UPWELL

PROTECTING TURTLES AT SEA

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

Final Survey Design and Technical Report

June 28, 2024

Contract Number: POP2023-01

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This project is commissioned through the Department of Conservation (DOC) New Zealand, Conservation Services Programme (CSP) against CSP project POP2023-01 and managed by Dr Karen Middlemiss (DOC Marine Species and Bycatch Team).

Project Background

West Pacific leatherback turtles 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. Fishery independent data on leatherback distribution and abundance are required to determine overlap with New Zealand commercial fisheries, inform national and regional risk assessments for this species and identify potential environmental indicators that could be used 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 is 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 seems likely.

As of 3 August 2023, the use of circle hooks (in line with WCPFC CMM 2018-04) became mandatory in New Zealand. The government is also in the process of developing a Bycatch Reduction Plan for sea turtles in New Zealand. Although all sea turtles are protected under New Zealand law, the leatherback turtle population in New Zealand's coastal waters remains classified as 'data deficient' due to insufficient information on abundance and distribution.

Leatherback sea turtles (*Dermochelys coriacea*) have multiple physiological differences from hard-shelled turtles, including unique thermoregulatory abilities that enable them to inhabit colder waters. Leatherbacks are a highly migratory, pelagic species found in all the world's oceans, except for Arctic and Antarctic waters. There are seven populations of leatherbacks and two of these populations (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 and Papua Barat, Indonesia) to areas where dense aggregations of gelatinous zooplankton occur (i.e., the California Current along the US West Coast and oceanic eddies off New Zealand's North Island).

The West Pacific leatherback population has declined 80% in the past 30 years, at an annual rate of 6%, to fewer than 1,500 mature breeding individuals (estimated at nesting beaches in Papua Barat, Indonesia where 75% of nesting activity occurs in the western Pacific). The 80% decline has been corroborated at the central California foraging ground (Benson et al. 2020). All West Pacific leatherbacks nest in the western Pacific, but distinct subpopulations (associated by nesting season) migrate to different foraging grounds throughout the Pacific. Leatherbacks nesting in the boreal summer (mid-year) travel to foraging areas in the South China Sea, North Pacific Transition Zone (Kuroshio Extension), and US West Coast waters post-nesting. 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).

Declining leatherback populations are largely attributed to fisheries bycatch, plastic pollution and ship strikes, as well as threats at nesting beaches. Leatherback migration routes cross multiple exclusive economic zones (EEZs) governed by dozens of countries, as well as the largely ungoverned high seas, making creation of cohesive protections for leatherbacks across their entire range very difficult. The recommended maximum number of mortalities (i.e., limit reference point or trigger point) within the US EEZ stretching from California to Washington cannot exceed 7.7 leatherbacks over five years, or an average of 1.54 leatherbacks per year to prevent further decline of this population (Curtis et al. 2015). At present, a single leatherback mortality in the California Dungeness crab fishery requires the Fish and Wildlife Director to take management action, potentially including area closures (CDFW 2020, 2024). Upwell and NOAA have provided regular updates to California's Dungeness Crab Risk Assessment and Mitigation Program throughout the foraging period when leatherbacks are present in California waters feeding on abundant jellies. The US federal government closes the Hawaii shallow-set longline fishery when the hard cap of 16 annual leatherback interactions is reached (NOAA 2024). The shallow-set longline fishery requires 100% observer coverage to monitor interactions and collect fisheries data on every trip (with the number of interactions transparently published online), plus crew are trained to properly dehook and disentangle bycaught turtles for improved survival outcomes.

The hard cap imposed on Hawaii's shallow-set longline fishery recognizes that interactions impact leatherbacks' viability and are not benign. Even when released alive, the stress or injuries sustained during capture may adversely affect their health and survival prospects. The potential for stress impacts or mortality varies depending on where a turtle is hooked (e.g., flipper, shoulder, mouth, esophagus, etc.), how long the turtle is hooked or entangled, and the depth at which the turtle is caught (e.g., near-surface versus deep-set longline). Some research has been done in this area (Neilson et al. 2011, Swimmer and Gilman 2012, Innis et al. 2014, Zollet and Swimmer 2019, Dodge et al. 2022), but more comprehensive research and evaluation on post-capture survival of leatherbacks hooked or entangled in longline and set gear is needed.

Potential bycatch mitigation measures to help reduce impacts to fisheries that catch leatherback turtles include: a) changes in gear type, such as the use of circle hooks instead of J-hooks to reduce hooking likelihood and injury severity or transitioning from single-line buoy systems for trap fisheries to 'on demand' (ropeless/pop-up) buoy systems to reduce entanglements, b) changes in timing of fishery operations (e.g., season or time of day), c) where and how deep gear is deployed, d) requiring the presence of trained observers, e) training fishers to safely handle and release bycaught turtles, and f) provision of equipment for dehooking and disentangling turtles. These measures are most successful when complemented by robust monitoring programs, including observation data from vessel-based reporting (via observers, cameras, captains and crew), as well as sources of fisheries-independent data, such as aerial surveys of leatherback distribution and abundance, and data from satellite tags deployed on leatherbacks to reveal movements, behaviors, and environmental habitat associations. Aerial survey and satellite tagging can provide reliable real-time updates on leatherback distribution, movements and abundance during each fishing season. Following multiple years of data collection, predictive models can be developed to help inform fisheries management decisions with the aim of helping fishers avoid costly interactions with leatherbacks.

Scope of Work

The Department of Conservation (DOC) New Zealand, Conservation Services Programme (CSP) contracted Upwell to conduct aerial surveys for leatherbacks off the Northeast North Island. Upwell will collect the data via aerial surveys conducted along transect lines to document leatherback distribution and estimate minimum abundance within two designated survey areas (a bycatch hotspot and a control site) in partnership with the National Oceanic and Atmospheric Administration (NOAA), Monash University, and the National Institute of Water and Atmospheric Research (NIWA).

The primary objective of this project (POP2023-01) is 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 North Island, where a high number of fisheries interactions have been reported. The specific objectives of this project are to:

1) Design and trial an aerial survey for leatherback sea turtles and associated 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 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 has incorporated feedback into the survey plan prior to the commencement of surveys. During 2024 we will also contract the aircraft for the aerial surveys and select observers.

During Year 2 (2025), aerial observers selected for the surveys will complete training on aviation health and safety, survey techniques, and identification of leatherbacks and other key species. Aerial surveys will be conducted to collect information on the minimum abundance and distribution of leatherback turtles, associated marine mammals and ecosystem indicator species (e.g., jellies, anchovies, *Mola mola*, large pelagic sharks). Aerial surveys will be weather-dependent, with field-based operations conducted during periods of expected leatherback presence and fisheries overlap.

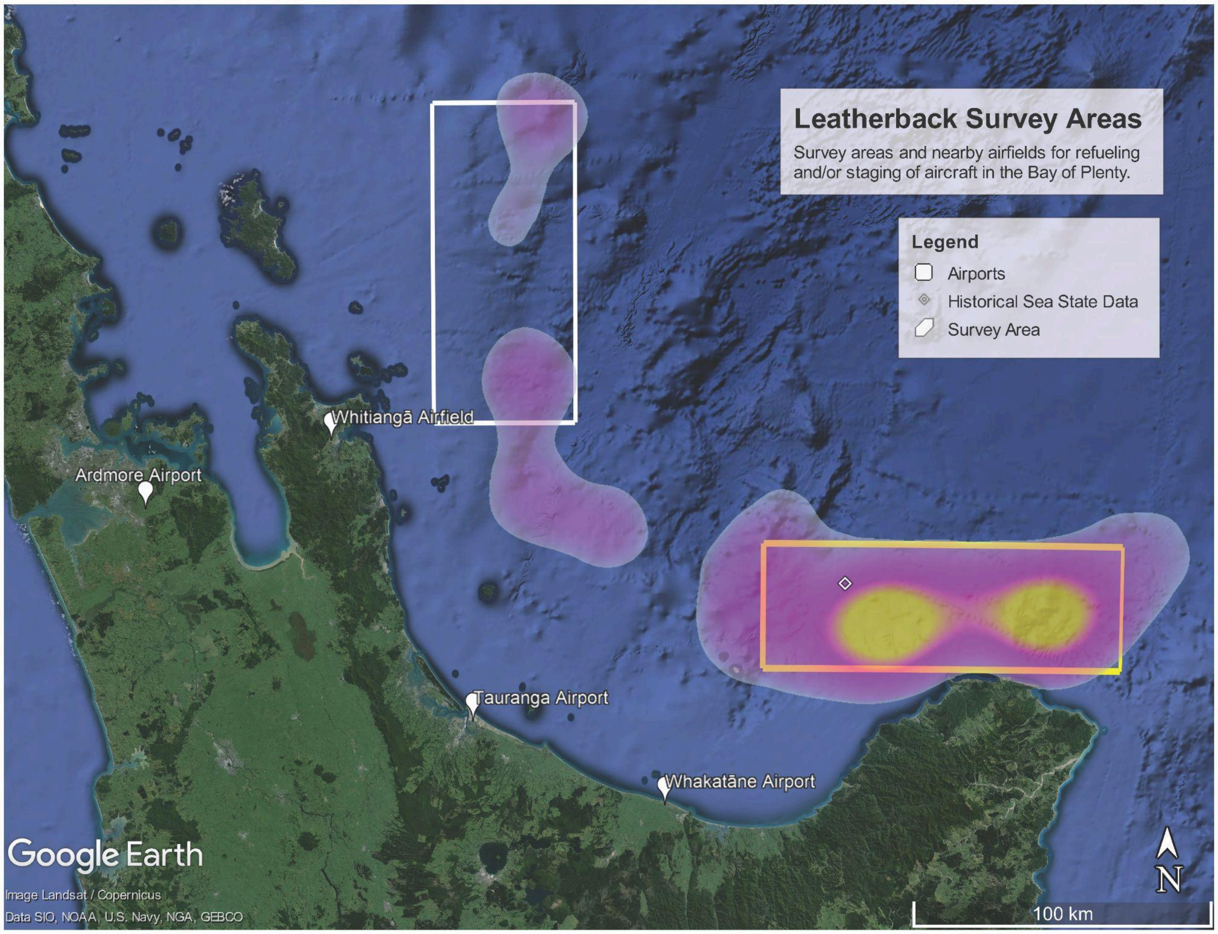
During Year 3 (2026) analysis of the data on leatherbacks and other sea turtles collected by aerial surveys will be reported to the New Zealand Department of Conservation - Conservation Services Programme (DOC-CSP). Associated data on minimum abundance and distribution of marine mammals and indicator species collected will also be reported. All relevant data will be transferred to DOC via electronic files. The project results will be presented to the CSP Technical Working Group with opportunities for discussion on the power of the survey design to detect changes in abundance of leatherbacks and recommendations for future work.

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 (NIWA) and Scott Benson (NOAA). 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 feasibility of running field operations from each location, and visiting three potential aircraft providers to evaluate suitability of aircraft, pilots, and airfield services prior to selection. The site visit included an open workshop for interested parties to meet the team on 10 May 2024.

Study Area and Timing

Two survey areas are proposed: 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. The proposed survey areas are approximately equal (hotspot 4,977 km^2 and control 5,013 km^2). Additionally, as the Hotspot survey area was naturally positioned along the 1000 meter isobath, the control area was designed to maintain similar depth gradients by also following the 1000 meter isobath. Aerial surveys will be conducted during peak leatherback encounter times, ideally during periods of high sea surface temperature (SST) correlated with higher rates of entanglement (Dunn et al. 2023).



Map 1: Survey Areas (control and hotspot) and nearby airfields

Aircraft Selection

Upwell will contract a high-winged, twin-engine fixed wing aircraft operated in compliance with Part 135 aviation requirements. The aircraft shall be powered by two engines and capable of maintaining a minimum altitude of 1000 feet under single-engine power while carrying four passengers and up to 100 pounds of survey equipment. It must be capable of maintaining slow airspeeds (90-100 knots) and circling safely at low altitude for extended periods of time with an expected endurance of 3.5 hrs. Side bubble windows installed on the passenger-seat windows of the aircraft will facilitate observation by the trained members of our team. If feasible, a belly port may also be utilized for observation and/or photography.

During the scoping trip, 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. The VulcanAir and Islander remain under consideration.

Image Set 1: VulcanAir aircraft owned by Union Airways with fixed high-wing twin engines (top), pilot and co-pilot seat for data recorder (bottom left), and two rows of passenger seats for left and right observer and optional belly observer (bottom right). Bubble windows to be installed on the second row, in the door and parallel window in front of the wing. Belly window port below the middle right seat. Photo credits: Scott Benson/NOAA.

Image Set 2: Britten Norman Islander aircraft owned by Island Aviation with fixed high-wing twin engines (top left and right), pilot and co-pilot seat for data recorder (bottom left), and three rows of passenger seats for left, right, and optional belly observers (bottom right). Bubble windows may be installed on the second row, in the door and parallel window in front of the wing. Photo credits: George Shillinger/Upwell.

Aerial Survey Design and Methods

The project team draws 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 utilizes the same well-established line-transect sampling methods (Buckland et al. 2001) to estimate 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 will provide minimum estimates of leatherback abundance and density, because this initial feasibility study will 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.

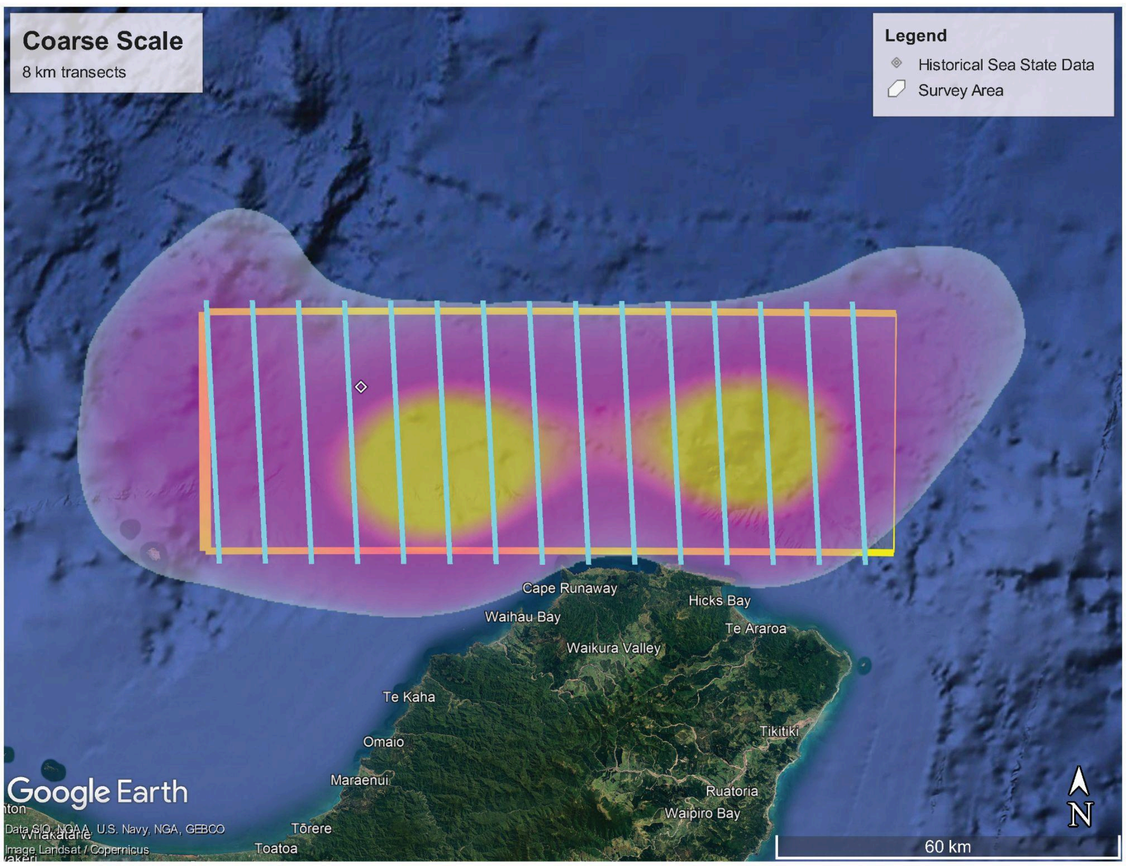
Image Set 3: Upwell/NOAA's California aerial survey plane. Partenavia in flight (top, photo credit Ralph Pace), experienced observer Katherine Whitaker in bubble window for left observer position (middle left, photo credit NOAA/SWFSC), Scott Benson in right bubble window observer position (middle right, photo credit NOAA/SWFSC), Sierra Fullmer in belly observer position (bottom left, photo credit Vicky Vásquez), pilot and Karin Forney data recording in co-pilot seat (bottom right, photo credit Scott Benson).

The aerial survey team will consist of at least two observers (one on the left, one on the right) and a data recorder who logs sightings, transect information and viewing conditions into a laptop computer connected to a Global Positioning System (GPS). Surveys will be flown at a target altitude of 200 meters when weather conditions are good (minimal cloud cover, sea state at or less than Beaufort 3) to allow efficient detection of leatherback turtles. The primary survey window will be early morning, before the onshore winds build in late morning. A second survey may occur later in the day, if the winds have dropped.

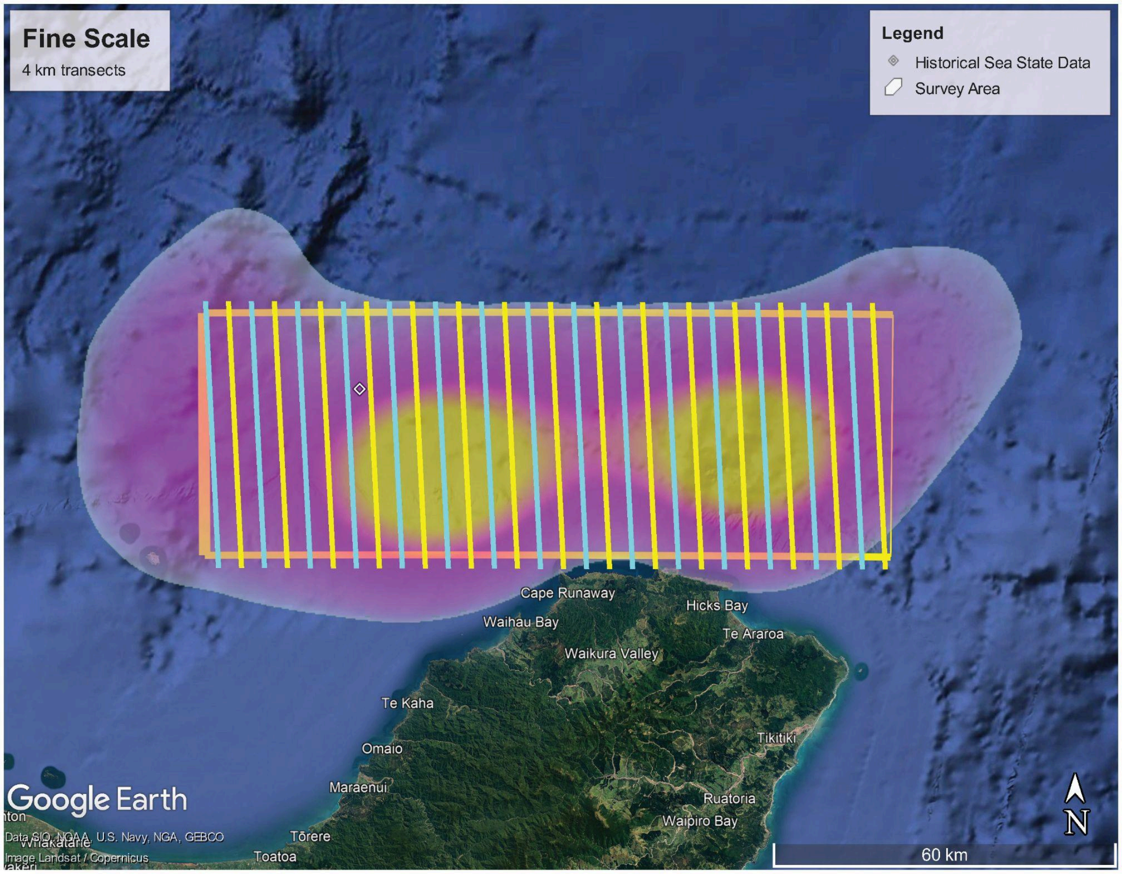
The survey design includes both coarse and fine-scale surveys. Initial surveys will be flown at a coarse scale to ascertain which areas merit further fine-scale surveying. The density of coverage in each area will be determined by the identification of suitable leatherback habitat, based on the concentration of prey (*e.g.,* sea jellies) and proxy species that feed on similar prey species (*i.e., Mola mola*) documented during the initial coarse-scale surveys.

Image Set 4: Images of sea nettles (top left), moon jellies (top right), ocean sunfish *Mola mola* (bottom left), and a *Mola mola* next to a leatherback turtle (bottom right) as viewed from a plane surveying at approximately 200 meters in altitude. Photo credits: Karin Forney and Scott Benson / NOAA Fisheries.

The transects were designed with systematic random sampling using Distance 7.5 release 2 software (Thomas et al. 2010) as parallel line transects evenly spaced 4 kilometers apart. Transects are 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). For initial coarse-scale surveys, every other transect line will be flown (8 kilometer spacing between transects). Based on the results of the initial coarse-scale surveys as well as consideration of remaining flight hours and weather, fine-scale surveys (4 kilometer transect spacing) will be flown on the skipped transect lines, either throughout each study area or within key areas of interest (i.e., suitable leatherback habitat). This approach will also provide replicated sampling of portions of the study area on different days.



Map 2: Coarse-scale (8 km spaced) transect lines within Hotspot Survey Area



Map 3: Fine-scale (4 km spaced) transect lines within Hotspot Survey Area

The survey design and budget afford the opportunity to complete both sets of 8-km lines once, providing coverage at 4-km resolution overall within the hotspot and control areas. However, additional good-weather days and reduced non-flight expenses may enable completion of additional replicate surveys. Based on a transit speed of 130 knots and survey speed of 100 knots, a coarse-scale survey of the bycatch hotspot covering 800 km of track line could be completed in 6.5 flight hours across two flights (including transit between transect lines and an additional 435 km to/from the nearby Whakatāne Airport for refueling). With ideal survey conditions and an additional 6.5 flight hours, fine-scale surveys can be completed by flying the parallel transect lines positioned between the coarse-scale transect lines. If weather opportunities are limited, fine-scale lines may be selectively surveyed in the areas of interest identified in initial coarse-scale surveys.

Surveys of the control area, using the above coarse and fine-scale method, may be conducted out of Whitianga Airfield. In the control area, 12 total flight hours (including transit time and refueling stops) would be required for fine-scale coverage.

Flight	Transit to Survey Area (130 knots)	Survey Lines (100 knots)	Survey Line Transit (100 knots)	Transit from Survey Area (130 knots)	Total
Hotspot Area Coarse Flight 1	55 km 15 min	368 km 120 min	56 km 18 min	100 km 25 min	**579 km** **178 min**
Hotspot Area Coarse Flight 2	108 km 27 min	322 km 105 min	48 km 16 min	170 km 43 min	**648 km** **191 min**
Control Area Coarse Flight 1	113 km 29 min	285 km 93 min	40 km 13 min	76 km 19 min	**514 km** **154 min**
Control Area Coarse Flight 2	70 km 18 min	333 km 108 min	48 km 16 min	82 km 21 min	**533 km** **163 min**

Table 1. Sample Survey distances and time estimates for each coarse-scale coverage of both survey areas. Distances and times are approximated based on the distances to/from the nearest refueling airport (Hotspot Area - Whakatāne Airport, Control Area - Whitianga Airfield) and are subject to change based on the airport of origin and environmental conditions that may impact the number and length of possible flights. Fine-scale coverage requires a duplicate set of flights for each area. Additional survey effort and circling over species of interest would require additional survey time, within fuel capacities.

Data Management

Data will be collected using a custom aerial survey data collection program, developed by NOAA, which creates simple text files with effort and sighting information. Upwell will conduct quality control and analysis of aerial survey data using custom R code to check for any errors in observation points and critical environmental data. Data will subsequently be analyzed and organized using Microsoft Excel or Google Sheets, Microsoft Word or Google Docs, Google Earth Pro and R software packages (e.g., *swfscAirDAS*, *Distance*, *dsm*).

Aerial survey reports will be uploaded to the shared online folder accessible only to authorized personnel. The Aerial Survey Data folder will be populated with files for survey data organized by file names indicating processing status (raw or processed), date, and location. Data will be backed up to a remote harddrive to ensure protection.

Data analyses will be included in project deliverables, including the post-survey progress report. Deliverables will be uploaded to the shared online folder in advance of each established deadline.

Outlook

The scope of work for this project (POP2023-01) includes the first aerial surveys of the eastern Bay of Plenty hotspot during the period of reported elevated leatherback presence and fisheries overlap to provide fishery independent information on leatherback minimum abundance and distribution. However, it is worth cautioning that the data collected in 2025 will be specific to that year. In a changing ocean with changing threats (e.g, shifting of fisheries effort and prey distribution), standardized regular monitoring is essential.

Regional baseline standards recommend conducting aerial surveys in multiple seasons within a single year and across consecutive years to account for interannual variation due to environmental factors or cohort effects (DCEEW 2024). Beyond the current scope of work, the establishment of a monitoring program with ongoing interannual surveys would improve understanding of the population status of West Pacific leatherbacks in New Zealand (to override the current 'data deficient' categorization). Data from aerial surveys can be used to calculate and compare population trends observed within key foraging habitats with those observed on nesting beaches (e.g., Benson et al. 2020).

Regular aerial surveys can also dovetail with vessel-based monitoring by using aerial platforms to find leatherbacks for deployment of satellite tags as they are often too cryptic to spot from the deck of a vessel. Satellite tags collect and transmit fisheries independent data on individual leatherbacks' movements, behaviors and habitat use. Tag-derived data on environmental factors like temperature (and even salinity and chlorophyll) is collected in concert with the leatherback's movements and yields precise in situ measurements in contrast with coarser satellite-derived remotely-sensed environmental datasets. Tag-derived data affords opportunities to visualize water column structure and to analyze turtle behaviors in the context of changing environmental variables, including temperature, salinity and chlorophyll. This data can also be used to corroborate modeled environmental datasets, and to inform species distribution models and fisheries risk management models that consider animal movements and fisheries gear overlap within a three dimensional environment (Barbour et al. 2022, Barbour et al. 2023).

Joint efforts with fishers are needed to collect information on observations and interactions as well as to collaboratively deploy tags on incidentally captured turtles as part of research to assess post-capture survival and mortality rates. Fishers' knowledge and experiences are vitally important to leatherback research and their partnership is essential to reducing incidental captures.

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