatively, exposure during critical periods of development for marine mammals can occur via maternal transfer to their young, either via the placenta during gestation, or when young are suckling (Tanabe 2002; Fossi & Marsili 2003).

Bioaccumulation is a process where an organism absorbs and stores a chemical substance (natural or anthropogenic) in its tissues at a higher rate than the substance is broken down or excreted from its body. High chemical stability and resistance to metabolic degradation means that a range of substances can remain active within the environment through several generations. Sediments, plants and / or plankton can absorb varying amounts of chemical pollutants once they are released into the marine ecosystem. Several contaminants tend to adsorb to fine-grained particles (e.g. silt and clay) due to their larger surface areas. Organisms such as seaweed and plankton can accumulate toxins in their tissues and, due to their persistence, these stored toxins usually remain in the organism until it dies or is eaten, when the chemicals are passed on to the consumer.

This build-up of pollutants within lower trophic organisms is later passed on in greater and greater concentrations through the trophic levels, a process known as biomagnification. Due to biomagnification, continued exposure, and thus storage, of a particular substance within the tissue(s) of an organism, chronic concentrations can occur even when environmental levels of the same substance are low or no longer existent. In addition, fat-soluble substances can be released when the fat is broken down for energy. Such toxins can circulate in the bloodstream of an animal, affecting particular tissues and / or disrupting the normal functions of hormones.

The constant processes of bioaccumulation and biomagnification taking place within marine mammals means that any testing for potential exposure to a contaminant (via skin scrapes or biopsies of blubber) cannot be easily linked to a single source and / or response from the animal.

3.2.1. Exposure concentration

Understanding the concentration of a contaminant being discharged into the environment can help with evaluating how likely a species will encounter the contaminant within their habitat at levels of potential concern. However, even with a sound knowledge of effluent quality, predicting the possible exposure of a marine mammal to chemical and biological pollutants and the animal's subsequent response is confounded by many still unknown factors. There is rarely a clear relationship between contaminant concentration and its likely impact on marine mammals (e.g. AMSA 2015). Instead, species' responses will vary due to prey preference and subsequent uptake, home range, species' sensitivities to pollutants, health and immunological status of individual animals, as well as other environmental conditions that affect the interaction, including synergies between pollutants, and other possible sources (e.g. Jones 1998; La Patra 2003).

Hence, there are currently no national or international guidelines used for monitoring contaminant exposure in marine mammals in relation to single sources. Exposure concentration is sometimes used as a broad-scale indicator of the likelihood of lethal effects (e.g. French-McCay 2009). However, current best practice for assessing exposure risk in the case of a discharge is based mainly on the quality of effluent, (i.e. wastewater) or the sediments and water column in the vicinity of an outfall. The quality of effluent is largely dependent on the original source of the wastewater (e.g. domestic or industrial), the level of treatment (e.g. secondary), final concentrations and persistence of any effluent contaminants (as compared to the most relevant standards or guidelines), and any mitigating factors such as additional dilution via a diffuser and / or dispersion within the receiving environment. These indicators are then considered against the likelihood of the species' exposure risk. Specific life-history characteristics that potentially increase the degree to which a species might be exposed to discharges include a preference for shallower, inshore waters along urbanised regions, year-round residency within a restricted home-range near to the discharge, or a carnivorous diet based mainly on prey species that are regularly exposed to the discharge.

3.3. Susceptibility and baseline health

Natural resistance is normally effective enough to protect healthy marine mammals from infectious disease or pollutants. But when the physiological integrity of an individual dolphin or whale is compromised by chronic pollutant levels, particularly during more sensitive life stages (such as during foetal or egg development), this may lead to immune suppression. Such a condition may lead to outbreaks of disease from pathogens already present in the environment or to pathogens already held by a host under a normal non-stressed situation (Rice & Arkoosh 2002).

A comprehensive review of pollutant concentrations across Southern Hemisphere marine mammals found that the species that tended to accumulate the greatest levels of pollutants were mainly smaller ones that inhabited coastal regions and were higher trophic level (fish-eating) animals (Evans 2003). Species that are present year-round will be more susceptible to both chronic (small amounts over several different periods) and acute (one large event) exposure than species with seasonal movement patterns. Species that are in the area to feed or breed will also be more susceptible to contaminants than if they were just traveling through a region.

4. ASSESSMENT OF RISK

Predicting the possible impacts of discharge effluents on New Zealand marine mammal species is complex and, as discussed in the previous section, this must currently be based mainly on the quality and type of effluents and the species' expected exposure risks.

4.1. Discharge quality

Stewart (2019) collated water and sediment quality information for the RNZ stormwater basin (SWB) discharge from a variety of data sources (i.e. RNZ, NRC consent and SOE monitoring, NIWA, Cawthron) relating to varying time periods (i.e. 2012–2019). These data were compared against the most relevant applicable ecological guidelines to determine which contaminants present in the discharge may be of potential concern. Stewart (2019) used a risk quotient (e.g. ratio of contaminant concentrations compared to applicable receiving environment concentration thresholds) to identify those water quality contaminants that could have potential ecological effects prior to dilution into the receiving environment. These results were then used as inputs to hydrological modelling using the various discharge scenarios to assess the worst-case scenario in terms of potential exposure concentrations to the receiving environment (Stewart 2019; Appendix 5).

Almost all 'traditional contaminants'[8] under all of the discharge scenarios had a risk quotient of less than one (meaning that concentrations would be unlikely to reach levels of concern in receiving waters), with most contaminant levels orders of magnitude less. Based on this analysis, the contaminants with the greatest potential to cause adverse effects in the receiving environment are ammoniacal-nitrogen (NH_4-N), zinc, copper and faecal coliforms (FC). However, once near-field and far-field dilution effects were considered, only NH_4-N and FC levels remained a concern in worst-case modelling scenarios. Stewart (2019) notes that this represents a *negligible* effect of traditional contaminants on the water quality of the receiving environment around the discharge locations.

A range of process chemicals are also used by RNZ to help with regular day-to-day operations including biocides, flocculants and biodispersants. Similar to personal care products (PPCPs) such as soaps and detergents, these chemicals are not tested for routinely in RNZ's discharges (nor is it currently possible to test for some) but have the potential to be present and enter the receiving environment. Stewart (2019) used

[8] Stewart (2019) defines traditional contaminants as, '…measured by virtually all analytical laboratories under standard and often validated methods, while most of the chemicals within the process chemical formulations are not;' and in this case, were '…normally measured routinely in Refining NZ SWB and receiving environment sites (for both water and sediment), while (due to lack of analytical capabilities) process chemicals are not.' The list of traditional contaminants tested is available in Stewart (2019) and includes heavy metals, metalloids, total petroleum hydrocarbon, phenols, PAHs, BTEX (benzene/toluene/ethylbenzene/xylene) and various nutrients.

a 'worst-case' SWB concentration for each chemical to calculate a risk quotient using a mass balance assessment against several tiers of guidelines / standards (see Stewart 2019 for more details). Under worst case scenarios, including accidental spills, only three of the 18 formulations had the potential for adverse effects on the receiving environment. However, Stewart (2019) discussed in detail how these particular contaminants are generally short lived (less than 48 hours), are biodegradable and do not bioaccumulate in the environment. As a result, he considers RNZ process chemicals to have *negligible* ecological effects on the receiving environment.

Stewart (2019) also found contaminant concentrations in sediments were relatively stable over the sampling period (i.e. 2012–2016). When used in 3-D hydrodynamic modelling, the worst-case estimates of maximum contaminant concentrations within sediments at the at the edge of the mixing zone and at receiving environment sites were considered *negligible*. The resulting total suspend sediments (TSS) from RNZ discharge (i.e. turbidity plume form discharge) were estimated to be well below NRC's average annual background TSS levels of around 20 mg/L.

The assessment of marine ecological values observed invertebrate assemblages (both soft sediment benthic and hard shore species) currently beneath and adjacent to the existing RNZ jetty at the point of discharge to be both diverse and abundant (De Luca 2019). In addition, body burden contaminant levels of shellfish within these locations were also generally lower than reference and the nearby Northport sites. De Luca (2019) noted that the four contaminants (2 phenols and 2 PAHs), found in slightly higher concentration in oysters at the RNZ jetty than some reference sites, are ubiquitous in the environment and, while they could be derived from RNZ activities, they also have a range of anthropogenic and natural sources. Ecotoxicology testing involved the collection of water from RNZ SWB in 2017 and 2019 (during 2 separate sampling occasions) and quantifying its toxic effects on a suite of standard laboratory test organisms. Results indicated that different rates of dilution are needed to ensure no toxicological effects on test organisms (De Luca 2019).

Combining all these lines of evidence, De Luca (2019) assessed the level of effect on marine ecological values from all the various RNZ discharge activities as ranging from *low* to *very low*. This assessment was based on the following:

- Out of all the traditional contaminants examined, only the following had risk quotients or concentrations that suggested the potential for adverse ecological effects:
    - ammoniacal-nitrogen (NH_4-N) – higher risk quotient likely due to data collected prior to 2015 plant upgrades; only trophic effects rather than any toxic effects on biota

    - faecal coliforms (FC) – sporadic and marginal exceedance of risk quotient mainly attributed to nesting colonies of red-billed gulls near the SWB each summer
    - zinc – exceedance of the 10% of Australia New Zealand Surface Water Quality Guidelines (ANZ SWQG) during rainfall events but below effects thresholds overall
- Out of the 18 process chemicals reviewed, few yielded a risk quotient > 1. However, where this occurred, those formulations were characterised as either readily biodegradable, non-bioaccumulative and / or having low persistence in sediment / water compartments (short term effects); hence, any subsequent effects were considered negligible.
- Body burden testing and ecotoxicology results support generally high water and sediment quality around the discharge sites:
    - greater concentrations of only 4 out of 42 contaminants were found near discharge sites relative to reference sites.

4.2. Marine mammal exposure

The marine mammal species with the highest potential exposure are individual bottlenose or common dolphins, leopard or fur seal and orca, and to a much lesser extent, a Bryde's, humpback or southern right whale (Table 2). However, even for these, overall exposure risk from the various RNZ discharges is expected to be low. The most probable pathway for exposure to discharge waters is expected to occur via the food chain (through prey species). Those marine mammal species known to visit and travel through the harbour entrance, and associated areas of the modelling domains, tend to be generalist feeders that potentially range and forage throughout the entire Northland coastline and beyond. Other visiting species, such as whales, often do not feed while migrating while more offshore species feed mainly on deeper water prey such as squid. The absence of any year-round resident marine mammals that regularly and consistently forage within the harbour entrance waters means that the chance of an individual animal ingesting prey or swimming through waters exposed to the discharge would be very low (Table 2).

Hence, the renewal of existing discharge activities is not expected to result in significant habitat loss for any marine mammals frequenting this region, nor result in any significant long-term or indirect effects on marine mammal species. This conclusion is based on the following:

- There is no population of marine mammal species that resides year-round within the harbour, discharge mixing zone and / or nearby Bream Bay waters.
- There is generally no evidence that the harbour entrance or waters potentially affected by the associated discharge activities serve as important, unique and / or

rare habitat for any marine mammal species in terms of feeding, breeding and / or migratory activities.

- Seasonal trends in occurrence indicate that both bottlenose and common dolphins, as well as orca, are more likely to visit these inshore areas over winter and spring months rather than regularly year-round.
- Very few (1 to 2 individuals) of the whales migrating past this region each winter (mainly June to September) would venture close to the vicinity of the harbour and most do not feed while migrating.
- Based on the generalist diet and roving nature of these species (e.g. leopard seal), it is expected that contact between individual animals and prey species exposed to the discharge would be very limited.
- Generally low levels of contaminants found in RNZ discharge waters or the receiving environment, including waters, sediments and organisms.

Table 2: Summary of effects on marine mammal species from RNZ discharges into Whangarei Harbour entrance.

Potential environmental effects	Spatial scale of effect on marine mammals	Persistence / duration of effect on marine mammals	Consequence(s) for marine mammals	Likelihood of effect	Avoidance / Mitigation Factors	Significance level of residual effect
Direct chemical contaminant exposure	**Medium to Large:** Limited mainly to the mixing zone and habitats associated with worst-case scenario exposure (< 5 km)	**Short to Persistent:** Dependent on types of contaminants	**Individual Level:** Limited potential for any individual to be directly exposed	**Not applicable to Low**	• Pre-treatment prior to discharge • Contaminant levels well below guideline levels; exceptions are FC and NH_4-N • No resident population of marine mammals in regular contact with discharge waters	**Nil to Negligible**
Indirect contaminant exposure via prey species	**Medium to Large:** Limited mainly to the mixing zone and habitats associated with worst-case scenario exposure (< 5 km)	**Short to Persistent:** Dependent on types of contaminants	**Individual Level:** Limited potential for any individual to consume prey items exposed to discharge waters	**Not applicable to Low**	• Testing suggests any effect on nearby benthic invertebrate communities is low to very low due to low contaminant concentrations • Negligible bioaccumulation and bioavailability of some contaminants • Generalist diet and extensive home ranges limit contact with exposed prey	**Nil to Negligible**

Definition of terms used in table:

- Spatial scale of effect: Small (tens of metres), Medium (hundreds of metres), Large (> 1 km)
- Persistence of effect: Short (days to weeks), Moderate (weeks to months), Persistent (years or more)
- Consequence: Individual, Regional, Population level
- Likelihood of effect: Not Applicable (NA), Low (< 25%), Moderate (25–75%), High (> 75%)
- Significance level: Nil (no effects at all), Negligible (effect too small to be discernible or of concern), Less than Minor (discernible effect but too small to affect others), Minor (noticeable but will not cause any significant adverse effects), More than Minor (noticeable that may cause adverse impact but could be mitigated), Significant (noticeable and will have serious adverse impact but could be potential for mitigation

5. SUMMARY OF EFFECTS

This report reviews and assesses RNZ's proposal to renew its current resource consents for discharges into lower Whangarei Harbour and their potential to adversely affect local and visiting marine mammals. Marine mammals are vulnerable to the bioaccumulation of anthropogenic contaminants due to their long-life spans, high trophic level diets, and coastal residency. As a result, local marine mammals are often considered when assessing the potential effects of discharge contaminants on marine ecosystem health globally as well as locally by tangata whenua.

Known factors that can influence the extent to which marine mammals may be affected by discharges include the types of contaminants present and potential pathways of exposure. Factors for which assessment is more challenging include the susceptibility and baseline health of individual animals or affected species. Currently, there are no national or international guidelines applicable to monitoring contaminant exposure in marine mammals from single discharge sources. The processes of bioaccumulation and biomagnification mean that direct testing for such exposures cannot be easily linked back to a single source. Instead, current best practice for assessing the exposure risk from discharge activities is based mainly on the quality and type of discharge combined with quantification of available dilution and supported by sediment and water quality data for the immediate vicinity of the discharge. These indicators are then considered against the likelihood of the species' exposure to discharges based on life-history dynamics such as home-range and diet tendencies.

The more common species occurring along the Whangarei coastline, and therefore those most likely to be affected by the proposed project, include bottlenose and common dolphins, orca and Bryde's whales. Several other species, that visit the area less frequently, are also considered in this report because of various life history dynamics (e.g. low population numbers) or as they are held in high regard culturally. However, the habitats within Whangarei Harbour, its entrance or those associated with nearby Bream Bay are not considered to be unique and / or limited for any marine mammal species in terms of feeding, breeding and / or migrating activities. There is no species known to reside year-round within the proposal area, nor any solely reliant on foraging habitats in the area.

Based on the findings of contaminant testing (both traditional and process chemicals) and hydrodynamic modelling, no marine mammals visiting or passing through the proposal area are likely to be exposed to contaminant concentrations that exceed threshold levels for potential effects. Additional mitigating factors, such as the temporary presence and generalist diet of these particular species, as well as the dilution and dispersion of the discharge into a high-energy marine environment, limit the exposure risk for individual marine mammals to discharge contaminants taken up from exposed prey. On these bases, potential effects on marine mammals from the proposal are considered negligible, and no mitigation is warranted.

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7. APPENDICES

Appendix 1. Sources of marine mammal data and information

Only broad-scale, regional information is available for most marine mammals using the general Whangarei Harbour / Bream Bay region. Multiple and finer-scale studies have been undertaken in both the Bay of Islands to the north and south in the wider Hauraki Gulf region. The studies and databases used to make summaries and assessments of the marine mammal species discussed in this report are listed below:

- DOC opportunistic database and stranding record database
- Marine mammal tourism data in the Bay of Islands and Hauraki Gulf region
- National Aquatic Biodiversity Information System (NABIS)
- Scientific research through University of Auckland:
    - R Constantine – various studies in Bay of Islands, Bryde's whales in the Hauraki Gulf, and humpback whales around New Zealand
    - G Tezanos-Pinto – research on bottlenose dolphins in Bay of Islands, and Bryde's whales in Hauraki Gulf
    - E Carroll – various studies on southern right whales
- Scientific research through Massey University at Albany:
    - K Stockin –various studies on common / bottlenose dolphins and Bryde's whales in the Hauraki Gulf
    - N Wiseman – studies on Bryde's whales in Hauraki Gulf
    - S Dwyer – various papers on cetaceans in the Hauraki Gulf and Great Barrier Island
    - K Hupman – various papers on common dolphins' fidelity in the Hauraki Gulf and leopard seals.
- Orca Research Trust – various Visser publications
- Berkenbusch K, Abraham ER, Torres L 2013. New Zealand marine mammals and commercial fisheries. New Zealand Aquatic Environment and Biodiversity Report No. 119. 110 p.
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- Stephenson F, Goetz K, Sharp BR, Mouton TL, Beets FL, Roberts J, MacDiarmid AB, Constantine R, Lundquist CJ 2020. Modelling the spatial distribution of cetaceans in New Zealand waters. Diversity and Distributions 26: 495-516.

Appendix 2. Marine mammal species summaries from Clement and Elvines (2015).

The marine mammals most likely to be affected by the proposed project include those species that frequent the Whangarei Harbour and Bream Bay regions year-round or on a semi-regular basis (see Table 1). Other species of concern include those that are more vulnerable to anthropogenic impacts due to various life-history dynamics (e.g. low population numbers) or species-specific sensitivities. Given the reference to whales in their name for the harbour, Tangata Whenua o Whangarei Te Rerenga Paraoa are also concerned about the continued presence of several species.

Residents include an inshore population of **bottlenose dolphins** known to range between Doubtless Bay to the north and Tauranga to the south (Constantine 2002). This Northland population shows varying degrees of site fidelity along this region, with consistent seasonal movements from deeper offshore waters in the summer to shallower inshore waters over winter throughout (e.g. Hartel et al. 2014; Dwyer et al. 2014). It is important to note that the number of individuals visiting the BOI is decreasing (Tezanos-Pinto et al. 2013). The decline may be due to high calf-mortality (Tezanos-Pinto et al. 2014) and / or simultaneous emigration to other areas within this region (Dwyer et al. 2014). This decline supports their current up-listing to *nationally endangered* by the New Zealand Threat Classification System (Baker et al. 2019) and makes them potentially more vulnerable to disturbance or changes within their distribution range.

Orca, belonging to a small regional North Island sub-population, are frequently sighted along the coastline between the BOI and Hauraki Gulf (Visser 2000). As frequent transients through Whangarei waters (Figure 2), they can be observed year-round but are more common in these waters during late winter and early spring where they may be targeting torpedo rays for food (Visser 2000, 2007, and pers. comm. 11 March 2015). Visser (2007) suggests that the tendency by orca to forage in and around enclosed harbours makes this species more susceptible to harbour developments. Orca are currently listed as *nationally critical* by the New Zealand Threat Classification System (Baker et al. 2019) based on low abundance.

Less information is known about the **Bryde's whale** populations in the proposal area compared to other nearby regions. Bryde's whales regularly frequent Whangarei waters (Figure 2), perhaps as they travel between BOI and the Hauraki Gulf hotspots. A small, residential population of whales is found year-round within the Hauraki Gulf region (Wiseman 2008; Wiseman et al. 2011). Here, their natural tendency to remain just below the surface of the water most of the time (91%) and their spatial overlap with the main shipping channels of Auckland makes them highly vulnerable to ship strikes (Constantine et al. 2015). This species is listed as *nationally critical* in New Zealand waters (Baker et al. 2019) due to low abundance and the high proportion of mortalities due to ship strikes (Constantine et al. 2015).

Several localised populations of **common dolphins** are also found year-round in the coastal waters off the BOI to Hauraki Gulf, being more prevalent within inshore waters over winter and spring months (Constantine & Baker 1997; Stockin et al. 2008). This species feeds on surface fish, such as schooling pilchards and yellow-eyed mullet, but also more pelagic fish species over continental shelf regions (e.g. Constantine & Baker 1997; Neumann & Orams 2005). Little is known about their actual population sizes and movements between these locations; however, the Hauraki Gulf region may be an important calving and / or nursing area (Stockin et al. 2008; Dwyer et al. 2014).

With established breeding colonies and several regular haul-out sites, **New Zealand fur seals** are considered year-round residents within Bay of Plenty and Coromandel Peninsula waters. More frequent sightings of fur seals are now reported within Hauraki Gulf waters as well as the occasional visiting seal within the Whangarei region as this species appears to be expanding northward. Fur seals are considered non-migratory but are known to easily and repeatedly cover large distances to find food. Some adults will travel out to open waters over winter while younger animals focus over shallower continental shelf waters. The departure of pups from colonies around late winter / spring months may be one explanation for recent sightings of fur seals off Whangarei over winter months.

An individual **leopard seal**, Owha, is also known to reside semi-seasonally in Marsden Point Cove marina at various times of the year (K. Hupman-NIWA, unpublished data) and other individuals have been reported over the years (Hupman et al. 2020). While generally Antarctic to sub-Antarctic in their distribution, individuals regularly visit warmer latitudes (Hückstädt 2015). Leopard seals prey on a variety of species (e.g. krill, penguins, birds, fish, seals), eating the prey where it is taken. This species tends to be solitary and due to their aggressive nature, precautions need to be taken when working in the water in their presence.

Several baleen whale species migrate through Northland waters from early winter (May) to the late spring months (November). Most whale species begin their northern migrations in late autumn or winter; humpbacks travel from May to August and southern right whales from July to September. **Southern right whales** can be observed with newborn calves from August onwards, particularly around the Northland region (Carroll et al. 2014), and may remain in any one area for up to four weeks (Patenaude 2003). The south-bound migration of **humpback whales** with their newborn calves begins in late September, passing through Northland waters until late November / December. Less is known about the timing of **blue whale** migrations past New Zealand, although most sightings are observed from late winter to early summer. Of these species, only southern right whales are considered *at risk - recovering* by the New Zealand Threat Classification System (Baker et al. 2019), as their preference for shallow, protected bays and coastal waters (particularly for calving) overlaps with numerous anthropogenic activities in New Zealand's waters.

Potential offshore residents, migrants and visitors to Northland waters include p**ilot whales**, several species of **beaked whales** (including Grey's beaked whales), **false killer whales**, **sperm whales** and **pygmy sperm whales** (DOC databases; Baker 2001; Zaeschmar et al*.* 2014; Brabyn 1990). These species are known as deep water species that spend the majority of their time offshore and feed on deep water prey, such as squid. Despite few sighting data, the strong prevalence of whale strandings from late spring to autumn suggests a general inshore movement within Northland waters for some of these species (particularly pilot whales) over summer months. It is important to note that some deep-water species are now thought to be more acoustically sensitive than other, more inshore marine mammal species (Cox et al. 2006).

Appendix 3. Proposed Regional Plan for Northland

Based on the available species data, I do not consider the coastal waters of Whangarei Harbour and Bream Bay to be ecologically significant habitat for any marine mammal species. Instead, this area represents only a small fraction of similar habitats available along the North Island's north-eastern coast that several species of marine mammal regularly utilise and migrate past on a regular basis.

I realise that this assessment of habitat is contrary to the "Significant Marine Mammals and Seabird Area" maps realised as part of the proposed Regional Plan for Northland (pRP). In my opinion, the ecological assessment criteria in Kerr (2016 - Appendix 5), as applied, are not appropriate for marine mammals. The mismatch of this ecosystem approach for marine mammals is also discussed by the authors of the maps, specifically noting that, *Marine ecosystems are hard to characterise in terms of spatial boundaries with the proposed criteria system. They are made up of many overlapping ecosystems, functions and connections working across a full range of spatial scales. A small estuary has benthic communities and algal communities that work on scales of 10-1000 m^2 and at the same time can be of prime importance to a range of coastal fish and marine mammals which are part of an ecosystem that is 1000s km^2*. (Kerr 2016a, p.6). The authors go on to say that, *Consideration of marine mammal values in this process provided another set of unique challenges for both Northland estuaries and coastal waters*. (Kerr 2016, p.11).

The final approach by the authors was to prepare a separate worksheet that describes marine mammal values over the whole coastal area (Kerr 2016, p.12). This approach has led to the entire Northland Coastal Management area now being labelled as 'Significant Marine Mammals and Seabird Area'.

In my opinion, none of these current assessment systems deal particularly well with marine mammals. The reasons for my view are that marine mammals are long-lived (i.e. 20-90 years), generally have large home ranges (10s to 100s of kilometres) that are highly variable from year to year, and can use several areas for the same or differing aspects of their life dynamics (e.g. feeding, breeding, resting, migrating). In addition, the distribution of marine mammals in New Zealand waters is currently changing in relate to climate change effects and will continue to do so into the future.

As far as I am aware, there is no policy or prohibited developments associated with the marine mammal map in the pRP. Therefore, this broad-scale application of 'significance' in this case diminishes any areas that may be important or significant to marine mammal species and others. I am concerned that the marine mammal maps inclusion will suggest to the public, and any commercial interests, that the Maps are based on the best and most up-to-date information on the marine mammals that live and visit the waters of Northland. This assumption is not the case in my opinion.

Appendix 4. Additional information on contaminants

Endocrine disrupting chemicals (EDCs)

There is ongoing concern over the potential adverse effects of environmental contaminants with endocrine and reproductive activities to cause what has been described as endocrine disruption in wildlife and humans (Colborn et al. 1996). Chemicals that can interfere with the normal functions of the endocrine system are referred to as endocrine disrupting chemicals (EDCs), and many are also known to affect reproductive function. The main mechanisms of toxicity by which EDCs disrupt the endocrine system are through mimicking steroid hormones (e.g. estrogens, androgens) and binding to specific cellular receptors modulating (agonistic; estrogenic or androgenic) or blocking a response (antagonistic; anti-estrogenic or anti-androgenic; Fossi & Marsili 2003; Diamanti-Kandarakis et al. 2009). Thousands of natural and synthetic chemicals are expected to have endocrine disrupting effects. However, it is important to note that EDCs may also cause toxicity through other mechanisms (e.g. Diamanti-Kandarakis et al. 2009).

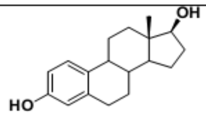
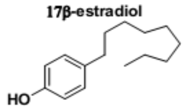
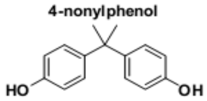
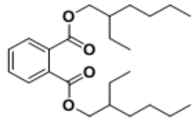
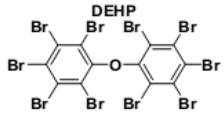
EDCs can be naturally occurring, such as hormones excreted by humans or phyto-estrogens found in plants. They can also be man-made chemicals, such as synthetic hormones and a range of chemicals, including pesticides and industrial chemicals like breakdown products of the surfactant alkylphenols, the plasticisers bisphenol-A and phthalates (Leusch et al. 2006). Alkylphenols (e.g. nonylphenol and octylphenol) are breakdown products of alkylphenol polyethoxylates (APEs). APEs have been used for more than 40 years in household domestic products such as cosmetics, emulsifiers, wetting agents, detergents, and dispersing agents. They are also used in many commercial sectors, including pulp and paper processing, textile manufacture, resins and synthetic coatings. Their widespread use has consequently led to the frequent detection of these compounds in effluent discharged into the environment. In addition, nonylphenol has also been detected in both industrial and municipal wastewater as it is a degradation product of alkylphenolic compounds with estrogenic activity (Desbrow et al. 1998; Sheahan et al. 2002).

Pharmaceutical and personal care products (PPCPs)

An area of increasing global concern in regard to emerging organic contaminants (EOCs) is the fate and environmental effects of pharmaceutically active products (PhACs; Kummerer 2009, 2010) and personal care products (Ternes et al. 2004), especially given the dramatic increase in the number of new products (Tremblay et al. 2011). At present, there is a general lack of information required to assess the environmental risk of these contaminants as highlighted by a review by Fent et al. (2006). Some potential issues include the rise in antibiotic resistant bacteria, decreased decomposition rates of other contaminants due to diminished natural microbial communities (Boxall et al. 2005; Kemper 2008; Snow et al. 2008), and multi-generational effects from combinations of PPCPs (e.g. Dietrich et al. 2010).

The main sources of EOCs into the environment have been identified as municipal wastewater discharges and agricultural wastes (US Geological Survey 2011). A wide range of pharmaceuticals and personal care products (PPCPs) such as antimicrobial agents, musks found in soaps, shampoos and toothpastes enter waste systems and ultimately the municipal wastewater. Many of these PPCPs are not completely removed by wastewater treatment technologies (Ternes et al. 2004; Liu Z –H et al. 2009). Recent New Zealand research into the presence of PPCPs in wastewaters and environmental matrices has focused mainly on PhACs in both sewage effluents and / or biosolids (Gielen 2007; Stewart et al. 2009). Results varied across treatment options and environmental compartments with some short and long-term effects on soil microbial communities (Gielen 2007) and potentially high concentrations of PhACs entering the marine receiving environment through soil and sediments (Stewart et al. 2009).

Table A.1 Endocrine disrupting chemicals (EDCs) of highest priority to New Zealand (Sarmah et al. 2006). EDCs are scored and ranked according to criteria such as source, potency, environmental concentrations, persistency, mobility, bioaccumulative potential and removal during treatment.

Class of EDC	Representative	EDC priority score[a]
Steroid Estrogens	 17β-estradiol	15
Alkylphenol ethoxylates and metabolites	 4-nonylphenol	14
Bisphenol A	 BPA	10
Phthalates	 DEHP	10
Brominated Flame Retardants	 BDE-209	9-11
Heavy Metals	Cd, As, Pb, Hg	7

[a] Sarmah *et al.* 2005