**Running head*:*** *At-sea seabird conservation*

# A novel combination of methods identifies priority conservation areas for an endemic California Current seabird

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**Abstract**

1. There are a growing number of pressures on marine biodiversity. Seabirds in particular, are one the most-threatened groups. The Black-vented Shearwater (*Puffinus opisthomelas*) is endemic to Mexican islands and the only shearwater living its entire life cycle in the California Current System (CCS); one of the most productive large marine ecosystems in the world. Marine Protected Areas in this region, however, were designed without consideration for accurate data on seabird distributions.
2. Here, 49 Black-vented Shearwaters were GPS-tracked from their main breeding colony (95% of the global population) over four seasons (2016-19) to estimate their at-sea distribution. Two methods were applied to identify priority conservation areas: the approach developed by BirdLife International to identify marine Important Bird and Biodiversity Areas (IBAs) and method using expectation-maximization binary clustering to identify core foraging areas.
3. One potential marine IBA close to the breeding colony and five core foraging areas were identified. These priority conservation areas were largely beyond the bounds of the current MPA network in the region.
4. Our results detail opportunities for improving the implementation of conservation and management measures in the CCS region with respect to seabirds. Our approach of combining site identification methods can be applied to other seabird species for which high-resolution tracking data are available and help guide conservation action plans and MPA design.

Keywords

Conservation planning, Marine IBA, GPS-tracking, At-sea distribution, Behavioral segmentation

# 1. Introduction

Many studies recognize the growing number of anthropogenic pressures on marine ecosystems (Brooks et al., 2020; Halpern et al., 2015; IPCC, 2019). International policy frameworks, such as the Convention on Biological Diversity and the United Nations Sustainable Development Goals (CBD, 2010; UN General Assembly, 2015), outline targets and goals that almost all nations have agreed that can mitigate the potentially negative consequences of such pressures. In particular, the latest globally aligned biodiversity targets recognize that conservation efforts should be focused on areas of particular importance for biodiversity, in an effectively and equitably managed way (CBD, 2020). Such global targets recognize that the percent area of seascapes covered by protected areas alone may not be enough to indicate effective protection of marine systems, due to the use of poor delineation methods, or a lack of on-the-ground management or monitoring (Visconti et al., 2019; Watson et al., 2014). Therefore, to deliver effective conservation outcomes and avoid the problem of “paper parks” (Di Minin & Toivonen, 2015; Wilhelm et al., 2014), it is necessary to prioritize action at relevant sites of importance for biodiversity (IPBES, 2019; Visconti et al., 2019; Zhao et al., 2020).

As a signatory member of the CBD and the Convention on Fishing and Conservation of Living Resources of the High Seas of 1958 (UN, 1967), Mexico has committed to protecting and improving conservation efforts for marine biodiversity. As such, Mexico has recently designated large portions (22.05%) of its Exclusive Economic Zone (EEZ) as marine protected areas (MPAs) (REDPARQUES & Pronatura México, 2018). Most of these areas coincide with, or include, marine priority regions for biodiversity (Arriaga-Cabrera et al., 2009). MPA designs took into account information on the presence of marine species such as mollusks, polychaetes, echinoderms, crustaceans, turtles, fish, birds, marine mammals, and plants (Arriaga-Cabrera et al., 2009). However, the MPA network was established without consideration for accurate at-sea distributions of seabirds, as no data existed during the planning process. This may be a critical gap in the MPA design given that many species of seabird are impacted by threats occurring at sea (Dias et al., 2019), which appropriately designed MPAs can help abate (Oppel et al., 2018, Handley et al., 2020).

There are few published data and detailed analyses identifying core use areas of seabirds in Mexican waters (Block et al., 2011; Soldatini et al., 2019). In the waters surrounding the northwest region of Mexico, there are some proposed sites of importance for seabirds which could contribute toward MPA design (Waliczky et al., 2018). These are Important Bird and Biodiversity Areas (IBAs) (BirdLife International, 2010), which are sites of importance for a focal species that have been identified using standardized and internationally agreed upon criteria (Donald et al., 2018; Waliczky et al., 2018). On land, the existing IBAs for seabirds in Mexico were delineated to encompass globally important seabird colonies (BirdLife International, 2015). Whereas for those in the marine environment, IBA boundaries were set based on the *foraging radius approach* that may not capture all the important core at-sea areas for species foraging in more pelagic habitats (Soanes et al., 2016) . Therefore, it is likely that the current IBA network for seabirds in Mexico is incomplete, making it critical to consider detailed distribution data to provide an enhanced understanding of where some of the most important marine areas for seabirds are. These data can serve as evidence useful for improving the spatial coverage biodiversity in Mexican waters by MPAs.

The waters surrounding Mexico have the third-highest seabird species richness globally and support the second-highest number of endemic breeding or feeding seabird species (Croxall et al., 2012). Given seabirds are often regarded as indicators of broader biodiversity (Gregory et al., 2003; Parsons et al., 2008), key distribution data for seabirds in Mexican waters could improve conservation and management measures for other species (Sergio et al., 2006). The Black-vented Shearwater (*Puffinus opisthomelas*, BVSH hereafter), a near-threatened species endemic to Mexican Pacific islands, plays an important role in the marine ecosystem of Mexico and is the only shearwater which spends its entire life cycle in the waters of west coast North America (i.e., the California Current System) (Birdlife International, 2016). The species has a restricted distribution, especially during the breeding season when they generally feed in the highly productive waters of the continental shelf, mainly on anchovies, sardines, and squid (Keitt et al., 2000). In the CCS, major fleets from the United States and China fish for shrimp and Humboldt squid (https://globalfishingwatch.org/map/). The species has not been recorded as bycatch in longline fisheries, nor has it been documented to be killed in gillnet (Caretta et al., 2004) or in purse-seine fisheries (Carle et al., 2019). However, evidence from several other shearwater species shows that bycatch, overfishing, and pollution are potential threats to the species (Dias et al., 2019; Lieske et al., 2014).

Due to the lack of accurate at-sea distribution information for this near-threatened species, the aim of this study is to describe the important at-sea areas of the BVSH during the breeding period. This is done utilizing two approaches: 1) by using an accepted method to identify IBAs based on the description of core areas at the population level (Beal et al., 2021; Lascelles et al., 2016), and 2) an approach based on the behavioral classification of tracks, to describe areas specific to foraging behavior (Garriga et al. 2016b). Using these complementary approaches to identify important sites will be critical for identifying areas in which potential threats should be monitored. Furthermore, these data may help enhance our understanding of how MPAs in the region account for biodiversity in their spatial design.

# 2. Materials and Methods

**Species and study site**

The California Current System, CCS, spans from the North Pacific Current (~50°N) to off Baja California, Mexico (~15–25°N) with a major discontinuity at Point Conception (34.5°N) and from the coast to approximately 1000 km offshore (Checkley & Barth, 2009). It is a highly productive region providing essential habitat to marine top predators (Block et al., 2011). The focus of this study was on a globally significant population of BVSH breeding on Natividad Island (Mexico, 27° 86' 25.59" N, 115° 17' 14.18" W, Figure 1), which hosts ~95% of the BVSH world population. Between 2016-2019, an average of 44,503 pairs of BVSHs bred on Natividad Island annually (unpublished data calculated after (Albores-Barajas et al., 2018). As such, it has been identified as a terrestrial IBA, code MX098 (BirdLife International, 2010), with an approximate 2 km buffer surrounding the island (BirdLife International, 2020; Vidal et al., 2009). The island is 8.65 $km^2$, arid, with little vegetation and is inhabited by approximately 80 families who are part of a fishing cooperative that manage voluntary no-take zones to ensure the sustainability of the marine resources (Bajo & Roelants, 2011). Due to the presence of the globally important colony of BVSH and other seabird colonies, Natividad Island and its small buffer are included in the El Vizcaino Biosphere Reserve (DOF, 2000) and the Pacific Islands Biosphere Reserve (DOF, 2016). Both these MPAs have an extensive marine surface area (respectively 287,787 ha and 1,091,083 ha), contributing to the 22.05% of Mexican EEZ currently in marine reserves (REDPARQUES &

Pronatura México 2018). Furthermore, the region is considered of conservation importance as a Marine Priority Area for Biodiversity (Arriaga-Cabrera et al., 2009).

## Tagging

Using bespoke dataloggers (Axy-Trek, Technosmart Europe, Rome, Italy), breeding BVSHs were tracked both during the incubation and chick-rearing periods from 2016-2019 (incubation $N_{birds}$ = 17, chick-rearing $N_{birds}$ = 38). The incubation period is approximately from March to June due to the asynchronicity of the species; chick-rearing may begin in May and last up to the end of July for later breeders. Dataloggers were attached to the back feathers of the birds using four strips of marine tape (Tesa® 4651, Tesa SE, Hamburg, Germany), weighing a total of 11 g (9 g of the instrument, 3.5 cm long x 2.5 cm wide x 0.5 cm high, plus 2 g of tape; < 3% of body mass similarly to other Puffinus shearwater studies (Bennet et al., 2019; Guilford et al., 2008) . All data loggers were configured to record GPS coordinates every 5 minutes. The pressure (used for calculating dive depth) was recorded at a frequency of 1 Hz. The colony was visited each night to check burrows, and upon the bird's return to the colony the loggers were retrieved. Both parents were tagged in each of 23 nests during the study period; for eight nests it was not possible to tag both birds, 9 birds were tagged on different years. No GPS-equipped bird failed to return to its burrow, and therefore 100% of deployed loggers were retrieved. Tags were deployed only when the nest chamber was accessible to catch the birds; if the tunnel was too long, the nest was monitored via burrow scope as part of a control group. We monitored 20 control nests in the same area and observed no significant difference in fledging success between control nests and nests with tagged birds, nor evident behavioural effects. However, this is a coarse metric that may not capture the full range of potential tag impacts (Chivers et al., 2016) as GPS deployment did not impact the breeding success of sampled birds compared to the control group (average reproductive success (n of chicks/n of laid eggs) of the 31 nest where at one bird was tagged = 0.83; average reproductive success of 20 control nests = 0.78).

### Data processing

The study period, followed a warming event in 2014–2015, and conditions varied annually with a strong El Niño event in 2015–2016, a gradual change to weak La Niña conditions in 2016–2017 and 2017–2018, and returning to weak El Niño in 2018-2019, which may influence seasonal distribution of the species (Soldatini et al., 2019). Here, the analysis goal was to identify priority sites for this shearwater population irrespective of annual variation, and as current guidelines for Key Biodiversity Area site identification (a standardized important site identification program similar to IBAs) suggest including at least three years of distribution data, the data were pooled all together (KBA Standards Appeals Committee, 2020).

Tracks with an irregular sampling frequency (i.e., containing time-gaps of 15 min to 1 hr) were selected. A continuous-time correlated random walk model, implemented via the Crawl package (Johnson & London, 2018; Johnson et al., 2008), was used to interpolate location points of selected tracks at a regular interval (1 hour) while the birds were at sea. Additionally, as the BVSH is a burrow-nesting species, tracking locations from when the birds were on nests were missing due to a lack of satellite reception. Therefore, we manually added location estimates for the burrows after confirming birds were actually on nests, based on regular nightly visits, to facilitate the model used for interpolating locations. Locations on land were removed before running subsequent analyses.

All analyses were performed in R 3.5.1 (R Development Core, 2018). The significance level for statistical tests was set at $\alpha = 0.05$ for all the analyses unless otherwise stated.

***Identification of marine Important Bird and Biodiversity Areas***

The approach applied was developed by BirdLife International which aims to identify important at-sea areas – based on tracking data - used by a threshold number of individuals, meaning a representative percentage of the population studied. Sites identified in this way can then be assessed against the global IBA criteria (Beal et al., 2021; Lascelles et al., 2016). This approach is based on three steps: (1) the identification of core use areas for each individual based on KDE, (2) the assessment of population-level representativeness of the tracked sample, and (3) extrapolation to the population level and delineation of areas meeting a threshold of importance (Beal et al., 2021; Lascelles et al., 2016). Utilization distributions (UD; i.e., spatial probability distributions) were estimated for every bird and the 50% isopleth of the UD was defined as the core use area. First Passage Time analysis was used to identify when birds performed area-restricted search behavior (Suryan et al., 2006; Weimerskirch et al., 2007) to ultimately determine the scale of the interaction with the environment. The median scale of area-restricted search identified by the analysis was 17 km, which was used as the smoothing factor for KDE (Lascelles et al. 2016). The representativeness of the tracked sample for the distribution of wider population was then quantified (Lascelles et al., 2016) using the repAssess function from the package track2KBA (Beal et al., 2021). This approach works by averaging a sample of individual UDs into a pooled UD and outlining a desired isopleth quantile (e.g., 50%), then calculating the percentage of out-sample locations falling within this pooled UD (referred to as the 'inclusion rate'). The degree to which the tracked sample is representative of the space used by the whole population is calculated by fitting a nonlinear least squares regression between sample size and inclusion rate and calculating the proximity to the asymptote. Depending on the level of representativeness of the sample, sites used by a threshold percentage of the population were delineated (Beal et al., 2021). Specifically, samples that are ≥90%, 80-89%, 70-79%, and <70% representative set the threshold for delineating a site as important for the local source population at 10%, 12.5%, 25%, and 50%, respectively. KDE was based on a grid of 500 cells (0.0125° per cell) and final sites were assessed against global IBA criteria (Donald et al., 2018).

***Identification of the foraging areas***

To analyze the area likely exploited for foraging, potential foraging events were identified using the Expectation-Maximization binary Clustering (EMbC) technique following Garriga et al. (2016b) with the 'EMbC' R package (Garriga et al., 2016a). This method clusters GPS locations based on speed (i.e., the displacement divided by the time between GPS locations) and turning angles (i.e., the net change in direction over three sequential GPS locations), identifying four main behavior-states. Data were classified using speed and turning angle and then automatically assigned to different clusters: low speeds and high turns (LH), which can be interpreted as intensive searching, high speeds and high turns (HH) as extensive searching, high speeds and low turns (HL) as transiting or relocation, and low speeds and low turns (LL) as resting. Secondly, KDE was performed on these potential foraging locations used to determine the "core foraging areas" for the population, defined as the 25% isopleth area. The EMbC results were validated by calculating the percentage of actual dives recorded from the pressure sensor data, which occurred in the foraging areas clustered as foraging activities (i.e., LH and HH clusters). More dives were expected to occur in areas of high foraging activity than areas classified for the other two EMbC categories such as resting (LL) and fast commuting plight (HL).

***Overlap analysis***

To assess the magnitude of variation within the breeding period and during the study period the percentage of spatial overlap was calculated between foraging areas used during incubation and chick rearing periods as well as among different years. Afterwards the polygons were pooled as per the KBA guidelines. The overlap of the final polygons obtained for the marine IBA analysis and the core foraging areas via the EMbC analysis were overlapped with the polygons of the existing IBA, no-take zones, MPA network, and important marine mammals areas (Arriaga-Cabrera et al., 2009) using 'rgeos' Package for R.

# 3. Results

Fifty-seven individual Black-vented Shearwaters (BVSHs) were tracked during total of 96 foraging trips from Natividad Island (Figure 2) whose characteristics are reported in Table 1. During the breeding period, the birds distributed along the coast of the Baja California Peninsula, ranging from the coastal waters of Vizcaino Bay and Ulloa Gulf to the deeper continental shelf-break waters centered in the Natividad Island area. Tracked birds ranged both northwards and southwards (Vizcaino Bay and Ulloa Gulf respectively, Figure 2), traveling a median 217.96 km (range: 4.32 km – 1265.15 km) from the colony, spending on average 3 d 19.6 h at sea per trip (range: 8 h – 468 h).

***Identification of the marine IBAs***

Our tracking sample was estimated to be 84.7% representative of the sampled population during the breeding period, which facilitated scaling up to the population level. Given this level of representativeness, an area used by 12.5% or more of the colony population was identified, which was then assessed against global marine IBA criteria (Figure 3a and b). The identified area is located around Natividad Island and was estimated to be used by approximately 30,000 individuals (Figure 3a), which amounts to nearly 50% of the global population of BVSH. This potential marine IBA covers an area of 326 km$^2$ and encompasses waters with a bathymetric range between 0 and 198 m (39.90 m average depth). The potential marine IBA identified here overlaps by 96.8% with the existing island buffer zone IBA, and it is almost wholly contained (89.9%) within the priority region for marine biodiversity, according to Arriaga et al. (2009) (Table 2). 20% of this potential marine IBA area overlaps with the Pacific Islands Biosphere Reserve and 57% with the El Vizcaino Biosphere Reserve, totalling 77% of the potential marine IBA falling within in MPAs (Table 2).

### *Identification of the foraging areas*

Areas derived from GPS locations identified as potential foraging areas encompassed 98% of independently recorded dive locations, suggesting accurate classification. Core foraging areas used during the incubation period covered a total area of 3366 $km^2$, which were partially included (overlap of 50%) into the wider foraging area used during the chick-rearing period 8292 $km^2$. Foraging areas used in each year were on average 23% (min 13.7%, max 35%) encompassed by the 4-year pooled foraging area distribution.

The core foraging areas identified from the 4-year pooled distribution were concentrated around Natividad Island towards Punta Eugenia with three spots along the central coast of El Vizcaino Bay and two south of the colony, on the edge of the continental slope (200 m isobath) and in shallower waters (<200 m depth) along the coast of the Gulf of Ulloa, close to the mouth of the San Ignacio Lagoon (Figure 4). Taken together, the five core foraging areas cover a total area of 713.2 $km^2$ with depth ranges between 45 m and 74 m (54.83 m median depth) for the three northern polygons, between 0 and 131 m (45.30 m average depth) for the central one around Natividad Island, and between 5 and 58 m (30.58 m average depth) for the southern area. The core foraging area close to Natividad Island overlaps and exceeds the current IBA MX098 site. In contrast, the spatial overlap with the priority region for marine biodiversity (Arriaga-Cabrera et al., 2009) is 91% for the core foraging area close to Natividad Island and 0% for the other four core foraging areas. The overlap of the core foraging areas with the MPA Pacific Islands Biosphere Reserve is 30% for the core foraging area close to Natividad Island and 0% for the other four core foraging areas. The overlap with the El Vizcaino Biosphere Reserve of the two southern core foraging areas sums to 80%, with the northern three core foraging areas not overlapping the reserve. The core foraging area close to Natividad Island marginally exceeds the potential marine IBA with an overlap of 97% (Table 2).

The areas resulting from a spatial merge if the potential mIBA, together with the foraging areas identified, indicate where special attention for the conservation of the BVSH is needed (Figure 5).

# 4. Discussion

The results of this study show that Black-vented Shearwaters (BVSHs) exploit the rich waters of the California shelf break and the upwelling zone of the California Current System. Despite traveling a maximum distance of 1759 km from the colony, tracked birds never strayed further than 140 km from the coastline, remaining largely in continental shelf-break waters between Natividad Island and Punta Eugenia. This distribution can be explained by the fact that the seabed topography promotes upwelling in this area, driving prey to surface waters, which the shearwaters likely take advantage of for foraging (Becker & Beissinger, 2003; Cairns & Schneider, 1990). The results obtained here reinforce the need for conservation of the BVSH to focus on the core use areas of the species.

Some other *Puffinus* shearwater species with colonies concentrated in a few islands, such as Balearic, Hutton's, Heinroth's and Rapa shearwaters, *P. mauretanicus, P. huttoni, P. heinrothi,* and *P. myrtae*, are vulnerable to several threats both in their colonies and at-sea (Bennet et al., 2019; Harrison, 2014). Hence they are recognized within a number of conservation policies (BirdLife International, 2021). Similarly, the BVSH is largely concentrated at a single main breeding colony (Albores-Barajas et al., 2018) and has a rather restricted range within nearby coastal habitats of the southern California Current System. In addition, the conservation status of the species (Birdlife International, 2016) calls for the implementation of more focused measures, similar to other cases of smaller populations of short-ranging shearwaters, like protecting the core use areas during breeding.

The two methods for estimating population-level spatial distributions applied in this study revealed different areas of importance for BVSHs. The approach for marine IBA identification revealed a globally important area used by a significant proportion of the breeding population of Natividad Island. These areas are likely used for short foraging trips (Figure 4) as well as general purposes such as rafting before landing on the colony or preening before heading to foraging areas, as observed in other shearwater species (Warham, 1996). The complementarity of the approaches highlights that while the method for marine IBA identification provided specific information on general core areas, further identification of five likely core foraging areas is possible through the more specific behavioral approach of EMbC (Garriga et al., 2016b). The focal use of those areas for foraging was validated using the diving information from GPS devices equipped with depth recorders. Pooling tracking data from incubation and chick-rearing across 4 years allowed delineating the wider area used by the species, including foraging areas used in different seasons as well under different oceanic conditions. Thus, the identified area surrounding the island should be proposed as a global marine IBA as meeting global IBA thresholds of importance. Furthermore the other five core foraging areas identified, should receive special attention during breeding period for the conservation of the BVSH.

Tracking data has improved our ability to accurately estimate the at-sea distributions of seabirds, leading to their increasing use in informing MPA design (e.g. (Davies et al., 2021a; Davies et al., 2021b). For example, MPAs based on at-sea observation had originally been designed to protect the species' foraging areas of the Hutton's shearwater. After more detailed GPS-tracking-based studies, however, the MPAs were deemed insufficient (Bennet et al., 2019). Similarly, in the case of the Scopoli's shearwater, *Calonectris diomedea*, GPS-derived distributions showed little overlap with a previously designated conservation area in Tunisian waters, causing the suggestion for boundary extensions of the marine conservation area (Grémillet et al., 2014). Existing MPAs were also found to only encompass 50% of the core areas used by Black-legged kittiwakes, *Rissa tridactyla*, in the English Channel, and by Balearic shearwater in the northwestern Mediterranean; suggesting an enhanced design of protected areas with detailed information on at-sea distributions (Meier et al., 2015; Ponchon et al., 2017). In this study, while parts of the at-sea distribution of BVSHs during the breeding period encompasses the boundaries of two of the largest MPAs in Mexico (El Vizcaino Biosphere Reserve and Pacific Islands Biosphere Reserve), both the important areas identified, and the entire species range, extend beyond the extent of existing MPAs. Critically, the marine portion of the existing IBA MX098 (a buffer area around Natividad Island) is smaller than the globally important and core foraging areas identified through our tracking analyses.

Through recognition of important conservation areas, the data from this study serves to guide conservation and management efforts for BVSHs in the California Current System (CCS), where the preservation of top predator populations remains a vital management priority (Halpern et al., 2009). Specifically, our study can proactively support the improvement of MPA design in the northwest marine region of Mexico, where the development of a management plan for the MPAs in the study area is still lacking. Our results also indicate that an extension of the existing marine

IBA could better reflect some of the most critical at-sea areas used by the shearwater population on Natividad Island. Given the presence of recognised threats to other shearwater species, such as fisheries bycatch, (Dias et al., 2019), and that Mexican and foreign commercial fleets target similar prey items in the area (mainly during the pre-breeding and incubation period (February to March, https://globalfishingwatch.org/map/) with less activity during the spring and chick-rearing period (April to July)), the specific areas identified via the mIBA and EMbC approaches should be further considered for protected area status in the future. Such protected areas should be designed and categorised accordingly, e.g., as a category IV MPA according to IUCN (Day et al., 2019), so any activities known to impact species can be appropriately mitigated. For example, within the two already recognized MPAs, specific restrictions on fisheries operations, such as the use of bycatch mitigation measures in long-line and purse-seine fisheries (Carle et al., 2019), may help avoid potential threats to seabirds in the priority conservation areas identified herein (Da Rocha et al., 2021).

Ultimately, given that none of the current MPAs in Mexican waters were designed based on high-resolution at-sea seabird distribution data, our approach outlines a solution that can be applied to other species and in new areas where further designation or re-design of MPAs may be required. Appropriately designed MPAs that can mitigate site-scale impacts will be critical to support species as broader impacts of climate change are still to be fully understood (Chape et al., 2008). Future studies should now focus on investigating and quantifying the threats occurring in the core use and core foraging areas. This knowledge would provide enhanced understanding of the efficacy of conservation measures needed to develop an action plan that can support populations of BVSH and other biodiversity into the future.

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**Tables and Figures**

**Table 1**. Summary table showing the general parameters calculated on complete trips of Black-vented shearwater during the breeding period over four seasons.

| Year | No. Tracked birds (incub-chick-rearing) | No. Trips (incub-chick-rearing) | Median (range) distance convered (km) | Median (range) distance covered (km) in the incubation period | Median (range) distance covered (km) in chick-rearing |
|---|---|---|---|---|---|
| 2016 | 7 (3-4) | 11 (3-8) | 104.66 (8.63 - 921.81) | 701.97 (104.66 - 799.52) | 53.73 (8.63 - 921.81) |
| 2017 | 11 (10-1) | 9 (9-0) | 307.74 (211.66 - 571.65) | 307.74 (211.66 - 571.65) | - |
| 2018 | 17 (0-17) | 34 (0-34) | 196.07 (4.32 - 1202.68) | - | 196.07 (4.32 - 1202.68) |
| 2019 | 21 (6-16) | 42 (5-37) | 189.25 (4.82 - 1265.15) | 878.25 (338.86 - 1265.15) | 174.18 (4.82 - 968.06) |
| Total | 57 | 96 | | | |

**Table 2.** The potential marine IBA (mIBA) covers an area of 326 km$^2$ and overlaps with the existing or proposed areas for conservation in the region (cons polygons). Percentage of overlap of the proposed mIBA are reported in **bold** and the percentage of overlap on the conservation designated polygons with the proposed mIBA are reported in *italics*.

| **Conservation designated polygon** | **Site/polygon name** | **Total area (Km$^2$)** | **mIBA *vs* cons polygons** | **cons polygons *vs* mIBA** |
|---|---|---|---|---|
| Marine priority regions for biodiversity (Arriaga-Cabrera et al., 2009) (no restriction) | Punta Eugenia-Isla Cedros | 3274 | **89.92** | *8.93* |
| Protected Area (marine portion, buffer area only mining restricted) | El Vizcaíno | 10447 | **0.20** | *0.006* |
| Marine Protected Area (no management plan available yet) | Islas del Pacífico de la Península de Baja California | 11612 | **20.3** | *0.6* |
| Pre-proposed IBA (no restriction) | Natividad Island (code MX098) | 47.7 | **14.2** | *96.8* |
| No-take zones (fishing restriction) | Natividad Island fishing cooperative | 4.86 | **1.49** | *100* |

**Table 3.** Overlap percentages of core use areas polygons and total area calculated for each year.

| Year | 2016 | 2017 | 2018 | 2019 | Total (km2) |
|---|---|---|---|---|---|
| 2016 | - | 21.4 | 18.3 | 45.5 | 2757.41 |
| 2017 | 10.5 | - | 22.2 | 13.7 | 5630.88 |
| 2018 | 14.8 | 36.9 | - | 35 | 3407.66 |
| 2019 | 22.8 | 14.1 | 22 | - | 5438.51 |

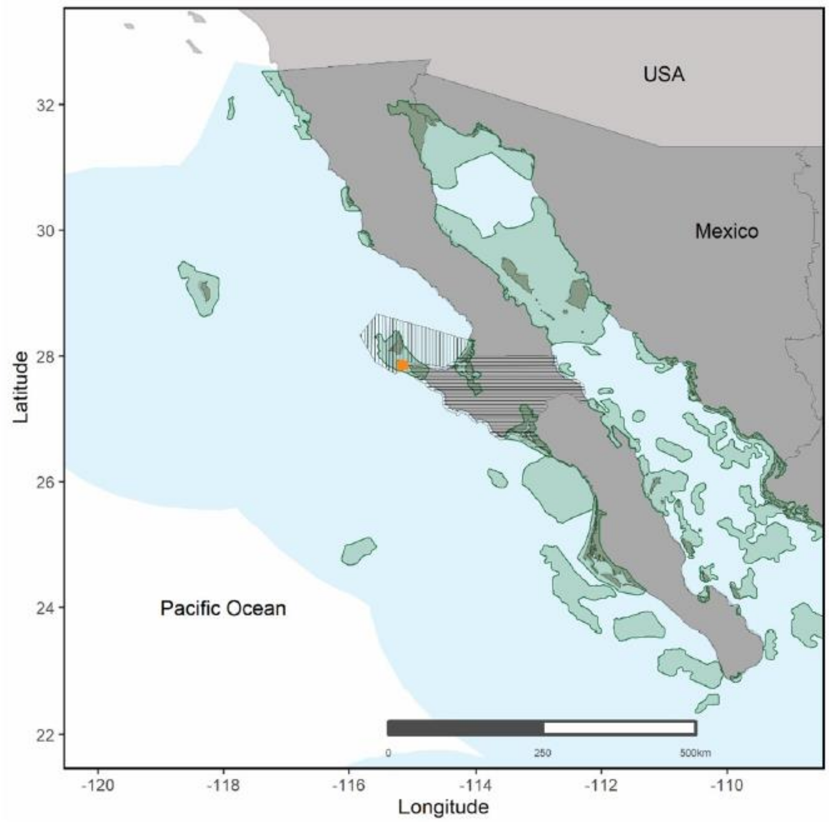


Figure 1 – Map of the study area with Baja California Peninsula in grey, EEZ in light blue, protected areas and their marine extensions in grey dashed lines representing two different MPAs: Pacific Islands Biosphere Reserve (North) and El Vizcaino Biosphere Reserve (South). Green polygons refer to the Marine Priority Areas for Biodiversity after Arriaga and colleagues (2009). Natividad Island is marked by an orange dot on the west coast of the Baja California Peninsula.

130x130mm (220 x 220 DPI)

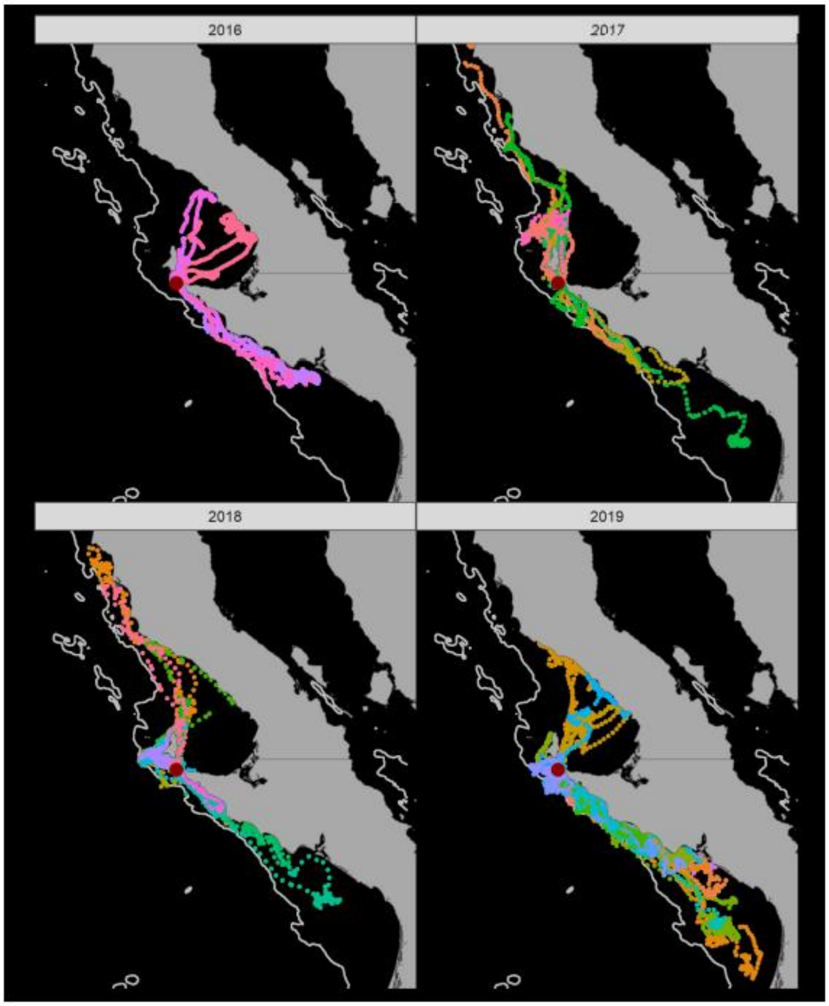


Figure 2 – Overview of breeding season tracking data for Black-vented Shearwaters breeding at Natividad Island (red dot) on the west coast of the Baja California Peninsula, Mexico. Land in grey. Sea in white. Bathymetry is represented by the grey solid line at depth of 1000 m. Colored lines represent the individual tracks of tagged birds in the 4-years.

583x708mm (72 x 72 DPI)

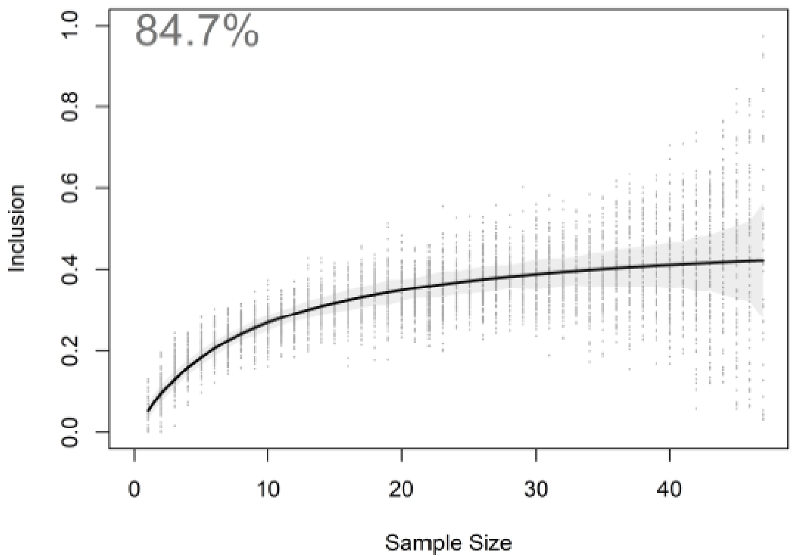


Figure 3 - Assessment for the representativeness of the tracking data to estimate how well the sample of data is deemed to represent the sampled population. We estimated our tracking sample (n = 49 individuals) to be 84.7% representative of the sampled population. See Beal et al. (2021) for further details.

406x330mm (236 x 236 DPI)

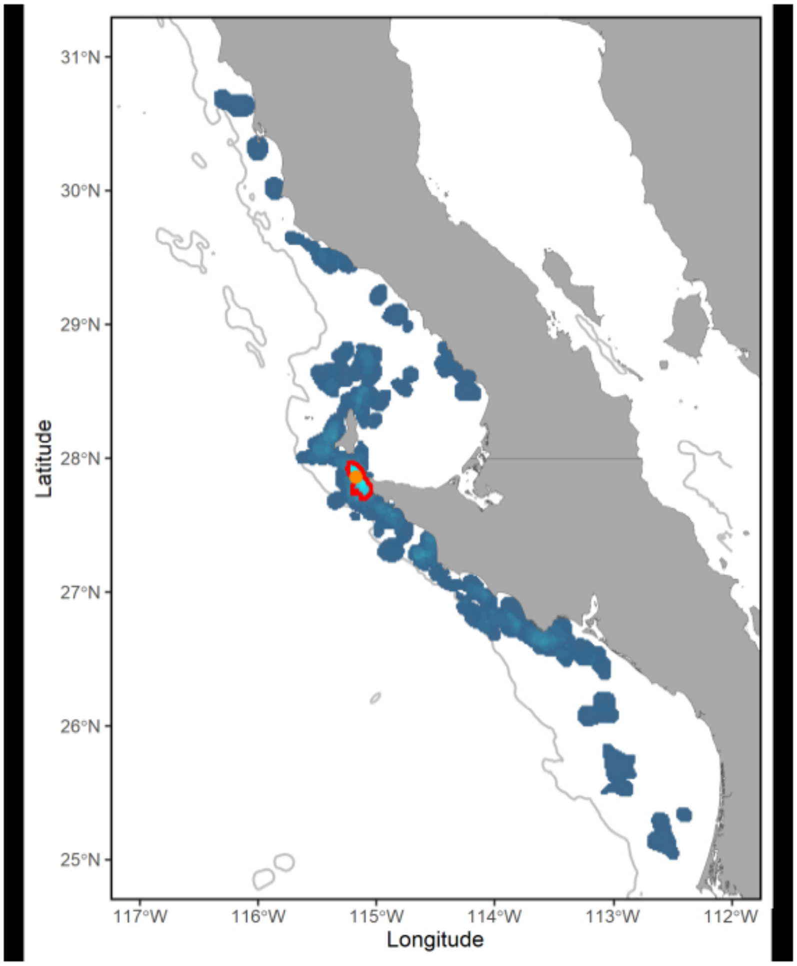


Figure 4a - Overall distribution area of the Black-vented Shearwater determined from tracking data collected over the 2016-2019 breeding seasons. After identifying the core use areas for each individual based on kernel density estimation, we assessed population-level representativeness of the tracked sample on a population estimate of 90,000 individuals (Albores-Barajas, Soldatini et al. 2018) and represented the abundance in blue gradient. Lighter blue represents higher number of birds. Orange dot indicates the colony location. Solid grey lines show the 1000 m isobath. The polygon of areas delimited applying the IBA approach in Lascelles et al. (2016) are shown in red.

583x708mm (72 x 72 DPI)

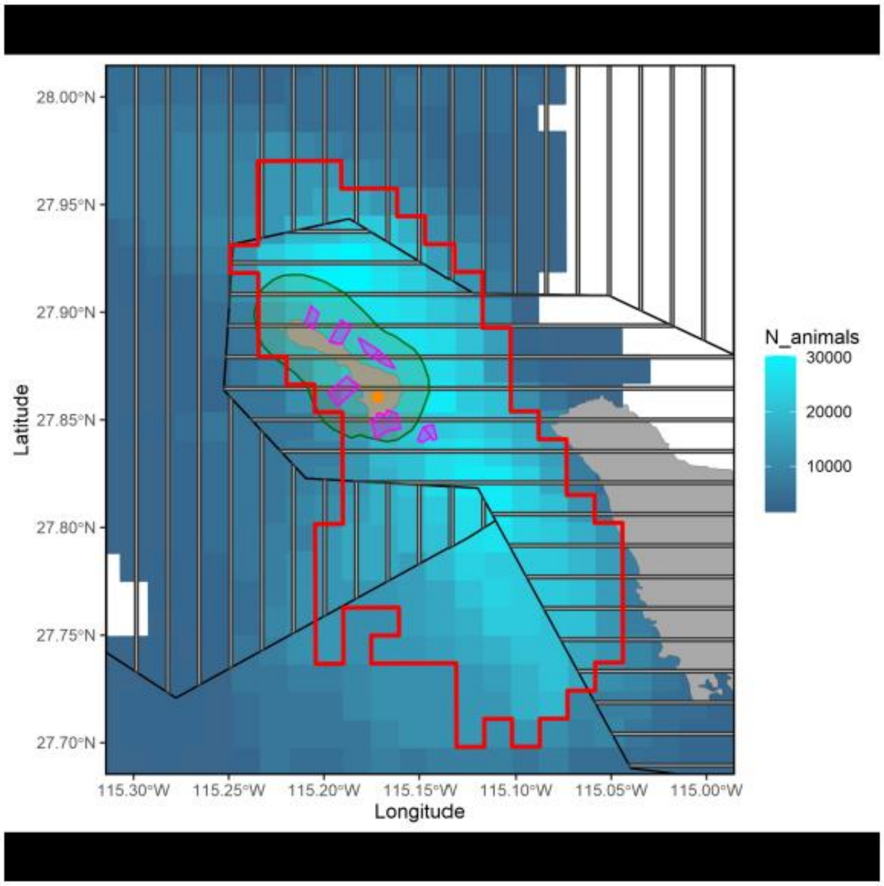


Figure 4b – Potential marine IBA polygon (red) in detail (cell size 0.0125°). Green border refers to the Marine Priority Areas for Biodiversity after Arriaga and colleagues (2009). Dashed lines represent MPAs: Pacific Islands Biosphere Reserve (vertical bars) and El Vizcaino Biosphere Reserve (horizontal bars). The pre-proposed IBA MX098 is reported in light green and the non-fishing areas instituted by local fishing cooperative are reported in pink. Orange dot indicates the colony location for Black-vented Shearwaters.

708x708mm (72 x 72 DPI)

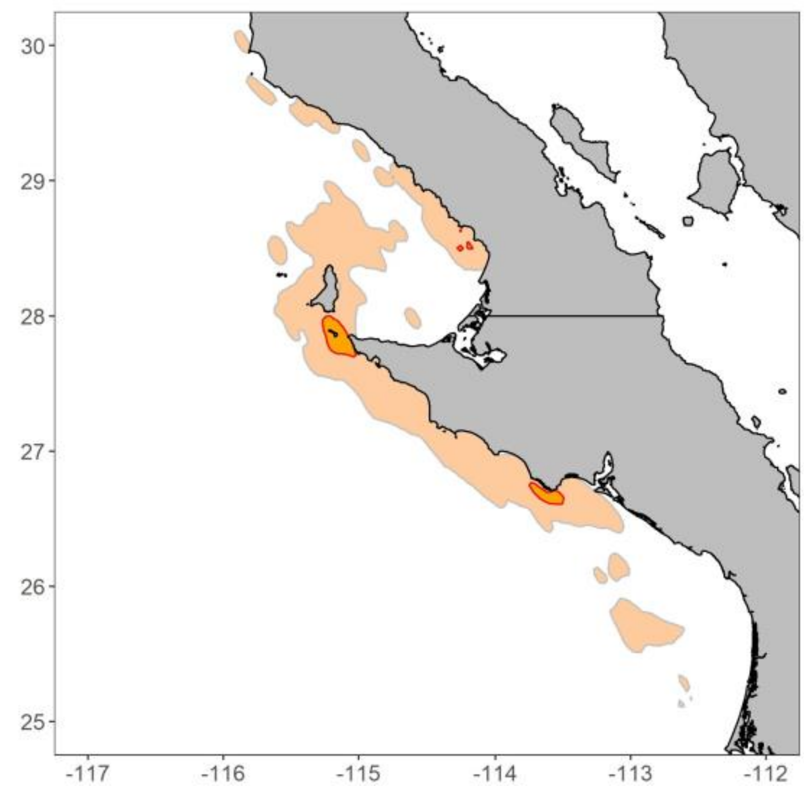


Figure 5 - Foraging areas derived from Expectation-Maximization binary Clustering (EMbC). Broad foraging areas indicated by 75% contour (light orange), core foraging areas indicated by 25% contour (dark orange).

155x175mm (300 x 300 DPI)