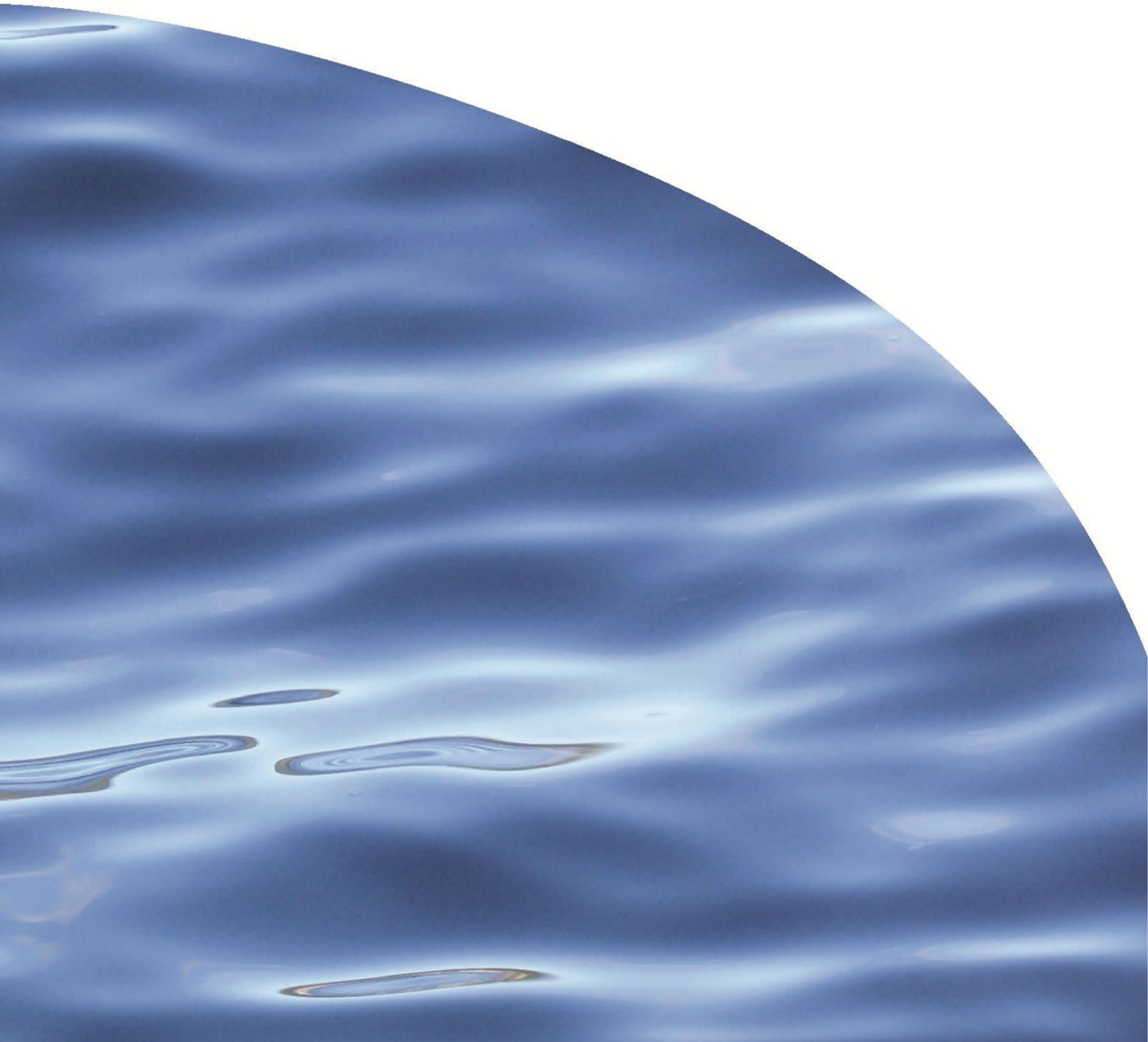
REPORT NO. 3387

AKAROA HARBOUR CRUISE SHIP VISITS: PRELIMINARY ECOLOGICAL RISK ASSESSMENT



AKAROA HARBOUR CRUISE SHIP VISITS: PRELIMINARY ECOLOGICAL RISK ASSESSMENT

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EXECUTIVE SUMMARY

Due to concerns relating to seabed and water quality degradation from cruise ship propeller wash and anchoring activities in Akaroa Harbour, Environment Canterbury (ECAN) requested that Cawthron perform a brief preliminary ecological risk assessment (ERA) on a number of potential effects (as identified by ECAN) of the Akaroa Harbour marine environment.

The characteristics and habits of the cruise ships that frequent Akaroa Harbour were compiled using available literature and data collected over three cruise ship seasons by ECAN (2013–2014, 2016–2017 and 2018–2019). During those periods Akaroa received an increasing number of cruise ships over time, with one to three vessels visiting per day. The potential effects resulting from cruise ship propeller wash and anchoring activities in Akaroa Harbour investigated in this assessment were:

Seabed	Anchor chain sweep seabed disturbance
	Propulsion turbulence seabed disturbance
	Modification of predator-prey interactions and loss of refugia
Water column	Sediment deposition and smothering from (continued) sediment resuspension
	Release of nutrients from sediment resuspension (plankton blooms)
	Reduced water clarity, increased turbidity and light attenuation from sediment resuspension
Marine mammals	Additional noise causing behavioural change, masking communication/prey detection, temporary auditory shifts or permanent injury
	Vessel strike causing injury, death and/or behavioural changes
	Increasing tourism exposure causing behavioural changes
	Increased suspended nutrients, contaminants and plankton blooms affecting prey species
	Increased turbidity decreasing foraging efficiency
Seabirds	Artificial light causing vessel strike (injury, death, disorientation, behavioural changes)
	Increasing tourism exposure causing behavioural changes
	Increased suspended nutrients, contaminants and plankton blooms affecting prey species
	Increased turbidity decreasing foraging efficiency

Ecological risk was assessed through consideration of the magnitude or consequence of an effect, potential risk to threatened habitats and taxa, and the likelihood of the effect occurring. Existing information sources were used to assess the sensitive taxa and habitats.

This assessment shows that the Akaroa Harbour receiving environment has ‘very high’ ecological values (e.g. threatened/nationally vulnerable Hector’s dolphins, multiple threatened seabirds, a customary fishing Taiapure, the Banks Peninsula marine mammal sanctuary and multiple areas of significant natural value/outstanding natural character). Results suggest that there is a ‘medium to low’ level of risk of ‘significant or unacceptable’ adverse ecological effects from anchoring and propulsion activities of cruise ships on these values. Based on the ERA, these effects could be considered ‘manageable using measures to avoid remedy or mitigate’. However, at present the level of confidence in the data available for this assessment is low, and the assessment relies heavily on expert judgement. Therefore, the provision of activity- and location-specific effect assessments is recommended to inform potential management approaches.

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1. INTRODUCTION

Environment Canterbury (ECAN) has concerns regarding the potential ecological effects of cruise ships visiting Akaroa Harbour. Concerns have stemmed from anecdotal observations and queries from local residents regarding seabed degradation from propeller wash and visible reductions in water quality (i.e. colour and clarity, Figure 1). In response, ECAN has requested that Cawthron perform a brief preliminary ecological risk assessment (ERA) on the following potential effects (identified by ECAN and the public) on the Akaroa Harbour marine environment:

- benthic ecological effects e.g. disturbance of soft sediments and subtidal hard substrates
- water column effects e.g. turbidity and total suspended solids concentrations
- marine mammal effects e.g. aquatic noise, frequent transit of large vessels
- seabird effects e.g. including impact of lighting from ships on coastal birds.

This preliminary ERA also briefly characterises the activity and the environment potentially effected, discusses gaps in knowledge, assesses risk, and provides recommendations for management.

It is the expectation that this ERA will be a starting point to support management decisions, further research and as a basis for communicating potential risks to affected parties, resource consent applicants and the general public.

Figure 1. A cruise ship and associated water clarity effects in Akaroa Harbour (image supplied by ECAN, April 2019).

2. RISK ASSESSMENT METHODS

The following sections explain the assessment approach used to ascertain specific ecological risks (i.e. benthic, water column, marine mammals and seabirds) from cruise ships in Akaroa Harbour. Methods used for this investigation were desk-top based, with specific focus on examination of existing information in the form of literature, databases, regional taxa lists and reports.

2.1. Literature review

Literature was reviewed to obtain background information on the Akaroa receiving environment (Section 4), cruise ship activities and characteristics (Section 2.3). In order to understand the potential effects of interest defined by ECAN, available literature that directly related to effects from cruise ships, either in Akaroa Harbour, in New Zealand, or internationally, was reviewed (summary in Appendix 1). The findings were used to inform the effects assessment component of this report (Section 6).

2.2. Risk assessment

Ecological risk was assessed using the Burgman (2005) and Ecological Impact Assessment New Zealand (EIANZ 2018) approaches. Both methods consider the magnitude or consequence of an activity, but, EIANZ (2018) places the emphasis on potential risk to threatened habitats and taxa, whereas the Burgman (2005) approach focusses more on the likelihood of the effect actually occurring. When considered in unison the two results can be complementary.

Existing information sources were used to assess the sensitive taxa and habitats of the harbour. In the first instance, an Akaroa Harbour-wide species list (Appendix 3) was extracted from the OBIS[1] (2019), NABIS[2] (2019) databases and local wildlife guides e.g. *A Guide to Marine Birds of Akaroa Harbour* (AIC 2019). The taxa list was then compared with available Department of Conservation threatened species lists for marine invertebrates, birds and marine mammals[3] (DOC 2013, 2016, 2019b). The 'value' of taxa and habitats, 'magnitude' of effects, and 'risk to ecological values', was determined using EIANZ 2018 value methods (Table 1). The spatial scale/extent of effects, and the persistence/duration of the effect were first considered to help determine appropriate values for 'consequence' and 'likelihood' (Burgman 2005). Both the Burgman (2005) and EIANZ (2018) approaches to risk assessment include a measure of confidence in the data used, as shown in Table 2.

[1] OBIS: Ocean Biogeographic Information System. Data extracted July 2019. https://obis.org/
[2] NABIS: National Aquatic Biodiversity Information System. Data extracted July 2019
[3] Note that any future assessments should also consider DOC threatened species lists for marine fish (including chondrichthyans) and macro algae.

Table 1. Modified definition tables for assigning, value, magnitude and overall risk, EIANZ (2018).

Value	Species/taxa - determining factors
Very high	Nationally threatened – critical or vulnerable
High	Nationally at risk – declining
Mod–high	Nationally at risk – recovering, relict or naturally uncommon
Moderate	Locally uncommon/rare, not nationally threatened or at risk
Low	Not threatened nationally, locally common indigenous species
Negligible	Exotic species, including pests, species having recreational value

Value	Habitat - determining factors
Very high	Supporting more than one national priority type*
High	Supporting one national priority type or naturally uncommon ecosystem
Moderate	Locally rare or threatened, supporting no threatened or at-risk species
Low	Nationally and locally common, supporting no threatened or at-risk species

** Refer to (MfE 2007) Protecting Our Places. National Priorities.*

Magnitude	Description
Very high	Total loss of, or very major alteration to, key elements/features of the existing baseline conditions, such that the post-development character, composition and/or attributes will be fundamentally change and may be lost from the site altogether; AND/OR Loss of a very high proportion of the known population or range of the element/feature.
High	Major loss or major alteration to key elements/features of the existing baseline conditions such that the post-development character, composition and/or attributes will be fundamentally changed; AND/OR Loss of a high proportion of the known population or range of the element/feature.
Moderate/ medium	Loss or alteration to one or more key elements/features of the existing baseline conditions, such that the post-development character, composition and/or attributes will be partially changed; AND/OR Loss of a moderate proportion of the known population or range of the element/feature.
Low/minor	Minor shift away from existing baseline conditions. Change arising from the loss/alteration will be discernible, but underlying character, composition and/or attributes of the existing baseline condition will be similar to pre-development circumstances or patterns; AND/OR Having a minor effect on the known population or range of the element/feature.
Negligible	Very slight change from the existing baseline condition. Change barely distinguishable, approximating to the 'no change' situation; AND/OR Having negligible effect on the known population or range of the element/feature.

Level of effect (M x E)		Ecological Value (E)				
		Very high	High	Moderate	Low	Negligible
Magnitude (M)	Very high / severe	Very high	Very high	High	Moderate	Low
	High	Very high	Very high	Moderate	Low	Very low
	Moderate / medium	High	High	Moderate	Low	Very low
	Low / minor	Moderate	Low	Low	Very low	Very low
	Negligible	Low	Very low	Very low	Very low	Very low
	Positive	Net gain	Net gain	Net gain	Net gain	Net gain

Level of effect	Effect range terminology
Nil	Nil Effects
Very low	Less than minor adverse effects
Low	Minor adverse effects
Moderate	More than minor adverse effects
High	Significant adverse effects that could be remedied or mitigated
Very high	Unacceptable adverse effects

Table 2. Spatial scale, persistence, likelihood, consequence, risk and confidence definitions (derived from Burgman 2005).

Spatial scale	Distance from discharge source
Extensive	25 km^2 +
Large	1 km^2 - 25 km^2
Medium	0.25 km^2 - 1 km^2
Localised	0.01 - 0.25 km^2
Immediate vicinity	<0.01 km^2

Persistence/duration	Timeframe
Indefinite recovery, even if stopped	10 years +
Long-term recovery if stopped	Years
Moderate recovery if stopped	Months
Rapid recovery if stopped	Days
Temporary	Hours

Level	Likelihood	Likelihood (%)	Description
1	Certain	100%	Will occur
2	Likely	50-99%	Likely to occur
3	Possible	25-50%	Uncommon but possible
4	Unlikely	1-25%	Occurring in exceptional circumstances
5	Remote	<1%	Highly unlikely to occur

Level	Consequence	Effects
1	Catastrophic	Local extinction, ecosystem collapse
2	Massive	Regional and long-term adverse impacts
3	Major	Regional medium-term adverse impacts
4	Moderate	Local medium-term adverse impacts
5	Minor	Local short-term adverse impacts
6	Negligible	No detectable adverse effects

Level	Risk	Definition
1-2	Extreme risk	Unacceptable
3-4	High risk	Manageable using measures to avoid remedy of mitigate
5-9	Medium risk	Acceptable using measures to avoid remedy of mitigate
10-16	Low risk	Acceptable with less than minor impacts anticipated
17-30	Very low risk	Negligible with no impacts

Confidence	Definition
Low	No data - lack of data, relies on expert judgement
Medium	Combination of existing data and expert judgement
High	Based on monitoring data and expert judgement

2.3. Key regulations

Applicable regulations relating to potential effects to water quality and seabed disturbance from cruise ship activities are provided in the Regional Coastal Environment Plan for the Canterbury Region (RCEP 2005). Though they were not part of the project scope for this assessment, a full assessment of regulatory requirements in relation to the effects described in this ERA should be undertaken prior to any subsequent AEE investigations. Special consideration should be given to the potential for reduction in risk levels provided by effects management, and any ecological protection provided by the regulations.

Other legislation, not considered here, which should be considered in any subsequent assessments are the Marine Biosecurity Act 2015, the Marine Mammal Protection Act 1978, the Marine Reserves Act 1971, and the Maritime Transport Act 1994. Management guidance could also be obtained from the Environment Southland 'Deed of Agreement' (ES 2008) with the New Zealand Cruise Ship Industry.

3. CRUISE SHIP ACTIVITY DESCRIPTION

An increasing number of cruise ships have been anchoring in Akaroa Harbour, offshore from the Wainui-Cape Three Points area (Figure 2). This section provides detail on the cruise ships' activities in terms of the number and size of the vessels visiting Akaroa, the vessel movements, travel speed, anchoring locations, anchor size and propulsion systems. The sections also provide discussion on the relative restrictions and requirements for large cruise ships (≤ 345 m, Akaroa Harbour Operational Requirements 2018) in Akaroa Harbour, specifically relating to the two documents listed below:

- **Akaroa Harbour Operational Requirements 2018** (herein referred to as the Requirements 2018)**:** This document provides operational guidance for any vessel entering the harbour (it is not specific to cruise ships). These Navigation Safety Operating Requirements prescribe the manner in which vessels must navigate within the Harbour.
- ***draft* Akaroa Harbour Principles of Operation 2019** (herein referred to as the Code 2019): This document provides specific operational guidance for cruise ship operators entering the harbour.

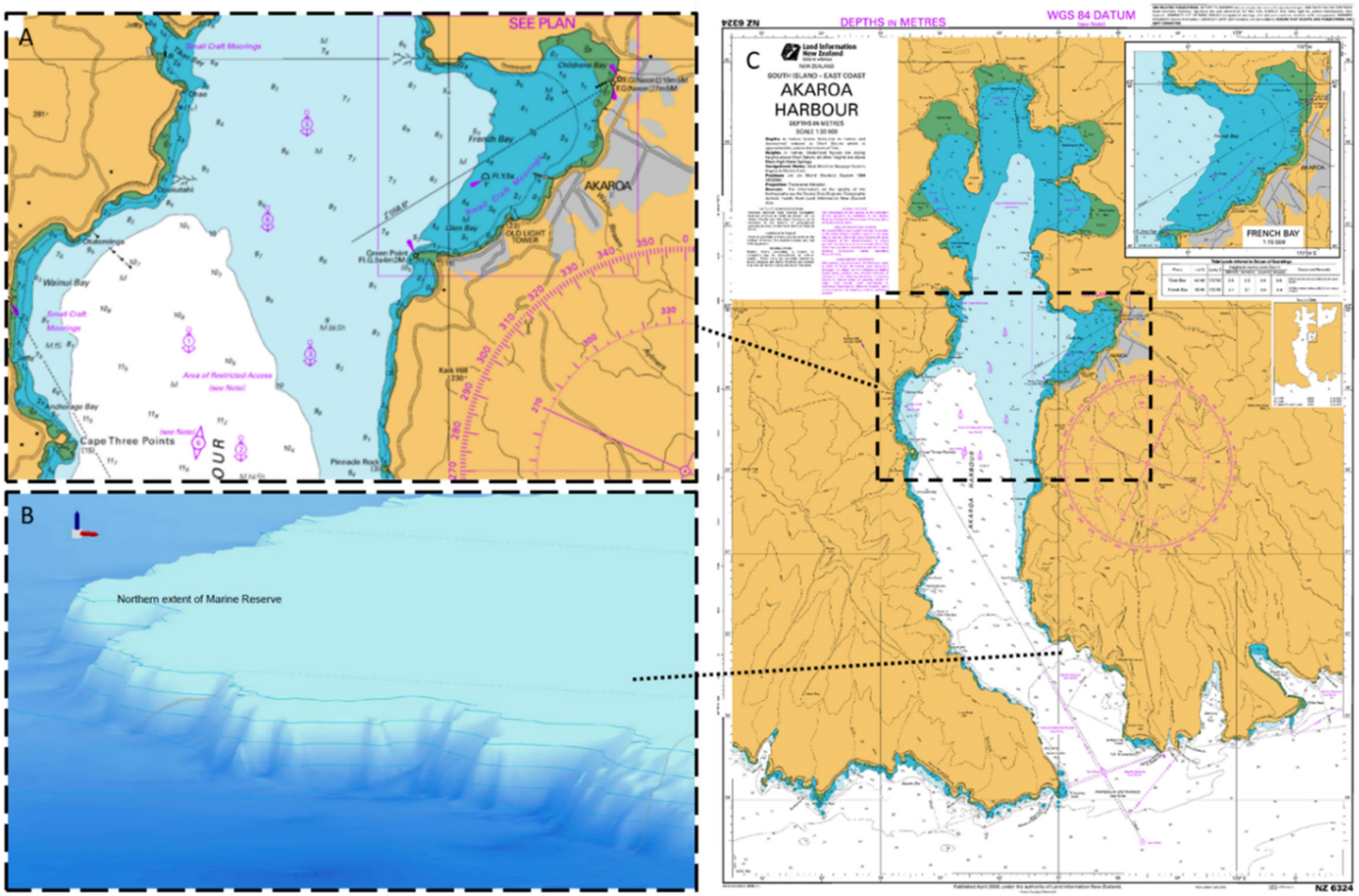

Figure 2. A) Anchorage locations (pink numbered anchor symbols) and, B) bathymetry example (exaggerated 3-dimensional bathymetry from Dunmore et al. 2015) in Akaroa Harbour. C) Modified LINZ Chart NZ 6324 (LINZ 2009) Akaroa Harbour (created 29 April 2019).

3.1. Frequency and length of stay

Data relating to the cruise ship visits to Akaroa were provided by ECAN and spans three cruise ship seasons (October to April 2013–2014, 2016–2017 and 2018–2019, Appendix 1). During those periods Akaroa received a total of 243 trips (comprising 38 different vessels). The per season trip number has increased over time from 73 trips by 19 vessels in the 2013–2014 season, to 93 trips by 21 vessels in 2018-2019 (Figure 3).

The three most frequent cruise ship vessels to Akaroa (Figure 4) over the investigated time period have been Celebrity Solstice (27 visits), Radiance of the Seas (24 visits) and the Sun Princess (20 visits).

Over the investigated time period (2013, 2016 and 2018 seasons), there was typically only one ship visiting the Harbour per day (82% of the time). However, on two occasions there were three vessels visiting on the same day, and on 34 occasions (17% of the time) there were two vessels visiting on a single day. In comparison, the Environment Southland 'Deed of Agreement' with The New Zealand Cruise Ship Industry specifies that no more than two vessels can be in any waterway, passage, fiord, bay or inlet at any one time.

Akaroa cruise ships are typically only in port for a single day (Lincoln University 2013) during daylight hours (Requirements 2018); although it is noted that this short-stay tendency does not appear to preclude the cruise ships from overnight anchorage should they request it. During the cruise ship season, days are longest during December (~15 daylight hours), and shortest during April (~10 daylight hours), which suggests the vessel have the option of being in port for longer during mid-season, compared to the season fringe.

Statistics NZ[4] reports that of all unique[5] passengers to New Zealand *roughly half visited … a Canterbury port (mainly Akaroa).* The number of passengers visiting Akaroa each season/year from 2015 to 2018 was variable, ranging from approx. 127,000 to 145,000 individuals. During the 2015–2018 period, spending by cruise visitors climbed from $27,000 to $35,000 per year. The increase in spending did not relate to passenger numbers but was attributed to increases in shore excursions (including overland tours) and onshore spending by passengers and crew.

Vessels intending to anchor in Akaroa Harbour have to obtain approval for entry from the Harbourmaster prior to arrival. At this point the Harbourmaster can request vessel information/specifications and plans the vessel's entry, exit and manoeuvring

[4] https://www.stats.govt.nz/information-releases/cruise-ship-traveller-and-expenditure-statistics-year-ended-june-2018

[5] A 'unique' passenger is a single count of each cruise ship passenger over the year, rather than as an arrival, a departure, or both.

approaches. Vessels entering the harbour are required to pay fees for wharf facilities and navigational safety/services (CCT 2014). However, Akaroa cruise ships do not have to pay a cruise ship-specific ‘marine fee,’ to contribute towards the costs of managing the marine environment in Akaroa, as is required by Environment Southland in Fiordland (ES 2008).

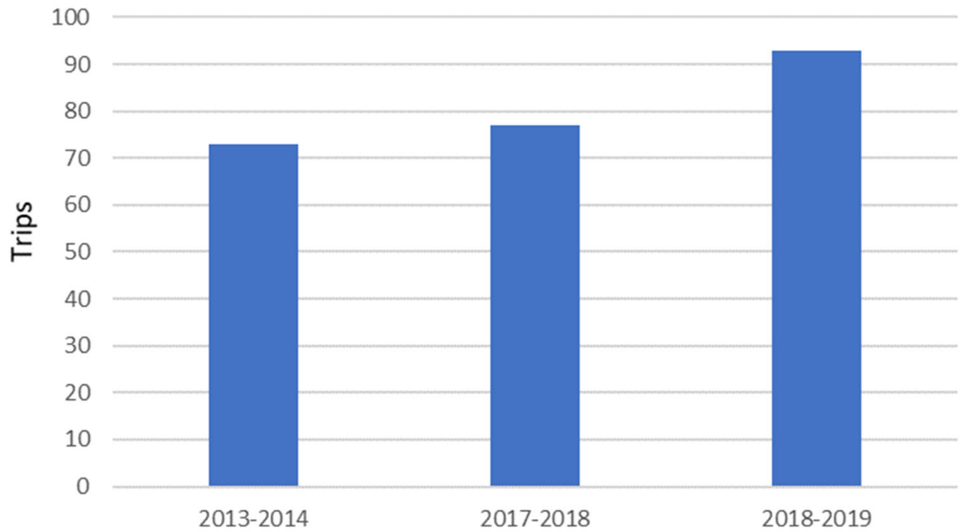

Figure 3. Cruise ship trips per season (October to April) to Akaroa Harbour (from available dataset).

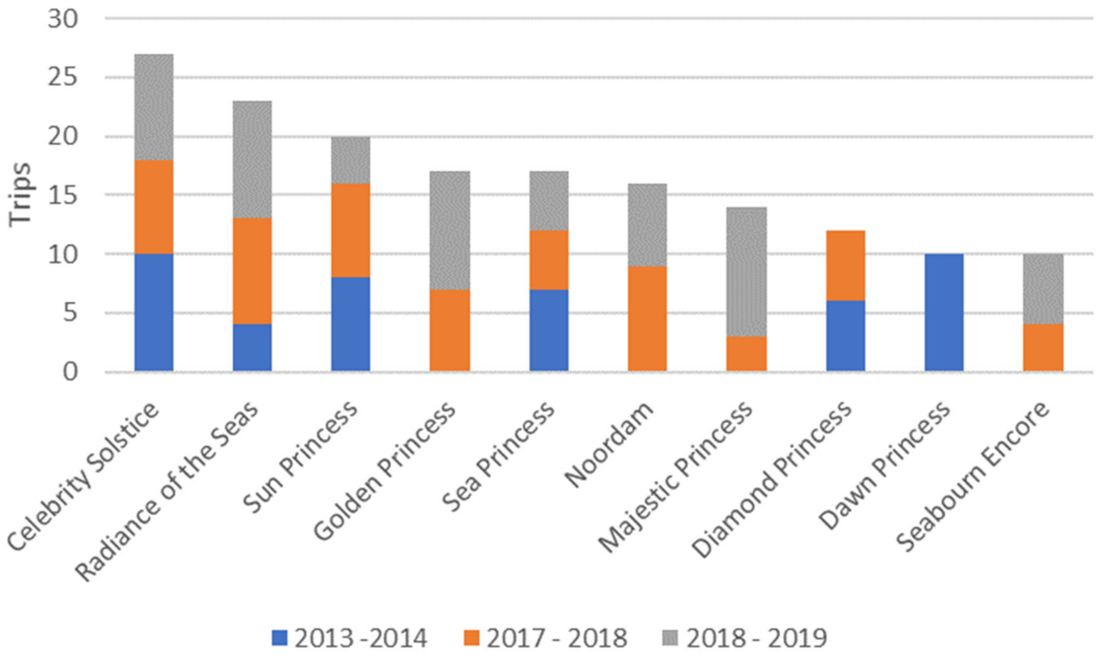

Figure 4. The ten cruise ships visiting Akaroa Harbour most frequently (from the available dataset).

3.2. Cruise ship characteristics

The following sections describe the general characteristics of the cruise ship vessels that frequent Akaroa Harbour. The description is based on data collected over three cruise ship seasons by ECAN (2013–2014, 2016–2017 and 2018–2019, Appendix 1) and what is known about the vessels in terms of size (length and draft), age, anchors, engines (and fuels) and methods of propulsion.

3.2.1. Length, draft and age

The maximum length of vessel to navigate within the harbour is 345 metres (Requirements 2018). The top ten most frequent cruise vessels (Figure 4) have lengths ranging from 210 m up to 330 m and include some of the longest cruise ship visitors: Majestic Princess at 330 m, Celebrity Solstice at 315 m and Radiance of the Sea at 293 m.

The draft or draught of a ship's hull is the vertical distance between the waterline and the bottom of the hull (keel). Draft is the key factor determining the minimum depth of water that a vessel can safely navigate. Eight of the top ten most frequent cruise ships to Akaroa Harbour had drafts over 8 m, and are therefore restricted to anchor points 1 and 2, Figure 2 (Figure 2, Requirements 2018).

Half the top ten most frequent visiting ships were over 17 years old and a third were over 20 years old.

3.2.2. Engines and propulsion

Of the top ten most frequent visiting ships to Akaroa Harbour (Figure 4) only one had gas-turbine power generation (Radiance of the Seas), the rest had diesel-electric engines. A large number of older cruise ships use diesel reciprocating engines; modern ships use either diesel-electric engines or gas turbines (lower levels of emissions). All ships rely on propellers/screws to be pushed through water, providing forward and reverse motion. There are three main types of propeller systems (Figure 5):

- Azipod™ propulsion systems are typically associated with new cruise ships. The system is situated outside the hull in the aft of the ship. The Azipod™ can turn 360 degrees and provide thrust in any directions (not possible for conventional systems). The Azipod™ system provide better manoeuvrability, higher speeds, and reductions in emissions, which as a whole optimises the ship's performance/efficiency.
- Conventional propeller systems are run by a shaft that passes through the stern tube and shaft tunnel to the propeller in the ship's hull. In this case this system's steering is done independently by a rudder.

- Integrated propeller-rudder systems integrate the propeller, hubcap, bulb and the rudder into a single unit. This configuration can increase efficiency, improve manoeuvrability, and reduces fuel consumption and emissions.

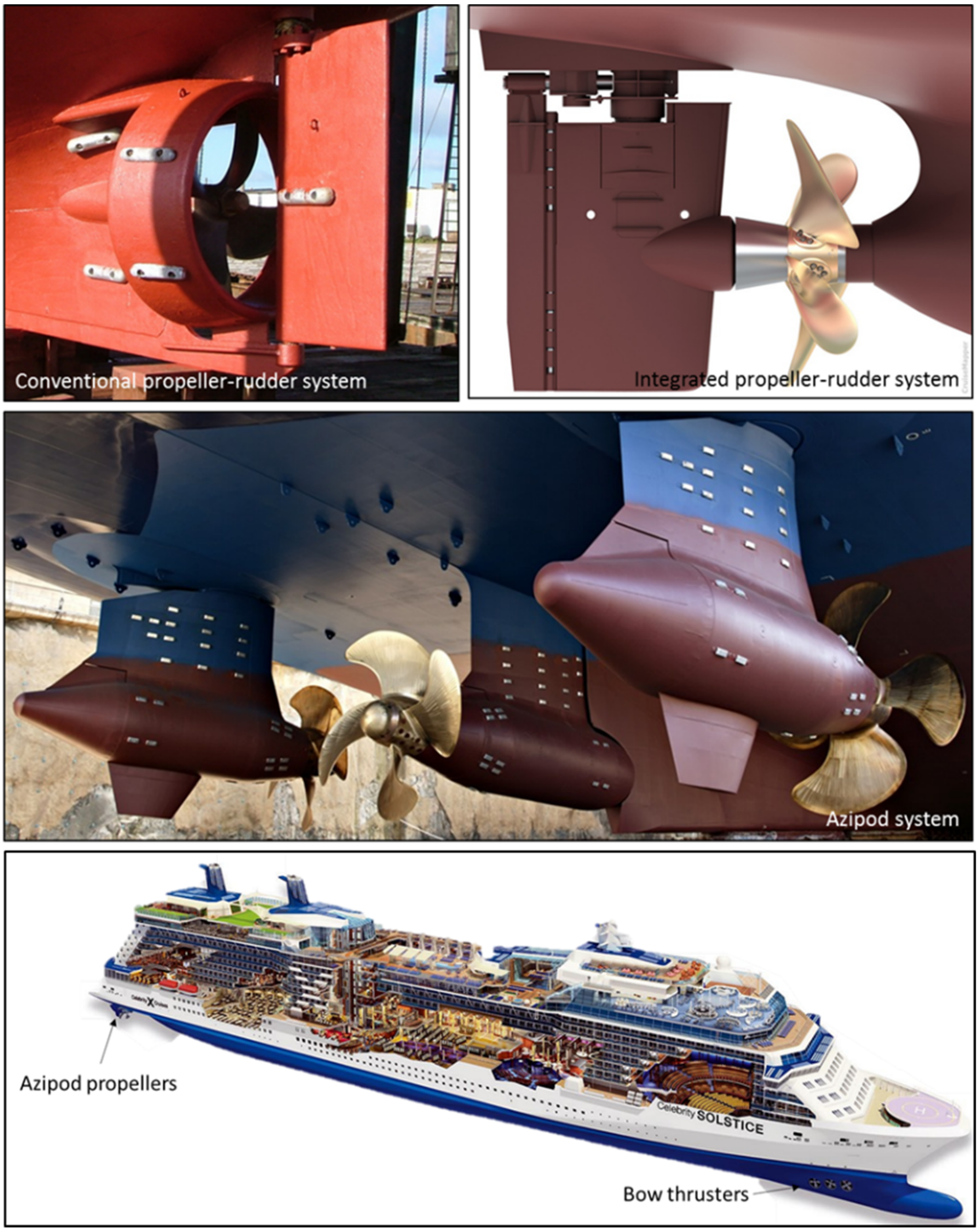

Figure 5. Top and middle: representative images of the main types of cruise-ship propulsion systems (https://www.cruisemapper.com). Bottom image: The propeller (Azipod™) and thruster (three transverse bow thrusters) configuration of Celebrity Solstice, the most frequent cruise ship to Akaroa Harbour (www.cruise-australia.net).

Only two of the top ten cruise ships visiting Akaroa Harbour have Azipod™-style thruster systems (Celebrity Solstice and Noordam), the remainder have conventional propeller-rudder type systems (Figure 5). In these conventional systems, the rudder influences the direction of the propeller jets, to enable turning left or right, consequently, the jet is split into two streams, one of which is directed downwards to the seabed, the extent of which can be changed with the rudder angle (Stoschek *et al.* 2014). Therefore, depending on the individual ship's propulsion configuration some ships will be more likely to cause seabed disturbance than others. However, further investigation would be required to confirm whether conventional systems are more likely to cause higher downstream water velocities than modern systems (e.g. Azipods™).

Depending on the manoeuvrability of the stern propulsion system, there will also be a number (2 to 6) of transverse thrusters to assist with directional changes. Thrusters are bi-directional and can be installed through the bow and/or stern (port to starboard).

The use of thrusters/propulsion systems are restricted in Akaroa Harbour (restrictions in place since 2012, Jim Dilley, ECAN Harbour Master, pers. comm.). The draft Code (2019) states that the use of thrusters:

- should be kept to a minimum once a vessel has anchored except where required for passenger transfer safety; provided that if used disturbance of the seabed be minimised as much as possible.
- for manoeuvring a vessel on arrival and departure will be in accordance with ensuring safe passage of the vessel. Where possible, the use of thrusters should be kept to a minimum and, where possible, not used.
- to turn a vessel during a wind change should be avoided unless required for the safety of the vessel or for passenger transfer safety.

Similarly, the Operational Requirements (2018) specifies that:

> the use of thrusters, manoeuvring equipment or dynamic positioning equipment should be kept to a minimum once a vessel has anchored. Effects of wash from this equipment can have a severe negative affect on the safety on vessels nearby. The use of such equipment may also cause disturbance to the seafloor and degradation of water quality.

An example of the seabed disturbance and degraded water quality is visible in Figure 1. The plumes created appear[6] similar to the discolouration seen during periods of rough weather and or high rainfall (Figure 6).

[6] As noted in https://www.ecan.govt.nz/do-it-online/harbourmasters-office/commercial-shipping/cruise-ships/

Using available satellite imagery (Figure 6 and Figure 7) it appears that plume size varies greatly, from virtually undetectable to hundreds of metres in length and width. The maximum surface area of the plumes observed was in the order of 1600 m^2 (approx. 800 m x 200 m). It is unlikely that the plume size reflects the true extent of seabed disturbance, which is likely to be more localised.

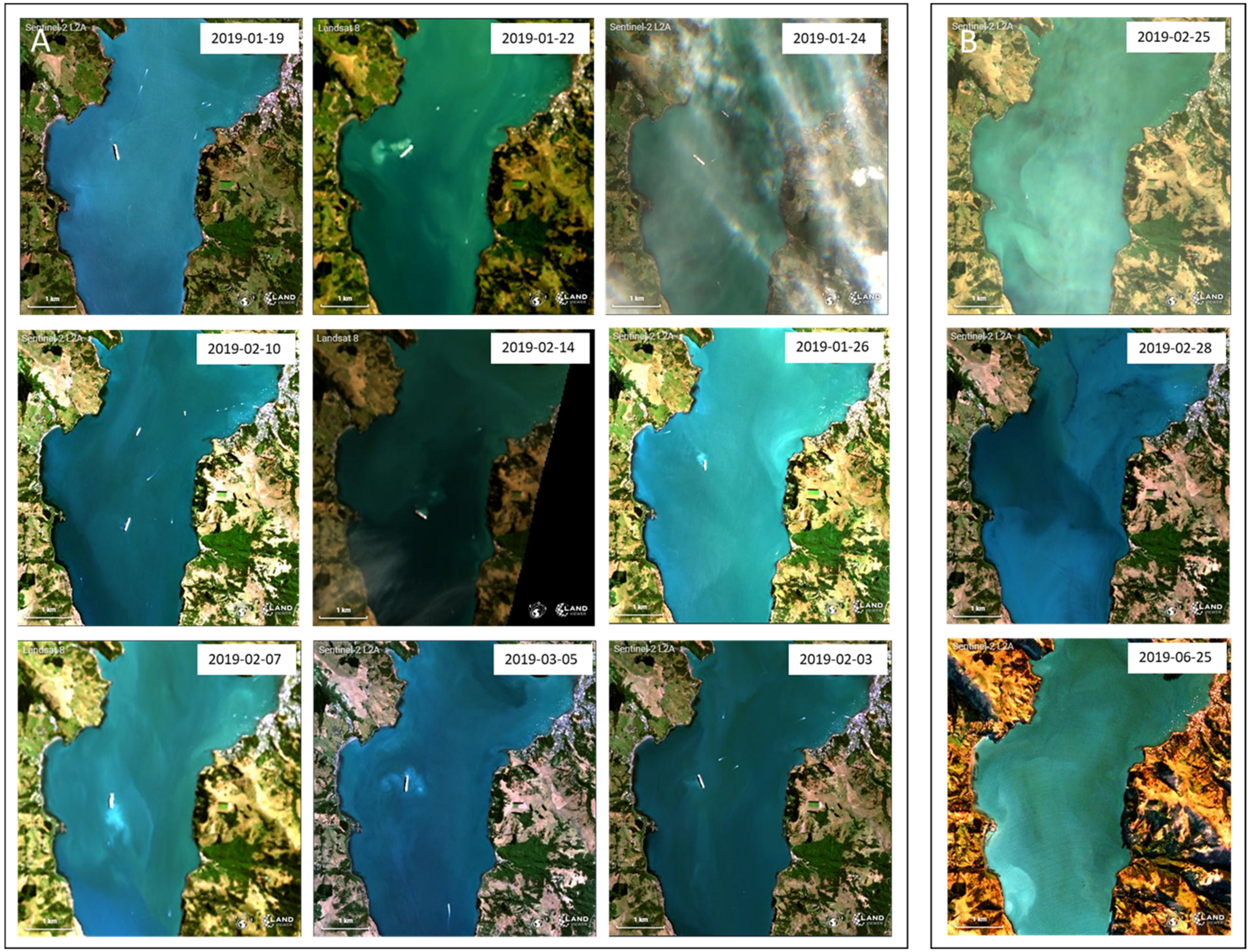

Figure 6. **A**. Representative satellite images of cruise ship plumes (January to March 2019) **B.** Representative satellite images of non-ship derived turbidity plumes (March and June 2019). Images extracted from the Earth Observing System (www.eos.com). Image capture date is on the top right-hand corner of each image.

3.2.3. Anchoring

Anchors typically work by penetrating the seabed at the anchor point, and then expanding the seabed hole to take the broader anchor sections. To maintain a good fix the anchor chain (rode) should lie flat on the seabed for a substantial distance, before arcing upwards towards the vessel. To break the anchor out of the seabed, the rode is pulled in until it is vertical from the vessel's bow roller. This rotates the anchor out of the seabed, releasing its hold.

The Operational Requirements (2018) describe the anchorage locations in Akaroa Harbour as providing 'good anchor holding' however, the document also notes that some vessel masters have reported poor holding at times and recommends additional lengths of shackle are laid. Cruise ships in Akaroa Harbour use approximately 4 shackles of chain (1 shackle = 27.4 m), equating to approximately 80–100 m of chain on the seabed (Jim Dilley, pers. comm.), with potential for 100-m radius (31,415 m^2) chain sweep areas at each of the four large ship anchorage areas (Figure 7).

There are restrictions (Requirements 2018) in place for where larger draft vessels, such as cruise ships, can anchor in the harbour (Figure 2, Figure 7). Larger draft vessels are restricted to the deeper anchorages (No.1 and No.2 for > 8 m draft, No.3 and No.6 for ≤ 8 m draft).

There are also restrictions (Requirements 2018) on where large draft vessels can go in the harbour, stating that *vessels exceeding 8 metres draft and intending to anchor must remain outside the 10 metre depth contour.* Also, if two large vessels (drafts > 8.0 metres) are to be anchored in Akaroa Harbour at the same time, the Operational Requirements (2018) specify that the first large vessel is to proceed inwards to use the No.1 anchorage. As the majority of the cruise ships visiting the harbour meet (or are close to) this criterion (> 8 m draft), the area within the 10 m depth contour is focused on as the area of impact in this report.

Boat activity in Akaroa Harbour also includes small vessels moving between harbours and bays, and anchoring. The intensity of the vessel movements varies among locations and seasons, with correspondingly variable potential environmental impacts depending on location, season and habitat type. For example, occasional anchoring on delicate habitats (e.g. sea grasses), even by small vessels using low-impact anchors, can have detrimental impacts, but higher frequency anchoring may only cause minor and short-term impacts on soft-sediment communities (Morrisey et al. 2018).

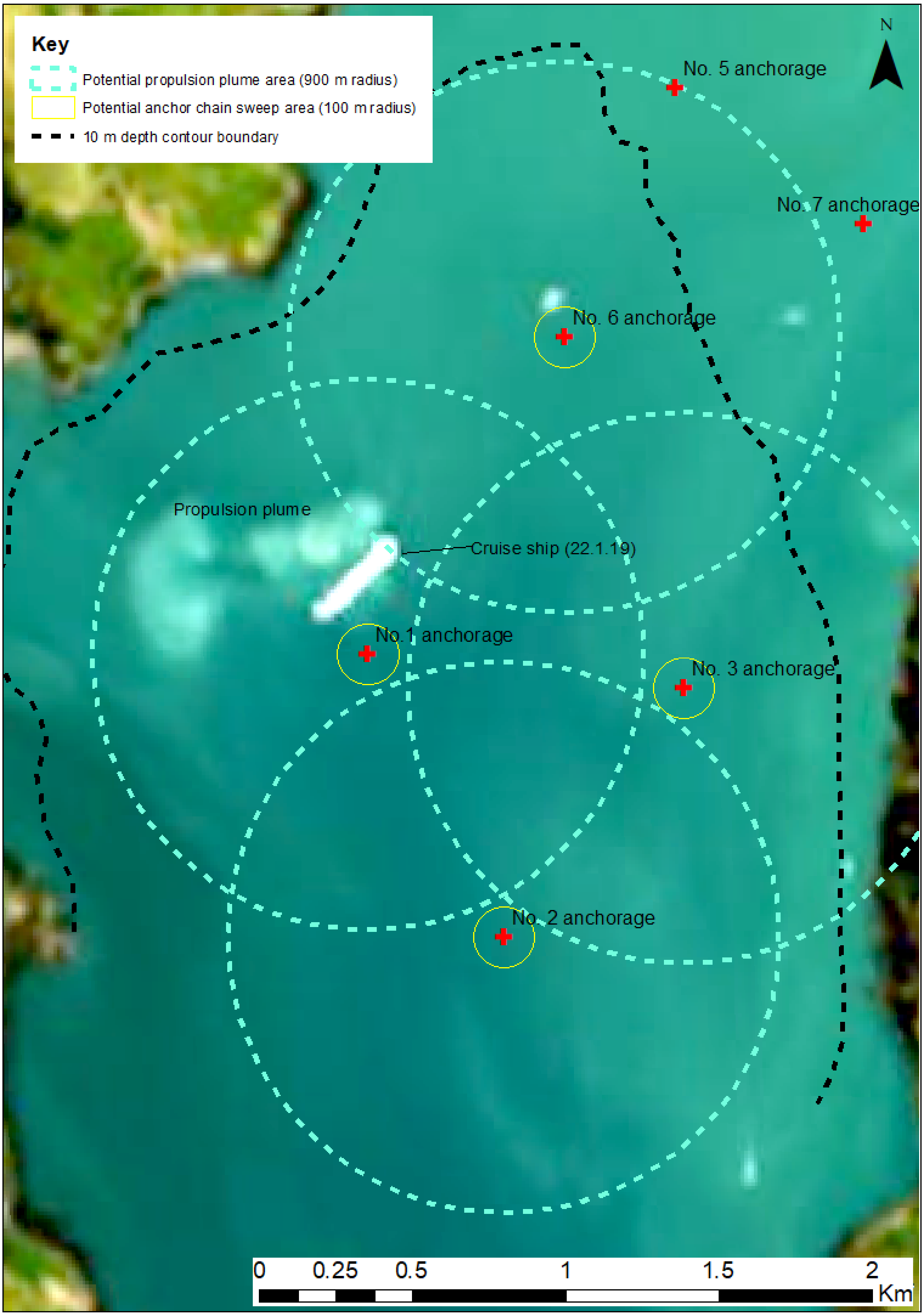

Figure 7. Potential cruise ship propulsion plume and anchor sweep areas. Representative image of cruise ship plume (taken on 22 January 2019) was extracted and rectified from the Earth Observing System (www.eos.com).

3.2.4. Emissions and discharges

Cruise ships produce liquid/solid wastes and air emissions. These can be subjected to varying degrees of treatment and released in a number of forms. Liquid wastes include sewage, grey water, bilge water, and hazardous waste (e.g. chemicals from photo processing, dry cleaning, printing, solvents for cleaning, batteries, light bulbs and pharmaceuticals). Solid wastes include food waste and packaging. Air emissions relate to engine fuel combustion by products.

Currently, cruise ships visiting New Zealand can use fuels (unfiltered residual) that emit sulphur, particulate matter and trace metals. Due to the restricted deeper anchorage requirements (Requirements 2018) for the most frequent cruise ship visitors to Akaroa Harbour, the vessels must keep engines running to maintain power. Power must be maintained to *ensure that a vessel's manoeuvring and navigation equipment is ready for immediate use at all times* (Requirements 2018). In some overseas ports (CIN 2018; Nilsen 2018), and as planned at the Port of Auckland (POAL 2017), vessels turn off the majority their engines and generators, and plug into port's shore power grid, reducing air emissions. Without this facility, diesel vessels (i.e. the majority of the most frequent cruise ships to Akaroa) can create carbon- and sulphur-rich air emissions (Figure 8).

Environment Canterbury reports[7] that air quality at Lyttelton (a port town frequented by cruise ships and other commercial vessels) is within World Health Organisation and national guideline values. The council views this site as having significantly higher quantities of air emissions (from shipping, rail, and road traffic) compared to Akaroa and have stated they are *confident there are no issues with air quality in Akaroa from cruise ships*. However, it is not clear if aesthetic issues/effects to outstanding landscapes, natural features and natural character have been considered (chapter 6, RCEP 2005).

New Zealand is signed up to the MARPOL annexes I, II, III and V and is currently consulting on Annex VI which relates to the prevention of air pollution from ships (0.5% sulphur cap on marine fuels). As well as this, there has been a commitment from the cruise ship industry in New Zealand to comply with Annex IV by January 2020 (Neil 2019) and it is a prerequisite in the Akaroa Harbour Operational Requirements (2018). If New Zealand accedes to Annex IV, it would mean low sulphur fuels would become a legal requirement for all cruise-ships visiting New Zealand.

[7] https://www.ecan.govt.nz/do-it-online/harbourmasters-office/commercial-shipping/cruise-ships/

Figure 8. Example of cruise ship air emissions in Akaroa Harbour (top image: https://akaroa.com).

3.2.5. Biosecurity

Harmful marine organisms (HMO) can be transported as part of biofouling communities on submerged surfaces (including within sea chests), in ballast and bilge water, or within debris or sediments associated with equipment or gear on cruise ships.

Biofouling risk from international vessels is managed through the Ministry for Primary Industries (MPI) Craft Risk Management Standard for Vessel Biofouling (CRS 2018). The standard requires all vessels to complete a biofouling declaration prior to entering New Zealand (at a 'Place of First Arrival,' POFA, the closest to Akaroa being Lyttelton Harbour) and to arrive with a 'clean hull' in accordance with specified biofouling thresholds. Likewise, ballast water from international vessels is managed through MPI's Import Health Standard (IHS) of the Biosecurity Act 1993 (MPI-IHS 2016), and by Maritime New Zealand under the Maritime Transport Act 1994 (MTA 1994) and the Marine Protection Rules Part 300 (MNZ-MPR 2016), which give effect to the International Convention for the Control and Management of Ships' Ballast Water and Sediments (BWM 2004). In contrast, bilge[8] water and the equipment/gear associated with cruise ships (commercial vessels) have no specific regulatory biosecurity management controls, but controls are often offered voluntarily, following best industry practice, in vessel-specific biosecurity management plans.

Marine biosecurity risks and potential mitigating and management tools relating to potential HMO vectors are typically defined in a regional risk assessments and/or

[8] Any entrained seawater that accumulates within the hull of a vessel (including in the engine room of larger vessels) and in the bilge sumps of smaller vessels, is contained in or on the vessel (e.g. for fish or bait), or is uncontained on the deck area of a vessel including in gear storage areas.

activity (or vessel) specific biosecurity management plans. This information was not available for this assessment.

3.2.6. Noise and light

Noise from cruise ships can travel significant distances over and through water. The draft Code (2019) specifies the following key noises resulting from cruise ship activities:

- ship's horn (signals)
- external announcements
- music (sound systems and display screens)
- underwater noise (engines, machinery etc.).

Each of these key noises have controls specified in the Operational Requirements (2018). The requirements are to: only use external noise when necessary (for manoeuvring and/or emergencies); use the lowest volume settings possible (as per Safety of Life at Sea requirements or a maximum of 65 dBA, whichever is applicable); and to minimise possible sources of high frequency noise below the waterline of the vessel (e.g. postponement of non-essential running of machinery and maintenance etc). Similarly, rules 8.21 c and d of the RCEP (2005) control noise from cruise ships outside of the operational area of ports.

Lighting is a conspicuous feature of cruise ships in the evening and at night. The draft Code (2019) specifies the following key lighting features resulting from cruise ship activities:

- large screen TV/displays
- deck lights.

Each of the specified light-emitting cruise ship features have controls described in the Operational Requirements (2018), which follow the guidance provided by the Department of Conservation. The operational requirements are to run displays at their minimum requirements and only use essential deck lighting (day or night). It is noted also that there is a requirement for all cruise ships to enter or leave the Harbour during daylight hours (2018). Similarly, Chapter 6 of the RCEP (2005) provides controls and implies a certain level of protection from human activities on the coastal environment, specifically relating to the (i) the life-supporting capacity of coastal ecosystems including significant indigenous flora and fauna and their habitats (effects to seabirds and marine mammals), (ii) outstanding landscapes and natural features, and (iii) natural character (aesthetic effects).

3.2.7. Support vessels

Cruise ships that visit the harbour anchor-off and disembark their passengers by launch tenders to the jetty in Akaroa. The tender boats can transport approximately 100 passengers at a time[9] (~ 20 minutes per trip) backwards and forwards from the ship to the main Akaroa wharf, all day from 7.30 am to 6 pm (weather dependent). There does not appear to be any restrictions on the frequency/number of tender launches during that period.

3.2.8. Speed and under keel clearance

The draft code (2019) contains vessel speed requirements (to ensure 'minimal adverse effects') that will be incorporated into the operating requirements for the coming season (not yet published). The specific requirements (Jim Dilley, pers. comm., 17 June 2019) will be as follows:

- the arrival and departure speed as the vessel approaches and departs
- the anchoring position is kept to a minimum to prevent seabed disturbance.

This includes:

- a maximum speed of 4 knots when UKC [under-keel clearance[10]] < 3 m
- 6 knots when UKC < 5 m".

At any other time, vessel masters must maintain a minimum under-keel clearance (UKC) of 1.6 metres (Requirements 2018).

Without sufficient UKC, and/or with sufficient speed, vessels can produce significant propeller and hull turbulence which can alter substrate stability and in turn, affect biological community composition (Sneddon *et al.* 2016). For example, the introduction of large, high-speed ferries to the Marlborough Sounds caused initial rapid and significant sediment transport and accretion on beaches and coastal environments up to 10 km from the sailing route. This effect has persisted in many places despite speed restrictions of < 18 knots, imposed on operators in 2000 (Morrisey *et al.* 2018).

Under keel clearance requirements in commercial ports are typically calculated by a number of factors relating to water level, ship characteristics and seabed characteristics (as described in the PIANC[11] 2014 Harbour Approach Channels - Design Guidelines). Requirements are often calculated using a port-wide modelling system such as dynamic under-keel clearance to ensure vessels maintain a safe distance from the seafloor. Keel turbulence assessments have often been based on

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[9] https://akaroa.com/cruise-ships/faq-akaroa-port
[10] UKC = the minimum total water depth at the location of the ship, minus the (dynamic) draft of the ship. Draft = the distance from the water's surface to the lowest point on the ship's keel.
[11] Permanent International Association of Navigation Congresses. https://www.pianc.org/about

the length, draft and/or speed of the vessel. However a case study in south-west Tasmania showed that the development of a model that considered vessel specifics (such as propeller size) to predict the turbulence pocket created by a specific ship was more accurate and helpful than size/speed restrictions alone (Ellis et al. 2005). The Akaroa Harbour UKC requirements are precautionary and are loosely based on a '10% of the vessel draft' rule, with the addition of further clearance distance intended to provide 'seabed protection' (Jim Dilley, pers. comm. 4 July 2019).

3.2.9. Visibility and wind speed restrictions

Vessels must not enter into the harbour or depart from an anchorage within the harbour when the visibility is less than 0.5 nautical miles, and no vessel may enter into the harbour or depart from any anchorage within the harbour between the hours of sunset and sunrise (Requirements 2018). The Operational Requirements also specify that no vessel shall enter into the Harbour when the wind speed within the harbour exceeds 30 knots (average wind speed over a period of 60 seconds). Though largely for navigation safety, some of the Operational Requirements (2018) will have implications for determining the risk levels associated with ecosystem effects, particularly relating to seabirds/marine mammal collisions and spills/discharge caused by accidental vessels collisions.

4. RECEIVING ENVIRONMENT CHARACTERISATION

There are no expert ecological assessments available in relation to the effects of cruise ship activites in Akaroa Harbour. The following paragraphs provide context to the risk assessment, but the information is not exhaustive, and expert assessments would be recommended to build on this information for any subsequent effects assessements/investigations. The following sections briefly describe the bathymetry, seabed, water column, biology and weather characteristics of the Akaroa Harbour receiving environment potentially affected by cruise ship visits.

4.1. Bathymetry

The bathymetry of Akaroa Harbour is illustrated in Figure 2, with key cruise ship anchoring areas (within the 10 m depth contour) identified. The Harbour itself is a narrow, SSE-oriented inlet, approximately 17 km in length, formed from collapsed caldera volcanoes (Fenwick 2004; Golder Associates 2009). Water depths range from 24-30 m at the entrance to 11 m in Wainui Bay (adjacent to the cruise ship anchorage locations). The width of the Harbour is relatively constant throughout, ranging from 2-3 km (Golder Associates 2009), with predominantly steep shorelines plunging to a relatively flat central bed (Figure 2).

The LINZ 2008 chart survey (Hart *et al.* 2009; LINZ 2009) showed a slight increase in charted depth of Akaroa Inlet, compared to the original 1952 survey (on the eastern side of the Harbour, Hart et al. 2009). In 2011, targeted bathymetric surveys (following the 2011 earthquakes) showed no change in depth (Requirements 2018). Similarly, Wainui Bay (adjacent the anchoring locations, Figure 2) is not considered a depositional environment (being a relatively high-energy site). In contrast, inner Takamatua Bay (also on the eastern side of the harbour) is reported to have experienced sediment accumulation and a reduction in depth since the 1952 survey (Hart *et al.* 2009).

4.2. Weather

The cruise ship anchorage areas are subject to strong wind gusts and wind funnelling, with sustained winds in excess of 40 knots being common. Winds generally blow up or down (SE/NW) the harbour, however, rapid SW wind changes also occur. The worst sea conditions occur when SE swells are in combination with SW winds. Only the SE swell can penetrate the harbour further than 2.5 nm. As specified in the Operational Procedures (2018), the safety of vessels can be compromised by these winds and early departure from the harbour may be required.

4.3. Seabed

4.3.1. Soft sediments

Previous studies show that there is a soft sediment subtidal seabed in Akaroa Harbour (ranging from sands closer to shore, to more silts and clays sub-tidally). However, inconsistencies in early sediment survey methods (as discussed in Hart et al. 2009; Hart & de Villiers 2012; Sneddon & Clement 2014) have hampered finer scale temporal and spatial comparisons, making it difficult to determine if the sediment texture has changed over time and whether there are other influencing factors at play (e.g. seasonal shifts in harbour processes or other anthropogenic influences). This limitation could be addressed with a consistent sampling program, following the methodology of the baseline Hart et al. (2009) sediment survey.

Sands are reported to be more common in the embayment shorelines and nearshore zones surrounding the cruise ship anchorage locations, most extensively in Duvauchelle, Robinsons and Takamatua bays (Hart *et al.* 2009). As defined in Hart et al. (2009), it is likely that the coarser material[12] found closer to the shore (intertidally) has resulted from wave turbulence preventing finer (silt and clay) materials from settling (Hart *et al.* 2009; and references therein, i.e. Hicks and Marra 1988). Some of these finer sediments appear to be accumulating in a depositional (sink) zone identified north of the cruise ship anchorage locations (Figure 9), in the central area between Akaroa Inlet and Robinsons Bay (Hart et al. 2009).

The sediment characteristics in the upper harbour bays vary slightly, e.g. more silt and muds at French Farm and Barrys Bay inlet, and extensive areas of sandy sediments at Duvauchelle, Robinsons and Takamatua (Bolton-Ritchie 2005a; Hart *et al.* 2009). These areas appeared to have become more variable over time, with patches (some extensive) of silty-sand and silt sediments (Hart *et al.* 2009). In the same way, mud-free sand was reported to be present in Akaroa Inlet during a 1988 survey, whereas silty-sand prevailed in 2009 (Hart *et al.*). There is also some evidence of sedimentation in the sheltered outer and northern parts of the Akaroa bays resulting from the Christchurch earthquake tsunami[13] (Hart & de Villiers 2012). However, in all cases, perceived changes in sediment texture were difficult to interpret (in terms of temporal change) or compare, due to disparities in sampling effort and methodologies.

In the outer reaches on the harbour (outer Duvauchelle Bay passing through the cruise ship anchorage locations and towards the harbour entrance), surface sediment transitions from mud to fine sands (Fenwick 2004). However, the study locations in

[12] not including those materials used for shoreline protection.

[13] Akaroa residents' recorded observations of sediment plumes in the harbour during the Christchurch earthquake tsunami in 2011. Following this, results from a one-off seabed sediment investigation by Hart and de Villers (2012), compared with previous results from Hart et al. (2009), showed that sediments in the central-upper harbour may have been suspended by the tsunami wave and deposited in the more sheltered outer and northern parts of the bays. However, as there was limited comparable data from previous investigations, it was not possible to rule out whether this was simply related to a seasonal (wintertime) shift in harbour processes.

Fenwick's (2004) work were not directly comparable with subsequent work (Hart et al. 2009; Sneddon & Clement 2014)[14] and direct temporal or spatial comparisons of these findings could not be made. According to CCC (2017) the Akaroa Harbour heads have 'loose seabed' and are a 'bad holding ground' (attributed to the southward exposure, and significant water currents/swells). The risk associated with these environmental conditions led (in part[15]) to the rejection of the proposal for relocating of the Akaroa wastewater outfall (presently located in Red House Bay, the inner harbour) beyond the heads of Akaroa Harbour (CCC 2017). In contrast, the soft sediments (silts and clays) that dominate the upper and central parts of Akaroa Harbour provide good anchoring (Requirements 2018, Figure 9).

Based on the trace metal composition of the subtidal sediments described in Fenwick (2004), it is reasonable to assume that there would be few anthropogenically-derived contaminants in the sediments at the Akaroa anchorage locations. Sediment metal concentrations in the Takamatua Bay and Childrens Bay intertidal zone were slightly elevated (though, within background concentrations) compared to other intertidal embayment's in Akaroa Harbour (Bolton-Ritchie & Lees 2012). The elevated sediment metal concentrations were suspected to be caused by stormwater inputs from Akaroa township and/or adjacent on-the-water activities. However, it was also noted that the results could also be a reflection of the volcanic soil origins, influenced by the local circulation and deposition patterns (Bolton-Ritchie & Lees 2012). Sediment organic content was generally low throughout the harbour, though slightly higher proportions of organic matter where detected in the inner harbour stations (Fenwick 2004). Generally, the sediment total nitrogen (~ 600 to 1300 mg/kg) and phosphorus (~ 600 to 700 mg/kg) concentrations from sampling stations in Fenwick (2004) followed these patterns as well and were typical of marine sediment concentrations (Gillespie *et al.* 2012).

[14] The Hart et al. (2009) study also showed a southward coarsening of sediments, but the transition to fine sands was not detected within the upper-harbours central axis. Unlike the Fenwick (2004) findings, no spatial gradients were detected and a high level of spatial uniformity in sediment texture was reported by Sneddon and Clement (2014). The difference between the two studies results was attributed to different grain size analysis methods.

[15] Refer to CCC (2017) for more detail.

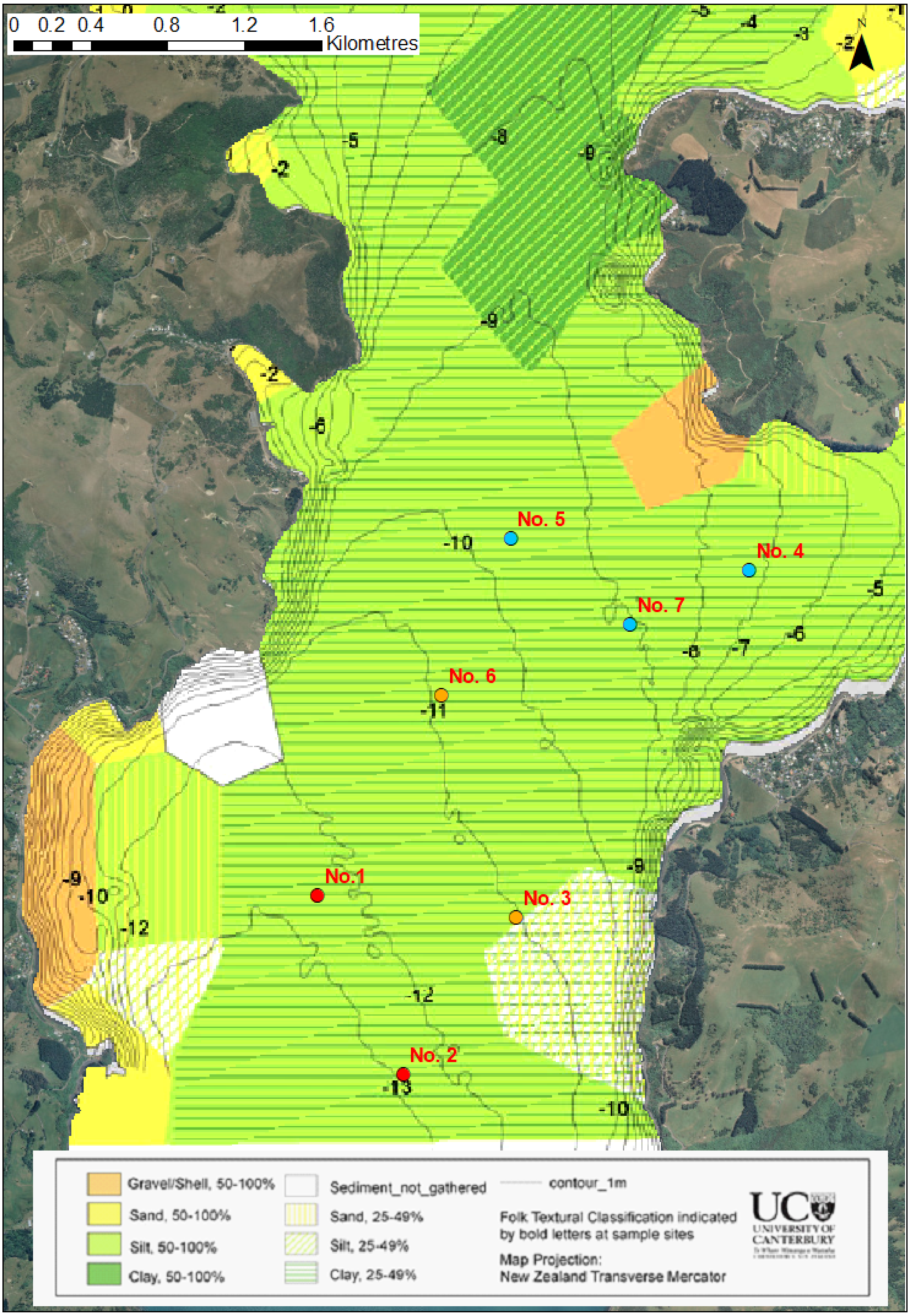

Figure 9. Upper Akaroa Harbour sediment textures and bathymetry with anchor points overlaid (large cruise ship specific anchorages = No.1, 2, 6 and 3). Sediment texture chart modified from Hart et al. (2009).

4.3.2. Rocky shores

The vast majority of rocky shore habitat in the Akaroa Harbour has not been surveyed (Figure 10). In general, the coastal habitat of the peninsula has a narrow margin of boulder-dominated reef that becomes soft sediment habitat (Figure 9 and Figure 10) up to several hundred metres from shore (Brough *et al.* 2018).

Fenwick's (2004) baseline study of rocky shore/reefs in the Akaroa Harbour surveyed three sites: Tikao Bay, Cape Three Point and Lucas Bay (Figure 10).

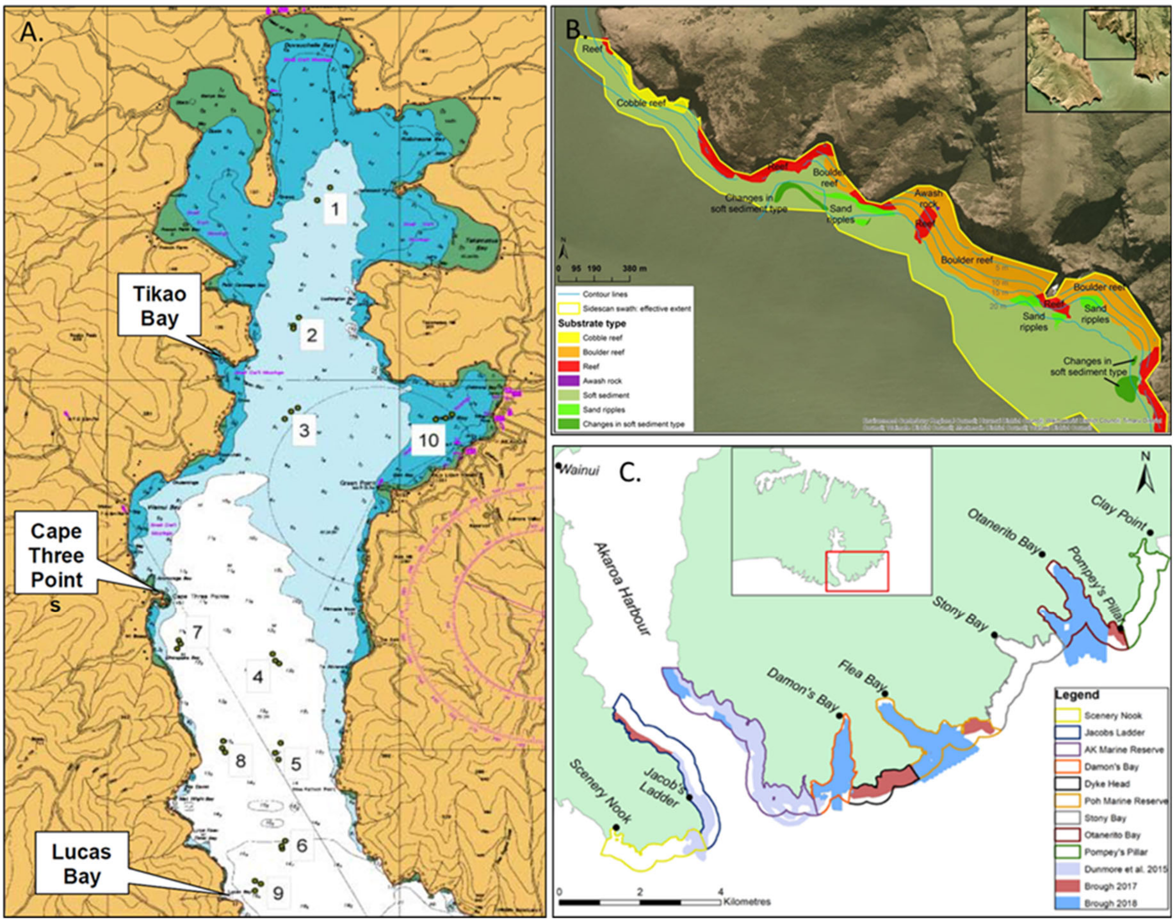

Figure 10. A. The Tikao Bay, Cape Three Point and Lucas Bay rocky shore sampling sites from Fenwick 2004. B. Example of broad-scale substrate mapping of the northern point of Akaroa Reserve, excerpt from Dunmore et al. 2015. C. Substrate mapping areas in the outer Akaroa Harbour, excerpt from Brough et al. (2018).

The shore at Lucas Bay rocky shore (near the harbour mouth, Figure 10) was described as an unbroken bedrock platform, starting from about 2.5 m below the extreme low-water spring tide level, after rising steeply from the subtidal depths. The platform was reported to be 6-8 m wide and open to high wave action from the open sea (Fenwick 2004).

The Cape Three Point rocky shore, adjacent to the cruise ship anchorages (Figure 9 and Figure 10), was described as unbroken bedrock (basalt), rising abruptly from the sublittoral[16] zone. The shore at this location has ledges, platforms and pools/crevices and spans about 9 m horizontally (Fenwick 2004).

The Tikao Bay rocky shore, north of the cruise ship anchorages (Figure 9 and Figure 10), was unbroken bedrock with some irregular dissections in the rock. It was markedly different to the other sites, being much more sheltered from wave action and the mid-day and afternoon sun. The shoreline rose from the sublittoral zone, into the intertidal zone and up into the surrounding bush line at an angle of 30-45 degrees (Fenwick 2004).

Since the 2004 investigation by Fenwick, there have been a few small-scale studies using side-scan sonar on the reef and near-shore environments in the harbour. The report by Dunmore et al. (2015) for the Department of Conservation focussed on the Akaroa Reserve coastline (examples in Figure 2b and Figure 10b). The limited sonar sensitivity restricted detection to large scale features only (e.g. reef edges, ripples and boulders) and was not able to distinguish between overlaid boulders and bedrock. However, findings confirmed the presence of bedrock reefs along the near shore of the Reserve, typically grading to boulder and cobble reefs, with soft sediments (mud/sand and pockets of sand and shells) toward the deeper centre of the harbour.

The most recent (and publicly available) study of hard-substrate habitat on the outer harbour and adjacent coastline (Figure 10) by Brough et al. (2018) identified boulder reefs (predominant); cobble reefs (common in the inner parts of the outer coastal bays) and complex combined bedrock-boulder reefs. Brough et al. (2018) also identified[17] variability in the size and distribution of physical habitats around Akaroa Harbour. This variability was particularly notable in the width of the reef margin.

As noted in Brough et al. (2018), a focus on the biological habitats represented in the region, identification of habitat sensitivity (i.e. to sedimentation) and extension of substrate mapping, would be helpful in characterising this aspect of the environment more adequately.

4.4. Water column

The most recent water quality study available for this assessment was by Dudley et al. (2019) which characterised the Akaroa Harbour water column in terms of nutrients, physico-chemical parameters and hydrodynamics. Prior to this study, Bolton-Ritchie

[16] The sea-shore zone lying immediately below the littoral (intertidal) zone.
[17] Brough et al. (2018) had access to other commercial and academic literature which were not available for this assessment e.g. reports relating to the Pōhatu Marine Reserve, recent side-scan sonar mapping of near-shore habitat in the region (Brough et al. 2018 and references therein) and a PhD project focussing on habitat selection in Hector's dolphins.

(2005b) undertook an assessment of water quality monitoring results spanning 1989 to 2004 (comparing against relevant standards) and 1989–2009 (Bolton-Ritchie 2013), and Sneddon and Clement (Sneddon & Clement 2014) undertook water quality testing in relation to the Akaroa WW outfall. The following sections summarise the key water column characteristics in Akaroa Harbour.

4.4.1. Hydrodynamics

Akaroa Harbour sites were similar to offshore waters, with a tidal prism is in the order of 75 million m^3, a freshwater inflow of 2.29 m^3/s (0.025 freshwater fraction) and a flushing time of 58 days (Dudley *et al.* 2019). The main source of fresh water from outside the harbour is the Rakaia River (50% of fresh water), followed by the Waitaki River (21%) and Rangitata River (10%). There are also treated effluent discharges from treatment plants at Duvauchelle and Akaroa, which total 0.0051 m^3/s (averaged over 2014-2018, Bell *et al.* 2014; Dudley *et al.* 2019). Mixing of inflows in the harbour is driven by wind circulation (Heuff *et al.* 2005a, b).

4.4.2. Salinity

Volume average salinities in Akaroa Harbour ranged between a minimum of 32.73 ppt in late May 2009 and a maximum of 34.5 ppt in mid-December 2009. Salinity was below 33.8 ppt from May through until August (Dudley *et al.* 2019).

4.4.3. Contaminants

There is little information available relating to water column contaminants in Akaroa Harbour. Shellfish samples collected from Cape Three Points (< 2 km from cruise ship anchorage No.1) as part of the Akaroa waste water outfall monitoring (Sneddon & Clement 2014) showed generally low concentrations of trace metals and indicator bacteria, suggesting low ambient levels of contamination in the water near the anchor locations. Consistent with this finding, the metal composition of the subtidal sediments described in Fenwick (2004) showed little in the way of anthropogenically-derived contaminants in the sediments at the Akaroa anchorage locations. However, it is possible that nutrients and organic matter from the sediments (Section 4.3) could become released into the water column with physical disturbance.

4.4.4. Nutrients

The nitrogen (N) and phosphorus (P) species monitored in Akaroa Harbour are nitrate + nitrite nitrogen (NO_XN), ammonia/ammonium (NH_XN), dissolved reactive phosphorus (DRP), total nitrogen (TN) and total phosphorus (TP). These forms of N and P commonly influence aquatic coastal primary production e.g. photosynthetic bacteria, phytoplankton and macroalgae. According to Dudley et al. (2019) the dominant sources of both nitrogen and phosphorus to the Akaroa Harbour are:

1. the off-shore ocean (55% of nitrogen, 69% of phosphorus)
2. local streams (33% of N and 18% of P)
3. the wastewater treatment plant discharges (1–2% of N and P)
4. rivers along the Canterbury and Otago coasts (10–12% of N and P, e.g. Lake Ellesmere/Te Waihora and the Rakaia River). Note, loadings are likely to occur in pulses following floods in the Rakaia or openings of the lake.

Akaroa Harbour is assumed[18] to be nitrogen limited[19].

4.4.5. Chlorophyll-a and phytoplankton

Chlorophyll-a is a measure of phytoplankton biomass and a primary symptom indicator of eutrophication in subtidal-dominated estuaries (Robertson *et al.* 2016). In coastal waters, high chlorophyll-a concentrations may occur during periods of high nutrient loading or upwelling of nutrients from deeper ocean waters. Chlorophyll-a concentrations in Akaroa Harbour increase gradually from the mouth (0.0008–0.0012 mg/L) toward in the inner harbour (0.0016–0.0019 mg/L, Figure 11). Assuming Akaroa Harbour is nitrogen limited, the predicted chlorophyll-a maximum is 0.007 mg/L, fitting within the range for a B-susceptibility score, indicating the ecological communities are slightly impacted by additional phytoplankton growth from elevated nutrient concentrations (0.003–0.008 mg/L for euhaline[20] estuaries, Robertson et al. (2016), as cited in Dudley et al. [2019]).

As might be expected with a B-susceptibility score, ten species of bloom-forming phytoplankton (at levels > 10,000 cells/L[21]) were recorded between 1999 to 2002 (ANZECC 2000; Bolton-Ritchie 2005b; Golder Associates 2009). This is despite the fact that optimal nutrient conditions for phytoplankton growth i.e. an N:P ratio of 16:1, did not occur in the samples collected between 1989–2004 (Bolton-Ritchie 2005b). Fenwick et al. (2003) collated data that showed periodically high nutrient concentrations and several phytoplankton blooms, including some involving known toxic species. Results suggest episodic events causing elevated nutrient concentrations, that are not detectable by the current monitoring regime, could be occurring.

4.4.6. Turbidity and suspended sediments

Turbidity in the Akaroa Harbour region is relatively low compared to other Canterbury coastal areas (Dudley et al. 2019), ranging from 1.32-2.19 NTU in the mid to outer

[18] Dudley et al. (2019) bases these predictions on the results of the 'phytoplankton susceptibility tool,' an analytical model by Robertson et al. (2016) used to predict the maximum likely chlorophyll-a concentration based on available potential total nitrogen and phosphorus concentrations, and the flushing time of the system.
[19] Nitrogen-limited ecosystems are those where primary production increases if nitrogen is introduced.
[20] Normal salinity seawater.
[21] As an interim guide, direct contact should be avoided when 15 000–20 000 cells/mL are present, depending on the algal species (ANZECC 2000).

harbour, to 2.19–3.38 NTU in the inner harbour (Figure 11). As might be expected, suspended solid concentrations follow the same pattern as turbidity level, with concentration ranges lower in the mid- to outer-harbour (3.98–5.68 mg/L) compared to the inner harbour (5.68–9.86 mg/L).

4.4.7. Seasonal variation

Seasonal patterns have been reported in the concentrations of some nitrogen phosphorus species in the Akaroa Harbour water column (Bolton-Ritchie 2005b, 2013). These patterns are thought to reflect the spring phytoplankton nutrient uptake and mid-late autumn nutrient release. Bolton-Ritchie (2005b) also described varying levels of water column stratification in nutrient concentrations, notably at the inner harbour sites, where the higher nutrient concentrations were thought to be associated with seafloor sediments remixed by waves and currents. Stratification can be expected to vary over time due to climatic factors, such as temperature, duration and strength of the wind. The nutrient concentrations of the inner harbour may maintain the ecologically important intertidal seagrass beds in the inner harbour, with Bolton-Ritchie (2005b) cautioning that the nutrient balance of this ‘internationally important harbour,’ could deteriorate due to the increasing burden from human population increases (i.e. increased sewage disposal, stormwater runoff etc). In contrast, Dudley et al. (2019) found concentrations of nitrogen and phosphorus species, chlorophyll-a, turbidity and total suspended solids to be relatively stable between summer and winter.

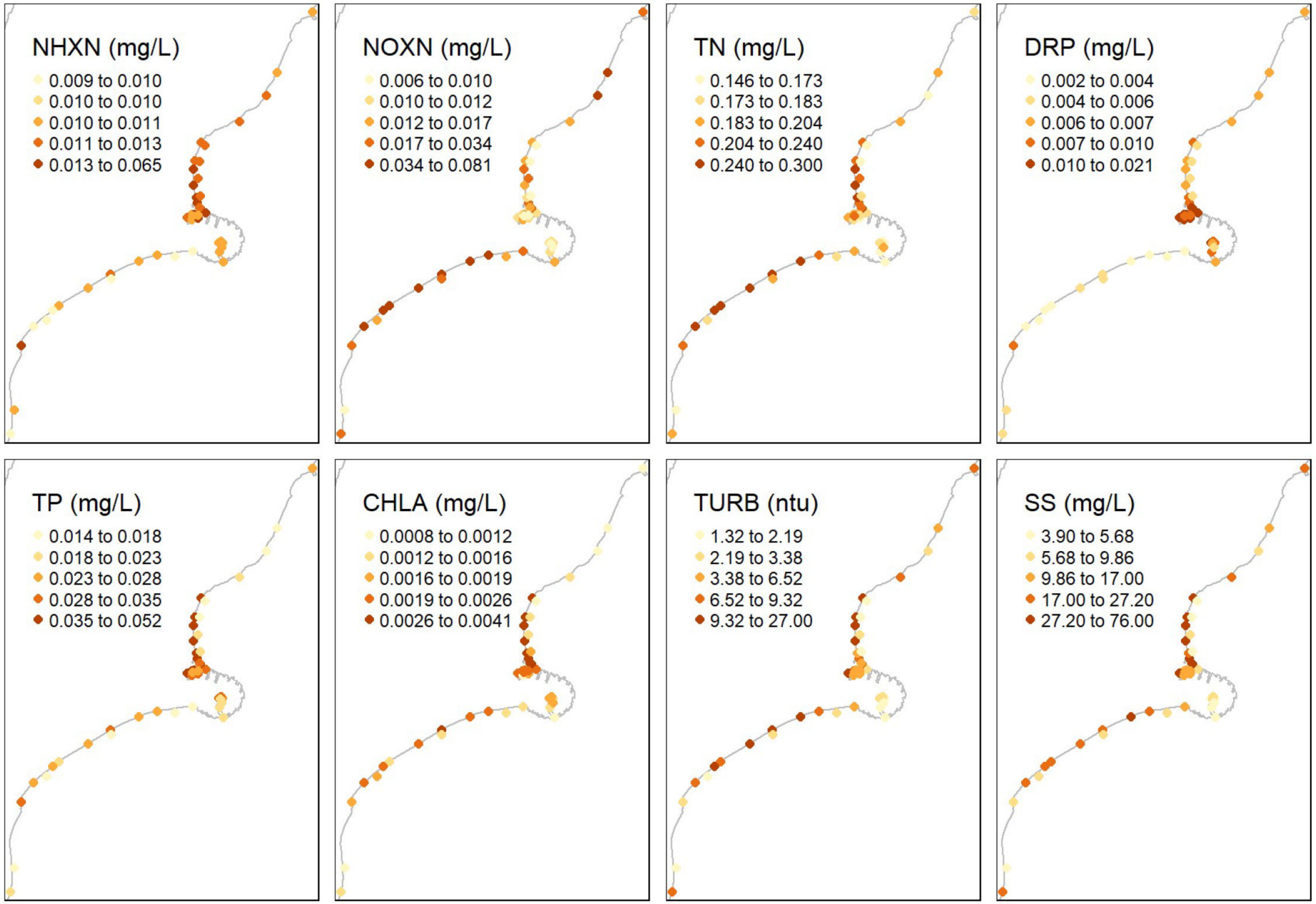

Figure 11. The ranges of water quality values across Canterbury coastal waters (extracted from Dudley et al. 2019). From seven sites in Akaroa Harbour, sampled monthly for a year, every five years since September 2007.

4.5. Biology

4.5.1. Rocky shore

Baseline data collected by Fenwick (2004) over three rocky shore sites (5 x quadrats per transect, 2 x transects per site, Figure 10) showed variability in the species diversity between sites, with notable dominance throughout of two species (primarily the barnacle *Chamaesipho columna* and to a lesser extent, the tube worm *Pomatoceros caeruleus*) in the mid/low-shore areas. All the intertidal species found in the study appeared to be largely controlled by wave exposure, with shading another potential influence (particulalry in Tikao Bay). The species found were considered to be widely distrbuted around Banks Peninsula and the wider South Island (Hart et al. 2009), though, Fenwick (2004) described the Cape Three Point (< 1.6 km from the cruiseship anchorage locations) habitat as warranting 'special attention' due to its rich biota and accessibility. No evidence of anthropogenic influences were detected on the intertidal areas investigated.

The giant kelp *Macrocystis pyrifera* is also known to occur on low intertidal rocky substrata in Akaroa Harbour. The seaweed is classified as having an 'at-risk – declining' conservation status by DOC (2019a), and is commercially harvested in the area[22]. Little is known about the prevalence of other potentially threatened rocky shore macroalgae in the vicinty of the cruise ships' anchorages.

4.5.2. Soft sediments

Intertidal flats

Bolton-Ritchie (2005a) investigated the macrofauna and seagrass (*Zostera muelleri*) cover of the intertidal flats of upper Akaroa Harbour. The 104 taxa identified were typical of enclosed harbour flats/estuaries, with molluscs, polychaetes and crustaceans dominating. Community composition was shown to vary relative to the physical and biological factors affecting each embayment. Notably, seagrass played a key role in stablising sediments. The majority of the biomass found (cockles and wedge shells) were described as mahinga kai, and were considered vauable food for wading birds. The report recommends that the Akaroa Harbour intertidal mudflats should be considered an area of signficant natural value (which they subsequently are in the most recent update of the RCEP 2005), and were considered in healthy condition. It is not clear if any follow up intertidal studies have been performed in the last 14 years.

Subtidal

Fenwick (2004) also collected baseline data over ten subtidal soft sediment sites (3 x replicate samples per site, Figure 10). Subtidal species ditributions were strongly correlated with wave exposure, sediment organic content, sediment copper and zinc

[22] Fisheries NZ quota management summary: https://fs.fish.govt.nz/Doc/24294/07_KBB_G_2017.pdf.ashx

concentrations and water depth. Metal concentrations, nutrient concentrations and sediment characteristics were generally typical of marine subtidal sediments, with no sediment contamination evident.

The soft-bottom communities showed increased diversity and mean faunal densities along the central axis of the harbour towards the harbour mouth (Fenwick 2004). Despite the differing sampling methodology, the total faunal diveristy (136 benthic species over 30 samples) in Akaroa Harbour was considered to be comparable if not slightly higher than that reported for other locations around Banks Peninsula. Fenwick (2004) summarised that the species composition, diversity and density patterns at the time of sampling suggest that the subtidal benthos has not been overly affected by anthropoengic influences.

A baseline benthic survey was also conducted (Sneddon & Clement 2014) in relation to the proposed Akaroa wastewater outfall diffuser. Ten sampling stations were orientated along the harbour centreline between Akaroa Inlet and Wainui Bay, and directly within the anchoring locations discussed in Section 3.2.3. A total of 53 macroinvertebrate taxa were identified in the samples, and the standard indices for diversity and evenness were moderate to high and varied little between stations, with no strong spatial trends detected. Sneddon and Clement (2014) stated that the nature of the benthos is likely to have moderatly rapid recovery from enrichment effects following ceasation of wastewater discharges. No taxa or assemblages of special conservation or scientific interest were found, and the benthos was typical of shallow protected coastal environments in the region. Differences between Sneddon and Clement (2014) and Fenwick (2004) results were attributed to methodological differences and or seasonal differences in survey timing.The potential benthic effects from anchorage-related seabed disturbance was not considered in either investigation.

4.5.3. Pelagics/fish

For exposed Akaroa Harbour environments (i.e. close to rocky reefs), the most important fishes reported by Fenwick et al. (2003, Table 3) were blue moki (*Latridopsis ciliaris*), blue cod (*Parapercis colias),* butterfish (*Odax pullus*), and to a lesser extent, red cod (*Pseudophycis bachus*; considered of lesser value). Blue cod and red cod were also reported to be widespread and abundant in deeper water. More recently, Källqvist et al. (2015) showed that the most frequently landed fish (recreationally) were blue cod, flatfish (*Rhombosolea* spp.), rock lobster (*Jasus edwardsii*) and sea perch (*Helicolenus percoides).* Acccording to Källqvist et al. (2015) the fish species targeted in the harbour have changed since a 1997 survey, notably, the catch per unit effort for red cod declined, and recreational fishing trips moved from the inner harbour to the vicinity of the harbour entrance.

In 2006 a Taiāpure was established in Akaroa Harbour for the protection of fish and shellfisheries from amateur/recreational overfishing (Källqvist et al. 2015). A combined maximum daily bag limit of 30 finfish per person, consisting of any combination of the species listed in the Taiāpure, was enacted.

Akaroa Harbour is within Fisheries Management Area (FMA) 3 South-East (Coast) and commercial fishing general statistical area 022 (Figure 12). While the Harbour is not closed to commercial fishing, the intensity of fishing within the harbour is generally low, e.g. baracoutta and anchovies (NABIS 2019). Beyond the Akaroa Heads, commercial fishing intensity increases to high levels along the eastern Banks Peninsula coast (Figure 12).

Table 3. Marine fishes recorded from Akaroa Harbour with indices of relative abundance: C = common, O = occasional, R = rare. Table from Fenwick et al. (2003).

Scientific name	Common name	Relative abundance
Aplodactylus arctidens	Marblefish	R
Chelidonichthys kumu	Red gurnard	O
Congiopodus leucopaecilus	Southern pigfish	R
Forsterygion lapillum	Common triplefin	O
Forsterygion varium	Variable triplefin	C
Forsterygion malcolmi	Mottled triplefin	C
Forsterygion flavonigrum	Yellow-black triplefin	O
Hemerocoetes monopterygius	Opalfish	C
Hippocampus abdominalis	Seahorse	R
Hypoplectrodes huntii	Red-banded perch	R
Latridopsis ciliaris	Blue moki	O
Notoclinops segmentatus	Blue-eyed triplefin	R
Nemadactylus macropterus	Tarakihi	R
Notolabrus celidotus	Spotty	C
Notolabrus fucicola	Banded wrasse	C
Obliquichthys maryannae	Oblique triplefin	R
Odax pullus	Greenbone	O
Parapercis colias	Blue cod	O
Pseudolabrus miles	Scarlet wrasse	C
Pelotretis flavilatus	Lemon sole	O
Raja sp.	Skate egg case	R

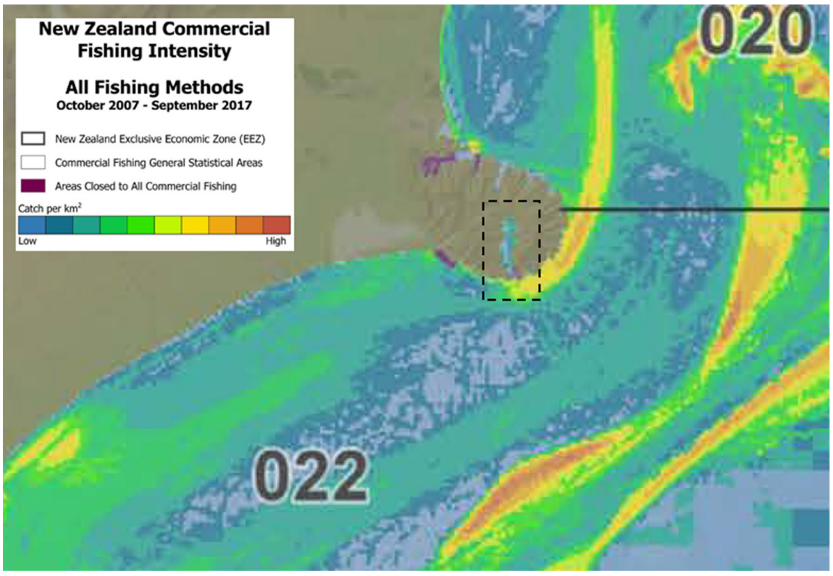

Figure 12. Akaroa Harbour (dashed box) commercial fishing intensity 2007 to 2017 (Fisheries New Zealand, 2019).

Other fishing restrictions in the harbour (i.e. South East Commercial Fishing Restrictions, NABIS 2019) cover flatfish (banned except for a restricted upper harbour area, from 1 April to 30 September), set netting (banned) and the Banks Peninsula Salmon Conservation Area in the nearby Banks Peninsula coastline outside the harbour (prohibition on trawling by large vessels within the designated area).

There are also important links between the Akaroa Harbour and its freshwater inputs (Hart *et al.* 2009). The harbour's freshwater inputs are reported to contain diverse invertebrate fauna, a number of native and other fish species including long-finned and short-finned eels, inanga, banded kokopu, perch, goldfish and brown trout. The harbour streams are considered to be important for recreation and as a mahinga kai resource, with high value assigned for swimming; moderate for walking, eeling and other fishing; and low for bird-watching, trout angling and waterfowl hunting.

4.5.4. Marine mammals

Akaroa Harbour sits within the Banks Peninsula Marine Mammal Sanctuary designed to protect Hector's dolphins (*Cephalorhynchus hectori hectori*) (Figure 13). Hector's dolphins, along with New Zealand fur seals (*Arctocephalus forsteri*), are considered to be common within the harbour (Fenwick et al. 2003). When the DOC threatened species list (DOC 2019b) was cross-referenced with the OBIS database records (extracted 8 July 2019), fur seals and Hector's dolphins were the only marine mammal record matches. These two species are likely to be the only two marine mammal species that are resident and present year-round within the harbour. However, other whale, dolphins and seal species are reported to visit occasionally (Fenwick *et al.* 2003) including orca (AIC 2019) bottlenose dolphins, southern right whales and dusky dolphins (Simon Childerhouse, Cawthron, pers. comm.). A full extract of the DOC marine mammal database, as part of any future assessments would likely provide more species to consider.

Hector's dolphins are endemic to New Zealand and are classified as *Threatened – Nationally Vulnerable* (DOC 2019b). Hector's dolphins are found in particularly high, although patchy, densities around Bank Peninsula, with Akaroa Harbour considered a 'core-habitat' of the species (Martinez 2010; MacKenzie & Clement 2014; DOC 2019b).

Hector's dolphins generally occupy shallow nearshore waters (e.g. less than 50 m depth but are reported out to 100 m depth). They are small (< 1.45 m long), with a generally short dive time and typically prefer feeding on demersal[23] fish species (Martinez 2010; Miller *et al.* 2013). Hector's dolphins are attracted to vessels (Martinez *et al.* 2011) and tend to be closer inshore and in higher densities within Akaroa Harbour during summer months, which coincides with the cruise-ship season. It is estimated that population of around 2,000 Hector's dolphins reside in the Banks Peninsula area (MacKenzie & Clement 2014), with a high turnover (estimated to be ~60 at any one time) of dolphins frequenting Akaroa Harbour (Martinez 2010). Akaroa Harbour is also known as an important area for females with calves in the summertime.

The Hector's dolphins visiting Akaroa Harbour are unique in that they exhibit diurnal movement, entering the harbour in the morning and exiting at night (Martinez 2010). If adversely effected by anthropogenic activities, they may have limited potential for replenishment from nearby healthy populations (Martinez 2010).

Hector's populations are commercially important to the region, with a long history of dolphin viewing (and more recently swimming), beginning in Akaroa Harbour in 1985 (Martinez 2010). Akaroa is the only location in New Zealand to have swimming with Hector's dolphins as a permitted commercial activity. Recent records show up to 18 dolphin swimming trips per day and 14 dolphin watching trips, during the summer season (Martinez *et al.* 2011). Martinez et al. (2011) recommended that regulators and industry consider a reduction in the level of exposure of the Akaroa Hector's population to tourism.

[23] near the seabed.

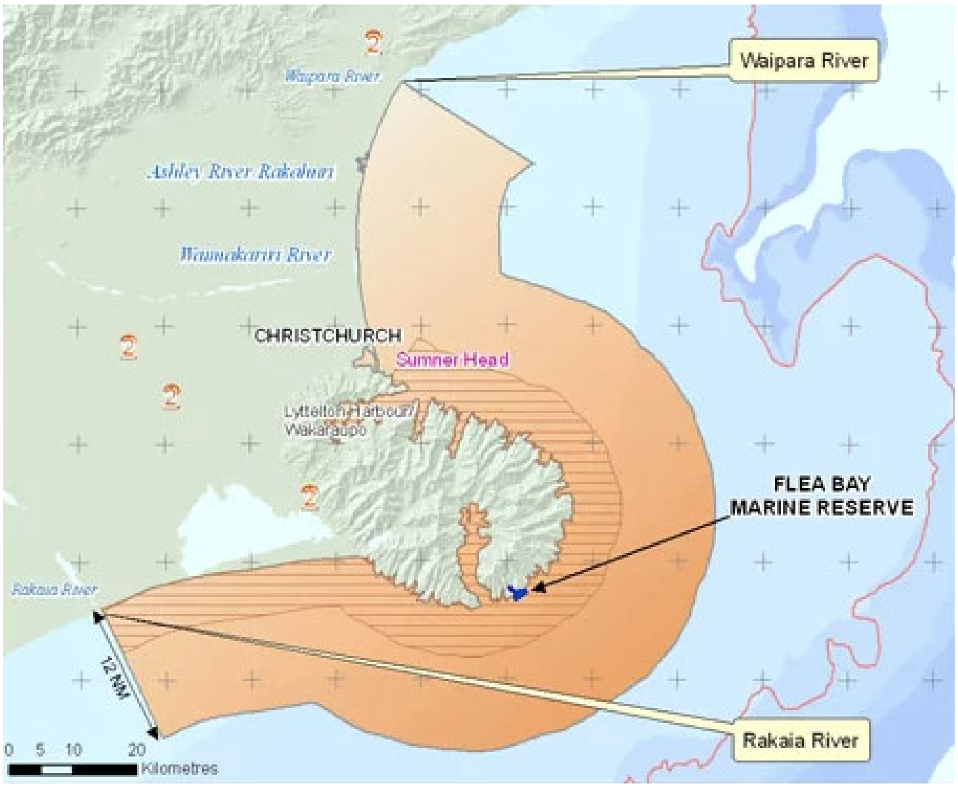

Figure 13. Banks Peninsula marine mammal sanctuary boundaries. Image obtained from www.doc.govt.nz.

4.5.5. Seabirds

Seabirds are the most threatened group of birds globally and New Zealand has the greatest number of resident seabird species in the world. The number of native seabird species surpasses the number of all native land, shore and freshwater birds combined. Here, we define seabirds as those species that spend some part of their lifecycle at sea, feeding in inshore or offshore waters (Whitehead *et al.* 2019).

While there are few official seabird records or investigations undertaken in the region, OBIS data extracts (extracted 8 July 2019) and *A Guide to Marine Birds of Akaroa Harbour* (2019) were cross-referenced with the DOC threatened species list (DOC 2012) which was available in a database XLS format[24]. More recent reiterations of threatened seabird were available in PDF format (DOC 2016), and appeared to be the same if not more conservative than the 2012 results. The results indicated that of the 39 bird species reported in the region, 21 species from Akaroa were classified in the DOC (2012)[25] seabirds list (as listed in Table 4). Two of the seabird matches were

[24] DOC (2012) lists are available in an XLS format making the Akaroa seabird records directly comparable using Excel©

[25] Not all DOC (2012) listed birds are classified as threatened, but they all have a conservation status assigned.

considered 'threatened' taxa, eight are classed as 'at risk,' and three are considered to be threatened overseas ('non-resident natives').

The Akaroa Information Centre provides *A Guide to Marine Birds of Akaroa Harbour* (2019) with the following summary of sea birds:

- White-flippered blue penguins are commonly observed in Akaroa, largely nocturnal on land, coming ashore after sunset and nesting in burrows, caves, rock crevices and, more rarely, under buildings. According to the guide, there is a large cave just north of the paua farm where hundreds of little blue penguins nest.
- Black-backed gulls and white-fronted terns have breeding colonies in the outer harbour and are commonly observed in Akaroa along with variable oyster catchers, little shags, spotted shags, northern royal albatross, fluttering and sooty shearwaters, white capped mollymawks and northern giant petrels.
- Australasian gannets, cape pigeons, pied stilts, white-faced herons, southern giant petrels, black browed albatrosses and yellow-eyed penguins are also reported to be rarely or infrequently seen in the area.

Table 4. Seabird data for Akaroa Harbour, with associated conservation status.

Common name	**Species**	**Category**	**Conservation status**
White-flippered blue penguin	*Eudyptula minor albosignata*	Threatened	Nationally Vulnerable
Yellow-eyed penguin	*Megadyptes antipodes*	Threatened	Nationally Vulnerable
Variable oystercatcher	*Haematopus unicolor*	At Risk	Recovering
Pied stilt	*Himantopus himantopus leucocephalus*	At Risk	Declining
White-fronted tern	*Sterna striata striata*	At Risk	Declining
Fluttering shearwater	*Puffinus gavia*	At Risk	Relict
Northern royal albatross	*Diomedea sanfordi*	At Risk	Naturally Uncommon
Sooty shearwater	*Puffinus griseus*	At Risk	Declining
White-capped mollymawk	*Thalassarche cauta steadi*	At Risk	Declining
Northern giant petrel	*Macronectes halli*	At Risk	Naturally Uncommon
Black-browed mollymawk	*Thalassarche melanophris*	Non-resident Native	Coloniser
Cape pigeon	*Daption capense capense*	Non-resident Native	Migrant
Southern giant petrel	*Macronectes giganteus*	Non-resident Native	Migrant
White-faced heron	*Egretta novaehollandiae*	Not Threatened	Not Threatened
Australasian gannet	*Morus serrator*	Not Threatened	Not Threatened
Paradise shelduck	*Tadorna variegata*	Not Threatened	Not Threatened
Little shag	*Phalacrocorax melanoleucos brevirostris*	Not Threatened	Not Threatened
Spotted shag	*Stictocarbo punctatus punctatus*	Not Threatened	Not Threatened
Southern black-backed gull	*Larus dominicanus dominicanus*	Not Threatened	Not Threatened
Mallard	*Anas platyrhynchos*	—	Introduced and naturalised
Canada goose	*Branta canadensis*	—	Introduced and naturalised

4.6. Protected, valued and significant sites

There are a number of highly valued and protected sites in the vicinity of the cruise ship anchorage locations in Akaroa Harbour:

- **Akaroa Marine Reserve** – Illustrated in Figure 14. Approximately 5 km from the nearest cruise ship anchorage location.
- **Pohatu (Flea Bay) Marine Reserve** – Illustrated in Figure 14, situated over 10 km from the nearest cruise ship anchorage location.
- **Banks Peninsula Salmon Conservation Area** – As described in Section 4.5.3., is situated over 8 km from the nearest cruise ship anchorage location.
- **Protected sites** – Wainui Jetty , T-Wharf, Robinsons Bay Jetty, Takamatua Bay Jetty, Daly's Wharf (RCEP 2005). The closest protected site (Wainui Jetty, St27, Figure 16) is approximately 1 km from the closest cruise ship anchorage location.
- **Natural character and landscapes** – the entire Akaroa coastline is considered as having outstanding natural character in the coastal environment, with some of the coastline listed in the coastal plan (RCEP 2005) as high value (Figure 15). The closest coastline is <1 km from the closest cruise ship anchorage location.
- **Onawe Peninsula** – listed as an outstanding natural feature/landscape in the district plan and as an area of significant natural value in the district plan and the coastal plan (RCEP 2005, Figure 16). The peninsula is over 4 km from the closest cruise ship anchorage location.
- **Akaroa Harbour tidal flats** – listed as an area of significant natural value in the district plan and the coastal plan (RCEP 2005, Figure 16). The closest sand flats to the cruise ship anchor locations are at Onawe Peninsula, French Farm Bay and Takamatua Bay (all > 4 km away).
- **Akaroa Heads** (> 10 km away) – listed as an area of significant natural value in the district plan and the coastal plan (RCEP 2005).

The following areas directly overlap with the anchorage locations:

- **Banks Peninsula Marine Mammal (MM) Reserve** – Figure 13. The entire Akaroa Harbour is part of the MM reserve.
- **Akaroa Taiapure** – the entire Akaroa harbour is significant to iwi/hapu - Illustrated in Figure 14), to: *manage, conserve and enhance fisheries resources for present and future generations to use and enjoy* (MPI 2017).
- Akaroa Harbour is also defined as an area that is to be **maintained in its present natural state** (map 6.5 of the RCEP 2005).
- Considering the harbour's high Māori cultural values, outstanding natural features and sub-areas of significant natural value, as well as protected areas, wetland, estuaries, and coastal lagoons, marine mammals and birds, ecosystems, flora and fauna habitats and scenic sites, it would be reasonable to considered it as having a very high ecological value.

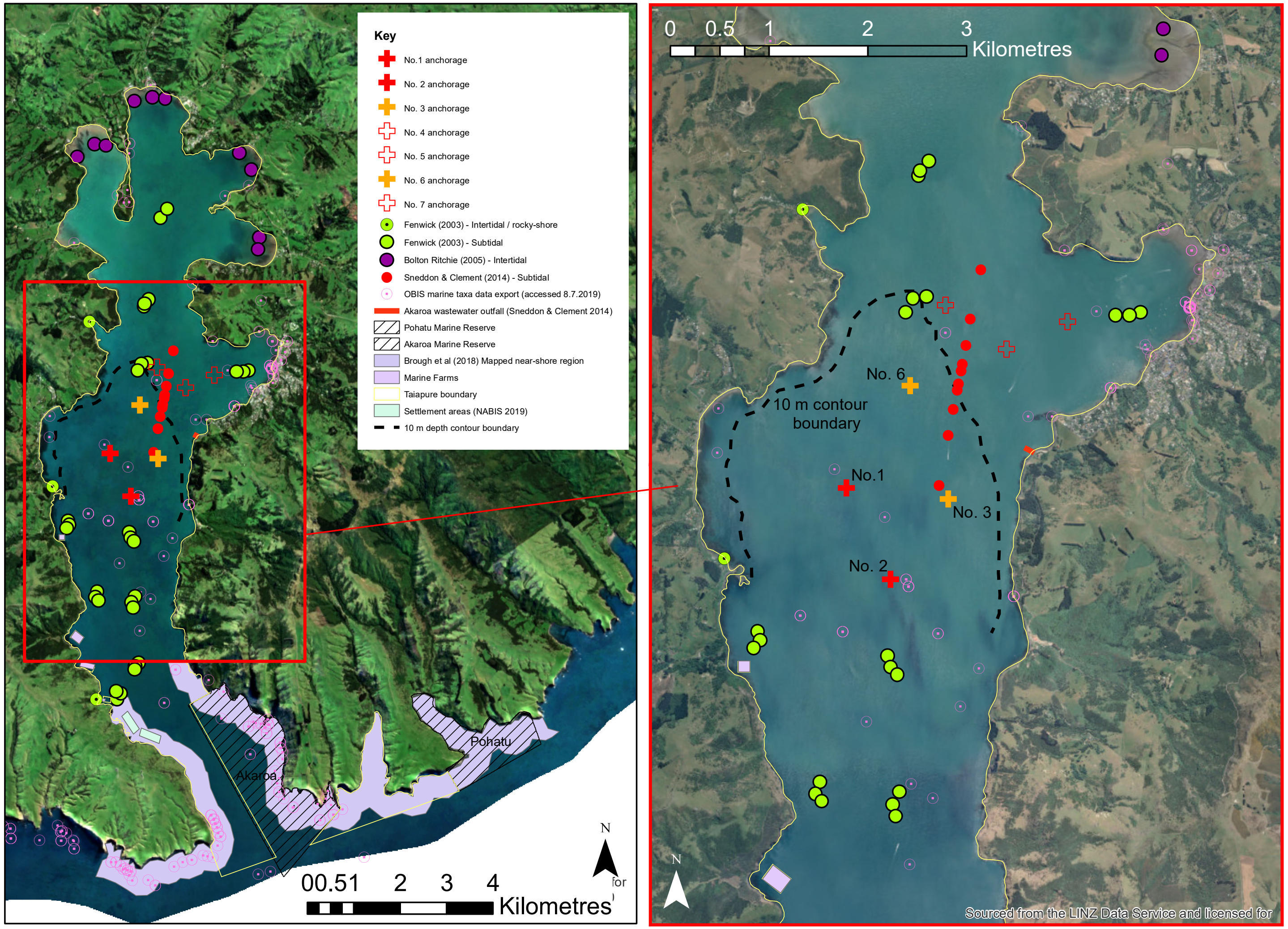

Figure 14. Summary of available biological and physical sampling data locations in Akaroa Harbour with cruise ship anchorages (notably 1, 2, 3 and 6), the 10 m depth contour boundary, aquaculture farms, marine reserves, and the Akaroa Taiapure boundary.

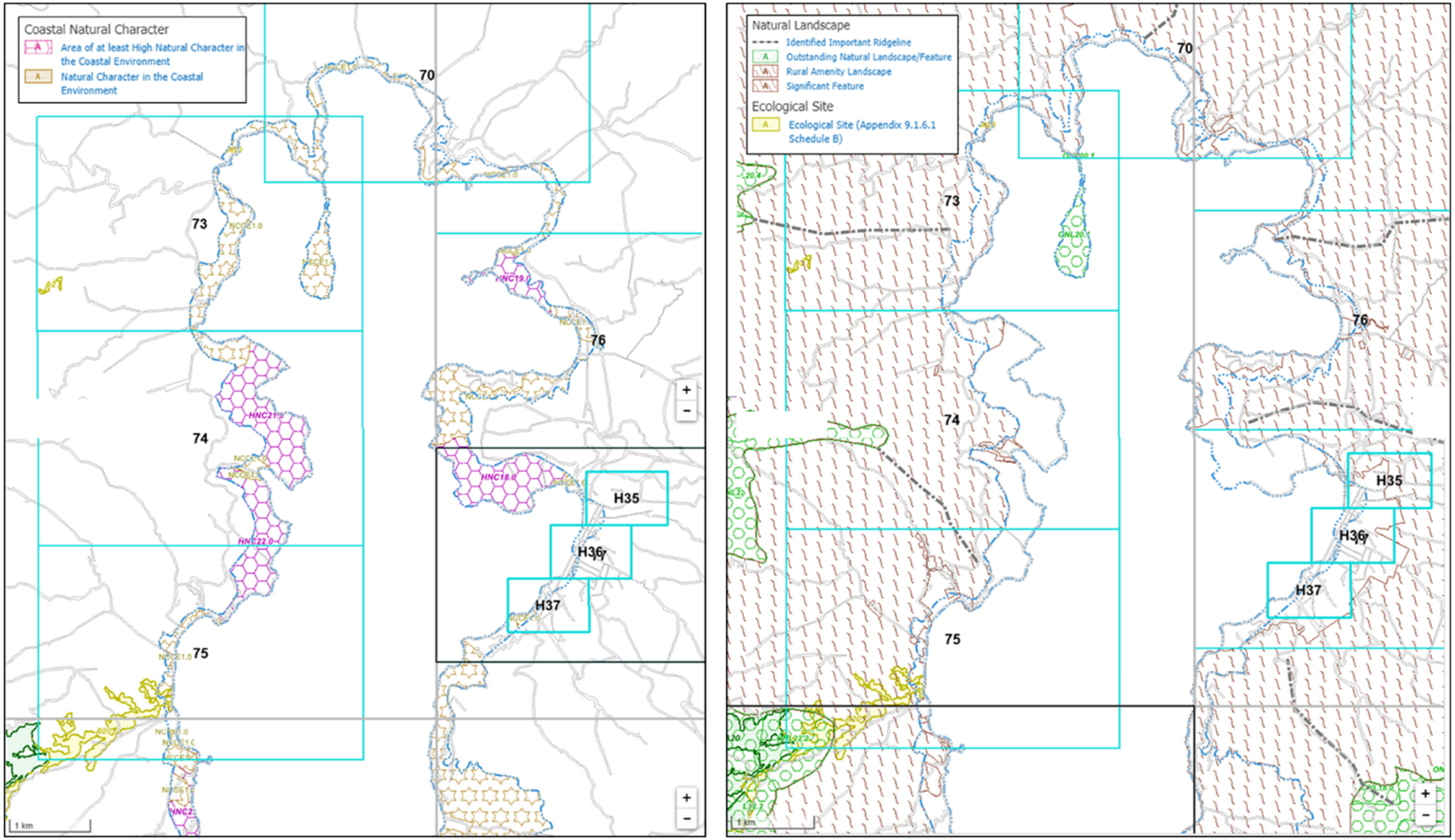

Figure 15. Areas of natural character, natural landscapes and sites of ecological significance in Akaroa Harbour, as identified in the district plan https://districtplan.ccc.govt.nz

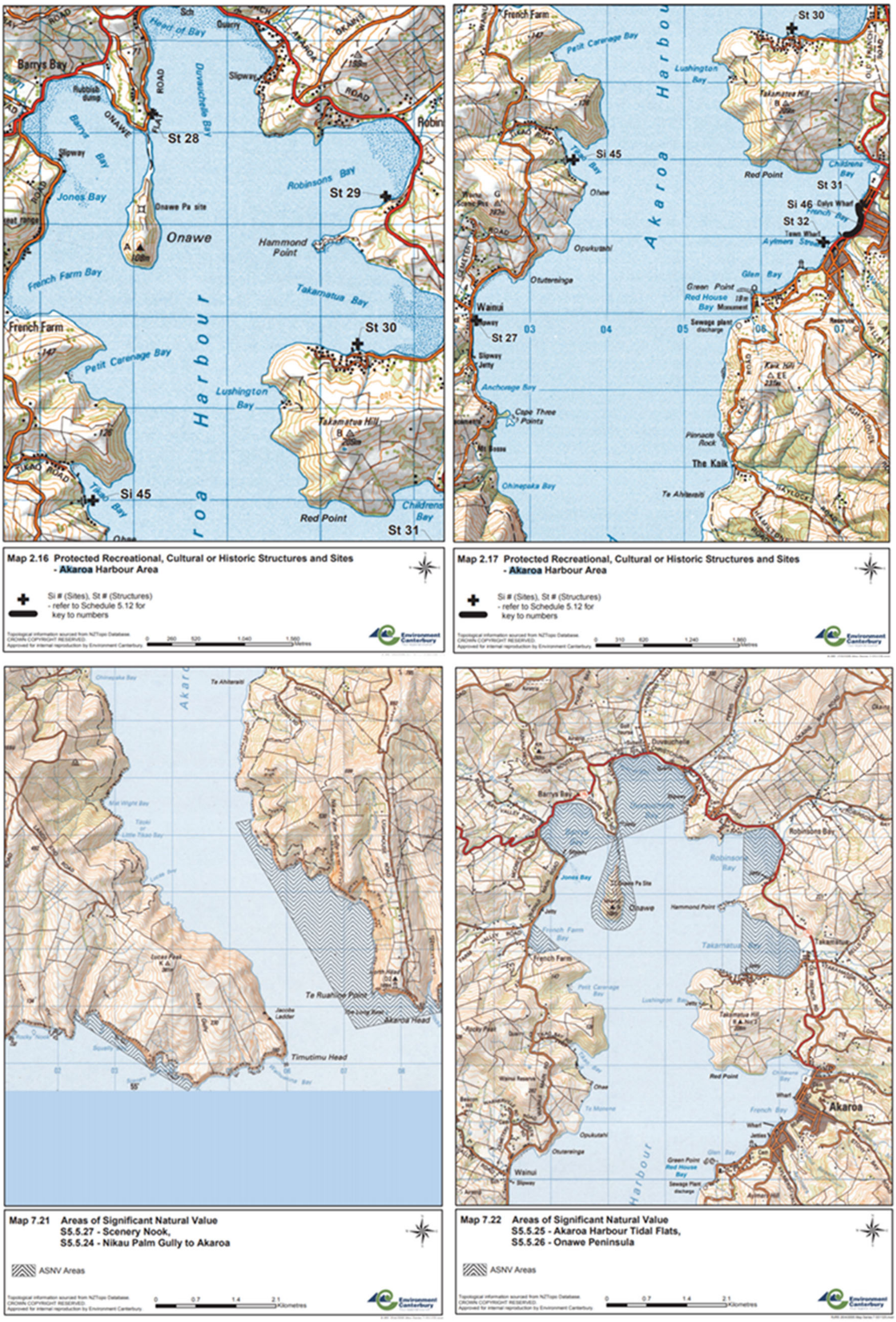

Figure 16. Protected sites and areas of significant natural value identified in the regional coastal environmental plan (extracted from the RCEP 2005).

4.7. Other characteristics

There are a variety of commercial, recreational and cultural activities that often take place while cruise ships are visiting Akaroa Harbour, notably:

- a prosperous tourism industry, e.g. charter fishing trip, dolphin watching/swimming, sight seeing etc.
- considerable recreational activities: boating, diving, snorkelling, kayaking, swimming
- substantial importance to local iwi – Te Rūnanga o Ngāi Tahu
- recreational fishing and gathering of shellfish
- aquaculture (salmon and shellfish farming)
- commercial fishing (as discussed in Section 4.5)
- giant kelp harvesting
- land-based farming
- wastewater and stormwater discharges
- human pressures/settlements (the population in the region is growing)
- historical activities – past deforestation/erosion/reclamation and land use changes resulting in increased sedimentation.

6. POTENTIAL ECOLOGICAL EFFECTS

The potential effects discussed in the following sections relate specifically to those identified in the project scope by ECAN, with any additional potential effects listed in Section 6.5. The effects discussion is not intended to be exhaustive, but to provide a starting point for any future effects assessments.

6.1. Benthic effects

6.1.1. Direct physical disturbance to the seabed

In relation to Akaroa Harbour, there are unlikely to be any direct effects (i.e. physical damage to habitat) to the coastal reef systems in the harbour from ship-propulsion turbulence and/or anchoring damage, simply due to the distance of the reef substrate from the anchoring locations (~750 m to 2 km). Any direct damage (from anchoring or propulsion turbulence) to substrate will be to sub-tidal soft sediment habitats, where the anchoring locations reside. Direct physical disturbance has been identified as one of the principal general threats to New Zealand marine habitats (MacDiarmid *et al.* 2012).

Disturbance by anchor chain scour

In situations where a single anchor is used, the anchor chain can be dragged repeatedly across the seabed through an arc of 360º around the anchor with changes in tide and wind. This repeated, localised scouring can clear a circular anchor chain scar in the surrounding seabed. To what depth the anchor chain can penetrate the sediments is unclear and is likely to vary based on the sediment type and anchor/chain characteristics. For example, a 11.5 ton commercial ship anchor can penetrate soft sediments to almost 1 m depth (Luger & Harkes 2013). It is unclear how deep an anchor chain could penetrate but, given chain and shackle weights can be in the order of 8-9 ton-force (Luger & Harkes 2013), it could be expected to have the same depth potential. Regardless, if we only assume a 1 mm depth of anchor chain penetration, if the cruise ships have an anchor sweep area of 31415 m^2 (Section 3.2.4) this equates to 31 m^3 of disturbed sediment, per anchor site.

Even in homogenous substrate types, chain-scour is considered likely to loosen sediments, making them more vulnerable to erosion by water movement (Morrisey et al. 2018). Gradual alteration of the sediment texture within the swing radius of the anchor chain may alter the physicochemical properties of the sediment, for example the depth and concentration of oxygen and organic content in the sediment profile. These changes may result in changes in the abundance and distribution of benthic communities living in and on the sediment (Morrisey et al. 2018). Furthermore, organisms such as tube-building worms and mat-forming micro-organisms can have a strong stabilising effect on the sediment, so that damage to these communities is likely to result in a further increase in erodibility, with effects persisting a number of months beyond the cessation of chain sweep activities.

Disturbance by propulsion systems

There is little information available of the effects of cruise ship propulsion turbulence in soft sediment benthic environments, with much of the focus in the literature on effects of cruise ship anchoring on reef systems where highly destructive outcomes can occur (PCE 2003). A brief search of available satellite imagery (Section 3.2.2) confirms that regular seabed disturbances are occurring in the vicinity of the cruise ships, with plumes extending almost 1 km from the anchored/ing vessel. Given the shape of the plume (point source flares rather than recurring circular anchor scour, outside of the anchor sweep area, Figure 7) it is likely that propulsion systems are causal agent (Jim Dilley, pers. comm.).

Though currents and wind add variability to the anchor chain sweep area of disturbance[26], it's relatively simple to estimate the potential disturbance area (and seabed disturbance can be considered a 'certain' effect, Table 5). However, it is not possible to accurately estimate the actual area of seabed disturbance from propulsion systems, other than having a localised spatial scale in the vicinity of the cruise-ship anchoring locations (Table 5), with potential for overlap within the anchor chain sweep areas. The level of disturbance is likely to be highly vessel-specific[27] (though it can be considered 'likely' to occur given the satellite observations, Table 5). In either case, there have been no 'before, after, control, impact' style investigations to determine the level (if any) of benthic community or substrate effects from either of the activities.

Typically, high rates of benthic disturbance reduce habitat structure, and result in: low diversity communities, the loss of structure-forming species and large/long-lived sedentary species, and associated reductions in primary production and ecosystem function (Morrisey *et al.* 2018). Many of the structure-forming and functionally important species on the seafloor are sensitive to physical disturbance. Biological traits (e.g., morphology, life history, dispersal characteristics) can determine both the sensitivity of different species to the disturbance impact, and their ability to recolonise disturbed habitats (Lundquist *et al.* 2013). No threatened marine invertebrates (DOC 2013) were present in the OBIS data and according to Sneddon and Clement (2014) no taxa or assemblages of special conservation or scientific interest were found in the vicinity of the anchor locations (though, lack of data does not preclude the possibility of them being present). Both Sneddon and Clement (2014) and Fenwick (2004)

[26] Currents will carry suspended sediment from the scour location and the vessel will swing depending on the current/wind and then stop until current or wind changes.

[27] An assessment of potential cruise ship soft-sediment impacts from turbulence was undertaken in Tasmania's south-west (Ellis et al. 2005) which showed that a predictive 'turbulence pocket' model that considered vessel specific characteristics (such as propeller size) was far more exact and helpful than size/speed restrictions alone (observations were used to validate the predictions). The modelling is now used by the Parks and Wildlife Service as a means to assess, on a case by case basis, whether a specific cruise ship may enter the Bathurst Channel.

considered the benthos typical of shallow protected coastal environments in the region, which suggests that recolonisation following cessation of a physical disturbance could be reasonably fast from the surrounding undisturbed seabed. However, estimating the relative impact of a particular physical disturbance on seabed habitats requires a prior understanding of co-occurring natural and anthropogenic processes of disturbance. While there is some understanding relating to hydro dynamics and water quality, how these dynamics influence benthic communities is not well understood in the Akaroa Harbour environment.

Assuming all physical disturbance stopped at the anchorage sites during the cruise ship off-season (May–September), some seabed recovery (return to background conditions) might be expected. However, even without repeat disturbance from multiple vessels, once sediments have been destabilised by the movement of the ground chain or turbulence from propulsion systems (or both), they are likely to continue to erode if water currents are sufficiently strong. Therefore, 'complete' benthic recovery at the anchorage sites is unlikely to be achievable. For example, in a study by Herbert et al. (2009) the recovery of benthic assemblages after removal of intertidal moorings in southern England was incomplete after 15 months, and in an experimental study by Dernie et al. (2003) full recovery of soft sediment assemblages from physical disturbance (of different intensities) took between approximately 2 and 7 months. Consequently, the direct ecological effects caused by increased sediment disturbance from cruise ships can be expected to be moderately persistent (in the order of months to year[s]) following cessation of activities.

Overall, direct adverse effects to the seabed from scour and propulsion-related physical disturbance is considered to be a less than minor to minor effect. It could have moderate level of persistence, low/minor level of magnitude, and potentially impacting at the localised scale. The overall risk to the seabed is considered to be high to medium[28], due to the high habitat value (supporting national priority #4; MfE 2007), the repeat nature of the disturbances, and the high likelihood of the effect occurring (anchor scour: 'certain' and propulsion systems: 'likely,' Table 5). However, due to a lack of benthic effects and recovery assessments, there is a 'low' level of confidence in the risk assessment.

6.1.2. Modification of predator-prey interactions and loss of refugia

In addition to direct mortality of benthic organisms caused by the movement of the ground chain and propulsion system turbulence, disturbance to the seabed around moorings may attract predatory and scavenging fish and invertebrates. Larger, deeper-burrowing organisms, normally protected from their predators, may become exposed to predation. Fish, epibenthic predators, seabirds and marine mammals may,

[28] the precautionary principle is expressed in the Rio Declaration (see references in EIANZ 2018), which stipulates that, 'where there are threats of serious or irreversible damage, lack of full scientific evidence shall not be used as reason for postponing cost-effective measures to prevent environmental degradation'.

thus, be affected indirectly by a reduction in the diversity and abundance of their prey or physical disruption to their feeding grounds around moorings, but the total area involved will be relatively small. Effects on seabirds and marine mammals are discussed in more detail in Sections 6.3 and 6.4.

Modification of predator-prey interactions and loss of refugia arising from physical disturbance from anchor chain and propulsion turbulence is considered to be a less than minor to minor effect. It could have moderate level of persistence, low/minor level of magnitude, potentially impacting in the 'immediate vicinity'. The overall risk to the seabed is considered to be low, the lower likelihood of the effect occurring ('possible,' Table 5) and the smaller scale of effects (immediate vicinity). However, due to a lack of benthic effects and recovery assessments, there is a 'low' level of confidence in the risk assessment.

6.2. Water column effects from resuspended sediments

Sediment resuspension can occur from anchor deployment, anchor chain sweep, propeller and thruster wash and turbulence (Murray 2005; Morrisey *et al.* 2018). Sediment resuspension can also occur indirectly from surge waves (moving laterally away from a large displacement vessel) that resuspend sediment closer to the bottom. In all cases, sediment disturbance results in increased levels of suspended solids and organic matter (SS) into the water column. As discussed in the previous section, once sediments have been destabilised by the movement of the ground chain or turbulence from propulsion systems, they are likely to continue to erode if water currents are sufficiently strong. Consequently, the indirect resuspension effects from increased sediment disturbance from cruise ships can be expected to be moderately persistent.

Based on satellite imagery observations (Figure 6), the spatial scale of resuspended sediments resulting from cruise ship activities varies greatly. Observations suggest that the plume ranges from virtually undetectable in the immediate vicinity, to hundreds of metres in length and width, extending into the wider harbour (Figure 7, in the order of 1600 m^2).

Suspended sediments can have a range of impacts on the marine environment, including benthic habitat smothering, release of contaminants, increased nutrient availability, reductions in dissolved oxygen and water clarity, increased turbidity, and effects on fish health. These impacts are discussed in the following sections.

6.2.1. Sediment deposition and smothering

As well as reducing visual clarity and light penetration with depth through the water column, high suspended sediment concentrations are also associated with coastal sedimentation, which results in smothering of biota, reduced feeding rates, poor biotic health, and reduced recruitment of sessile animals and plants, and attachment of invertebrates to rocky substrate (Dudley *et al.* 2019). Given this, sediment deposition can greatly affect the composition and the ecology of temperate algal reef communities (e.g. kelp), and potentially lead to the dominance of algal turfs in many intertidal and subtidal rocky habitats (Morrisey *et al.* 2018).

Sediment accumulation (estimated by reductions in water depth over time, Section 4.1) in Akaroa Harbour is suspected to occur in the inner Takamatua Bay (on the eastern side of the harbour). However, the time-series is sparse, with differences inferred between just two surveys (1952 and 2008 surveys, Hart et al. 2009). No evidence of anthropogenic effects (i.e. sedimentation) were noted in the Fenwick (2004) investigation. Anecdotal observations from a local resident report increases sedimentation over time and changes of reef algal communities on other nearby shorelines (Te Monene beach, 2–3 km from the anchorage locations, Dale Flewellen, Akaroa resident, pers. comm.). No scientific investigations have been made to validate the observations.

Based on the sediment plumes observed from satellite imagery (Figure 6) the spatial scale of effects is likely to vary greatly. Therefore, the range and extent of sedimentation might be considered to do the same. The effects of repeat sediment resuspension and the resulting sediment deposition could be expected to extend over moderate to high distances, depending on the hydrodynamic (and other dispersive) conditions at the time. Recovery from such processes could be equally long-lasting.

The risk of sediment deposition and smothering is considered a significant effect, which could have a 'moderate to long-term' level of persistence (months to years), impacting at a harbour-wide scale. The overall risk of sediment deposition and smothering occurring is considered medium, due to the likelihood of occurrence ('likely' based on satellite imagery) and the consequence ('moderate') to high value species and habitats (potential changes to composition and ecology of the nationally at risk – declining giant kelp). However, due to a lack of activity-specific observations and investigations, there is a 'low' level of confidence in the risk assessment.

6.2.2. Release of contaminants and nutrients

Seabed disturbance can also result in contaminant re-mobilisation/resuspension into the surrounding environment and transformation of contaminants into more bioavailable or toxic chemical forms (Morrisey *et al.* 2018). Based on the metal composition of the subtidal sediments described in Section 4.3, it is reasonable to assume that there would be little in the way of anthropogenically-derived contaminants in the sediments at the Akaroa anchorage locations. However, it is possible that nutrients and organic matter from the sediments (also reported in Section 4.3) are released into the water column more frequently. Higher levels of nutrients and organic matter in the water column can enhance the growth of water column organisms (bacteria and protozoa), increase pelagic and benthic photosynthesis and alter carbon and nitrogen cycling. They can also increase pelagic and benthic respiration rates and dissolved oxygen demands which, in turn, influence turbidity and water clarity (Morrisey *et al.* 2018). It is unclear how frequent such planktonic/algal blooms occur in Akaroa Harbour, but at least one has been recorded recently. A harbour-wide bloom of *Alexandrium catenella* resulted in a health warning[29] advising the public not to collect or consume shellfish harvested from Akaroa Harbour, due to the risk of paralytic shellfish poisoning (warning was lifted July 2017). Alteration of the nutrient balance in the harbour could also have detrimental effects on seagrass beds within the inner harbour (Bolton-Ritchie 2005b).

Similar to the sedimentation-related effects, the effects of repeated contaminant and nutrient release could be expected to extend over moderate to high distances, depending on the hydrodynamic conditions at the time. Recovery from such processes could be equally long-lasting.

The risk of contaminants and nutrient release is considered a <u>significant</u> potential effect, which could have a 'moderate to long-term' level of persistence (months to years), impacting at a harbour-wide scale. However, the overall risk of contaminants and nutrient release occurring is considered <u>low</u>, due to the relatively low likelihood of occurrence ('possible' based on satellite imagery) and the 'moderate' consequence to high value species and habitats (potential changes to composition and ecology of the nationally at risk – declining giant kelp, and the inner harbour seagrass beds). Due to a lack of activity-specific observations and investigations, there is a 'low' level of confidence in the risk assessment.

6.2.3. Reduced water clarity, increased turbidity and light attenuation

Reduced water clarity and increased turbidity caused by suspended particles reduces the amount of available light in the water column, which in turn, reduces optical range and light energy for photosynthesis. This affects primary production, plant and animal distributions and ecological health, aesthetic quality and recreational values (Dudley *et al.* 2019). When water clarity and turbidity influences combine with other sediment disturbance-derived effects (reduced availability of oxygen, nutrients, lack of firm substratum for settlement and recruitment and increase in physical disturbance) it would be reasonable to assume an increase on the overall stress on localised algal and invertebrate communities (Morrisey *et al.* 2018).

Turbidity and suspended sediment levels in the Akaroa Harbour region are considered relatively low compared to other Canterbury coastal areas (Figure 11), and levels are typically within the thresholds for low-risk of adverse ecological effects in marine water (0.5–10 NTU, southeast Australia; Table 3.3.3, ANZECC 2018). Due to the site-specific relationship between turbidity and light attenuation (Green & Cornelisen 2016;

[29] https://www.ecan.govt.nz/your-region/your-environment/water/health-warnings/marine-biotoxin-warnings/

Dudley *et al.* 2019), it should be considered along with temporal and or seasonal variables. Dudley et al. (2019) stated that the turbidity levels in Akaroa Harbour were relatively stable between summer and winter. However, it may be that the available data were not collected at temporal and spatial scale capable of detecting small but repeat resuspension events (i.e. monthly sampling for 1 year every 5 years, Dudley et al. 2019). The duration and frequency of these resuspension events (from chain sweep and/or propulsion systems, or other natural mechanisms) affecting light availability are likely to be more influential than individual events alone. Dudley et al. (2019), stated that *total light availability matters for perennial benthic primary producers the turbidity level at any given time is less important than the total light availability over longer time scales, i.e. weeks to months.* They used the example of perennial kelps, that might be expected to be less prone to adverse impacts in the winter (a time of naturally high turbidity and low growth and reproduction), than during summer, when unusually high turbidity would be more likely to compromise growth and reproduction. Given that cruise ship disturbance occurs specifically during the summer period, and largely during the daytime, repeat resuspension from cruise-ship anchoring and propulsion activities could impact the surrounding plant communities, including the at-risk–declining perennial kelp, *M. pyrifera*.

Increased suspended sediment load and turbidity can be persistent because once sediments have been destabilised by the movement of the ground chain, they are likely to continue to erode if water currents are sufficiently strong.

Site-specific water quality data relating to specific cruise ships anchoring and propulsion effects would help determine the volumes of sediment being disturbed, the SS concentrations being resuspended, and the total SS loading (over time) in the receiving environment.

Overall, the risk of reduced water clarity, increased turbidity and light attenuation is considered a significant potential effect, which could have a ‘moderate to long-term’ level of persistence (months to years), potentially impacting the immediate vicinity to a harbour-wide scale. The overall risk of reduced water clarity, increased turbidity and light attenuation occurring is considered medium, due to the likelihood of occurrence (‘likely’ based on satellite imagery) and the ‘moderate’ consequence to high value species and habitats (potential changes to composition and ecology of the nationally at risk – declining giant kelp, and the inner harbour seagrass beds). Due to a lack of activity-specific observations and investigations, there is a ‘low’ level of confidence in the risk assessment.

6.3. Marine mammal effects

The most important interactions between marine mammals and coastal development usually result from anthropogenic activities within important marine mammal habitats (i.e. feeding or nursing grounds). Specifically, these potential effects to marine mammals result from increases in vessel activity, underwater noise, and seabed disturbance within the general region.

The key marine mammal taxa impacted by cruise ship activities in Akaroa Harbour are likely to be Hector's dolphins and fur seals[30]. As the entire harbour is within the Banks Peninsula Marine Mammal Sanctuary, which is designed to protect Hector's dolphins from harmful human impacts, understanding the effects from cruise ship activities and how they interact with all other pressures on marine mammals in the region is of great importance (Martinez 2010).

Effects on marine mammals would typically be evaluated as part of an expert, site-specific marine mammal assessment. Therefore, the risks of these potential effects on marine mammals are discussed briefly in the following preliminary assessment and are summarised in Table 5.

6.3.1. Noise

Increases in underwater noise can affect marine mammals because they rely heavily on underwater sounds for communication, orientation, predator avoidance and foraging (Slabbekoorn *et al.* 2018). Additional underwater noise may adversely affect marine mammals through changes in behaviour, masking of important communication or prey detection, temporary auditory shifts or permanent injury.

Additional noise is likely to be generated by the cruise ship itself moving through the harbour (e.g. propeller and engine noise) and also when anchored (e.g. generators). In addition, smaller tender vessels moving passengers between the ship and Akaroa wharf will also add additional noise to the environment.

Effects relating to increased underwater noise from cruise ships on marine mammals, and specifically relating to Hector's dolphin, is considered a minor to more than minor effect. If such an effect occurs, the most likely outcome would be displacement of dolphins from an area around the cruise ship. This effect could have a 'temporary to moderate' level of persistence as it is likely to be limited to the time that a cruise ship is present in the harbour, but depending on the cruise ship frequency, may have longer lasting effects to behaviour (reduced visiting/displacement) or as a result of permanent injury. This effect could potentially impact at a harbour-wide scale due to the propagation of noise throughout the Harbour. The overall risk of increased underwater noise on Hector's dolphins is considered low, due to the imposed noise restrictions. However, it is noted that the airborne noise restrictions are unlikely to reduce underwater noise, and the below water requirements seem largely voluntary

[30] Other marine mammals in the area have not been addressed separately in this preliminary assessment, though general effects are likely to be similar. Any future effects assessments should include consideration of other potentially affected marine mammal taxa (e.g. by obtaining marine mammal sighting data from the Department of Conservation).

and would not be easily regulated. Overall, due to a lack of activity-specific observations and data, there is a 'low' level of confidence in this assessment. Further investigation into how much extra noise is added by cruise ships and the resulting behaviour/reactions of the dolphins would increase the confidence levels of this assessment.

6.3.2. Vessel strike

Marine mammal collisions with a cruise ship hull or propeller could be fatal or result in significant physical injuries. Vessel strike with Hector's dolphins is possible, particularly due to their high densities in the area. They are also attracted to vessels and while they tend to avoid fast moving vessels, a slow-moving cruise ship with a bow-wake would be attractive.

There are records of ship strike killing two Hector dolphin calves in Akaroa Harbour, though it is not clear what vessel(s) was/were responsible (Martinez 2010). As the cruise ships are often stationary and move at relatively slow speeds, potential for ship strike will only be during entry and exit of the Harbour. A higher risk is likely from the smaller tender vessels, associated with tourist movement to and from the cruise ships, and which generally move at higher speeds.

The risk of vessel strike to marine mammals, specifically Hector's dolphin, is considered a significant to unacceptable effect, which could have 'moderate to long-term' level of persistence, impacting initially in the immediate vicinity of the vessels while they are manoeuvring, but potentially resulting in harbour-wide and regional (Bank Peninsula) scale changes (depending on the interaction between the resident Banks Peninsula populations). The overall risk of vessel strike occurring to Hector's dolphins is considered medium to low, due to the low speed requirements (Section 3.2.8) and being at anchor for most of their visit, but this is potentially higher for the tender vessels (similar to other faster moving vessels in the harbour). However, due to a lack of activity-specific observations, the coincidence of dusk-time cruise ship and dolphin movements (exiting the harbour), and evidence of vessel strike in the area, there is a 'low' level of confidence in the risk assessment.

6.3.3. Increasing tourism exposure causing behavioural changes

Increasing cruise ship presence, and associated increases in tourism activity, adds to the already high levels of tourism exposure in the region (discussed Section 4.5.4). This increase is counter to key recommendations from Martinez et al. (2011) for regulators and industry to consider a reduction in the level of exposure of the Akaroa Hector's dolphin population to tourism.

Behavioural effects (e.g. reduction in feeding or resting behaviour) might be expected to persist only while the vessels are present, though the behaviour of Hector's dolphins (e.g. frequency of diving) is reported to change over the course of the Akaroa tourist season, even without the consideration of cruise ship activities (Martinez 2010). This could suggest the dolphins are sensitive to increasing tourism pressure over time, as well as changing seasonally (i.e. with higher populations in January, coinciding with cruise ship prevalence). The area of effect increases based on the number of cruise ships and tender vessels being used per day, and the frequency of their use, and the risks associated with those vessels.

Changes in behaviour of marine mammals, specifically the threatened Hector's dolphin, is considered a significant to unacceptable effect. Given that Hector's dolphins already exhibit behavioural changes in relation to tourism activities in the region further pressures could potentially persist from moderate to long-term, impacting at a harbour-wide or regional (Banks Peninsula) scale (depending on the interaction between the resident Banks Peninsula populations). The overall risk of behavioural changes occurring to Hector's dolphins, is considered medium to low, with a 'low' level of confidence in the available data.

6.3.4. Adverse effects on prey species

Resuspension and disturbance of sediment (and contaminants) could have indirect effects on marine mammals from feeding up the food chain[31], both through exposure to contaminants and from direct physical displacement of prey species. As noted in Section 4.5.3, there is some concern over Akaroa fish populations changing over time, therefore further investigation into the additional impacts of resuspended sediments and increased nutrients should be considered.

Adverse effects on the prey species of marine mammal from cruise ships, particularly Hector's dolphins, is considered a significant to unacceptable effect (Table 5). It could have a moderate to long-term level of persistence (months-years), potentially impacting at a harbour-wide scale. The overall risk to prey species eaten by Hector's dolphins is considered low (Table 5), due to the localised nature of the effects, and the mobile nature of the prey species. However, due to a lack of fisheries assessments, the general concern over Akaroa fisheries species and the lack of activity-specific observations, there is a 'low' level of confidence in the risk assessment.

6.3.5. Decreased foraging efficiency due to increased turbidity

It is unlikely that foraging success will be reduced by increased turbidity in the water column. Hector's dolphins are known to prefer turbid coastal waters and use echolocation to detect and catch prey, which is not influenced by turbidity. Pinnipeds (e.g. fur seals) are considered to be primarily visual predators but there is no evidence of a decrease in foraging efficiency for pinnipeds from increased turbidity.

[31] Hector's dolphins and seals typically have high burdens of contaminants due to their tendency for residing in coastal habitat and feeding at high trophic levels (Martinez 2010) and are therefore particularly vulnerable to bioaccumulation. Resuspension of sediment contaminants (if any) are likely to have indirect effects on MM from feeding up the food chain.

A decrease in foraging efficiency from effects of cruise ships on marine mammals, notably the threatened Hector's dolphin, is considered a minor to more than minor (Table 5) effect, which could have a 'temporary to moderate' level of persistence potentially impacting at a 'harbour-wide' scale. The overall risk of reduced foraging efficiency to Hector's dolphins (and fur seals) is considered very low (Table 5), due to their proven abilities to forage in turbid waters. However, due to a lack in activity-specific observations, there is a 'low' level of confidence in the risk assessment.

6.4. Sea bird effects

The most important interactions between seabirds and anthropogenic activities usually relate to important habitats of the species (i.e. feeding, breeding or brooding grounds). Specifically, these potential impacts include: an increase in vessel activity, which directly results in the production of unnatural light, and indirectly (through sediment disturbance and resuspension) has potential for introducing contaminants and reducing foraging success.

The key seabird taxa of concern include those threatened and at-risk species noted as common in the area, as they are most likely to interact with cruise vessels. Also of concern are other nationally threatened species (listed below), which may be less common, but for which any interaction may have an effect. It is noted that seabird records for the region are sparse and the lists provided below is not exhaustive.

Often seen threatened or at-risk seabirds:

- White-flippered blue penguin *Eudyptula minor albosignata*
- Variable oystercatcher *Haematopus unicolor*
- Northern royal albatross *Diomedea sanfordi*
- Fluttering shearwater *Puffinus gavia*
- Sooty shearwater *Puffinus griseus*
- White-capped mollymawk *Thalassarche cauta steadi*
- Northern giant petrel *Macronectes halli*

Rarely seen threatened or at-risk seabirds:

- Pied stilt *Himantopus himantopus leucocephalus*
- White-fronted tern *Sterna striata striata*
- Black-browed mollymawk *Thalassarche melanophris*
- Cape pigeon *Daption capense capense*
- Southern giant petrel *Macronectes giganteus*
- Yellow-eyed penguin *Megadyptes antipodes*

Effects on seabirds are likely to be restricted to within the harbour, where the seabed disturbance and increase in artificial light from cruise ships is likely to occur. The effects might be expected to persist only while the vessels are present, though it is possible that seabirds, like dolphins, could be sensitive to increasing tourism pressure and effects may remain even after vessels have departed.

Disturbing and/or removing seabed sediment in itself is not expected to directly affect any seabirds known to frequent Akaroa Harbour waters, however there is potential for indirect flow-on effects relating to the health of prey resources of seabirds. This could include bioaccumulation of contaminants that may be associated with resuspended sediments and loss or disturbance of prey species due to habitat loss, benthic disturbance or turbidity plumes. There is also the risk of adverse effects relating to artificial light and vessel strike. This would typically be evaluated as part of an expert, site-specific seabird assessment and only a preliminary effects assessment has been undertaken in this report with the risk summarised in Table 5.

6.4.1. Artificial light and vessel strike

Illuminated cruise ships can create confusion causing birds to crash-land, and rendering them either injured, or vulnerable to predation or further injury and death (Code 2019; Whitehead *et al.* 2019). These effects typically occur during new moon phases, or when skies are obscured by cloud. Evidence of this occurring in New Zealand is reported in Whitehead et al. (2019) where 67 Buller’s and flesh-footed shearwaters collided with an illuminated cruise ship destined for the Port of Auckland. Whitehead et al. (2019) concluded that many of the resultant bird deaths could have been avoided if ship crews were educated on how to manage seabirds that come aboard.

Typically, cruise ships in Akaroa are only in port for a single day, during daylight hours, although it is noted that this does not preclude the cruise ships from over-night anchorage or arrivals/departures, should they request it. During this time, Operational Requirements (2018) specify that light-emitting cruise ships follow the guidance provided by the Department of Conservation, to run display screens at their minimum requirements and only use essential deck lighting (day or night). Cruise ship crew education on how to handle and release seabirds and any additional pressures from tender vessels should also be considered in any subsequent seabird assessments.

Adverse effects from cruise ship lighting on seabirds, and notably threatened taxa, is considered a significant to unacceptable effect, which could have a ‘temporary to long-term’ level of persistence, potentially impacting up to ‘harbour-wide’ (local effects) and ‘regional’ scales (through population-level changes). The overall risk to seabirds is considered low (for daytime only visits) to medium (for night-time visits), given adverse effects have been noted from cruise ships elsewhere in New Zealand, and vessels are not precluded from over-night stays. However, due to a lack in activity-specific observations, there is a 'low' level of confidence in the risk assessment.

6.4.2. Adverse effects on prey species

Resuspension and disturbance of sediment (and contaminants) could also have indirect effects on seabirds feeding up the food chain, both through exposure to contaminants and from direct physical displacement of foraging biota for prey species. While there is little to suggest that there are any contaminants of concern in the harbour sediments (Section 4.3), there is already some concern over Akaroa fish populations changing over time (Section 4.5.3) and evidence of planktonic blooms occurring in the harbour (Section 6.2.2). Therefore, further investigation into the additional impacts of resuspended sediments and increased nutrients should be considered.

Adverse effects to threatened seabird prey species is considered a significant to unacceptable effect, which could have 'moderate to long-term' level of persistence, at 'harbour-wide' spatial scales. However, the overall risk from cruise ships to seabird prey species is considered low, due to the localised nature of the effects and the mobile nature of the prey species. However, there is some concern for seabird prey species in general, given this, and due to a lack in activity-specific observations, there is a 'low' level of confidence in the risk assessment.

6.4.3. Increased turbidity decreasing foraging efficiency

The turbid waters associated with cruise ship seabed disturbances, and ongoing sediment resuspension, could dramatically reduce foraging success of visual nearshore and continental shelf foragers e.g. fluttering shearwaters, little penguins, terns, especially New Zealand fairy terns, gulls, and various shag species.

Adverse effects on seabird foraging efficiency, notably to threatened taxa, is considered a minor to significant effect, which could have 'temporary to moderate' levels of persistence, at 'harbour-wide' spatial scales. Overall, there is considered to be a low to medium level of risk of effects to seabird foraging efficiency occurring. This is due to the potential for ongoing sediment resuspension, the likelihood of effects occurring ('possible') and the consequence of effects ('moderate' to 'major') to valued habitat and taxa. However, there is some uncertainty about the frequency and extent of high turbidity events (Section 6.2.3), and an overall lack in activity-specific observations, therefore there is a 'low' level of confidence in the risk assessment.

6.4.4. Increasing tourism exposure causing behavioural changes

Increasing cruise ship presence, and associated increases in tourism activity, adds to the already high levels of tourism exposure in the region (discussed Section 4.5.4). It is not clear whether this effect could have an influence on seabird behaviour, and this should be considered in any subsequent assessments.

Behavioural changes on seabirds caused by cruise ship activities, notably to those taxa listed as threatened, is considered as a significant to unacceptable effect, which could potentially persist from 'moderate to long-term', impacting at a 'harbour-wide' scale. The overall risk from cruise ships to seabird behaviour efficiency is considered low to medium, due to the likelihood of effects occurring ('possible') and the consequence of effects ('moderate' to 'major') to valued habitat and taxa. However, there is a 'low' level of confidence in the available data.

Table 5. Summary of ecological risks associated with cruise ship activities in Akaroa Harbour. Potential effects listed here are not exhaustive and relate to those specifically identified in the project scope.

				Potential effects on ecological values (EIANZ 2018)					Risk of adverse effects occurring (Burgman 2005		
	Potential effects	Spatial scale	Persistence	Magnitude (M)	Ecological value (E)		Level of effects		Likelihood (L)	Consequence (C)	Risk level (L x C)
					Species value	Habitat value	(M x E)	Effect range			
Seabed	Anchor chain sweep seabed disturbance - direct effects to the seabed	Localised	Months	Low/minor	**Low:** Not threatened nationally, common locally	**High:** Supports national priority # 4 (MfE 2007) Customary fishing Taiapure, Marine mammal sanctuary Multiple areas of significant natural value	Very low - Low	Less than minor to minor	Certain (1)	Moderate (4)	High (4)
	Propulsion turbulence seabed disturbance - direct effects to the seabed	Localised	Months	Low/minor			Very low - Low	Less than minor to minor	Likely (2)	Moderate (4)	Medium (8)
	Modification of predator-prey interactions and loss of refugia	Immediate vicinity	Months	Low/minor			Very low - Low	Less than minor to minor	Possible (3)	Moderate (4)	Low (12)
Water column	Sediment deposition and smothering from (continued) sediment resuspension	Medium: Harbour-wide	Months - years	Moderate	**High:** 'Nationally at risk – declining" Giant kelp		High	Significant	Likely (2)	Moderate (4)	Medium (8)
	Release of nutrients from sediment resuspension (plankton blooms)	Medium: Harbour-wide	Months - years	Moderate			High	Significant	Possible (3)	Moderate (4)	Low (12)
	Reduced water clarity, increased turbidity and light attenuation from sediment resuspension	Immediate vicinity to medium (harbour wide)	Months - years	Moderate			High	Significant	Likely (2)	Moderate (4)	Medium (8)
Marine mammals	Additional noise - changes in behaviour, masking important communication/ prey detection, temporary auditory shifts or permanent injury	Medium: Harbour-wide	Hours - months	Low/minor	**Very high:** 'Threatened – Nationally Vulnerable' Hector's dolphins		Low - Moderate	Minor to more than minor	Likely (2)	Minor (5)	Low (10)
	Vessel strike causing injury, death and/or behavioural changes	Immediate vicinity (while manoeuvring) to a regional scale	Months - years	Moderate to high			High - Very high	Significant to unacceptable	Possible (3)	Moderate (4) – Major (3)	Medium (9) - Low (12)
	Increasing tourism exposure causing behavioural changes	Medium: Harbour-wide	Months - years	Moderate to high			High - Very high	Significant to unacceptable	Possible (3)	Moderate (4) – Major (3)	Medium (9)-Low (12)
	Increased suspended nutrients, contaminants and plankton blooms affecting prey species	Medium: Harbour-wide	Months - years	Moderate to high			High - Very high	Significant to unacceptable	Unlikely (4)	Moderate (4) – Major (3)	Low risk (12-16)
	Increased turbidity decreasing foraging efficiency	Medium: Harbour-wide	Hours - months	Low/minor			Low - Moderate	Minor to more than minor	Remote (5)	Moderate (4)	Very low (20)
Seabirds	Artificial light causing vessel strike (injury, death, disorientation, behavioural changes)	Immediate vicinity to Harbour-Region- wide	Months - years	Moderate to high	**Very high:** Multiple threatened and at-risk seabirds		High - Very high	Significant to unacceptable	Night - Likely (2) Day - Remote (5)	Moderate (4) – Major (3)	Night - Medium (6-8) Day - Very/low (15-20)
	Increasing tourism exposure causing behavioural changes	Medium Harbour-wide	Months - years	Moderate to high			High - Very high	Significant to unacceptable	Possible (3)	Moderate (4) – Major (3)	Medium (9)-Low (12)
	Increased suspended nutrients, contaminants and plankton blooms affecting prey species	Medium: Harbour-wide	Months - years	Moderate to high			High - Very high	Significant to unacceptable	Unlikely (4)	Moderate (4) – Major (3))	Low (12-16)
	Increased turbidity decreasing foraging efficiency	Medium: Harbour-wide	Hours - months	Low/minor to moderate			Low - High	Minor to significant	Possible (3)	Moderate (4) – Major (3)	Medium (9)-Low (12)

6.5. Other potential effects for consideration

Some other potential effects that were outside the scope of his report, but which should be considered in any subsequent ecological impact assessments, are discussed briefly in the following sections. These are not included in Table 5.

Effects on fish/pelagics and fisheries

Aside from being potential prey sources for marine mammals and seabirds, effects to fish and pelagics are relevant as they are valued in terms of recreational and commercial fishing, mahinga kai and in terms of biodiversity and ecosystem function.

Effects on macroalgae

With the exception of giant kelp, which was discussed in Section 4.3 (classified as at risk – declining), little has been discussed here in relation to the commercial and/or ecological value of macroalgae in the region. This should be considered in any subsequent effects assessments.

Potential for accidental discharges / spills from ships visiting Akaroa.

Discharged liquid wastes can affect organisms in a marine ecosystem, either causing direct toxicity or indirectly changing the physicochemical balance of the ecosystem. Shellfish and filter-feeding organisms are particularly vulnerable as they can bioaccumulate contaminants and pathogens to harmful levels. Toxic discharges can also biomagnify/accumulate up the food chain, causing persistent sublethal physiological stress.

Given the frequency of visitation of cruise ships to the area, and the high value of the environment and resident threatened taxa, the effects of normal operational vessel discharges should also be considered in any future assessments.

In areas of high shipping traffic (cruise ships, recreational yachts, fishing charters, etc.) such as Akaroa Harbour, there is potential for collisions resulting in petrochemical spills and accidental spills/discharges due to faulty discharge retention system, or deliberate bypassing of the retention systems. Although a spill event could be considered 'unlikely' to occur, if an event was to occur it could be of large spatial scale, persistent (long term recovery) and of massive consequence to the entire Akaroa Harbour ecosystem. Consideration of any regionally specific oil spill response plans, and the local response strategies (e.g. the rapid response equipment located in Akaroa, Jim Dilley, pers. comm.), as developed for Fiordland (and discussed in PCE 2003), would go some ways to assess this risk.

Biosecurity risk of international ships visiting Akaroa

Unwanted marine organisms could be introduced to Akaroa from vessel hulls, ballast water and equipment. A marine biosecurity assessment could address the risk associated with this scenario.

Ecological effects from air emission

The council views Lyttelton Port as having significantly higher quantities of air emissions (from shipping, rail, and road traffic) compared to Akaroa and have stated they are *confident there are no issues with air quality in Akaroa from cruise ships*. However, there are no site or activity-specific data to support this. The potential for aesthetic effects/issues to outstanding landscapes and natural features and natural character should also be considered (RCEP 2005).

Threats to local industry, marine farming and aquaculture

Even without considering the potential for accidental spills and discharges from the cruise ships, some of the potential adverse water column effects (discussed in Section 6.2) resulting from the cruise ship anchoring and propulsion activities could influence the wider Akaroa Harbour region. This could have implications for all industry in the region, but particularly marine farming, and macroalgal harvesting, which occur in the vicinity of the cruise ship operations (Figure 14). As well as industry, other valuable ecosystem services (the benefits that humans gain from healthy, functioning ecosystems) should be considered in any future assessments (e.g. producing food, supporting nutrient cycles etc).

Cumulative effects in the harbour

Particularly relating to (but not restricted to) increasing tourism pressures on the Akaroa Harbour eco-system (biology, seabed, water quality etc). The specific and/or cumulative effects of other forms of boating impacts on ecological values are largely unknown in Akaroa Harbour.

7. SUMMARY

Overall results from this risk assessment suggest that cruise ship anchoring and propulsion activities have potential for 'significant or unacceptable' adverse ecological effects to the 'very high' ecological values of Akaroa Harbour. The key 'very-high' ecological value in Akaroa Harbour identified through this assessment results from:

- the threatened and nationally vulnerable Hector's dolphins,
- multiple threatened seabirds
- the customary fishing Taiapure
- the Banks Peninsula marine mammal sanctuary
- multiple areas of significant natural value and outstanding natural character.

Any potential effects which might adversely impact on these values increased the ecological risk level in the assessment. However, when the 'likelihood' of an effect was considered, the ecological risk of the effects assessed here were typically 'medium or low' and at worst 'high,' which could be considered 'manageable using measures to avoid remedy of mitigate.'

Higher levels of risk (high-medium) were associated with direct seabed disturbance effects, given it is likely to occur. However, unlike the indirect effects described in this report (i.e. water column, marine mammal and seabird effects), the direct seabed disturbances from anchoring and propulsion could be considered to have less than minor to minor adverse ecological effects, due to the 'low' species value, but still 'high' habitat values.

At present the level of confidence in the data available for this assessment is low, relying heavily on expert judgement. Confidence could be improved with the provision of site- and activity-specific investigations into the actual ecological effects from cruise ships in Akaroa Harbour. Similarly, any future assessments should consider other potential effects identified in this assessment e.g. fisheries, the risk of accidental discharge/spills, air emissions, biosecurity threats, threats to local industry/aquaculture, and cumulative effects.

7.1. Recommendations

At present the only certain means of managing or mitigating the identified risks associated with cruise ships in Akaroa Harbour (Table 5) would be to stop cruise ships anchoring or manoeuvring in the harbour. A reduction of cruise ship visits could be an option, but to what level, and to which vessels, would be guess-work without adequate site-, vessel- and activity-specific investigative data.

A comprehensive assessment of ecological effects (AEE) should be commissioned to address the potential cruise ship effects specifically relating to seabed disturbance. Such an assessment should be comprised of, but not be limited to (see Section 6.5 for other considerations), expert assessments for fisheries, marine mammals, seabirds and benthic communities, as well as addressing threats to local industry/aquaculture, and cumulative effects.

The expert assessments should also address how different vessels might have differing levels of effects, whether the benthic community recovers to their natural state following the end of the cruise ship season, and exactly what is the 'natural state'[32], as well as investigating the potential for continued sediment resuspension and sedimentation within Akaroa Harbour. This can be achieved though field sampling, observations of cruise ships activities and provision of detailed vessel-specific plans/engineering information. The provision of this information will increase the level of confidence in any subsequent ecological effects risk assessments and enable suitable mitigation and or management tools to be implemented.

[32] Refer to Map 6.5 of the RCEP (2005) and Section 5.6 of this report.

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9. APPENDICES

Appendix 1. Akaroa Harbour cruise ship data summary, as provided to Cawthron by ECAN.

Vessel	Length	Date	Rise	Set	Day	Date	Month	Year	Season
Sea Princess	261	Tue 15 Oct 13	636	1952	Tue	15	Oct	13	2013 -2014
Sun Princess	260	Thu 24 Oct 13	622	2003	Thu	24	Oct	13	2013 -2014
Oosterdam	290	Tue 05 Nov 13	604	2019	Tue	5	Nov	13	2013 -2014
Sun Princess	260	Wed 06 Nov 13	603	2021	Wed	6	Nov	13	2013 -2014
Celebrity Solstice	315	Tue 12 Nov 13	556	2029	Tue	12	Nov	13	2013 -2014
Oosterdam	290	Fri 15 Nov 13	553	2033	Fri	15	Nov	13	2013 -2014
Sea Princess	261	Sat 16 Nov 13	552	2034	Sat	16	Nov	13	2013 -2014
Celebrity Solstice	315	Thu 21 Nov 13	547	2041	Thu	21	Nov	13	2013 -2014
Radiance of the Seas	293	Thu 21 Nov 13	547	2041	Thu	21	Nov	13	2013 -2014
Dawn Princess	266	Wed 27 Nov 13	543	2048	Wed	27	Nov	13	2013 -2014
Sun Princess	260	Fri 29 Nov 13	542	2050	Fri	29	Nov	13	2013 -2014
Pacific Pearl	247	Mon 02 Dec 13	541	2054	Mon	2	Dec	13	2013 -2014
Celebrity Solstice	315	Fri 06 Dec 13	540	2058	Fri	6	Dec	13	2013 -2014
Dawn Princess	266	Tue 10 Dec 13	540	2102	Tue	10	Dec	13	2013 -2014
Sea Princess	261	Wed 11 Dec 13	540	2103	Wed	11	Dec	13	2013 -2014
Sun Princess	260	Thu 12 Dec 13	540	2104	Thu	12	Dec	13	2013 -2014
Oosterdam	290	Fri 13 Dec 13	540	2105	Fri	13	Dec	13	2013 -2014
Celebrity Solstice	315	Sun 15 Dec 13	540	2106	Sun	15	Dec	13	2013 -2014
Caledonian Sky	91	Wed 18 Dec 13	541	2108	Wed	18	Dec	13	2013 -2014
Diamond Princess	290	Fri 20 Dec 13	542	2109	Fri	20	Dec	13	2013 -2014
Sun Princess	260	Wed 25 Dec 13	544	2112	Wed	25	Dec	13	2013 -2014
Diamond Princess	290	Thu 26 Dec 13	545	2112	Thu	26	Dec	13	2013 -2014
Dawn Princess	266	Fri 27 Dec 13	546	2112	Fri	27	Dec	13	2013 -2014
Celebrity Solstice	315	Mon 30 Dec 13	548	2113	Mon	30	Dec	13	2013 -2014
Silver Shadow	186	Mon 30 Dec 13	548	2113	Mon	30	Dec	13	2013 -2014
Radiance of the Seas	293	Fri 03 Jan 14	554	2113	Fri	3	Jan	14	2013 -2014
Seabourn Odyssey	200	Sat 04 Jan 14	554	2113	Sat	4	Jan	14	2013 -2014
Oceanic Discoverer	63	Mon 06 Jan 14	556	2113	Mon	6	Jan	14	2013 -2014
Celebrity Solstice	315	Wed 08 Jan 14	558	2113	Wed	8	Jan	14	2013 -2014
Silver Shadow	186	Thu 09 Jan 14	559	2112	Thu	9	Jan	14	2013 -2014
Seven Seas Voyager	204	Sun 12 Jan 14	603	2111	Sun	12	Jan	14	2013 -2014
Orion	103	Sun 12 Jan 14	603	2111	Sun	12	Jan	14	2013 -2014
Diamond Princess	290	Mon 13 Jan 14	604	2111	Mon	13	Jan	14	2013 -2014
Dawn Princess	266	Wed 15 Jan 14	607	2110	Wed	15	Jan	14	2013 -2014
Seabourn Odyssey	200	Wed 15 Jan 14	607	2110	Wed	15	Jan	14	2013 -2014
Sea Princess	261	Thu 16 Jan 14	608	2109	Thu	16	Jan	14	2013 -2014
Oceanic Discoverer	63	Thu 16 Jan 14	608	2109	Thu	16	Jan	14	2013 -2014
Diamond Princess	290	Sun 19 Jan 14	612	2107	Sun	19	Jan	14	2013 -2014
Sun Princess	260	Mon 20 Jan 14	615	2107	Mon	20	Jan	14	2013 -2014
Seven Seas Voyager	204	Tue 21 Jan 14	616	2105	Tue	21	Jan	14	2013 -2014
Oosterdam	290	Fri 24 Jan 14	619	2102	Fri	24	Jan	14	2013 -2014
Celebrity Solstice	315	Tue 28 Jan 14	623	2101	Tue	28	Jan	14	2013 -2014
Dawn Princess	266	Fri 31 Jan 14	625	2059	Fri	31	Jan	14	2013 -2014
Silver Whisper	186	Fri 31 Jan 14	625	2059	Fri	31	Jan	14	2013 -2014
Diamond Princess	290	Thu 06 Feb 14	636	2050	Thu	6	Feb	14	2013 -2014
Seabourn Odyssey	200	Thu 06 Feb 14	636	2050	Thu	6	Feb	14	2013 -2014

Vessel	Length	Date	Rise	Set	Day	Date	Month	Year	Season
Celebrity Solstice	315	Fri 07 Feb 14	637	2049	Fri	7	Feb	14	2013 -2014
Sea Princess	261	Sat 08 Feb 14	638	2048	Sat	8	Feb	14	2013 -2014
Oceanic Discoverer	63	Sun 09 Feb 14	640	2046	Sun	9	Feb	14	2013 -2014
Oosterdam	290	Tue 11 Feb 14	642	2044	Tue	11	Feb	14	2013 -2014
Diamond Princess	290	Wed 12 Feb 14	643	2043	Wed	12	Feb	14	2013 -2014
Dawn Princess	266	Thu 13 Feb 14	647	2039	Thu	13	Feb	14	2013 -2014
Sun Princess	260	Sun 16 Feb 14	650	2036	Sun	16	Feb	14	2013 -2014
Seabourn Odyssey	200	Sun 16 Feb 14	650	2036	Sun	16	Feb	14	2013 -2014
Amadea	193	Tue 18 Feb 14	653	2033	Tue	18	Feb	14	2013 -2014
Radiance of the Seas	293	Wed 19 Feb 14	654	2031	Wed	19	Feb	14	2013 -2014
Oceanic Discoverer	63	Wed 19 Feb 14	654	2031	Wed	19	Feb	14	2013 -2014
Oosterdam	290	Fri 21 Feb 14	657	2028	Fri	21	Feb	14	2013 -2014
Dawn Princess	266	Sun 23 Feb 14	659	2025	Sun	23	Feb	14	2013 -2014
Pacific Dawn	245	Sun 02 Mar 14	708	2013	Sun	2	Mar	14	2013 -2014
Pacific Pearl	247	Mon 03 Mar 14	710	2011	Mon	3	Mar	14	2013 -2014
Marina	239	Wed 05 Mar 14	712	2007	Wed	5	Mar	14	2013 -2014
Sea Princess	261	Fri 07 Mar 14	715	2004	Fri	7	Mar	14	2013 -2014
Dawn Princess	266	Tue 11 Mar 14	720	1958	Tue	11	Mar	14	2013 -2014
Sun Princess	260	Sat 15 Mar 14	724	1951	Sat	15	Mar	14	2013 -2014
Celebrity Solstice	315	Mon 17 Mar 14	727	1948	Mon	17	Mar	14	2013 -2014
Sea Princess	261	Wed 19 Mar 14	729	1944	Wed	19	Mar	14	2013 -2014
Oosterdam	290	Fri 21 Mar 14	732	1941	Fri	21	Mar	14	2013 -2014
Dawn Princess	266	Mon 24 Mar 14	735	1935	Mon	24	Mar	14	2013 -2014
Radiance of the Seas	293	Mon 24 Mar 14	735	1935	Mon	24	Mar	14	2013 -2014
Celebrity Solstice	315	Thu 27 Mar 14	739	1930	Thu	27	Mar	14	2013 -2014
Dawn Princess	266	Sun 06 Apr 14	653	1812	Sun	6	Apr	14	2013 -2014
The World	196	30-Apr	719	1728	Wed	30	Apr	14	2013 -2014
Golden Princess	290	Sat 07 Oct 17	651	1942	Sat	7	Oct	17	2017 - 2018
Noordam	289	Tue 31 Oct 17	611	2013	Tue	31	Oct	17	2017 - 2018
Celebrity Solstice	315	Mon 06 Nov 17	603	2021	Mon	6	Nov	17	2017 - 2018
Voyager Of The Seas	311	Wed 08 Nov 17	601	2024	Wed	8	Nov	17	2017 - 2018
Noordam	289	Sat 11 Nov 17	557	2028	Sat	11	Nov	17	2017 - 2018
Radiance of the Seas	293	Sun 12 Nov 17	556	2029	Sun	12	Nov	17	2017 - 2018
Celebrity Solstice	315	Thu 16 Nov 17	552	2035	Thu	16	Nov	17	2017 - 2018
Golden Princess	290	Mon 20 Nov 17	548	2040	Mon	20	Nov	17	2017 - 2018
Radiance of the Seas	293	Thu 23 Nov 17	546	2044	Thu	23	Nov	17	2017 - 2018
Noordam	289	Thu 30 Nov 17	542	2052	Thu	30	Nov	17	2017 - 2018
Sun Princess	260	Fri 01 Dec 17	541	2053	Fri	1	Dec	17	2017 - 2018
Celebrity Solstice	315	Mon 04 Dec 17	540	2057	Mon	4	Dec	17	2017 - 2018
Norwegian Jewel	294	Thu 07 Dec 17	540	2100	Thu	7	Dec	17	2017 - 2018
Radiance of the Seas	293	Fri 08 Dec 17	539	2101	Fri	8	Dec	17	2017 - 2018
Sea Princess	261	Sat 09 Dec 17	539	2102	Sat	9	Dec	17	2017 - 2018
Regatta	181	Sun 10 Dec 17	539	2103	Sun	10	Dec	17	2017 - 2018
Noordam	289	Mon 11 Dec 17	539	2103	Mon	11	Dec	17	2017 - 2018
Celebrity Solstice	315	Thu 14 Dec 17	540	2106	Thu	14	Dec	17	2017 - 2018
Sun Princess	260	Thu 14 Dec 17	540	2106	Thu	14	Dec	17	2017 - 2018
Seabourn Encore	210	Fri 15 Dec 17	540	2107	Fri	15	Dec	17	2017 - 2018
Silver Shadow	186	Fri 15 Dec 17	540	2107	Fri	15	Dec	17	2017 - 2018
Silver Shadow	186	Sat 23 Dec 17	543	2111	Sat	23	Dec	17	2017 - 2018
Diamond Princess	290	Tue 26 Dec 17	545	2112	Tue	26	Dec	17	2017 - 2018
Radiance of the Seas	293	Wed 27 Dec 17	545	2113	Wed	27	Dec	17	2017 - 2018

Vessel	Length	Date	Rise	Set	Day	Date	Month	Year	Season
Sea Princess	261	Wed 27 Dec 17	545	2113	Wed	27	Dec	17	2017 - 2018
Celebrity Solstice	315	Thu 28 Dec 17	546	2113	Thu	28	Dec	17	2017 - 2018
Golden Princess	290	Fri 29 Dec 17	547	2113	Fri	29	Dec	17	2017 - 2018
Caledonian Sky	91	Sun 31 Dec 17	548	2113	Sun	31	Dec	17	2017 - 2018
Maasdam	219	Sun 31 Dec 17	548	2113	Sun	31	Dec	17	2017 - 2018
L'Austral	142	Mon 01 Jan 18	549	2114	Mon	1	Jan	18	2017 - 2018
Diamond Princess	290	Thu 04 Jan 18	552	2114	Thu	4	Jan	18	2017 - 2018
Sun Princess	260	Tue 09 Jan 18	557	2113	Tue	9	Jan	18	2017 - 2018
Maasdam	219	Tue 09 Jan 18	557	2113	Tue	9	Jan	18	2017 - 2018
Noordam	289	Wed 10 Jan 18	558	2112	Wed	10	Jan	18	2017 - 2018
Sea Princess	261	Wed 10 Jan 18	558	2112	Wed	10	Jan	18	2017 - 2018
Seabourn Encore	210	Thu 11 Jan 18	559	2112	Thu	11	Jan	18	2017 - 2018
Norwegian Jewel	294	Fri 12 Jan 18	601	2112	Fri	12	Jan	18	2017 - 2018
Golden Princess	290	Thu 18 Jan 18	608	2108	Thu	18	Jan	18	2017 - 2018
Caledonian Sky	91	Mon 22 Jan 18	613	2105	Mon	22	Jan	18	2017 - 2018
Radiance of the Seas	293	Mon 22 Jan 18	613	2105	Mon	22	Jan	18	2017 - 2018
Sun Princess	260	Mon 22 Jan 18	613	2105	Mon	22	Jan	18	2017 - 2018
Maasdam	219	Fri 26 Jan 18	619	2102	Fri	26	Jan	18	2017 - 2018
Sea Princess	261	Sat 27 Jan 18	620	2101	Sat	27	Jan	18	2017 - 2018
Celebrity Solstice	315	Mon 29 Jan 18	623	2059	Mon	29	Jan	18	2017 - 2018
Seabourn Encore	210	Thu 01 Feb 18	627	2056	Thu	1	Feb	18	2017 - 2018
Diamond Princess	290	Thu 01 Feb 18	627	2056	Thu	1	Feb	18	2017 - 2018
Norwegian Jewel	294	Mon 05 Feb 18	633	2051	Mon	5	Feb	18	2017 - 2018
Radiance of the Seas	293	Mon 05 Feb 18	633	2051	Mon	5	Feb	18	2017 - 2018
Golden Princess	290	Tue 06 Feb 18	634	2050	Tue	6	Feb	18	2017 - 2018
Regatta	181	Fri 09 Feb 18	638	2046	Fri	9	Feb	18	2017 - 2018
Silver Whisper	186	Fri 09 Feb 18	638	2046	Fri	9	Feb	18	2017 - 2018
Pacific Jewel	245	Sat 10 Feb 18	640	2044	Sat	10	Feb	18	2017 - 2018
Celebrity Solstice	315	Mon 12 Feb 18	643	2041	Mon	12	Feb	18	2017 - 2018
Seabourn Encore	210	Mon 12 Feb 18	643	2041	Mon	12	Feb	18	2017 - 2018
Noordam	289	Tue 13 Feb 18	644	2040	Tue	13	Feb	18	2017 - 2018
Diamond Princess	290	Thu 15 Feb 18	647	2037	Thu	15	Feb	18	2017 - 2018
Golden Princess	290	Fri 16 Feb 18	648	2036	Fri	16	Feb	18	2017 - 2018
Azamara Journey	181	Sat 17 Feb 18	649	2034	Sat	17	Feb	18	2017 - 2018
Sea Princess	261	Sat 17 Feb 18	649	2034	Sat	17	Feb	18	2017 - 2018
Diamond Princess	290	Wed 21 Feb 18	655	2028	Wed	21	Feb	18	2017 - 2018
Noordam	289	Thu 22 Feb 18	656	2026	Thu	22	Feb	18	2017 - 2018
Sun Princess	260	Sat 24 Feb 18	659	2023	Sat	24	Feb	18	2017 - 2018
Carnival Legend	294	Mon 26 Feb 18	702	2020	Mon	26	Feb	18	2017 - 2018
Azamara Journey	181	Wed 28 Feb 18	704	2016	Wed	28	Feb	18	2017 - 2018
Queen Mary 2	345	Thu 01 Mar 18	706	2015	Thu	1	Mar	18	2017 - 2018
Seven Seas Voyager	206	Thu 01 Mar 18	706	2015	Thu	1	Mar	18	2017 - 2018
Noordam	289	Tue 06 Mar 18	712	2006	Tue	6	Mar	18	2017 - 2018
Sun Princess	260	Fri 09 Mar 18	716	2001	Fri	9	Mar	18	2017 - 2018
Radiance of the Seas	293	Tue 13 Mar 18	721	1954	Tue	13	Mar	18	2017 - 2018
Celebrity Solstice	315	Fri 16 Mar 18	725	1948	Fri	16	Mar	18	2017 - 2018
Diamond Princess	290	Sat 17 Mar 18	726	1946	Sat	17	Mar	18	2017 - 2018
Sun Princess	260	Thu 22 Mar 18	732	1937	Thu	22	Mar	18	2017 - 2018
Radiance of the Seas	293	Fri 23 Mar 18	733	1935	Fri	23	Mar	18	2017 - 2018
Pacific Jewel	245	Sun 25 Mar 18	736	1932	Sun	25	Mar	18	2017 - 2018
Noordam	289	Wed 04 Apr 18	648	1814	Wed	4	Apr	18	2017 - 2018

Vessel	Length	Date	Rise	Set	Day	Date	Month	Year	Season
Sun Princess	260	Wed 04 Apr 18	648	1814	Wed	4	Apr	18	2017 - 2018
Radiance of the Seas	293	Thu 12 Apr 18	657	1800	Thu	12	Apr	18	2017 - 2018
Majestic Princess	330	Tue 02 Oct 18	-	-	Tue	2	Oct	18	2017 - 2018
Golden Princess	290	Wed 17 Oct 18	-	-	Wed	17	Oct	18	2017 - 2018
Majestic Princess	330	Fri 19 Oct 18	-	-	Fri	19	Oct	18	2017 - 2018
Majestic Princess	330	Sat 27 Oct 18	-	-	Sat	27	Oct	18	2017 - 2018
Sea Princess	261	Fri 02 Nov 18	-	-	Fri	2	Nov	18	2018 - 2019
Noordam	289	Sat 03 Nov 18	-	-	Sat	3	Nov	18	2018 - 2019
Caledonian Sky	91	Wed 07 Nov 18	-	-	Wed	7	Nov	18	2018 - 2019
Majestic Princess	330	Sat 10 Nov 18	-	-	Sat	10	Nov	18	2018 - 2019
Noordam	289	Tue 13 Nov 18	-	-	Tue	13	Nov	18	2018 - 2019
Golden Princess	290	Tue 13 Nov 18	-	-	Tue	13	Nov	18	2018 - 2019
Celebrity Solstice	315	Thu 15 Nov 18	-	-	Thu	15	Nov	18	2018 - 2019
Carnival Legend	294	Sun 18 Nov 18	-	-	Sun	18	Nov	18	2018 - 2019
Golden Princess	290	Mon 26 Nov 18	-	-	Mon	26	Nov	18	2018 - 2019
Radiance of the Seas	293	Mon 26 Nov 18	-	-	Mon	26	Nov	18	2018 - 2019
Celebrity Solstice	315	Tue 27 Nov 18	-	-	Tue	27	Nov	18	2018 - 2019
Sun Princess	260	Wed 28 Nov 18	-	-	Wed	28	Nov	18	2018 - 2019
Majestic Princess	330	Sat 01 Dec 18	-	-	Sat	1	Dec	18	2018 - 2019
Sea Princess	261	Sat 01 Dec 18	-	-	Sat	1	Dec	18	2018 - 2019
Pacific Explorer	261	Sun 02 Dec 18	-	-	Sun	2	Dec	18	2018 - 2019
Maasdam	219	Mon 03 Dec 18	-	-	Mon	3	Dec	18	2018 - 2019
Radiance of the Seas	293	Thu 06 Dec 18	-	-	Thu	6	Dec	18	2018 - 2019
Celebrity Solstice	315	Fri 07 Dec 18	-	-	Fri	7	Dec	18	2018 - 2019
Norwegian Jewel	294	Sat 08 Dec 18	-	-	Sat	8	Dec	18	2018 - 2019
Golden Princess	290	Sun 09 Dec 18	-	-	Sun	9	Dec	18	2018 - 2019
Sun Princess	260	Tue 11 Dec 18	-	-	Tue	11	Dec	18	2018 - 2019
Majestic Princess	330	Sat 15 Dec 18	-	-	Sat	15	Dec	18	2018 - 2019
Caledonian Sky	91	Sat 15 Dec 18	-	-	Sat	15	Dec	18	2018 - 2019
Maasdam	219	Sun 16 Dec 18	-	-	Sun	16	Dec	18	2018 - 2019
Radiance of the Seas	293	Sun 16 Dec 18	-	-	Sun	16	Dec	18	2018 - 2019
Celebrity Solstice	315	Tue 18 Dec 18	-	-	Tue	18	Dec	18	2018 - 2019
Majestic Princess	330	Fri 21 Dec 18	-	-	Fri	21	Dec	18	2018 - 2019
Golden Princess	290	Thu 27 Dec 18	-	-	Thu	27	Dec	18	2018 - 2019
Celebrity Solstice	315	Fri 28 Dec 18	-	-	Fri	28	Dec	18	2018 - 2019
Norwegian Jewel	294	Sat 29 Dec 18	-	-	Sat	29	Dec	18	2018 - 2019
Seabourn Encore	210	Mon 31 Dec 18	-	-	Mon	31	Dec	18	2018 - 2019
Pacific Jewel	245	Tue 01 Jan 19	-	-	Tue	1	Jan	19	2018 - 2019
Sea Princess	261	Wed 02 Jan 19	-	-	Wed	2	Jan	19	2018 - 2019
Majestic Princess	330	Fri 04 Jan 19	-	-	Fri	4	Jan	19	2018 - 2019
Caledonian Sky	91	Sun 06 Jan 19	-	-	Sun	6	Jan	19	2018 - 2019
Radiance of the Seas	293	Mon 07 Jan 19	-	-	Mon	7	Jan	19	2018 - 2019
Celebrity Solstice	315	Sat 12 Jan 19	-	-	Sat	12	Jan	19	2018 - 2019
Azamara Quest	181	Mon 14 Jan 19	-	-	Mon	14	Jan	19	2018 - 2019
Golden Princess	290	Tue 15 Jan 19	-	-	Tue	15	Jan	19	2018 - 2019
Silver Muse	213	Tue 15 Jan 19	-	-	Tue	15	Jan	19	2018 - 2019
Seabourn Encore	210	Wed 16 Jan 19	-	-	Wed	16	Jan	19	2018 - 2019
Sun Princess	260	Thu 17 Jan 19	-	-	Thu	17	Jan	19	2018 - 2019
Radiance of the Seas	293	Sat 19 Jan 19	-	-	Sat	19	Jan	19	2018 - 2019
Majestic Princess	330	Sun 20 Jan 19	-	-	Sun	20	Jan	19	2018 - 2019
Celebrity Solstice	315	Wed 23 Jan 19	-	-	Wed	23	Jan	19	2018 - 2019

Vessel	Length	Date	Rise	Set	Day	Date	Month	Year	Season
Norwegian Jewel	294	Fri 25 Jan 19	-	-	Fri	25	Jan	19	2018 - 2019
Regatta	181	Fri 25 Jan 19	-	-	Fri	25	Jan	19	2018 - 2019
Sea Princess	261	Sat 26 Jan 19	-	-	Sat	26	Jan	19	2018 - 2019
Seabourn Encore	210	Sun 27 Jan 19	-	-	Sun	27	Jan	19	2018 - 2019
Radiance of the Seas	293	Tue 29 Jan 19	-	-	Tue	29	Jan	19	2018 - 2019
Azamara Quest	181	Thu 31 Jan 19	-	-	Thu	31	Jan	19	2018 - 2019
Majestic Princess	330	Fri 01 Feb 19	-	-	Fri	1	Feb	19	2018 - 2019
Norwegian Jewel	294	Mon 04 Feb 19	-	-	Mon	4	Feb	19	2018 - 2019
Noordam	289	Thu 07 Feb 19	-	-	Thu	7	Feb	19	2018 - 2019
Celebrity Solstice	315	Thu 07 Feb 19	-	-	Thu	7	Feb	19	2018 - 2019
Radiance of the Seas	293	Fri 08 Feb 19	-	-	Fri	8	Feb	19	2018 - 2019
Sun Princess	260	Sun 10 Feb 19	-	-	Sun	10	Feb	19	2018 - 2019
Caledonian Sky	91	Mon 11 Feb 19	-	-	Mon	11	Feb	19	2018 - 2019
Carnival Legend	294	Mon 11 Feb 19	-	-	Mon	11	Feb	19	2018 - 2019
Regatta	181	Mon 11 Feb 19	-	-	Mon	11	Feb	19	2018 - 2019
Majestic Princess	330	Wed 13 Feb 19	-	-	Wed	13	Feb	19	2018 - 2019
Noordam	289	Fri 15 Feb 19	-	-	Fri	15	Feb	19	2018 - 2019
Azamara Quest	181	Sat 16 Feb 19	-	-	Sat	16	Feb	19	2018 - 2019
Golden Princess	290	Sun 17 Feb 19	-	-	Sun	17	Feb	19	2018 - 2019
Seabourn Encore	210	Sun 17 Feb 19	-	-	Sun	17	Feb	19	2018 - 2019
Radiance of the Seas	293	Mon 18 Feb 19	-	-	Mon	18	Feb	19	2018 - 2019
Columbus	247	Tue 19 Feb 19	-	-	Tue	19	Feb	19	2018 - 2019
Regatta	181	Wed 20 Feb 19	-	-	Wed	20	Feb	19	2018 - 2019
Queen Elizabeth	294	Mon 25 Feb 19	-	-	Mon	25	Feb	19	2018 - 2019
Majestic Princess	330	Wed 27 Feb 19	-	-	Wed	27	Feb	19	2018 - 2019
Radiance of the Seas	293	Thu 28 Feb 19	-	-	Thu	28	Feb	19	2018 - 2019
Sea Princess	261	Sat 02 Mar 19	-	-	Sat	2	Mar	19	2018 - 2019
Amadea	193	Mon 04 Mar 19	-	-	Mon	4	Mar	19	2018 - 2019
Seabourn Encore	210	Mon 04 Mar 19	-	-	Mon	4	Mar	19	2018 - 2019
Noordam	289	Tue 05 Mar 19	-	-	Tue	5	Mar	19	2018 - 2019
Golden Princess	290	Tue 05 Mar 19	-	-	Tue	5	Mar	19	2018 - 2019
Majestic Princess	330	Wed 06 Mar 19	-	-	Wed	6	Mar	19	2018 - 2019
Pacific Jewel	245	Sun 10 Mar 19	-	-	Sun	10	Mar	19	2018 - 2019
Noordam	289	Thu 14 Mar 19	-	-	Thu	14	Mar	19	2018 - 2019
Golden Princess	290	Fri 15 Mar 19	-	-	Fri	15	Mar	19	2018 - 2019
Seabourn Encore	210	Sat 16 Mar 19	-	-	Sat	16	Mar	19	2018 - 2019
Majestic Princess	330	Mon 18 Mar 19	-	-	Mon	18	Mar	19	2018 - 2019
Queen Elizabeth	294	Mon 25 Mar 19	-	-	Mon	25	Mar	19	2018 - 2019
Golden Princess	290	Thu 28 Mar 19	-	-	Thu	28	Mar	19	2018 - 2019
Crystal Symphony	238	Fri 29 Mar 19	-	-	Fri	29	Mar	19	2018 - 2019
Radiance of the Seas	293	Sat 30 Mar 19	-	-	Sat	30	Mar	19	2018 - 2019
Celebrity Solstice	315	Wed 03 Apr 19	-	-	Wed	3	Apr	19	2018 - 2019
Noordam	289	Fri 12 Apr 19	-	-	Fri	12	Apr	19	2018 - 2019
Golden Princess	290	Sat 13 Apr 19	-	-	Sat	13	Apr	19	2018 - 2019

Appendix 2. Summary of specific cruise ship effect literature

New Zealand-specific

- 'Just cruising?' a review by the Parliamentary Commissioner for the Environment (PCE 2003). Which summarised the potential environmental effects of cruise ships in New Zealand.
- Two reports by Mendez (2010, 2011) which discuss the effects of tourism in Akaroa Harbour on Hector's dolphin behaviour.
- A seabird assessment by Whitehead et al. (2019) that considers (as a component of the report) the impact of lighting from cruise ships in New Zealand.
- Two reports by Lincoln University (2003, 2013) which focus on visitor experiences and expenditure, and business stakeholder perceptions relating to cruise ship tourism in Akaroa and community attitudes to Akaroa hosting cruise ship arrivals.
- The 'Deed of Agreement' between the New Zealand Cruise Ship Industry and Environment Southland (ES 2008). Which, although it does not exempt cruise ship owners and/or operators from their regulatory obligations (i.e. if their activities fall outside of the controlled activities in the coastal plan), does provide terms and conditions[33], that cruise ship owners and/or operators can comply with to avoid the requirement for resource consent for their activities.
- The New Zealand cruise ship sustainability guide (CISG 2018). Where Cruise Lines International Association (CLIA) describes its efforts to partner with ports, local government, travel and tourism businesses etc to address 'environmental concerns' by developing long- and short-term solutions.

International literature

- The Congressional Research Service's report on Cruise Ship Pollution (CRS 2010) which discusses the background, laws, regulations and key issues associated with cruise ship pollution.
- An impact assessment by Murry and Associates (Murray 2005) relating to cruise ships visiting Key West, Florida. The report presents and summarises a large array of site-specific studies relating to suspected turbidity, sedimentation, disturbance and biological effects, arising from cruise ship and other large vessel traffic in the Key West area. The report concludes that adverse effects to water quality and bottom habitats were evident in the main channel and harbour, however, notes that's belief of wider water quality effects appear 'unfounded.'
- The investigation 'Impact of cruise ship turbulence on benthic communities' by Ellis et al. (2005) provides a case study of effects of propulsion turbulence from

[33] E.g. The deed requires vessels to have insurance and pay specific cruise ship marine fees, as well as have the following certifications: International Oil Pollution Prevention (IOPP) Certificate, Contract of Spill Response, International Anti-Fouling System Certificate (or equivalent), Statement of Compliance for Sewage Pollution Prevention, Prevention of Air Pollution Certificate of Compliance, Proof of Financial Responsibility & Approval for Non Tank Vessel.

cruise ships to soft sediment environments, set in Tasmania's south west. The report concludes that instead of using the typical characteristics such as ship length, draught and tonnage to gauge the impact of a ship, a more accurate model should include the depth of propeller submergence, propeller diameter, and the typical operational speed (rpm) of the propeller whilst manoeuvring and underway, with each cruise ship considered separately. The model developed in this assessment is now used Wildlife Service to finalise their permit process for cruise ships wishing to access the area.