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RESEARCH ARTICLE

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Progressing delineations of key biodiversity areas for seabirds, and their application to management of coastal seas

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Abstract

Aim: Decision-making products that support effective marine spatial planning are essential for guiding efforts that enable conservation of biodiversity facing increasing pressures. Key Biodiversity Areas (KBAs) are a product recently agreed upon by an international network of organizations for identifying globally important areas. Utilizing the KBA framework, and by developing a conservative protocol to identify sites, we identify globally importants places for breeding seabirds throughout the coastal seas of a national territory. We inform marine spatial planning by evaluating potential activities that may impact species and how a proposed network of Marine Management Areas (MMAs) overlap with important sites.

Location: Southwest Atlantic Ocean.

Methods: We collated a national inventory of all breeding locations for seabirds, including abundance records where available, and complementary estimates of at-sea distribution. We delineated areas of importance in coastal seas following approaches tailored to the ecology of species and assessed areas against global KBA criteria. To determine opportunities for species conservation and management, we reviewed which human activities have been documented to impact the target species globally via IUCN Red List accounts, and also assessed the overlap of important sites with a proposed MMA network.

Results: We identified global KBAs for nine seabird species (Anatidae, Diomedeidae, Laridae, Procellariidae, Spheniscidae, Stercorariidae) throughout national coastal seas. Globally important areas where multiple species overlapped were only partially accounted for in key zones of the proposed MMA network.

Main Conclusions: Development of a conservative protocol to identify marine sites for assessment against KBA criteria, revealed opportunities for enhancing a network of proposed Marine Management Areas in coastal seas. The framework we apply in this study has broad relevance for other systems where the design or review of management plans for the marine environment is required.

KEYWORDS
at-sea distribution, key biodiversity areas, marine megafauna, marine spatial planning, seabirds

1 | INTRODUCTION

Marine ecosystems, particularly those in coastal seas, are projected to come under increasing pressures as human populations rise and global demands for resources increase; the consequence being likely social, economic and environmental costs if pressures are poorly managed (Bindoff et al., 2019; Chamberlain et al., 2022; Halpern et al., 2019). To avoid such scenarios, global initiatives such as the post-2020 Global Biodiversity Framework (CBD, 2020) and the Sustainable Development Goals (UN General Assembly, 2015), outline key directions that nations should work towards. Specifically, these Multinational Environmental Agreements (MEA) identify targets to achieve the sustainable use of marine resources along with the conservation of marine biodiversity and ecosystems. Marine spatial planning (MSP) that results in effective, and implemented, management plans is a key route through which nations can achieve these targets. Complementing these political commitments is also a growing body of knowledge regarding the interventions that can support targets being met (Douvere, 2008; Hays et al., 2019; Maxwell et al., 2020). This knowledge includes decision-making products that foster identification of important areas for biodiversity in the marine environment, in which the effects of potentially harmful practices should be mitigated (Douvere, 2008; Smith et al., 2019).

Among the many decision-making products, Key Biodiversity Areas (KBAs) have recently been adopted by an international network of organizations as an overarching framework for identifying important areas across multiple taxa (IUCN, 2016). This unique collaboration facilitates the identification of globally important sites under a single currency, where all accepted sites undergo consultation, expert review and are curated in a globally accessible database (KBA Standards and Appeals Committee, 2020). KBAs are recognized as sites "important for the global persistence of biodiversity," and identified where sites contain a significant proportion of a species' global population or ecosystem extent, host a threshold proportion of a species genetic diversity, or host ecologically intact communities. These global criteria are applicable to all macro-organisms, and assessment of sites against KBA criteria is based on quantitative thresholds and standardized guidelines to support consistent application (IUCN, 2016; KBA Standards and Appeals Committee, 2020). To support decision-making for possible management action, the KBA guidelines recognize that sites should be considered as "manageable units" when delineating boundaries. However, KBAs come with no legal standing and are rather considered a valuable information product that can support data-led management of terrestrial or marine systems (Smith et al., 2019). For example, the main subset of KBAs include the long-established Important Bird and Biodiversity Areas (Donald et al., 2018), which have informed how nations meet global targets, which sites should contribute to MEAs or be considered for enhanced protection or management, guided investment decisions, and which have been recognized as important wildlife areas for local communities (Waliczky et al., 2018).

Seabirds are a key taxonomic group heavily reliant on coastal seas given that all species breed on land and either forage in coastal seas or must transit through coastal seas to reach pelagic foraging grounds (Hamer et al., 2002). They are also one of the most threatened groups of all birds, as numerous human activities are known to impact species (Dias et al., 2019). Because of the relative ease through which seabird populations can be monitored on land and at sea as opposed to other marine species, they are, however, a key taxonomic group that can play a critical role guiding marine spatial planning efforts (Davies et al., 2021; Mallory et al., 2019; McGowan et al., 2013), and have long been considered indicators of broader biodiversity patterns (Boersma, 2008; Furness & Camphuysen, 1997; Hazen et al., 2019). Additionally, there is a growing body of evidence detailing the critical ecosystem services these birds provide (Estes et al., 2011; Signa et al., 2021). Hence, implementing management actions that benefit the persistence or recovery of seabird populations can be highly beneficial not only for specific seabird species, but also for the ecosystems on which birds rely on.

A key challenge towards the conservation of seabirds—and indeed many other marine megafauna—is to determine which sites should likely be prioritized most for potential conservation or management interventions. In marine environments, this challenge is particularly apparent when there is limited data detailing species distributions at sea. Several methodologies for estimating seabird at-sea distribution in un-sampled regions have been proposed (Critchley et al., 2018, 2019; Dias et al., 2018; Franklin, 2010; Grecian et al., 2012; Grimm et al., 2016; Soanes et al., 2016; Thaxter et al., 2012; Wakefield et al., 2017; Warwick-Evans et al., 2017, 2018; Zhang et al., 2017). Yet, determining which method is most appropriate to derive species at-sea distributions should be considered in the context of available data for a given species and its typical foraging ecology (Bolton et al., 2019; Cleasby et al., 2018; Oppel et al., 2018). In the context of formally identifying KBAs triggered by seabird populations, only one other study has thus far considered an approach which largely relied on animal tracking data to identify KBAs (Beal et al., 2021; Handley et al., 2020). Furthermore, this study largely identified KBAs only in instances where direct evidence was available to determine species distributions, and also recognized that parts of the KBA network for the region would likely remain incomplete until further evidence or methodological advancement became available to identify additional KBAs (Handley et al., 2020). Therefore, establishing additional protocols for identifying at-sea sites for seabirds that can be assessed against KBA criteria is critical for ensuring that places necessary for the persistence of these species can be identified.

In the South Atlantic Ocean, within the coastal seas of the Falkland Islands which host numerous globally important seabird populations (Augé et al., 2018; Baylis et al., 2019, 2021), there have been incomplete efforts at MSP and no Marine Protected Area (MPA) proposals. A recent project, however, culminated in proposals for Marine Management Areas (MMAs) in the Falkland Islands including one in the coastal seas. These MMAs are areas that may include MPAs which have biodiversity conservation as a priority, but can also include other zoned areas. As yet though, the primary, publicly available, data underpinning the MMA proposal was derived via the "Assessment of Fishing Closure Areas as Sites (AFCAS)" (FIG, 2021a), and currently there has been no systematic, standardized and/or widely adopted approach to account for other biodiversity (such as seabirds) within the broader marine spatial planning efforts in the Islands.

Initiatives at the Falkland Islands which have aimed to support MSP efforts, and have focused on upper trophic-level predators such as seabirds (Augé et al., 2018; Baylis et al., 2021), typically focused on the identification of important areas at sea via distribution data from at-sea surveys and animal tracking, with a focus on the entire EEZ. Additionally, previous efforts both at the Falkland Islands (Forster, 2010) and beyond (Carroll et al., 2019), found that data collected by observers at-sea showed no demonstrable link between distance from land with areas containing a high number of different species, aggregations of listed threatened species, or terrestrial locations with high seabird abundance. Therefore, despite at-sea surveys playing a valuable role in estimating important areas for some species, unless conducted across the entire range of interest of focal species they may be missing areas important for certain activities of species that range beyond sampled areas (González-Solís et al., 2002; Granadeiro et al., 2017; Warham, 1996).

While earlier efforts have been critical to understand where some of the important places for seabirds are in Falklands waters, there has also not yet been a concurrent evaluation of which human activities may impact these seabird populations. This knowledge of both where important places are and what might impact species will be critical to guide the development of a biodiversity-informed approach for good standards of marine management in the coastal seas of the Falkland Islands (FIG, 2021a; O'Leary et al., 2019). Therefore, this study focuses on identifying critical areas for seabirds in the coastal seas of the Falkland Islands, as these areas are where several human activities are currently documented to, or will likely, occur (Augé et al., 2018; Marengo et al., 2020). We collated the largest record of seabird breeding location and abundance data from numerous sources and develop a conservative protocol to estimate the distribution of species throughout their known breeding range at the Falkland Islands. Specifically, we identified key areas surrounding breeding colonies where ecologically relevant behaviours such as rafting, preening, bathing, foraging or transiting between foraging trips occur, depending on the species. Recognizing that the Falkland Islands are a signatory to key international environmental agreements (FIG, 2020), we assess areas against global KBA criteria (IUCN, 2016) to determine the importance of specific places for species in an international context. For each of the studied species, we review documented accounts to inform which potential human activities could impact species (Dias et al., 2019; IUCN, 2021). We discuss the application and limitations of our results for informing MSP efforts in the Islands, and in the context of a recent proposal for Marine Management Areas, and note the broad applicability of our approach to other systems where the design or review of management plans for the marine environment are required.

2 | METHODS

2.1 | Study region

The Falkland Islands are situated in the south-west Atlantic Ocean (between 51–53°S and 57°30′–61°30′W), 450 km north-east of the southern tip of South America. The two main islands (West and East Falkland), and some 750 smaller islands (including rocks and reefs), make up the Falklands archipelago; covering an area of 12,173 km^2 (Otley et al., 2008). Their position places them at the south-eastern edge of the highly productive Patagonian Shelf, which is a major feeding area for marine top predators in the South Atlantic (Croxall & Wood, 2002). These highly productive waters, coupled with the large number of islands and diverse array of coastal habitats across the Falkland Islands support numerous seabird populations of many species (Otley et al., 2008). Much of the coastal seas of the Islands have also recently been recognized as a global KBA for Sei Whales (*Balaenoptera borealis*; Key Biodiversity Areas Partnership, 2022a).

Within the waters of the Falkland Islands Exclusive Economic Zone (EEZ), human activities include: transportation and shipping, tourism, fisheries, oil and gas exploration (Augé et al., 2018; Marengo et al., 2020), and more recently there has been consideration for the development of an aquaculture (open-pen salmon farming) industry (Bridson, 2018; FIG, 2019). Activities in these waters are largely managed by Falkland Islands Government and a number of mitigation measures, such as spatio-temporal restrictions on fisheries operations and best practices for mitigating seabird bycatch in fisheries, are in place to reduce negative impacts to seabird populations (FIG, 2021b). In recognition of the globally important populations of seabirds and seals breeding at the Falkland Islands, and of the inshore waters that play a critical role in the early life cycles of many of the Falkland Islands' commercially significant fish species, commercial fishing in the inshore area (up to 3 nautical miles of the Falklands coastline) has also not been permitted since 1986 (FIG, 2021a).

2.2 | Data requirements: marine KBAs for seabirds in coastal seas

Key Biodiversity Area criteria are distinguished across five key categories: (A) Globally threatened biodiversity, (B) Geographically restricted biodiversity, (C) Ecological integrity (sites with wholly intact ecological communities), (D) Biological processes and (E) sites with high irreplaceability measured through quantitative analysis (IUCN, 2016). Delineating relevant boundaries is an essential prerequisite of the KBA assessment process. Boundaries should be ecologically relevant and should provide a basis for potential management activities (KBA Standards and Appeals Committee, 2020). The typical data required to determine relevant marine boundaries for areas of assessment against species-specific KBA criteria for seabirds are breeding location data and at-sea distribution data (or estimates thereof) coupled with site and global population (abundance) estimates of mature individuals, and the IUCN Red List status of the species. That is, quantitative data typically play a key role in assessing sites for seabird species against KBA criteria (other assessment parameters are permitted when assessing sites against certain KBA criteria).

The primary KBA criteria considered for this study were the presence of significant numbers of globally threatened species (KBA criterion A1), whether a site holds a significant proportion (≥10% and ≥10 reproductive units) of the global population size of a geographically restricted species (KBA Criterion B1), or whether a site holds a significant aggregation, representing ≥1% of the global population size of a species during one or more life history stages or processes (KBA Criterion D1a; IUCN, 2016).

In areas where KBAs have not been previously identified, biodiversity element layers (spatial data layers representing the distribution of individual species where KBA criteria are met) can be identified first before being aggregated into one or more KBAs. These element layers can inform species specific management actions that should be considered within the boundaries of the final KBA (s) (KBA Secretariat, 2019).

2.3 | Species data for KBA assessment

We performed an initial scoping exercise and collated the most comprehensive dataset available to date of breeding and non-breeding location records for 27 species of Falkland Islands seabirds. A total of 11,153 records (to be provided in Supplementary Material subject to peer review process) were obtained from both published and unpublished sources which included the Falkland Islands Seabird Monitoring Programme (FISMP; Crofts & Stanworth, 2019), the Falkland Islands Biodiversity Database (FIBDB; FIG, 2013) and the Falkland Islands Coastal Bird Dataset (FICBD; Echevarría et al., 2020). These datasets include records for species presence, absence, abundance and geographical distribution. Only the abundance records were used for further analyses in the KBA site assessment process, as KBA criteria and quantitative thresholds should be applied to the best available data for a given species. For seabirds, these data typically relate to estimates of number of mature individuals (which can be derived from breeding pairs); although other assessment parameters also exist for assessing sites against KBA criteria (IUCN, 2016). Given, the majority of abundance records reflected only a best count for a given location (i.e. a single count only), therefore all records were standardized to represent a best count only, based on the most recent records for a particular location (Appendix S1: Count types).

Of the collated population records identified for potentially assessing sites of individual species against KBA criteria, data for many species were discarded given: (i) records were not always systematically collected, (ii) related to species that were not globally threatened and for which breeding populations at the Falkland Islands are <1% of global population estimates (therefore, unlikely to trigger species specific KBA criteria) or (iii) data related to wide-ranging species whose individuals do not tend to aggregate in specific areas (therefore identification of KBAs to support site-based management approaches is not suitable [Oppel et al., 2018]). Therefore, of the data available for the 27 species, we identified a key suite of 12 species (3057 breeding location records) for which to assess species-specific areas in the coastal seas of the Falkland Islands that could be compared against global KBA criteria (Table 1).

Data from the overall scoping exercise also serves as a key reference that facilitates species-specific data gap analyses and can be used to inform future research and monitoring needs of species (Appendix S1: Future research and monitoring and Survey record types for species – status and overview).

2.4 | Delineating areas for assessment against KBA criteria

The primary aim of defining geographic boundaries of areas to be assessed against KBA criteria is to define an area that provides the best conditions for the persistence of the biodiversity elements (i.e. the specific species). As such, boundaries should be ecologically relevant and should provide the basis for potential management activities (KBA Standards and Appeals Committee, 2020). Within the context of the coastal seas of the Falkland Islands, we followed conservative approaches to estimate the island-wide at-sea distribution of species for areas which could be assessed against relevant KBA criteria. We tailored the approach to each species (Appendix S1: KBA species layers) given the differences across the 12 species at-sea distributional patterns and the low levels or absence of tracking data available for seven of the 12 key species (Table 1). Specifically, we identified important areas for seabirds at sea on a 1 km × 1 km grid that served to represent the species ecology alongside the conservation goals being considered (Cleasby et al., 2020). As such, we identified areas which accounted for:

- the year-round distribution of an endemic species (Falkland Steamer Ducks), via an island buffer-based approach,
- key preening and washing areas, rafting areas or transit corridors for wide-ranging or non-flying species (Black-browed Albatross, Slender-billed Prion, Southern Giant Petrel, Sooty Shearwaters, Magellanic Penguins, Southern Rockhopper Penguins, Brown Skua, Dolphin Gull), via an island or colony buffer-based approach,
- the likely foraging areas of near-shore foraging species (Gentoo Penguin, Imperial Shag, Rock Shag), via a radius-based density decay function; an approach which estimates the proportion of the population likely to be using the waters surrounding a given breeding colony up to a threshold distance, and where areas closest to the colony are weighted to represent highest abundance compared to areas farthest from the colony (Critchley et al., 2018; Handley et al., 2021)

For each approach, the radius used to create the buffer for each species was based on published information (see details in Table 1). The outputs from each of these approaches yields a species-specific

TABLE 1 Twelve key species considered for marine KBA delineation and the approaches (Buffer types), with associated metrics, to delineate marine KBA boundaries for species in the coastal seas of the Falkland Islands.

Common Name Code Red List Status	Buffer type	Buffer rationale	Buffer distance	Buffer details	References (buffer)	Global population estimate (best count: Mature individuals)
Black-browed Albatross BBAL *LC*	Colony	Preening and bathing area	5 km	Buffer is based on preening and washing areas determined from GPS and immersion loggers during the incubation and brood-guard period.	Granadeiro et al. (2017)	1,400,000[A]
Brown Skua BRSK *LC*	Island	Preening and bathing area	2 km	Given there are no published tracking studies for this species at the Falkland Islands, and because the species relies on marine areas for preening and bathing, a conservative buffer indicating marine use areas was set in accordance with the most conservative estimate based on available records for Rock Shags (see below).	Other studies (Carneiro et al., 2015)	27,000[A]
Dolphin Gull DOGU *LC*	Island	Preening and bathing area	2 km	Given there are limited tracking studies for this species at the Falkland Islands, and because the species relies on marine areas for preening and bathing, a conservative buffer indicating marine use areas was set in accordance with the most conservative estimate based on available records for Rock Shags (see below).	Masello et al. (2013)	12,850[A]
Falkland Steamer duck FLSD *LC*	Island (incl. Main islands)	Year-round distribution	5 km	White et al. (2002) reported no records further than 8 km from shore. Augé et al. (2018) assumed equal distribution around all of Falkland Islands. Five kilometre is a conservative buffer in alignment with that used for the procellariiformes, and based on expert consultation. Given Falkland Steamer Ducks typically nest as territorial pairs and are endemic to the Falkland Islands (a key factor for assessing species against KBA criteria B1: "Geographically restricted species"), we delineated buffers around all islands with known breeding pairs.	(Augé et al., 2018; White et al., 2002) Expert consultation: Sally Poncet, Paulo Catry	12,500[B]

(Continues)

TABLE 1 (Continued)

Common Name Code Red List Status	Buffer type	Buffer rationale	Buffer distance	Buffer details	References (buffer)	Global population estimate (best count: Mature individuals)
Gentoo Penguin GEPE *LC*	Mean-max radius with density decay function	Island-wide foraging areas	21 km	Mean-maximum distance travelled from colony during incubation/chick-rearing.	Baylis et al. (2019)	774,000[A]
Imperial Shag IMSH *LC*	Mean-max radius with density decay function	Island-wide foraging areas	16 km	Mean-maximum distance travelled from colony during chick-rearing.	Crofts et al. (2014) and Masello et al. (2010)	TBC[D]
Magellanic Penguin MAPE *LC*	Colony	Preening and bathing area, transit corridors.	5 km	As a wide-ranging, non-flying species, with a mean-maximum distance travelled from colonies during incubation/chick-rearing of 298 km, we rather considered a conservative buffer of 5 km around colonies in accordance with buffers set for other species. This conservative approach aligns with the concept of “manageable unit” for KBAs in the context of assessing inshore areas for conservation at the Falkland Islands.	Boersma et al. (2002) and Putz et al. (2002)	2,700,000[A]
Rock Shag ROSH *LC*	Mean-max radius with density decay function	Island-wide foraging areas	2 km	Mean-maximum distance travelled from colony during chick-rearing	Crofts et al. (2014)	TBC[D]
Slender-billed Prion SBPR *LC*	Island	Preening and bathing area	5 km	Buffer is based on species with similar known ecology; Black-browed Albatross.	See Black-browed Albatross	7,000,000[C]

TABLE 1 (Continued)

Common Name Code Red List Status	Buffer type	Buffer rationale	Buffer distance	Buffer details	References (buffer)	Global population estimate (best count: Mature individuals)
Sooty Shearwater SOSH *NT*	Island	Rafting area	5 km	Given there are limited tracking studies for this species at the Falkland Islands, and because shearwaters are known to rely on marine areas surrounding colonies for rafting (Warham, 1996), a buffer was set in accordance with species of similar known ecology; Black-browed Albatross.	Bonnet-Lebrun et al. (2020) and Richards et al. (2019)	8,800,000[A]
Southern Giant Petrel SGPE *LC*	Colony	Preening and bathing area	5 km	Buffer is based on species with similar known ecology; Black-browed Albatross, and because elsewhere in their range birds always showed periods on the sea surface immediately after departure and just before arrival, indicating that all birds started and finished foraging trips by bathing at sea.	González-Solís et al. (2002)	101,800[A]
Southern Rockhopper Penguin SRPE *VU* (A2, A3, A4)	Colony	Preening and bathing area, transit corridors.	5 km	As a wide-ranging, non-flying species, with a mean-maximum distance travelled from colonies during chick-rearing of 139 km, we rather considered a conservative buffer of 5 km around colonies in accordance with buffers set for other species. This conservative approach aligns with the concept of "manageable unit" for KBAs in the context of assessing inshore areas for conservation at the Falkland Islands.	Tracking studies for consideration: (Masello et al., 2010; Pütz et al., 2018)	2,500,000[A]

Note: Global population estimate references: A: See species specific IUCN Red List accounts, B: Woods and Woods (1997), C: Falabella et al. (2019), D: Yet to be confirmed subject to taxonomic revision. Red list status: LC, least concern; NT, near threatened; VU, vulnerable.

raster layer with estimates of number of birds per cell. Depending on the species-specific approach, we either estimated the distribution of birds at-sea only from colonies which met relevant KBA criteria, or we estimated the island-wide distribution of birds at-sea and then identified the specific areas which met global KBA criteria (i.e. those cells which had greater than or equal to the requisite number of birds depending on the KBA criteria. See Appendix S1: KBA species layers).

2.5 | Final KBA boundaries

To avoid the cell-based nature of areas through the identification process and to delineate practicable management units, where relevant, the final marine KBA boundaries were converted to polygons which were further smoothed using Gaussian kernel regression, where the bandwidth was set according to the number of vertices in each polygon (Strimas-Mackey, 2018). Also, where areas identified as KBAs already overlapped with currently existing KBAs, the boundary of the pre-existing KBA was revised (following consultation with the original proposer) to account for these new areas, as per recommendations in the KBA guidelines (KBA Standards and Appeals Committee, 2020; Appendix S1: Overlap with currently existing global KBA).

2.6 | Human activities: interactions with target species

To inform the actions that could support the persistence of the 12 target species, we identified documented past, current and future human activities known to impact species populations through analysis of the relative IUCN Red List accounts (https://www.iucnredlist.org/) and supporting material from the recent global assessment to seabirds (Dias et al., 2019). These resources document human activities known to impact species at a global level, whereby impact is recognized as a process that affects the current conservation status of a species by causing a population or range reduction. Knowledge of human activities known to impact species serves as the necessary reference point when considering actions that will mitigate impact to species. In addition to analysing the species-specific data, we also downloaded all data for species at the family level to further assess the potential impact that any emerging human activity—in a local context—may have on a particular species.

2.7 | Overlap between KBAs and proposed MMAs

To assess how the globally important areas—the KBAs—would be supported by the recent MMA proposal, we assessed the overlap between target species KBA element layers and the proposed MMAs for the coastal seas of the Falkland Islands. Overlaps were assessed via a spatial join (function: st_join) in the sf package (Pebesma, 2018), using R (R Core Team, 2020).

3 | RESULTS

3.1 | KBA identification

Within the coastal seas of the Falkland Islands, we identified areas at sea meeting KBA criteria for nine of the 12 target species (Figure 1, Table 2). For the other three species, in the context of this study, a lack of official global population estimates as per the IUCN Red List precluded assessments of sites against KBA criteria, and data for these species were not considered further for defining the final KBA(s) boundaries (the data were considered, however, in the context of nationally important sites: Table 2, Appendix S1: KBAs with regionally important populations).

Where the identified species-specific element layers met KBA criteria, these areas represent some of the most important areas globally for the studied species, holding between approximately 3.2% (Sooty shearwater) and 100% (Falkland Steamer duck) of their global populations depending on the species. Not all target species, however, had abundance estimates available for all known breeding locations (Figure 2); therefore, it is feasible that other areas could meet KBA criteria in the future when the requisite species data become available. From the species-specific element layers meeting KBA criteria, these extend up to 5 km from the coastline. These species-specific element layers were either island wide (Falkland Steamer Duck – criterion B1) or were concentrated around a specific breeding location (Sooty Shearwater – criterion D1a). Some areas of the Falklands coastal seas have up to six overlapping species-specific KBA element layers. Those areas with highest overlap of species-specific KBA element layers were around the Jason Islands, New Island, Bird Island and Saunders Island (Figure 3).

Regarding final KBA identification beyond the level of individual species layers, nearly all areas identified were entirely within the boundary of the pre-existing KBA (Baines & Weir, 2020; Key Biodiversity Areas Partnership, 2022a), and one other area around Beauchêne Island was identified as a new KBA. Where species-specific KBA element layers extended beyond the bounds of the pre-existing KBA in the south-west region of the Islands (beyond Bird Island), the boundary of the pre-existing KBA was extended to account for the globally important areas identified for five of the study species. Therefore, results from this study showcase the revised and pre-existing (identified in 2020) KBA surrounding the main islands (Falkland Islands Inshore KBA), and we identify a new KBA around Beauchêne Island (Beauchêne Marine KBA; Figure 3, Table 2).

3.2 | Human activities: interactions with target species

According to documented accounts, human activities known to impact the 12 target species at the global scale in the marine environment include climate change, severe weather, aquaculture, bycatch,

FIGURE 1 Individual species-specific KBA element layers for breeding seabirds in the coastal seas of the Falkland Islands. KBA element layers refer to the individual species distribution layers which had areas that met KBA criteria at the species level. See details in Table 2.

overfishing, disease, energy production, mining, hunting/trapping and pollution. Ten of the 12 target species (excluding Dolphin Gull and Slender-billed Prion) are known to be impacted by one or more of these activities (Table 3).

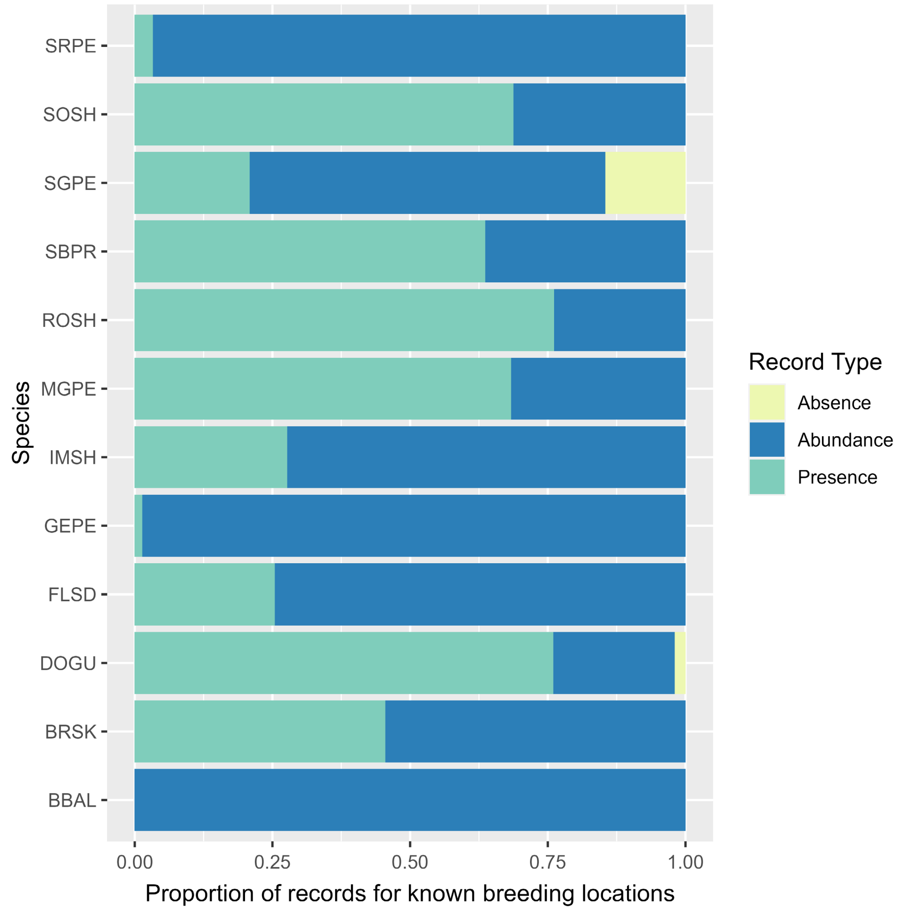
Two additional human activities (human intrusions and disturbance, and transportation and service corridors) have not been documented as causing impacts to any of the 12 target species; however, world-wide, they are known to impact closely related species in all of the six families represented, with the exception of Diomedeidae (albatrosses) (Table 3). Three families in particular—Laridae (gulls), Procellariidae (petrels, prions and shearwaters) and Phalacrocoracidae (cormorants)—are impacted by the greatest number of categories of human activities. Bycatch and overfishing (along with climate change and severe weather) are known to impact the greatest number of species for each family of the 12 target species. Aquaculture and transportation and service corridors are known to impact Anatidae (ducks) as well as Laridae, Procellariidae and penguins.

TABLE 2 Overview of target species assessment against global KBA criteria showcasing population information and KBA criteria met for individual species layers. Spatial data in Figure 1.

Final KBA(s)	Species (common name)	Lower estimate (No. of mature individuals in KBA)[A]	Upper estimate (No. of mature individuals in KBA)[A]	% Global pop threshold in KBAs (lower:upper)	Number of breeding locations contributing to KBA[B]	Breeding stage	KBA criteria
Falkland Islands Inshore	Black-browed Albatross	16,821	570,398	1.2:40.7	14 (Tot = 19, Ab = 19)	Breeding	D1a
	Brown Skua	450	1116	1.7:4.1	2 (Tot = 33, Ab = 18)	Breeding	D1a
	Dolphin Gull	192	1272	1.5:9.9	4 (Tot = 50, Ab = 11)	Breeding	D1a
	Falkland Steamer duck	37,500	37,500	100:100	Island wide	Year-round	B1
	Gentoo Penguin	7746	105,984	1:13.7	23 (Tot = 75, Ab = 74)	Breeding	D1a
	Imperial Shag	DNQ	DNQ	–	– (Tot = 123, Ab = 89)	Breeding	–
	Magellanic Penguin	DNQ	DNQ	–	– (Tot = 183, Ab = 58)	Breeding	–
	Rock Shag	DNQ	DNQ	–	– (Tot = 88, Ab = 21)	Breeding	–
	Slender-billed Prion	688,000	4,668,000	9.8:66.7	2 (Tot = 11, Ab = 4)	Breeding	D1a
	Sooty Shearwater	280,000	280,000	3.2:3.2	1 (Tot = 16, Ab = 5)	Breeding	D1a
	Southern Giant Petrel	1090	38,184	1.1:37.5	11 (Tot = 41, Ab = 31)	Breeding	D1a
	Southern Rockhopper Penguin	5012	388,828	0.2:15.6	35 (Tot = 61, Ab = 59)	Breeding	A1b, A1d, D1a
Beauchêne Marine	Black-browed Albatross	14,232	216,376	1:15.5	4 (Tot = 4, Ab = 4)	Breeding	D1a
	Southern Rockhopper Penguin	21,154	211,552	0.8:8.5	3 (Tot = 3, Ab = 3)	Breeding	A1b, A1d, D1a

Note: A: Lower estimate of mature individuals in KBA refers to lowest abundance estimate of any single cell meeting KBA criteria within overall final KBA, whereas upper estimate of mature individuals in KBA refers to summed maximum abundance estimates for species across the entire final KBA. B: Tot, Total number of extant breeding locations considered from the initial scoping exercise to identify areas for assessment against KBA criteria; Ab, number of breeding locations with associated abundance records. Where Tot = Ab, all breeding locations were used to consider areas for assessment against KBA criteria. Where Tot ! = Ab, future research and monitoring efforts are needed for comprehensive assessments of species populations across the Falkland Islands. DNQ: Species data did not qualify given lack of official global population estimates as per the IUCN Red List.

FIGURE 2 Proportion of the type of available records for all known breeding locations for a given species. Records reflect the most recent estimate available for a given location. Record types include; absence (a species was previously recorded breeding at the site but as of the most recent count, the species was not recorded as breeding at the site), abundance (the species was recorded as breeding at the site and a record indicating the number of birds is available), presence (the species was recorded as breeding at the site but a record indicating the number of birds is not available). While only abundance records were used for the final KBA analysis, for those species which have a majority of presence only records, further research and monitoring efforts to obtain abundance estimates for these species would enhance marine spatial planning efforts across the Falkland Islands. Species codes described in Table 1.



3.3 | Overlap between KBAs and MMAs

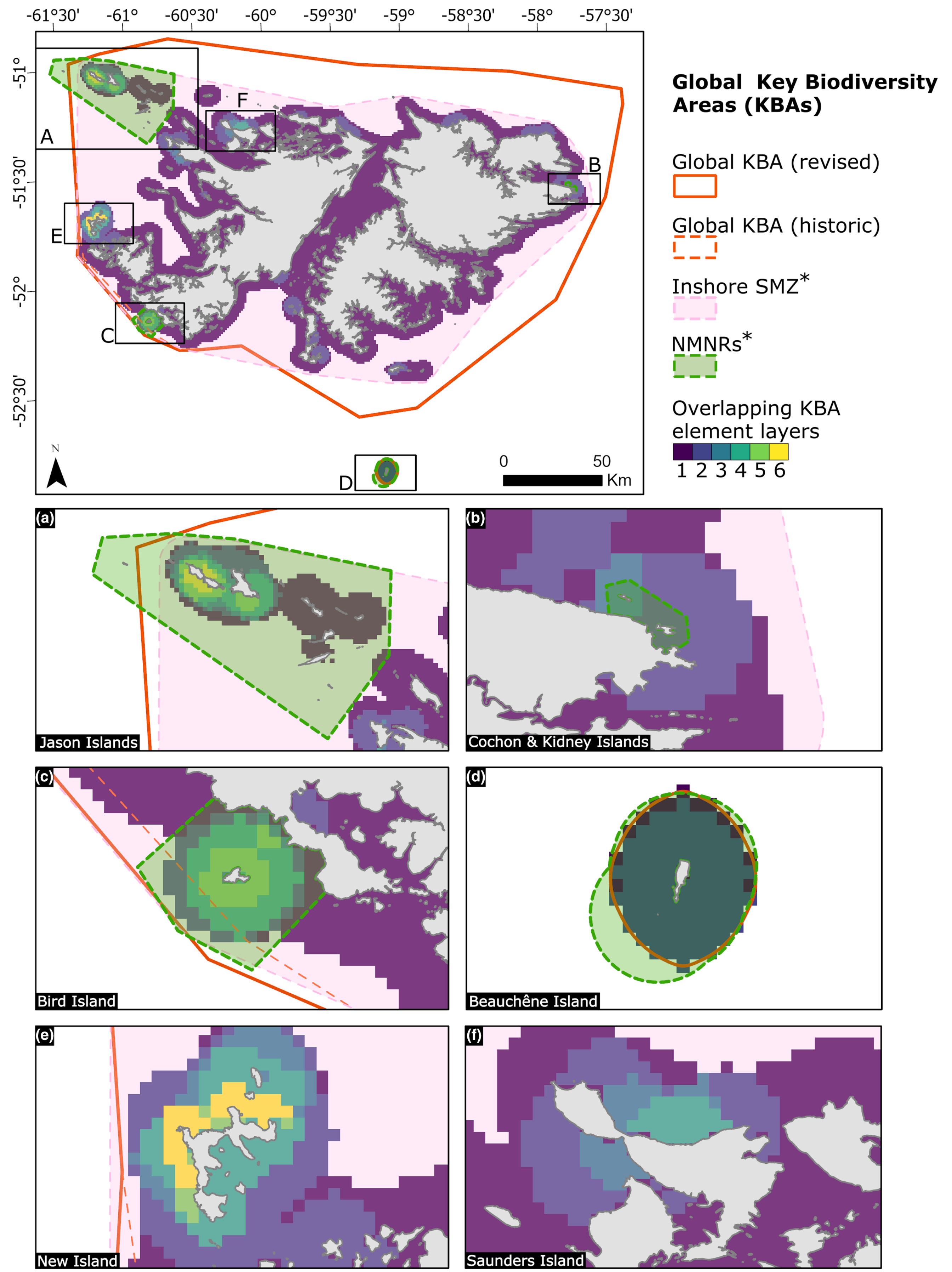
In terms of overlap between target species KBAs and the recently proposed zones of the MMAs, all nine species-specific KBAs overlapped with the Inshore Sustainable Multi-use Zone (SMZ). Specific zoned areas within the coastal seas which had the highest number of overlapping layers include the Jason Islands Group NMNR (six overlapping layers), then the Bird Island NMNR (five overlapping layers), Cochon and Kidney Islands NMNR (three overlapping layers), and the Beauchêne Island MMA (two overlapping layers). Outside of the specific zoned areas, other areas with high overlap of KBA element layers include New Island (six overlapping layers) and Saunders Island (four overlapping layers) (Figure 3, Table 4). Preliminary assessments also show several more marine areas around the Islands support high seabird diversity when considering regionally important populations (Appendix S1: KBAs with regionally important populations).

4 | DISCUSSION

Through this study which sought to assess for globally important areas for breeding seabirds throughout the coastal seas of a national territory, we developed a replicable protocol that supports the identification of KBAs for upper-trophic level central place foragers. Specifically, because our approach relied upon published estimates of birds' distributions whose colony origins and abundance estimates were also known from published records, it has broad applicability for identifying KBAs in other areas inhabited by populations of central place foragers, but for where there is limited direct information regarding the at-sea distribution of species. Application of our approach supported identification of nine new species-specific KBA element layers contributing to an area extension of a pre-existing marine KBA for the Falklands Islands (Baines & Weir, 2020; Key Biodiversity Areas Partnership, 2022a), and leading to the identification of a new KBA in the coastal seas around the remote Beauchêne Island. These important areas represent those used by the birds for rafting, preening, bathing, foraging or as necessary transit corridors between foraging trips, depending on the species. Our conservative approach for identifying globally important areas for seabirds means that only the most likely species-specific KBA element layers were identified (i.e. typically in those areas immediately surrounding larger colonies, where the highest numbers of birds occur).

By assessing the documented accounts of human activities known to impact species according to the IUCN Red List and key published records (Dias et al., 2019), our results indicate that there are several activities which could impact individual species (at a global level). More broadly, however, our results also indicate that there are additional activities documented to impact species at the family level both in terms of number of activities acting on specific seabird families and general activities acting on all families.

Regarding the differences in spatial extents between the identified species-specific KBA element layers in the coastal seas and



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Global Key Biodiversity Areas (KBAs)
Global KBA (revised)
Global KBA (historic)
Inshore SMZ*
NMNRs*
Overlapping KBA element layers
1 2 3 4 5 6
(a)
Jason Islands
(b)
Cochon & Kidney Islands
(c)
Bird Island
(d)
Beauchêne Island
(e)
New Island
(f)
Saunders Island

FIGURE 3 Overlapping KBA element layers for breeding seabirds in the coastal seas of the Falkland Islands. KBA element layers refer to the individual species distribution layers, which had areas that met KBA criteria at the species level. We considered data from 27 species originally. Data from nine species met global KBA criteria within in the coastal seas of the Falkland Islands. The distribution layers of the nine species can be found in Figure 1, and their associated global KBA criteria in Table 2. Also shown are the revised (nominated to KBA secretariat) and pre-existing KBA, and the proposed *MMA zones: SMZ (Sustainable Multi-use Zone) and NMNR (National Marine Nature Reserve) following the project led by the South Atlantic Environmental Research Institute under the Darwin Plus project (DPLUS071, see here). MMA data valid as of November 2021.

proposed Marine Management Areas (MMA), this study highlights that there is still much to consider regarding how all available biodiversity data for the Falkland Islands should be utilized for delivering a marine management approach that can support safeguarding globally significant biodiversity within the coastal seas of the Falkland Islands.

4.1 | Globally important sites

The hotspots of importance we identified align with recent multi-taxa efforts which identified important sites for upper trophic-level predators (seals and seabirds) more generally throughout the Falkland Islands Exclusive Economic Zone (Augé et al., 2018; Baylis et al., 2021), and more specifically the near-pristine inshore environment for whales (Baines & Weir, 2020, Key Biodiversity Areas Partnership, 2022a). However, our results differ in that they showcase an island-wide KBA for multiple seabird species, reinforcing the global significance of these sites for the persistence of biodiversity. Recent efforts have also recognized the value of this area for other upper trophic-level predators such as dolphins (Franchini et al., 2020). Furthermore, the globally important areas identified in this study also host critical habitat supporting larval life history phases of squid and fish (Agnew, 2002), and large extents of near-pristine kelp forests supporting numerous other biodiversity (Bayley et al., 2021; Mora-Soto et al., 2021), which may merit further KBA status.

Key to the value of these KBAs as inputs for decision-making is to consider the spatio-temporal consistency of sites, as the movement of species over time, especially those with different ecologies, is a primary challenge in area-based management of marine species (Chamberlain et al., 2022; Moffitt et al., 2011). Seabirds in general, however, are recognized to have typically high annual survival and exhibit high breeding-site fidelity (Hamer et al., 2002). Specific to the species in this study, high breeding site fidelity has been observed for the same or related species such as the sea ducks (Mallory, 2015), penguins (Williams & Rodwell, 1992), gulls (Stenhouse & Robertson, 2005), cormorants (Sapoznikow & Quintana, 2008), shearwaters (Sugawa et al., 2014), albatrosses and petrels (Bried et al., 2003). At the Falkland Islands, many seabird breeding sites have remained predictable over time (Catry et al., 2019; Crofts & Stanworth, 2019). Consequently, the areas we identified as globally important are expected to be stable across years, further benefitting confidence in the use of these sites as a key input for marine spatial planning efforts by decision-makers.

4.2 | Human activities: interactions with target species

In this study, the groups of seabirds which may be most impacted if new activities were to arise in Falklands coastal seas are the gulls, ducks, petrels/prions/shearwaters, and cormorants; most of which have a primarily inshore distribution (Oppel et al., 2018). Critically, of the overall activities our results show to impact seabird families at a global level (bycatch and overfishing, energy production and mining, pollution, aquaculture, and transportation and service corridors [Table 4]), aquaculture is a key activity for which potential future impacts should be accounted for. This is because aquaculture is an industry (industrial scale open-pen salmon farming specifically) under consideration for development, that if operationalized would operate within the coastal marine environment of the Falkland Islands (Bridson, 2018; FIG, 2019). Therefore, these operations would overlap with the globally important sites identified for seabirds in this study. The documented environmental impacts of salmon farming on seabird populations include direct impacts such as displacement from feeding grounds due to increased boat traffic, bird strike from attraction to light and also entanglement in anti-predator nets. Pollution and altered ecosystem dynamics can also have indirect effects on seabird populations (Bridson, 2018; Weitzman et al., 2019).

4.3 | Management implications

Results from this study support recognition of which species or areas would benefit from further consideration of conservation and management interventions. Specifically, with regards to the recent proposed zoning of the Inshore MMA, our results highlight both the areas around New Island and Saunders Island having equivalent or higher total numbers of overlapping globally important sites for species in these areas. Similarly, New Island and Saunders Island, as well as the area around Sea Lion Island were also identified by Augé et al. (2018) as areas having the highest conservation or ecological scores. Yet, within the recent MMA proposal none of these areas are considered for National Marine Nature Reserve (NMNR) status. A preliminary conclusion may be that these areas were omitted because the original focus of the MMAs was constrained to fisheries data used in the "Assessment of Fishing Closure Areas as Sites (AFCAS)" (FIG, 2021a), rather than a process that uses all available biodiversity data. Indeed, the current MMA proposal recognizes that

TABLE 3 Documented human activities—as per the IUCN Red List accounts (https://www.iucnredlist.org/) and Dias et al. (2019)—known to impact species at the global scale in the marine environment at both the family (○) and species (●) level, for the 12 species considered for KBA specific analyses.

Family	Common name	Climate change and severe weather	Human intrusions and disturbance	Aquaculture	Bycatch (only)	Bycatch and Overfishing	Diseases	Energy production and mining	Hunting / trapping	Overfishing (only)	Pollution	Transportation and service corridors
Anatidae	Ducks	○		○	○	○		○		○	○	○
	Falkland Steamer Duck										●	
Diomedeidae	Albatrosses	○			○	○					○	
	Black-browed Albatross	●			●							
Laridae	Gulls	○	○	○	○	○		○	○	○	○	
	Dolphin Gull											
Phalacrocoracidae	Cormorants	○	○		○	○		○		○	○	
	Imperial Shag									●		
	Rock Shag									●		
Procellariidae	Petrels, Prions, Shearwaters	○		○	○	○		○	○	○	○	○
	Slender-billed Prion											
	Sooty Shearwater	●			●							
	Southern Giant Petrel				●							
Spheniscidae	Penguins	○		○	○	○	○	○	○	○	○	○
	Gentoo Penguin	●				●	●				●	
	Magellanic Penguin	●		●	●	●		●	●		●	
	Southern Rockhopper Penguin	●				●	●	●			●	
Stercorariidae	Skuas	○			○					○		
	Brown Skua	●			●							

TABLE 4 Individual species-specific KBAs overlapping with each of the proposed zones of the inshore MMA. For details of each zone, please see Figure 3

Family	Species KBA element layers	Inshore SMZ	Jason Islands NMNR	Bird Island NMNZ	Cochon and Kidney Islands NMNR	Beauchene Island NMNR
Anatidae	Falkland Steamer Duck	●	●	●	●	
Diomedeidae	Black-browed Albatross	●	●	●		●
Laridae	Dolphin Gull	●		●		
Procellariidae	Slender-billed Prion	●		●		
	Sooty Shearwater	●			●	
	Southern Giant Petrel	●	●			
Spheniscidae	Gentoo Penguin	●	●			
	Southern Rockhopper Penguin	●	●	●	●	●
Stercorariidae	Brown Skua	●	●			

it does not have biodiversity conservation as the primary objective (Baylis et al., 2021).

Best practice management interventions that could support the identified globally significant biodiversity sites include those such as the renewed IUCN MPA Guidelines (Day et al., 2019), or other associated area-based management tools (Grorud-Colvert et al., 2021; Visconti et al., 2019). These offer a variety of options to support conservation of biodiversity, such as spatio-temporal restrictions on certain activities that have proved successful in mitigating impacts of activities to species in marine systems elsewhere (Trathan et al., 2014). As with this study, further analyses based on new data for seabirds, or for other taxa, are likely to lead to further KBA nominations in Falklands waters. With this prospect of identifying more species-specific KBA element layers, a key challenge for decision-makers will be to determine which interventions, and at what scales, will be most appropriate for conserving biodiversity. In the case of the near-pristine (Baylis et al., 2021; Mora-Soto et al., 2021), and highly connected Falklands marine system (Agnew, 2002; Payne et al., 2019; Signa et al., 2021; Tabak et al., 2016), there is a unique opportunity to proactively consider the best suited actions that would be able to maintain the globally significant biodiversity in all relevant areas of Falklands waters.

4.4 | Limitations and future recommendations

Identifying important sites against the global KBA Standard means that certain sites considered nationally important may be overlooked given they do not meet required thresholds. Similarly, utilizing global IUCN Red List accounts to document activities that may impact species, may mean that likely activities which are not yet documented will be insufficiently accounted for (e.g. see Slender-billed Prion in Table 3). Nevertheless, with marine management considerations underway at the Falkland Islands, the globally important sites we identified—with their expected stability in space—support recognition of key areas within Falklands waters against internationally recognized standards (Rose et al., 2020).

It is possible, however, that the globally important sites identified across the Falkland Islands in this study may underrepresent the total number of globally important areas for species that use the coastal seas of the islands. This underrepresentation is likely because both the absence of local (i.e. breeding locations with abundance estimates, Figure 2) and global population estimates (Table 2), coupled with taxonomic uncertainty for the shag populations (Rawlence et al., 2021; Schrimpf et al., 2018), meant analyses for certain species were limited by available quantitative data. Further baseline population census work will be particularly critical for Brown Skuas, Dolphin Gulls, Imperial Shags, Rock Shags, Magellanic Penguins, Slender-billed Prions and Sooty Shearwaters (Appendix S1: Future research and monitoring and Survey record types for species – status and overview). Such data would contribute to an enhanced assessment of species-specific KBA element layers, and would further enable understanding the global significance of biodiversity in coastal seas of the Falkland Islands.

Obtaining up-to-date population data, as well as fine-scale at-sea distribution estimates (Baylis et al., 2021) would serve as part of the necessary baseline required to monitor the impact of potential activities in future, and would significantly strengthen opportunities to guide efforts which could support lasting ecosystem functioning of the region (Kullberg et al., 2019). While for some species direct census efforts may be required, for others, the use of contemporary tools for monitoring in remote locations such as acoustic monitoring, time-lapse cameras, satellite or aerial imagery, may offer solutions for obtaining these abundance (in some cases likely only relative abundance) estimates in future (Brownlie et al., 2020; Edney & Wood, 2021; Walsh et al., 1995). Beyond enhancing the understanding of the importance of the Falklands marine environment for seabird populations in an international context, these data would contribute to increased understanding of local management needs; especially given that preliminary assessments comparing sites for species against local (as opposed to global) population estimates show several more marine areas around the Islands support relatively high seabird diversity (Woods & Woods, 1997; Appendix S1: KBAs with regionally important populations).

4.5 | Broader application

Central-place foraging behaviour is not unique to seabirds, and is exhibited by other upper-trophic level central-place foragers whose populations are easier to monitor, such as seals (Costa & McHuron, 2022). However, while a number of research programmes regularly collect data that would facilitate the identification of KBAs following the protocol we applied in this study, formal identification of KBAs for both seabirds and other central-place foragers is still in its infancy. Where formal KBA identification occurred for related species at South Georgia and the South Sandwich Islands (SGSSI; see: https://www.keybiodiversityareas.org/sites/search), the assessment contributed to a revised management plan of the sustainable use SGSSI MPA (Handley et al., 2020; Key Biodiversity Areas Partnership, 2022b); highlighting the utility of these products for decision-makers. For other major sub-Antarctic archipelagos such as the Prince Edward Islands (South Africa), Crozet and Kerguelen (France), and Heard & McDonald Islands (Australia), these all have well established research programmes where marine KBA scoping has not yet been conducted, but will likely be feasible (Heerah et al., 2019; Hindell et al., 2020; Reisinger et al., 2018; Thiers et al., 2016). While each of these archipelagos do have management plans in place, knowledge of globally important sites assessed against standardized criteria could further facilitate recognition of the important biodiversity within these regions in an international context.

Beyond key regions or the taxonomic groups for which KBA scoping exercises are likely more feasible, is also the recognized need to enhance methods through which sites suited to assessment against KBA criteria can be identified. Recent efforts have included suggestions for improvements in the way animal tracking data could be used to identify KBAs (Baylis et al., 2021), and also how KBA criteria may need to evolve when considering criteria related to vulnerability or irreplaceability of species in isolated marine jurisdictions (Riera et al., 2020). Although independent to the KBA framework, other processes to identify important sites for species (e.g. Important Marine Mammal Areas, Important Shark and Ray Areas) can also act as opportunities to stimulate ways in which KBAs for marine species might be identified in future (Tetley et al., 2022). We suggest that the recently released KBA training course (conservationtraining.org) would be a valuable place where future modules specific to the identification of KBAs for different taxa, or from varied data sources, could be hosted.

5 | CONCLUSION

This study contributes to a growing number of ways in which KBAs can be identified in the marine environment, increasing the opportunities for these products to inform decision-making processes. Specific to the case-study, our results can enhance the development of a required management approach for the coastal seas of the Falkland Islands. It is only with effective management, enacted over relevant scales, that preservation of marine ecosystem functioning, and associated benefits such as resilience of systems to climate change, can be maintained (Bindoff et al., 2019; Boyd et al., 2008). Management plans will need to consider both site scale actions and connectivity of sites requiring management, as the dynamic nature of marine ecosystems means that holistic interventions (i.e. interventions acting beyond and across sites) are likely best for supporting marine biodiversity (Boyd et al., 2008; Le Tissier, 2020). Without such appropriately designed management plans, designated areas run the risk of not providing the benefits they intend to deliver (Maxwell et al., 2020).

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CONFLICT OF INTEREST

All authors declare that they have no conflicts of interest.

DATA AVAILABILITY STATEMENT

Raw population estimates and colony location data used for the analysis are available in Data S1. Final data used for the analysis is also available in Data S2. R Code used to conduct the analysis is available upon request. Key Biodiversity Area layers can be requested via: http://www.keybiodiversityareas.org/home.

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BIOSKETCH

Team members of the BirdLife International Marine Programme and Falklands Conservation led this work, with support from a number of key affiliates. A part of the research focus for many of the team members is on the use of biologging technology to investigate marine top predator foraging ecology, and its applications towards the conservation of marine vertebrates. Team members provide a range of evidence to international fora in support of marine spatial planning, with a focus that can provide positive conservation outcomes for seabirds and their associated biodiversity.

Author contributions: JMH, EH, AS, MD conceived and designed the research. JMH, conducted the analyses, with contributions to species population data, analytical tools and methods from all authors. JMH, EH, AS wrote the manuscript with contributions from all authors.

SUPPORTING INFORMATION

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

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