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LETTER

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Decisive conservation action in areas beyond national jurisdiction is urgently required for seabird recovery in the face of global change

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Abstract

Areas beyond national jurisdiction, or the high seas, are vital to life on Earth. However, the conservation of these areas, for example, through area-based management tools (ABMTs), is challenging, particularly when accounting for global change. Using decision science, integrated population models, and a Critically Endangered seabird (Kuaka; *Pelecanoides whenuahouensis)* as a case study, we evaluated potential ABMTs in the high seas under global change and different governance structures, while accounting for uncertainty and imperfect compliance. Our study highlighted that global change in these areas will likely cause population declines of ~60% by 2050. However, decisive conservation action could cost-effectively address predicted declines, particularly when implemented as soon as possible and under the Biodiversity Beyond National Jurisdiction Treaty. We illustrate how decision science can transparently navigate a complex seascape of management decisions and we advocate for its wider integration in the management of the largest sections of our planet, the high seas.

KEYWORDS

area-based management tools, areas beyond national jurisdiction, decision analysis, high seas governance, integrated population model, management compliance, marine protected areas, *Pelecanoides whenuahouensis*

1 | INTRODUCTION

Areas beyond national jurisdiction (the high seas) cover nearly two thirds of the ocean surface and ~90% of the ocean volume on Earth (Visalli et al., 2020; Nocito et al., 2022). The high seas support an extreme abundance and diversity of life, global nutrient cycles, carbon sequestration, climate regulation, fisheries, tourism, and other economic activities (Rochette et al., 2014; Popova et al., 2019). Despite recent commitments through the United Nations Convention on Biological Diversity to protect 30% of the globe, including the high seas, by 2030 (30 × 30; Dinerstein et al., 2019, CBD, 2023), currently only ~1.2% of the high seas are protected (Visalli et al., 2020). High seas biodiversity faces numerous threats including commercial fishing, pollution, and climate change (Laffoley et al., 2019). Additionally, the governance of the high seas is complex and fragmented, with multiple invested bodies, including Regional Fisheries Management Organizations (RFMOs; Table 1), whose mandates cover managing fisheries and their impacts on nontarget species within their competence area, and the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR), whose mandate extends beyond that of RFMOs and includes explicit conservation objectives. However, there is no single overarching legal framework for the conservation and management of all activities within the high seas, complicating conservation efforts (Blanchard, 2017). To address these challenges, the overarching Agreement under the United Nations Convention on the Law of the Sea on the conservation and sustainable use of marine biological diversity of areas beyond national jurisdiction, also known as the Biodiversity Beyond National Jurisdiction Treaty (BBNJ), was recently adopted (United Nations General Assembly, 2023). This is a multilateral, legally binding treaty that covers marine genetic resources, area-based management tools (ABMTs), environmental impact assessments, and capacity building.

Marine conservation across the seascape is mostly provided through ABMTs. ABMTs are tools for geographically defined areas through which one or several sectors or activities are managed to achieve specific conservation and sustainable use objectives (United Nations General Assembly, 2023). ABMTs can provide various levels of protection from minimal (extensive extraction allowed) to full protection (e.g., no-take zones) through different guidelines or legislation, depending on location and relevant threats (Grorud-Colvert et al., 2021). Locations for ABMT proposals have been based on bathymetry features or presence of important congregations of threatened species (e.g., Davies, Carneiro, Tarzia et al., 2021; Davies, Carneiro, Campos et al., 2021). For seabirds, one of the most threatened species groups (Dias et al., 2019), target areas for ABMTs, can be identified using tracking, as illustrated by a new 600,000 km^2 ABMT within the North Atlantic high seas (Davies, Carneiro, Tarzia et al., 2021; Davies, Carneiro, Campos et al., 2021). However, the remoteness of the high seas can reduce ABMT compliance (Collins et al., 2021). Although often assumed, the efficacy of ABMTs in reversing current and preventing future population declines has rarely been tested a priori, especially in the high seas.

TABLE 1 Glossary of acronyms used in this article.

Acronym	Meaning
ABMT	Area-based management tool
BBNJ Treaty	Biodiversity Beyond National Jurisdiction Treaty (Agreement under the United Nations Convention on the Law of the Sea on the conservation and sustainable use of marine biological diversity of areas beyond national jurisdiction; United Nations General Assembly, 2023)
CCAMLR	Commission for the Conservation of Antarctic Marine Living Resources
RFMO	Regional Fisheries Management Organization

Conservation decisions, particularly those pertaining to high seas ABMTs, are highly challenging due to extreme uncertainty, multiple competing values, complex management alternatives, and irreversible consequences (e.g., extinction) (Hemming et al., 2022). In such situations, decision science aids rational and transparent decision-making by articulating objectives relevant to a decision, identifying management alternatives, and predicting consequences while accounting explicitly for uncertainty (Canessa et al., 2020; Hemming et al., 2022). Decision science offers an ideal approach to overcome the challenges of decision-making in the high seas, including for ABMTs, yet it is rarely applied in this context, despite the recent focus on the BBNJ Treaty and 30 × 30.

In this study, we used the Critically Endangered Kuaka (Whenua Hou Diving Petrel; *Pelecanoides whenuahouensis*) to demonstrate how decision science can aid decisions on ABMTs in the high seas for species recovery, now and in the future. Kuaka consistently use a distinct area in the high seas of the Southern Ocean, which is therefore of high conservation concern (Fischer, Debski, Spitz et al., 2021). We used decision science to evaluate the cost-effectiveness of alternative ABMTs for Kuaka either under RFMO/CCAMLR or BBNJ governance by combining integrated population models, expert elicitation, and decision trees. Our predictions incorporated various sources of uncertainty, including uncertainty that a proposed ABMT will be successfully established and imperfect compliance. To our knowledge, our study is the first a priori assess-

TABLE 2 Specification of alternative area-based management tool (ABMT) for Kuaka management in areas beyond national jurisdiction, summarizing mitigation measures for each perceived future threat.

	Alternative area-based management tool						
		RFMO/CCAMLR governance			BBNJ governance[a]		
Threat	**Status quo**	**Voluntary mitigation**	**Compulsory mitigation**	**Compulsory seasonal closure**	**Voluntary mitigation**	**Compulsory mitigation**	**Compulsory seasonal closure**
Deck strikes	RFMO/CCAMLR led light mitigation	Regulatory laws for all fishing vessels: (1) minimizing light use, (2) avoiding movements at night, (3) eliminating unnecessary lights, (4) shielding lights, (5) using recommended spectra, (6) using black-out blinds wherever possible, and (7) using safe handling and release techniques		Regulatory laws put in place to create a spatiotemporal closure to all extractive fishing in the area during the nonbreeding period (January–August). Compliance will be monitored and enforced. Results in elimination of lights from fishing boats	As “Compulsory mitigation” under RFMO/CCAMLR governance, but measures extended to other marine users including transiting (cargo) vessels, cruise ships, or vessels associated with energy infrastructure		As “Compulsory seasonal closure” under RFMO/CCAMLR governance. Additionally, no energy infrastructure permitted. Transiting vessels and cruise ships subject to regulatory laws
Resource Competition with humans	RFMO/CCAMLR-led catch limits (e.g., CCAMLR krill limits)	As status quo		Spatiotemporal closure to all extractive fishing during January–August	As status quo		As “Compulsory seasonal closure” under RFMO/CCAMLR governance
Bycatch	RFMO/CCAMLR-led bycatch mitigation	Best practice mitigation measures as stated by ACAP		Spatiotemporal closure to all extractive fishing during January–August	As “Compulsory mitigation” under RFMO/CCAMLR governance		As “Compulsory seasonal closure” under RFMO/CCAMLR governance
Collisions with energy infrastructure	Status quo guidelines: (1) grouping turbines to avoid alignment perpendicular to main flight paths or migration corridors, (2) timing construction/maintenance to avoid sensitive periods, to reduce disturbance from boats, helicopters, and personnel	As status quo		As status quo	Measures put in place: (1) minimizing light use, (2) eliminating unnecessary lights, (3) shielding lights, (4) using recommended spectra, (5) using black-out blinds wherever possible, (6) using safe handling and release techniques		No energy infrastructure is permitted

(Continues)

TABLE 2 (Continued)

Threat	**Alternative area-based management tool**						
		RFMO/CCAMLR governance			**BBNJ governance**[a]		
	Status quo	**Voluntary mitigation**	**Compulsory mitigation**	**Compulsory seasonal closure**	**Voluntary mitigation**	**Compulsory mitigation**	**Compulsory seasonal closure**
Vessel- and infrastructure-derived pollution	Existing pollution guidelines (see, SIOFA, CCAMLR, SPRFMO, IMO, etc.)	As status quo		Spatiotemporal closure to all extractive fishing during January–August	As status quo		Spatiotemporal closure to all extractive fishing during January–August. No energy infrastructure is permitted
Plastic pollution	No relevant measure	As status quo		As status quo	As status quo		As status quo
Marine climate change impacts	No relevant measure	As status quo		As status quo	As status quo		As status quo
Catastrophes	No relevant measure	As status quo		As status quo	As status quo[b]		As status quo[b]

Note: Each ABMT could be introduced either from 2030 to 2040 onward. Note that voluntary mitigation incorporates the same measures as compulsory mitigation, but the two may differ in the level of compliance.

Abbreviations: BBNJ, Biodiversity Beyond National Jurisdiction Treaty; CCAMLR, Commission for the Conservation of Antarctic Marine Living Resources; RFMO, Regional Fisheries Management Organization; SIOFA, Southern Indian Ocean Fisheries Agreement; SPRFMO, South Pacific Regional Fisheries Management Organisation; IMO, International Maritime Organization.

[a]For ABMTs implemented under BBNJ, BBNJ would make recommendations to RFMOs and CCAMLR on implementation corresponding to their competences (United Nations General Assembly, 2023).

[b]Although ABMTs that may be able to catastrophes are included in the BBNJ Treaty (United Nations General Assembly, 2023), such alternatives were not included in this species recovery assessment here.

ment of ABMT effectiveness in the face of global change as well as the first application of decision science to identify cost-effective high seas ABMTs for species recovery.

2 | METHODS

2.1 | Study species

Kuaka are Critically Endangered seabirds and historically inhabited dunes throughout southern Aotearoa (New Zealand; Fischer et al., 2020). Invasive predators extirpated all colonies, except on Whenua Hou (Fischer et al., 2020). Kuaka persist there in a single colony (0.018 km^2). Whenua Hou was declared free of invasive predators in 2000, yet the Kuaka population remained at ~200 adults, well below carrying capacity (Fischer et al., 2020, 2022). Ongoing threats impact Kuaka within their breeding range: storm-induced erosion of breeding habitat, interspecific competition for burrows, and inshore vessel strikes (collisions following light-pollution-induced disorientation) (Fischer et al., 2023). During the nonbreeding period (January–September), Kuaka migrate to the high seas south of Australia (Fischer, Debski, Spitz et al., 2021). The core nonbreeding area covers ~1.5 million km^2 (Figure 1), where Kuaka encounter no direct anthropogenic threats. However, this beneficial situation is likely to change as human activities within the high seas expand in the future (e.g., Krüger et al., 2018).

2.2 | Decision framing and objectives

The Kuaka population is extremely small, so all future threats, including high seas threats, require decisions about mitigation to minimize extinction risk. We used various decision analytical tools to evaluate the need for, and the cost-effectiveness of, ABMTs within the high seas nonbreeding range of Kuaka. We identified two fundamental objectives for ABMTs: (1) maximizing the Kuaka population size (number of adults in 2050) and (2) minimizing establishment costs (total cost in NZ$ of ABMT establishment to the New Zealand Department of Conservation).

2.3 | Target area

To develop ABMTs for future Kuaka management in the high seas, we first identified the target area using a tracking dataset spanning multiple nonbreeding periods (Fischer, Debski, Spitz et al., 2021) together with a standardized workflow (*track2KBA*; Beal et al., 2021) to delineate a proposed Key Biodiversity Area (IUCN, 2016) for Kuaka (Supplemental Material S1). This area was then simplified by minimizing the area-to-boundary ratio (Handley et al., 2020), enhancing the practicality of ABMTs, and resulting in our final target area (Figure 1a).

2.4 | ABMT alternatives

To identify the most cost-effective ABMT for Kuaka conservation, we developed several alternative management strategies. We first used formal expert elicitation (Hemming et al., 2018) to identify future threats in the target area. Seven diving petrel experts were asked to define future threats, identify which vital rates those threats would impact (juvenile survival, adult survival, breeding probability, breeding success; Fischer et al, 2022, 2023), and articulate during which decade impacts would occur (2020–30, 2030–40, and 2040–50). At this stage, experts were not yet asked to provide insights on the magnitude of threats (see below). During a follow-up online discussion, experts were shown anonymous summaries of responses and discussed mitigation measures for each threat. Experts could then revise their initial answers. Experts highlighted vessel strikes due to increased light pollution under increased anthropogenic activity (Fischer, Debski, Taylor et al., 2021), marine climate change impacts (IPCC, 2023), resource competition with humans following the expansion of Antarctic krill fisheries (Trathan, 2023), and expanding energy infrastructure (e.g., high seas wind farms; Zheng et al., 2018) as most likely future high seas threats (Figure 1b). Simultaneously, experts were asked to provide input for mitigation measures, which we distilled into Status Quo and 12 fully specified ABMT alternatives (Table 2). ABMT alternatives included voluntary mitigation, compulsory mitigation, and compulsory seasonal closures, implemented from 2030 or 2040 onward, under either RFMO/CCAMLR or BBNJ (enabling mitigation of threats beyond fishing) governance. For ABMTs implemented under the BBNJ Treaty, recommendations on the implementation of measures would be made to RFMOs and CCAMLR falling within their competences (United Nations General Assembly, 2023).

2.5 | Predicting ABMT establishment costs

We estimated the total costs to the New Zealand Department of Conservation of establishing ABMTs using standard business planning procedures. We first defined the perceived full-time equivalents and timespan (years) of personnel required to advocate internationally for the establishment of an ABMT. We then used the pay bands

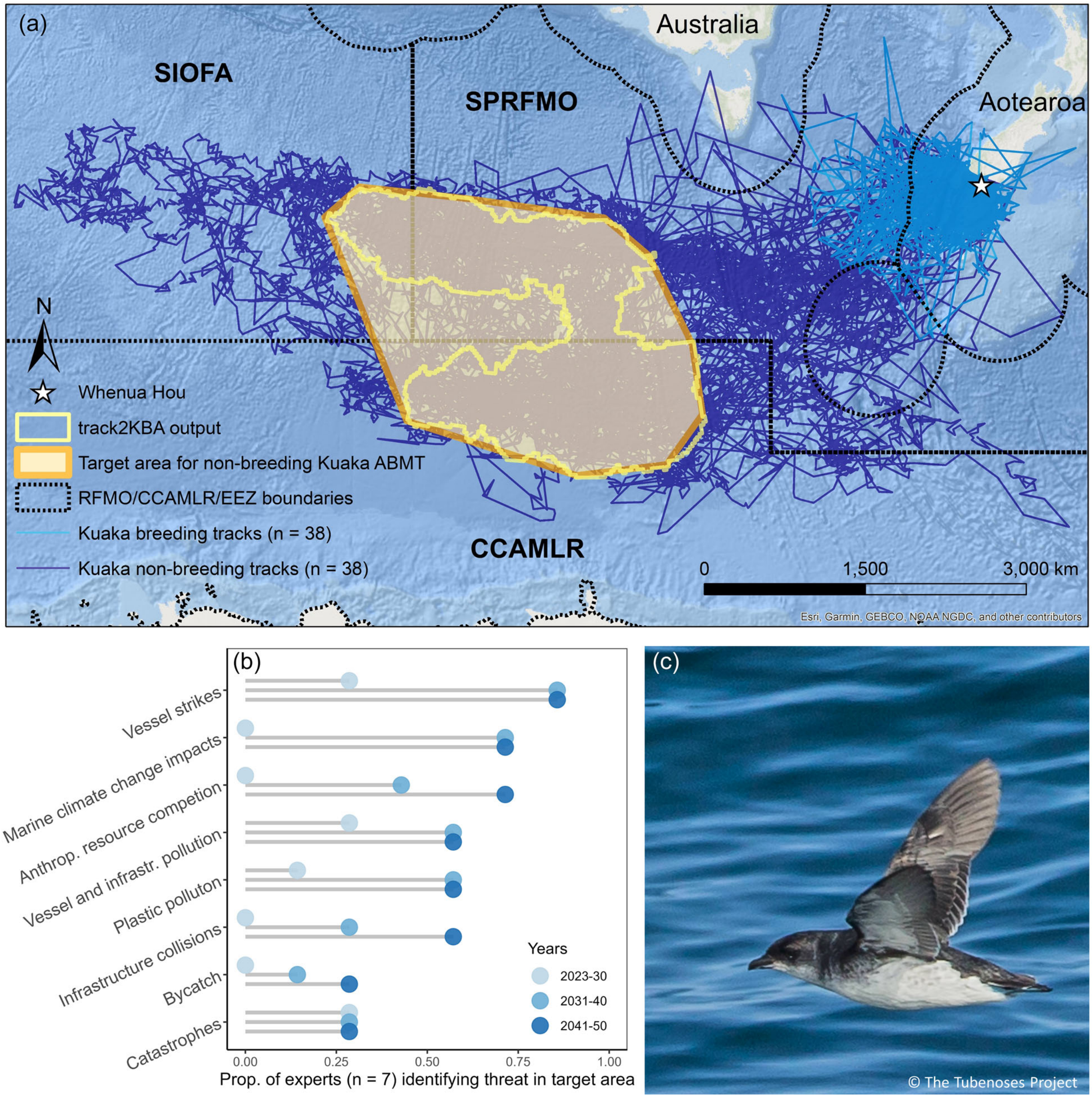

FIGURE 1 Target area in the high seas for future Kuaka area-based management tools as identified using tracking data (a), future threats perceived by experts to impact Kuaka within this area (b), and the first-ever photograph of a Kuaka at sea (C; credit: H Shirihai, the Tubenoses Project). CCAMLR, Commission for the Conservation of Antarctic Marine Living Resources; SIOFA, Southern Indian Ocean Fisheries Agreement, SPRFMO, South Pacific Regional Fisheries Management Organization.

per full-time equivalent in New Zealand $ (DOC, 2021) to define an annual cost range. To incorporate uncertainty, we considered costs to be uniformly distributed over this range and randomly drew 5000 values, which we multiplied by the full-time equivalents and years required to derive a total establishment cost estimate per ABMT (Supplemental Material S2).

2.6 | Predicting Kuaka population size under ABMTs

To predict the Kuaka population trajectory under each ABMT, we combined an integrated population model fitted to long-term data with formally elicited expert judgment where empirical data were unavailable (Supplemental Material S3). Our integrated population model combined an open-population state-space Cormack–Jolly–Seber model, two generalized linear mixed-effect models for breeding probability and success, and a hierarchical count model (Fischer et al., 2022). This model allowed us to estimate current vital rates and population size, while accounting for all sources of uncertainty. For parameters that could not be estimated empirically (i.e., impacts of future threats on vital rates per ABMTs, ABMT establishment probabilities, and ABMT compliance), we conducted two further expert elicitations following standardized protocols (Hemming et al., 2018), which were hosted through user-friendly Shiny apps containing the relevant background information on Kuaka, the anticipated threats, and the ABMT alternatives: a biological expert elicitation with seven diving petrel experts and an implementation expert elicitation with six high seas governance experts.

Through the biological expert elicitation, we obtained four-point estimates on how vital rates were perceived to change following the onset of all anticipated future threats in conjunction (Figure 1b and Section 2.4) and how the ABMTs would mitigate these impacts (assuming 100% compliance) for each decade. To integrate expert judgment in our model, we (1) rescaled each expert response to 100% confidence (Speirs-Bridge et al., 2010), (2) fitted individual beta-PERT distributions, (3) resampled and refitted those distributions to combine them into single beta distributions, and (4) used the differences between cumulative density functions of current model-derived estimates and expert-elicited estimates of vital rates to derive normally-distributed β-coefficients (Fischer et al., 2022, 2023). These transformations allowed us to estimate past vital rates and population size and project the fates of Kuaka under different ABMTs simultaneously.

Through the implementation expert elicitation, we obtained four-point estimates of probabilities of the establishment of ABMTs, assuming that the estimated costs could be covered (Supplemental Material S2), and the perceived level of compliance per ABMT if established. To integrate this expert judgment into the model, we repeated steps 1–3 in the biological elicitation above and derived aggregated beta-distributed parameters. We then incorporated uncertain establishment using a decision tree approach (Figure 2; Fischer et al., 2023; McMurdo Hamilton et al., 2023), and imperfect compliance by multiplying ABMT-specific β-coefficients per vital rate with the beta-distributed compliance parameter.

Ultimately, we projected the Kuaka population under Status Quo excluding future threats, Status Quo, including future threats, and 12 ABMT alternatives under three different scenarios: (1) assuming perfect compliance and guaranteed establishment, (2) including imperfect compliance, and (3) including imperfect compliance and uncertain establishment.

2.7 | Cost-effectiveness analysis

We assessed the balance between the cost of establishing each ABMT and their effectiveness (projected Kuaka population size) through the incremental cost-effectiveness ratio (Ferrière et al., 2021). We first drew 5000 random values from predicted cost and population distributions and then calculated the incremental cost-effectiveness ratio by dividing the difference between ABMT k and status quo costs by the difference between ABMT k and status quo effectiveness. We assumed perfect covariance between, and equal weight placed on, cost and effectiveness. Considering the objectives, the closer the ratio was to zero, the better.

3 | RESULTS

3.1 | Population projections under ABMTs

When ignoring anticipated global change, predictions indicated a stable Kuaka population trajectory ($N_{ad,2050} = 189$; 95% CI = 36–574), yet under global change and without intervention, all Kuaka vital rates were predicted to deteriorate increasingly over the next three decades, resulting in a predicted population decline of ~60% by 2050 ($N_{ad,2050}$ = 77; 14–258) (Figures 2–4). All high seas ABMTs were predicted to counter this future decline, albeit to varying degrees. When assuming perfect compliance and guaranteed establishment, mitigation implemented in 2040 under RFMO/CCAMLR governance performed the worst ($N_{ad,2050}$ = 96; 18–312), whereas a seasonal closure implemented in 2030 under BBNJ governance performed the best, as it prevented the impending population decline ($N_{ad,2050}$ = 182; 39–536). In general, ABMTs established under BBNJ governance outperformed those established under RFMO/CCAMR governance.

Levels of compliance were predicted to vary, albeit with high levels of uncertainty (Figure 3). Voluntary mitigation measures were predicted to have the lowest levels of compliance, and seasonal closures the highest, regardless of governance structure and implementation year. Imperfect compliance considerably reduced the effectiveness of all ABMTs to counter the future population decline, but the order of ABMT performance remained largely unchanged (Figure 4).

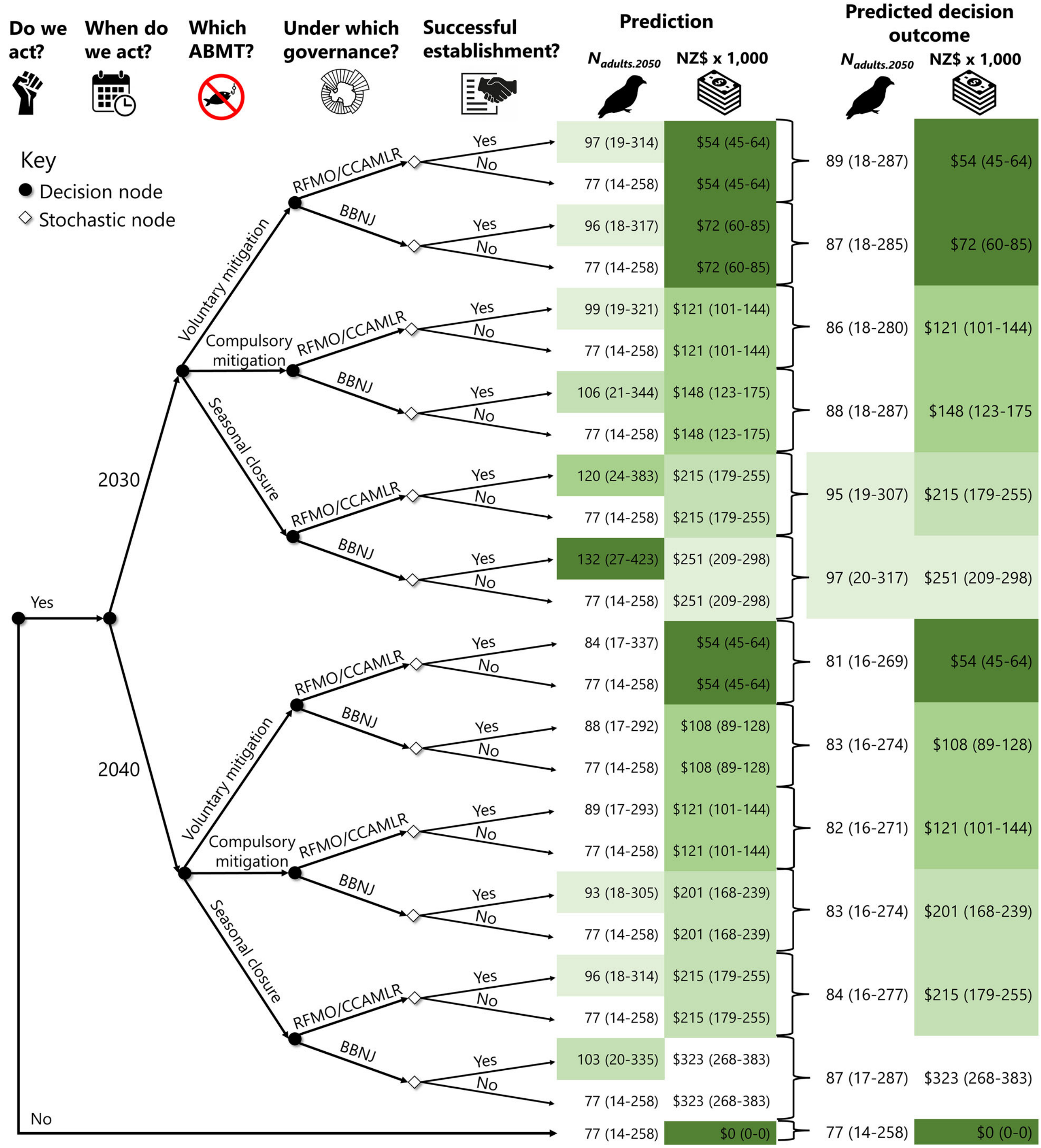

FIGURE 2 Decision tree illustrating predicted (decision) outcomes of area-based management tools (ABMTs) for Kuaka management in the high seas in medians (95% CIs). Darker shades of green indicate more desirable outcomes per objective. *Source*: Artwork provided by A Jearwattanakanok.

Similarly, there was considerable uncertainty on ABMT establishment probability estimates (Figure 3). Voluntary mitigation measures were considered more likely to be established successfully than compulsory mitigation and seasonal closures. Imperfect compliance and uncertain establishment further reduced the performance of ABMTs (Figure 4), but the ranking of ABMTs remained largely unaltered.

3.2 | Costs of ABMT establishment

Establishment costs varied highly between ABMTs (Figure 2, Supplemental Material S2). Aside from status quo (0$), establishing voluntary mitigation measures under RFMO/CCAMLR (regardless of year) was considered the least expensive (54,000; 45,000–64,000$) as it required the least resource (0.3 full-time equivalents

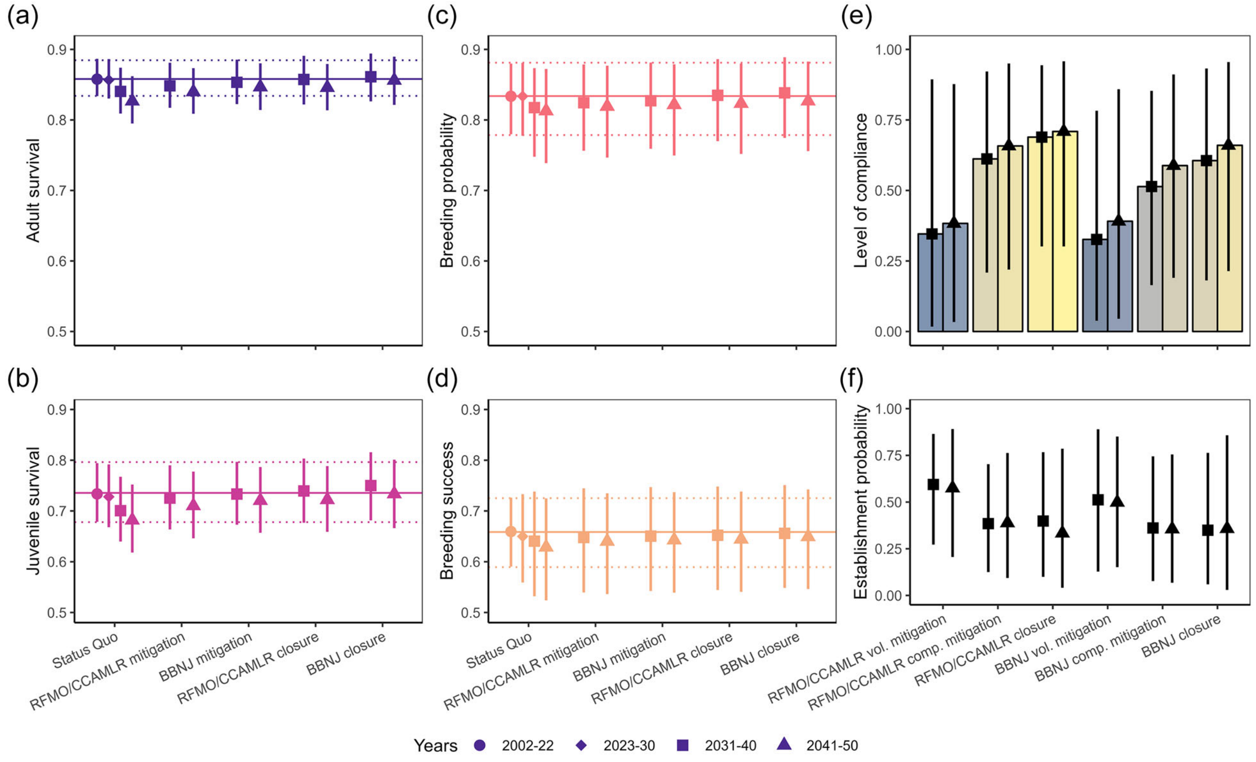

FIGURE 3 Estimated and predicted vital rates of Kuaka under area-based management tools (ABMTs) in the high seas (a–d), levels of compliance (e), and probability of establishment (f) of high seas ABMTs for Kuaka. Symbols represent medians with 95% CIs.

across 2 years), whereas establishing a seasonal closure under BBNJ governance in 2040 was considered the most expensive ABMT (323,000; 268,000–383,000$) as it required the most investment (0.9 full time-equivalents across 4 years).

3.3 | Cost-effectiveness of ABMTs

Cost-effectiveness of high seas ABMTs for Kuaka management varied considerably, but ABMTs established in 2030 were consistently predicted to be more cost-effective than ABMTs established in 2040 (Figure 5, Supplemental Material S4). Assuming perfect compliance and guaranteed establishment, voluntary mitigation under RFMO/CCAMLR governance in 2030 was the most cost-efficient ABMT, whereas a seasonal closure under BBNJ governance in 2040 was the least cost-effective. Seasonal closures established in 2030, under BBNJ or RMFO/CCAMLR governance, were the only ABMTs with positive uncertainty bounds. Imperfect compliance and uncertain establishment reduced the cost-effectiveness of ABMTs but did not reshape the cost-effectiveness landscape (Supplemental Material S4).

4 | DISCUSSION

Our analyses predicted that without intervention, Kuaka are likely to decline by ~60% by 2050, indicating that expected gains of current conservation efforts (Fischer et al., 2023) are likely to be undone by future impacts in the high seas. However, high seas ABMTs can prevent the predicted decline. Evaluated ABMTs differed substantially in effectiveness and cost. Voluntary mitigation measures established in 2030 through RFMO/CCAMLR governance were predicted to be the most cost-effective solution, but compulsory seasonal closures established in 2030 were the only ABMTs with certain conservation benefits. Seabirds like Kuaka thus require holistic conservation across land, inshore waters, and the high seas.

Our results highlighted early and decisive action in the high seas as paramount for conservation success and cost-effective management. Early implementation was predicted to limit population declines, as ABMTs prevented future threats. Delayed implementation resulted in more substantial declines, as ABMTs addressed threats after they arose. Early establishment would also be cheaper, requiring less international negotiation effort, as establishing high seas ABMTs is a complex process. Member countries of RFMOs, CCAMLR, and/or the BBNJ Treaty must

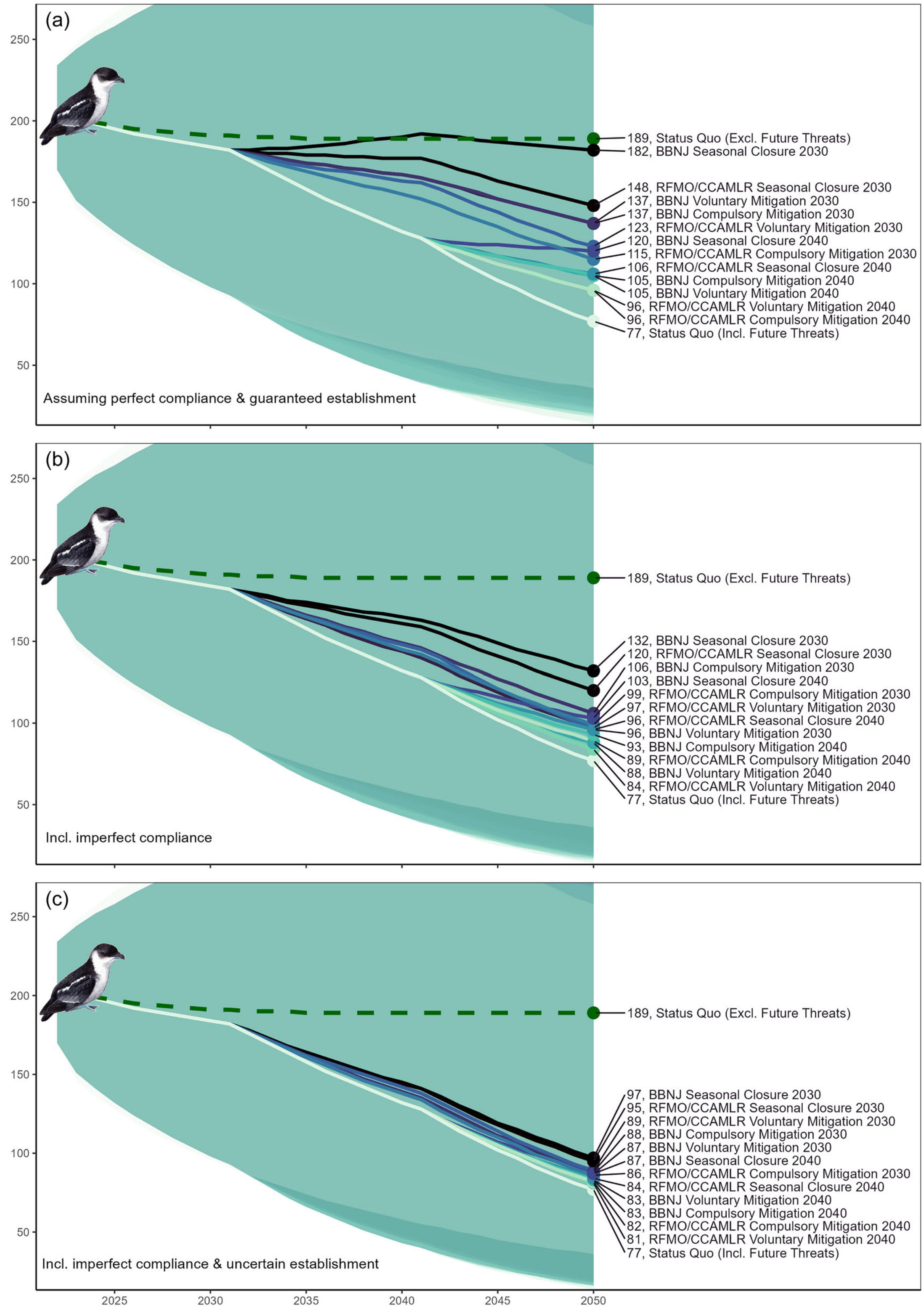

FIGURE 4 Kuaka population projections under various high seas area-based management tools, with (solid lines) or without impacts of future change (dashed dark-green line), assuming perfect compliance and guaranteed establishment (a), imperfect compliance, but guaranteed establishment (b), and imperfect compliance and uncertain establishment (c). Lines represent predicted medians; shading represents 95% CIs. *Source*: Artwork provided by A Jearwattanakanok.

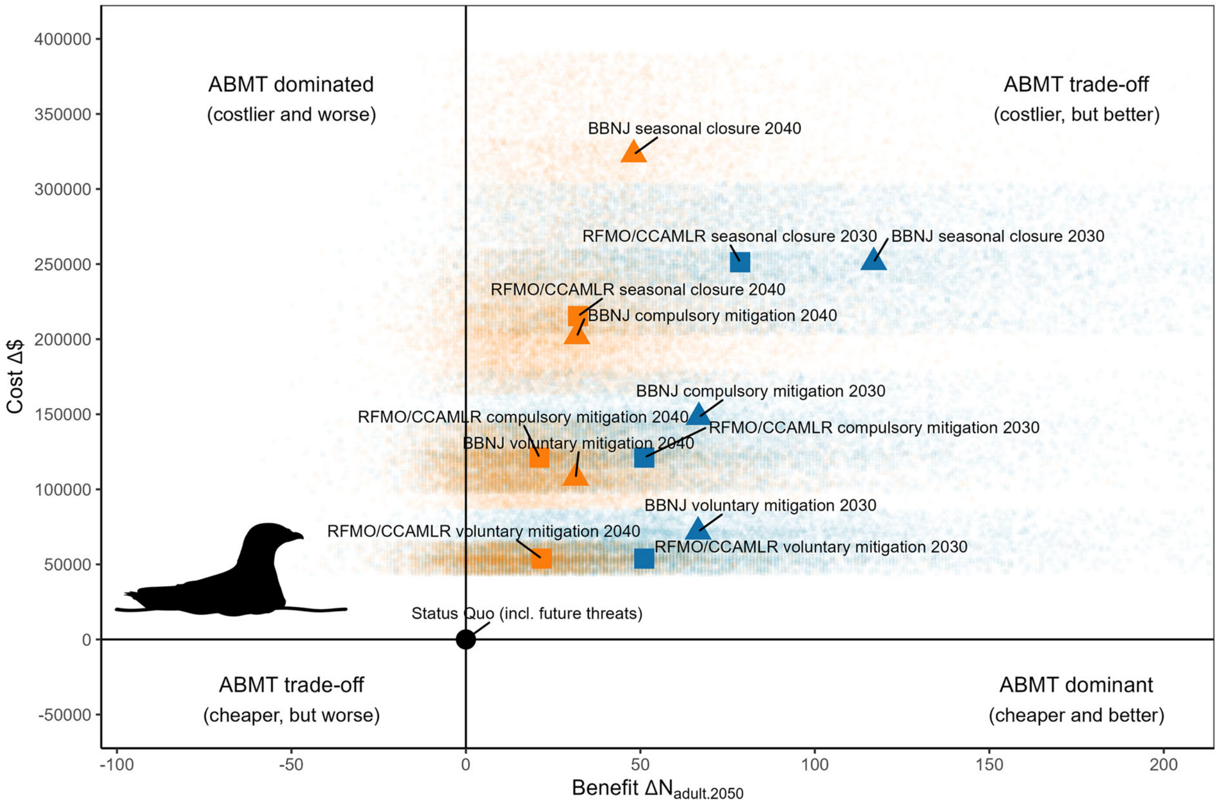

FIGURE 5 Cost-effectiveness of high seas area-based management tools (ABMTs) for Kuaka management, assuming perfect compliance and guaranteed establishment. Solid symbols represent medians, whereas translucent symbols represent 5000 random draws per ABMT, illustrating uncertainty. Orange symbols represent ABMTs established in 2030, and blue symbols indicate ABMTs established in 2040. Triangles represent ABMTs established under Biodiversity Beyond National Jurisdiction Treaty (BBNJ) governance, and squares indicate ABMTs established under Regional Fisheries Management Organization (RFMO)/Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) governance. Cost-effectiveness graphs of ABMTs, while accounting for imperfect compliance and uncertain establishment, can be found in Supplemental Material S4. *Source*: Artwork provided by J de Hoop.

cooperate, and their internal processes can be challenging for conservation, particularly when consensus decision-making is employed (e.g., most RFMOs and CCAMLR; Wright et al., 2015; Haas et al., 2020). For example, commercial interests can challenge ABMT establishment, as was the case for the Ross Sea Region Marine Protected Area (Brooks et al., 2019). Our target area is currently spared from commercial interests (Fischer, Debski, Spitz et al., 2021), but this beneficial situation is likely to change. Once commercial interests are established, ABMT establishment costs were expected to increase, as international negotiation challenges would increase. Considering both the impending threats in the face of global change and the biological benefits and cost-effectiveness of acting early, decisive conservation action in the high seas is crucial.

The BBNJ Treaty creates a global governance framework for the implementation of conservation management and as such has the power to instigate urgently needed decisive high seas conservation action. Our predictive assessment of the effectiveness of conservation action under BBNJ governance reinforces the Treaty's potential for conservation. Experts expressed substantial uncertainty about BBNJ governance, partially because ABMTs proposed through the BBNJ Treaty would partially rely on implementation through other bodies. Yet, experts also considered the BBNJ Treaty the most beneficial governance structure for conservation action in the high seas because of its ability to address threats beyond fisheries (e.g., offshore renewables; Zheng et al., 2018). The BBNJ Treaty will utilize majority decision-making, reducing the power of single countries in negotiations, and providing a framework for coordination and cooperation across oceans, potentially resulting in more robust ABMTs (Haas et al., 2020; United Nations General Assembly, 2023). Thus, the BBNJ Treaty may enable the decisive, wide-reaching conservation action required for species recovery and overarching global conservation goals such as 30 × 30 (Dinerstein et al., 2019, CBD, 2023).

Decision science can transparently inform future decisions on high seas ABMTs, but like all decisions, the best choice depends on the underlying values (Hemming et al., 2022). We assumed two equally weighted objectives;

explicit weighting and/or additional objectives would be a logical next step beyond the scope of our study (e.g., Fischer et al., 2023). An additional objective could be to maximize ecosystem benefits of ABMTs (e.g., Davies, Carneiro, Tarzia et al., 2021; Davies, Carneiro, Campos et al., 2021), as ≥33 additional seabird, marine mammal, and elasmobranch species utilize our target area, 45% of which are threatened (Supplemental Material 5). Including this objective would further highlight the ecological importance of this vast area of ocean (into which only a small number of Kuaka disperse; Fischer, Debski, Spitz et al., 2021). Another objective could be to minimize economic impacts of ABMT establishment. However, the commercial use of our target area is still absent (Fischer, Debski, Spitz et al., 2021). Considering the high ecosystem value and the currently limited commercial value, this would likely further highlight compulsory (seasonal) closures in 2030 under the BBNJ Treaty, as the preferred ABMT choice across objectives.

Despite the vital importance of the high seas to life on Earth, conservation in these areas is extremely challenging. Our study highlights three key conclusions: (1) global change in the high seas will cause species declines, (2) early, decisive conservation action is more cost-effective to address these declines, and (3) BBNJ governance could facilitate the implementation of the required action in the high seas. We advocate for wider use of decision science and predictive analyses such as ours to transparently navigate the complex seascape of management decisions in the high seas as the BBNJ Treaty and 30 × 30 gain traction.

AUTHOR CONTRIBUTIONS

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DATA AVAILABILITY STATEMENT

Out of respect of the Rangatiratanga (sovereignty) and Kaitiakitanga (stewardship) that Kāi Tahu as Mana Whenua and Mana Moana (people of the land and the sea) exercise over Kuaka and Whenua Hou, data can only be made available following consultation. The corresponding author can be contacted to facilitate such consultation.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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