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REPORT NO. 3901

STUDYING ANTHROPAUSE EFFECTS ON MARINE ECOLOGY IN NEW ZEALAND: A PRELIMINARY DATA ASSESSMENT OF SELECTED MARINE TOURISM AREAS

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STUDYING ANTHROPAUSE EFFECTS ON MARINE ECOLOGY IN NEW ZEALAND: A PRELIMINARY DATA ASSESSMENT OF SELECTED MARINE TOURISM AREAS

OLIVIA JOHNSTON, PAULA CASANOVAS

Prepared for Environment Southland, Canterbury Regional Council and Otago Regional Council

Ministry of Business, Innovation & Employment Envirolink Grant: 2306-ESRC507

CAWTHRON INSTITUTE
98 Halifax Street East, Nelson 7010 | Private Bag 2, Nelson 7042 | New Zealand
Ph. +64 3 548 2319 | Fax. +64 3 546 9464
www.cawthron.org.nz

REVIEWED BY:
Carlos Campos

APPROVED FOR RELEASE BY:
Grant Hopkins

ISSUE DATE: 26 June 2023

RECOMMENDED CITATION: Johnson O, Casanovas P. 2023. Studying Anthropause effects on marine ecology in New Zealand: a preliminary data assessment of selected marine tourism areas. Prepared for Environment Southland, Canterbury Regional Council and Otago Regional Council. Cawthron Report No. 3901. 58 p. plus appendix.

EXECUTIVE SUMMARY

Cawthron Institute was contracted by Environment Southland Regional Council (ES), Otago Regional Council (ORC) and Canterbury Regional Council (CRC) through an Envirolink advice grant (2306-ESRC507) to provide a preliminary desktop investigation of marine ecological data and tourism activities in five marine tourism areas of interest (AOI; Milford Sound / Piopiotahi, Stewart Island / Rakiura, Otago Harbour / Otakou, Akaroa Harbour and Kaikōura Peninsula). The suitability of the compiled data has been investigated for understanding the impact of tourism activities on marine ecology during the COVID-19 pandemic border lockdown in New Zealand from 19 March 2020 to 31 July 2022 (the Anthropause). Finally, data analyses recommendations for detecting marine tourism-related impacts during the Anthropause are discussed.

This preliminary investigation represents Stage one of our Anthropause investigation. It is anticipated that the data identified here will be analysed in Stage two of the study. The following paragraphs summarise the data types identified and the associated considerations for any future analyses of these data.

Tourism activities (explanatory variables)
Potential explanatory variables for determining Anthropause-related marine tourism effects to ecological variables are passenger vessel traffic data and the number and intensity of marine tourism operations at each AOI. For each of these categories, we have gathered and characterised data relating to cruise ship movements (international operators), geospatial passenger vessel density and identification of local operators within each AOI. Differences in vessel traffic, management and characteristics between the AOIs will need to be considered in any future interpretation of results.

Ecological data suitability (response variables)
Hundreds of potential ecological data sources were identified and characterised for the AOIs to determine their suitability for assessing Anthropause effects (Appendix 1). Of these, between 15 to 27 potentially 'suitable' ecological data sources were identified for each AOI. Each of the potential datasets spanned the Anthropause period, were robust (high sampling effort), were located within or near to the AOIs and were available either on request or publicly. Overall, we found multiple potential types of ecological data (e.g. marine species presence and distribution, water quality measurements, litter type surveys) for the AOIs that could be used for future study of Anthropause effects in Stage two.

Proposed Stage two data analysis approach
We suggest a conceptual model be developed that follows a Multiple Levels and Lines of Evidence (MLLE) approach. Using this approach, each potentially suitable causal data type (e.g. species abundance and distribution) may be used as potential 'lines of evidence' to collectively infer causality from the explanatory variable(s) (e.g. passenger vessel traffic density, number of local tourism operator vessel trips, etc.). Each MLLE result could then be integrated to assess the overall ecological effect of marine tourism activity. Causality could

then be inferred from sequential analysis of the lines of evidence and / or from statistical analysis (e.g. a Bayesian approach).

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1. INTRODUCTION

The Cawthron Institute (Cawthron) has been contracted by Environment Southland Regional Council (ES), Otago Regional Council (ORC) and Canterbury Regional Council (CRC) through an Envirolink[1] advice grant (2306-ESRC507) to provide a preliminary desktop investigation of existing marine ecological time-series data and tourism activities occurring at five key marine tourism locations or 'areas of interest' (AOI) during the COVID-19 pandemic border lockdown in New Zealand from 19 March 2020 to 31 July 2022,[2] hereafter referred to as the Anthropause. The Anthropause term was introduced by Rutz et al. (2020) and is now used globally to describe the substantial reduction in human mobility observed during early COVID-19 lockdowns.

We have investigated the suitability of the existing data for understanding the ecological impact of site-specific marine tourism[3] activities. We also provide recommendations for analysing datasets deemed 'suitable' for detecting marine tourism-related impacts. This preliminary investigation represents Stage one of our Anthropause investigation. It is anticipated that the data identified here will be analysed in Stage two of the study (see Section 1.1. for further detail).

Based on project inception discussions with each council,[4] this investigation focuses on five AOIs: Milford Sound / Piopiotahi, Stewart Island / Rakiura, Otago Harbour / Otakou, Akaroa Harbour and Kaikōura Peninsula.

1.1. Project scope

The overall aim of the project is to improve councils' understanding of the ecological impacts of marine tourism on each AOI to enable informed management of tourism. The outcomes of Stage one presented here provide the foundations for delivering this knowledge by:

1. reviewing international and national literature on the Anthropause in the marine ecological context and discussing the data types used (e.g. remote sensing data, population demographics, etc) and the preliminary findings of ecological effects.
2. providing site-specific descriptions and regulatory context of the marine tourism activities (local and international operators) at each of the AOI.
3. summarising the available data for each AOI and their suitability for the assessment.

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[1] Administered by the Ministry of Business, Innovation & Employment – Science and Innovation (https://www.envirolink.govt.nz/)

[2] Border closure / opening dates obtained from https://covid19.govt.nz/about-our-covid-19-response/history-of-the-covid-19-alert-system/

[3] Marine tourism in this context includes any marine surface water activity that relies on tourists / customers to operate, e.g. cruise ships, whale watching, dolphin swimming, charter boats, etc.

[4] Video conferencing undertaken on 7 October 2022 (ES), 13 October 2022 (ORC), 10 March 2022 (CRC).

4. discussing the potential methodological approach to analyse datasets deemed to be ‘suitable’ for assessing specific marine tourism-related impacts (Stage two of the investigation).

The following section details the methods used to obtain ecological and marine traffic data at the AOIs.

1.2. Study hypothesis

The working hypothesis is that the reduction in marine tourism activities as a result of the COVID-19 travel restrictions led to measurable improvements to marine ecology. In this context, marine ecological improvements are assessed based on measures of sediment and water physico-chemistry, biology and wildlife behaviour.

To test this hypothesis, we will compare data collected during periods of reduced international travel / tourism with data collected during periods with normal levels of tourism to determine whether improvements to marine ecology can be measured. This report, representing Stage one of the investigation, identifies potential marine tourism effects, determines the suitability of data sources for studying Anthropause impacts and recommends approaches for analysing the data in the next stage of the project.

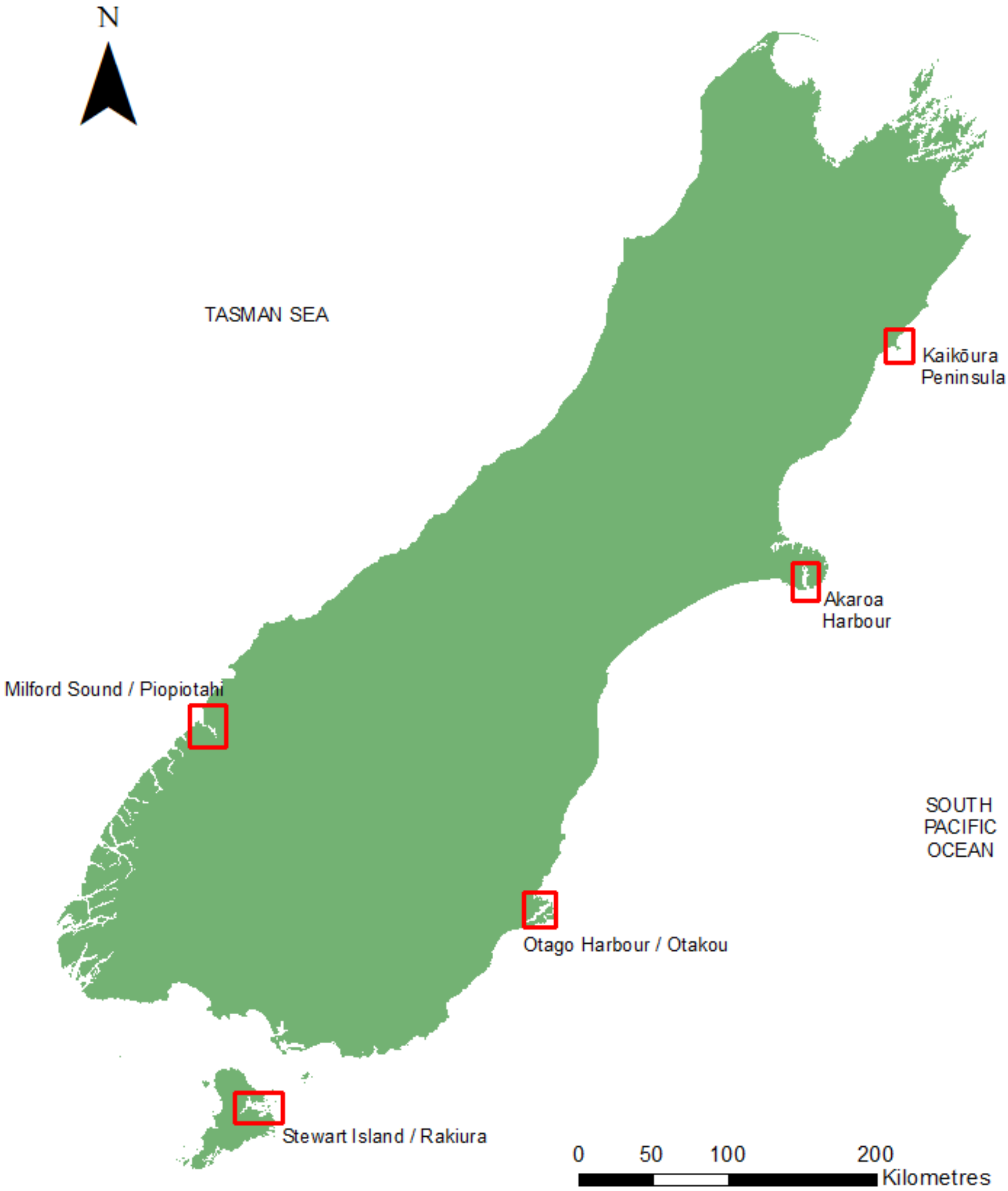

Figure 1. Marine tourism areas of interest investigated in the South Island of New Zealand (red boxes). These are: Milford Sound / Piopiotahi, Stewart Island / Rakiura (Environment Southland Regional Council jurisdiction), Otago Harbour / Otakou (Otago Regional Council jurisdiction), Akaroa Harbour and Kaikōura Peninsula (Canterbury Regional Council jurisdiction).

2. METHODS

2.1. Review of marine Anthropause studies

An online narrative literature review of publicly available published research and reports (grey literature) was undertaken using Google™ search engine. Literature that referenced 'Anthropause' and 'marine' and / or 'effects' were included in the search. The literature was then summarised, and the ecological effects that were identified in each study were compiled. Following this, the types of data that were used in the investigations were identified and the investigative / statistical approaches noted.

2.2. Marine tourism activities at areas of interest

To identify marine tourism operators and vessel traffic movements at each AOI, data were, in the first instance, requested from each council's local Harbour Master. In the absence of any council data, the marine and coastal ecotourism operators identified as part of the Sustainable Seas National Science Challenge[5] were used to identify the local tourism operators. A request was also made to access a recent student[6] thesis with study data on New Zealand marine tourism operators. However, this thesis and the associated data have not been provided or approved for use.

Activities relating to international operators (cruise ships) were identified and described using the cruise ship scheduling logs provided through the New Zealand Cruise Association (NZCA) website.[7] In addition, passenger vessel[8] traffic density (hrs/km^2) data were obtained from the Global Maritime Traffic (GMT) website[9] from their extensive global automatic identification system (AIS[10]) vessel traffic data. Density data were available in a variety of formats,[11] including vessel positions and dates (as Excel CSV files). Data were pooled per year or month and were filterable by vessel type (e.g. passenger vessels) and date (from 2011 to present).

2.3. Ecological data acquisition

This project was limited to marine ecological data publicly available from online databases (Appendix 1) or data requested from various relevant custodians. To gather

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[5] www.sustainableseaschallenge.co.nz
[6] https://www.biosecurity-toolbox.org.nz/staff-member/jess-phipps/
[7] https://newzealandcruiseassociation.com/
[8] Including sailing craft (AIS number 36) and pleasure craft (AIS number 37) (these include commercial passenger vessels and some [but not all] recreational vessels and racing sail craft), and larger passenger ships (AIS numbers 60–69).
[9] https://globalmaritimetraffic.org/gmtds.html
[10] Automatic Identification System (AIS) is a method of tracking other vessels using a global positioning system (GPS) receiver or transceiver operating on the dedicated marine VHF channels.
[11] Also included: GIF movies of vessel movements, GridFloat, NetCDF and GeoTiff type files.

these data, we communicated with the councils and a range of key organisations (e.g. Department of Conservation, New Zealand Ornithological Society, University of Otago, etc.) who hold or know of existing data for the AOIs. Online resources were also reviewed for potential data sources. When data wasn't described or available online, we asked key personnel from each organisation to provide us with a description of the data and the location of relevant information. We also asked whether the data custodians would be interested in participating in Stage two of the Anthropause research.

Information obtained for each set of data was summarised, including assignment of key metadata (e.g. data description and who, why, when, where and how the data were collected). The purpose of this was to allow end-users to readily assess the type and amount of marine ecological data existing for each AOI.

The available spatial information of the sampling / investigation sites was also recorded (either as coordinates or maps) in case a geospatial approach to data analysis is required in Stage two. Furthermore, the councils would have the option of integrating metadata sources into a GIS mapping package to improve data management and information retrieval in the future.

2.4. Determining data suitability

Each data source identified in the metadata summary table for each AOI was also assessed for suitability for investigating the Anthropause impacts. Data suitability was based on four key characteristics, each assigned to one of three potential values (0,1 or 2):

1. Time series spanning Anthropause period? *
   Pre-, mid- and post- = 2
   Pre- and post- = 1
   Other / no = 0
   **Pre-Anthropause = prior to 19 March 2020; Mid-Anthropause = 19 March 2020–31 July 2022; Post-Anthropause = after 31 July 2022.*

2. Proximity of study sites to marine tourism activities?
   Immediate (< 50 m) = 2
   Close (> 50 m < 1 km) = 1
   Distant (> 1 km) = 0

3. Dataset robustness?
   Strong (high sampling effort, data collected by scientists) = 2
   Moderate (moderate sampling effort, collected following strict methodology) = 1
   Weak (low sampling effort, inconsistent data collection and / or approach) = 0

4. Data availability?
   Publicly available or supplied by custodian = 2
   Potentially available on request = 1
   Unavailable (or ND) = 0

   Overall data suitability ranking (sum of characteristics 1–4)
   8 = Excellent
   6–7 = Very good
   4–5 = Moderate
   2–3 = Low
   0–1 = Poor

Data was deemed 'potentially suitable' for use in Stage two of the investigation (data analysis) if the total ranking (the sum of the characteristics 1–4) was either, 'Very good' or 'Excellent' (in bold above). Following this, the potential data analysis approaches for Stage two were described.

3. REVIEW OF MARINE 'ANTHROPAUSE' STUDIES

Since March 2020,[12] many countries around the world have implemented a number of non-pharmaceutical interventions (e.g. stay at home orders, curfews, quarantines) commonly known as 'lockdowns' to control the spread of COVID-19. These lockdowns caused drastic reductions in human travel and outdoors activity, and this period, coined 'Anthropause' (Rutz et al. 2020), provides a unique opportunity to understand the ecological impacts of human activity (particularly tourism activities) in the marine environment (Bates et al. 2020, 2021a, 2021b; Rutz et al. 2020; Rutz 2022). Anecdotally, there is evidence that many animal species experience little disturbance, while others seem to have come under increased pressure (Armstrong et al. 2022). Globally, these extraordinary circumstances are being used to enhance understanding of how human activity affects marine ecology (Pine et al. 2021; Bennett et al. 2020; Patrício Silva et al. 2020; Rutz et al. 2020).

In New Zealand, there have been three recent studies that have investigated marine tourism effects (in Akaroa Harbour) and Anthropause-type[13] effects (in Picton and Hauraki Gulf). The findings of each study are summarised below:

1) **Vessel traffic influences distribution of New Zealand's endemic dolphin *Cephalorhynchus hectori* (Carome 2021; Carome et al. 2022a, 2022b).** This study examined the relationships between the growth in cruise ship visits and tours focused specifically on dolphins, and the long-term trends in summer distribution of Hector's dolphins at Akaroa Harbour from 2000 to 2020 (calculated via kernel density estimation of 2,335 sightings from over 8,000 km of standardised survey effort). Dolphin habitat preference varied over time, with the greatest change occurring between 2005 and 2011 and 2012 and 2015. Dolphin distribution shifted towards the outer harbour after 2011 and then remained relatively consistent. The observed shift in distribution coincided with the more than fourfold increase in annual cruise ship visits to Akaroa Harbour. Based on these results, it is likely that further investigation of dolphin distribution spanning the Anthropause period would help to answer questions around recovery times (e.g. did dolphins return to the inner Harbour when cruise ships ceased?) and causality (e.g. was it the cruise ship traffic or other environmental effects, such as climate, causing the shift?). Given its temporal and spatial suitability, this dataset has been included in the 'potentially suitable data' list for Akaroa Harbour (Section 5.3).

2) **The footprint of ship anchoring on the seafloor (Watson et al. 2022).** Commercial port congestion (causing increased time at anchor) and consequent seabed disturbance was investigated over the Anthropause period. Multibeam

[12] https://en.wikipedia.org/wiki/COVID-19_lockdowns

[13] Note: neither study used the term Anthropause and instead referred to the COVID-19 pandemic period.

bathymetry data before (2017) and during (2021) the Anthropause period were used in the vicinity of Picton in the South Island of New Zealand. This study showed the footprint of anchoring, characterised by increased sea floor roughness, was preserved for over 4 years in this low-energy, muddy substrate environment. Results suggested anchor disturbance effects can persist for a number of years. The authors surmised that the COVID-19 pandemic provided an opportunity to highlight future issues relating to unrelenting port congestion and shallow water benthic habitat destruction. Similarly, multibeam bathymetric data would likely be a suitable data source to assess sea floor disturbance impacts / recovery during the Anthropause at the AOIs if more data (at higher resolution) spanning the Anthropause become obtainable (public availability of New Zealand bathymetry data are limited to 2016 at a 250 m resolution, Appendix 1).

3) **A gulf in lockdown: how an enforced ban on recreational vessels increased dolphin and fish communication ranges (Pine et al. 2021).**
As result of the COVID-19 lockdown, New Zealand's busiest coastal waterway, the Hauraki Gulf Marine Park, became bereft of almost all recreational and non-essential commercial vessels. In some areas, ambient sound levels dropped nearly threefold in the first 12 hours, with fish and dolphins experiencing an immediate increase in their communication ranges (up to 65%). These data demonstrated how noise from small vessels can impact underwater soundscapes, and how marine animals will have to adapt to ever-growing noise pollution. Similarly, hydrophone data would likely be a suitable data source to assess impacts to the underwater soundscape at the AOIs during the Anthropause; however, suitable data at the specific AOI identified in this study have not yet been identified.

The studies listed above highlight the difference between the vessel traffic intensity at different ports (cargo vs passenger / recreational vessels) during the Anthropause. Based on this, it is important to consider all types of vessel traffic (not just passenger vessels alone) as explanatory variables, as commercial cargo vessel movements at some ports may have increased during the Anthropause, even when passenger and recreational vessels decreased.

The 'Marine Anthropause Research Synthesis (MARS) Project'[14] is a global online collaborative science network with participants who study the relationships between humans and marine ecosystems during the COVID-19 Anthropause. The science network aims to openly publicise the effects of the Anthropause on ocean systems to improve and inform our understanding of marine conservation. The MARS Project also provides a comprehensive reference list of current global scientific literature[15] relating to ecological research undertaken during the COVID-19 Anthropause. A summary of

[14] https://www.anthropauseproject.ca/about/
[15] https://www.anthropauseproject.ca/literature/

the marine ecological effect-based findings to date is provided in Table 1 below, along with the types of data that have been used:

- **Automatic Identification System (AIS) data** for marine traffic for determining vessel pressure (March et al. 2021; Rutz et al. 2022).
- **Multibeam bathymetric data** for determining seabed disturbance (Watson et al. 2022).
- **Long-term air quality monitoring** for determining vessel emissions (Gaiser et al. 2022; Mannarini et al. 2022; Muche et al. 2022).
- **Satellite remote sensing** to detect water quality (e.g. using the kd490[16] diffuse attenuation coefficient; Callejas et al. 2021) and primary productivity changes over the Anthropause period (e.g. chlorophyll-*a* sensing[17]; Shehhi & Abdul Samad 2021; Seelanki & Pant 2021).
- ***In situ* water quality monitoring** (e.g. Patterson Edward 2021; Mallik et al. 2022).
- **Long-term population demographic studies** on marine / coastal animals have been used to show, sometimes dramatic, shifts in spatial extent and reproductive success (e.g. Gaiser et al. 2022; Muche et al. 2022; Lewis et al. 2022; Mallik et al. 2022).
- **Benthic sediment / community surveys** e.g. testing for changes to sediment chemistry and macrofaunal communities during the Anthropause period (e.g. in areas where bottom trawling was halted; Mosbahi et al. 2022).
- **Underwater noise** e.g. hydrophone recording surveys (Pine et al. 2021; Muche et al. 2022).
- **Litter and microplastic surveys** for determining plastic ‘recovery’ (Hassan et al. 2022; Akhbarizadeh et al. 2021; Muche et al. 2022).

The majority of investigations reviewed here examined single ecological data types (as listed above and in Table 1). None of these studies undertook a weight-of-evidence (or multiple lines of evidence) approach to study Anthropause impacts for the AOIs (Hall & Giddings 2000; Norris et al. 2005). However, it is our understanding that the MARS study is undertaking this at a global scale, and that any Stage two results could contribute to this global project.

Most ecological effects (and associated trends) were investigated in areas where marine traffic and activities were high prior to the start of the COVID-19 Anthropause (Wetz et al. 2022). We also note that many of the studies in Table 1 did not discuss seasonality or climate-related variables in their analyses.

[16] The Moderate Resolution Imaging Spectroradiometer (MODIS) on board the NASA Earth Observing System (EOS) Aqua satellite provides information on the Kd490 diffuse attenuation coefficient in water. This measure indicates how strongly light intensity at a specified wavelength is attenuated within the water column and is often used as a proxy for water clarity.
[17] For example, https://www.oceancolour.org/

Table 1. Examples of potential ecological effects identified in the published literature relating to the COVID-19 Anthropause (internationally and nationally) and the associated research trends (with references).

Effect	Anthropause trends	References
Marine traffic	Reduced vessel traffic in tourist areas; increased port congestion	March et al. 2021; Rutz et al. 2022
Reduced shipping emissions	Reduced sulphur emissions from shipping; atmospheric brightening	Gaiser et al. 2022; Mannarini et al. 2022; Muche et al. 2022
Natural area use	Increased domestic use of natural areas, e.g. fishing, poaching and recreation; decreased tourism pressure	Diffenbaugh et al. 2020; Gaiser et al. 2022; Muche et al. 2022; Rutz et al. 2022
Water clarity / quality	Improvements to water quality (WQ), clarity (kd490 as proxy) and faecal indicator bacteria (FIB) concentrations; excessive use of disinfectants reducing WQ	Niroumand-Jadidi et al. 2020 (water clarity); Callejas et al. 2021 (water clarity); Patterson Edward et al. 2021 (FIB and WQ); Ishan et al. 2022 (general pollution); Wetz et al. 2022 (FIB and WQ); Muche et al. 2022 (WQ data summary); Mallik et al. 2022 (WQ summary, incl. disinfectants)
Wildlife behaviour	Improvements (or shifts) to population dynamics and changes to wildlife territories	Rutz et al. 2020 (general); Pine et al. 2021 (dolphin / fish); Gaiser et al. 2022 (general); Muche et al. 2022 (general); Gilby et al. 2020 (birds); Sumasgutner et al. 2021 (birds); Lewis et al. 2022 (seabirds); Quesada-Rodriguez et al. 2021 (turtles); Mallik et al. 2022 (general summary)
Underwater noise	Reduced (tested using hydrophones)	Pine et al. 2021 (Hauraki Gulf Marine Park, NZ); Muche et al. 2022 (general summary).
Benthic disturbance	Increase in anchor footprint and sediment roughness in commercial ports	Watson et al. 2022 (Picton, NZ)
Reef fish	Increased evenness and / or densities	China et al. 2021; Patterson Edward et al. 2021
Personal protective equipment (PPE)-related litter	Increased PPE-related litter	Hassan et al. 2022; Akhbarizadeh et al. 2021; Muche et al. 2022
PPE microplastics	Evidence of decreased and increased densities in different locations	Patterson Edward et al. 2021; Akhbarizadeh et al. 2021
Primary productivity and altered food webs	Reduced concentrations of chlorophyll-*a* (e.g. from reduced aerosol particle loading); potential for trophic cascades or changing fishing / harvesting outcomes	Gaiser et al. 2022 (trophic cascades); Shehhi & Abdul Samad 2021 (remote sensing, North Europe, South China and Southeast USA); Seelanki & Pant 2021 (remote sensing, Indian Ocean)
Benthic macrofauna and sediment chemistry	The absence of trawling during the Anthropause led to a significant increase in biomass, number of species and abundance of total macrofauna	Mosbahi et al. 2022 (benthic surveys, Mediterranean Sea)

4. MARINE TOURISM ACTIVITIES IN AREAS OF INTEREST

Tourism makes a huge contribution to New Zealand's economy, generating over $40 billion and employing over 200,000 people per annum.[18] The pause in tourism-related activities during the COVID-19 lockdown presents a unique opportunity to measure and understand the ecological effects of tourism activity, and consequently gives councils and communities the chance to improve decision-making regarding marine tourism activities and their management. This understanding can result in three types of outcomes: environmental, economic and experiential – since tourists will be able to experience an improved environment.

Marine tourism areas, by nature, are typically significant and valued natural ecosystems, and councils have an obligation to preserve and protect these habitats (NZCPS 2010). With all participating councils projected (by MBIE[19]) to have increased levels of cruise ship visitation over the next few years, it is likely that this will correlate to an overall increase in marine tourism activities (e.g. local cruises, whale / dolphin / seal / bird watching, kayaking, diving charters, fishing charters etc). A better understanding of the impact of these activities on the marine environment would therefore inform a range of planning and operational issues, as well as align with the coastal policy requirements of each council.

The marine tourism operators from each of the five AOIs (Milford Sound / Piopiotahi, Stewart Island / Rakiura, Otago Harbour / Otakou, Akaroa Harbour and Kaikōura Peninsula) and their regional regulatory context[20] (applicable coastal planning regulations for each location) are described below.

Note 1. As well as regional coastal planning requirements, a Department of Conservation (DOC) concession permit is typically required to operate in a national park[21] (land-based), undertake commercial activities involving marine mammals[22] or wildlife[23] and operate watercraft for commercial activities (e.g. kayaking, boat landings, use of DOC wharves).[24]

Note 2. Vessels operating in New Zealand territorial seas are also subject to regulations from:[25] the Resource Management (Marine Pollution) Regulations 1998 (also administered by regional councils), the Maritime Transport Act 1994 (administered by Maritime New Zealand) and the Biosecurity Act 1993 (administered by Biosecurity New Zealand).

[18] https://www.tia.org.nz/about-the-industry/quick-facts-and-figures/
[19] https://www.mbie.govt.nz/assets/1c8d18774f/cruise-infrastructure.pdf
[20] The Resource Management Act 1991 (RMA) is administered by regional councils around the country through council-specific regional coastal plans.
[21] Access/easements: Running your business or activity (doc.govt.nz)
[22] Interacting with marine mammals: Apply for permits (doc.govt.nz)
[23] Interacting with wildlife: Apply for permits (doc.govt.nz)
[24] Watercraft activities: Running your business or activity (doc.govt.nz)
[25] Operating tourist vessels in New Zealand waters - Maritime NZ

4.1. Milford Sound / Piopiotahi

4.1.1. Local operators

Local marine tourism operators in Fiordland are required to have a resource consent to operate in the Fiordland National Park, as per the Fiordland Marine Management Act (FMMA 2005) and the Operative Regional Coastal Plan for Southland (RCPS 2013).

During the 2017–2020 period, there was a slight increase in numbers of local marine tourism operator consents allocated in the Milford Sound / Piopiotahi area (from 71 to 75; ES 2023a). Of these consents, the majority were classified as day trips, backcountry trips (to access remote areas), overnight trips, kayaking and vessel pilotage.

The total number of trips annually in the Milford Sound / Piopiotahi area were between approximately 14,000 and 16,000 from 2017 to 2019 (ES 2023a), with summertime vessel movements in the order of 130 per day.[26] Following lockdown (during 2020), the number of trips in Milford Sound / Piopiotahi reduced to just 25% of the pre-lockdown vessel traffic (approximately 4,000 trips; ES 2023a).

Of the above consented operations, only seven ecotourism operators were identified in the Milford marine area as part of the Sustainable Seas Challenge (SSC).[27] This was perhaps due to a lack of willingness for project participation. The ecotourism operations identified in SSC were:

1. **Descend Diving.** Scuba diving tours in Milford Sound / Piopiotahi.
2. **Rosco's Milford Kayaks**. Offers a variety of kayaking tours in Milford Sound / Piopiotahi.
3. **JUCY Cruise**. Offers scenic Milford Sound / Piopiotahi cruises and land transport from Queenstown and Te Anau.
4. **Fiordland Discovery**. Offers multi-day scenic boat expeditions in Fiordland National Park and Stewart Island / Rakiura on board the *Fiordland Jewel*.
5. **Mitre Peak Cruises**. Offers small scenic cruises in Milford Sound / Piopiotahi with packages (including cruise, coach, flight) from Te Anau and Queenstown.
6. **Southern Discoveries**. Offers nature cruises in Milford Sound / Piopiotahi and packages that include cruises coupled with either coach transport, or kayaking and scenic flights.
7. **Milford Discovery Centre and Underwater Observatory.** Milford Sound / Piopiotahi Observatory is New Zealand's only floating underwater observatory. Visitors can view underwater from a viewing room 10 m below sea level (operated by Southern Discoveries).

[26] https://www.es.govt.nz/repository/libraries
[27] Marine and coastal ecotourism operators - Sustainable Seas National Science Challenge (sustainableseaschallenge.co.nz)

The Milford harbour facilities were upgraded in 2013,[28] including a new breakwater and additional wharves, to deal with congestion during peak cruising periods (described in the section below). The commercial vessels operate out of the harbour at Freshwater Basin, with the majority offering tourist cruises. In addition, the wharf at Deepwater Basin permanently berths 16 commercial fishing vessels and has a recreational marina for licenced berth holders.

Although not strictly marine tourism, the activities at the Milford airport should also be considered given the proximity and interconnectedness with the area's marine tourism activities. The small airport is based at the Milford Sound village, at the head of the fiord that has served the village, tourism industry and fishing boats since 1952. The following airlines use the Milford airspace and contribute to the marine tourism activities in the area (drop offs to cruises and overnight stays), including but not limited to:

- True South Flights (Queenstown)
- Southern Alps Air (Wānaka)
- Milford Sound Scenic Flights (Queenstown)
- Glenorchy Air (Glenorchy Airport, Queenstown)
- Milford Helicopters & Fly Fiordland (Glenorchy Aerodrome, Martins Bay, Te Anau)
- Aspiring Helicopters (Wānaka)
- Air Safaris (Lake Tekapo)
- Air Milford (Queenstown)
- Fiordland by Seaplane (Te Anau)
- Heliworks (Queenstown)
- Glacier Southern Lakes Helicopters / Helicopters Queenstown (Queenstown).

While a number of studies have discussed the impact of flyovers to the visitor experience in Milford (Oyston 2010) or the synergistic effect of combined tourism-related stressors (Sirota 2006), there appears to have been no past studies on the impact of flights (numbers / intensity / noise) to marine wildlife in Milford (e.g. marine mammals). There are also no publicly available flight data over the Anthropause period. Anecdotally, the airport is very busy when weather allows. It is reportedly open / used for approximately 150 days a year,[29] with up to 250 movements a day[30] and approximately 2,431 landings and 681 overflights per year.[31] More detailed data should be obtained through an official information request to the New Zealand Ministry of Transport.[32]

[28] https://www.es.govt.nz/repository/libraries
[29] https://www.1news.co.nz/2021/07/29/milford-airport-removal-sparks-anger-for-pilots/
[30] https://www.stuff.co.nz/business/120938850/coronavirus-milford-operator-raises-safety-concerns-over-closure-of-flight-information-service
[31] https://www.milfordopportunities.nz/assets/Projects/MOP-Gap-Analysis-Summary-Document.pdf
[32] https://www.transport.govt.nz/about-us/what-we-do/queries/how-to-access-milford-sound-piopiotahi-aerodrome/

4.1.2. International operators (cruise ships)

As a way to implement the Regional Coastal Plan requirements, international cruise ship operators entering into the Fiordland marine area are required to have acknowledged and signed the 'Environment Southland Deed of Agreement between Cruise Ship Operators and Environment Southland' ('The Deed'; ES 2021).

The Deed (ES 2021) specifies that only two cruise ships are allowed within Milford Sound / Piopiotahi per day and identifies the only approved cruise ship anchorages off Williamson Point in Harrisons Cove (Figure 2). At this anchorage, a maximum of four ancillary vessels (i.e. tenders) are also allowed per ship. There are no limits in place for the number of visits larger vessels can make annually.

The New Zealand Cruise Association (NZCA)[33] cruise ship schedules were available for download for the 2018–2019, 2019–2020 and the forecasted 2022–2023 schedules. It is assumed the 2020–2021 and 2021–2022 schedules are not provided, as there were no cruise ships allowed (or scheduled) into the country during that time (i.e. during the Anthropause). The NZCA location entry in the Southland region has no Milford Sound / Piopiotahi specific location data and only defines the 'Fiordland' region as a destination (i.e. the schedules do not specify the exact location of the port trip or anchorage). The number of scheduled trips to Fiordland (some of which may not have visited Milford Sound / Piopiotahi) are summarised below. The data shows a clear reduction in traffic during the lockdown period (2020–2022):

- 2018–19 = 116 trips scheduled (4 trips cancelled)
- 2019–20 = 101 trips scheduled (30 trips cancelled)
- 2020–21 = 0 trips scheduled
- 2021–22 = 0 trips scheduled
- 2022–23 = 102 trips scheduled (no trips cancelled)

Note that the records for the 2022/23 season may have changed due to more recent cancellations occurring.

Cruise ships typically arrived and departed Fiordland on the same day, with the occasional overnight trip. The cruise trip season in Fiordland was from late September to early April (spring to autumn).

[33] https://newzealandcruiseassociation.com/#

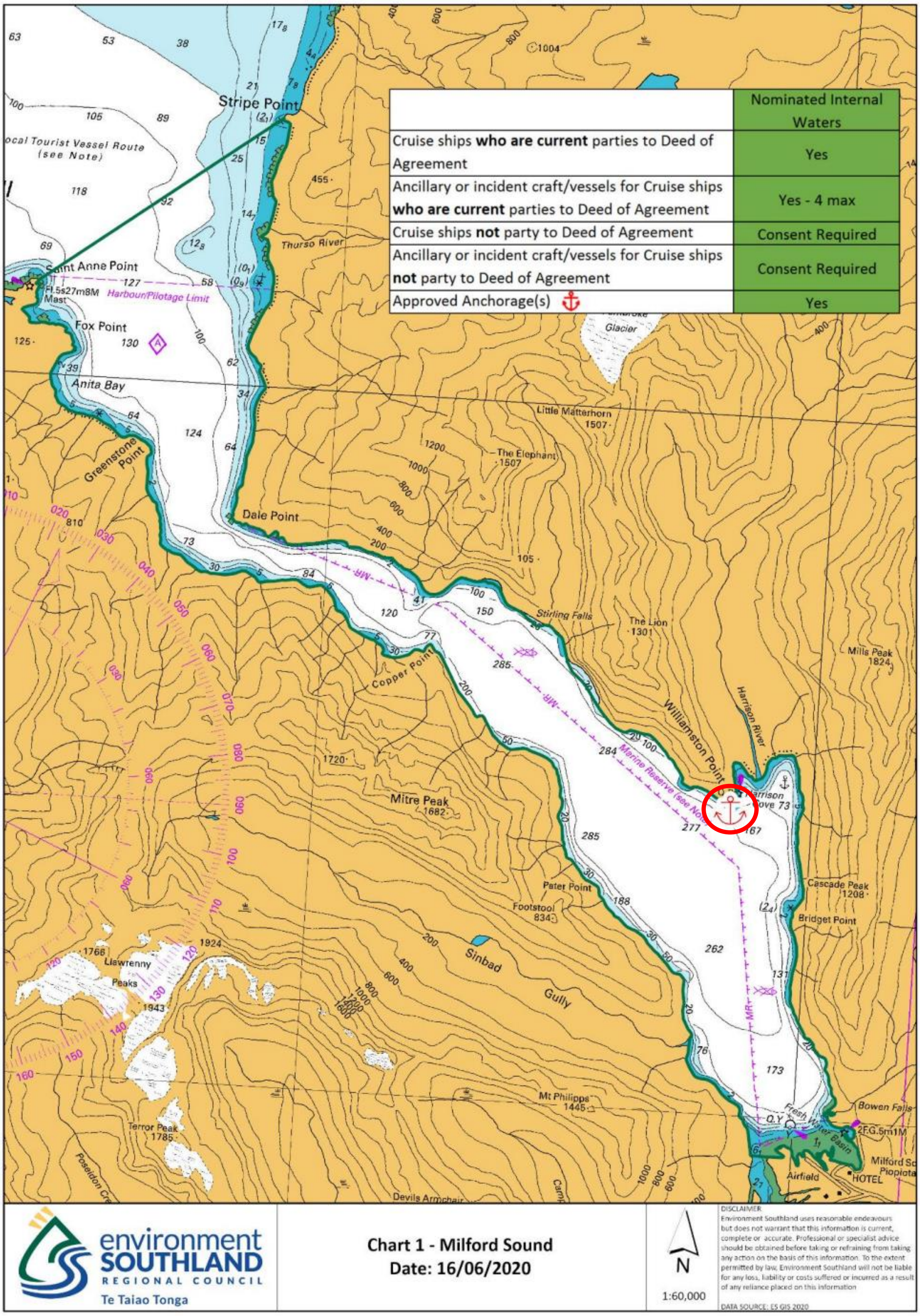

Figure 2. Milford Sound / Piopiotahi designated cruise ship anchoring location (red circle). Extracted from the Deed of Agreement between Cruise Ship Operators and Environment Southland (ES 2021).

Preliminary investigation of the Global Maritime Traffic (GMT 2023) passenger vessel density maps shows a decrease in passenger vessel traffic (defined in Section 2.2) during the Anthropause (Figure 3). Although vessel traffic during the Anthropause was lower than the pre-Anthropause period, local operators appeared to remain active within the inner Milford Sound / Piopiotahi during some of this time (December 2021; Figure 3), and there appears to have been a lag in vessel traffic following the borders reopening (i.e. reduced vessel density).

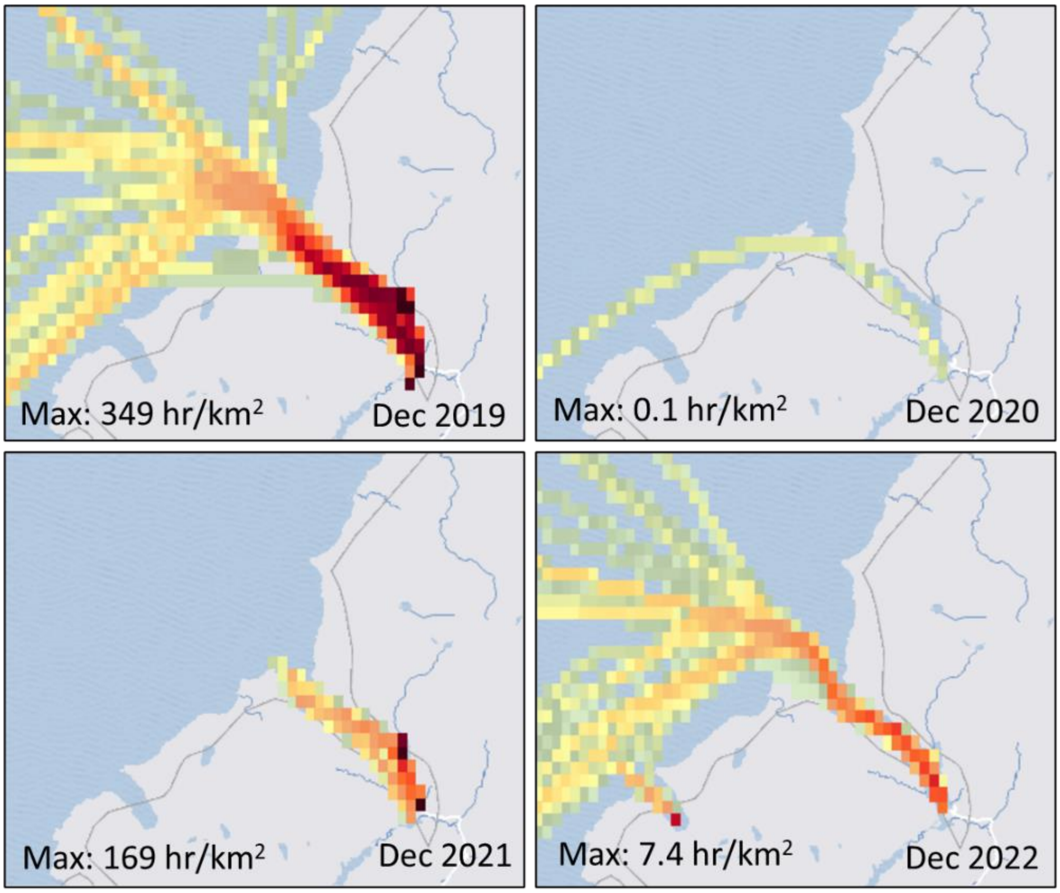

Figure 3. Passenger vessel density (hr/km^2) during December 2019, 2020, 2021 and 2022 in the vicinity of Milford Sound / Piopiotahi. Excerpts taken from GMT 2023. The 2020 and 2021 images represent periods during the Anthropause (19 March 2020 to 31 July 2022). Darker colours represent higher densities.

4.2. Stewart Island / Rakiura

4.2.1. Local operators

Local marine tourism operators in Stewart Island / Rakiura are not required to have a resource consent to operate in the area, as per the Operative Regional Coastal Plan for Southland (RCPS 2013). Therefore, unlike for Milford Sound / Piopiotahi, the regional council doesn't maintain a list of ecotourism operators (consent holders). However, nine marine ecotourism operators were identified in the vicinity of Oban, Stewart Island / Rakiura (the main township of the island) as part of the SSC[34] (given their base location, it is assumed that they mostly operate in the Halfmoon Bay and Paterson Inlet / Whaka a Te Wera areas). This list may not be exhaustive.

- **Rakiura Charters.** Offers birding, wildlife and scenic tours on Stewart Island / Rakiura. Also offers water taxi services, customised tours or group experiences.
- **Aihe Eco Charter and Water Taxi**. Operates exclusively around Stewart Island / Rakiura, offering cruises, wildlife viewing, pelagic birding, water taxi charters, hunter transport and Freshwater River / Mason Bay packages. *Aihe* (the vessel) is also available for private charters, customised tours and group bookings.
- **Bravo Adventure Cruises**. Offers scenic charters and pelagic seabird trips around Stewart Island / Rakiura. Also offers charters for transporting hunting or tramping parties.
- **Aurora Charters.** Offers scenic trips around Stewart Island / Rakiura aboard the *Aurora*. Also specialises in pelagic bird trips and offers transport options for kayaks and hunting parties.
- **Phil's Sea Kayak.** Offers guided sea kayak tours of Stewart Island / Rakiura.
- **Stewart Island Adventures.** Offers snorkel and freediving guided tours around Stewart Island / Rakiura.
- **Mana Charters**. Offers boat charters for hunting, diving, tramping, harbour cruises and scenic tours around Bluff and Stewart Island / Rakiura.

Although not identified in the SSC ecotourism project, Stewart Island / Rakiura also has a regular ferry service35 between Bluff and Oban (Stewart Island / Rakiura) and ferries to Ulva Island (the 'Ulva Island Explorer'36) from Realnz37. The following ecotourism operators in the region were also identified by Environment Southland:

- **Gravity Fishing Limited.**[38] Offers fishing trips (multi-day, day, groups of up to 12 people) around Stewart Island / Rakiura (based in Bluff).

[34] Marine and coastal ecotourism operators - Sustainable Seas National Science Challenge (sustainableseaschallenge.co.nz)
[35] https://www.stewartisland.co.nz/organisations/travelling-to-stewart-island/stewart-island-experience-ferry/
[36] https://www.realnz.com/en/experiences/cruises/ulva-island-explorer/
[37] https://www.realnz.com/en/destinations/stewart-island/
[38] https://gravityfishing.co.nz/

- **Heritage Expeditions.**[39] Offers expedition-style travel around Stewart Island / Rakiura and subantarctic areas aboard the 140-guest ship *Heritage Adventurer* and 18-guest yacht *Heritage Explorer* (based in Christchurch).

4.2.2. International operators (cruise ships)

Similar to Milford / Piopiotahi, international cruise ship operators entering into the coastal marine area around Stewart Island / Rakiura are required to have acknowledged and signed the Deed of Agreement (ES 2021; Figure 4).

At Stewart Island / Rakiura, the Deed (ES 2021) specifies that cruise ships may only enter Halfmoon Bay (Oban) and Paterson Inlet / Whaka a Te Wera (directly south of Oban). Only two cruise ships are allowed within Paterson Inlet / Whaka a Te Wera per day at one of the three approved cruise ship anchorages (Figure 4). At these anchorages, a maximum of four ancillary vessels (i.e. tenders) are also allowed per ship. There are no limits in place for the number of visits larger vessels can make annually.

The number of NZCA[40] scheduled cruise ship trips to Stewart Island / Rakiura are summarised below, showing a clear reduction in traffic during the lockdown period (2020–2022):

- 2018–19 = 17 trips scheduled (0 trips cancelled)
- 2019–20 = 17 trips scheduled (7 trips cancelled)
- 2020–21 = 0 trips scheduled
- 2021–22 = 0 trips scheduled
- 2022–23 = 21 trips scheduled (no trips cancelled)

Note that that records for the 2022/23 season may have changed due to more recent cancellations occurring.

Cruise ships typically arrived and departed Stewart Island / Rakiura on the same day. The cruise trip season in Stewart Island / Rakiura was from November to March / April (summer).

[39] https://www.heritage-expeditions.com/about/

[40] The only vessel specific records (schedule) for cruise ships available for this assessment were from the New Zealand Cruise Association (NZCA) website, and included the 2018–2019, 2019–2020 and the forecasted 2022–2023 schedules. It is assumed the 2020–2021 and 2021–2022 schedules are not provided, as there were no cruise ships allowed (or scheduled) into the country during that time.

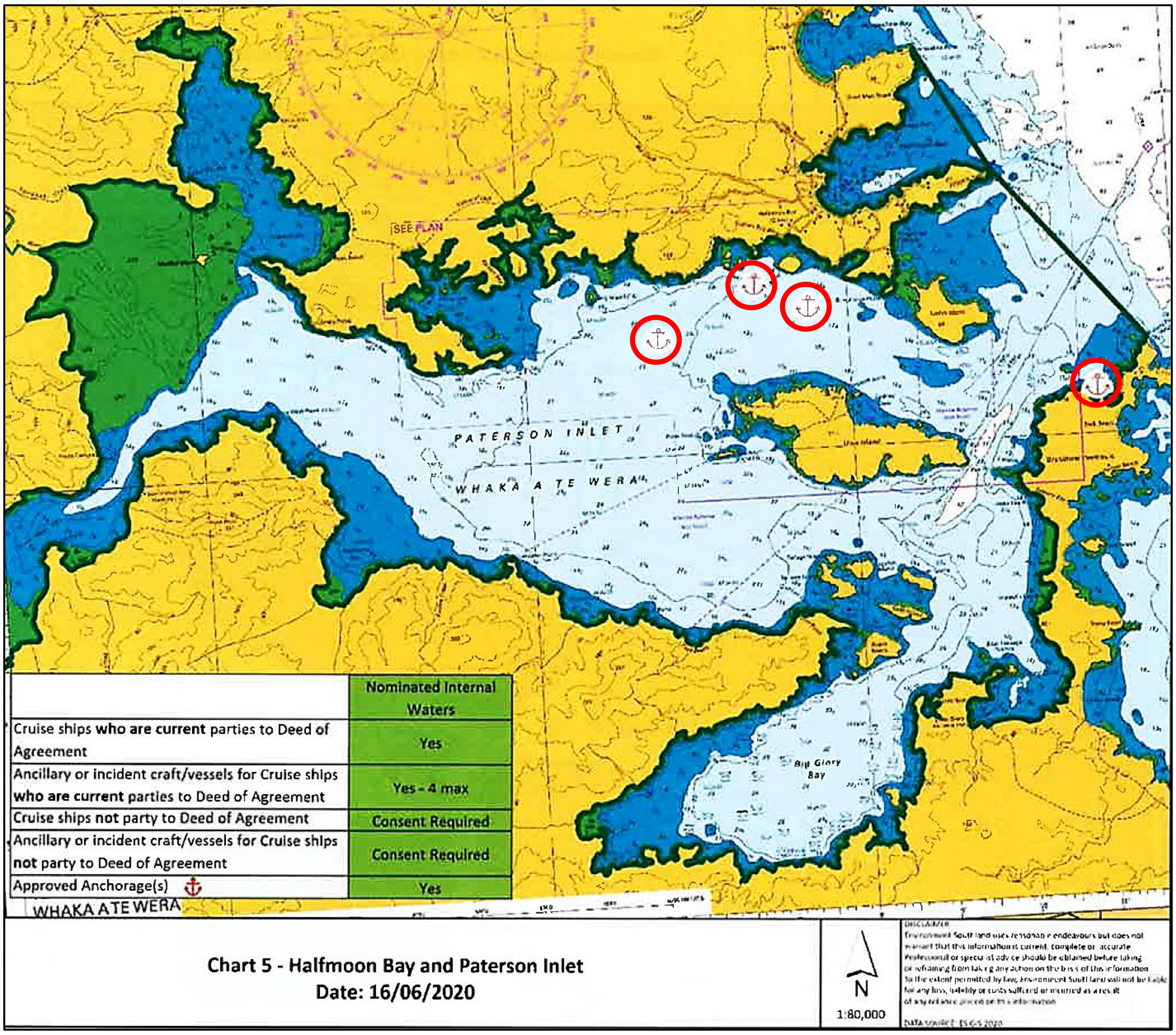

Figure 4. Stewart Island / Rakiura designated cruise ship anchoring locations (red circles). Extracted and cropped from the Deed of Agreement between Cruise Ship Operators and Environment Southland (ES 2021).

Preliminary investigation of the Global Maritime Traffic (GMT 2023) passenger vessel density maps shows a decrease in passenger vessel (defined in Section 2.2) traffic during the Anthropause (Figure 5). Although vessel traffic during the Anthropause was lower (0 hr/m^2 during December 2021) than the pre-Anthropause period (up to 52 hr/m^2), local passenger vessels appeared to be active in the vicinity of Stewart Island / Rakiura during some of this time (December 2020; Figure 3). There also appears to have been a slight lag in vessel traffic following the borders reopening (i.e. slightly reduced vessel density in December 2022).

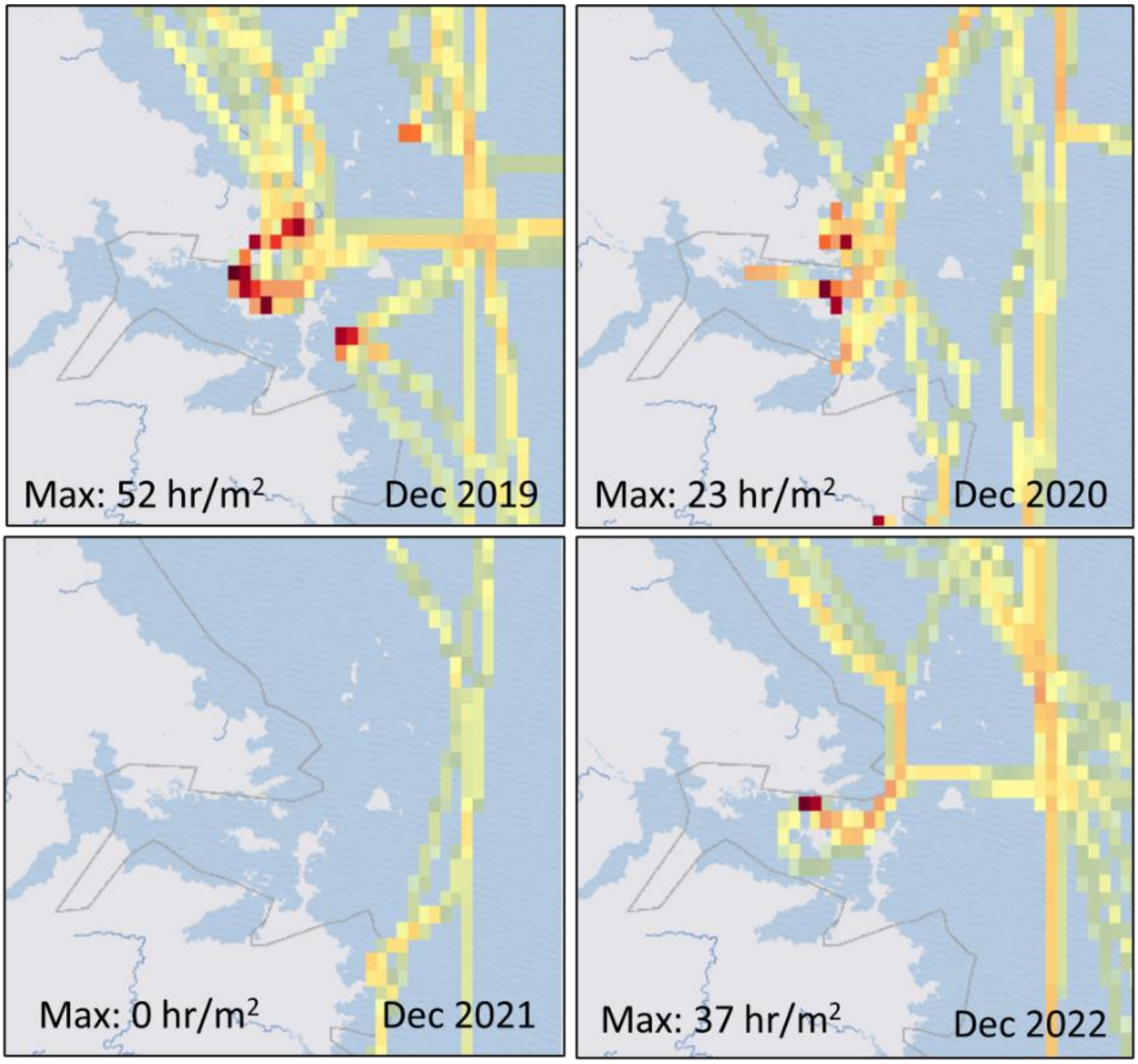

Figure 5. Passenger vessel density (hr/km^2) during December 2019, 2020, 2021 and 2022 in the vicinity of Stewart Island / Rakiura (Paterson Inlet / Whaka a Te Wera). Excerpts taken from GMT 2023. The 2020 and 2021 images represent periods during the Anthropause (19 March 2020 to 31 July 2022). Darker colours represent higher densities.

4.3. Otago Harbour / Otakou

4.3.1. Local operators

Local marine tourism operators in Otago Harbour / Otakou are not required to have a resource consent to operate, as per the Regional Coastal Plan for Otago (ORC 2012). Therefore, the Otago Regional Council doesn't maintain a list of ecotourism operators (consent holders). However, 14 marine ecotourism operators were identified in Otago Harbour / Otakou as part of the SSC.[41] This list may not be exhaustive.

- **Monarch Wildlife Cruises & Tours.** Offers wildlife cruises and tours in Dunedin.
- **Back to Nature Tours**. Offers nature tours and activities in Dunedin.
- **UntamedNZ Tour Company.** Offers half-day or full-day shore excursion around Dunedin or multi-day adventures.
- **Horizon Tours.** Offers small group tours with a focus on wildlife, Māori culture, and the history of Dunedin and the Otago Peninsula.
- **Dive Otago**. Offers diving professional career courses, diver training (PADI) and dive trips.
- **Elm Wildlife Tours.** Offers wildlife tours on the Otago Peninsula, Dunedin.
- **Port to Port Cruises and Wildlife Tours.** Include albatross wildlife cruises, ferry transfers and private charters around the Otago Harbour / Otakou.
- **Penguin Place.** Private conservation reserve dedicated to helping the endangered yellow-eyed penguin / hoiho. Offers interpretive tours of the conservation reserve.
- **Natures Wonders Naturally**. Offers wildlife tours on the Otago Peninsula, Dunedin.
- **The Royal Albatross Centre.** Provides wildlife and cultural tours of Taiaroa Head where the world's only mainland breeding colony of royal albatross / toroa is located, the historic Fort Taiaroa and the little blue penguin / kororā colony at Pilots Beach.
- **Port to Port Cruises and Wildlife Tours**. Includes albatross wildlife cruises, ferry transfers and private charters around the Otago Harbour / Otakou.
- **4 Nature Tours.** Specialises in small group guided nature tours around Dunedin, including viewing yellow-eyed penguins / hoiho.
- **Wild Earth Adventures**. Offers sea kayaking tours and lessons around the Otago Peninsula.
- **Nature Quest NZ Ltd**. Specialises in nature, botanical and birding tours (e.g. albatross and penguins).

[41] Marine and coastal ecotourism operators – Sustainable Seas National Science Challenge (sustainableseaschallenge.co.nz)

There is also the Otago Yacht Club Inc. (off Magnet Street), which caters for small passenger vessels, with large vessel berthing facilities at Port Chalmers (managed by Port Otago Ltd).

4.3.2. International operators (cruise ships)

Port Otago recently spent $750,000 on a dedicated space for cruise passengers at Port Chalmers. The cruise terminal has 250,000 passengers passing through annually.[42]

Port Otago operates a cruise terminal at Port Chalmers during the cruise ship season to accommodate passengers' needs. The majority of cruise ships berth at Port Chalmers, but smaller cruise ships can berth in Dunedin port. While the cruise ships do not require resource consent to access Otago Harbour / Otakou, the New Zealand Maritime Security Act 2004 and associated regulations require all vessels entering ports that service international shipping (e.g. Port Chalmers and Dunedin Port) to work within set rules. Cruise ship access requirements[43] for facilities at Port Chalmers and Dunedin do not appear to contain limits to the number of cruise ships that can anchor or berth in the Harbour per day, or the use of tenders. There are also no limits in place for the number of visits cruise ships can make annually.

The number of NZCA[44] scheduled cruise ship trips to Otago Harbour / Otakou (includes ports described as either 'Dunedin' or 'Port Chalmers') are summarised below, showing a clear reduction in traffic during the lockdown period (2020–2022):

- 2018–19 = 118 trips scheduled (4 trips cancelled; 1 October 2018 to 30 March 2019)
- 2019–20 = 112 trips scheduled (18 trips cancelled; 1 October 2019 to 19 April 2020)
- 2020–21 = 0 trips scheduled
- 2021–22 = 0 trips scheduled
- 2022–23 = 110 trips scheduled (no trips cancelled; 26 October 2022 to 9 April 2023)

Note that the records for the 2022/23 season may have changed due to more recent cancellations occurring.

The available data show cruise ships typically arrived and departed Otago Harbour / Otakou on the same day. The cruise trip season in Otago Harbour / Otakou was from October / November to March / April (spring / summer).

[42] https://www.portotago.co.nz
[43] https://www.portotago.co.nz/cruise-ships/tour-operators/
[44] The only vessel specific records (schedule) for cruise ships available for this assessment were from the New Zealand Cruise Association (NZCA) website, and included the 2018–2019, 2019–2020 and the forecasted 2022–2023 schedules. It is assumed the 2020–2021 and 2021–2022 schedules are not provided, as there were no cruise ships allowed (or scheduled) into the country during that time.

Preliminary investigation of the Global Maritime Traffic (GMT 2023) passenger vessel density maps shows a decrease in passenger vessel traffic during the Anthropause (Figure 6). Although vessel traffic during the Anthropause was lower (0 hr/m^2 during December 2021) than the pre-Anthropause period (up to 623 hr/m^2), local passenger vessels appeared to be active in the vicinity of Otago Harbour / Otakou during some of this time (e.g. December 2020; Figure 6). There also appears to have been a lag in vessel traffic following the borders reopening (i.e. slightly reduced vessel density in December 2022).

Figure 6 (December 2019 and 2020) appears to show high passenger ship densities at Portobello (adjacent to the Port Chalmers berthing facilities), suggesting vessels may be anchoring or holding position there, as well as at the Port Chalmers and Port Otago berthing facilities. From the data available (GMT 2023), it is not clear what type of passenger vessels these are (they could be recreational vessels, smaller commercial passenger vessels or cruise ships).

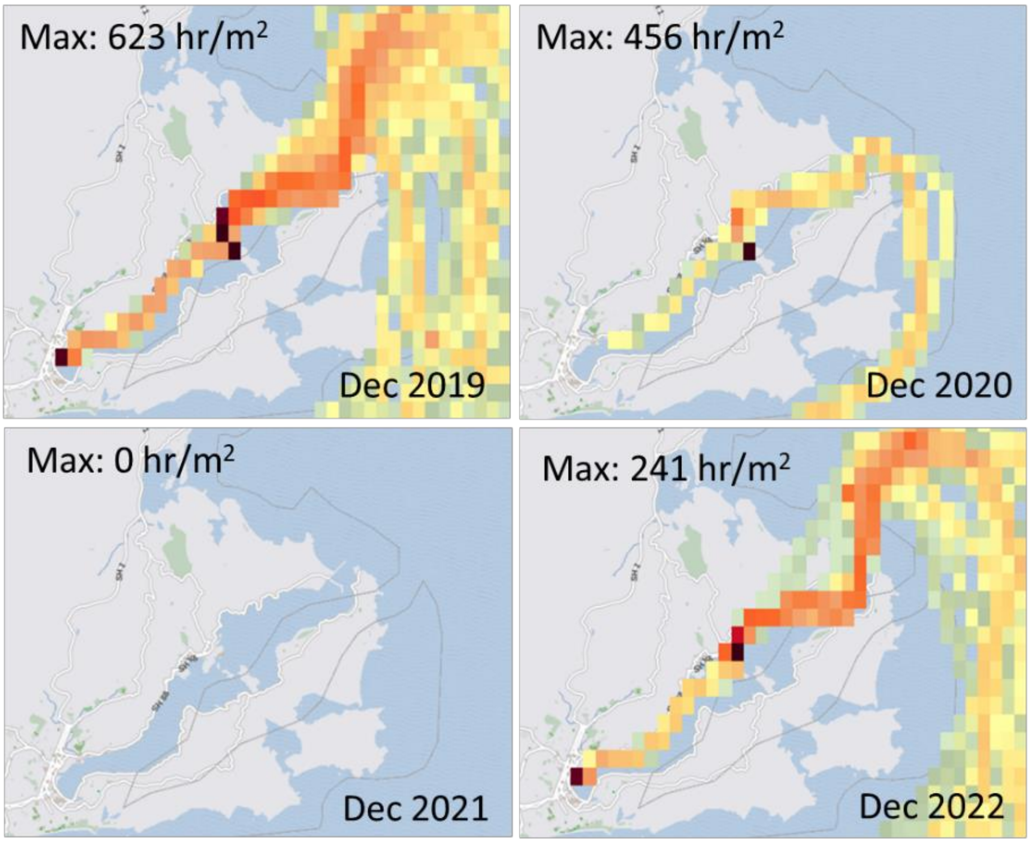

Figure 6. Passenger vessel density (hr/km^2) during December 2019, 2020, 2021 and 2022 in the vicinity of Otago Harbour / Otakou. Excerpts taken from GMT 2023. The 2020 and 2021 images represent periods during the Anthropause (19 March 2020 to 31 July 2022). Darker colours represent higher densities.

4.4. Akaroa Harbour

4.4.1. Local operators

Local marine tourism operators in Akaroa Harbour are not required to have a resource consent to operate in the harbour, as per the Regional Coastal Environment Plan (RCEP 2005). Therefore, the council (CRC) does not maintain a list of ecotourism operators (consent holders). However, 10 marine ecotourism operators were identified in the harbour as part of the SSC[45]. This list may not be exhaustive.

- **Onuku Dolphin Swim.** Offers Hector's dolphin swimming experiences in Akaroa harbour.
- **Coast Up Close**. Offers ocean tours and marine wildlife experiences in Akaroa as well as group tours and fishing charters.
- **Black Cat Cruises**. Offers harbour cruises and swimming with dolphins' experiences in Akaroa.
- **The Southern Wanderer Scenic Cruises.** Akaroa wildlife cruises (8 passenger vessel).
- **Akaroa Dolphins**. Offers dolphin harbour nature cruises in Akaroa. Private charters are also available.
- **Akaroa Seal Colony Safari**. Offers seal colony tours in Akaroa.
- **Akaroa Fox Sail**. Offers wildlife cruises in Akaroa as well as private charters.
- **Pohatu Penguins**. Offers Penguin tours and Wildside Discovery tours in the Akaroa area. Also offers sea kayaking safaris and a farm-stay experience.
- **Ecoseaker Ltd**. Offers dolphin swimming experiences and harbour cruises in Akaroa.
- **Akaroa Guided Sea Kayak Safaris.** Offers guided kayaking tours in the Akaroa marine reserve, viewing Hector's dolphins, New Zealand fur seals / kekeno and a variety of sea birds.

In addition, the Akaroa Yacht Club Inc. (off Beach Road) caters for small passenger vessels, with larger vessel berthing facilities (e.g. cruise ship tenders) available at Akaroa wharf, which is managed by Christchurch City Council.

4.4.2. International operators (cruise ships)

Christchurch City Council is planning a new wharf for Akaroa, which will help to cater for cruise ship tender vessels and local operators. The Akaroa Harbour Navigation Safety Operating Requirements (CRC 2022a) specify the obligations and restrictions of cruise ships entering the harbour (e.g. vessel length, speed, under-keel clearance, visibility, night-time travel restrictions, thruster use, etc.). The principles of operation were developed with the community to safeguard the unique Akaroa Harbour environment. It also specifies where anchoring in the harbour can take place, which is

[45] Marine and coastal ecotourism operators - Sustainable Seas National Science Challenge (sustainableseaschallenge.co.nz)

largely dependent on the draft of the vessel and the shallow nature of the inner harbour. There are four anchorages for visiting cruise ships from the 10 m depth contour adjacent Wainui Bay, heading northeast towards French Bay (Figure 7).

The CRC (2022a) requirements also specify that only two vessels greater than 100 m length between perpendiculars (LBP) may anchor in Akaroa Harbour at any one time, and no vessel > 50,000 tonnes displacement may anchor within Akaroa Harbour without resource consent[46] or scientific evidence of no adverse effects. There are also limits[47] in place for the number of visits larger vessels can make annually.

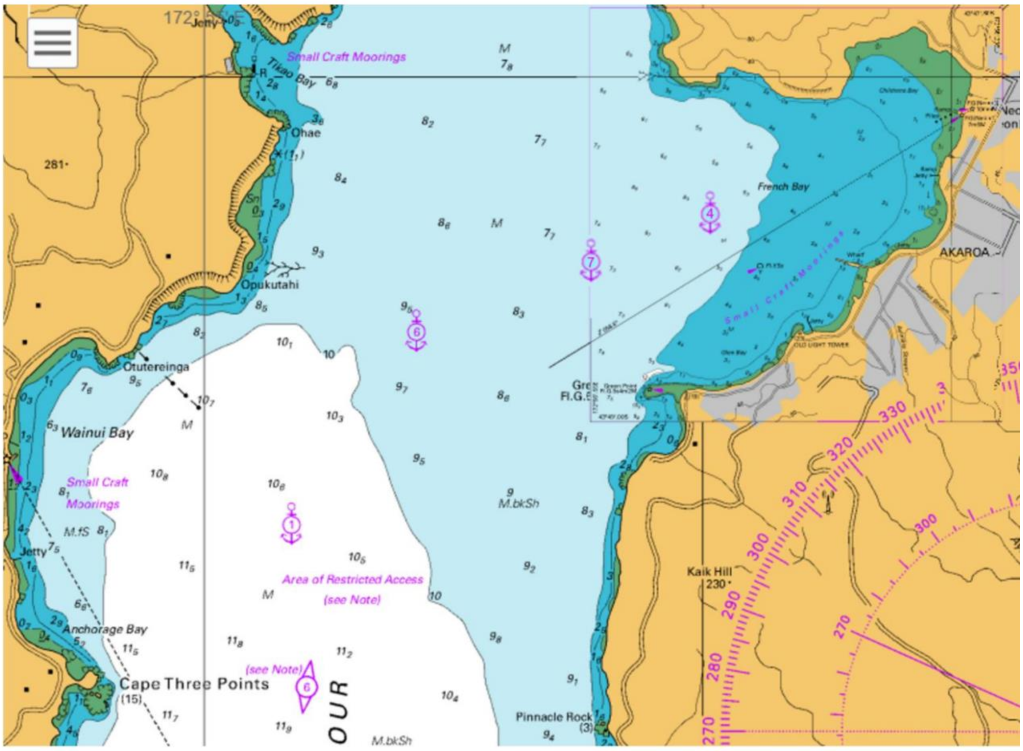

Figure 7. Anchorage locations for large vessels in Akaroa Harbour (purple anchor symbols). Vessels exceeding 8 metres draft and intending to anchor must remain outside the 10-metre depth contour. Site no.1: anchorages for vessels over 8.0 metres draft. Site no.6: anchorages for vessels 8.0 metres draft or less. Site no.7: anchorages for vessels 5.0 metres draft or less. Site no.4: anchorages for vessels 4.0 metres draft or less. Excerpt taken from CRC (2022a).

[46] The RCEP (2005) allows for the disturbance of the seabed of up to 5 m^3 in any 12-month period (a permitted activity.

[47] Allowable visits anchoring per 12-month period:
i. Vessels < 100 m LBP: multiple visits
ii. Vessels > 100 m but < 150 m LBP: 3 visits
iii. Vessels > 150 m but < 200 m LBP: 2 visits
iv. Vessels > 200 m but < 260 m LBP: 1 visit
v. Vessels > 260 m LBP: Consent or scientific evidence of no adverse effects required.

The number of NZCA[48] scheduled cruise ship trips from 2018–2023 to Akaroa are summarised below, the scheduling shows a clear reduction in traffic during the lockdown period (2020–2022):

- 2018–19 = 91 trips scheduled (2 trips cancelled; 2 October 2018 to 13 April 2019)
- 2019–20 = 78 trips scheduled (15 trips cancelled; 5 October 2019 to 20 April 2020)
- 2020–21 = 0 trips scheduled
- 2021–22 = 0 trips scheduled
- 2022–23 = 17 trips scheduled (no trips cancelled; 19 November 2022 to 15 March 2023)

Note that the records for the 2022/23 season may have changed due to more recent cancellations occurring.

The available data show cruise ships typically arrived and departed Akaroa Harbour on the same day. The cruise trip season in Akaroa Harbour was from October / November to March / April (spring / summer).

Preliminary investigation of the Global Maritime Traffic (GMT 2023) passenger vessel density maps shows a decrease in passenger vessel traffic during the Anthropause (Figure 8). Passenger vessel traffic during the Anthropause was consistently lower (0 hr/m^2 during December 2021 and 2022) than pre- and post-Anthropause periods (up to 94–544 hr/m^2 in 2019 and 2022, respectively). Unlike other AOIs, there was a higher density of passenger vessel traffic following the borders reopening (i.e. December 2022).

[48] The only vessel specific records (schedule) for cruise ships available for this assessment were from the New Zealand Cruise Association (NZCA) website, and included the 2018–2019, 2019–2020 and the forecasted 2022–2023 schedules. It is assumed the 2020–2021 and 2021–2022 schedules are not provided, as there were no cruise ships allowed (or scheduled) into the country during that time.

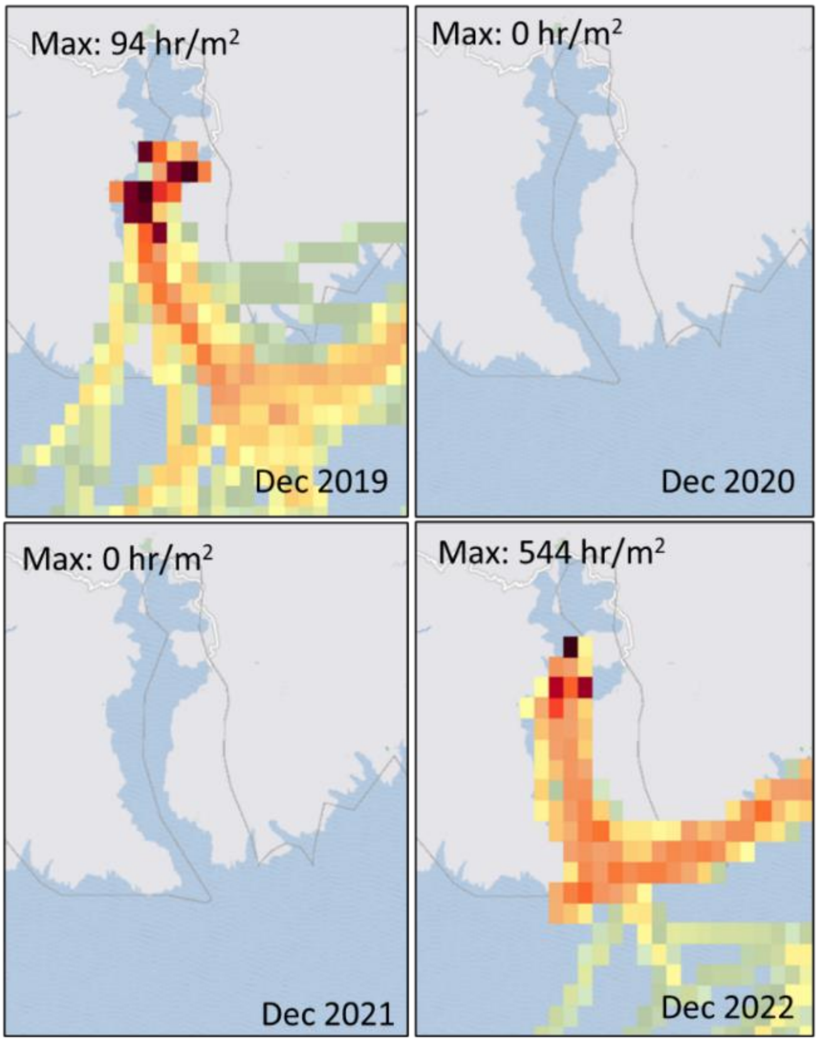

Figure 8. Passenger vessel density (hr/km^2) during December 2019, 2020, 2021 and 2022 in the vicinity of Akaroa Harbour. Excerpts taken from GMT 2023. The 2020 and 2021 images represent periods during the Anthropause (19 March 2020 to 31 July 2022). Darker colours represent higher densities.

4.5. Kaikōura Peninsula

4.5.1. Local operators

Local marine tourism operators in Kaikōura are not required to have a resource consent to operate, as per the Regional Coastal Environment Plan (RCEP 2005). Therefore, the council does not maintain a list of ecotourism operators (consent holders). However, 16 marine ecotourism operators were identified in the Kaikōura marine coastal area as part of the SSC[49]. This list may not be exhaustive.

- **Wings Over Whales**. Offers whale watching flights and scenic flights based out of Kaikōura.
- **Albatross Encounter Kaikōura**. Offers albatross and sea bird watching tours in the Kaikōura area.
- **Dolphin Encounter Kaikōura**. Offers interactive dolphin swimming in the Kaikōura area.
- **Kaikōura Kayaks.** Offers wildlife and other kayaking guided tours in the Kaikōura area as well as paddle board hire.
- **South Pacific Helicopters.** The sister company to Wings over Whales. Offers whale flights and scenic flights.
- **Seal Swim Kaikōura.** Offers a swimming with seals experience on the east coast.
- **Kaikōura Helicopters**. Offers scenic flights including whale watching flights in Kaikōura. Also provides commercial applications using helicopters in the Kaikōura region.
- **Seal Kayak Kaikōura**. Offers guided sea kayak tours, including New Zealand fur seal / kekeno viewing and sunset tours.
- **Whale Watch Kaikōura**. Offers whale watching tours in Kaikōura.
- **Kiwi Surf Experience**. Offers surf lessons, surf hire and accommodation in Kaikōura.
- **Kaikōura Fishing Charters.** Offers sightseeing and crayfishing and deep-water fishing trips.
- **Kaikōura Fishing Tours.** Offers a 2-hour excursion with the opportunity to catch a variety of fish, including crayfish (New Zealand lobster), which are plentiful around the Kaikōura coastline. Three- and 4-hour excursions are also available, as well as full-day trips.
- **Kaikōura Marine Tours.** Offers 'eco tours' for environmentally aware travellers to view the unique marine wildlife around Kaikōura.
- **Top Catch Charters.** Offers small group fishing tours in Kaikōura aboard a purpose built 6.2 m Osprey boat, *First Light*.
- **Seamist Fishing Charters.** Offers a range of fishing charters, from 2 to 7 hours, for up to 20 people.

[49] Marine and coastal ecotourism operators - Sustainable Seas National Science Challenge (sustainableseaschallenge.co.nz)

- **Rodfather Fishing Charters Kaikōura.** Offers fishing and diving charters year-round for all levels of fishing experience. Half-, full-day and evening fishing charters are available with fishing gear provided.

South Bay Harbour (managed by Kaikōura District Council) is the primary hub for marine-based activities around Kaikōura, with many of the operators listed above actively using the harbour daily. As well as the tourism operators with the largest vessels (up to 30 m in length) and the local commercial fishing fleet, the harbour caters for the coastguard and recreational vessels. The South Bay Harbour is in the process of planning an upgrade[50] to remediate the lack of space and address the changes in wave patterns and ocean currents since the Kaikōura earthquake. The upgrade will also improve substandard onshore facilities for commercial and recreational users. The plan includes the expansion of existing operations and future proofing for alternative uses, e.g. marine berth hire, cruise ship tender berthing, aquaculture, and / or marine research facilities.

4.5.2. International operators (cruise ships)

The Kaikōura Peninsula Navigation Safety Operating Requirements (CRC 2022b) specify the obligations of, and restrictions to, cruise ships visiting Kaikōura Peninsula (vessel length, speed, under-keel clearance, visibility, night-time travel restrictions, available wharves for land access, etc.). It also specifies where anchoring around the peninsula can take place, and the available wharves for land access. There are two possible anchorages identified for visiting cruise ships to the north and south of the peninsula (Figure 9). However, cruise ships are permitted to anchor anywhere as long as the under-keel clearance is achieved.

The CRC (2022b) requirements do not specify a maximum number of vessels for anchorage at any one time. There is, however, a vessel length restriction of 215 m, above which the operator needs the Harbour Master's permission to enter the area. There are no limits in place for the number of visits cruise ships can make annually.

The number of NZCA scheduled cruise ship trips from 2018–2023 to Kaikōura are summarised below, with a clear reduction in traffic during the lockdown period (2020–2022):

- 2018–19 = 9 trips scheduled (0 trips cancelled; 8 November 2018 to 5 March 2019)
- 2019–20 = 12 trips scheduled (3 trips cancelled; 3 October 2019 to 21 April 2020)
- 2020–21 = 0 trips scheduled
- 2021–22 = 0 trips scheduled
- 2022–23 = 16 trips scheduled (no trips cancelled; 14 Nov 2022 to 16 Mar 2023)

[50] https://www.Kaikōura.govt.nz/assets/Uploads/South-Bay-Harbour-Redevelopment-Business-Case.pdf

Note that the records for the 2022/23 season may have changed due to more recent cancellations occurring.

The available data show cruise ships typically arrived and departed Kaikōura on the same day. The cruise trip season in Kaikōura was from October / November to March / April (spring / summer).

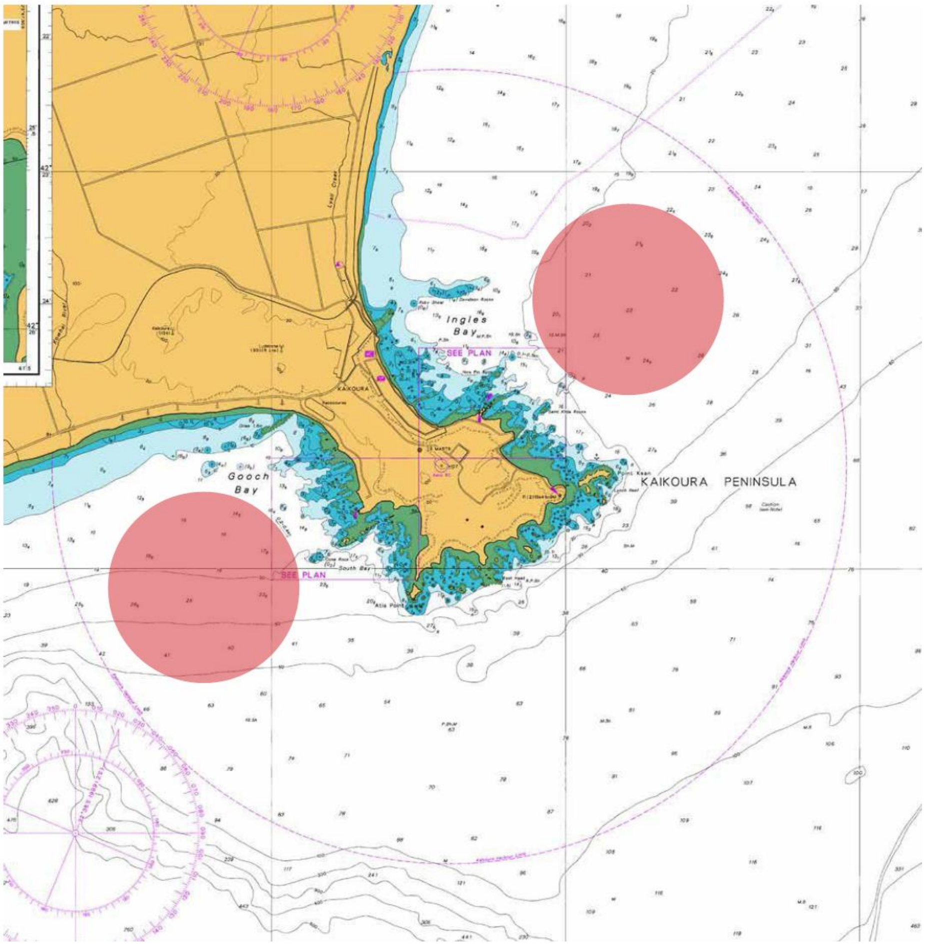

Figure 9. Possible anchorage locations for large vessels in the vicinity of Kaikōura Peninsula (red circles). Masters may anchor to the southwest or northeast of the peninsula. It is also permitted to slow steam or drift rather than anchor. Source: CRC (2022b).

Preliminary investigation of the Global Maritime Traffic (GMT 2023) passenger vessel density maps shows a decrease in passenger vessel traffic during the Anthropause (Figure 10). Passenger vessel traffic during the Anthropause was notably lower (0 hr/m^2 during December 2021 and 2022) than pre- and post-Anthropause periods (up to 38–14 hr/m^2 in 2019 and 2022, respectively). There appears to be a slightly lower density of passenger vessel traffic following the borders reopening (lag period), compared to the pre-Anthropause period (i.e. December 2022).

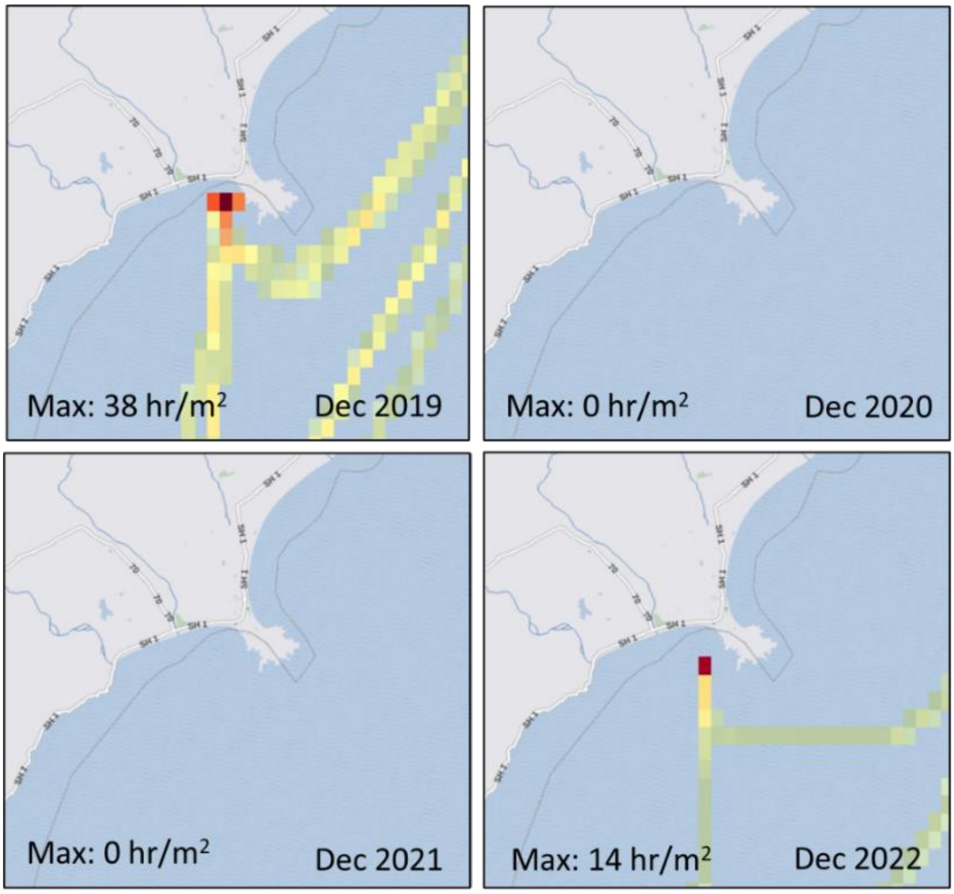

Figure 10. Passenger vessel density (hr/km^2) during December 2019, 2020, 2021 and 2022 in the vicinity of Kaikōura Peninsula. Excerpts taken from GMT 2023. The 2020 and 2021 images represent periods during the Anthropause (19 March 2020 to 31 July 2022). Darker colours represent higher densities.

5. DATA SUITABILITY AND PRELIMINARY FINDINGS

All data compiled are available in Appendix 1, and the data summary below represents a description of the potentially suitable data sources (ranked 6 or higher) for each AOI.

Emerging forms or sources of data (not identified in the tables below) may become available over time. Therefore, the data sources identified below should be regarded as preliminary, and all current available datasets should be considered in the Stage two assessment. For example, although not currently defined as 'suitable', multibeam bathymetric data[51] could also be a suitable data source to assess sea floor disturbance impacts / recovery during the Anthropause at the AOIs (Section 3).

5.1. Milford Sound / Piopiotahi

Of the 85 ecological data sources reviewed for Milford Sound / Piopiotahi (Appendix 1), 15 data sources were deemed potentially suitable for further (Stage two) analyses (Table 2). The potentially suitable data types presented in Table 2 include marine species presence and distribution (e.g. benthic and pelagic data), water quality measurements (using both *in situ* and remote sensing methods), marine mammal and bird sightings, and records of incidents (bycatch) and litter surveys. Note that there were no commercial fisheries data, as commercial fishing is not permitted within Milford Sound / Piopiotahi. These data sources comprise eight national (nationwide), three local (studies exclusively in Milford Sound / Piopiotahi) and four international databases.

Table 2. Potentially suitable data sources for an assessment of Anthropause marine tourism effects in **Milford Sound / Piopiotahi.**

Dataset	Data type	Date range	Sampling frequency
NIWA-SCENZ Ocean Colour Application (Pinkerton et al. 2022)	Monthly measurements of chlorophyll-*a*	2019–present	Monthly
NZOA-ON (2022) New Zealand Ocean Acidification Observing Network	Water samples analysed for dissolved inorganic carbon and alkalinity; pH, pCO_2 and carbonate ion concentration and saturation states are then calculated	2015–present	Sampled every 2 months

[51] The available bathymetric data characterised from the data acquisition search was limited in terms of temporal coverage and resolution (public availability of New Zealand bathymetry data are limited to 2016 at a 250 m resolution; Appendix 1). Because of these issues, it was not included in the 'potentially suitable data' list for all AOIs; however, if further information is obtained in the interim, it should be considered for Stage two of the investigation.

Dataset	Data type	Date range	Sampling frequency
DOC (2023a) Marine mammal sightings database (Hector's / Māui and other MM sightings and incidents)	Data of sighting, circumstances, location, species name, number of individuals, distance from shore, number of juveniles. Includes photos and videos (however, data owner did not append these to CSV files provided)	2002–present	Intermittent data; less frequent during lockdown
eBird (2023) International bird database	Approx. 6 Milford bird sighting locations with bird counts. Raw data are only available on request	Varies, depending on site, e.g. Milford Sound / Piopiotahi by boat site: 1990–2023	Randomly but regularly (multiple times per month)
Environment Southland (ES 2023b) Wastewater treatment plant receiving water monitoring dataset	Receiving waters: dissolved oxygen saturation concentration, pH, temperature, conductivity, *E. coli*, enterococci; Discharge: discharge volume / composition	2008–present	4 times annually
Meridian Energy physical and biological monitoring of Doubtful Sound (Goodwin 2022; Dunmore et al. 2019)	Intertidal rock wall photo quadrats. Subtidal rock wall photo quadrats. Vertical rock wall dive transect (collection of indicator data). Horizontal rock wall dive transects (black coral & indicator species counts)	Annually from 1997–2016, then 2019. (next one in 2024)	Annually
The Tawaki Project (Tawaki 2023)	The marine ecology, breeding biology and population dynamics of the Tawaki	2014–present	Annually
OBIS (2023) Multi database	Marine species presence records, measurements and facts (datasets)	1952–2019 (ongoing)	Varies / multiple data types
NZODN (2023) Open access to ocean data	Multiple databases available for download, e.g. moored instrument data, water column data (i.e. alkalinity, carbon, salinity, temperature), fish and squid occurrence data, air pressure, air temperature	Varies depending on database, but historic data (pre-2018) to 2023	Varies / multiple data types
Ocean colour CCI portal (Sathyendranath et al. 2019)	Chlorophyll-*a* concentrations	1997–2022 (ongoing)	Daily or monthly
Litter Intelligence – litter surveys (LI 2023)	The type and quantity of litter found during beach monitoring surveys at Milford Sound / Piopiotahi foreshore	2020–2022 (ongoing)	1–2 times annually
DOC seabird database request	DOC databases*	TBD	TBD
MfE (2023c) Oceanic and coastal primary productivity 1998–2017	Measures the concentration of phytoplankton in ocean water around NZ using satellite data	1998–2017	Monthly
DOC (2023c) Hector's and Māui dolphin incident database	Hector's and Māui dolphin incidents based on reported events. Incidents include dead or stranded Hector's and Māui dolphins and those caught by fishers	1921–2023 (ongoing)	Intermittent. Quarterly data updates: early May, Aug., Nov. and Feb. each year
Argo (2000) Ocean biogeochemistry database	Argo float data: oxygen, nitrates, pH, chl-*a*, suspended particulates, down irradiance, Underwater Vision Profiler	2000 to present (ongoing)	Transmissions vary depending on Argo selected

* Project-wide data request made to DOC on 27 February 2023.

5.1. Stewart Island / Rakiura

Of the 82 ecological data sources reviewed for Stewart Island / Rakiura (Appendix 1), 17 data sources were deemed potentially suitable for further (Stage two) analyses (Table 3). The potentially suitable data types presented here (Table 3) include marine species presence and distribution (e.g. benthic, intertidal and pelagic data), water quality measurements (using both *in situ* and remote sensing methods), marine mammal, commercial fisheries data, bird sightings / bycatch and litter surveys. These data sources comprise 12 national (nationwide), one local (studies exclusively in Stewart Island / Rakiura) and four international databases.

Table 3. Potentially suitable data sources for an assessment of Anthropause marine tourism effects in **Stewart Island / Rakiura.**

Dataset	Data type	Date range	Sampling frequency
NIWA-SCENZ Ocean Colour Application (Pinkerton et al. 2022)	Chlorophyll-*a* monthly time series	2019–present	Monthly
DOC (2023a) Marine mammal sightings database (Hector's / Māui and other MM sightings and incidents)	Data of sighting, circumstances, location, name of species, number of individuals, distance from shore, number of juveniles. Includes photos and videos (not attached to CSV files)	2002–present	Intermittent data; less frequent during lockdown
eBird (2023) International bird database	Approx. 7 Stewart Island / Rakiura bird sighting locations with bird counts. Raw data are only extractable on request	Varies depending on site e.g. Jacky Lee Island, 1911–2023	Randomly but regularly (multiple times per month)
Marine Metre Squared Project – Oban (MM2 2022)	Intertidal surveys. Quadrats, transects. Data outputs available online.	2014–2020 (ongoing)	Intermittently, multiple time per year / season. Ongoing.
LAWA (2023) Can I swim here? Recreational water quality monitoring data	Water quality data includes: SiteID, SampleID, collection date, value and units. Parameters measured: enterococci, faecal coliforms, temperature, salinity, pH	2017–2022 (ongoing)	~4 times per month over bathing season
NZODN (2023) Open access to ocean data	Multiple databases available for download, e.g. moored instrument data, water column data (i.e. alkalinity, carbon, salinity, temperature), fish and squid occurrence data, air pressure, air temperature	Varies depending on database, but historic data (pre–2018) to 2023	Varies / multiple data types
Ocean colour CCI portal (Sathyendranath et al. 2019)	Chlorophyll-*a* concentrations	1997–2022 (ongoing)	Daily or monthly
DOC (2023b) New Zealand sea lion demographics	Sea lion sighting records, tags, brandings and microchips, dates, locations*	Stewart Island / Rakiura – 2011–2021 (ongoing)	Intermittent

Dataset	Data type	Date range	Sampling frequency
Litter Intelligence – litter surveys (LI 2023)	Nature and quantity of litter found during beach monitoring surveys at Stewart Island / Rakiura foreshore	2020 only (ongoing)	~2 times annually at each site
MPI (2023) Fisheries data reported by commercial fishers to MPI / Central Observer Database (COD) contains data collected by observers on fishing vessels	*Official information request to be made to MPI. Note: MARLIN is the metadata database that MPI uses to document its scientific data	From 2009/10 to 2018/19 (ongoing)	Intermittent
OBIS (2023) Multi database	Marine species presence records, measurements and facts (datasets)	1952–2019 (ongoing)	Varies / multiple data types
DOC seabird database request	DOC databases*	TBD	TBD
MfE (2023c) Oceanic and coastal primary productivity 1998–2017	Measures the concentration of phytoplankton in ocean water around NZ using satellite data	1998–2017 (ongoing)	Monthly
DOC (2023c) Hector's and Māui dolphin incident database	Hector's and Māui dolphin incidents based on reported events. Incidents include dead or stranded dolphins and those caught by fishers	1921–2023 (ongoing)	Intermittent. Quarterly data updates: early May, Aug., Nov. & Feb. each year
The Yellow-Eyed Penguin Trust (YEPT 2023)	Nests counts (population trends), egg counts, chick survival (breeding success). Marking and tracking (sighting records) of birds (survival rate)	1980–2023 (ongoing)	Annually
Sanford's monthly water quality and annual benthic quality monitoring program (ADS Environmental Services 2022)	Control & impact sites in Big Glory Bay (bay-wide monitoring plan). Sediments: grain size, total organic matter, total organic carbon, copper and zinc concentrations, appearance of sulphide depth, sediment colour, depth of redox layer, H_2S content, no. of indiv.l infauna, no. and type (opportunistic or enrichment tolerant) of species / taxa, species diversity (infauna), epifaunal taxa present, seabed features / burrows / holes, visual % coverage of bacterial matting, and degree of visual outgassing. Water: chl-*a*, total ammonia nitrogen, dissolved oxygen, nitrate, nitrite, total nitrogen, total phosphorous, dissolved reactive phosphorous, salinity and water clarity. Council provides data on request.	2008–2023 (ongoing)	Annual benthic sampling and monthly water quality sampling
Argo (2000) Ocean biogeochemistry database	Argo float data: oxygen, nitrates, pH, chl-*a*, suspended particulates, down irradiance, Underwater Vision Profiler	2000 to present (ongoing)	Transmissions vary depending on Argo selected

*Project-wide data request made to DOC on 27 February 2023; data request also made to New Zealand Sea Lion Trust on 27 February 2023.

5.2. Otago Harbour / Otakou

Of the 104 ecological data sources reviewed for Otago Harbour / Otakou (Appendix 1), 27 data sources were deemed potentially suitable for further (Stage two) analyses (Table 4). The potentially suitable data types presented here (Table 4) include marine species abundance and distribution (e.g. benthic and intertidal monitoring), water quality measurements (using both *in situ* and remote sensing methods), marine mammal and bird sightings and records of incidents (bycatch), litter surveys and fisheries data. These data sources comprise 17 national (nationwide), six local (studies exclusively in Otago Harbour / Otakou) and four international databases.

Table 4. Potentially suitable data sources for an assessment of Anthropause marine tourism effects at **Otago Harbour / Otakou**.

Dataset	Data type	Date range	Sampling frequency
NIWA Porthole: National Marine High Risk Site Surveillance (NMHRSS) (MBP 2022a)	Marine species presence information. Over 16,000 sampling locations	2003–present (ongoing)	Surveys completed summer and winter since 2003
NIWA Porthole: Port Biological Baseline Surveys (PBBS) (MBP 2022b)	Marine species presence information	2003 and 2006	2 surveys; 2968 data records
NIWA Porthole: Marine Invasive Taxonomic Service (MITS) (MBP 2022c)	Nonindigenous marine species samples collected	2005, 2014, 2016, 2019, 2022. (ongoing)	Intermittent. 36 data records; all NIWA Porthole data potentially able to be combined
NZOA-ON (2022) New Zealand Ocean Acidification Observing Network	Water samples analysed for dissolved inorganic carbon and alkalinity; pH, pCO_2, carbonate ion concentration and saturation states are then calculated	2015–present	Sampled every 2 months
Otago Harbour / Otakou Conditions (PML 2022b): Water quality sensor	Real-time (hourly) surface temperature, salinity, dissolved oxygen, pH, chl-*a* and dissolved oxygen	2014–present	Hourly
Portobello Marine Laboratory (PML 2022a) Long-term sea surface temperature record	Sea surface temperature (SST)	1953–present	Daily
Healthy Harbour Watchers (HHW 2022)	Temperature, salinity, and dissolved oxygen, pH, dissolved reactive phosphorus, nitrate / nitrite, chl-*a*, enterococci	2010–present	Monthly or every 2–3 months; varies
DOC (2023a) Marine mammal sightings database (Hector's / Māui and other MM sightings and incidents)	Data of sighting, circumstances, location, name of species, number of individuals, distance from shore, number of juveniles. Includes photos and videos (not attached to CSV files)	2002–present	Intermittent data; frequent during lockdown

Dataset	Data type	Date range	Sampling frequency
NIWA-SCENZ Ocean Colour Application (Pinkerton et al. 2022)	Chlorophyll-*a* monthly time series	2019–present	Monthly
LAWA (2023) Can I swim here? Recreational water quality monitoring data.	Water quality data include: SiteID, SampleID, collection date, value and units. Parameters measured: enterococci, faecal coliforms, temperature, salinity, pH	2017–2022 (ongoing)	~4 times per month over bathing season
POL "Project Next Generation" 3-yearly environmental monitoring: In-harbour assessment 2013 (baseline), 2018 and 2021 (eScientific 2022)	Aerial (drone) photography of Aramoana salt marsh, parts of Papanui Inlet & Harwood seagrass, seagrass assessment, cockle bed analysis, rocky reef assessment, deep channel assessment, Aramoana salt marsh assessment	2013–2021 (ongoing)	3-yearly
Ravensdown Ltd Dunedin Works: Benthic Monitoring (Leduc et al. 2021)	5-yearly marine monitoring programme; various data types documenting sediment macrobenthic communities, benthic macroalgae, & sediment chemistry analyses for a range of specified 'Impact' and 'Reference' sites	2006, 2011, 2016, 2021 (ongoing)	5-yearly
Munida Microbial Observatory Time-Series (MMOT 2022)	Surface water analysed for pCO_2, temperature, salinity on transect from Taiaroa Head Water samples for dissolved reactive phosphorus, nitrate-nitrogen, dissolved reactive silica, and fluorescence at station 7 km offshore from Taiaroa Head	1998–present	Approx. every 2 months
Marine Metre Squared Project – Otago Harbour / Otakou (MM2 2022)	Intertidal surveys. Quadrats, transects. Data outputs available online	2012–present	Regularly, multiple time per year / season
Litter Intelligence – litter surveys (LI 2023)	Nature and quantity of litter found during beach monitoring surveys. Sites: Otago Peninsula – Portobello South (Pipe cove) & Otago Peninsula – Portobello north shore	2019–2022 (ongoing)	2–4 times annually
eBird (2023) International bird database	Approx. 26 Otago bird sighting locations with bird counts. Raw data are only extractable on request	Varies depending on site, e.g. Quarantine Otago Shag Roost Site[52]: 2017–2023	Randomly but regularly (multiple times per month)
NZODN (2023) Open access to ocean data	Multiple databases available for download, e.g. moored instrument data, water column data (i.e. alkalinity, carbon, salinity, temperature), fish and squid occurrence data, air pressure, air temperature	Varies depending on database, but historic data (pre–2018) to 2023	Varies / multiple data types
Ocean colour CCI portal (Sathyendranath et al. 2019)	Chlorophyll-*a* concentrations	1997–2022 (ongoing)	Daily or monthly

[52] https://ebird.org/hotspot/L6046114?yr=all&m=&rank=mrec

Dataset	Data type	Date range	Sampling frequency
DOC (2023b) New Zealand sea lion demographics	Sea lion sighting records, tags, brandings and microchips, dates, locations*	South Island: 1994–2022 Stewart Island / Rakiura: 2011–2021 (ongoing)	Intermittent
OBIS (2023) Multi database	Marine species presence records, measurements and facts (datasets)	1876–2019 (ongoing)	Varies / multiple data types
MPI (2023) Fisheries data reported by commercial fishers to MPI / Central Observer Database (COD) contains data collected by observers on fishing vessels	Official information request to be made to MPI. Note: MARLIN is the metadata database that MPI uses to document its scientific data	From 2009/10 to 2018/19, (ongoing)	Intermittent
DOC seabird database request	DOC databases**	Otago Royal Albatross Colony 2013–2022; Other seabirds to be determined (ongoing)	To be determined
MfE (2023a) Coastal and estuarine water quality, trends, 2006–2020	Nutrient: ammoniacal nitrogen, nitrate-nitrite nitrogen, total nitrogen (unfiltered), dissolved reactive phosphorus, and total phosphorus (unfiltered) Microbiological: faecal coliforms, enterococci and chl-*a* Optical: visual clarity, turbidity, and suspended solids (inorganic and organic) Physico-chemical: dissolved oxygen, pH, salinity and temperature	2006–2020 (ongoing)	Varies / multiple data types
MfE (2023b) Coastal and estuarine water quality, state, 2016–2020	Nutrient: ammoniacal nitrogen, nitrate-nitrite nitrogen, total nitrogen (unfiltered), dissolved reactive phosphorus, and total phosphorus (unfiltered) Microbiological: faecal coliforms, enterococci and chl-*a* Optical: visual clarity, turbidity, and suspended solids (inorganic and organic) Physico-chemical: dissolved oxygen, pH, salinity and temperature.	2016–2020	Varies / multiple data types
MfE (2023c) Oceanic and coastal primary productivity 1998–2017	Measures the amount of phytoplankton in ocean water around NZ using satellite data. year, month, region, indicator, value, measurement (mean), units, coastal environment	1998–2017	Monthly
DOC (2023c)	Hector's and Māui dolphin incidents based on reported events. Incidents	1921–2023 (ongoing)	Intermittent

Dataset	Data type	Date range	Sampling frequency
Hector's and Māui dolphin incident database	include dead or stranded dolphins and those caught by fishers		Quarterly data updates: early May, Aug., Nov. and Feb. each year
Argo (2000) Ocean biogeochemistry database	Argo float data: oxygen, nitrates, pH, chl-*a*, suspended particulates, down irradiance, Underwater Vision Profiler	2000 to present (ongoing)	Transmissions vary depending on Argo selected

*Project-wide data request made to DOC on 27 February 2023; data request also made to New Zealand Sea Lion Trust on 27 February 2023.
**Project-wide data request made to DOC on 27 February 2023; data request also made to the Royal Albatross Colony – Tairoa Heads on 27 February 2023.

5.3. Akaroa Harbour

Of the 84 ecological data sources reviewed for Akaroa Harbour (Appendix 1), 19 data sources were deemed potentially suitable for further (Stage two) analyses (Table 5). The potentially suitable data types presented here (Table 5) include: marine species presence and distribution (e.g. benthic, intertidal and pelagic data), water quality measurements (using both *in situ* and remote sensing methods), marine mammal and bird sightings / bycatch and litter surveys. These data sources comprise 10 national (nationwide), four local (studies exclusively in Akaroa Harbour) and four international databases.

Table 5. Potentially suitable data sources for an assessment of Anthropause marine tourism effects at **Akaroa Harbour.**

Dataset	Data type	Date range	Sampling frequency
State of the environment surface water quality database (CRC 2023a)	State of the Environment water quality monitoring (SOE) sites. Parameters measured: nutrients, turbidity, total suspended solids, chl-*a*, temperature, salinity, enterococci and faecal coliforms (in key shellfish areas), metals (in specific locations) and, if not sampling from helicopter, also: dissolved oxygen, pH, wind speed and visual clarity	1989–2022 (ongoing)	Varies between sites. 7 sites within Akaroa Harbour
Recreational water quality monitoring surface water quality database (CRC 2023a; LAWA 2023)	Recreational water quality monitoring (for bathing and shellfish collecting). Parameters: enterococci, faecal coliforms, temperature, salinity, pH. *Also available on LAWA	2017–2022 (ongoing)	Sampled weekly from mid-Nov. to mid-Mar. 7 sites within Akaroa Harbour
Intertidal sediments and biota monitoring (CRC 2023b)	Benthic infauna (core), epifauna (quadrat), seagrass and algae cover, sediment grain size and sediment quality	2009–2022 (ongoing)	Annual

Dataset	Data type	Date range	Sampling frequency
Hector's dolphin distribution in Akaroa dataset (Carome 2021; Carome et al. 2022).	Data was requested from Tom MacTavish (pers. comm. Tom MacTavish, DOC scientist, 13.10.22); not yet supplied. Metadata based on meeting with DOC and CRC representatives[53]	1988–2023 (ongoing)	TBD
NIWA-SCENZ Ocean Colour Application (Pinkerton et al. 2022)	Chlorophyll-*a* monthly time series	2019–present (ongoing)	Monthly
DOC (2023a) Marine mammal sightings database (Hector's / Māui and other MM, sightings and incidents)	Data of sighting, circumstances, location, name of species, number of individuals, distance from shore, number of juveniles. Includes photos and videos (not attached to CSV files)	2002–present (ongoing)	Intermittent data; less frequent during lockdown.
eBird (2023) International bird database	Approx. 9 Akaroa Harbour sighting locations with bird counts. Raw data are only extractable on request	Varies depending on site, e.g. boat trips in Akaroa Harbour and just outside harbour entrance, 2008–2023	Randomly but regularly (multiple times per month)
Akaroa wastewater treatment plant receiving environment monitoring (CCC 2023)	Surface water samples are taken from 5 sites west of the outfall and at 2 control sites: 1 at French Bay and 1 at the proposed site of a new outfall. Parameters: temperature, total nitrogen, ammonia, dissolved inorganic nitrogen, total phosphorus, dissolved reactive phosphorus & chl-*a*	2017–2023 (ongoing)	4 times per year
Duvauchelle Wastewater Treatment Plant receiving environment monitoring	At 6 receiving environment sampling sites, 0.5 m below the surface of the water. Each sample analysed for the concentration of faecal coliforms, enterococci, ammoniacal nitrogen, total nitrogen and dissolved reactive phosphorus, and the time samples are taken. Data may cease being collected from approx. July 2023. Data request required from Josh McDonald-Davis (pers comm. Melanie Burns, Marine Ecologist at CRC, 24.5.23)	2011–2023	Sampled at least 5 times over a 30-day period, commencing on 27 Dec. and at least 3 samples shall be collected within the period 27 Dec. to 10 Jan.
Litter Intelligence – litter surveys (LI 2023)	Nature and quantity of litter found during beach monitoring surveys at Akaroa Harbour foreshore	2020–2022 Varying survey sites (ongoing)	Intermittent and varied between (3) survey sites. *Possible to pool data
NZODN (2023) Open access to ocean data	Multiple databases available for download, e.g. moored instrument data, water column data (i.e. alkalinity, carbon, salinity, temperature), fish and squid occurrence data, air pressure, air temperature	Varies depending on database, but historic data (pre-2018) to 2023	Varies / multiple data types

[53] Meeting details: 13 October 2022 (1pm–2pm). Attended by: Jim Dilly (ECAN), Thomas MacTavish (DOC), Melanie Burns (ECAN) and Olivia Johnston (Cawthron).

Dataset	Data type	Date range	Sampling frequency
Ocean colour CCI portal (Sathyendranath et al. 2019)	Chlorophyll-*a* concentrations	1997–2022 (ongoing)	Daily or monthly
MPI (2023) Fisheries data reported by commercial fishers to MPI / Central Observer Database (COD) contains data collected by observers on fishing vessels	*Official information request to be made to MPI. Note: MARLIN is the metadata database that MPI uses to document its scientific data	From 2009/10 to 2018/19, (ongoing)	TBD
OBIS (2023) Multi database	Marine species presence records, measurements and facts (datasets)	1928–2019 (ongoing)	Varies / multiple data types
MfE (2023a,b) Coastal and estuarine water quality, trends	Nutrient: ammoniacal nitrogen, nitrate-nitrite nitrogen, total nitrogen (unfiltered), dissolved reactive phosphorus and total phosphorus (unfiltered) Microbiological: faecal coliforms, enterococci and chl-*a* Optical: visual clarity, turbidity and suspended solids (inorganic and organic) Physico-chemical: dissolved oxygen, pH, salinity and temperature	2006–2020 (ongoing)	Varies / multiple data types
MfE (2023c) Oceanic and coastal primary productivity	Measures the concentration of phytoplankton in ocean water around NZ using satellite data	1998–2017 (ongoing)	Monthly
DOC (2023c) Hector's and Māui dolphin incident database	Hector's and Māui dolphin incidents based on reported events. Incidents include dead or stranded dolphins and those caught by fishers	1921–2023 (ongoing)	Intermittent. Quarterly data updates: early May, Aug., Nov. and Feb. each year
DOC seabird database request	DOC databases	TBD	TBD
Argo (2000) Ocean biogeochemistry database	Argo float data: oxygen, nitrates, pH, chl-*a*, suspended particulates, down irradiance, Underwater Vision Profiler	2000 to present (ongoing)	Transmissions vary depending on Argo selected

*Project-wide data request made to DOC on 27 February 2023.

5.4. Kaikōura Peninsula

Of the 62 ecological data sources reviewed for Kaikōura Peninsula (Appendix 1), 18 data sources were deemed potentially suitable for further (Stage two) analyses (Table 6). The potentially suitable data types presented here (Table 6) include: marine species presence and distribution (e.g. benthic, intertidal and pelagic species data), water quality measurements (using both *in situ* and remote sensing methods), marine mammal and bird sightings / bycatch and litter surveys. These data sources comprise nine national (nationwide), five local (studies exclusively around Kaikōura Peninsula) and four international databases.

Table 6. Potentially suitable data sources for an assessment of Anthropause marine tourism effects at **Kaikōura Peninsula.**

Dataset	Data type	Date range	Sampling frequency
State of the environment surface water quality database (CRC 2023a)	State of the Environment water quality monitoring (SOE) sites. Parameters measured: nutrients, turbidity, total suspended solids, chl-*a*, temperature, salinity, enterococci, and faecal coliforms (in key shellfish areas), metals (in specific locations) and, if not sampling from helicopter, also: dissolved oxygen, pH, wind speed and visual clarity	Historic–2023 Timeframe varies between sites (ongoing)	3 sites around Kaikōura Peninsula, 1 site each at Oaro Beach, Waipapa Bay and Conway Flat. Varies between sites. Further investigation required
Recreational water quality monitoring surface water quality database (CRC 2023a; LAWA 2023)	Recreational water quality monitoring (for bathing and shellfish collecting). Parameters: enterococci, faecal coliforms, temperature, salinity, pH. Also available on LAWA	Historic–2023 (ongoing)	4 sites around Kaikōura Peninsula, 1 site each at both Peketa Beach and Mangamanu Beach. Sampled weekly from mid-Nov. to mid-Mar.
DOC (2023a) Marine mammal sightings database (Hector's / Māui and other MM, sightings and incidents)	Data of sighting, circumstances, location, name of species, number of individuals, distance from shore, number of juveniles. Photos and videos (not attached to CSV)	2002–present (ongoing)	Intermittent data; less frequent during lockdown
NIWA-SCENZ Ocean Colour Application (Pinkerton et al. 2022)	Chlorophyll-*a* monthly time series	2019–present (ongoing)	Monthly
eBird (2023) International bird database	Approx 5 Kaikōura Peninsula sighting locations with bird counts. Raw data are only extractable on request	Varies depending on site, e.g. Kaikōura offshore site: 2000–2023	Randomly but regularly (multiple times per month)
NZODN (2023) Open access to ocean data	Multiple databases available for download, e.g. moored instrument data,water column data (i.e. alkalinity, carbon, salinity, temperature), fish and squid occurrence data, air pressure, air temperature	Varies depending on database, but historic data (pre-2018) to 2023	Varies / multiple data types
Recovery of rocky intertidal and subtidal communities affected by the 2016 Kaikōura earthquake. (Falconer et al. 2022; Alestra et al. 2021; Schiel et al. 2021; Thomsen et al. 2021)	Nearshore community assessments included both intertidal surveys (16 sites sampled in Nov. 2021) and subtidal surveys (6 sites sampled in May 2022), which covered a broad range of uplifts (between 0.0–6.4 m)	2019, 2020, 2021 and 2022	2019, 2020, 2021 (x2 surveys) and 2022 (x1)

Dataset	Data type	Date range	Sampling frequency
Long-term monitoring of sperm whales in Kaikōura, New Zealand: (Van der Linde 2010)	Whale abundance and population dynamics in Kaikōura	1990–2010 (potentially ongoing)	Intermittent but regular
Ocean colour CCI portal (Sathyendranath et al. 2019)	Chlorophyll-*a* concentrations	1997–2022 (ongoing)	Daily or monthly
Litter Intelligence – litter surveys (LI 2023)	Nature and quantity of litter found during beach monitoring surveys at South Bay, Kaikōura foreshore	2019–2023 (ongoing)	x1 surveys 2019 x1 surveys 2021 x4 surveys 2022 x1 surveys 2023
MPI (2023) Fisheries data reported by commercial fishers to MPI / Central Observer Database (COD) contains data collected by observers on fishing vessels	Official information request to be made to MPI. Note: MARLIN is the metadata database that MPI uses to document its scientific data	From 2009/10 to 2018/19 (ongoing)	TBD
MfE (2023c) Oceanic and coastal primary productivity	Measures the concentration of phytoplankton in ocean water around NZ using satellite data: year, month, region, indicator, value, measurement (mean), units, coastal environment	1998–2017 (ongoing)	Monthly
DOC (2023c) Hector's and Māui dolphin incident database	Hector's and Māui dolphin incidents based on reported events. Incidents include dead or stranded dolphins and those caught by fishers	1921–2023 (ongoing)	Intermittent. Quarterly data updates: early May, Aug., Nov. and Feb. each year
DOC seabird database request	DOC databases*	TBD	TBD
OBIS (2023) Multi database	Marine species presence records, measurements and facts (datasets)	1868–2019 (ongoing)	Varies / multiple data types
Hector's dolphins in the Kaikōura area (KORI 2023a)	Boat-based coastal surveys, photographing dolphins to the north and south of the Kaikōura Peninsula, and trying to learn more about their habitat and behaviours. Data request still to be made	2013–present (ongoing)	TBD
Little blue penguin in the Kaikōura area (KORI 2023b)	Colony population dynamics. Weighing and measuring eggs and chicks to ensure they are healthy, and banding penguins. *Data request still to be made	2012–present (ongoing)	TBD
Argo (2000) Ocean biogeochemistry database	Argo float data: oxygen, nitrates, pH, chl-*a*, suspended particulates, down irradiance, Underwater Vision Profiler	2000–present (ongoing)	Transmissions vary depending on Argo selected

* Project-wide data request made to DOC on 27 February 2023.

6. DATA ANALYSIS APPROACH

In this report we present the preliminary recommendations for the proposed methodological approach to analyse the datasets deemed 'suitable' for assessing marine tourism-related impacts over the Anthropause period (Stage two of the investigation). The ecological data deemed to be potentially suitable in Section 5 span the Anthropause period (appropriate time series and / or potential for ongoing data collection), are in close proximity to marine tourism activities, are robust (high levels of sampling replication and scientifically sound) and are readily available for use in Stage two of the assessment.

We suggest the statistical analysis in Stage two follows a Multiple Levels and Lines of Evidence (MLLE) approach (Hall & Giddings 2000; Norris et al. 2005), whereby each potentially suitable causal data type (e.g. species abundance and distribution) is used as a potential 'line of evidence' to infer causality from the explanatory variable(s) (e.g. passenger vessel traffic density). To do this, we must first gain full access and approval for use of the datasets (note: approvals have already been sought and / or obtained as part of this assessment; however, an official agreement between parties would be required). Once approvals are obtained, we would interrogate the raw datasets to verify their suitability for this assessment. A conceptual research model would then be developed to define the research questions, the potential effects (from the causal data) and how the effects will be measured.

Developing the conceptual model

A conceptual model for inferring that a given explanatory variable causes a particular change in the system is integral to developing a strong data analyses approach. Therefore, we suggest that each potential data source at each AOI (to be investigated in relation to the explanatory variable(s), e.g. marine traffic density and / or cruise ship presence) should have the following model components defined:

1. an individual hypothesis
2. potential effects
3. research questions
4. potential covariates (other potential causal factors, such as climate)
5. causal effect criteria (what measure of the data constitutes an effect).

Each of these conceptual models could then be used in the quantitative weight-of-evidence approach (see MLLE description above) in which multiple lines of evidence can be considered when estimating causality. For example, the following conceptual model uses one line of evidence that could be weighted when estimating the causality of a marine tourism activity:

<u>Hypothesis</u>

High levels of marine tourism activity change the distribution and abundance of marine species in the AOIs (based on other Anthropause findings internationally).

Potential effects
An increase of marine species in the vicinity of the AOIs; a decrease of marine species in the vicinity of the AOIs; a change in distribution patterns within the AOIs.

Research questions

- **a.** Did the abundance of fish / penguins / dolphins / macrofauna in the AOIs change during the Anthropause period when marine tourism stopped?
- **b.** Did AOIs that are accustomed (pre-Anthropause) to lower marine tourism activities exhibit less detectable effects (in the form of species abundance and distribution changes) during the Anthropause?
- **c.** Did AOIs that are accustomed (pre-Anthropause) to more local operator marine tourism activities and less international operators exhibit less detectable effects (in the form of species abundance and distribution changes) during the Anthropause?
- **d.** Are effects detectable at larger commercial AOIs (such as Port Otago, Otago Harbour / Otakou) compared to AOIs where these activities are less prevalent?

Covariates: sea surface temperature, chlorophyll-*a* concentrations.

Causal criteria: a strong correlation between species distribution / abundance and vessel traffic (explanatory variable), and a poor correlation between covariates.

The conceptual model components defined during this process may be suitable for all AOIs (generic), while others might be specific to one or several AOIs, e.g. individual (data within sites, e.g. Tawaki Project, Milford Sound / Piopiotahi) and broad-scale data (data across sites, e.g. national databases such as eBird, the DOC marine mammal sightings, remote sensing data).

Defining the data analysis approach
Until the conceptual models are defined, it is difficult to assign an appropriate data analysis method for each of these models. However, as the data sources investigated in this Stage one assessment have associated geospatial and temporal data, it is likely that a geospatial analysis-type approach will be appropriate. Where datasets are spatially and temporally patchy (e.g. marine mammal sightings database) the data should be standardised before analysis. Using this approach, criteria (e.g. distribution and / or abundance of species) can be displayed and analysed for strong temporal and spatial correlations with the explanatory variables such as vessel traffic density.

Following the analyses of each MLLE, the results would be integrated to assess the environmental effect of marine tourism activity. We could apply a sequential analysis of lines of evidence using a weight-of-evidence approach (Hull & Swanson 2006). We could also quantitatively integrate these different lines of evidence using a Bayesian approach (Schleier et al. 2015). With this method, an overall probability of a broad-scale ecological effect occurring can be calculated from all the MLLE data findings (e.g. using all the individual correlation results in a global test). This would be represented as a probability distribution from which the probability of exceeding a risk threshold can be estimated (e.g. the probability of 80% of the MLLE having strong correlations). To visualise the data and carry out analyses, we would use ArcGIS Pro and ‘R’ statistical computing tools.[54]

[54] R Core Team. 2023. R: a language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing. https://www.R-project.org/
ESRI. 2023. ArcGIS Pro: Release 3.1. Redlands (CA): Environmental Systems Research Institute. https://pro.arcgis.com/

7. SUMMARY

This preliminary desktop investigation identified marine ecological data and tourism activities taking place at five key marine tourism AOIs (Milford Sound / Piopiotahi, Stewart Island / Rakiura, Otago Harbour / Otakou, Akaroa Harbour and Kaikōura Peninsula). The suitability of existing data has also been investigated for understanding the environmental impact of marine tourism activities on their environment during the COVID-19 Anthropause (from 19 March 2020 to 31 July 2022). Based on this data collection and preliminary data analysis, we provide recommendations for further analyses to detect marine tourism-related impacts during the Anthropause in the next stage of the project. The following paragraphs summarise the data types identified (e.g. the data that might represent tourism activities and possible ecological causal data) and the associated considerations for any future analyses of these data.

Tourism activities (explanatory variables)

Potential explanatory variables for determining Anthropause-related marine tourism effects to the ecological variables identified were passenger vessel traffic data and the number and intensity of marine tourism operations at each AOI. Therefore, we have gathered and characterised data relating to cruise ship movements (international operators), geospatial passenger vessel density and identification of local operators within each AOI. In addition, it is possible that the aircraft flight logs (landings per day) could be used as an explanatory variable, as they potentially have both indirect (supporting marine tourism) and direct links (causative impacts) to marine tourism activities. Obtaining aircraft flight log data would require an official information request to the New Zealand Ministry of Transport.[55]

Milford Sound / Piopiotahi was the only AOI that had complete records of local ecotourism operators in service and the number of trips each operator was undertaking. Except for Milford Sound / Piopiotahi, where the general location (local destination) for each trip was provided, none of the AOIs had information available relating to exact local operator vessel journeys (in terms of positions / tracks). However, we were able to compile a list of marine tourism operators, and aircraft operators, at the AOIs using those identified in the SSC[56] ecotourism project and via online searches. While the local operator results presented here are not necessarily exhaustive, they do provide a valuable insight into the number of local and domestic market operators in each region, some of which may have operated during periods of the COVID-19 lockdown (i.e. when domestic tourism was allowed but international visitors were banned). Given the limits of the local operator data, it will potentially only be useful in future (Stage two) data analysis as an explanatory variable for Milford Sound / Piopiotahi (e.g. as trip numbers and destination data), unless more detailed trip data can be obtained for the other AOIs.

[55] https://www.transport.govt.nz/about-us/what-we-do/queries/how-to-access-milford-sound-piopiotahi-aerodrome/
[56] Marine and coastal ecotourism operators - Sustainable Seas National Science Challenge (sustainableseaschallenge.co.nz)

Preliminary investigation of passenger vessel traffic characteristics (GMT 2023) appeared to vary between AOIs, notably:

1. vessel traffic density data for December each year from 2019 to 2022 showed that some AOIs (Milford Sound / Piopiotahi, Otago Harbour / Otakou and Stewart Island / Rakiura) have evidence of passenger vessel movements (albeit at low densities) during the Anthropause period. This may be related to local / domestic market operators in the region operating during some of the lockdown period.
2. Some AOIs had higher passenger vessel densities outside of the Anthropause period compared to others, e.g. Otago Harbour / Otakou, Akaroa Harbour (> 500 hr/m^2) and Milford Sound / Piopiotahi (> 300 hr/m^2), whereas Stewart Island / Rakiura and Kaikōura typically had lower vessel densities (< 50 hr/m^2).
3. There were several approaches used for regulating marine tourism at each AOI, with Milford Sound / Piopiotahi, Akaroa Harbour and Kaikōura having official operational guidelines around the number of vessels allowed per day (or per year) and where the vessels could anchor. Cruise ship access requirements for facilities at Port Chalmers and Dunedin do not appear to contain limits to the number of cruise ships that can anchor or berth in the harbour per day. There are also no limits in place for the number of visits cruise ships can make annually. However, numbers are likely limited by the berthing capacity at the wharf. Unlike other AOIs, vessel tenders are unlikely to be used in Otago Harbour / Otakou because of the direct berthing access. However, the potential for cruise ship anchoring (and the use of vessel tenders) within other areas of the harbour are not clear and should be investigated further, i.e. vessel density maps on Figure 6 appear to show high passenger ship densities at Portobello (adjacent to Port Chalmers), suggesting vessels may be anchoring or holding position there as well as at Port Chalmers and Port Otago.
4. Otago Harbour / Otakou was the only AOI investigated that had wharf berthing facilities for international cruise ships (rather than specified anchoring locations). Otago Harbour / Otakou was also the only AOI that included a large commercial port that directly receives international vessels (Places of First Arrival[57]).

These differences in vessel traffic, management and characteristics between the AOIs will need to be reviewed in future interpretation of results. The vessel density data for all vessel types (not just passenger vessels) should also be considered in any future data analysis, particularly for commercial ports such as Otago Harbour / Otakou. This is because the overall level of shipping may have increased in commercial ports during the Anthropause (potentially counteracting the decrease in marine tourism).

Ecological data suitability (causal data)

Hundreds of potential ecological data sources were identified and characterised for the AOIs to determine if they might be potentially suitable for future analysis of marine tourism-derived effects during the Anthropause (Appendix 1). Multiple potentially

[57] https://www.mpi.govt.nz/resources-and-forms/registers-and-lists/places-of-first-arrival-seaports/

'suitable' ecological data sources were identified for each AOI (between 15 and 27; Section 5). Each of these potential data sources spanned the Anthropause period and were robust (high sampling effort), were located within or near to the AOIs, and were available either on request or publicly. Of these data sources, some were location-specific (e.g. consent-based monitoring) and others were consistent across all AOIs, e.g. DOC marine mammal sightings database (DOC 2023a), international bird database (eBird 2023), NIWA-SCENZ Ocean Colour Application (Pinkerton et al. 2022), etc. Overall, there appears to be multiple potential lines of ecological data for all the AOIs that could be used for future data analysis in Stage two.

Proposed Stage two data analysis approach
We suggest a clear conceptual model is first developed that follows a Multiple Levels and Lines of Evidence (MLLE) approach. Using this approach, each potentially suitable causal data type (e.g. species abundance and distribution) may be used as potential 'line of evidence' to infer causality from the explanatory variable(s) (e.g. passenger vessel traffic density, number of local tourism operator vessel trips, etc.). As the data sources investigated here have associated geospatial and temporal data, it is likely that a geospatial analysis-type approach will be appropriate. Using this approach, criteria (e.g. distribution and / or abundance of species) can be displayed and analysed for strong temporal and spatial correlations with the explanatory variables. Following the analyses of each MLLE, these results could be integrated to assess the overall environmental effect of marine tourism activity. This effect can be estimated by sequential analysis of lines of evidence (Hull & Swanson, 2006) and / or a Bayesian approach (Schleier et al. 2015).

Finally, Stage two of the assessment should not be limited to using the data identified in this report. If further suitable data / knowledge becomes available over time, this should also be considered for Stage two analysis.

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Appendix 1. Ecological metadata summary for Milford Sound / Piopiotahi, Stewart Island / Rakiura, Otago Harbour / Otakou, Akaroa Harbour and Kaikōura Peninsula. Data collated and described here was limited to those data that were publicly available through online searches, or that were provided by data custodians.

See attached electronic appendix.