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Murihiku ki Te Tonga: A Ngāi Tahu-led Research and Monitoring Programme for Te Moana-tāpokopoko-a-Tāwhaki, the Ross Sea Sector

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Murihiku ki Te Tonga: A Ngāi Tahu-led Research and Monitoring Programme for Te Moana-tāpokopoko-a-Tāwhaki, the Ross Sea Sector

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Abstract

This paper introduces the Murihiku ki Te Tonga – Ross Sea Sector research and monitoring programme (MKTT) launched by the Māori tribe of southernmost New Zealand, Ngāi Tahu ki Murihiku. As the first indigenous-led Antarctic & Southern Ocean research programme in the world, MKTT is developing scientific approaches that are critically informed by mātauranga Māori (Māori traditional knowledge), with a particular focus on use of environmental indicator species (tohu taiao), explicit consideration of seasonal and higher-order spatiotemporal variability, and of the connectivity of the Ross Sea region to the southern Pacific Ocean. The purpose of MKTT is to implement effective, targeted research & monitoring of the Ross Sea Sector between New Zealand and Antarctica, including the Ross Sea region Marine Protected Area (RSrMPA), consistent with Ngāi Tahu principles and the articulated Specific Objectives of the RSrMPA. Following successful pilot expeditions to the Ross Sea in 2023 and 2024, MKTT is intended to serve as the basis for a network of national and international partners, the Ross Sea Alliance, to support ongoing effective, cooperative, and coordinated research & monitoring in the RSrMPA.

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Introduction

In February 2023, Ngāi Tahu ki Murihiku[1] embarked on its first scientific expedition to the Ross Sea region and the New Zealand Subantarctic Islands in partnership with Christchurch-based tourism operator Heritage Expeditions. This voyage signalled the beginning of a new, indigenous-led Ross Sea Sector Research & Monitoring Programme, *Murihiku ki Te Tonga*[2], that was officially launched at the 2023 XIII SCAR (Scientific Committee for Antarctic Research) Biology Symposium held in Christchurch, New Zealand, 31 July to 04 August 2023. Two further ship-based expeditions to the New Zealand Subantarctic and the Ross Sea regions were completed successfully together with partner Heritage Expeditions in January and February 2024. The proposed programme will build on this pilot work and will include annual field work in the Ross Sea Sector for the next ten years, with a minimum of one full transect from Awarua-Bluff to Scott Base and additional expeditions to Subantarctic Islands every year.

Ngāi Tahu ki Murihiku represents the four southern subtribes of Ngāi Tahu, the principal Māori iwi (indigenous tribe) of the South Island of New Zealand. Its takiwā (tribal area) includes the province of Southland, surrounding waters, and three of the five New Zealand Subantarctic Islands (The Snares, Auckland Islands, Campbell Island; Fig. 1). Ngāi Tahu refer to the seas south of New Zealand as *Te Moana-tāpokopoko-a-Tāwhaki,* corresponding to the Ross Sea Sector from New Zealand to the Antarctic Continent including the Ross Sea region (Fig. 1). While it is highly implausible that Māori or other Polynesian mariners visited the Antarctic Continent, as has been claimed, it is known that Polynesians[3] and their dogs travelled to the New Zealand Subantarctic Islands as early as the 13th Century and there is a rich history of engagement of Māori with Te Moana-tāpokopoko-a-Tāwhaki both before and after the arrival of Europeans in New Zealand [1, 2]. Ngāi Tahu ki Murihiku have existing extensive fisheries interests in southern New Zealand waters and place high cultural and economic importance on the traditional annual harvest of juvenile tītī (muttonbird/sooty shearwater, *Ardenna grisea*) [3]. Tītī breed on the New Zealand Subantarctic Islands and forage in the northern part of the Ross Sea region during the chick-provisioning stage [4]. A range of other seabird species utilise both the Ross Sea region and New Zealand waters (*e.g.*, Cape petrels *Daption capense*, various albatross species). Marine mammals including Type-C killer whale (*Orcinus orca*), sperm whales (*Physeter macrocephalus*), humpback whales (*Megaptera novaeangliae*), elephant seals (*Mirounga leonina*) and leopard seals (*Hydrurga leptonyx*) commute between New Zealand waters and the Ross Sea [5-8]. As a result, there is a strong awareness of physical and ecological connectivity between New Zealand and Antarctica and of the importance of the Southern Ocean for marine productivity. However, existing research and monitoring measures do not adequately accommodate highly mobile marine species such as tītī, sperm whales, and killer whales [3, 9, 10].

Increasingly, the effects of climate change have the potential to mask or amplify alterations in the marine ecosystems of the Ross Sea region resulting from fisheries and other direct interventions. There is therefore an urgent need for research that can support flexible and responsive management of a rapidly changing marine environment [11]. Increasing pressure on the high seas [12], including areas in the Ross Sea Sector of the Southern Ocean, requires effective policy informed by scientific evidence to avoid degradation of these areas and to support international consensus through the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR). As is the case for indigenous peoples elsewhere, traditional harvesting of marine resources according to Ngāi Tahu *tikanga* (customary practice) aims to balance utilisation with sustainability to preserve the productivity of marine ecosystems in perpetuity. This approach has significant parallels with the aspirational goal of ecosystem-based management (EBM) and the founding principles of CCAMLR as expressed in Article II. However, despite being considered the best-practice approach for ensuring sustainability of marine activities [13, 14], a full implementation of EBM remains aspirational in New Zealand and in the

[1] The southern subtribes of Ngāi Tahu, a Māori (indigenous) nation of the South Island of New Zealand

[2] 'From Murihiku to the South'. Murihiku is the Te Reo (Māori language) name of the southernmost region of New Zealand

[3] Māori refers to the indigenous peoples of New Zealand. The Auckland Islands were visited by Polynesians around the same time as New Zealand was settled, by ancestors of present-day Māori

CCAMLR Convention Area. Stock assessment and modelling efforts are comprehensive, detailed, and world-leading for the fished species Antarctic toothfish (*Dissostichus mawsoni*) [15], as well as for fish bycatch (macrourids, skates), but adequate data series and monitoring methodologies for marine mammals and birds are currently absent or provide limited coverage in space and time, relative to the spatiotemporal scale of ecosystem patterns and processes that actually drive marine productivity at the scale of the Ross Sea sector. We propose that in addition to existing efforts, a new approach is required, combining insights based on traditional ecological knowledge with novel and cost-effective monitoring technologies, to efficiently address the Specific Objectives for the RSrMPA [6].

To remedy this, Murihiku Regeneration, a public trust created by Ngāi Tahu ki Murihiku, set up the Murihiku ki Te Tonga (MKTT) Ross Sea Sector Research & Monitoring Programme. With this programme we propose an alliance of iwi (Ngāi Tahu) with established New Zealand and international research institutions, domestic industry partners, and New Zealand government agencies responsible for management of Antarctic activities, conservation and fisheries (Antarctica New Zealand, Ministry of Primary Industries, Department of Conservation).

Purpose

The purpose of MKTT is to create and implement research & monitoring that is comprehensive, targeted, cost-effective, validated, and critically informed by mātauranga Māori (Māori traditional ecological knowledge); and that can contribute to the ongoing and effective management of the Ross Sea Sector, including support for the RSrMPA and its Specific Objectives.

Scientific Approach

The research programme introduced in this paper is Ngāi Tahu-led and brings resilient Ngāi Tahu traditions into a critical dialogue with *mātauranga Pākehā*[4] and with the wider CCAMLR science community. There is global consensus for the position that indigenous traditional environmental knowledge is essential for effective ocean management [16]. While mātauranga Māori has been misunderstood as essentially unknowable or incompatible with mātauranga Pākehā, Māori traditional ecological knowledge and other scientific approaches converge in EBM of marine ecosystems. Both systems emphasise complex connectivity, spatial and temporal variation caused by multiple environmental drivers, rational (*i.e.* sustainable) use of marine resources, and management using ecological indicators [17-19]. In traditional Māori resource management, ecological indicators (*tohu taiao*) signal changes in ecosystem state, for example through changes in abundance or reproductive performance of marine birds and mammals, or the timing and location of seasonal migrations [10, 17, 20-24]. Signals arising from monitoring these indicators feed back into management by adjusting and/or declaring catch limits, protected areas, or *rāhui* (temporary bans on harvesting) [17, 25]. Another key mātauranga concept is consideration of environmental processes that are aligned with lunar and higher-order cycles rather than only with the Gregorian calendar [26], which may be particularly relevant for marine species [27].

The concept of tohu taiao is echoed in scientific studies in the Southern high latitudes that posit a link between marine predators and climate variability attributed to the El Niño-Southern Oscillation (ENSO) and the Southern Annular Mode, SAM [28]. For long-lived species, effects manifest primarily as variation in reproductive performance and recruitment [3, 19, 21, 23, 29]. In the South Sandwich Islands region, pup production of Antarctic fur seals (*Arctocephalus gazella*) is closely linked to sea surface temperature (SST) anomalies. This relationship is mediated via availability of krill, which in turn depends on sea ice [28]. Long-term data series for marine birds and mammals (*e.g.* the CCAMLR Ecosystem Monitoring Programme, CEMP) confirm the need for simultaneous monitoring of *multiple* indicator species together with relevant physical drivers (at spatial scales comparable to the ecosystem processes known to drive regional variability) as essential prerequisites for a meaningful interpretation of ecosystem change [30-33]. The importance of this point cannot be overstated: Without observing

[4] Te Reo (Māori language) term for non-Māori of European descent

and considering the wider ecological context, it is not possible to establish causality for even major population changes of indicator species in a particular location, for example the observed increase in Adélie penguin colony counts in the southern Ross Sea region [34-36]. The inability to explain such phenomena carries the risk of committing both Type I and Type II errors[5] with regard to asserting the impacts of fishing on the ecosystem, creating the potential for uncertainty and conflict among stakeholders, and making effective and timely management intervention difficult.

Successful use of both tohu taiao and EBM requires (a) selection of relevant indicators (species and species response parameters), (b) accurate monitoring of indicators, and (c) monitoring at temporal scales (frequency and duration) and over spatial areas that are appropriate for the ecosystem being observed. In a traditional setting, selection of tohu taiao would be based on multi-generational careful observation of the marine environment and its response to natural change and varying levels of harvest. In the case of the Ross Sea region, focal species for the RSrMPA were chosen on the basis of assumed or potential trophic competition with existing fisheries (for toothfish) or potential future fisheries (for krill), based on best-available science at the time the MPA was established. Four focal species (Adélie penguins *Pygoscelis adeliae*, emperor penguins *Aptenodytes forsteri*, Weddell seals *Leptonychotes weddellii*, killer whales *Orcinus orca*) were selected because these predators are constrained by their physiology and/or reliance on land-based colonies to forage in shallow and/or coastal regions, where even temporary or localised prey depletion by fisheries could be expected to affect their reproductive success (RSrMPA Specific Objective vii and viii). But there are other known and plausible toothfish predators active over the Ross Sea Slope and northern seamounts (sperm whales, beaked whales, elephant seals, Type-D killer whales) that may also affect or be affected by changes in the toothfish population, thereby providing useful indicators. And other abundant marine mammal species (*e.g.*, crabeater seals, leopard seals, minke whales, humpback whales) and vast assemblages of flying seabirds, including tītī, are almost certainly sensitive indicators of changes affecting krill and silverfish (RsrMPA Specific Objective vi) and of "*large-scale ecosystem processes responsible for the productivity and functional integrity of the ecosystem*" (RSrMPA Specific Objective v; [3, 6]). By monitoring focal species foraging across the full extent of the Ross Sea Shelf, Slope and northern Ross Sea region, the MKTT programme will empower investigation of the ecosystem effects of displacing and/or concentrating fishing effort following the establishment of the RSrMPA, to ensure that the RSrMPA fulfils its intended purpose, *viz*. to allow for rational use and at the same time "*conserve natural ecological structure, dynamics and function throughout the Ross Sea region at all levels of biological organisation, by protecting habitats that are important to native mammals, birds, fishes and invertebrates*" [6].

Particularly with regard to marine mammals and birds, New Zealand research efforts to date in the CCAMLR area have primarily taken place in southern McMurdo Sound during the summer season, providing only limited insight into ecosystem dynamics at the scale of the RSrMPA (Annex 91-05/C; [6]). From all CCAMLR Members, there has been very little monitoring of Ross Sea top predators except in the immediate vicinity of permanent Antarctic bases, reflecting logistical and technological constraints. However in the last ten years, satellite remote sensing has expanded spatial coverage and substantially advanced the understanding of Antarctic and Southern Ocean ecosystems [37, 38]. Examples include the measurement of marine primary production and of its physical drivers, *e.g*. sea surface temperature (SST) and sea ice cover, over large ocean regions [39-42]. New technologies are can deliver a similar geographical expansion of data collection specifically with reference to top predators, which may then serve as ecosystem indicators,; but while environmental variation has been linked to marine bird and mammal indicators elsewhere in the Southern Ocean, there is currently no model for the Ross Sea Sector that links physical drivers of marine productivity with effects on top predator species [17, 31].

For marine mammals and birds, existing remote sensing methodologies are subject to significant methodological limitations that reduce their utility for management purposes: Satellite counts of seals

[5] Type I refers to the erroneous rejection of the null hypothesis ('false positive': *e.g*., concluding that an observed change in ecological variables is caused by fishing when it is due to natural variation or other factors); Type II refers to erroneous acceptance of the null hypothesis ('false negative'; *e.g*., failing to detect impacts of fishing)

may be <40% of reference counts; seal pups, critical for monitoring reproductive performance of pinniped populations, cannot be counted; results for focal species are highly sensitive to detectability bias; and very little work has been done to date to quantify inherent sources of uncertainty [17, 31, 32, 38, 43, 44]. One of the key indicator species, Adélie penguins, is too small (body size, not population) to be counted from low Earth orbit, and so the New Zealand annual count of breeding Adélie penguins only covers southern colonies accessible by helicopter from Scott Base[6]. It is rarely possible to count northern Ross Sea Adélie penguin colonies. Not only are these northern colonies closer to potentially fished areas and would be expected to respond first to potential impacts, they also represent almost two-thirds of the total breeding population of Adélie penguins in the Ross Sea region (S. Emslie, pers. comm.; [45]). Satellite detection and identification of large cetaceans, a promising method for assessing their habitat use and movements, is affected by cloud cover and suffers from lack of ground-truthing [46]. By contrast, remotely piloted aircraft systems (RPAS) are cost-effective, low-impact, and accurate [47] but have limited spatial coverage. We propose that without the ability to collect reliable top predator data at high frequency and over ecologically meaningful spatial scales, it will be difficult or impossible to discern stochastic or periodic environmental variation from the effects of climate change, or to discern or assert the ecosystem effects of extraction (*e.g.*, fishing, bycatch) or of management interventions limiting that extraction (*e.g.*, catch limits, the RSrMPA).

A major component of ecosystem research by New Zealand in the Ross Sea region has focussed on the construction of a Ross Sea trophic ecosystem model incorporating all major taxa [48]. These efforts provide substantial insight into factors affecting ecosystem dynamics at the level of primary production and zooplankton and their predators, but its utility for understanding dynamics affecting top predators is limited because: (a) model predictions at higher trophic levels are not fitted to actual observations, but instead depend critically on lower and middle-level trophic relationships that are unknown, impossible to observe directly, and subject to complex interactions; (b) data collection at ecologically relevant scales is prohibitively expensive; and (c) the model's boundaries and spatiotemporal resolution do not match seasonal dynamics or interannual variation for RSrMPA focal species designated in Conservation Measure 91-05 or of the other potential indicator species mentioned above [6, 19, 21, 28]. We propose that this approach provides necessary insight but is not sufficient to effectively address relevant Specific Objectives for the RSrMPA.

The MKTT programme will address the identified gaps in existing research efforts in the Ross Sea Sector by:

(1) focusing biological and environmental monitoring efforts on the two extreme ends of the food web, that is i) primary productivity and its main physical drivers (sea ice extent, sea surface temperature, chlorophyll *a*) and ii) top predator species;

(2) implementing rigorous ground-truthing, error analysis, and validation/calibration of remotely sensed measurements for marine bird and mammal indicator species, to ensure the resulting data can serve as the basis for management and policy;

(3) explicitly considering the spatiotemporal attributes and requirements of data collection to ensure ecological relevance in relation to ecosystem drivers including climate change, seasonal variation, effects of fishing, and non-cyclical variation (*e.g.*, ENSO, SAM, stochastic sea ice events);

(4) emphasising the connectivity of the Ross Sea region to the Subantarctic and New Zealand waters, in particular regarding seasonally migrating species or species foraging in the Ross Sea region (whales and birds);

(5) synthesising conventional and traditional conceptual frameworks for ecosystem-based management of marine resources.

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[6] Helicopters used in the New Zealand Antarctic programme are restricted from operating over open water, which restricts access to colonies near Ross Island (Fig. 1)

We elaborate these numbered objectives as follows:

(1) A selective focus on observable physical and biological indicators, rather than the classical reductionist approach of attempting to represent the entire ecosystem as a quantitative model (essentially a 'clockwork' ecosystem; [49]), is in good agreement with both indigenous traditional ecological knowledge approaches and recent mainstream research [50, 51]. As apex consumers, marine mammals and birds integrate the combined effects of bottom-up environmental factors that drive marine productivity and their assimilation through middle trophic levels. These predators thereby create a quantifiable signal out of complex interactions that are otherwise unobservable and cannot be modelled explicitly at the resolution required. We intend to concentrate on modelling only climate and oceanographic drivers of marine productivity in the Ross Sea Sector, and then relating this to existing data series (*e.g*., tītī harvest records, colony census data for southern elephant seals and Adélie penguins [52-54]) and new information (*e.g.*, reproductive performance for killer whales and pinnipeds, timing of whale migrations) collected as part of our programme. This approach simplifies data collection, allows greater spatiotemporal resolution, provides a unifying framework for new and existing data series from a variety of sources, and is aligned with RSrMPA Specific Objectives (in particular i, iii, v, and vii; [6]). Long-term data series for indicator species can serve as the basis for testing species responses to decadal-scale climate variability and climate change. Reliable information regarding the abundance, seasonal movements, and spatiotemporal overlap of Ross Sea region top predators with fishing activities (including both focal species and additional species such as sperm, minke, and humpback whales) is essential for assigning causality, *i.e*., discerning impacts of fishing *vs*. climate change or natural variation.

(2) Effective and efficient research & monitoring in the Ross Sea Sector absolutely requires the use of remote sensing of Antarctic wildlife from high-altitude and low-earth orbit platforms to address fundamental knowledge gaps for key air-breathing vertebrate predators at spatiotemporal scales relevant to the RSrMPA (see priority elements listed in Table 2, Annex C, CM 91-05 [6]). To overcome existing methodological limitations, we have initiated a programme of validation/calibration of remote sensing using multiple platforms, sensor modalities, and locations. At this time, detectability biases for marine mammals and penguins (including sensor-based detection bias, physical availability or visibility of animals in surveyed locations, species and age class misidentification) are poorly constrained, resulting in unknown error profiles and large confidence intervals. Furthermore, existing data series may not be representative of population dynamics at the scale of the RSrMPA, (*e.g*., by sampling a small or unrepresentative subset of the population).

We will address current technological limitations by (a) rigorous quantification of detectability bias using small RPAS and static sensors (survey cameras, passive acoustics), (b) using fixed-wing high-performance RPAS to complete seasonal surveys over large areas of priority habitats in the Ross Sea region, and (c) ground-truthing satellite detection of whales with passive acoustic monitoring and ship-based RPAS. This will provide accurate information at ecologically relevant spatial scales and frequencies and reveal mechanistic links with oceanographic drivers detectable via satellite, creating a basis for ongoing cost-effective monitoring at high spatiotemporal resolution over large areas to better enable responsive management [17, 31].

(3) Monitoring ecosystem variation through top predators (marine mammals and birds) provides an effectively targeted environmental monitoring programme that allows data collection at scales relevant to the ecosystem and to the fished stocks. This is particularly relevant in the case of Ross Sea Antarctic toothfish, which occupies a similar trophic level in the food web as most air-breathing predators [55].

- Via their seasonal and life cycle movements, top predators integrate environmental signals over large and ecologically relevant spatial scales, comparable to (or larger than) the scale of largest management units within which CCAMLR manages fisheries (*e.g*. the Ross Sea Sector).
- Because top predators detect and respond to changes in environmental conditions affecting their own food supply, their directed movements and changing spatial distributions provide a sensitive indicator of *ecologically relevant* interannual variability.

- Because top predators are long-lived and store trophic energy over multiple years (as body fat), changes in reproductive success reflect relevant environmental change at the scale of years, and changes in population size reflect ecosystem-scale change at the scale of decades. This is compatible with the temporal scale at which CCAMLR is required to manage human activities, as defined in Article II (c) of the Convention on the Conservation of Antarctic Marine Living Resources [56].

By recognising the spatiotemporal scales at which top predator populations utilise the marine environment and seeking to identify the most important environmental drivers of the resultant patterns, our monitoring programme will utilise and benefit from the subtlety and complexity of top predator responses in space and time, rather than being confounded and misled by them. To illustrate why the design of monitoring programmes matters, consider a long-term annual data series of surveying land-based top predator colonies, with numbers of breeding individuals as the indicator variable. The conclusions drawn from observed changes in abundance over time are likely to differ depending on whether a representative proportion of the population is monitored or not. In the first case (monitoring covers all or most of the population, *and* individuals reporting to breeding colonies represent a more or less constant fraction of the total adult stock), interannual changes in total counts and in movement between colony sites could provide a sensitive indicator of bottom-up environmental drivers affecting local prey availability, providing insight into marine secondary productivity, trophic relationships, and adaptive predator behaviours. But without that understanding at the scale of the full population, changes in predator numbers at any particular colony, especially a colony at the periphery of the larger distribution, could easily be misinterpreted to reflect changes in total population size when the actual causes may be inter-colony movement or variation in the proportion of adults showing up to breed.

Alternatively, consider a monitoring programme focused primarily on oceanographic modelling and remotely sensed indicators of ocean productivity (*i.e.* chl *a*) but without simultaneous comprehensive monitoring of top predator species. Climate cycles or ice-dynamic events, including stochastic events such as caused by iceberg calving [57], can drive major changes in ocean primary productivity. But CCAMLR has no ability or mandate to manage photosynthesis. Middle trophic levels of the marine food web are invisible to remote sensing satellites and often difficult to quantify: we do not currently know whether an observed increase in ocean primary productivity will (a) affect trophic assimilation to higher levels of the food web and impact species (*i.e*., fish and krill) for which CCAMLR is responsible for management decisions, or will (b) merely create a temporary local algal bloom with no significant consequences for productivity at higher trophic levels.

An advantage of utilising top predator species is that they provide a sensitive indicator of environmental change at spatial and temporal scales that are both ecologically relevant and closely aligned with the ecosystem- and decade-scale mandate of the CCAMLR Convention as defined in Article II.

(4) A core concept of our programme is connectivity between the Ross Sea region, New Zealand, and the wider Pacific. Examples include by tītī and sperm whales. The lifecycle of tītī links different ocean regions, with adults foraging in the northern Ross Sea region during the chick provisioning stage and in the northern Pacific during the non-breeding season. Like other migratory seabirds, tītī integrate and transmit climate signals across space and time and potentially provide an early-warning system for major climate events [3, 4, 58, 59]. This is relevant to the management of the Ross Sea region fishery insofar as (a) responsive management must take into account shifts in marine productivity that affect recruitment and/or stock biomass; and (b) flying seabirds are currently not well surveyed in the Ross Sea region, despite being a significant part of the marine food web in the Southern Ocean (or any ocean); and (c) as highly mobile top predators, seabirds respond rapidly to spatiotemporal changes in marine productivity, making them suitable as ecosystem indicators [60, 61].

Adult sperm whales migrate to the Ross Sea region to feed on toothfish during the austral summer [7]. It is likely that this includes whales that also visit New Zealand waters. Significant overlap in sperm whale sighting locations with historical and existing toothfish catch along the Ross Sea continental slope strongly suggests that the continental slope is an important foraging area for sperm whales. The establishment of the RSrMPA resulted in a partial closure of productive fishing grounds along the Ross Sea Slope and this may have effectively mitigated any potential threat to sperm whales, by protecting their feeding areas. Alternately, it is equally possible that the existing RSrMPA boundaries have inadvertently displaced and concentrated fishing effort into whale foraging grounds: further research is needed to understand this. Although there have been no recent reports of sperm whale sightings from commercial toothfish vessels in the Ross Sea fishery, or of depredation of longlines by whales, this may reflect a lack of temporal overlap between the fishery (which operates in a very narrow seasonal window) and whales (for whom foraging seasonality is unknown). Dedicated effort, including by Murihiku ki Te Tonga, have demonstrated the presence of adult male sperm whales on the Ross Sea continental slope beyond any doubt [7, 8, 62, 63]. Recent deployments of hydrophones on the Iselin Bank and near the Scott Seamount to detect the presence of sperm whales [8, 64] create opportunities for tracking of movements of individuals using acoustic and photo-ID mark-recapture: by targeting sperm whale populations in coastal areas of South Island New Zealand, where they are easily accessible, we will establish photographic and acoustic identification profiles for individual adult males. In combination with acoustic and visual monitoring in Ross Sea region feeding grounds, this will enable identification and tracking of whales, and elucidate migratory patterns and connectivity of the RSrMPA with other regions.

Research to Date

Field work and data collection on the first three expeditions (February 2023, January and February 2024) completed since the launch of the MKTT Programme are listed in Table 1. All three expeditions followed a similar itinerary on the vessel *Heritage Adventurer*, with a representative ship track (February 2024) shown in Fig. 2. Some preliminary outcomes include:

Testing of new experimental protocols. An important goal of the initial phase of our field work is testing of new experimental protocols, standard operating procedures, and risk management plans. For several decades, no New Zealand marine research programme in the Ross Sea region has operated small boats[7]. Remotely piloted vehicles (either aerial systems, RPAS or underwater, ROV) remain severely underutilised in the study of marine mammals and birds. Our programme appears to be the first New Zealand marine research team to make significant use of small boats and to deploy RPAS and ROVs from small boats. Working with private sector partner Heritage Expeditions gave our research team access to both polar-class inflatable craft ('zodiac milpro'; Fig. 3) and staff with experience in rapid deployment from ships and navigating in sea ice. This very significantly increased our ability to access study sites on land, on ice, and at sea throughout the Ross Sea region. For example, the long-term research programme on killer whales in McMurdo Sound, previously carried out from helicopters and fast ice [8, 65, 66], was greatly facilitated by our ability to follow whales into pack ice and open water and deploy RPAS, underwater cameras and acoustic sensors. RPAS have a much smaller environmental footprint than helicopters and, unlike helicopters, elicit little or no behavioural response in marine mammals and birds when appropriate protocols are followed [67, 68]. Use of RPAS also permitted extensive documentation of feeding behaviour by whales in open water, which was previously impossible (Fig. 3).

High-resolution aerial surveys including multispectral cameras. To enable accurate monitoring of wildlife over representative areas, aerial or low earth orbit remote sensing is essential. RPAS are the methodology of choice for ground-truthing and validation of remote sensing from satellites and high-altitude platforms. We completed a very-high resolution georeferenced survey of the Cape Adare Adélie penguin colony and tested the efficacy of multispectral and thermal sensors for accurate detection of pinnipeds on different substrates (land and sea ice). Surveys were completed in under three hours, suggesting that it would be feasible to complete accurate monitoring of relatively large sites (several km^2) multiple times per season.

Continuation of long-term whale research. Data collection for the 'TPA' research programme on Antarctic killer whales and other whales established in 2013 [8, 69] has resumed after a three-year hiatus. In addition to Type-C killer whales as a designated RSrMPA focal species, we also collect

[7] With the exception of fishing vessels using small boats to transfer observers

photo-ID and behavioural observations for Type-B killer whales, sperm whales, humpback whales and minke whales. In January 2024, a Type-C killer whale calf was photographed in southern McMurdo Sound showing prominent foetal folds. Foetal folds in killer whales indicate an age of likely less than 30 days (certainly less than 55 days; [70]) and raise the question whether Type-C killer whales undergo latitudinal migrations north to give birth [5].

Aerosol measurements. A 'GRIMM' particulate sampling device for quantifying atmospheric aerosols was deployed on behalf of the New Zealand National Institute for Water and Atmospheric Research (NIWA) on the transect from New Zealand to the southern Ross Sea and back. There is uncertainty regarding the contribution of marine aerosols to cloud formation over the Southern Ocean, which in turn introduces error into climate models [71, 72]. Regular expeditions for the foreseeable future provide a platform for similar opportunistic research.

The Importance of International Partnerships and Next Steps

As the first indigenous-led Antarctic research programme, Murihiku ki Te Tonga relies on cooperation with established partners to build capacity for conservation and management of the Ross Sea Sector. We see particular value in public-private partnerships and in creating networks that bring together diverse stakeholders, including commercial fishing companies, Government agencies, and conservation tourism operators. However, appropriate management of the Ross Sea region is a task that requires international cooperation. Having demonstrated the capacity for completing successful research expeditions to the Ross Sea region, we see as the next major milestone the construction of an international alliance of like-minded partners to support a reset and a revitalisation of scientific efforts for effective, cooperative, and coordinated research & monitoring in the RSrMPA. Ongoing cooperation in the Ross Sea region remains important. At this time, six nations maintain active stations in the Ross Sea region: New Zealand, the USA, Italy, Germany, South Korea, and China; Australia and France are close neighbours; and the European Union, alongside other Members, supports MPAs in the Southern Ocean. The recent signing on May 04, 2024, of a Memorandum of Agreement (MOA) between Antarctica New Zealand and the German national centre for polar and marine research (Alfred-Wegener-Institute, AWI) in the presence of both Foreign Ministers signals new opportunities for international science cooperation in the Southern Ocean. Through Murihiku ki Te Tonga, we will implement the following steps:

- support, enable and administer a Ross Sea Alliance as an expression of *kaitiakitanga* (stewardship) over Te Moana tāpokopoko-a-Tāwhaki;
- signal the need for a values-based network of international collaborators and welcome registrations of interest from partners;
- develop a cohesive oceans strategy that incorporates indigenous, science, national and international partnerships to reflect the interconnectivity of marine ecosystems;
- host wānanga (meetings and workshops) as part of our Murihiku Regeneration Energy, Oceans and Innovation Strategy, starting in November 2024 (events will be live streamed);
- We encourage interested parties to contact us directly, connect to us through our website, and welcome suggestions for projects and collaborations.

In closing, we hope that our partners in other CCAMLR Member countries see value in a Ross Sea Alliance, as outlined in this paper and in a short outreach video (link):

"Mō tātou, ā, mo kā uri a muri ake nei"

For our children and their children after us

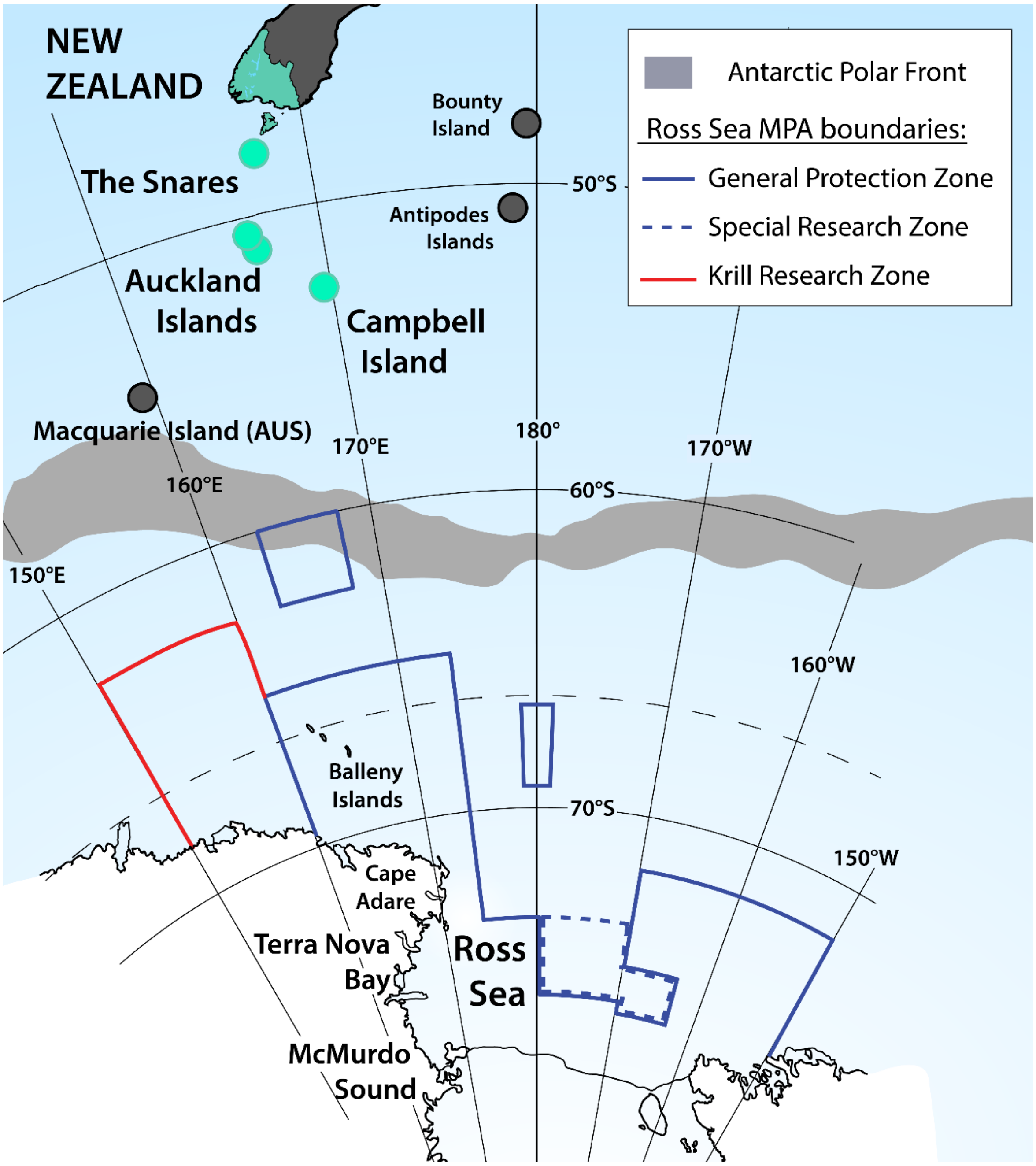

Figure 1: The Ross Sea Sector from New Zealand to the Ross Ice Shelf, including the Ross Sea region Marine Protected Area. The tribal area (takiwā) for Ngāi Tahu ki Murihiku is shown in green and includes Southland, Stewart Island, and three of the New Zealand Subantarctic Islands.

Table 1: Data collected by Murihiku ki Te Tonga in the Ross Sea Sector, February 2023 to March 2024

Parent Data Set	Description	Location	Type
Aerial Remote Sensing – drone surveys and multispectral imaging			
MRAQ23-CDA-01	Type-C killer whales	McMurdo Sound	multispectral still images
MRAQ24A-CDS-01	Fully georeferenced drone survey of Sandy Bay sea lion colony using multiple drones and sensors	Enderby Island 50°29'59"S 166°17'05"E	Aerial video, visual, thermal and multispectral still images; point cloud
MRAQ24A-CDS-02	Fully georeferenced drone survey of the Cape Adare Adélie penguin colony	Cape Adare 71°18'17"S 170°11'50"E	Aerial visual stills
MRAQ24A-CDA-01	Thermal imaging of Weddell seals on sea ice	Terra Nova Bay 74°41'48"S 164°02'56"E	Aerial thermal plus visual stills
Aerial Remote Sensing – foraging behaviour and photo-identification			
MRAQ24A-CDA-02 MRAQ24A-CDA-03	Minke whale foraging behaviour Type-B killer whale foraging behaviour	Drygalski Ice Tongue 75°31'44"S 165°48'58"E McMurdo Sound 77°34'43"S 166°00'44"E	Aerial video
MRAQ24A-CDA-04 MRAQ24B-ADA-01	Type-C killer whales Type-B killer whales	McMurdo Sound Cape Adare 71°37'28"S 170°12'18"E	Aerial video (including oblique for photo-ID)
Photo-identification from vessels			
MRAQ23-PID-KW MRAQ24AB-PID-KW MRAQ23-PID-MS MRAQ24AB-PID-MS MRAQ24AB-REC-VS	Photo-ID images of killer whales Photo-ID images of other whales Photo documentation of foraging (prey identifiable) by seabirds	Various Various Cape Adare	Ground/ship still Ground/ship still Ship still
Underwater filming, acoustics, opportunistic sampling			
MRAQ24B-ROV-01	ROV underwater video	McMurdo Sound	Underwater video
MRAQ24AB-UWS	360° camera recording	Various	Underwater 360° video
MRAQ24AB-ACX	Underwater acoustic testing	Various	Hydrophone recordings (.wav)
MRAQ24B-ATM	Continuous aerosol sampling	Transect from Bluff to Scott Base	Particle counts from ship-borne sensor

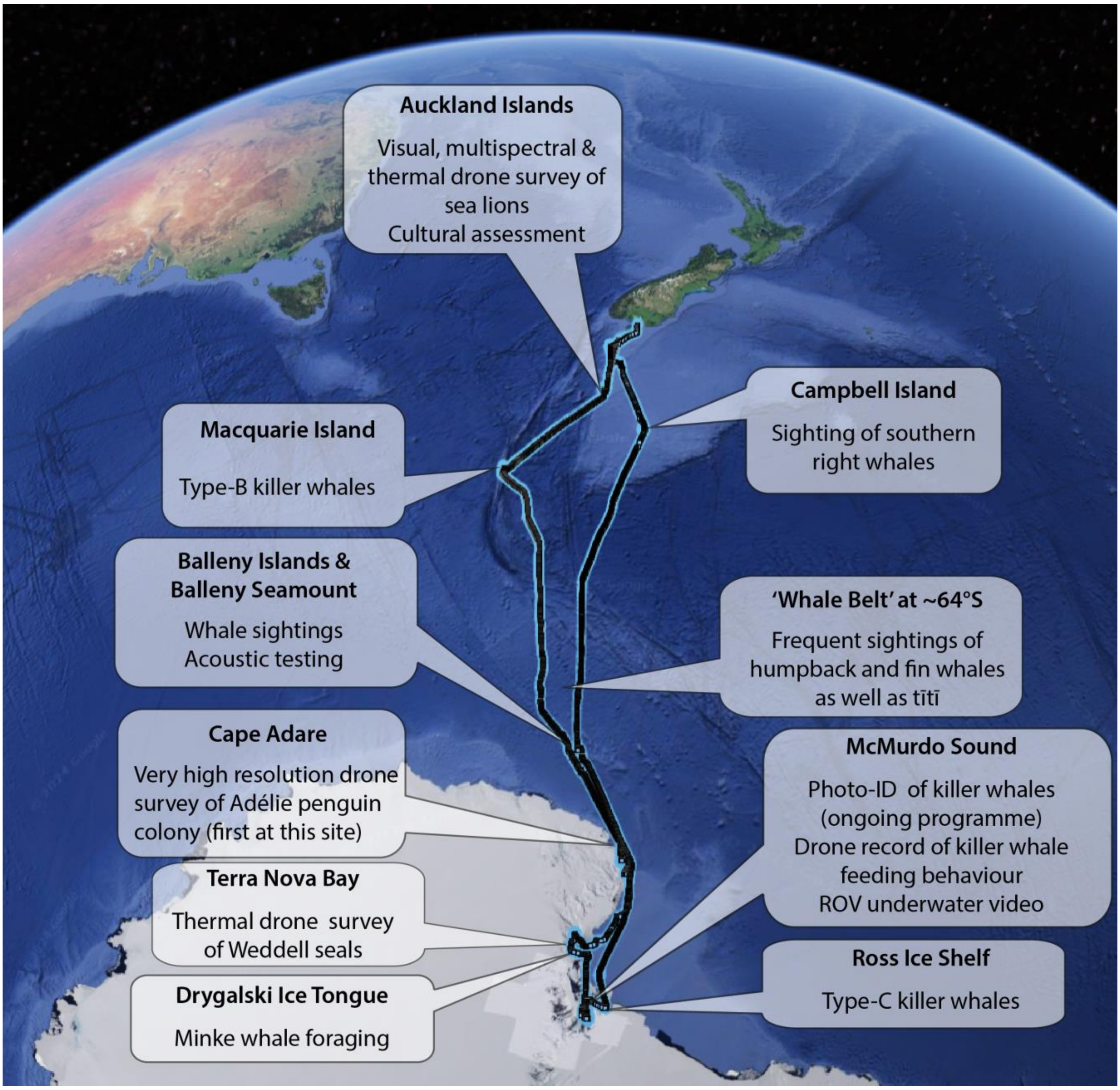

Figure 2: Cruise track of the *Heritage Adventurer* (February 2024) with primary locations and data sets.

Base map courtesy of Google Earth

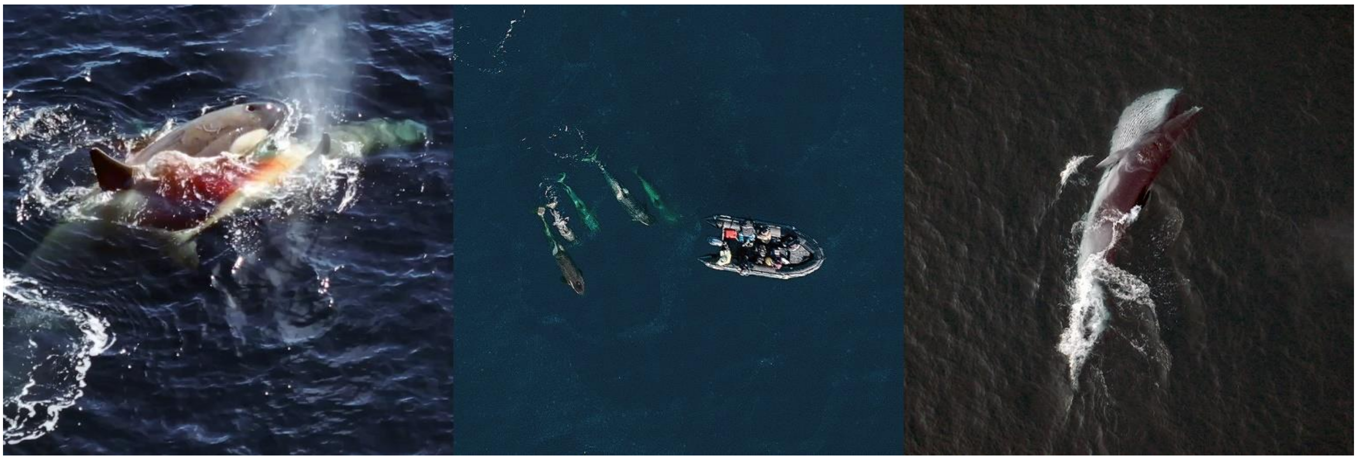

Figure 3: Studying whales in the Ross Sea using small boats and remote piloted aerial systems.
Left to right: Type-B killer whale hunting Adélie penguins; small boats (zodiac) allow close approach to whales in open water, here a group of adult and subadult Type-C killer whales in southern McMurdo Sound; lunge-feeding minke whale (*Balaenoptera bonaerensis*) near the Drygalski Ice Tongue. Image credit: Colin Aitchison/Skyworks

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