Aerial survey of leatherback turtles in the waters off North Island, New Zealand

Final Report

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1. Executive Summary

West Pacific leatherback sea turtles (*Dermochelys coriacea*) are a Critically Endangered leatherback population that has declined by nearly 90% in recent decades. They face ongoing threats from fisheries bycatch throughout their migratory range. To address critical data gaps regarding leatherback abundance and distribution in New Zealand's waters, the Department of Conservation's Conservation Services Programme (DOC-CSP) contracted Upwell Turtles (Upwell), in partnership with Monash University and Earth Sciences New Zealand, to design and implement New Zealand's first fishery-independent aerial survey targeting leatherbacks in the Bay of Plenty. This multi-year project aimed to estimate minimum abundance, characterize distribution within a known bycatch hotspot and a control site, and evaluate environmental conditions associated with turtle presence.

The project successfully established local survey capacity, refined survey design through stakeholder consultation, completed observer training, and conducted aerial surveys during the expected seasonal peak for leatherback presence. Although no leatherbacks were detected—likely reflecting anomalous environmental conditions and atypically low regional turtle presence—surveys confirmed detectability by documenting one turtle just outside the survey area and generated substantial auxiliary data on marine megafauna and ecosystem indicators. The project demonstrated the feasibility of aerial surveys in New Zealand waters, identified key logistical and environmental constraints, and highlighted the need for greater survey flexibility, expanded effort and continued investment in fishery-independent monitoring. These findings provide an essential foundation for future research and management aimed at reducing leatherback bycatch and improving protection for this transboundary, critically endangered population.

2. Project Background

West Pacific leatherback sea turtles (*Dermochelys coriacea*) are Critically Endangered due to a variety of anthropogenic impacts, including bycatch (incidental capture) in commercial fisheries throughout their range. Leatherbacks predominantly interact with New Zealand surface longline commercial fisheries that target swordfish and bigeye tuna off the northeast North Island in Fisheries Management Areas (FMA) 1 & 2 during summer and autumn. Fisheries independent data on leatherback distribution and abundance are required to determine overlap with New Zealand commercial fisheries, inform national and regional risk assessments, and identify potential environmental indicators to avoid or reduce fishery interactions.

Research by Dunn et al. (2022, 2023) highlights a recent and significant increase in interactions of leatherbacks with New Zealand's longline fisheries. Reported fishery captures, based on Ministry observer and fisher self-reported data, increased substantially from a historical annual average of 15.5 to 50 in 2020–21. Nearly all of these (97.7%) captures were reported from surface longline fisheries. Most captures (85.3%) were self-reported by fishers; observer coverage was sparse. Just 9.4% of the vessels reported 94.5% of the leatherback captures, with one vessel reporting 40.4% of all captures. Some non-reporting of captures seemed likely.

As of 3 August 2023, the use of circle hooks in surface longline fisheries (in line with WCPFC CMM 2018-04) became mandatory in New Zealand. Although all sea turtles are protected under New Zealand law, New Zealand's leatherback population is classified as 'data deficient' due to insufficient information on its abundance and distribution.

Leatherback turtles have a suite of unique physiological attributes and behaviors that enable them to occupy cooler water than hard-shelled sea turtles. Leatherbacks are highly migratory and distributed across the world's oceans except for the Arctic and Antarctic. Of the seven populations of leatherbacks, two (West Pacific and East Pacific) occur within the Pacific Basin. West Pacific leatherbacks migrate from nesting beaches in the western Pacific (Papua New Guinea, Solomon Islands, Indonesia and Vanuatu) to areas where dense aggregations of gelatinous zooplankton occur (e.g., the California Current along the US West Coast and oceanic eddies off New Zealand). These prey items include jellyfish and tunicates such as pyrosomes or salps, which may accumulate in some of these areas, particularly the shelf margins and in offshore areas with oceanographic features that retain zooplankton, such as fronts, eddies, or convergence zones (Benson et al. 2011).

The West Pacific leatherback population declined by about 87% between 1984 and 2017 (Tapilatu et al. 2013; Martin et al. 2020), at an annual rate of 6%, to 790 nesting females in 2015–2017 (estimated at nesting beaches in Papua Barat, Indonesia where 75% of nesting activity occurs in the western Pacific; Martin et al. 2020). A similar rate of decline (80%) has been estimated from aerial survey data between 1990 and 2017 at the central California foraging ground (Benson et al. 2020). All West Pacific leatherbacks nest in the western Pacific, but distinct subpopulations (associated with the timing of nesting season) migrate to different foraging grounds throughout the Pacific (Benson et al. 2011). Post-nesting leatherbacks from the boreal summer (mid-year) nesting subpopulations travel to foraging areas in the South China Sea, North Pacific Transition Zone (Kuroshio Extension), and the US West Coast. Leatherbacks that nest in the boreal winter (end-of-year) forage in the waters off Australia, New Zealand, and nearby Indonesian seas (Molucca, Ceram, and Halmahera, and Banda Seas; Benson et al. 2011, Bailey et al. 2012, Hays et al. 2023, Dunn et al. 2023).

Leatherback population declines in the Pacific are largely attributed to fisheries bycatch, plastic pollution and ship strikes, as well as threats at nesting beaches (Tiwari et al., 2013). Leatherbacks migrate through multiple exclusive economic zones (EEZs) and across vast stretches of ungoverned high seas habitats (Harrison et al. 2018). Their highly transboundary nature makes the creation of cohesive protections for leatherbacks across their entire ranges and life histories very difficult.

2.1 Scope of Work

The Department of Conservation (DOC) New Zealand, Conservation Services Programme (CSP) contracted Upwell to conduct an aerial survey for leatherbacks off the Northeast North Island to document leatherback distribution and estimate minimum abundance within two designated survey areas (a bycatch hotspot and a control site), in partnership with Monash University and Earth Sciences New Zealand (previously the National Institute of Water and Atmospheric Research, NIWA).

The primary objective of this project (POP2023-01) was to provide the first fishery-independent data on the distribution and minimum abundance of leatherback sea turtle numbers within a given hotspot off the Northeast coast of North Island, where a high number of fisheries interactions had been reported. The specific objectives of this project were to:

1) Design and trial an aerial survey for leatherback sea turtles and other marine megafauna in an eastern Bay of Plenty hotspot during a temporal window of historically elevated leatherback observed presence and fisheries overlap;

2) Provide fishery-independent information on the minimum abundance of leatherbacks inside the bycatch hotspot and within a control site, as well as other marine megafauna and ecological indicator species observed during flights; and

3) Provide information on the distribution of leatherbacks in relation to environmental variables known to influence their distribution.

In Year 1 (2024), we initiated the study with a scoping phase to conduct stakeholder and partner consultations, engage in reconnaissance to assess logistics, including conditions on the water (e.g., habitat suitability), and ground truth assumptions. Our team presented the proposed design of the aerial survey to the Conservation Services Programme (CSP) Technical Working Group on 25 June 2024 and incorporated feedback into the survey plan prior to the commencement of surveys. During 2024, we conducted pre-survey preparations, including aircraft and observer contracting, health and safety planning, survey design improvements, organization of observer training, and logistical coordination for the 2025 aerial surveys.

During Year 2 (2025), aerial observers selected for the surveys completed training on aviation health and safety, survey techniques, and identification of leatherbacks and other key species. The aerial surveys were conducted in March to collect information on the minimum abundance and distribution of leatherback turtles, as well as other marine mammals and ecosystem indicator species (e.g., jellyfish, anchovies, ocean sunfish, large pelagic sharks). Aerial surveys were weather-dependent, with field-based operations conducted during March 2025, a period of expected leatherback presence and fisheries overlap based on previous characterizations of captures (Dunn et al. 2022, 2023). Additionally, during the survey period on March 18, 2025, DOC coordinated a hui in Whakatāne with the field team and Māori from Te Whānau a Apanui to share experiences and knowledge from our project and their Hinemoana II Waka project.

Following the survey period in Year 2 (2025), data collected by aerial surveys underwent analysis. The results are included within this report to the New Zealand Department of Conservation - Conservation Services Programme (DOC-CSP). Reported data includes minimum abundance and distribution of marine mammals and indicator species and analyses of survey format performance. This report also includes analyses of leatherback bycatch by the commercial surface longline fleet from commercial fishing reports (data provided by Fisheries New Zealand). All relevant data will be transferred to DOC via electronic files. The project results will be presented to the CSP Technical Working Group on 12 December 2025, with opportunities for discussion and recommendations for future work.

2.2 Scoping Trip

In addition to remote project scoping correspondence, the team conducted an in-person site visit from 7–11 May 2024 with participation by Dr George Shillinger (Upwell), Dr Sean Williamson (Monash University), Dr Matt Dunn (Earth Sciences NZ) and Scott Benson (Upwell). The team primarily engaged in reconnaissance to examine available aircraft, assess logistics and local conditions (e.g., weather expectations and habitat suitability), and ground truth assumptions. This included talking to local fishers experienced in operating spotter aircraft, evaluating airfields along the coast to determine the feasibility of running field operations from each location, and visiting three potential aircraft providers to evaluate the suitability of aircraft, pilots, and airfield services prior to selection. The site visit included an open workshop for interested parties (Appendix A) to meet the team on 10 May 2024.

2.3 Study Area and Timing

Two survey areas were delineated: the bycatch ‘Hotspot’ identified by Dunn et al. (2022, 2023) in the eastern Bay of Plenty and an additional control area in the western Bay of Plenty (Figure 1). The survey areas were designed to be approximately equal (Hotspot 4,915 km^2 and Control 5,195 km^2). Additionally, as the Hotspot area is naturally positioned along the 1000 meter isobath, the control area was designed to maintain similar depth gradients by also following the 1000 meter isobath. During the survey period in March 2025, the control area was extended 12 km south by adding 3 transect lines (Figure 2) to further investigate the region near the potential leatherback sighting from the initial fine-scale surveys during week one.

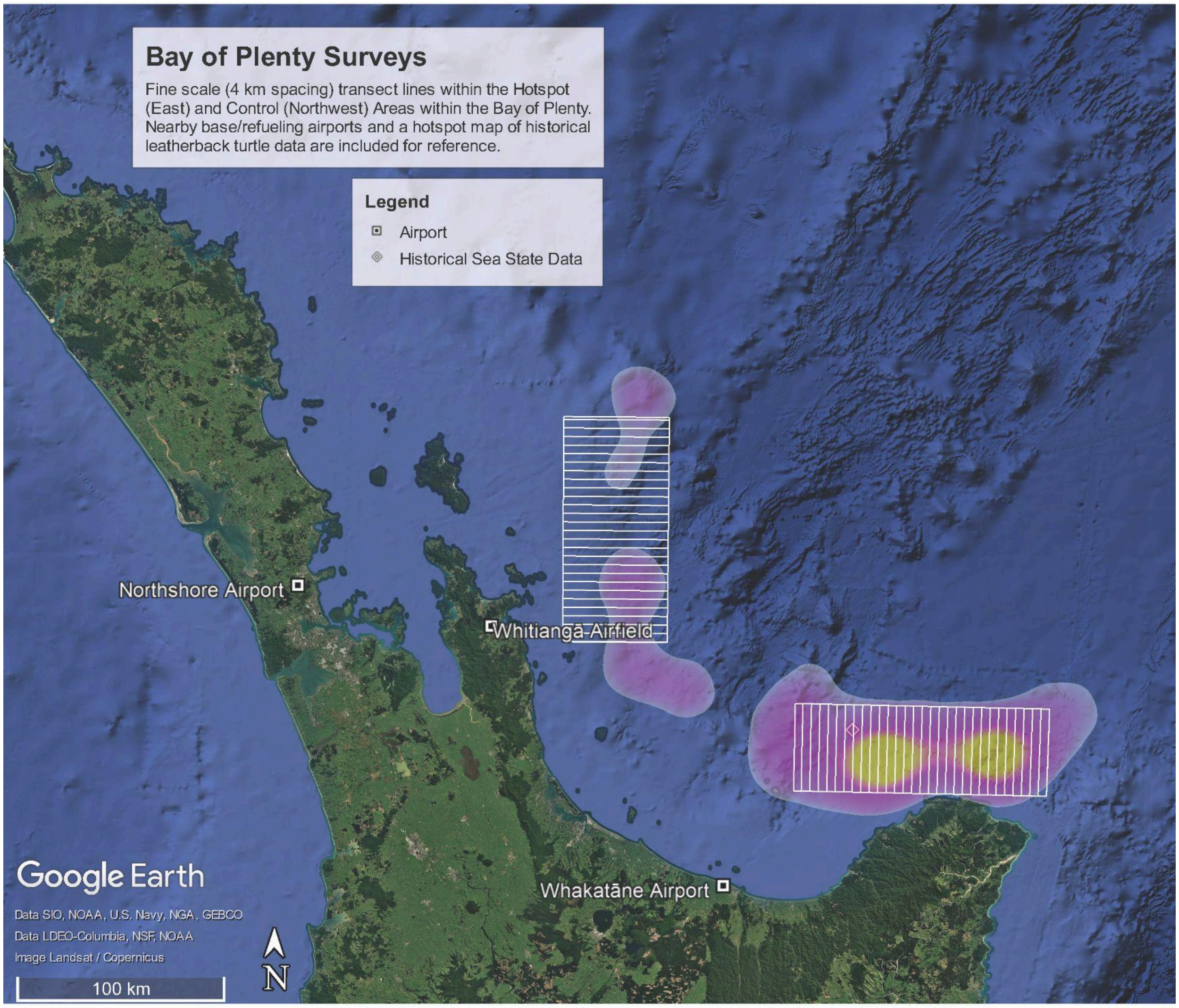

Figure 1: Fine-scale (4 km spaced) transect lines within Hotspot and control areas, with nearby airports and a hotspot map of historical leatherback data included.

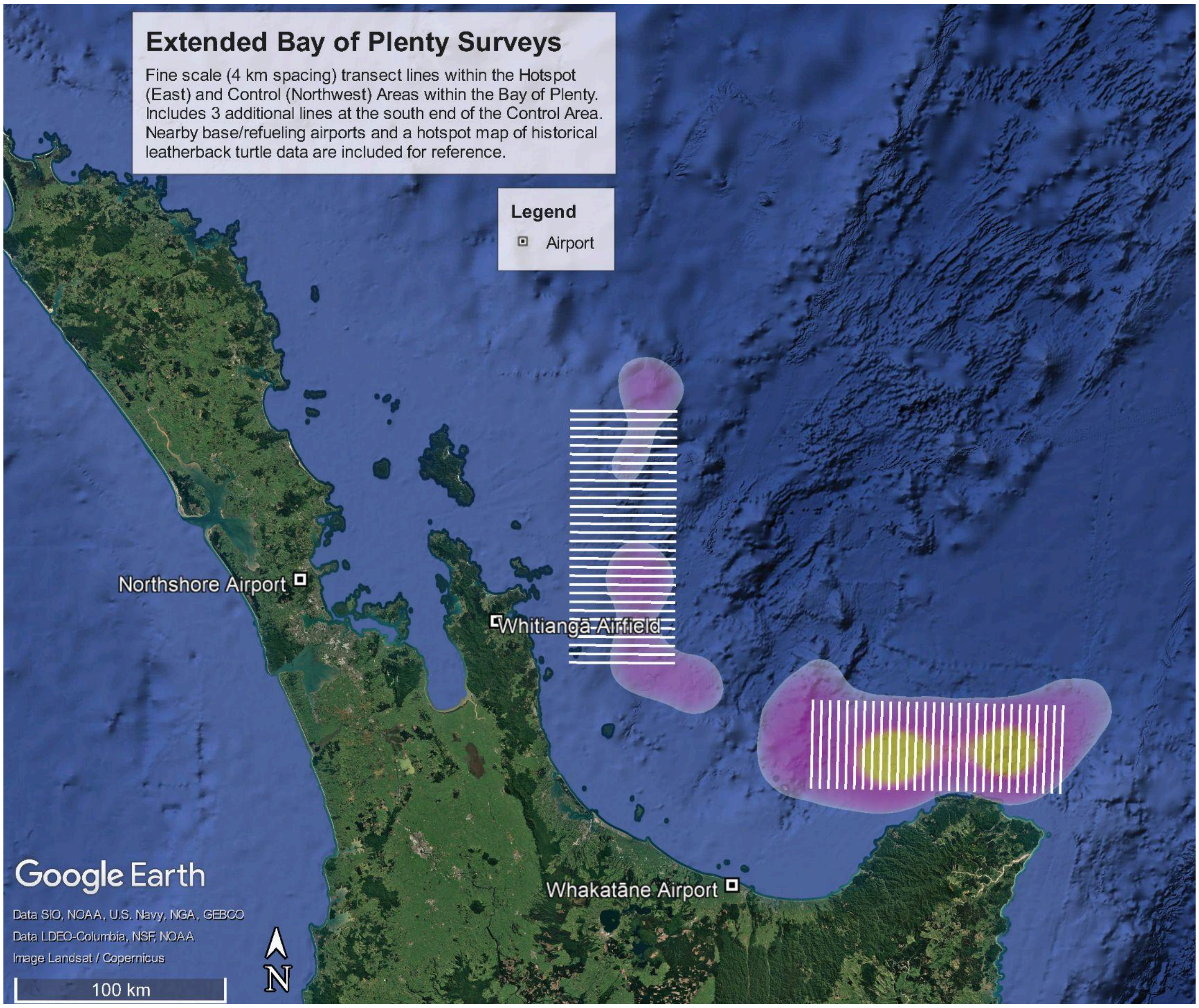

Figure 2: Fine-scale (4 km spaced) transect lines within Hotspot and control areas, including extension to the south end of the control area (Northwest grid). Nearby airports and a hotspot map of historical leatherback data are also included.

Table 1: Boundary (corner) coordinates of selected Hotspot and control areas, including the southern extension of the control area.

Corner	**Hotspot Area**		**Control Area**	
Northwest	37°09’00” S	177°16’48” E	35°57’00” S	176°03’00” E
Northeast	37°09’00” S	178°37’48” E	35°57’00” S	176°36’00” E
Southeast	37°31’12” S	178°37’48” E	37°00’30” S	176°36’00” E
Southwest	37°31’12” S	177°16’48” E	37°00’30” S	176°03’00” E

Aerial surveys were conducted during historical peak leatherback encounter times (March 2025) when weather conditions were expected to be the most favorable for aerial surveys (mostly sunny and calm). March is also a period with elevated sea surface temperature (SST), which was found to correlate with higher rates of entanglement (Dunn et al. 2023). Surveys began on 11 March and extended through 22 March. Fieldwork was based out of Auckland's North Shore Airport (control area) or Whakatāne Airport (Hotspot area). To maintain flexibility, Upwell made cancellable lodging and transportation contingency plans for the duration of the survey window at each field site (see below). Exact dates at each location were determined just before the start of the surveys, based upon forecasted weather conditions in the Bay of Plenty.

2.4 Aircraft Provider Selection

The team evaluated three aircraft for the project: a Piper Aztec operated by Sunair, a VulcanAir (Partenavia) operated by Union Airways, and a Britten Norman Islander operated by Island Airways. Following a test flight, the Piper Aztec was ruled out because of its low-wing configuration that obstructed visibility. After further evaluations of pilot experience, safety measures, and plane configurations, Upwell opted to extend a contract offer to Island Aviation.

In August of 2024, Upwell contracted Island Aviation to provide a high-wing, twin-engine aircraft (Britten Norman Islander), maintained under Part 135 aviation requirements for the March 2025 surveys. A second Britten Norman Islander aircraft was also available to the team as a backup (or for parts), if needed. The aircraft was capable of maintaining a minimum altitude of 200 meters under single-engine power while carrying five passengers and survey equipment. The aircraft had a minimum flight endurance of 3-3.5 hours without refueling, while carrying up to 5 passengers and equipment with a combined weight of up to 450 kilograms at a cruising speed of 90–120 knots. Side bubble windows installed on the passenger-seat windows of the aircraft facilitated downward observation by the trained members of our team, and separate flat windows were available for lateral viewing. The aircraft was configured as follows:

- Pilot & Co-pilot seats
- Data recorder seated in row 2
- Left/Right forward-facing seats at bubble windows in row 4
- Left/Right forward-facing seats at flat windows in row 5

Island Aviation provided two fully trained pilots. A fully trained pilot was defined as having accumulated the following minimum flight times prior to the Survey Period: 1) 1000 hours of total pilot time with 500 hours as PIC, including 100 hours in the preceding 12 months; 2) 50 hours (PIC, SIC or dual) on overwater flights at ~200m altitude, similar to those described in the survey methods; and 3) 50 hours PIC on the specified aircraft or a multi-engine aircraft of like make and model within the preceding 12 months, including 25 hours in the last 6 months. The pilot in command was required to be capable of maintaining slow airspeeds (90-100 knots), a consistent heading along transects, and circling at ~200 meters altitude safely without losing speed or altitude, to allow identification and enumeration of species of interest. Each pilot assigned to this fieldwork had a commercial pilot's license with Part 135 certification, medical certification and underwater egress certification valid for the entirety of the Survey Period.

An optional mounted camera provided by Island Aviation was included in the initial contract. However, Upwell decided not to pursue this option after a team discussion of the associated limitations, including difficulty identifying species on a flat 2-D viewing angle, the added costs of the camera and mounting equipment, and the time required for image analysis.

Image Set 1: Britten Norman Islander aircraft owned by Island Aviation with fixed high-wing twin engines (top left and right), pilot and co-pilot seats (bottom left), and three rows of passenger seats for bubble and flat window observers and data recorder (bottom right). Bubble windows are installed on the fourth row. Photo credits: George Shillinger/Upwell.

2.5 Observer Selection and Hiring

In addition to Upwell's team of experienced observers, a team of local observers from project collaborators and DOC was recruited for training and capacity building. Experienced observers included Scott Benson (Upwell), Karin Forney (Upwell), Sierra Fullmer (Upwell), and Sarah Dwyer (DOC). Additional observers, who received training before and during the flights, included George Shillinger (Upwell), Sean Williamson (Monash), Irene Middleton (Earth Sciences NZ), Brit Finucci (Earth Sciences NZ), and Matt Dunn (Earth Sciences NZ). Observer participation agreements and subcontracts (if required) were coordinated directly with each organization. A subcontract was established with Earth Sciences NZ to support costs for the training and participation of Earth Sciences NZ observers and equipment provisioning (discussed below).

2.6 Health and Safety Plans

Island Aviation and DOC's Aviation Risk Advisor, Jeremy Feasey, audited the Health and Safety Plan for the aerial surveys. Detailed contingency plans were developed for over-water flight hazards, including but not limited to organizational setup, in-flight loss of control, system component failure, fuel miscalculation and quality, and emergency ditching and subsequent survival. These contingency plans included the acquisition of appropriate safety equipment and safety training of all participants (observers and pilots). Safety equipment included two life rafts (Rukuwai 6-person Waypoint), one personal flotation device with attached personal locator beacon per passenger/pilot (Baltic Legend 305 harness SLA PFD with an attached RescueME PLB1, or Crewsaver Seacrewsader 275N vests with inbuilt AIS), and one safe-cutting tool per passenger in case of equipment entanglement. In addition to equipment and training, we scheduled six team members whenever feasible throughout the survey window to enable a rotating "base" position for observer rest and ground-based flight tracking using FlightAware, a flight tracking website, as well as cellular communications.

2.7 Observer Training

All survey participants were required to have current emergency underwater egress training. To support this, Upwell coordinated a custom Helicopter Underwater Egress Training (HUET) course, modified for fixed-wing aircraft, through Wood Training. This training was held on 4 February 2025 in New Plymouth, New Zealand, and attended by observers and pilots from Earth Sciences NZ, DOC, Upwell and Island Aviation for certification completion or renewal. A separate Aviation Aircraft Underwater Escape and Survival training was arranged through ERGT Australia for Monash University observers on 4 December 2024.

Prior to the field season, observers received field methods and species identification training for marine species in the Bay of Plenty region. This training was adapted from existing Upwell/NOAA protocols to include an overview of distance sampling methods, plane configurations and viewing angles, general species identification and relevant identification methods. Sarah Dwyer (DOC) and Earth Sciences NZ observers had experience with local species. Additional species of interest included cetaceans, pinnipeds, manta/devil rays, sharks and hard-shelled turtles. New Zealand-specific information and images were incorporated from DOC and Earth Sciences NZ resources, including Bay of Plenty sightings, manuscripts and reports by local experts (i.e., Malcolm Francis and Maryanne Nygaard), and imagery provided by local groups (i.e., Manta Watch NZ). The training was held online on 19 February 2025.

2.8 Logistics Coordination

Once the survey dates were finalized, lodging accommodations were reserved within a 20-minute drive of each base-airport for the duration of the survey window, including the optional extension period. Team housing (Upwell/Earth Sciences NZ/Monash) with 24-hour cancellation policies was reserved through Airbnb in 1-week intervals (March 9-17, 17-24, 24-29) to maximize the flexibility of the project planning. In the event additional housing was required, DOC and/or incoming observer(s) stayed in a nearby hotel.

Within the observer schedule, designated travel days were included in the planning based upon their origin. International flights were booked into Auckland. Island Aviation agreed to transport up to five observers between North Shore and Whakatāne when moving field sites. The provision of one car for use in the field was included in the Earth Sciences NZ subcontract and driven to the field site by the scheduled Earth Sciences NZ observer(s). Additional rental car(s) reserved by DOC/Upwell facilitated local travel and airport transportation.

2.8.1 Aerial Survey Design and Methods

The project team drew on 30+ years of experience designing and conducting aerial line-transect surveys for coast-wide and adaptive fine-scale surveys to examine trends in leatherback abundance off central California (Benson et al. 2007, 2020). The survey framework developed for New Zealand surveys utilized the same well-established line-transect sampling methods (Buckland et al. 2001) with the goal of estimating the minimum number of leatherback turtles within the Bay of Plenty survey areas. Australia's National Guidelines for the Survey of Cetaceans, Marine Turtles and the Dugong (DCCEEW 2024) were reviewed when developing aerial survey techniques and methods to confirm method standardization.

The surveys were designed to provide minimum estimates of leatherback abundance and density, because this initial feasibility study did not include the development of correction factors for perception bias and availability bias (Marsh and Sinclair 1989) during the survey. Such correction factors require considerable additional cost and effort, i.e., using independent observer teams that allow capture-recapture methods (Borchers et al. 1998, Hiby & Lovell 1998, Carretta et al. 1998), circle-back methods that require prior baseline data on species densities (Hiby 1999), and/or dive behavior data to estimate the proportion of time a leatherback turtle is at or just below the water surface and available to be seen by the aerial team (Benson et al. 2007, 2020). Based on the results of the current study, future projects may be able to develop and implement methods to estimate these sources of detection bias and provide absolute estimates of abundance.

The transects were designed with systematic random sampling using Distance 7.5 release 2 software (Thomas et al. 2010) as one set of parallel line transects (per survey area) evenly spaced 4 km apart (see Map 1). Transects were oriented north-south in the Hotspot area and east-west in the control area, to survey across the bathymetric gradient, as recommended for representative sampling of the study area (Buckland et al. 2001, Thomas et al. 2010). The control area survey extension to add additional lines south of the original southernmost line was determined by replicating the east and west longitudinal boundaries of the transect lines listed in Table 1 and maintaining the 4-km spacing between transect lines, converted into latitudinal coordinates.

Image Set 2: Aerial Observers demonstrating the bubble window (top left, photo credit DOC), aerial observers and data recorder in the plane (top right, photo credit Sierra Fullmer), aerial observers next to the Britten Norman Islander operated by Island Airways (bottom).

The aerial survey team consisted of four observers (two on the left, two on the right) and a data recorder who logged sightings, transect information and viewing conditions into a laptop computer connected to a Global Positioning System (GPS). The bubble-window observers searched the area from below the aircraft (90 degrees) to approximately 55 degrees, beyond which the landing gear obscured visibility. The flat-window observers searched the area from approximately 55 degrees to 12 degrees, providing complete coverage of a 1-km strip on each side of the aircraft.

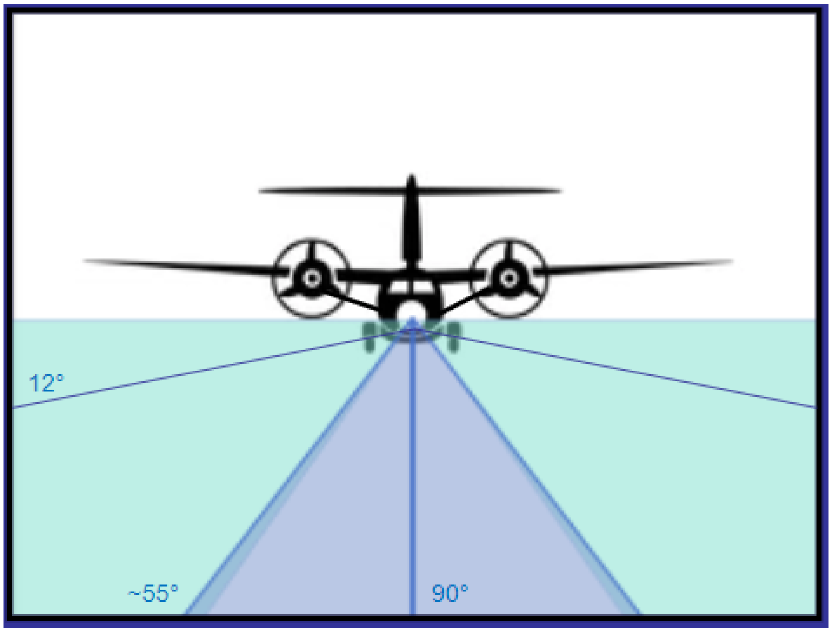

Figure 3: Approximate viewing angles of observers in bubble (blue) and flat (green) windows to demonstrate survey coverage. Photo credit: Sierra Fullmer.

Surveys were flown at a target altitude of 200 meters when weather conditions were good (minimal cloud cover, sea state at or less than Beaufort 3) to allow efficient detection of leatherback turtles. The primary survey window was early morning, before the onshore winds built in late morning. A second survey occasionally occurred later in the day if the winds stayed low.

Utilizing forecasted weather conditions and available weather radar information, a tentative survey plan was developed before each flight. This plan was developed in communication with the pilots and incorporated estimated fuel capacity to include, in order of priority: transit time from the base airport to survey site (45-60 min), transit time to base airport or a closer refueling airport, additional time for unexpected delays/airport changes, the completion of selected survey lines including between lines (15-20 min per line), and additional time for circling/off-line species identification.

Based on an estimated fuel time of 4.5 hours, most surveys included 6-10 survey lines (2.5 to 3 hours of survey time). Lines were flown in the order that optimized weather conditions during that flight. The initial plan was discussed with the pilots, and in-air adjustments to the region and number of survey lines were made as necessary through communication with the pilots. Refueling airports closer to the control and/or Hotspot area improved these coverages and allowed for more flexibility in the event of landing due to inclement weather or fuel limitations.

The survey design included the option of both coarse (8 km spacing, surveying every other transect line) and fine-scale surveys. Due to the realized weather patterns, all surveys were flown at fine-scale (4 km spacing) coverage, with minimal time between surveys of the same area.

In addition to the extensive pre-survey species identification training held in February of 2025, providing the observers with the skillsets and knowledge of local species, the project lead(s) ensured in-flight overlap of experienced and new observers on both sides of the aircraft to provide double validation when in doubt. When species were unable to be identified on first sighting, the aerial team either used the lowest taxonomic identifier the observer team could be certain of or, if weather and survey conditions allowed, circled back to the animal(s) for an additional look. When circling, the observers were considered "off effort" to minimize potential duplication of sighting data and solely focused on resighting and identifying the species of interest. The observer team also opportunistically took photos of species of interest, which have been provided to DOC for future database availability. Due to the nature of the aerial survey altitude and speed, as well as the priority of survey coverage for turtles, photography was not prioritized for any species sightings. Following the completion of the survey effort, all sighting images were compiled and matched with the date and location of the sighting according to their metadata.

2.8.2 Data Management

Data were collected using a custom aerial survey data collection program, developed by NOAA, which creates simple text files with effort and sighting information. Upwell conducted quality control and analysis of aerial survey data using custom R code to check for any errors in observation points and critical environmental data. A custom R code was also written to extract species count and sighting position data from the text files, to allow for real-time tracking and relaying of sighting information for non-leatherback species to relevant, authorized personnel.

The aerial survey data were uploaded to the shared online folder accessible to authorized personnel. The Aerial Survey Data folder was organized by data type with file names indicating processing status (raw or processed, if relevant), date and location. Data have been backed up to a remote hard drive to ensure protection.

3. Aerial Survey Effort

The survey design and budget afforded the opportunity to target good-weather windows (light winds and mostly sunny conditions), and the team completed both sets of 4-km lines once, providing overall coverage at 4-km resolution within the hotspot and control areas. Based on the results of these initial surveys, as well as consideration of remaining flight hours and weather, additional surveys were conducted within a key area of interest (i.e., suitable leatherback habitat). Additional good weather days in the control area and reduced non-flight expenses enabled a 12-km (three transect line) extension to the southern end of the control area and the completion of replicate sampling in the south control area on different days. An initial fine-scale survey of the control area was completed in fifteen and a half flight hours across three days of flying during the first week (11-15 March). An additional four and a half hour flight day was conducted in the southern end of the control area during the second week (21 March). A fine-scale survey of the bycatch hotspot was completed in sixteen and a half flight hours across three days of flying during the second week (16-22 March). A total of 36.5 flight hours were completed across ten survey flights (Figure 4), with 2877.6 kilometers of transect lines surveyed systematically (Table 3).

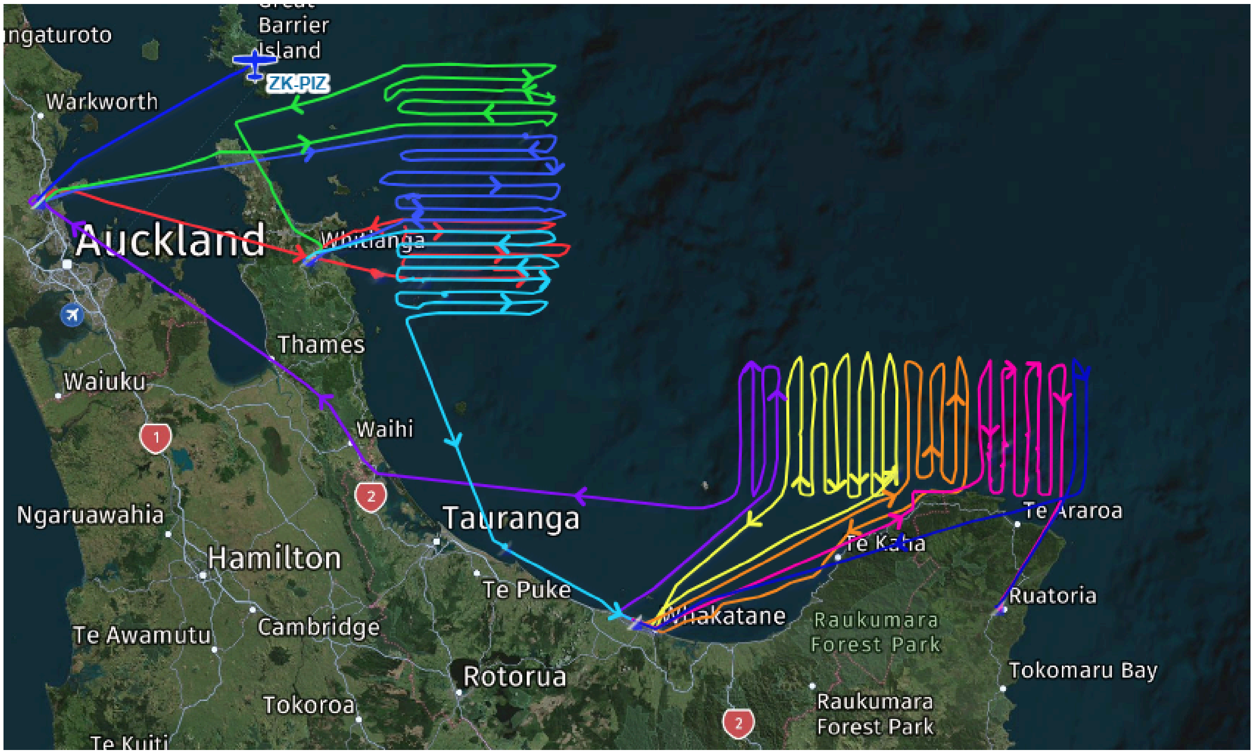

Figure 4: Flight effort across survey period, recovered from the aircraft's V2 tracking software. Each color is an independent flight; however, the northernmost survey of the control area conducted on March 11 was unavailable to be included in the figure. Photo credits: Karen Middlemiss, DOC / V2 TrackViewer.

4. Sighting and Effort Data

Species of interest were recorded during the aerial surveys. Leatherback turtles were the primary species of interest, but other species recorded included cetaceans, elasmobranchs, albatross and New Zealand fur seals. Observers also noted the presence of ocean sunfish and classified them according to size, since observations of large ocean sunfish are strongly correlated with the presence of leatherback turtles. The results are presented in alphabetical order by common name below (Table 2).

Table 2: All species observed and the number of sightings of each in each area. When large groups of individuals were sighted together, the counts provided included best estimates based on additional off-effort circling and consensus among the survey team, indicated by an asterisk. Ocean sunfish were sub-classified by size (small <0.6m, medium 0.6 - 1.2m, large >1.2m), due to large molas sharing prey species with the study's target species: leatherback turtles.

Species	Individuals Sighted (Total)	Individuals Sighted (Hotspot)	Individuals Sighted (Control)
Albatross (*Diomedeidae* spp.)	38	19	18
Arnoux's beaked whale (*Berardius arnuxii*)	3	0	3
Blue shark (*Prionace glauca*)	4	4	0
Blue whale (*Balaenoptera musculus*)	2	0	0
Bryde's whale (*Balaenoptera edeni*)	3	0	3
Common bottlenosed dolphin (*Tursiops truncatus*)	2301*	1453*	767*
Common minke whale (*Balaenoptera acutorostrata*)	1	0	1
False killer whale (*Pseudorca crassidens*)	236	6	30
Spinetail devil ray (*Mobula mobular*)	3	1	1
Oceanic manta ray (*Mobula birostris*)	11	1	2
Goose-beaked whale (*Ziphius cavirostris*)	8	2	6
Gray's beaked whale (*Mesoplodon grayi*)	2	2	0
Killer whale (*Orcinus orca*)	2	2	0
Leatherback turtle (*Dermochelys coriacea*)	1	0	0

Species	Individuals Sighted (Total)	Individuals Sighted (Hotspot)	Individuals Sighted (Control)
Long-finned pilot whale (*Globicephala melas*)	82	52	30
Mesoplodont beaked whale (*Mesoplodon spp.*)	4	4	0
Ocean sunfish (*Mola spp.*), large	82	26	51
Ocean sunfish (*Mola spp.*), medium	16	7	9
Ocean sunfish (*Mola spp.*), small	5	2	3
New Zealand fur seal (*Arctocephalus forsteri*)	1	0	1
Risso's dolphin (*Grampus griseus*)	8	5	3
Short-finned pilot whale (*Globicephala macrorhynchus*)	14	0	14
Smooth hammerhead (*Sphyrna zygaena*)	4	3	1
Sperm whale (*Physeter macrocephalus*)	12	0	12
Whale shark (*Rhincodon typus*)	2	0	1
Unidentified dolphin	241*	5	170*
Unidentified large whale	4	1	1
Unidentified marlin	2	0	2
Unidentified shark	20	7	10

4.1 Control Area

Due to predicted high winds and cloud cover in the hotspot area, the team began the field season in Auckland, based out of Northshore airport, to conduct surveys in the control area during better weather conditions. On March 11, two survey flights covered the southernmost and northernmost extensions of the area, taking advantage of a northbound pocket of low winds between weather cells (Figure 5). Just before the start of the first survey line, a leatherback turtle was spotted by the data recorder on the western end of the survey line. Attempts to relocate the turtle after circling back were unsuccessful, which may have been due to the turtle diving below the surface. A storm system with predicted high winds and widespread cloud cover prevented surveys on

March 12 and 13, but the remaining control area transect lines were completed during surveys on March 14 (Figure 6) and 15 (Figure 7), once the weather system had passed. After relocating to Whakatāne, the team had an opportunity on 21 March to resurvey the southern grid of the control area (Figure 8), where the leatherback was sighted on 11 March. In addition to re-surveying five of the southernmost lines (Control 23-27), three transects with 4-km spacing were added (Control 28-30) to investigate the area with the most potential, near the Alderman Islands.

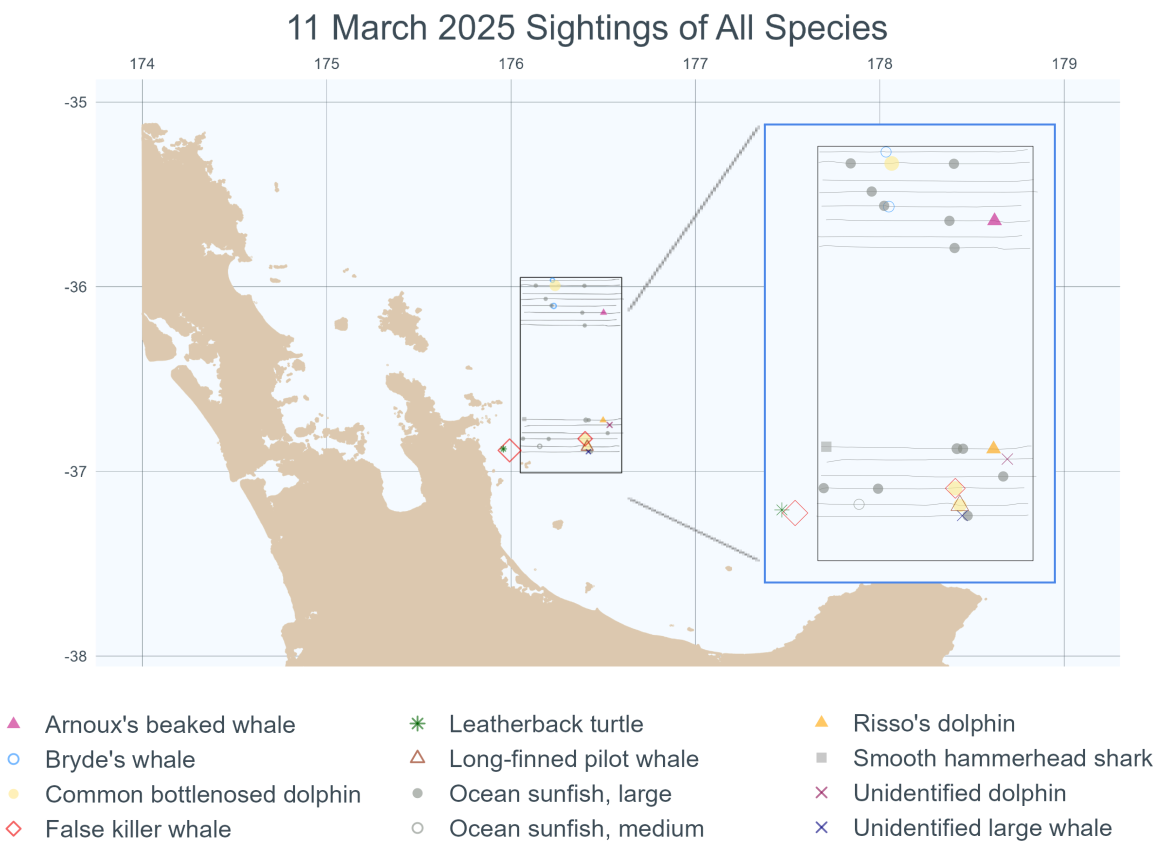

Figure 5: Aerial survey effort and species identification off control area, March 11. Symbol sizes represent the number of animals counted during the sighting, with large symbols representing more animals. The inset shows a magnified view of the Control area with effort and sightings on March 11, including a leatherback turtle sighting (✳) just west of the Control Area boundary.

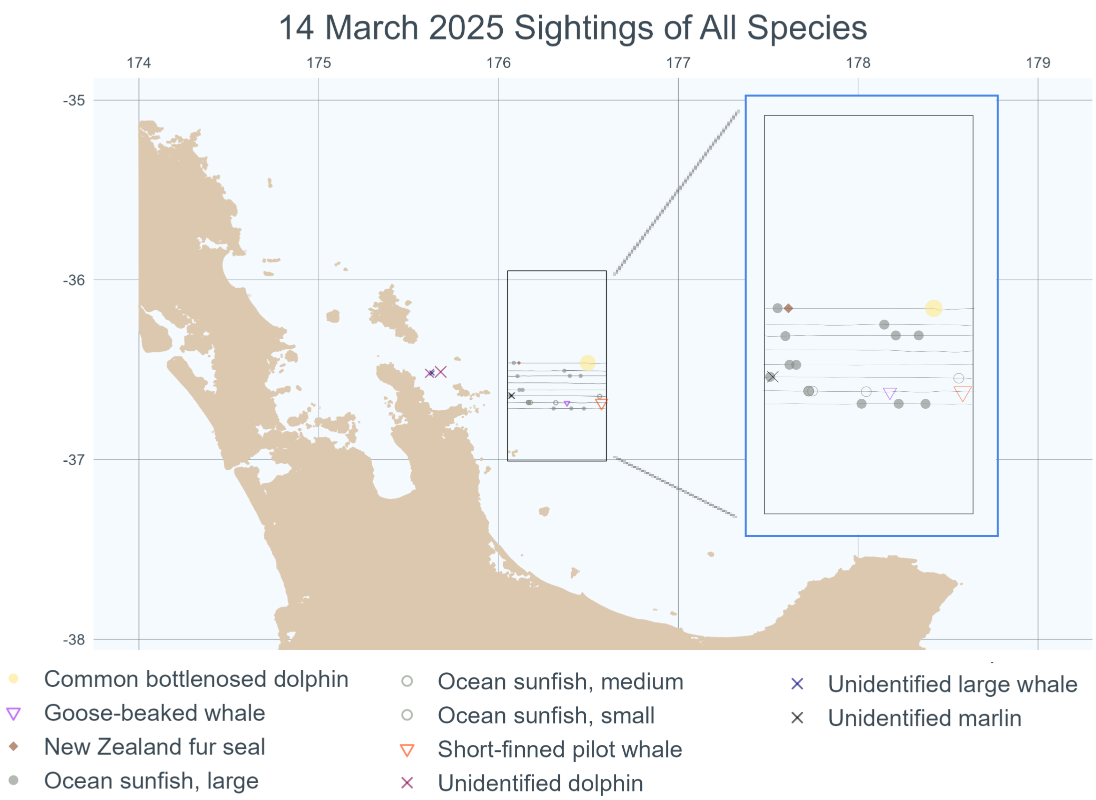

Figure 6: Aerial survey effort and species identification off control area, March 14. Symbol sizes represent the number of animals counted during the sighting, with large symbols representing more animals. The inset shows a magnified view of the Control area with effort and species sightings on March 14.

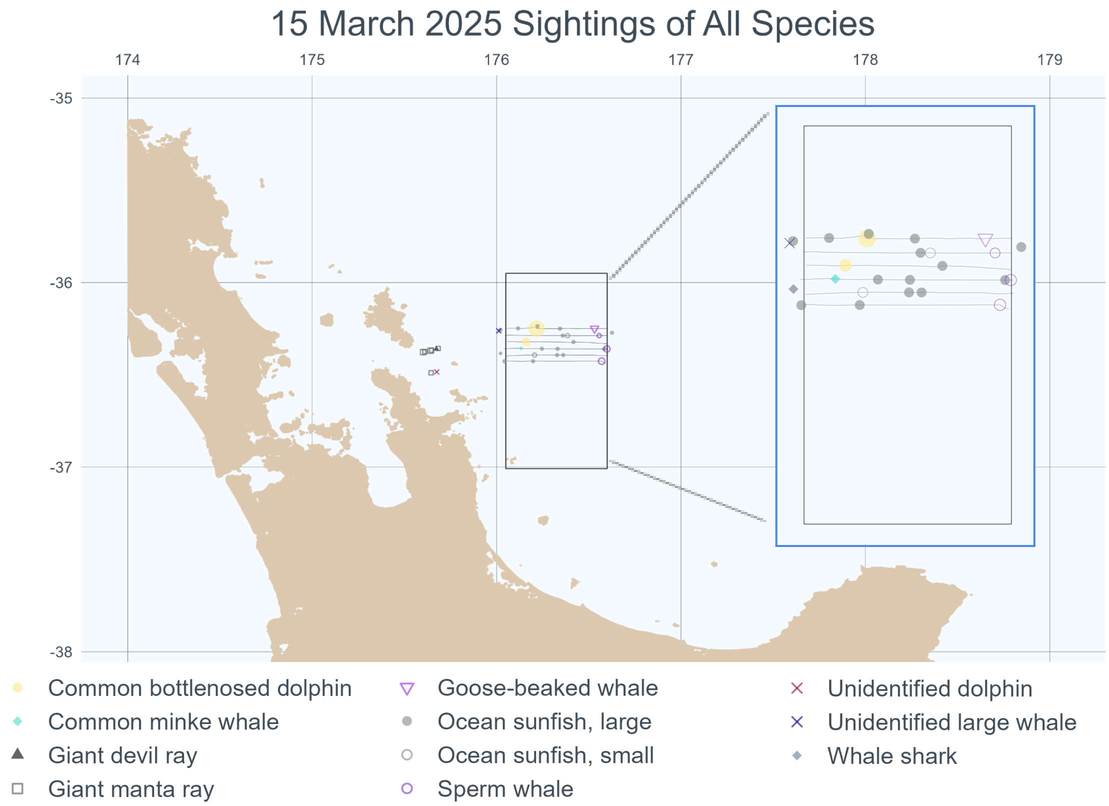

Figure 7: Aerial survey effort and species identification off control area, March 15. Symbol sizes represent the number of animals counted during the sighting, with large symbols representing more animals. The inset shows a magnified view of the Control area with effort and species sightings on March 15.

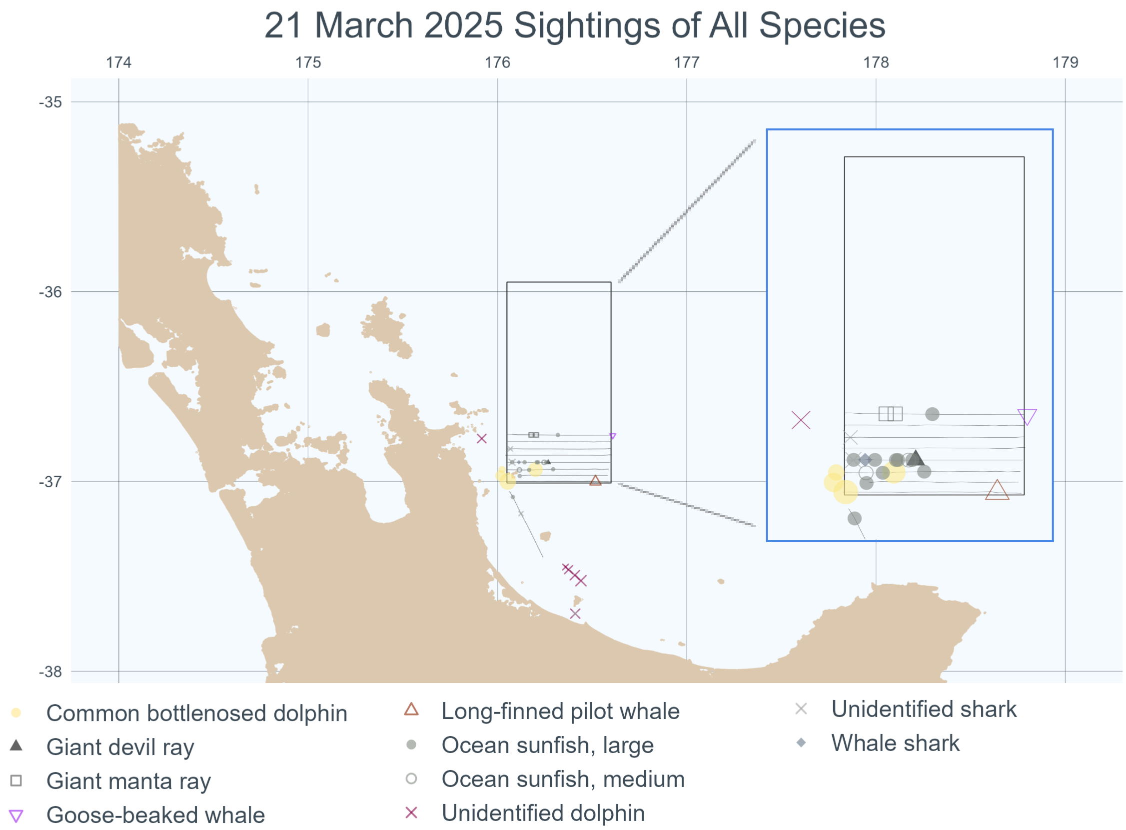

Figure 8: Extended aerial survey effort and species identification off control area, March 21. Symbol sizes represent the number of animals counted during the sighting, with large symbols representing more animals. The inset shows a magnified view of the Control area with effort and species sightings on March 21.

4.2 Hotspot Area

Throughout the majority of the survey period, the eastern end of the hotspot area had persistent high winds that increased throughout the day, requiring consistent monitoring and more flexibility in allowable wind conditions. Most surveys of the hotspot area were flown in the mornings to reduce the wind effect, but often still had a Beaufort 2+ sea state. After the team completed initial surveys in the control area, on the morning of 16 March, the western end of the hotspot area had low winds and less than ten percent cloud cover. To take advantage of this survey opportunity, the team flew from Northshore airport to survey the hotspot area (Figure 9), using Whakatāne as a refueling stop. Due to another series of nearby low and high pressure systems, high winds prevented surveys from 17-19 March. On 17 March, the observer team relocated to Whakatāne, but the pilots and aircraft did not join them until 19 March to reduce expenses associated with standby days away from base. The transect lines just north of Cape Runaway were surveyed on 20 March (Figure 10), though the water was noticeably bluer and lacked the species diversity seen in the control area. The remaining transect lines on the eastern end of the hotspot area were surveyed on 22 March (Figure 11), with increased species diversity identified on the eastern side of East Cape.

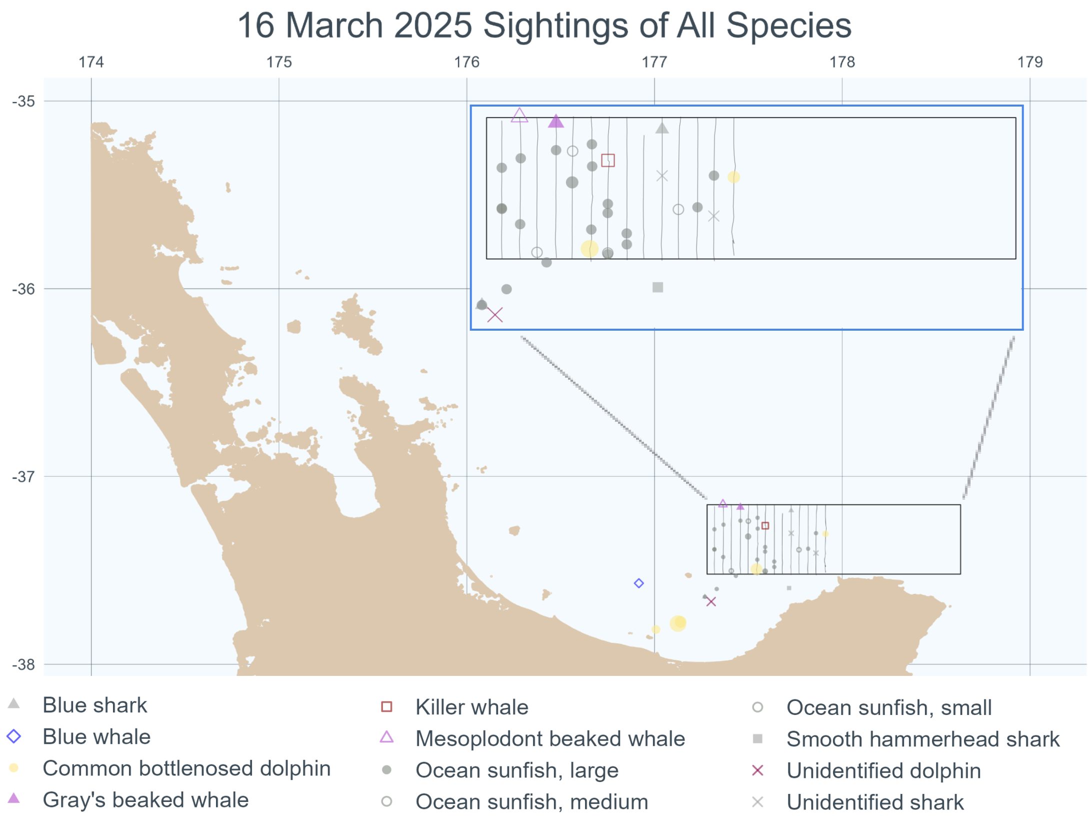

Figure 9: Aerial survey effort and species identification off Hotspot area, March 16. Symbol sizes represent the number of animals counted during the sighting, with large symbols representing more animals. The inset shows a magnified view of the Hotspot area with effort and species sightings on March 16.

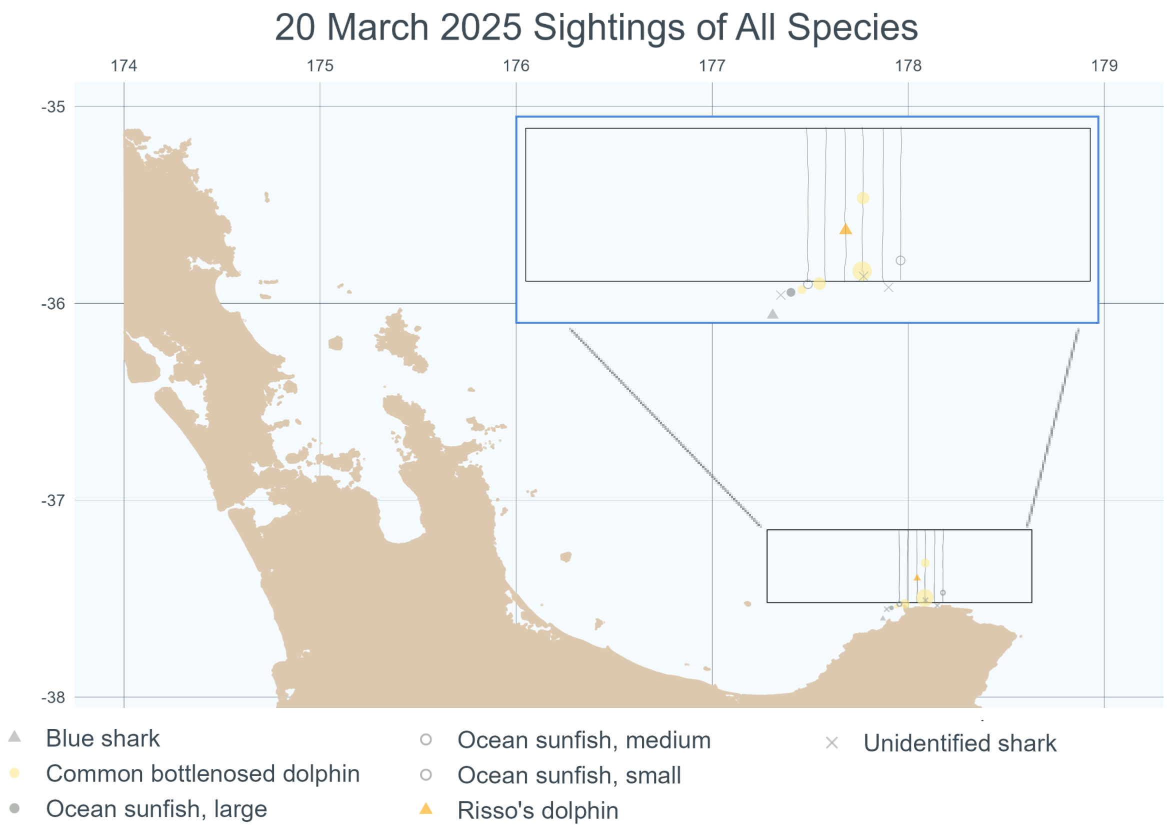

Figure 10: Aerial survey effort and species identification off Hotspot area, March 20. Symbol sizes represent the number of animals counted during the sighting, with large symbols representing more animals. The inset shows a magnified view of the Hotspot area with effort and species sightings on March 20.

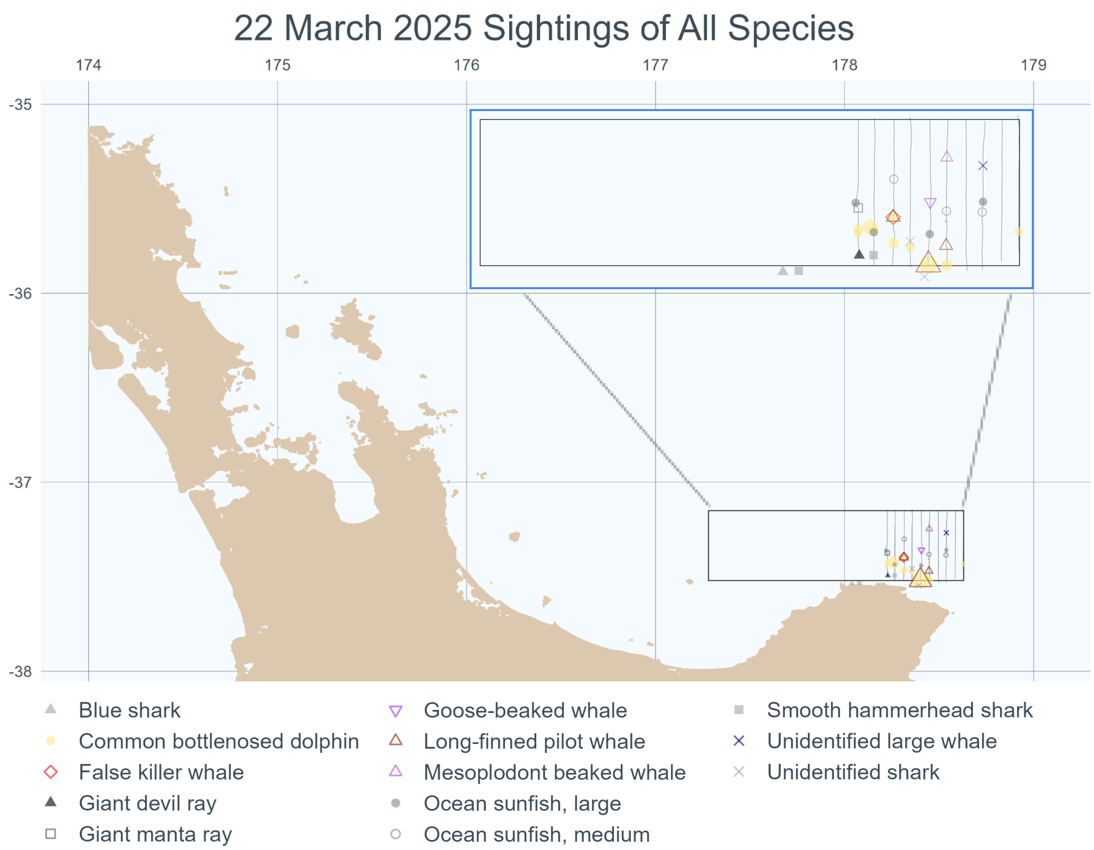

Figure 11: Aerial survey effort and species identification off Hotspot area, March 22. Symbol sizes represent the number of animals counted during the sighting, with large symbols representing more animals. The inset shows a magnified view of the Hotspot area with effort and species sightings on March 22.

Across all surveys, a high level of species diversity was identified, particularly of cetaceans, sharks and rays (Figure 12). The highest level of activity and the leatherback turtle sighting were located in the southwestern section of the control area, which warrants further exploration.

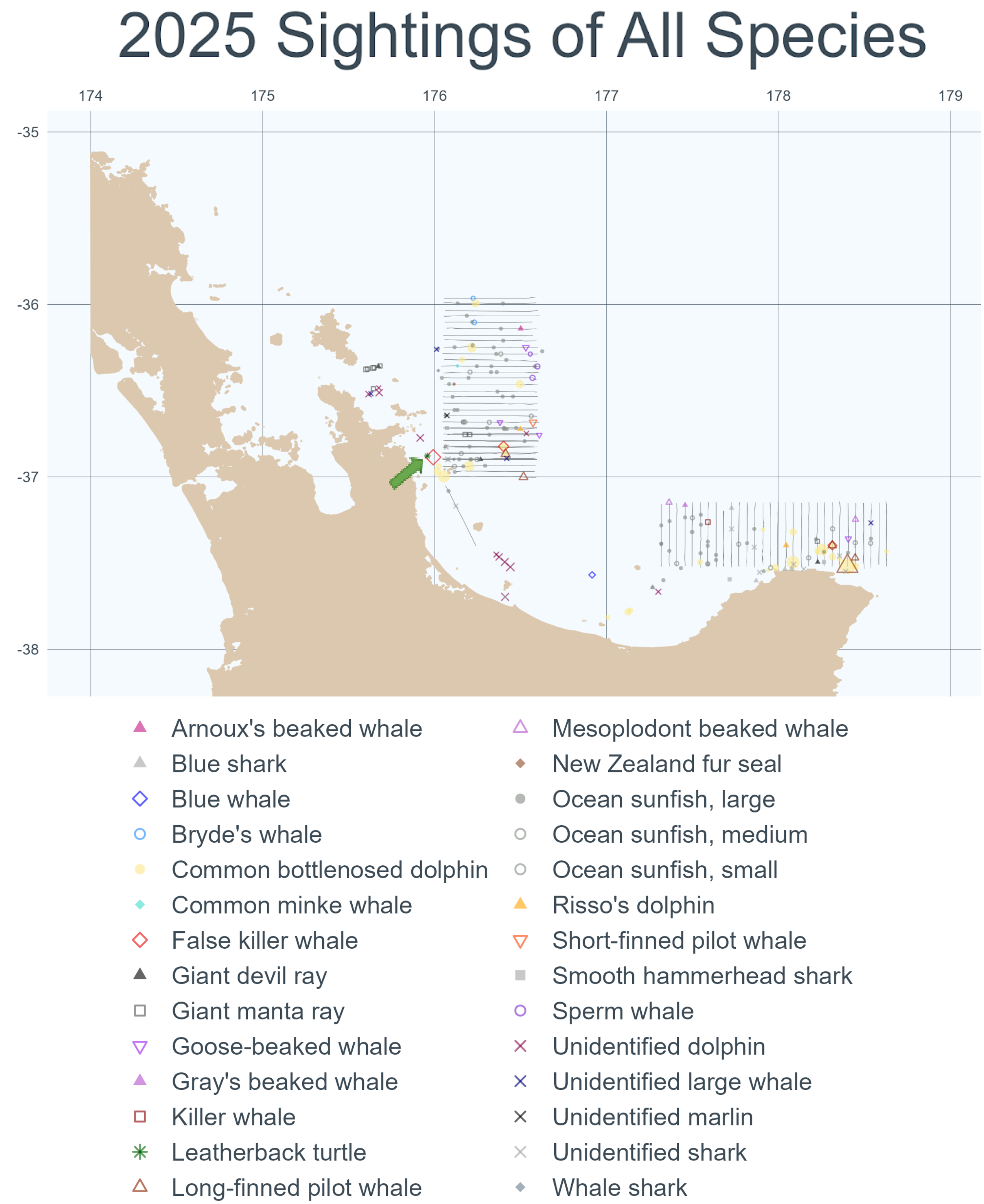

Figure 12: Completed aerial survey effort and species identification in Bay of Plenty, 11-22 March 2025. Symbol sizes represent the number of animals counted during the sighting, with large symbols representing more animals. A green arrow indicates the location of the leatherback sighting on March 11.

Table 3: Aerial survey effort (kilometers surveyed), number of sightings, and species observed while actively surveying within each Beaufort sea state.

Beaufort Sea State	Effort (km)	Sightings	Sightings Per km	Total Animals Sighted	Species (Common Name)
1	354.3	27	0.0762	788	Albatross; Common bottlenosed dolphin; Common minke whale; Long-finned pilot whale; New Zealand fur seal; Ocean sunfish, large; Ocean sunfish, medium; Risso's dolphin; Smooth hammerhead; Unidentified shark
2	1701.5	112	0.0658	922	Albatross; Blue shark; Bryde's whale; Common bottlenosed dolphin; False killer whale; Giant devil ray; Giant manta ray; Goose-beaked whale; Gray's beaked whale; Killer whale; Long-finned pilot whale; Mesoplodont beaked whale; Ocean sunfish, large; Ocean sunfish, medium; Ocean sunfish, small; Risso's dolphin; Short-finned pilot whale; Sperm whale; Unidentified dolphin; Unidentified large whale; Unidentified marlin; Unidentified shark; Whale shark
3	636.3	34	0.0534	414	Albatross; Arnoux's beaked whale; Common bottlenosed dolphin; Giant manta ray; Long-finned pilot whale; Mesoplodont beaked whale; Ocean sunfish, large; Ocean sunfish, small; Sperm whale; Unidentified shark
4	59.9	0	0	0	
5	122.4	1	0.0082	2	Common bottlenosed dolphin
6	3.3	0	0	0	
All	2877.6	174	0.0605	2126	See Table 2

5. Observer & Platform Configuration Analyses

We further evaluated the survey methodology, including observer configuration and detection rates by observer position. Despite efforts to ensure a clear view of the transect line, our analyses indicate the presence of a ‘blind’ (reduced-visibility) spot below the plane extending ~100 m, indicating sightings were missed on or near the transect line. Consequently, the aircraft and observer configuration does not meet the key assumption that all animals on the trackline are detected and that detection probability decreases monotonically with distance. Left-truncation (*i.e.,* excluding the closest 100m) is possible using distance sampling methods but substantially increases uncertainty and potential bias, and ideally should be avoided if data can be collected in a better way. We therefore recommend that future surveys, especially those for density estimation, prioritize aircraft with a belly window. Nonetheless, the configuration used provided excellent capacity-building opportunities, allowing experienced observers to overlap with and train new personnel. Post-survey maintenance by Island Aviation also revealed a floor hatch in the secondary Britten Norman Islander, offering a potential belly-window configuration option with minimal (non-structural) aircraft modifications.

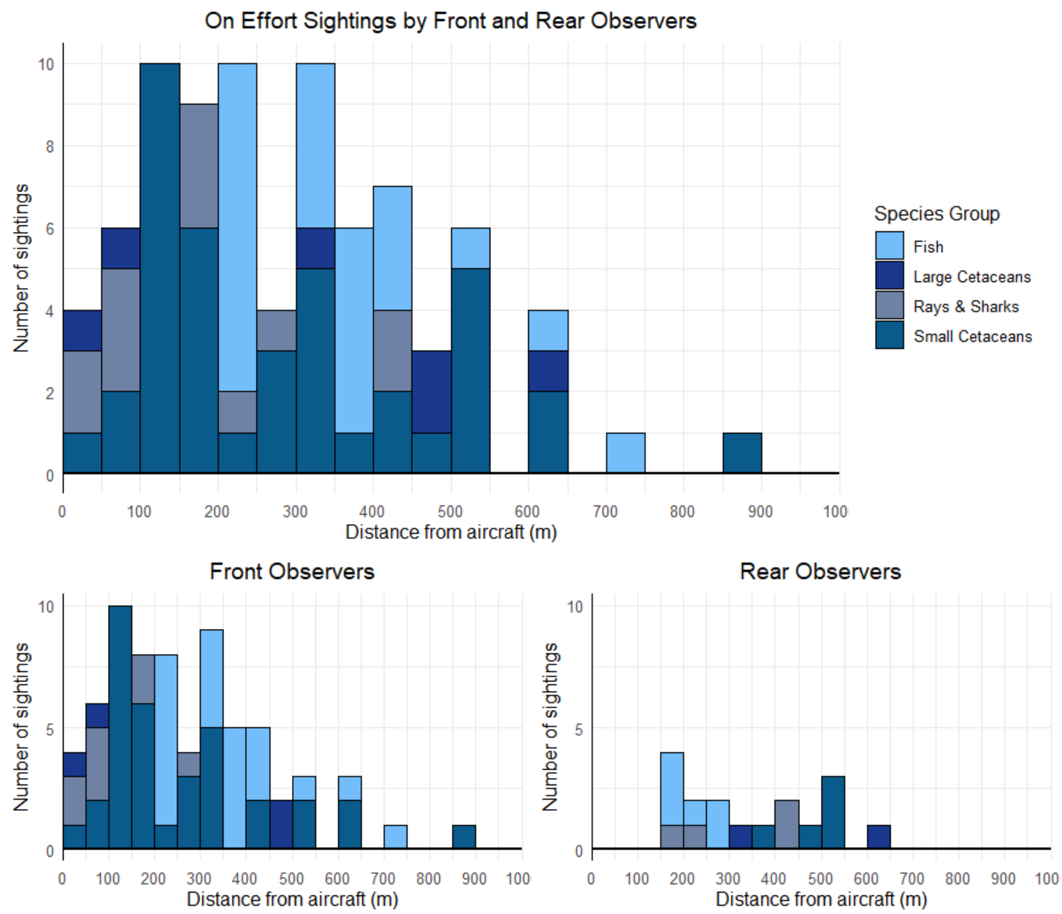

Figure 13: Observer detection rates for all observers, front observers (bubble windows) and rear observers (flat windows), binned into 50-meter increments by distance from the aircraft, across all on-effort aerial survey data in the Bay of Plenty, 11-22 March 2025. Large cetaceans included species averaging <10 meters in length (*i.e.,* blue whale, Bryde's whale, sperm whale), while small cetaceans included dolphins and whales up to 10m in length (*i.e.,* beaked whale species, minke whale).

6. Environmental Characterization

6.1 Bathymetry

The surveys were designed to cross bathymetric gradients from shallow shelf waters (<200 m) across the slope (200-2000), although the control area had a wider shelf and therefore included greater coverage of shelf waters (Figure 14). As expected, beaked whales and sperm whales were documented in the deepest waters, in some cases associated with submarine canyons. Bottlenose dolphins, long-finned pilot whales and false killer whales were observed in shelf and slope waters, while short-finned pilot whales, Risso's dolphins and Bryde's whales were associated with slope waters. Manta rays, devil rays and a whale shark were observed primarily in shallow shelf water. Large ocean sunfish, which are known to be associated with leatherback foraging habitat elsewhere in the Atlantic and Pacific Ocean (Houghton et al. 2006; S. Benson, unpublished), were widespread in shelf and slope waters of the control area, and seen most frequently in the western half of the hotspot area. The single leatherback turtle was observed in shallow waters near Whitianga, just inshore of the densest sightings of large ocean sunfish.

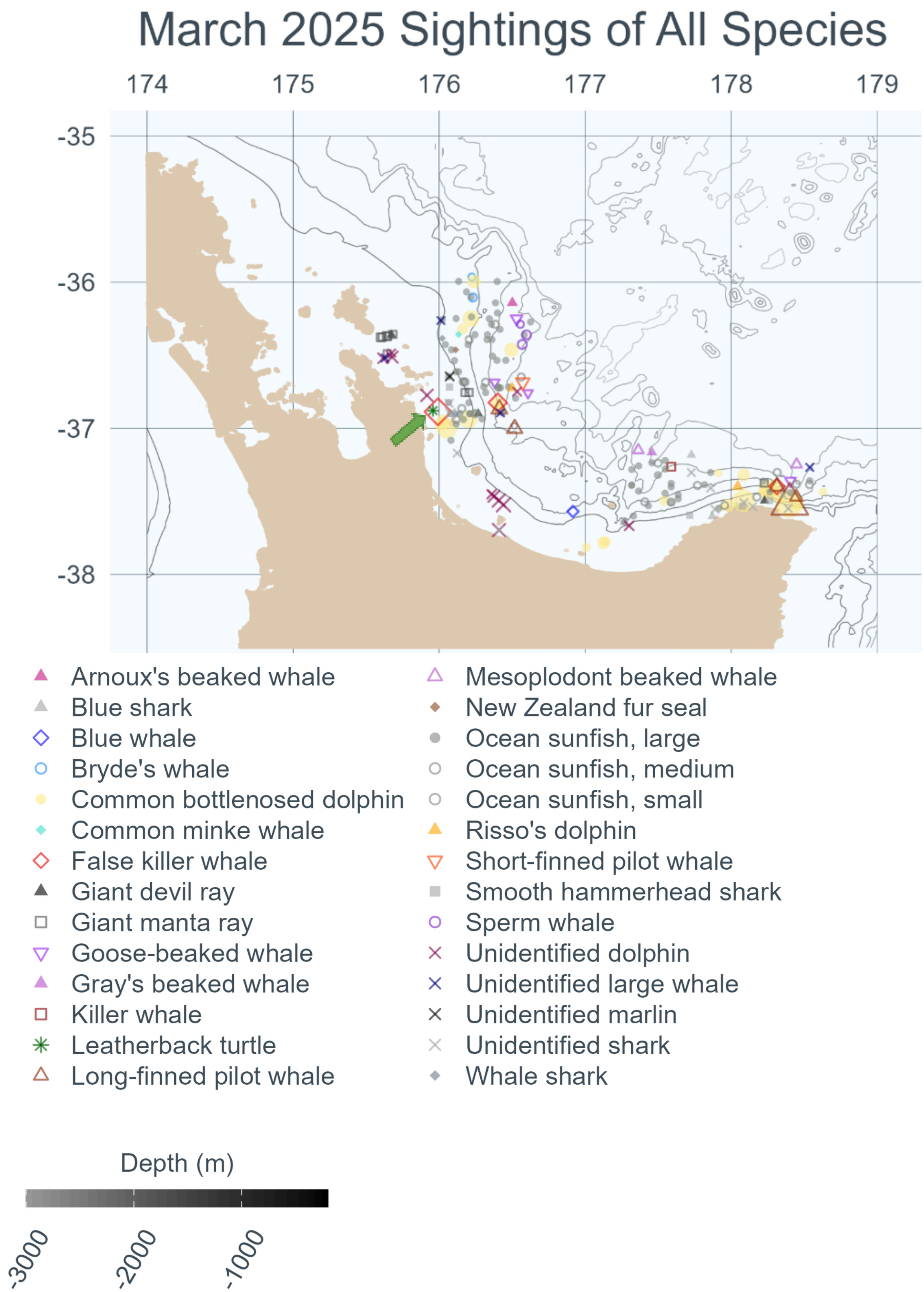

Figure 14: All recorded sightings during aerial surveys in the Bay of Plenty, 11-22 March 2025, superimposed over the Bay of Plenty bathymetry. Symbol sizes represent the number of animals counted during the sighting, with large symbols representing more animals. Isobaths are included at depths of 200m, 500m, 1000m, 1500m, 2000m and 3000m. A green arrow indicates the location of the leatherback sighting on March 11.

6.2 Sea Surface Temperature and Chlorophyll

Sea surface temperature (SST) and chlorophyll are generally correlated, with higher chlorophyll in regions with cooler SSTs. This was apparent within the Bay of Plenty, as the highest chlorophyll levels were very close to shore where waters were coolest (<20˚C). The warmest waters (>22˚C) were present in the western Bay of Plenty north of Great Barrier Island, although there was an overall decrease in SST during our study period throughout the Bay of Plenty. Sighting patterns for tropical and cosmopolitan cetacean species were as expected, with false killer whales and Bryde's whales documented primarily in the warmest waters and bottlenose dolphins and pilot whales found in a wider range of SST values. Manta rays, devil rays and whale sharks were associated with moderate SST and chlorophyll levels. The single leatherback turtle was observed in relatively warm water (approx. 21˚C; Figure 15a), with moderate chlorophyll levels (Figure 16a).

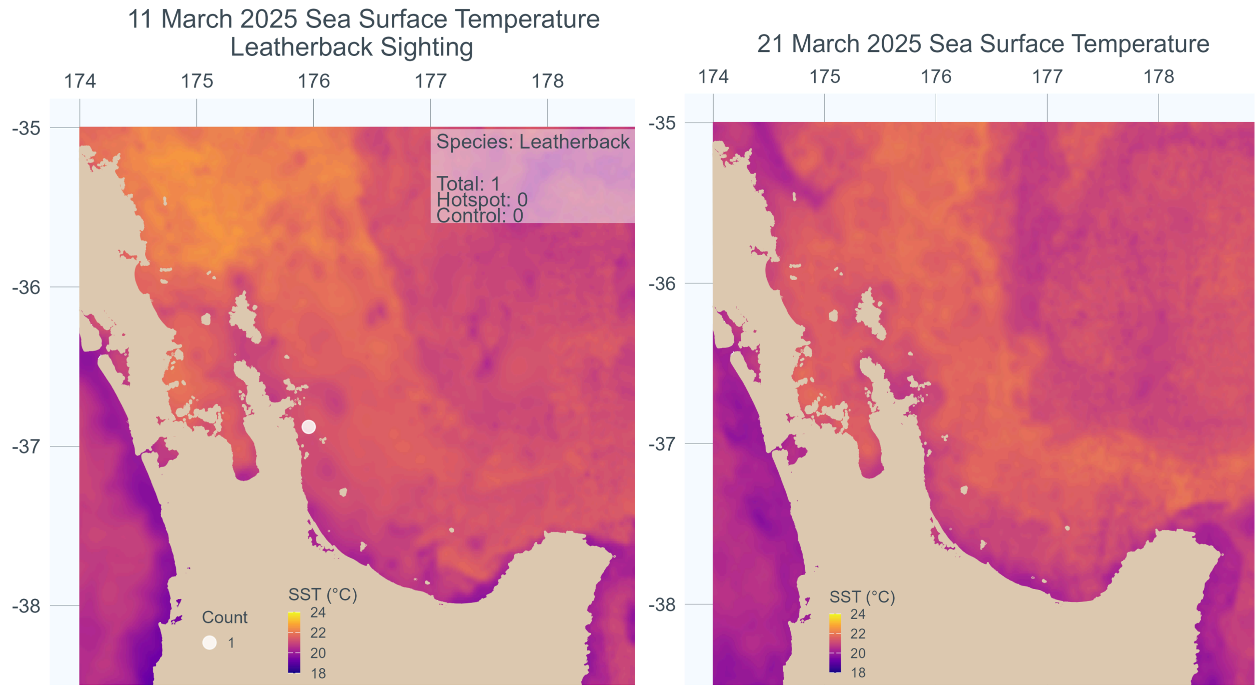

Figure 15: Sea surface temperature during aerial surveys in the Bay of Plenty control area on a) 11 March 2025 and b) 21 March 2025 derived from the JPL MUR daily 1-km SST analysis (JPL MUR MEaSUREs Project, 2015; dataset ID: jplMURSST41, accessed Nov 5 2025).

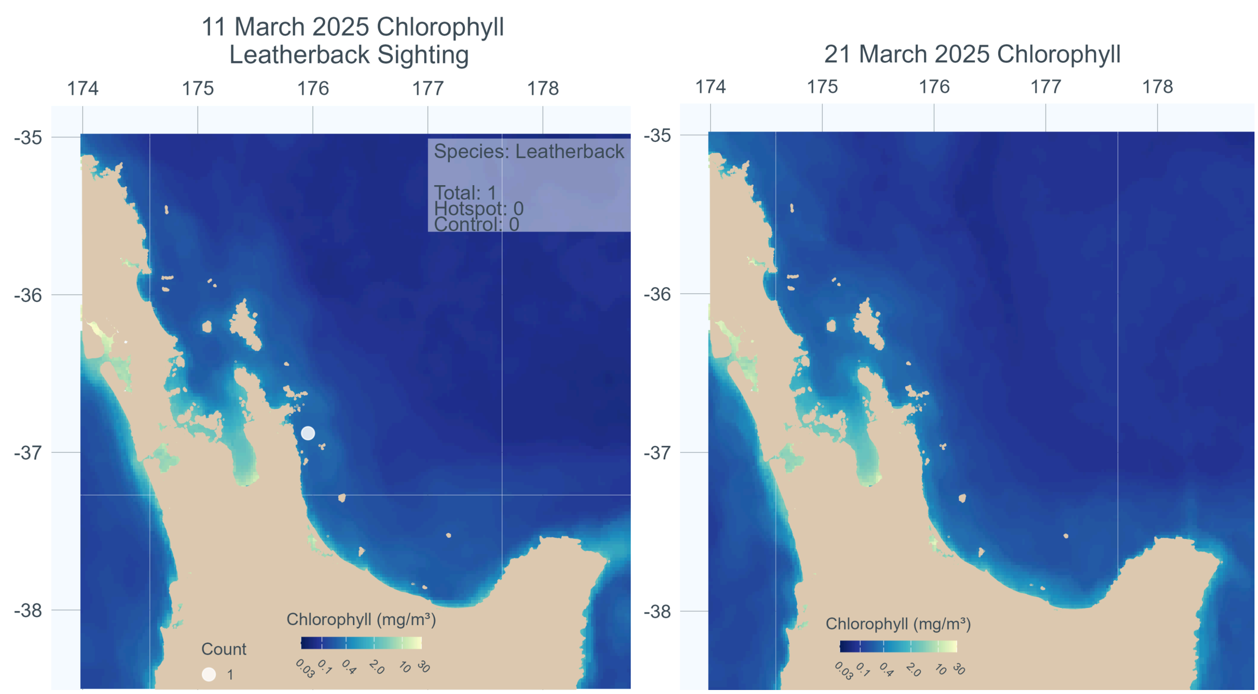

Figure 16: Spatial distribution of chlorophyll-a concentration around northern New Zealand during aerial surveys in the Bay of Plenty control area on a) 11 March 2025 and b) 21 March 2025, derived from NOAA CoastWatch daily 2 km dataset (noaacwNPPN20S3ASCIDINEOF2kmDaily; NOAA NESDIS Ocean Color Science Team & NOAA CoastWatch, 2025, accessed Nov 5 2025).

6.3 Surface Currents

The main eddy located northeast of the Bay of Plenty was fairly constant throughout the surveys, from March 11 to 21. The surface currents within the control area were slower than within the Hotspot Area, likely influencing some of the species distributions. The survey regions with the highest surface currents, particularly the Hotspot area's northern boundary, had few species sightings. In contrast, a majority of the sightings occurred in areas with surface currents less than 0.5 m/s. Specifically, plankton-feeders were found more commonly in the low-current areas, including manta rays, devil rays and whale sharks. Additionally, the single leatherback sighting occurred outside the western boundary of the control area in an area that maintained low surface currents throughout the survey period, suggesting this may act as a retention area. Although not surveyed, another potential low-current retention area was apparent just north of Tauranga.

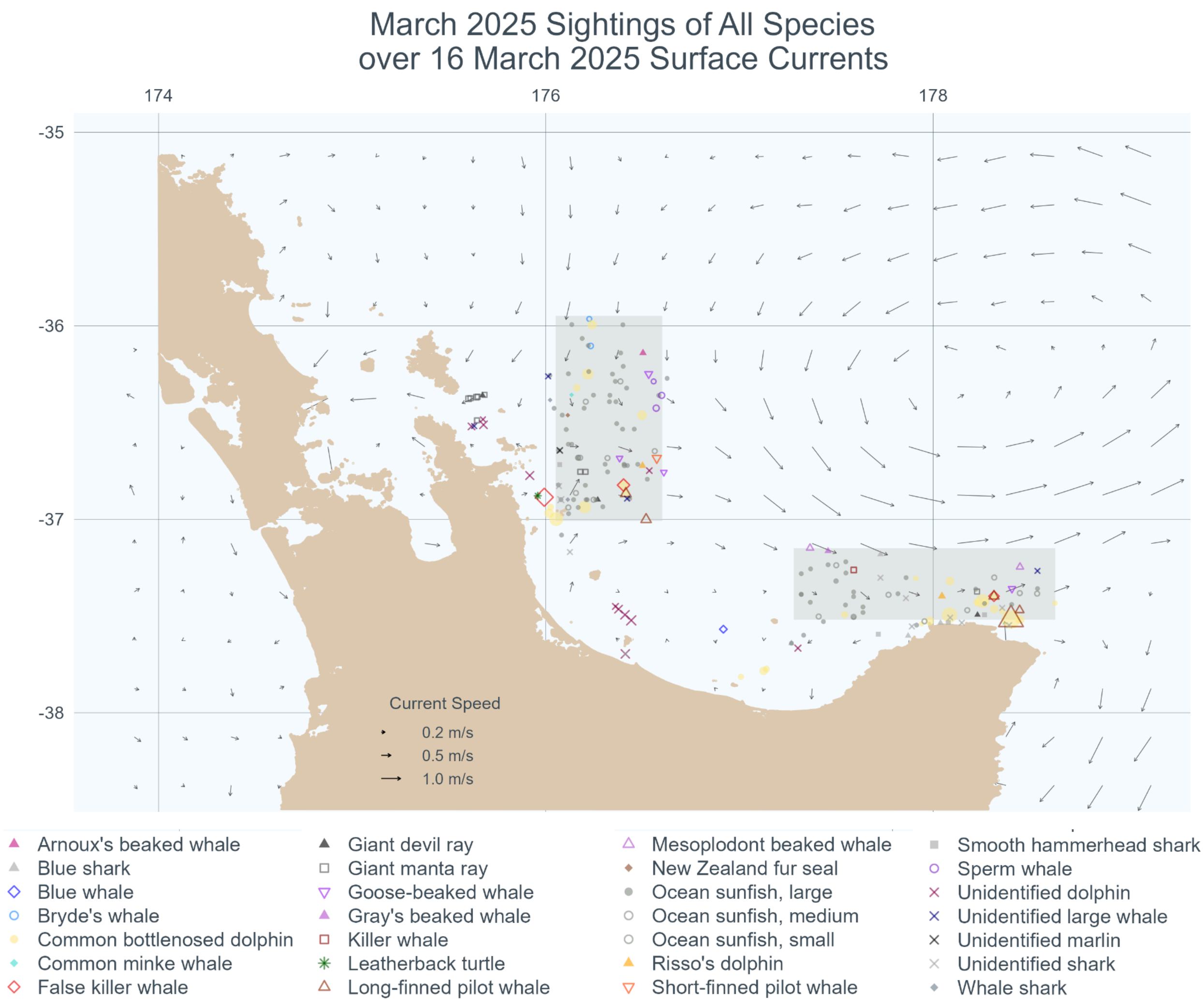

Figure 17: All recorded sightings during aerial surveys in the Bay of Plenty, 11-22 March 2025, superimposed over surface currents derived from NOAA NESDIS CoastWatch (noaacwBLENDEDNRTcurrentsDaily; NOAA NESDIS CoastWatch, n.d., accessed Nov 5 2025). Symbol sizes represent the number of animals counted during the sighting, with large symbols representing more animals.

7. Bycatch Comparison

These environmental analyses provide a reference point to compare with environmental conditions and bycatch events reported in Dunn et al. (2023), who reported the greatest bycatch in the Bay of Plenty in the height of summer. The SST encountered during the 2025 survey was within the expected SST at which peak encounters historically took place (18-22°C; Dunn et al., 2021, 2023).

The commercial catch and effort and bycatch report datasets, as used by Dunn et al. (2023), were updated to 30 June 2025 (Fisheries New Zealand RepLog 16837). The surface longlines reported 40 leatherback interactions in the 2024-25 year (to end June), making it the second highest annual bycatch between 2007-08 and 2024-25 (the highest being 50 leatherbacks in 2020-21). Of the 40, five were encountered during the survey dates, of which four were off the west coast (Figure 18).

The relatively high encounter of leatherbacks off the west coast North Island in summer 2025 did not appear to be caused by a substantive shift in fishing effort (Figures 18 & 19), and seems to be an exception in the time series.

Between 2007-08 and 2020-21, most of the leatherbacks were reported by a relatively small part of the fleet (90.7% by five vessels; Dunn et al., 2021). The same vessels continued to report most of the encounters in 2025. However, the apparent change in spatial distribution of encounters in 2025 meant that 11 leatherbacks were reported by vessels off the west coast North Island, which had never previously reported a leatherback encounter.

Further work to repeat the models of Dunn et al. (2021) and Dunn et al. (2023), but with environmental data updated to 2025, to see if those models could explain the observed pattern of captures in 2025 and explain why the hot-spot survey did not encounter leatherbacks, was beyond the scope of the current contract.

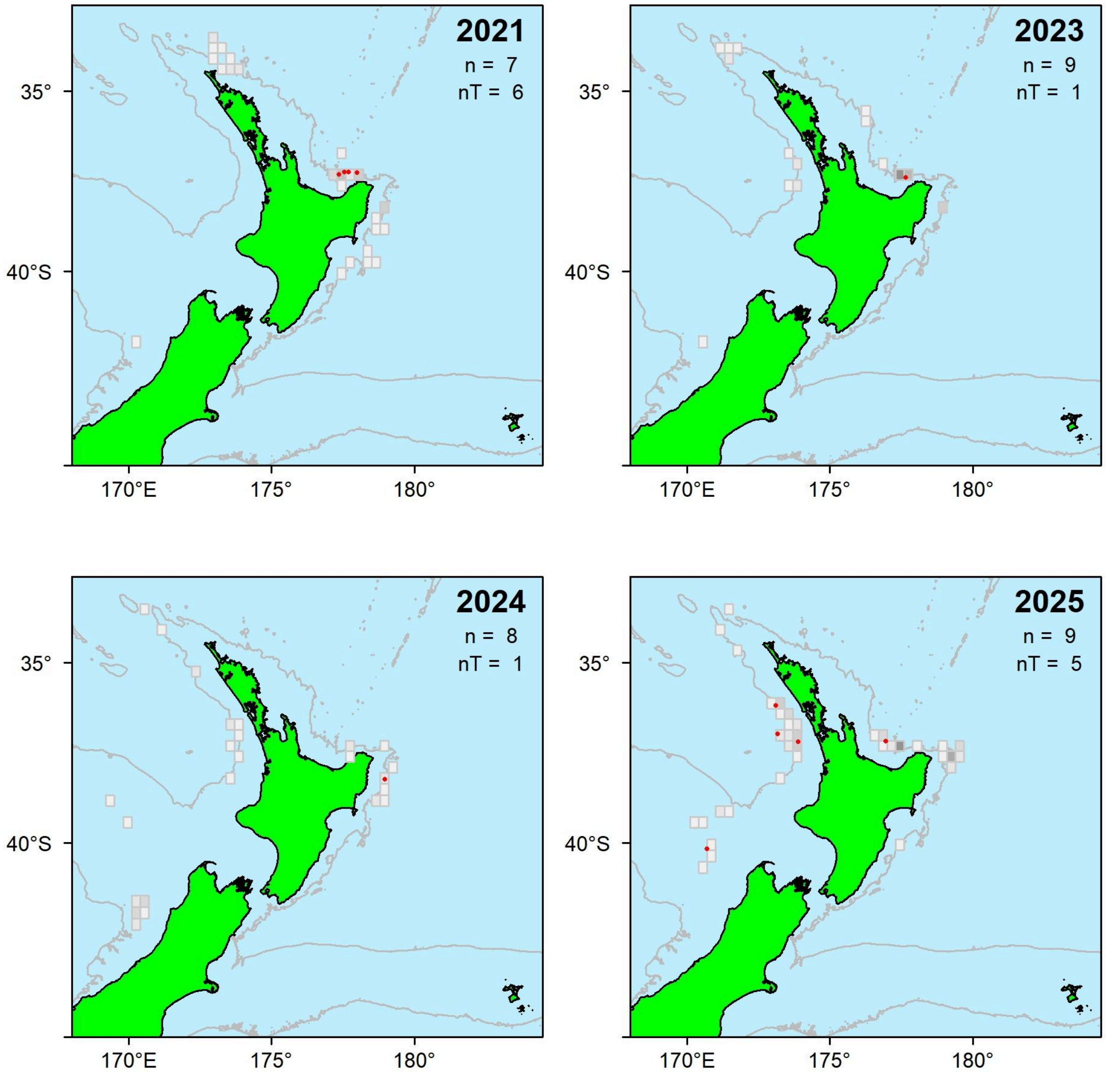

Figure 18: Reported encounters of leatherback turtles from the commercial surface longline fishing fleet during the aerial survey dates (red points) by year. Relative fishing effort is shown as the image layer, where darker shaded cells indicate greater fishing effort. nT is the number of leatherback turtles reported. n is the maximum number of fishing events in any one cell.

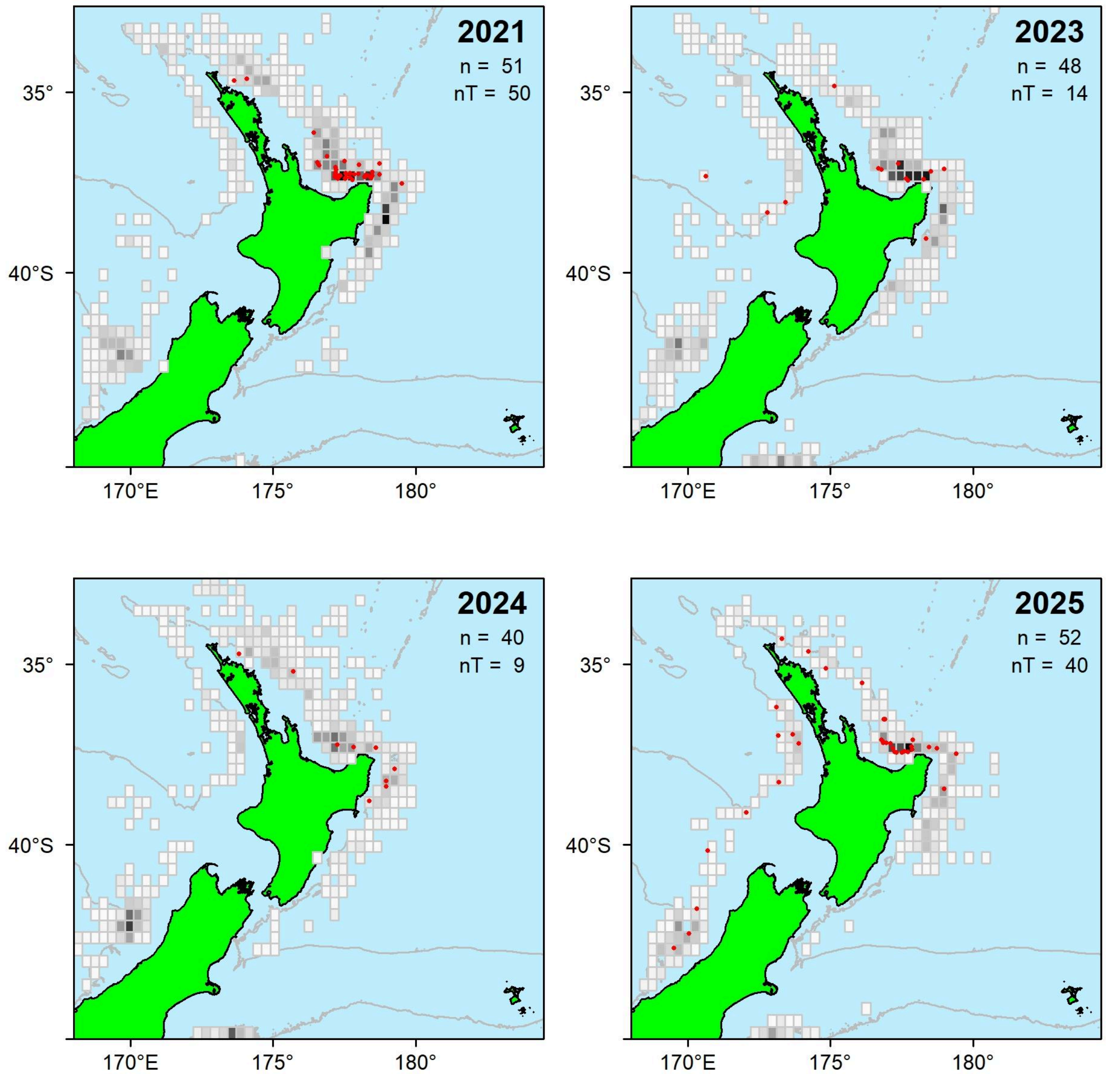

Figure 19: Reported encounters of leatherback turtles from the commercial surface longline fishing fleet for the entire fishing year (red points), where fishing years run from 1 October to 30 September, except in 2025, which includes data only to 30 June. Relative fishing effort is shown as the image layer, where darker shaded cells indicate greater fishing effort. nT is the number of leatherback turtles reported. n is the maximum number of fishing events in any one cell.

8. Density and Abundance Estimation

Although the goal of this feasibility study included the estimation of leatherback density and abundance if sufficient sightings were made, only one leatherback was observed off-effort (when not engaged in standard surveys). Consequently, we were unable to conduct this analysis. The only species for which sufficient sightings were made to estimate density using standard distance sampling analyses (Buckland et al. 2001) was the ocean sunfish (n=103 sightings, Table 2). For other species, it may be possible to obtain density estimates by combining species with similar sighting characteristics to provide adequate sample sizes for the estimation of detection functions (Buckland et al. 2001).

9. Conclusions

The sightings data provide additional insights into the diversity of megafauna in the Bay of Plenty, the majority of which are protected species, including all observed marine mammals and most sharks and rays. The data also allow comparisons between the two survey regions and their environmental conditions. Although the survey may have had limited success for leatherbacks during March 2025, it captured substantial information on other protected species, many of which are poorly studied and of interest to the New Zealand Department of Conservation. Future aerial surveys could be optimized to target key habitats for priority species and address multi-species questions.

Although the survey occurred in the historical hot-spot and at the historical seasonal peak for fishery interactions, no leatherbacks were seen during the survey. The leatherback that was seen was just outside of the survey grid; this at least serves as confirmation that the survey was (and would be) able to detect turtles. The analyses of fishery bycatch suggested 2025 was not typical, with few leatherback interactions in the Bay of Plenty in March; instead, most of the bycatch in March was off the west coast, an area where interactions had historically been low. There was no clear difference in fishing effort that would explain this change; for example, the effort distribution was similar in the previous year (2024) when no leatherback interactions were reported off the west coast. The Bay of Plenty remained the clear spatial hotspot for interactions in 2025, so the survey was in the “right” place, but it appears that few or no leatherbacks were there when the survey occurred.

One of the main survey constraints was the availability and flexibility of resources, which could be increased through higher budget adjustments or cost reductions afforded by greater reliance on the local capacity provided by this project, which trained local observers and aircraft providers. Increased flexibility in survey timing may allow survey efforts to take advantage of less predictable good weather or longer periods of ideal weather based on near-real-time forecasts. For example, the highly variable weather conditions influenced our survey opportunities, and methodologies were adapted mid-survey to optimize survey conditions within each flight. Planning and budgeting for additional time to cover regions with extended periods of poor weather, such as the eastern portion of the hotspot area, may also improve the survey opportunities. A more central placement of the team’s “home” airfield may offer greater flexibility to cover multiple study areas; however, this may increase the cost of ‘stand-by’ days away from the aircraft’s base near Auckland. Future efforts could further improve the flexibility of target areas based on the survey’s purpose. For example, capture and tagging surveys may need to be located more inshore and centered around the vessel’s port or range, in addition to the species range.

This project’s effort to establish local partnerships by providing observer training and experience specific to leatherback monitoring, standardizing procedures and procurement of specialized equipment for leatherback surveys broadens capacity for future efforts. With pathways now in place, readying aircraft and having observers on standby with local coordination could increase the likelihood of surveys overlapping with peak leatherback presence. Weather conditions pose a primary risk to the completion of aerial survey work. We were unable to conduct aerial surveys during periods when the cloud cover was extensive, reducing the visibility into the water column, or when winds exceeded Beaufort sea state 4 conditions. Due to the nature of New Zealand's fluctuating weather patterns, this requires planning surveys outside of historic or peak storm seasons and the constant monitoring of weather conditions to take advantage of any windows of ideal conditions. During 2025, the warm-water conditions and calmer weather occurred in February, earlier than expected based on historical climate reports. This also coincided with leatherback turtle sighting reports at the beginning of 2025 (Karen Middlemiss, personal communication, January 9, 2025).

Mechanical problems or limited availability of the specialized survey aircraft required for this research may also pose a risk to the completion of this work. No such problems were encountered during the reporting period, and contract provisions affording use of a backup aircraft were not exercised. Coordination of maintenance schedules with the aircraft provider enabled the availability of contracted aircraft without interruption.

Leatherbacks are very rare and cryptic animals, making them difficult to locate even when suitable foraging habitat can be located. Environmental variation leads to interannual variability in the presence and quality of suitable foraging habitat, and therefore, total leatherback abundance. Based on the results to date, it appears that foraging habitat may have been limited spatially and temporally within the Bay of Plenty during March 2025, and leatherback abundance also appeared to be relatively low in the Bay of Plenty during the aerial survey dates this year. Reports of large jellyfish blooms coincided with reports of leatherback sightings in December of 2024 and January of 2025, suggesting that these foraging habitats do exist within the Bay of Plenty and need further exploration. Historical sighting reports from whale watching vessels off the coast of Tauranga have recorded leatherback turtles within the Bay of Plenty between November and March, though records are sparse and additional data are needed. The protection of foraging leatherbacks within New Zealand's waters would benefit from further investigation of the coastal region south of Whitianga, between the Alderman Islands to Tauranga, where several sightings have been reported, including from this aerial survey effort.

The relatively small number of opportunistic sighting reports (from whale-watching activities, etc.) and only one leatherback turtle found during the surveys on 11 March suggests that more must be done to understand this threatened population.

10. Recommendations

Aerial surveys have been used successfully off the U.S. West Coast to identify regions of leatherback presence and to document trends and habitat associations, involving substantial effort, including over 50 flight hours and 8+ days on the water per season across multiple years. By comparison, the surveys conducted here represent only a fraction of that effort. Nevertheless, aerial survey data may also be useful for developing species distribution or dynamic movement models for leatherbacks off New Zealand. Changes in fishing behavior, such as bycatch mitigation, will make it difficult to interpret trends in leatherback numbers from commercial bycatch data, as declines could reflect either mitigation success or population decreases. To determine true trends, fishery-independent surveys are needed, with aerial surveys being the most effective. In this study, we demonstrated the feasibility of conducting effective aerial surveys within the Bay of Plenty and built local capacity to do so in the future; however, the current platform was not ideal as it did not provide adequate downward visibility to meet the assumptions of distance sampling. Nonetheless, aerial surveys can provide a foundation for identifying static or dynamic management actions that may reduce leatherback bycatch in New Zealand Fisheries.

11. Acknowledgements

This project was funded by the Department of Conservation project POP2023-1. This project was designed by Clinton Duffy (formerly DOC, now Auckland Museum). We thank Dr Karen Middlemiss (DOC), aircraft providers at Union Airways, Island Aviation, Sunair and representatives of Pelco Fishing. DOC treaty partner engagement included iwi and hapu from the Hauraki Gulf Marine Park and Bay of Plenty regions. The research team acknowledges the importance of honu to tangata whenua in the rohes covered by this research project. We thank all those who have provided us with feedback and guidance on the project.

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Appendix A: Attendees of the open workshop for interested parties to meet the team, held on 10 May 2024 at Earth Sciences New Zealand's Auckland offices.

Organization	**Attendees**
New Zealand Department of Conservation	Karen Middlemiss, Nicole Steven
Earth Sciences New Zealand (Formerly NIWA)	Brit Finucci, Irene Middleton, Matt Dunn, Lydia Hayward
Upwell	George Shillinger, Scott Benson, Sierra Fullmer (virtual), Kayla Sargent (virtual), Karin Forney (virtual)
Monash University	Sean Williamson
Conservation International	Mark Erdmann