A baseline ecological assessment of Ascension Island's shallow-water seamounts as candidate Marine Protected Areas

October 2018

ACKNOWLEDGEMENTS

This project was funded by grants awarded by the European Union's voluntary scheme for Biodiversity and Ecosystem Services in Territories of European overseas (BEST; project 1599), the Darwin Initiative (project DPLUS064), National Geographic Pristine Seas and the UK Foreign and Commonwealth Office and involved more than 20 researchers and marine conservationists from 7 institutions.

The project team are indebted to the captains and crews of the British Antarctic Survey research vessel the RRS James Clark Ross and the MV Extractor (St Helena) without whose seamanship and tireless support this work would not have been possible.

CITATION: Weber, S.B., Richardson, A.R., Broderick, A.C., Brown, J., Campanella, F., Godley, B.J., Howard, F., Hussey, N., Meeuwig, J., Rose, P., Shepherd, M., Thompson, C., van der Kooij, J., Witt, M.J. (2018) *A baseline ecological of Ascension Island's shallow water seamounts as candidate marine protected areas.* Ascension Island Government Conservation & Fisheries Department. 56 pp. Available at …

With funding from

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. EXECUTIVE SUMMARY

1.1 Seamounts are known to provide habitat for a wide range of marine species, often acting as 'oases' of life in expanses of comparatively unproductive deep water 'desert'. However, they remain among the least studied, and least protected, marine ecosystems globally. Recognition of this shortfall has catalysed international efforts to better understand seamount ecology and increase their representation within marine protected area networks.

1.2 Three prominent seamounts are located within the exclusive economic zone (EEZ) of Ascension Island: the Harris-Stewart seamount lies over deep abyssal plain 260 km to the west of Ascension while the Grattan and Young[1] seamounts, collectively known as the 'southern seamounts', are situated adjacent to the mid-Atlantic ridge 280 – 320 km to the southeast (Figure 1.1). Owing to their extreme isolation, these features have remained virtually unexplored and their significance for biodiversity has been largely inferred from work carried out elsewhere.

1.3 Between January 2017 and September 2018 a major programme of research was undertaken to improve the state of knowledge of Ascension Island's seamount ecosystems and provide the scientific evidence to inform their inclusion within a large-scale marine protected area (MPA) that is planned for the Territory. The primary objective of the project was to study aggregations of 'marine megafauna' - large-bodied marine vertebrates such as sharks, predatory fish, seabirds and dolphins – that often associate with seamounts and are potentially threatened by commercial longline fisheries that operate in Ascension Island's EEZ. In particular, the study aimed to map the geographic extent of such aggregations as a basis for proposing biologically-relevant MPA boundaries.

1.4 To achieve this, a novel combination of stereo baited remote underwater video systems (BRUVs), hydroacoustic surveys and vessel-based census methods was used to investigate how the abundance and diversity of marine life changes with distance from the seamount summits. Several types of telemetry tags were also deployed to track the movements of individual animals and assess their residency and ranging behaviour, which is important to evaluate the effectiveness of any future MPA. In total, more than 500 hours of underwater video footage were collected and analysed, 540 km of visual survey transects were completed and 73 sharks, tuna and billfish were fitted with telemetry tags. The project also produced the first high-resolution bathymetric maps of Ascension's seamounts which reveal their varied geomorphology in unprecedented detail.

1.5 As is typical with seamounts, bathymetry had a profound influence on the ecology of the features surveyed. Grattan and Young are shallow seamounts with peaks rising into the sunlit euphotic zone (the top 200 m of the water column) and both supported substantially higher abundance, diversity and biomass of pelagic sharks and fish compared to surrounding deeper water. This 'zone of enrichment' was apparent across the research methods used and extended from 2 – 10 km of the summit depending on the species or taxon. Both seamounts also showed evidence of tidally-induced upwelling and elevated zooplankton biomass in surface waters which may help to explain their importance for higher predators. In contrast, no pronounced

[1] During the course of this project the Ascension Island Government decided to colloquially name this currently unnamed feature after veteran local diver Henry 'Jimmy' Young who was amongst the first to explore Ascension's inshore marine environment and has been a committed advocate for its protection. The name 'Young Seamount' is adopted throughout this report.

biomass plume or elevated species abundances were apparent over the Harris-Stewart seamount, the majority of which lies at depths greater than 500 m.

1.6 **Silky sharks** (*Carcharhinus falciformis*) and **Galapagos sharks** (*Carcharhinus galapagensis*) were the dominant shark species encountered on the southern seamounts and often occurred at high densities within 5 km of the summits of these features. Both species were also highly resident, with many acoustically-tagged individuals remaining within the southern seamounts for periods > 235 days (the duration of the tracking study). Silky sharks showed a stronger tendency to disperse with 50% of individuals exiting the seamounts within 100 days of capture. During periods of residency, tagged sharks were detected over the seamounts for an average of > 15 hours per day and are (very conservatively) estimated to have spent 95% of their time within 50 km of the summits. The majority of tagged individuals remained on the seamount where they were originally captured; however approximately 20 % moved between Grattan and Young, or vice versa, at least once during the study suggesting that these features should be treated as a single system for the purposes of managing shark populations. Neither Galapagos nor silky sharks were detected on Harris-Stewart.

1.7 The high density of sharks found on the southern seamounts is presumably sustained by the sizeable aggregations of **pelagic fishes** that also associate with these features. Rainbow runner (*Elagatis bipinnulata*), yellowfin tuna (*Thunnus albacares*) and wahoo (*Acanthocybium solandri*) were particularly prevalent in BRUV footage and all were significantly more abundant within 2.5 km of the summits of Grattan and Young when compared to pelagic baselines. Atlantic sailfish (*Istiophorus albicans*) were also observed more frequently within 10 km of the summits of these features. Bigeye tuna (*Thunnus obesus*) were rarely detected on BRUVs but were captured and tagged with pop-up satellite archival tags at all of the seamounts studied. Tag retention times in tuna were generally poor; however, both bigeye and yellowfin exhibited some fidelity to the seamounts over periods of up to 210 and 86 days, respectively. Home ranges of bigeye and yellowfin tagged at the southern seamounts were strongly centred on the seamounts themselves indicating a degree of residency over the short to medium term. In contrast, bigeye tagged on the Harris-Stewart Seamount spent much of their time in the north-western quadrant of the EEZ in an area favoured by long-liners targeting this species.

1.8 Several other **oceanic shark** and **billfish** species were also recorded at lower frequency on Ascension's seamounts, often as solitary individuals. These included shortfin mako (*Isurus oxyrinchus*), oceanic whitetip (*Carcharhinus longimanus*), blue shark (*Prionace glauca*) smooth hammerhead (*Sphyrna zygaena*) and Atlantic blue marlin (*Makaira nigricans*). The presence of whale shark (*Rhincodon typus*), bluntnose sixgill shark *(Hexanchus griseus)*, smalltooth sand tiger (*Odontaspis ferox*) and swordfish (*Xiphias gladius*) was also confirmed. Many of these wide-ranging species occur at low density throughout Ascension Island's EEZ and more data are needed to determine whether they congregate disproportionately around seamounts. Blue shark were the most common oceanic shark species encountered on all seamounts, although frequencies were comparable to those recorded in other offshore areas. Unlike resident aggregations of Galapagos and silky sharks, tracking of small numbers of oceanic whitetip, blue shark and swordfish suggests that these oceanic species are transient visitors to Ascension's seamounts and typically move away over periods of days to weeks.

1.9 **Seabirds** were generally present at low densities on all seamounts, although locally higher abundances of sooty terns (*Onychoprion fuscatus*) and Ascension frigate birds (*Fregata aquila*) were apparent within 5 km of the summits of the southern seamounts, particularly on Grattan. Both of these species are known to associate with surface-schooling predatory fish when feeding and may be drawn to seamounts by predictable aggregations of tuna and carangids. None of the seamounts studied appear to be important for **cetaceans** with only a single oceanic dolphin (*Stenella* sp.) observed in the vicinity of Harris-Stewart.

1.10 **Overall, the scientific case for the protection of the southern seamounts is exceptionally strong**. Both Grattan and Young support notable aggregations of pelagic sharks and fish including a number of vulnerable and protected species. Several of these species are also highly resident with restricted home ranges making them amenable to protection within marine reserves. Based on the available data, 'halos' of enhanced biological activity extend to at least 10 km from the summits and potentially as far as 20-30 km. There is also evidence of connectivity between features suggesting that the southern seamounts should be treated as a single system for management purposes, with protection extended to the 80 km corridor that separates them.

1.11 **The ecological significance of the Harris-Stewart seamount is less clear.** No well-defined halo of enhanced pelagic species richness and abundance was apparent and many of the characteristic megafauna found around the southern seamounts were absent. Greater water depth likely explains these differences; however, greater depth also places the summit plateau of Harris-Stewart beyond the detection limits of the research methods used in this study making it impossible to rule out an enrichment effect deeper in the water column.

1.12 Although the results of this project provide the first detailed insight into Ascension Island's seamount ecosystems, further study will inevitably add to our knowledge of these places and allow the extents of their 'biodiversity footprints' to be redrawn. Given the remaining uncertainties, particularly concerning Harris-Stewart, **a precautionary approach would be to adopt a 40 km protection buffer** based on the maximum zone of influence reported in an extensive analysis of fisheries catch around seamounts in the Pacific Ocean [Morato et al. 2010]; (Figure 1.1).

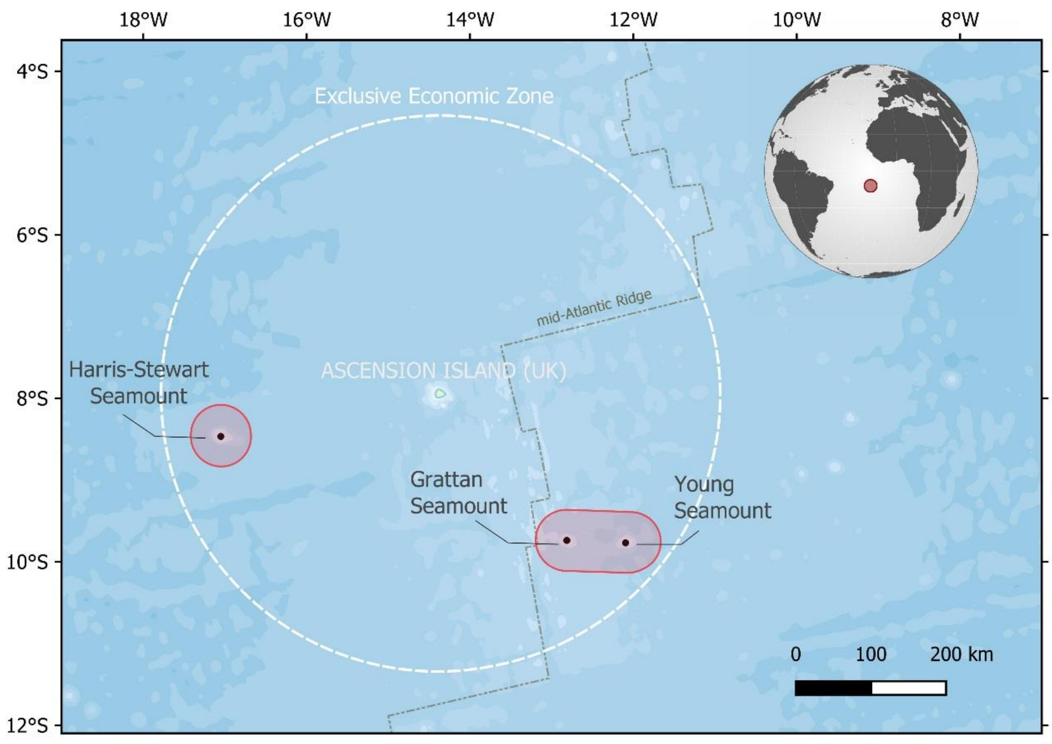


Figure 1.1 Locations of study seamounts with proposed protection buffers highlighted in red.

2.1 SEAMOUNTS: OCEAN OASES

Seamounts are submerged mountains, typically volcanic in origin, that do not reach the surface of the ocean to become islands. More than 30,000 of these features have been identified worldwide covering some 5% of the ocean floor [Kim & Wessel 2011; Yesson et al. 2011]. Like mountains on land, seamounts are very varied environments. However, where their summits rise close enough to the surface they are often associated with hotspots of abundance and diversity of marine life, leading to analogies with 'oases' in comparatively unproductive deep-water 'deserts' [Morato et al 2008; 2010].

Various characteristics of seamounts are thought to contribute to this bio-enriching effect. In addition to providing rare patches of colonisable, rocky habitat in the deep sea, seamounts can interfere with ocean processes in a number of ways that help to stimulate biological productivity in surface waters. Ocean currents forced to pass over and around them can drive localised upwellings that stir up nutrients and create ideal conditions for filter feeders such as corals and sponges that colonise the seabed. Seamounts can also obstruct the daily, vertical migrations of zooplankton, trapping them in shallower waters where they provide food for a multitude of small marine animals. These in turn sustain populations of larger predators, including highly-mobile, pelagic species that are attracted by feeding opportunities and can congregate around seamounts in considerable numbers. The resulting 'halos' of enhanced biological richness can be impressively large, in some cases extending up to 40 km from the summits themselves [Morato et al 2010].

Unsurprisingly, the predictable abundance of marine life found around seamounts has also made them focal points for fisheries in many parts of the world. These have often been managed unsustainably resulting in long-term ecosystem damage [reviewed in Pitcher et al. 2010]. Bottom trawling has perhaps inflicted the most significant and well-documented impacts [Clark et al. 2007; Victorero et al. 2018]. However, fisheries targeting pelagic species have also caused the collapse of large predator populations [Luiz and Edwards 2011]. While these species can be very numerous around seamounts, a combination of extreme isolation and high levels of residency mean they are often quickly depleted and slow to recover, contributing to the 'boom and bust' dynamics that have come to characterise many seamount fisheries [Clark et al. 2007].

Evidence of the biodiversity value and ecological fragility of seamounts has accumulated rapidly in recent years. Nevertheless, they remain among the least studied, and least protected, marine ecosystems globally. According to recent estimates, only 0.4 - 4% of seamounts have been explored for scientific purposes [Kvile et al. 2014] and fewer than 2% are contained within existing protected area networks [Yesson et al. 2011]. Many seamounts lie in remote, high-seas areas which has hampered research and management activities. There is therefore an urgent need to study and prioritise for protection those seamounts that do lie within national jurisdictions and where effective management may be rapidly achievable.

2.2 TOWARDS AN EVIDENCE-BASED ASCENSION ISLAND OCEAN SANCTUARY

This report summarises the findings of an 18-month project that aimed to establish the biodiversity value of three previously unexplored, tropical seamounts located within the exclusive economic zone (EEZ) of Ascension Island, a UK Overseas Territory in the South Atlantic Ocean. The Grattan, Young and Harris-Stewart seamounts lie approximately 260 – 320 km to the west and southeast of Ascension, which is itself more than 2000 km from the nearest continental land mass (Figure 1.1), and this isolation has contributed to a severe lack of knowledge on even the most basic aspects of their ecology.

The primary motivation for the project was to strengthen the evidence base for a large-scale marine protected area that is due to be designated in the Ascension's waters in 2019. The intention to close at least 50% of Ascension Island's EEZ to commercial fishing was announced in 2016 as part of the UK Government's 'Blue Belt' initiative, which aims to promote and enhance the sustainable use of marine resources, both domestically and within the Overseas Territories and Crown Dependencies. As an interim measure, commercial tuna long-lining activities that have operated intermittently in Ascension's waters since the 1980s were also suspended in the southern half of the EEZ while longer-term plans for marine management could be put in place. The location of major seamounts was an important consideration when setting the boundaries of this temporary closed area; however, until now, the significance of these features for marine life has been largely inferred from studies carried out elsewhere.

Between January 2017 and September 2018 a major programme of research was undertaken to address key knowledge gaps relating to Ascension's seamounts, many of which were identified in the Scientific Roadmap for MPA designation launched by the Ascension Island Government following a 2016 review of research priorities[2] (Box 2.1). The project considered three core questions are of central relevance to MPA design and performance:

1. Do Ascension's seamounts support higher abundance and diversity of marine megafauna than surrounding open-ocean habitats?

2. What is the sphere of influence of these features in terms of any zone of enhanced biological activity?

3. How long do individual sharks, tuna and billfish reside around seamounts and how extensive are their movements or onward migrations?

The principle expedition to the seamounts took place between 19th May and 4th June 2017 and involved two research vessels (Figure 2.1) and more than 20 scientists from six institutions. Scoping and follow-up visits were also carried out during offshore fishery patrols in February 2017 and February 2018. Several complementary marine survey techniques were used to characterise seamount habitats and their associated pelagic megafauna communities.

[2] Available from: http://www.ascension-island.gov.ac/wp-content/uploads/2013/12/Scientific-roadmap-Summary-of-workshop-final.pdf

Box 2.1 Actions in the 2016 Scientific Roadmap addressed by this project:

1.2. Continue tracking of tunas, sharks, billfish and seabirds that are impacted by fisheries, including in inshore waters, to understand residency times and connectivity between different areas in the inshore, and with the seamounts and areas further offshore.

1.3. Identify potential aggregation areas through at-sea abundance surveys (for both marine megafauna and species at lower trophic levels e.g. plankton and flying fish)

1.4. Conduct research on seamounts to understand their importance and role for key pelagic species as well as quantifying their benthic fauna

1.5. Understand the range of influence of key hotspot areas to determine required size of protected area around these sites.

A suite of aquatic telemetry methods was also used to explore how individual pelagic predators use seamounts. A brief description of the methods used and a summary of the main findings are presented in sections 2 – 4 of this report with additional detail included in the technical annexes.

Research activities were primarily focussed on large-bodied, pelagic species as these were identified as being most at risk from commercial long-lining activities that operate in the Ascension Island EEZ. Ascension Island has never licensed commercial trawl or bottom fisheries in its EEZ, and there is currently no offshore mining or prospecting that could impact on benthic (seabed) ecosystems. Nevertheless, the opportunity afforded by the expedition was used to gather preliminary data on the benthic habitats and communities of the seamounts surveyed which will be reported elsewhere. Evidence of marine plastic pollution on these remote peaks was also gathered during the expedition and has been summarised by Barnes et al. 2018.

Figure 2.1. Ascension Island Government's offshore research charter, the MV Extractor (left) and the RRS James Clark Ross (right) during the May 2017 seamounts expedition.

SECTION 3. THE HABITATS

3.1 BATHYMETRY AND GEOMORPHOLOGY

Prior to this project very little hydrographic or scientific mapping had been carried out around Ascension's seamounts meaning information about fundamental habitat characteristics, such as accurate bathymetry and the precise locations of their summits, was generally lacking. To fill this critical knowledge gap, a hull-mounted multibeam echosounder was used to compile seamless, high-resolution (25 m) bathymetric maps extending from the summit of each feature down to the 500m or 1000m isobath (as time allowed), providing the first detailed view of the complex and varied geomorphology of the three seamounts studied (Figure 3.1).

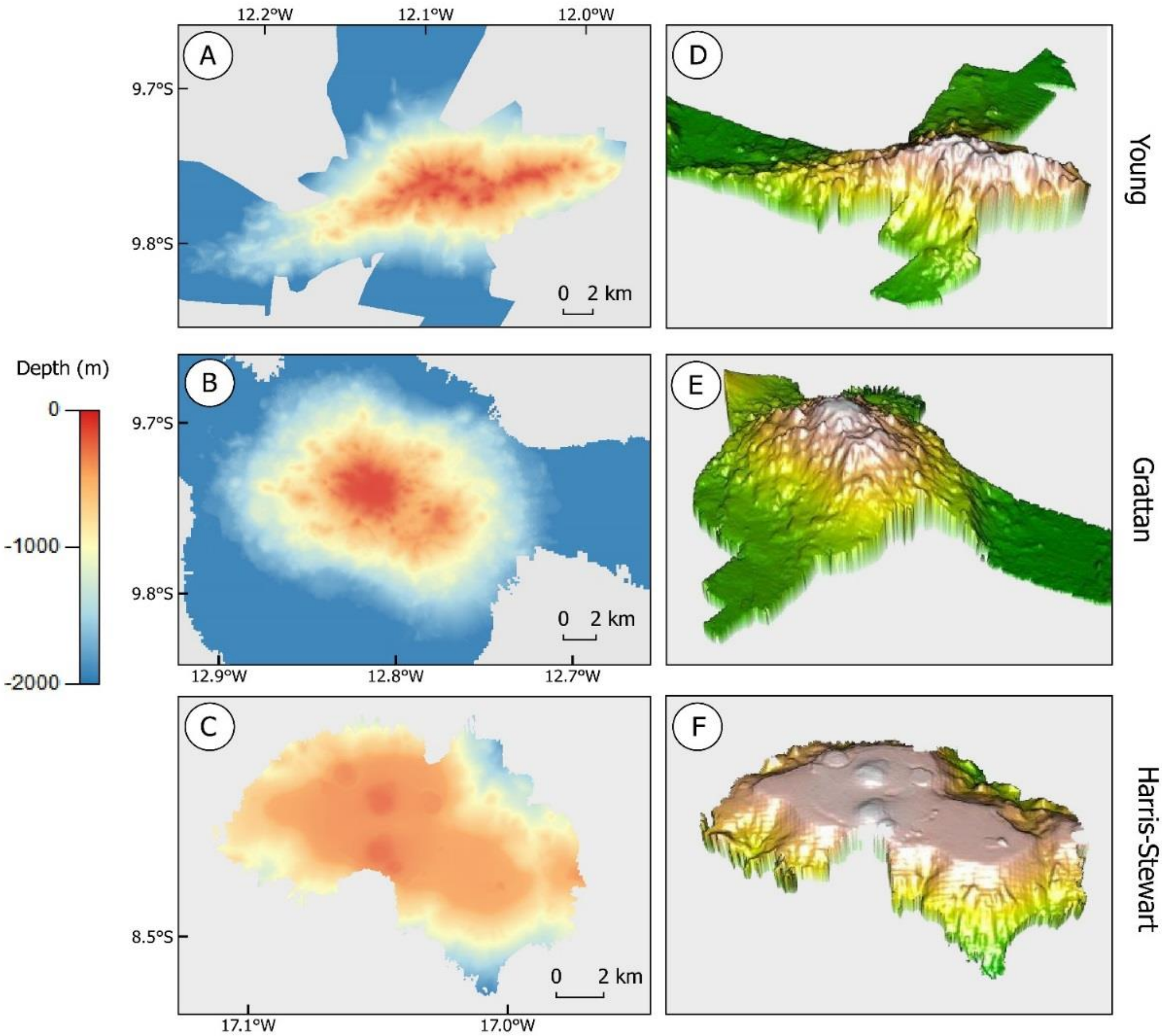


Figure 3.1. High resolution bathymetry (A-C) and three-dimensional topography (D-F) of the Young, Grattan and Harris-Stewart seamounts.

Table 3.1. Physical characteristics of the study seamounts

Seamount	Minimum depth (m)	Area (km^2)		Distance from (km)	
		< 200 m	< 500 m	Ascension Is.	Mid-Atlantic Ridge
Grattan	101	6.1	27.5	256.1	39.3
Young	77.3	3.4	31.3	314.5	117.7
Harris-Stewart	265.5	0	41.2	295.2	396.3

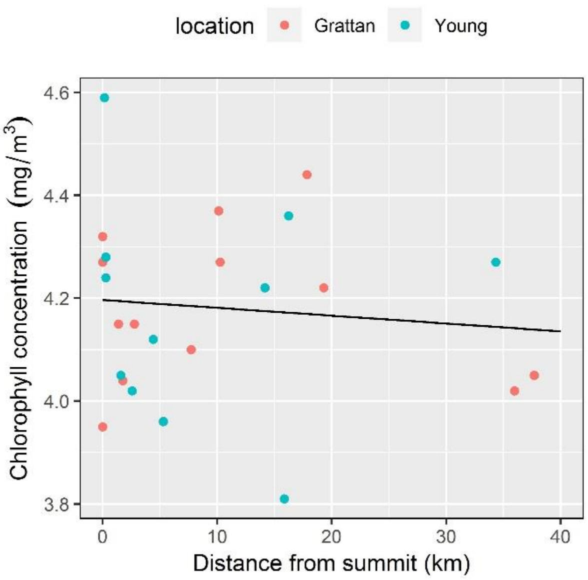
The Grattan and Young seamounts are located on or adjacent to the mid-Atlantic ridge and are both shallow features rising to within 70 - 100 m of the surface (Table 3.1). The Grattan seamount sits on a projection of the mid-Atlantic ridge known as the Grattan Bank and consists of a single, well-defined cone with a flattened summit, plateau at 100-200 m depth measuring approximately 2.5 x 3.0 km. The Young Seamount is located ca. 80 km due east of Grattan and is separated from it by a deep water channel descending to >3000 m depth. The bathymetry of the Young Seamount was particularly poorly known prior to the current study (being based entirely on coarse satellite altimetry data); however, it proved to be the shallowest and most topographically complex of all the features studied, consisting of 10-12 distinct sub-peaks arranged along a ridge, the highest of which reaches within 76m of the surface.

Compared to the Southern Seamounts, The Harris-Stewart seamount represents an altogether different geophysical setting. Rising above an otherwise featureless expanse of abyssal plain 300 km to the west of Ascension and 400 km west of the mid-Atlantic Ridge, Harris-Stewart is the deepest and presumably most ancient of the features studied. It could be more accurately described as a guyot, or 'tablemount', with an expansive summit plateau lying at a depth of approximately 500 m. The plateau is punctuated in places by several distinctive, domed sub-peaks, the southernmost of which constitutes the shallowest point of the seamount at a depth of 265m.

3.2 OCEANOGRAPHY

Interactions between seamounts and oceanographic phenomena such as currents, tides and eddying can have a profound influence on their ecology and on the distribution of marine life around them. Thus, while a detailed analysis of ocean processes was beyond the scope of this project, a preliminary assessment of the biological and physical oceanography of the study seamounts was carried out to provide context and inform further work. Conductivity-temperature-depth (CTD) profilers were used to record temperature, salinity, dissolved oxygen and chlorophyll A concentration (a measure of primary production) in the top 100 m of the water column at varying distances from the seamount summits. In addition, fourteen archival data loggers recording temperature and relative current velocity (tilt) were also deployed at various locations around the summits of the Grattan and Young seamount to generate longer term oceanographic time series (dataloggers were integrated in VR2AR acoustic receivers deployed as part of aquatic telemetry studies; Section 5.2, Figure 5.5).

CTD profiles showed a typical pattern for tropical oceanic waters consisting of a relatively uniform surface mixed layer extending to a mean depth of 53 m (± 13m SD) followed by an abrupt thermocline with a pronounced 'deep chlorophyll maximum' at 85 ± 12 m depth. No gradients in chlorophyll A concentration or in any physical oceanographic parameters were detected in relation to distance from the seamount summits (linear regression, all $p > 0.05$; Figure 3.2). However, time series from data loggers provided evidence of tidally-induced upwelling on both Grattan and Young, with strong 12.4 hour periodicity in temperature and current fields that corresponds with the frequency of the dominant semi-diurnal lunar tide (Figure 3.3; Annex Figure S3.1). Such upwellings can be caused as ocean tides flow over and around seamounts forcing up colder, nutrient-rich water from depth. The tidal signal was strongest at intermediate depths (~ 200 m) for temperature and at specific geographic locations for current strength, most notably on the southernmost and northernmost points of the Grattan summit plateau (G2 and G5, Figure 5.5).



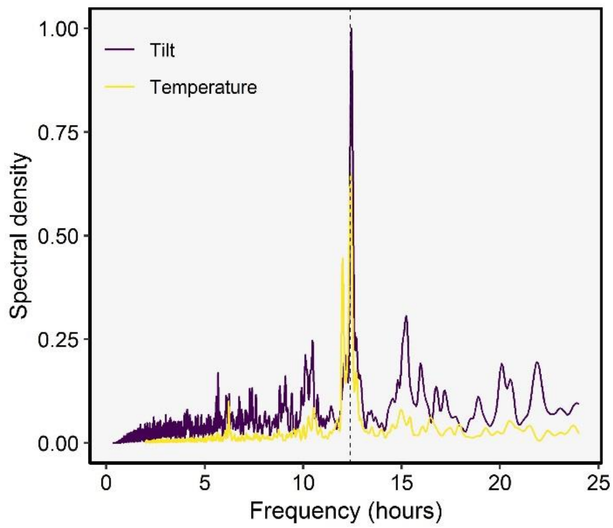


Figure 3.2 Relationship between maximum chlorophyll A concentration in the water column (i.e. deep chlorophyll maximum) and distance from the summits of the Southern Seamounts. Regression line was fitted by linear regression.

Figure 3.3 Density spectrum from fast Fourier transform showing dominant 12.4-hour periodicity in temperature and current strength (tilt) time series recorded by a fixed receiver deployed on the summit of the Grattan seamount. Spectra for all 14 receiver stations are plotted in Annex Figure S3.1.

SECTION 4. THE PELAGIC COMMUNITIES

Several complementary marine survey techniques were used to study the pelagic megafauna communities associated with Ascension's seamounts. These included bioacoustic surveys (to estimate total water column biomass), baited remote underwater video systems (for community composition and relative abundances of sharks and fish) and vessel-based counts of surface-orientated species such as seabirds and cetaceans. Incidental sightings were also recorded wherever they occurred. A description of the techniques and a summary of the main findings are briefly outlined below with more detailed methodology provided in the technical annexes that accompany this report.

In order to establish the significance of Ascension's seamounts as 'biodiversity hotspots', surveys were organised along transects radiating out from the seamount summits in all cardinal directions (i.e. north, east, south, west) to a distance of 20 – 40 km, allowing any gradients in the abundance and diversity of marine life to be detected (Figure 4.1). A limit of 40 km was selected based on the maximum radius of influence reported in an extensive meta-analysis of fisheries data around Pacific seamounts [Morato et al. 2010]. The bulk of the surveys were carried out during the principle scientific expedition in May-June 2017 and thus provide contemporaneous, albeit temporally limited, estimates of how pelagic communities are organised around seamounts.

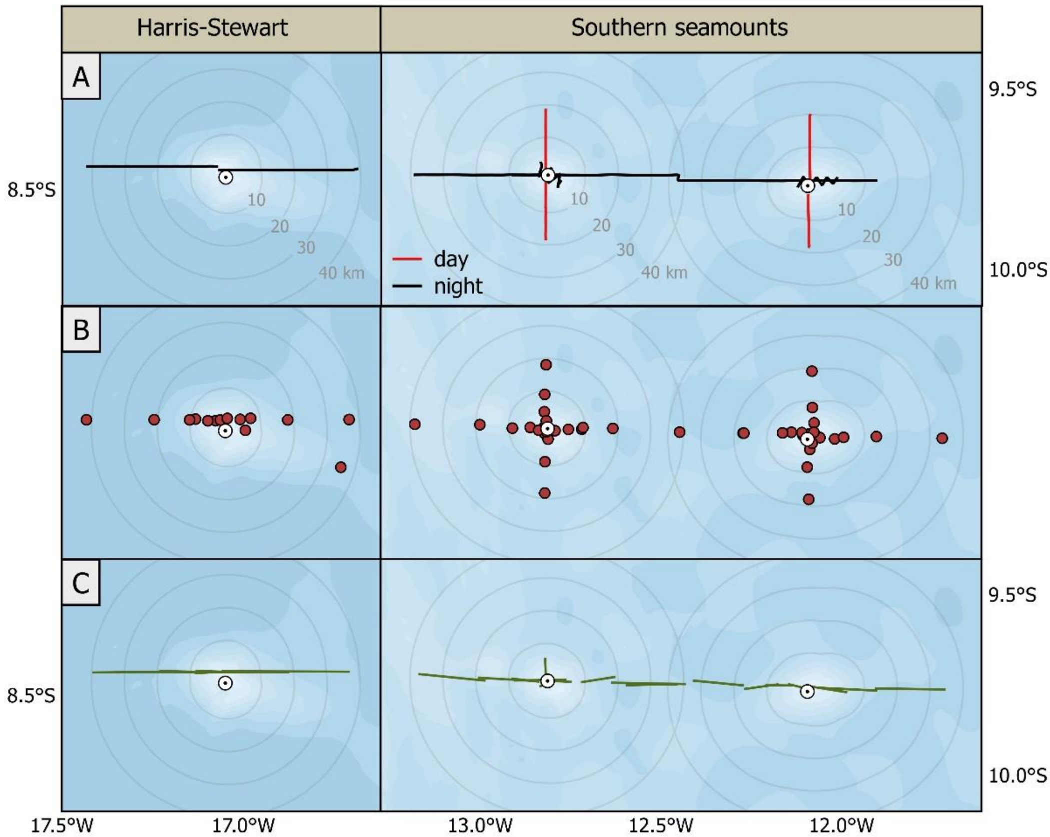


Figure 4.1. Sampling design used for pelagic community surveys of seamounts. A) hydroacoustic survey transects, B) pelagic BRUV deployments and C) vessel-based visual transects for seabirds and cetaceans. Seamount summits and distance buffers in 10km increments are also shown.

4.1 HYDROACOUSTIC SURVEYS

Hydroacoustic surveys use scientific-grade echosounders, or sonar, to measure the distribution and abundance of marine life in the water column. Echosounders transmit sound into the water which is reflected back by any animals that fall within the beam as the ship progresses along its track. Information about these 'echos', including their depth, strength and the position of the animal within the beam is recorded and processed to produce an image called an echogram from which estimates of biomass can be extracted.

For the purposes of this project, acoustic backscatter data was collected using a hull-mounted Simrad EK80 echosounder transmitting at three frequencies (38, 70 and 120 kHz). The survey design at each seamount consisted of two perpendicular transects (20-40 km long) running in the north-south and east-west direction intersecting the peak of the seamount (Figure 4.1). In addition, zig-zag surveys were conducted over the peaks of the southern seamounts to provide better spatial coverage. Due to operational constraints only a single transect could be completed at Harris-Stewart and the timing of the surveys also varied: north-south transects were always carried out during daytime and the remaining data were gathered at night. In total, acoustic surveys provided data on animal abundance over 325 km of transect, from the surface of the ocean to 200m depth (Figure 4.1A). Although it was not possible to identify individual species in the resulting echograms, we were able to discriminate between three broad taxonomic classes - fish, fluid-like zooplankton and gas-bearing zooplankton - based on their sound scattering properties. For each taxa, nautical area scattering coefficient (NASC; an integrated measure of the strength of acoustic backscatter that is related to biomass) was calculated for 500 m distance sampling units spanning the length of each transect and analysed with respect to distance to the nearest seamount.

Significant biomass accumulations were apparent in echograms collected over the Grattan and Young seamounts, with sharp increases in NASC attributable to pelagic fish and fluid-like zooplankton (including copepods and euphausids) detected within 1.5 – 5 km of the summits of both features (Figures 4.2 and 4.3). This trend was apparent in both nocturnal and diurnal surveys for fish on the Grattan seamount and in nocturnal surveys only on Young, probably because daytime transects on the latter did not intersect key areas of the summit ridge.

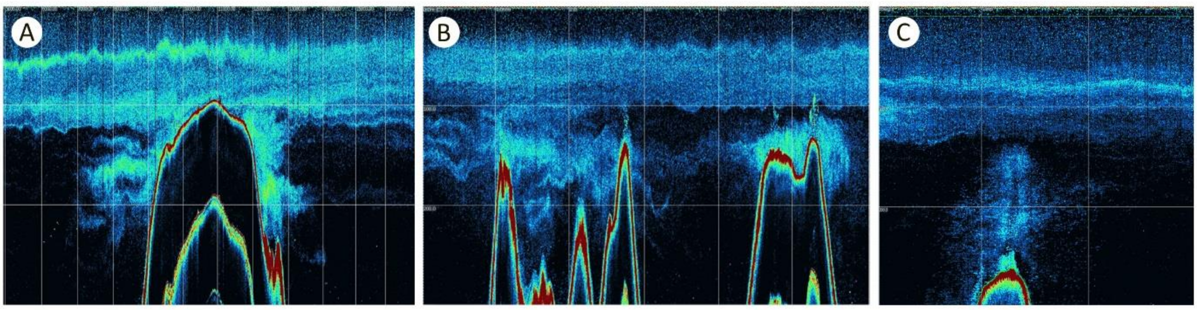


Figure 4.2 Nocturnal echograms showing biomass plumes over the Grattan (A), Young (B) and Harris-Stewart (C) seamounts. Colour intensity represents the strength of the acoustic backscatter in decibels, with the dark red band marking the position of the seabed. The sea surface is located at the top of the image. A 1km horizontal x 100 m vertical grid is overlaid for scale reference.

Upward trends in zooplankton abundance were also only detected at night when many planktonic organisms migrate into the epipelagic zone from deeper in the water column. Over seamounts, these vertical migrants can become trapped during the daytime forming a dense layer close to the seabed that would likely be indistinguishable from the substrate in our acoustic surveys. If we consider nocturnal survey data only, NASC attributable to fish and sharks was 8 times higher within 2.5 km of the summit of the Grattan seamount and twice as

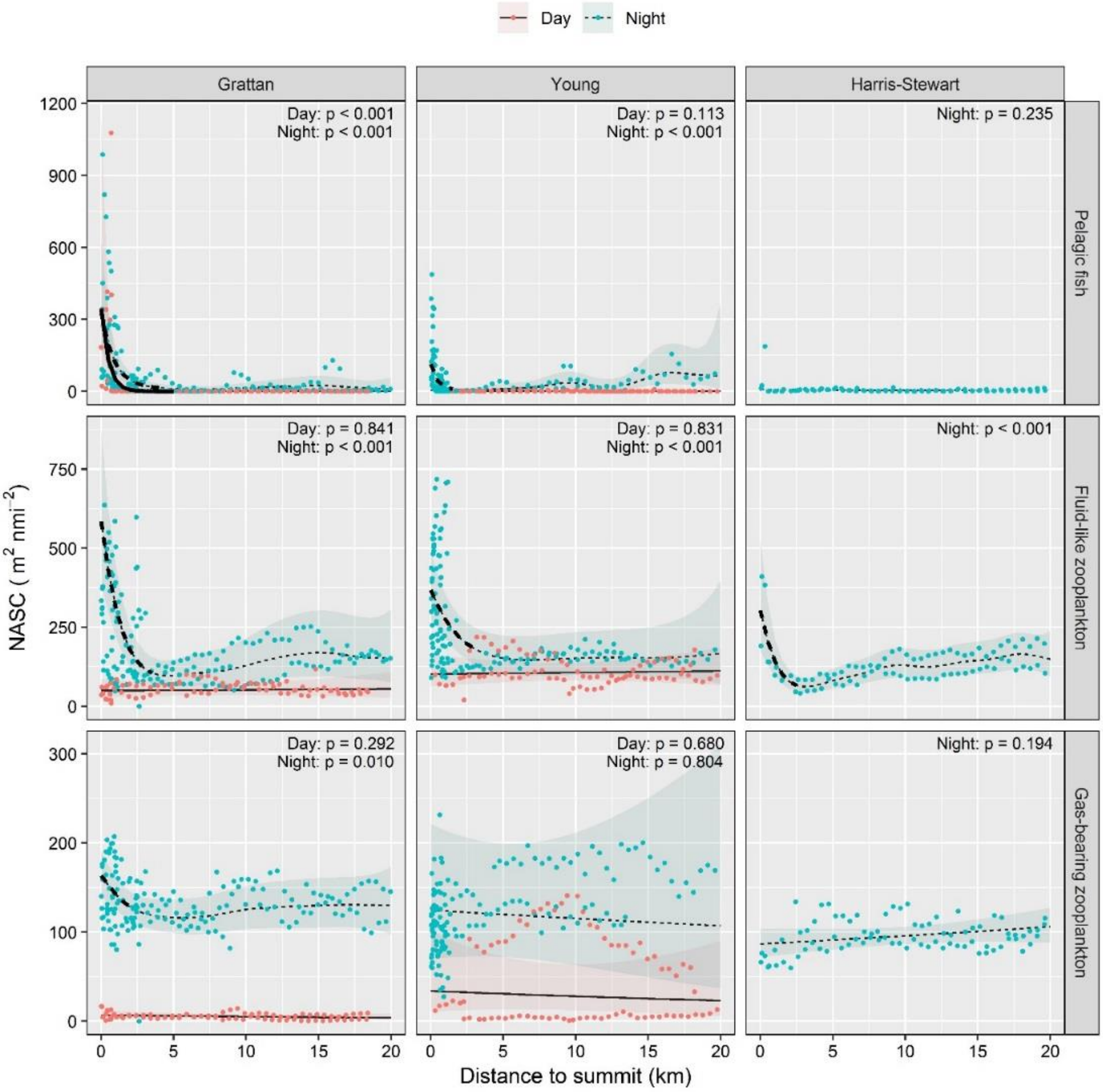


Figure 4.3 Relationship between distance to seamount summits and total epipelagic (0 – 200 m) biomass of three taxonomic groups of marine organisms estimated using hydroacoustic surveys. Data points are the centroids of 500 m elementary distance sampling units used for echo-integration and calculation of nautical area scattering coefficient (NASC), a proxy for biomass. Regression lines and associated 95% confidence envelopes were fitted using thin plate spline regressions with an AR(1) autocorrelation structure. Emboldened sections of each curve represent regions of statistically significant change in NASC according to the approximate first derivatives of the fitted spline. Approximate p-values of the fitted smoothing splines are also shown.

high within 2.5 km of Young when compared to the rest of their respective transects. NASC for fluid-like zooplankton was approximately twice as high within 2.5 km of both features. Fish and sharks therefore constituted a much larger proportion of epipelagic biomass in the vicinity of the Grattan seamount, accounting for 19 % of total nocturnal NASC within 2.5 km of the summit compared to just 5 % at distances of 2.5 – 20 km.

Although hydroacoustic survey data reveal strong upward trends in fish and zooplankton abundance in the vicinity of the southern seamounts, this biomass was not evenly distributed around them. The survey design was neither intended nor well-suited for mapping fine-scale patterns of biomass accumulation; however, clear hotspots of pelagic fish and shark abundance were apparent along the southern rim of the Grattan summit plateau and at the westernmost and easternmost ends of the Young ridge (Figure 4.4) which broadly correspond to activity centres identified through aquatic telemetry (Section 5.2). This patchy distribution probably accounts for the small proportion of total variation in fish and fluid-like zooplankton biomass explained by distance to summit alone (Figure 4.3: deviance explained = 32 – 42%)

Compared to the southern seamounts, hydroacoustic survey coverage over Harris-Stewart was limited and restricted to nocturnal transects only. As with the other seamounts surveyed, fluid-like zooplankton were significantly more abundant within approximately 2.5 km of Harris-Stewart (Figure 4.2) and there was some evidence of a peak in pelagic fish biomass immediately over the summit; however this relationship was driven by a single, highly influential sample that was excluded during model checking (Figure 4.3). Harris-Stewart lies deeper than the 200 m detection limit of the acoustic configuration used in the present study and the lack of high-resolution bathymetry prior to surveys also meant that transects did not exactly intersect the shallowest point of this feature. The possibility of deeper and more localised accumulations of pelagic fish around this feature cannot be ruled out, therefore.

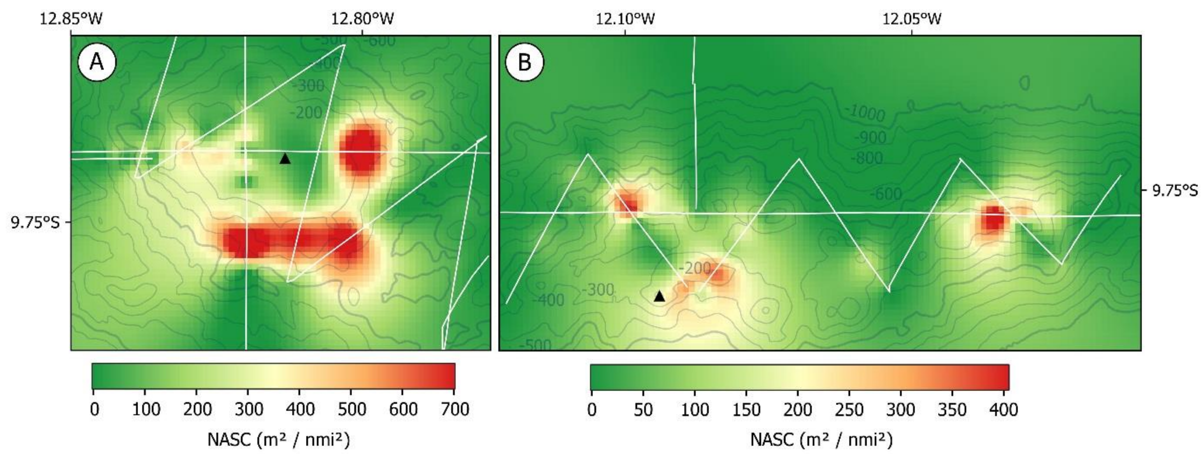


Figure 4.4 Hotspots of pelagic fish and shark abundance over the summits of the A) Grattan and B) Young seamounts derived from hydroacoustic survey data. Heat maps were generated by β-spline interpolation of nautical area scattering coefficient (NASC) for each 500 m elementary distance sampling unit on a 100 x 100 m grid. White lines represent the path of hydroacoustic survey transects and filled triangles mark the shallowest point of each seamount. Note that interpolation combines both nocturnal and diurnal survey data and will be unreliable in areas with no survey coverage meaning the locations of hotspots are approximate only.

4.2 PELAGIC BAITED REMOTE UNDERWATER VIDEO SYSTEMS (BRUVs)

4.2.1 Methods

Pelagic stereo BRUVs consist of drifting, underwater camera assemblies trained on a bait cannister that helps to attract animals that might be in the vicinity. BRUVs were deployed in sets of five rigs suspended at a depth of 10 m and spaced 200 m apart along shorted, floated longlines. Deployments were spaced in an exponential fashion at nominal distances of 0, 10, 20, 40 km from the summit and on the 500m and 1000 m isobaths to account for more abrupt transitions in biological communities expected close to the seamounts themselves (Figure 4.1). Each camera rig gathered continuous video footage over a two-hour period which was then analysed to identify and count all recorded individuals. To avoid double-counting, abundance was estimated as the maximum number of individuals of a given species recorded in a single frame (MaxN). The deployment followed standard practices as outlined in Bouchet et al. 2018.

Analysis of count data from BRUVs was carried out in two stages. To investigate whether abundances of individual species were higher around seamounts than in offshore areas in general we firstly used non-parametric Chi-squared tests (for presence/absence) and Mann-Whitney U tests (for counts) to compare probability of occurrence and MaxN recorded at several distances from the seamount summits with a reference dataset of 57 BRUVs deployed randomly > 50 km from any topographic feature. Only species observed in three or more deployments were considered in the analysis. We also excluded a number of small, widespread pelagic species (e.g. driftfish and flyingfish) and commensal species (pilot fish, remora and sharksuckers). Logistical constraints did not allow for sampling elsewhere in Ascension's EEZ coincidental with the principle seamounts expedition meaning the reference dataset is comprised of deployments made during fisheries patrols in January-February 2017 and 2018. Distance bins for grouping seamount BRUVs were spaced exponentially (0, 2.5, 5, 10, 20, 40 km) to account for greater sampling effort closer to the summit. We also pooled data for the neighbouring Grattan and Young seamounts as patterns in community structure around these features were qualitatively similar. Nevertheless, the number of deployments in distance bins further from the summit was generally too low to give the statistical power needed to detect differences with the reference dataset. As such, and given the exploratory nature of this study, we chose not to systematically correct for the familywise error rate (risk of false positives) in pairwise comparisons for each species as this can further reduce statistical power and inflate the probability of producing false negatives. Where results differed using Bonferroni correction this is highlighted below.

In cases where significant differences were found with pelagic baselines, penalised thin plate spline regression was then used to explicitly model non-linear relationships between abundance and distance to summit. However, as in hydroacoustic surveys, the localised distributions of many species around seamounts meant that distance-only models often provided a relatively poor fit to the data, particularly for species only observed in very close proximity to the summits.

4.2.2 Results

Between 26th Jan 2017 and 31st Jan 2018 a total of 58 BRUVs deployments were made in the vicinity of Ascension's seamounts (Grattan: n = 23; Young: n = 21; Harris-Stewart: n = 13) recording 29 species of pelagic sharks, fish and cetaceans (Annex Table S4.1). Species richness of sharks and pelagic fishes increased significantly within 7 km of the summits of the Grattan and Young seamounts (Figure 4.5). Galapagos sharks, silky sharks, rainbow runner, yellowfin tuna, blue sharks, Atlantic sailfish and wahoo were the most frequently observed species (present in > 10% of deployments) and, with the exception of blue sharks, all were observed more frequently and were more abundant around these features when compared to pelagic baselines (Figures 4.6 – 4.7; Annex Figures S4.1 – S4.3). Galapagos and silky sharks were never observed in offshore reference BRUVs which is consistent with evidence from aquatic telemetry studies (Section 5.2) suggesting that these species are strongly feature-associated. Competition with large resident, aggregations of these species may also explain why blue sharks showed a tendency to be less common close to the southern seamounts than in offshore areas more generally (Figure 4.7).

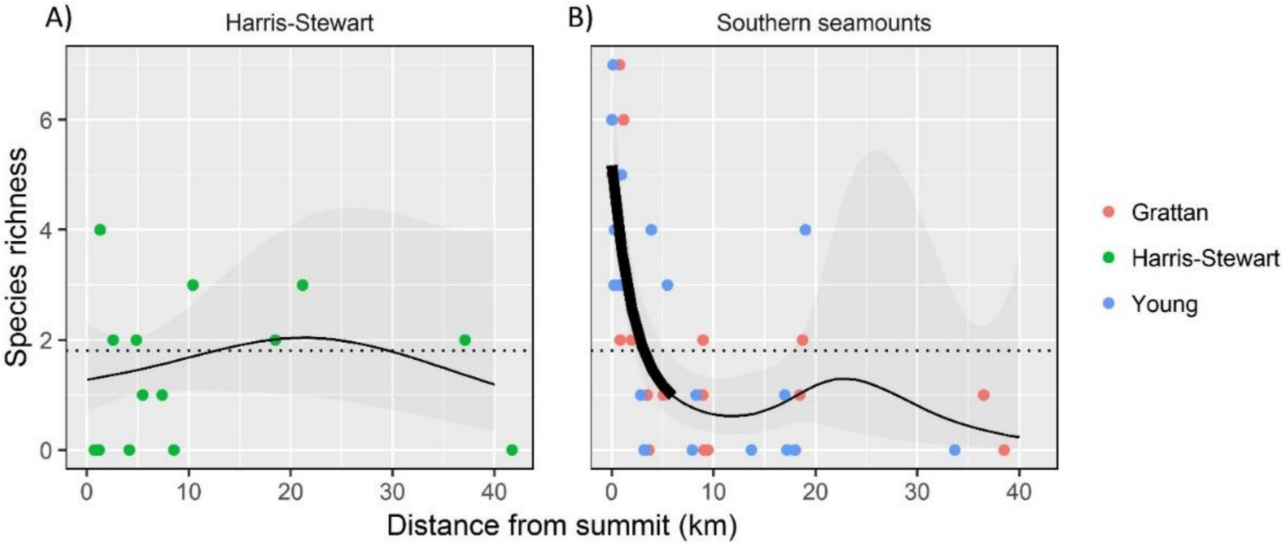


Figure 4.5. Variation in species richness of pelagic fishes and sharks recorded by mid-water BRUVs deployed at varying distances from the summits of A) the Harris-Stewart Seamount, and B) the Grattan and Young seamounts. Species richness is the number of different species observed at least once per deployment. Trend lines and associated 95% confidence intervals (shaded polygons) were fitted using thin plate spline regression. Model comparison favoured a model in which Grattan and Young were clustered compared to one in which they were treated separately ($\Delta AIC_c = 6.0$). Emboldened portions of the curve represent regions of statistically significant change in species richness according to the approximated first derivatives of the fitted spline. The average species richness recorded by 57 pelagic BRUVs deployed in offshore areas > 50 km from any topographic feature are also shown as a baseline for comparison (broken lines).

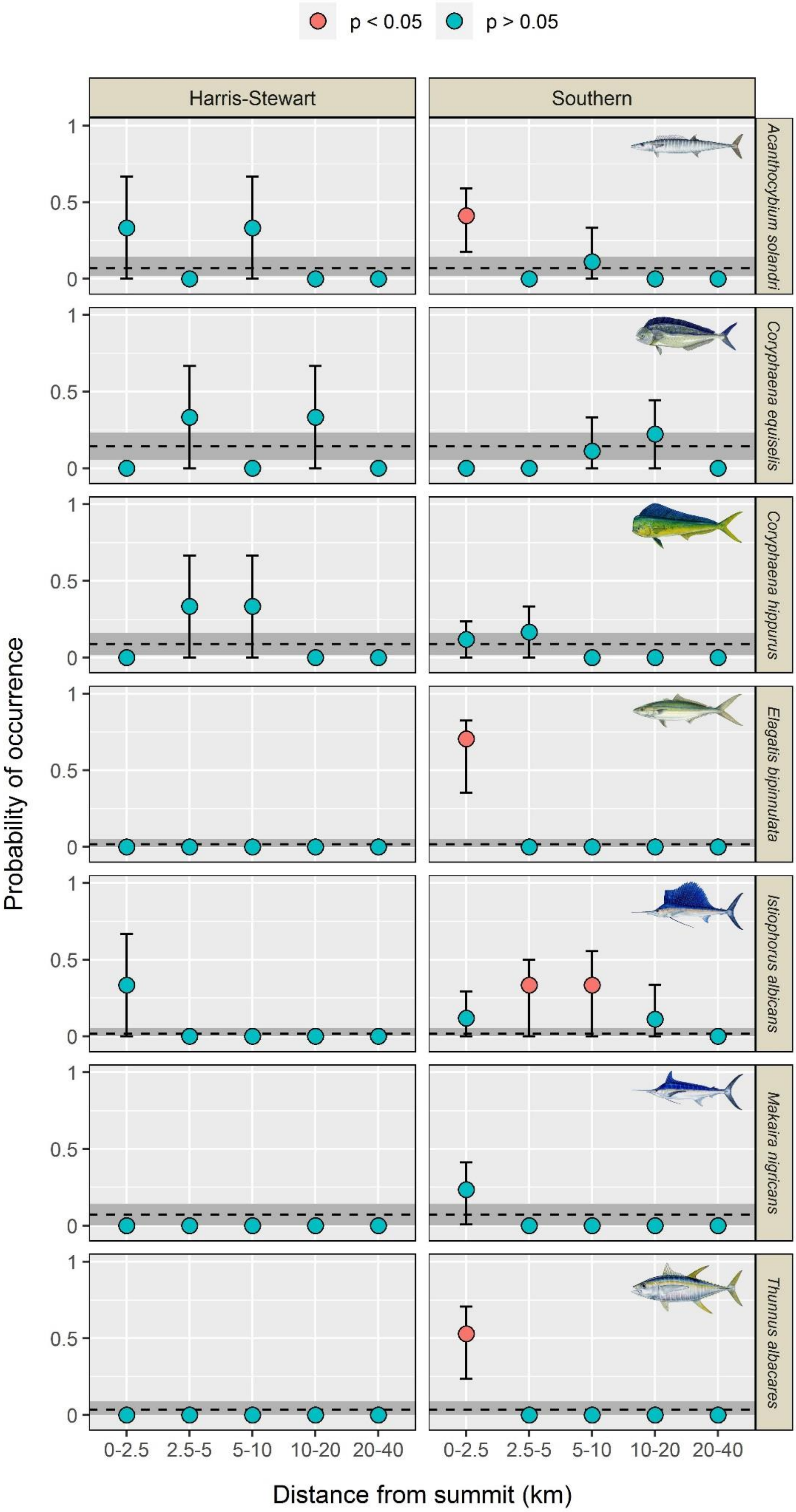


Figure 4.6. Probability of occurrence of large-bodied pelagic fish species in mid-water BRUVs deployed at varying distances from the summits of the Harris-Stewart and Southern Seamounts. Plotting symbols and error bars are the mean occurrence probability and bootstrapped 95% confidence intervals (CI) calculated in exponentially increasing distance bins to reflect greater sampling effort closer to the summit. Points are shaded to according to whether they differ significantly (Chi-squared test, $p < 0.05$) from pelagic baselines derived from 57 BRUVs deployed more than 50 km from any island or seamount at randomly selected sites throughout the Ascension Island EEZ (means and 95% CIs represented by broken lines and shaded polygons, respectively). Fish illustrations © Diane Roam Peebles.

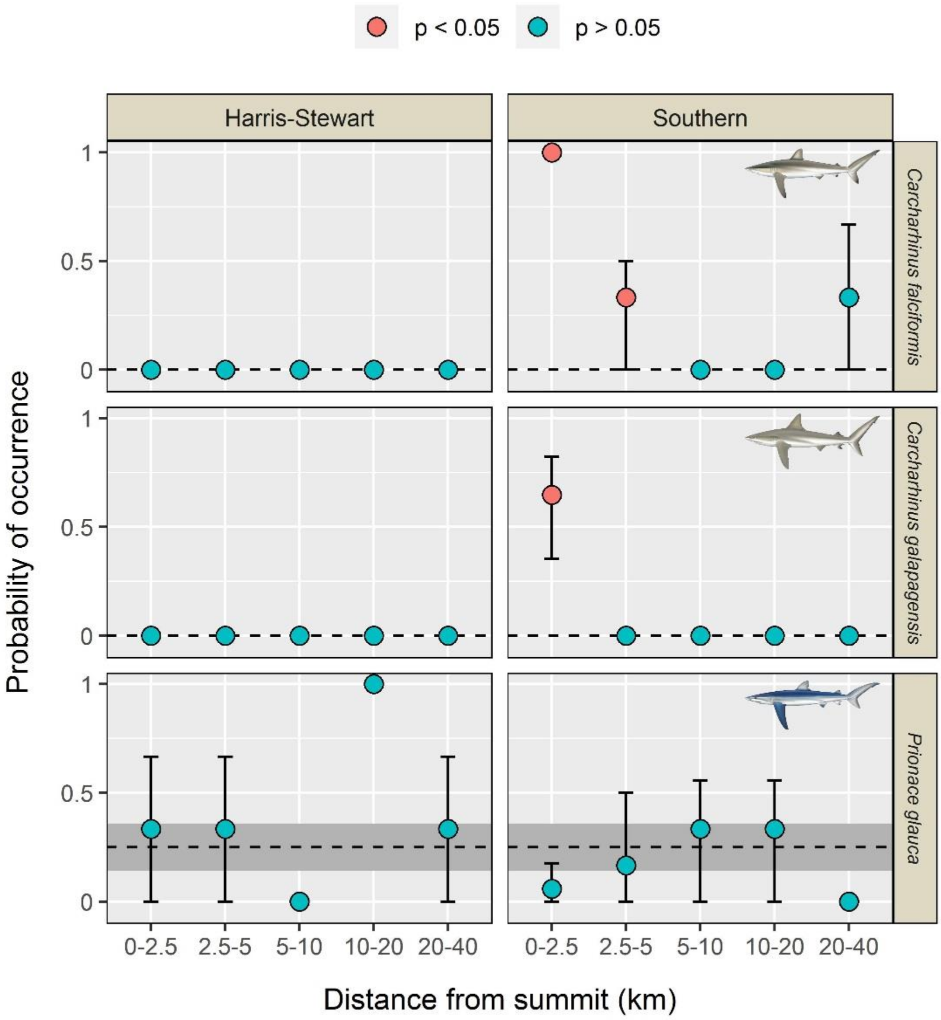


Figure 4.7. Probability of occurrence of pelagic shark species in mid-water BRUVs deployed at varying distances from the summits of the Harris-Stewart and Southern Seamounts. As in Figure 2.2, mean probability of occurrence of each species in each distance bin is compared to baseline values from offshore reference BRUVs deployed throughout the Ascension Island EEZ (mean is broken line and 95% confidence intervals is represented by shaded polygon). Shark illustrations © Marc Dando.

Consistent with the results of the hydroacoustic surveys, species abundances in BRUVs typically increased sharply within 2.5 km of summits of the southern seamounts; however, some variation was apparent. Galapagos sharks, yellowfin tuna and rainbow runner were only observed in BRUVs deployed within 2 km of the Grattan and Young seamounts and had very localised distributions (Annex Figure S4.4). For example, all were essentially absent from the eastern end of the Young summit ridge (Annex Figure S4.4). As such simple distance-abundance relationships for these species were often not statistically significant, despite them being present in high numbers in some areas (Figure 4.8). By comparison, silky sharks appeared to be more widely distributed around the seamounts, with evidence of increasing abundance as far as 5-7 km from the summits (Figures 4.7 and 4.8). The most distant detection of this species occurred approximately equidistant between the Grattan and Young seamounts (~ 36.5 km from summit; Annex figure), which is consistent with evidence of connectivity between these features from telemetry studies (see section 5.2). Atlantic sailfish were also encountered over a wide range of distances from the seamounts (0 – 19 km) and were observed more frequently over the 2.5 – 10 km range than in pelagic baseline datasets (Figure 4.6). These differences were not statistically significant when applying Bonferroni *p*-value correction for multiple comparisons, probably due to the small number of deployments in bins further from seamount summits. Indeed, when considering all BRUVs deployed within

20 km of the southern seamounts (n = 41), overall probability of occurrence was 20 % compared to just 2 % in offshore reference BRUVs (Chi-squared test, p = 0.008).

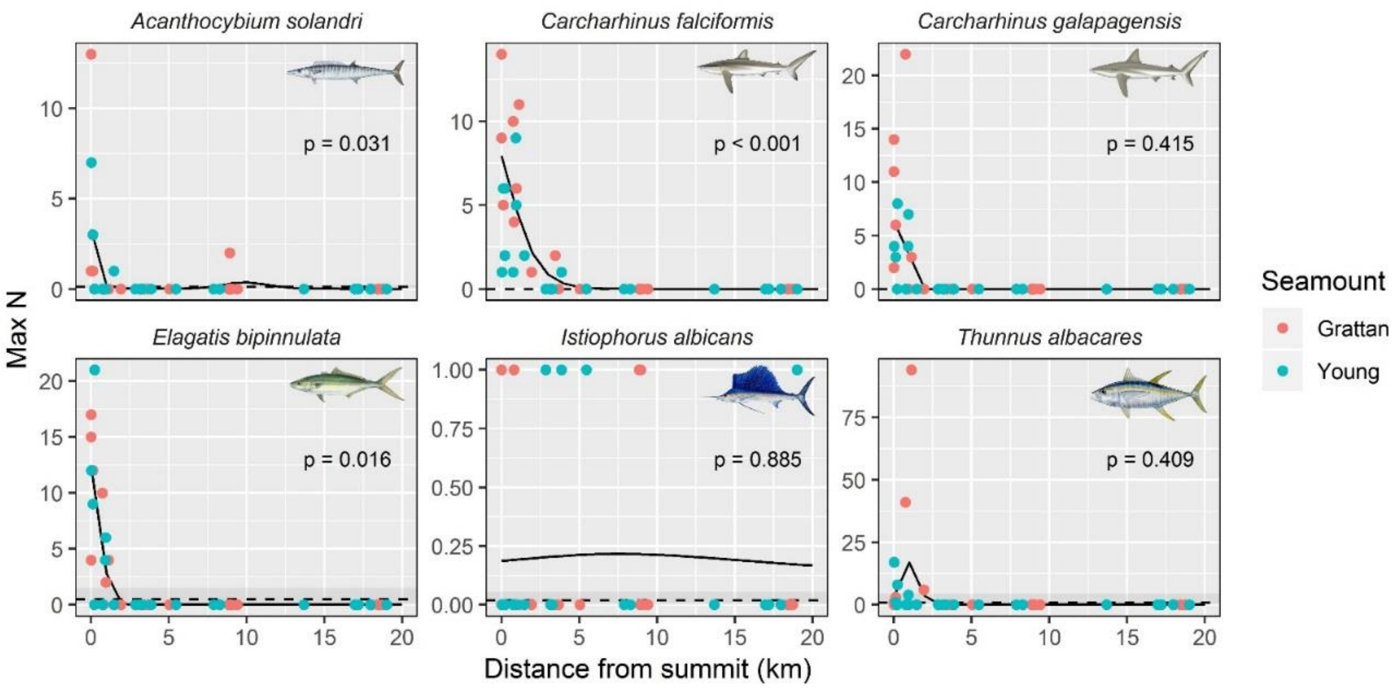


Figure 4.8 Relationship between abundance (Max N) of six commonly-encountered species in mid-water BRUVs species and distance to the summits of Ascension's southern seamounts. For clarity, only deployments made within 20 km of the seamounts are plotted**.** Solid regression lines are penalised thin plate splines fit using a negative binomial error distribution. Broken lines and shaded polygons represent mean abundance and 95% confidence envelopes from 57 offshore reference BRUVs deployed more than 50 km from any topographic feature (islands, seamounts etc.). Fish illustrations © Diane Roam Peebles; shark illustrations © Marc Dando.

As was the case in hydroacoustic surveys, BRUVs detected no increase in epipelagic species richness with distance from the Harris-Stewart Seamount (Figure 4.5) and many of the characteristic species of pelagic communities on the Southern Seamounts, such as yellowfin tuna, rainbow runner, silky sharks and Galapagos sharks, were apparently absent. When considering large, pelagic species, only blue shark and common dolphinfish were recorded in more than 10% of deployments (Annex Table) but probability of occurrence was not significantly higher than in offshore areas more generally (Figure 4.7). Overall, blue sharks were detected on 43 % of all BRUVs deployed within 40 km of Harris-Stewart (n = 14) compared to 25 % of offshore reference BRUVs, but this difference was not statistically significant (Chi-squared test, p = 0.32).

Further sampling may yet reveal elevated abundances of a number of less common species, such as oceanic sharks and billfish, around Ascension's seamounts. For example, Atlantic blue marlin were observed on 38% BRUVs deployed within 1.2 km of summit of Grattan (n = 8) compared to just 7% in offshore baselines (Chi-squared test, $p = 0.05$; Figure 4.6). Large aggregations of skipjack tuna (MaxN > 150) were also observed within 1km of the summit of Grattan but were not encountered in offshore reference BRUVs despite greater sampling effort. The limited statistical power to infer trends in abundance of some scarcer species despite intensive sampling highlights the challenges with gathering fishery-independent data on species distributions and abundance in large, offshore MPAs which will need to be considered carefully when designing future monitoring protocols.

4.3 VESSEL-BASED VISUAL TRANSECTS

4.3.1 Methods

Vessel-based visual transects are amongst the simplest marine census technique and involve counting the number of individuals encountered within a given distance of a moving vessel along a transect of known length and duration. They are useful for seabirds and species that spend a significant amount of their time at surface, such as marine mammals and turtles. Flying fish can also be effectively enumerated using this method as they are typically disturbed into flight by the motion of the vessel [Oxenford et al. 1995]. The latter are an important prey species for a variety of oceanic predators so it is of interest to understand how their abundance varies with distance from seamounts.

Seabirds and cetaceans were censused using an adaptation of the European Seabirds at Sea protocol (described in [Camphuysen et. al 2004]) which involves counting the number of individuals observed in a 300 m wide strip-transect. The transect is subdivided into distance bands (0 – 100, 100 – 200, 200 – 300m) for counting animals on or in the water and regular 'snapshots' of the number of birds in flight over the transect are also taken. In practice no cetaceans or resting seabirds were observed during seamount surveys so distance sampling methods were not required. Relative abundances of flying fish were estimated following Oxenford et al. [1995]. School sizes of airborne fish disturbed by the vessel were estimated to the nearest 5 for schools of more than 15 individuals and to the nearest 10 for schools of over 30. It was not possible to reliably differentiate between species in flight so total numbers are presented instead; however identification of small numbers of individuals that landed on deck suggest that tropical two-winged flying fish (*Exocoetus volitans*) were particularly common.

All counts were performed by a single observer positioned on the port bow of the vessel, travelling at a constant speed of approximately 8 knots. Counts were carried out along belt-transects running in an E-W direction over the seamounts (Figure 4.1C) and were summed in five-minute bins as recommended by [Camphuysen et. al 2004] and [Oxenford et al. 1995] to provide the spatial resolution needed for modelling relationships with distance from seamounts. Because of the need to carry out other survey techniques in parallel, transects were not continuous and instead consisted of several temporally-discrete, overlapping segments. For consistency with BRUV counts, the average number of individuals of each species counted in exponentially-increasing distance bands from the seamounts was calculated (according to the distance between the centroid of each five-minute sampling period and the closest seamount) and compared with pelagic baselines from 144 similar surveys carried out in Ascension Island's EEZ more than 50 km from any island or seamount.

Table 4.1. Abundances of seabird species observed during vessel-based visual surveys of Ascension's seamount. Counts are corrected for effort by dividing by the total transect length on each seamount (shown in parentheses).

			Density (individuals/km)		
Family	**Species**		**Grattan**	**Harris**	**Young**
Fregatidae	*Fregata aquila*	Ascension frigatebird	0.049	0.000	0.008
Hydrobatidae	*Oceanodroma castro*	Band-rumped storm petrel	0.070	0.026	0.104
Laridae	*Gygis alba*	White tern	0.016	0.000	0.000
	Onychoprion fuscatus	Sooty tern	0.460	0.009	0.088
Procellariidae	*Procellariidae sp*	Shearwaters/petrels	0.092	0.000	0.008
Sulidae	*Sula dactylatra*	Masked booby	0.000	0.004	0.000
	Sula leucogaster	Brown booby	0.005	0.000	0.000
			(185)	(229)	(125)

4.3.2 Results

Between 26th January 2016 and 31st Jan 2018 a total of 540 km of strip transects were surveyed over 34 hours. No cetaceans (whales and dolphins) were observed in the vicinity of any of the seamounts which is consistent with results of BRUVs (only a single oceanic dolphin sighted 37 km from the Harris-Stewart seamount). A total of 163 seabirds were counted representing at least 7 species (Table 4.1). Sooty terns were the most commonly observed species in the Southern Seamounts (n = 96), followed by band-rumped storm petrels (n = 26), shearwaters (n = 18) and Ascension frigate birds (n = 10). Seabird densities around the Harris-Stewart seamount were low, with band-rumped storm petrels being the most frequently observed species. Observers were not possible to reliably identify shearwaters to species level; however positive ids made during the seamount expedition and during offshore surveys carried out elsewhere in Ascension's EEZ suggest that the majority are likely to have been Cory's shearwaters (*Calonectris borealis*).

In general, counts of seabirds were too infrequent to reliably model relationships between abundance and distance from the seamounts and results should therefore be considered preliminary in nature. Of the seven species encountered, only Ascension frigatebirds and sooty terns showed some evidence of locally higher abundance in the vicinity of the Southern Seamounts (Figure 4.9). Both of these species were more common within 5 km of Grattan than in more distant surveys (Kruskal-Wallis test followed by post-hoc Dunn test with Benjamini-Hochberg p-value correction, all $p <= 0.05$) although only frigatebirds were present in higher numbers when compared to offshore baselines (Mann-Whitney U-test, Ascension frigate: $p < 0.001$; sooty tern: $p = 0.18$) and this difference was based on a small number of observations ($n = 8$; Figure). We found no evidence that flying fish - the principle prey species of these seabirds – were more abundant around seamounts; if anything, flying fish densities around Grattan were lower than in offshore areas more generally (Figure 4.9). However, both sooty terns and Ascension frigatebirds are known to forage in association with surface-schooling predators such as tuna and rainbow runner which are also locally abundant within 5km of the Southern Seamounts (Figure 4.6).

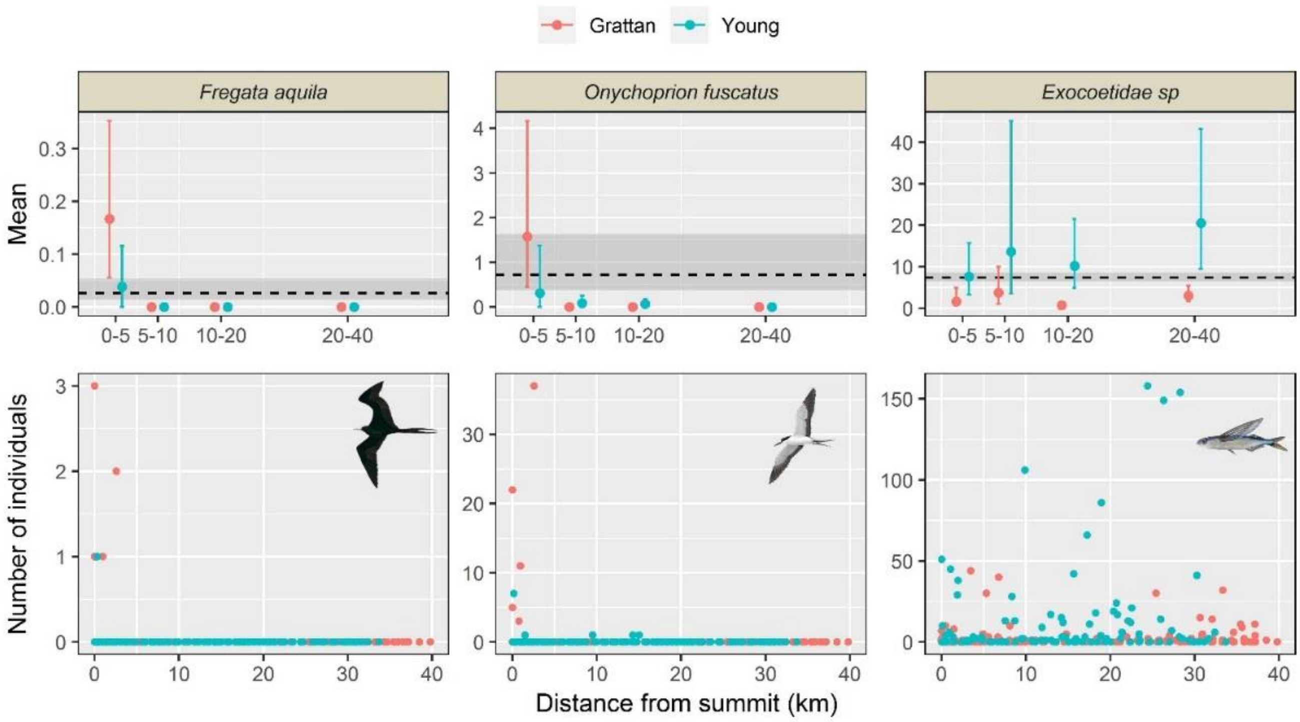


Figure 4.9. Vessel-based counts of two species of oceanic seabirds, Ascension frigatebirds (*Fregata aquila*) and sooty terns (*Onychoprion fuscatus*), and their principle prey species (flying fish; Exocoetidae sp.) in relation to distance from the summits of Ascension's southern seamounts. Lower panels show total numbers of individuals counted in each five-minute sampling window. Means and bootstrapped 95% confidence intervals are summarised over four distance bands in the upper panels along with baseline values derived from surveys carried out in offshore areas > 50 km from any topographic feature (means and 95% confidence intervals represented by broken line and shaded polygons, respectively).

Although they did not show any clear trends in abundance with distance from the seamounts, when considering all surveys carried out within 20 km of the summits, shearwaters were also observed more frequently in the vicinity of Grattan than in offshore reference surveys (mean count per sampling window: Grattan = 0.13, offshore baseline = 0.02; Mann-Whitney U test, $p < 0.001$). Previous work has shown a strong affinity for foraging around seamounts in Cory's shearwaters (Morato et al. 2008). However, since this species is a non-breeding migrant visitor to Ascension's waters, the temporal mismatch between the bulk of the seamount surveys (May-June) and offshore reference surveys (Jan – Feb) means it is currently difficult to separate a seasonal effect from an aggregation effect.

Additional surveys are needed to increase the statistical power and temporal coverage for investigating seabird associations with seamounts; however, based on the small numbers of individuals encountered it does not appear that the southern seamounts are important foraging hotspots for seabird species breeding on Ascension, which is consistent with the results of tracking studies carried out previously [Oppel et al. 2015; Oppel et al. 2017]

4.4 Incidental sightings

In addition to species captured for telemetry studies and recorded during quantitative surveys using BRUVs and vessel-based transects, a number of other large, marine vertebrates were also casually observed or detected through alternative means in the vicinity of the southern seamounts. These sightings are briefly reported here to aid in the compilation of species lists.

Deep-water drop cameras deployed by National Geographic Pristine Seas confirmed the presence of bluntnose sixgill sharks (*Hexanchus griseus*) at several locations around the summits of both the Grattan and Young seamounts between depths of 230 and 760 m (Figure 4.10). A tooth found embedded in a VR2AR acoustic receiver deployed on the summit of Grattan for telemetry and environmental monitoring studies has been also been positively identified as belonging to a small-tooth sand tiger shark (*Odontapsis ferox*).

In terms of epipelagic species, large schools of black jack (*Caranx lugubris*) were filmed forming mixed aggregations with rainbow runner, tuna and Galapagos sharks close to the surface on the Grattan seamount. Given their abundance it is surprising that this species has so far not been detected by BRUVs. A single whale shark also interacted with the research vessel over the summit of Grattan and was filmed using a pole-mounted camera.

Figure 4.10. Bluntnose sixgill shark filmed using a custom made drop camera at 760 m depth on the Grattan seamount. Image © National Geographic Pristine Seas.

SECTION 5. AQUATIC TELEMETRY

5.1 Methods

Aquatic telemetry refers to a suite of research methods that use electronic devices to track the movements and behaviours of individual animals. Understanding how individuals use space is important for designing and evaluating the likely effectiveness of marine protected areas, as well as contributing to our knowledge of rarely-observed marine species. We used three types of telemetry tags to study the movements of pelagic sharks and fishes associated with Ascension's seamounts, each with relative strengths and limitations (Figure 5.1):

Smart position-only tags (SPOTs) are capable of transmitting GPS-quality locations in real time and are therefore suitable for studying fine-scale movements and home range behaviour. However, they require the animal to surface periodically in order to transmit which can result in infrequent fixes for many marine species and may give a biased view of space use if surfacing is more likely to occur in particular areas. They are most commonly mounted on the dorsal fins of sharks.

Pop-up satellite archival tags (PSATs) use light levels and other environmental data (e.g. sea surface temperature, bathymetry) to estimate the location of an animal on the Earth's surface. PSATs continuously archive data and transmit it via satellite when they are shed or released at the end of the deployment, meaning they do not require the animal to surface, but the locations returned are very approximate. As such, they are most useful for studying long-distance migrations in species that spend little time at the surface. At finer scales the only reliable location is the position of the animal when the tag released.

Passive acoustic telemetry tags emit uniquely coded sequences of 'pings' that are detected by receivers positioned on the seabed whenever the animal is within range. Because these devices can be surgically-implanted and have minimal power consumption they can gather data over long periods of time. However, they cannot provide information on movements that extend beyond the detection limits of the receiver array. On seamounts, bathymetry severely constrains the area over which receivers can be deployed meaning this method is most suited to studying residency and fine scale habitat use around the summits of shallow features.

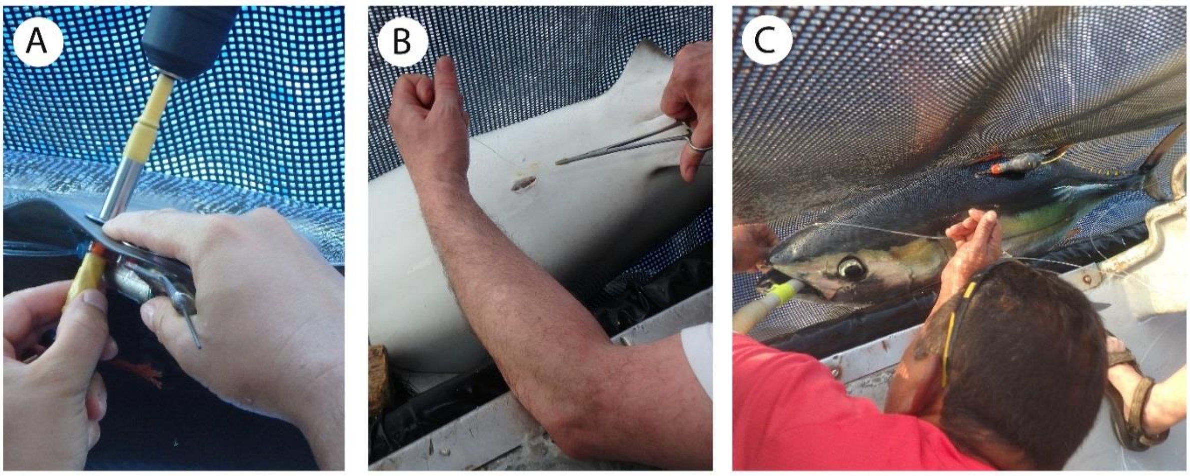


Figure 5.1 Deployment of telemetry tags on marine megafauna at Ascension's seamounts. A) SPOT mounted on a Galapagos shark's fin; B) surgical implantation of an acoustic tag in a silky shark; C) PSAT deployed on a yellowfin tuna

Tagging effort was primarily directed towards Galapagos and silky sharks and tunas as these species are both important components of Ascension's seamount communities (see Section 3) and are either the targets of commercial fisheries or are known to be heavily impacted by them. However, other large, pelagic species encountered in the vicinity of the summits were also opportunistically tagged to begin building spatial datasets for these rarer taxa.

5.2 Galapagos and silky sharks

5.2.1 Tag and receiver deployments

Between 30th May and 2nd June 2017 a total of 17 Galapagos and 18 silky sharks were fitted with acoustic tags around the summits of the Grattan and Young seamounts (Annex Table S5.1). Of these, 19 were double-tagged with fin-mounted SPOTs (9 Galapagos and 10 silky) and a single individual was fitted with a SPOT tag only. Tagged populations consisted of similar classes (mean fork length: Galapagos: 127.5 ± 23.5 cm; silky: 125.2 ± 14.3 cm; Student's t-test, $p = 0.73$) and were heavily biased towards males despite randomized sampling. Only two (12%) of the Galapagos sharks tagged and five (28%) of tagged silky sharks were female, which is significantly lower than expected given an equal sex ratio (Chi-squared goodness-of-fit test: Galapagos: $p = 0.002$; silky: $p = 0.06$). Fourteen VR2AR acoustic receivers were also deployed encircling the summits of the Grattan and Young seamounts (seven per seamount) to log detections of tagged sharks. Receivers were spaced an average of 1.5 km apart (range = 0.88 – 3.4 km) and deployed at depths ranging from 84 – 306 m (mean ± SD = 159 ± 54 m). Receiver arrays were deployed between 1st and 3rd June 2017 and recovered between 22nd and 24th January 2018, giving a study period of 235 days. Four silky sharks and two Galapagos sharks that were never detected following deployment (which may indicated tag failure or mortality as well as dispersal) are excluded from subsequent analyses, although results are qualitatively unchanged if they are included.

5.2.2 Residency, site fidelity and dispersal

The majority of acoustically-tagged Galapagos and silky sharks spent extended periods of time around Ascension's southern seamounts, with minimum mean residence times of 141 and 235 days respectively[3] (Table 5.1). During periods of residency both species exhibited a similarly high level of site attachment, with average attendance rates of > 15 hours per day on the summit receiver arrays and fewer than 5 absences longer than 24 hours (Table 5.1). However, silky sharks were more likely to disperse away during the study, resulting in a significantly lower mean residency index (0.56 vs. 0.97; Table 1). Indeed, all of the Galapagos sharks that were detected at the least once were still located within the southern seamounts when the acoustic tracking study ended, while detections for 50% of silky sharks ceased after periods of 4 – 95 days. The movements of these individuals after leaving the seamounts is generally not known; however infrequent SPOT locations from three double-tagged silky sharks indicate that two remained in the vicinity of the Ascension Island EEZ for periods of up to 65 days while

[3] Because many sharks were still located on the seamounts at the end of the acoustic tracking study it is not possible to estimate absolute residence times.

a third embarked on an extended, 3000 km migration into the southwest Atlantic and was last located over the Rio Grande Rise – a seismic ridge approx. 1000 km off the coast of Brazil which is a known hotspot of fisheries bycatch for oceanic sharks (Figure 5.3) [Carvalho et al. 2011].

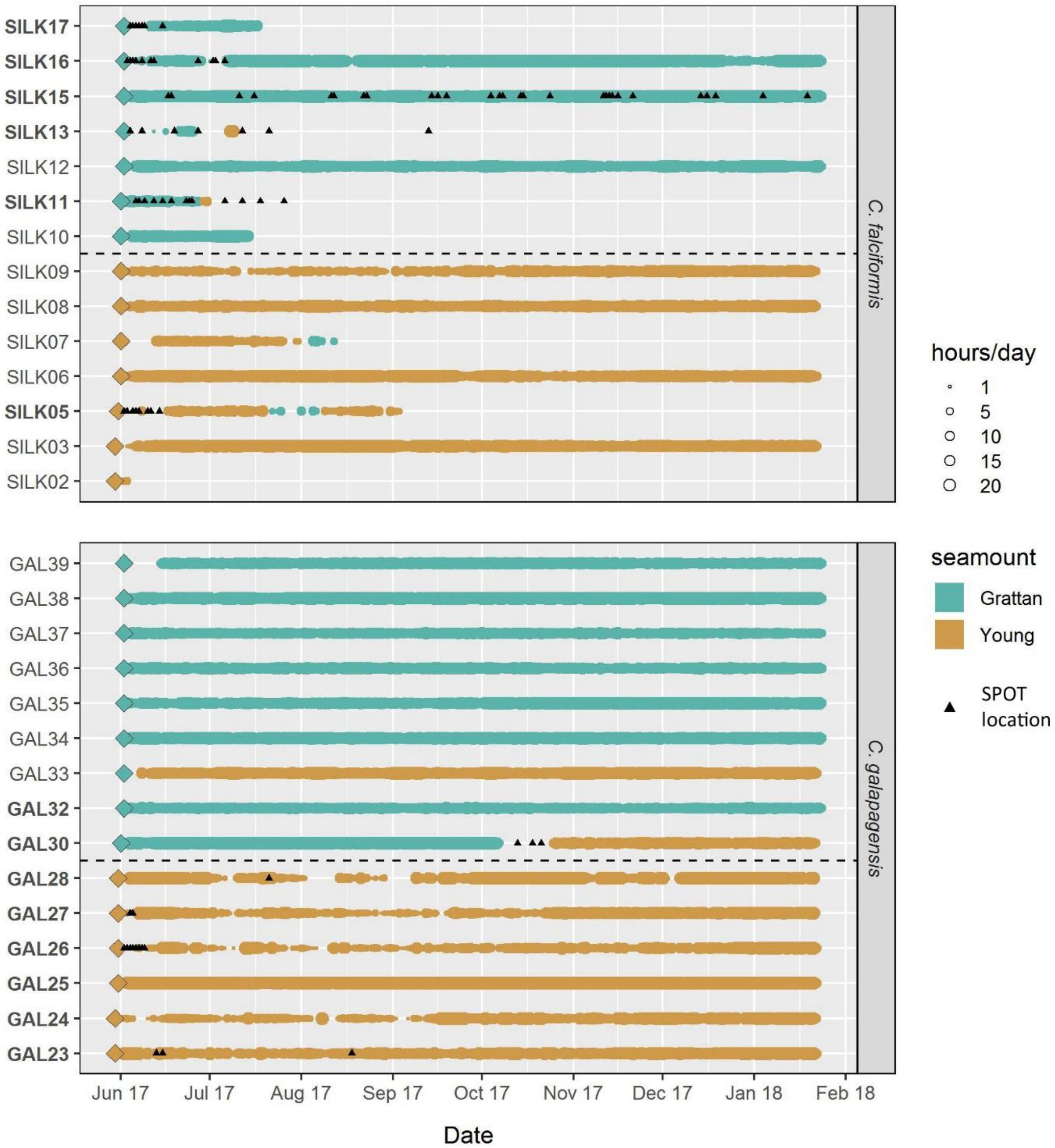


Fig 5.2 Detection histories of 29 acoustically-tagged Galapagos and silky sharks on fixed receiver arrays deployed on the summits of the Grattan and Young seamounts. Daily detections are coloured according to the seamount on which they occurred and scaled according to the number of hours in which the individual was in attendance (i.e. detected at least once). The temporal distribution of SPOT locations transmitted by double-tagged animals (highlighted in bold face) are also shown. Six individuals (two Galapagos and four silky) that were never detected following release are excluded.

Table 5.1 Comparison of standard attendance metrics for acoustically-tagged Galapagos and silky sharks on the Southern seamounts. Residency index is the proportion of total tracking days for which an individual was detected at least once on the summit receiver arrays and residence time is the interval between deployment and last detection. Note that because many individuals were still present on the seamounts when the study ended, minimum mean residence times are reported and no statistical comparison is possible. Confidence intervals (CI) were estimated by non-parametric bootstrap with 1000 iterations and statistical comparisons between species were performed using generalized linear models with appropriate error distributions for each metric.

	Silky shark		Galapagos shark		
Metric	Mean	CI	Mean	CI	*p*-value
Residence time (days)	>141	-	> 235	-	-
Residency index	0.56	0.35– 0.77	0.97	0.94 – 0.99	<0.001
Absences > 24 hours	3	1 – 4	4	2 – 9	0.42
Hours detected/day	14.9	12.6 – 17.1	16.7	14.9 – 18.4	0.75
Total detections/day	140	103 – 182	140	100 – 190	0.98
Receivers visited/day	3.4	2.7 – 4.1	2.8	2.2 – 3.4	0.15

Although tagged sharks generally remained on the seamount on which they were originally tagged, six individuals (21%; four silky and two Galapagos) moved between Grattan and Young, or vice versa, at least once during the study (Figure 5.2). There was no significant difference between species in the probability of switching seamounts (Chi-square test, p = 0.31); however the nature of these movements was distinct. In Galapagos sharks, translocations between seamounts were permanent within the timeframe of the study whereas in silky sharks they tended to be temporary and precede an apparent dispersal event (Figure 5.2). Interestingly, SPOT locations transmitted by a Galapagos shark during one such translocation suggest that, rather than taking a direct route, this individual travelled more

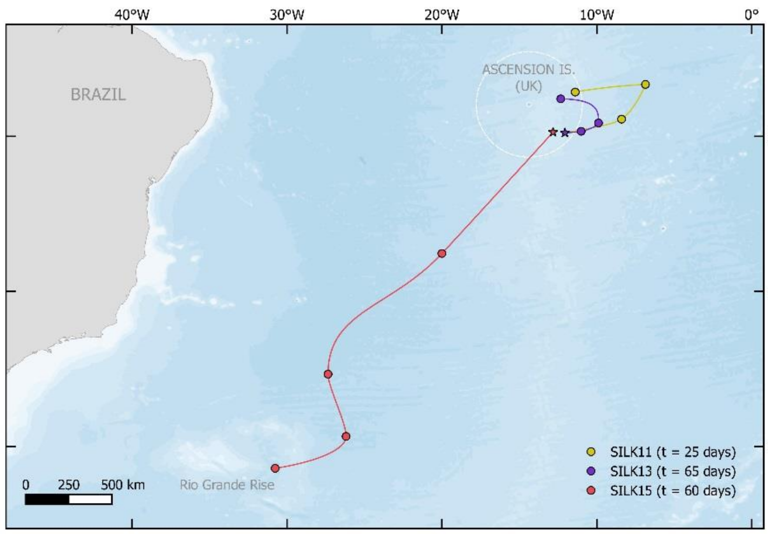


Figure 5.3. Movements of SPOT-tagged silky sharks after leaving Ascension's southern seamounts. An individual was regarded as having dispersed away from the seamounts following its last detection on passive acoustic telemetry arrays positioned on the summits.

than 200 km to the north during the 18 days between leaving Grattan and reappearing on Young.

5.2.3 *Home range size*

One of the primary objectives of the project was to define the home range sizes of seamount-associated sharks as a basis for recommending biologically-relevant MPA boundaries. Unfortunately, SPOT locations were too sparse to allow robust estimation of home range behaviour for the majority of individuals, presumably because they did not spend sufficient time at the surface (Figure 5.2). Of the 19 individuals fitted with SPOTs, eight failed to transmit (three silky and five Galapagos) and a further four posted fewer than 10 locations. For the remaining individuals, fixes were often clustered during a short period of apparently atypical, surface-orientated behaviour immediately following deployment (Figure 5.2; Figure 5.4D-F). During these 9–14 day periods sharks spent 95% of their time within 30–50 km of the seamounts but were never (or only infrequently) detected on the summit receiver arrays. Once acoustic detections stabilised, SPOT transmissions typically ceased suggesting that these post-tagging movements may represent an induced 'flight' response that is not representative of natural behaviours. Home ranges for these individuals should therefore be regarded as an overestimate of how far sharks typically travel from the seamounts during periods of

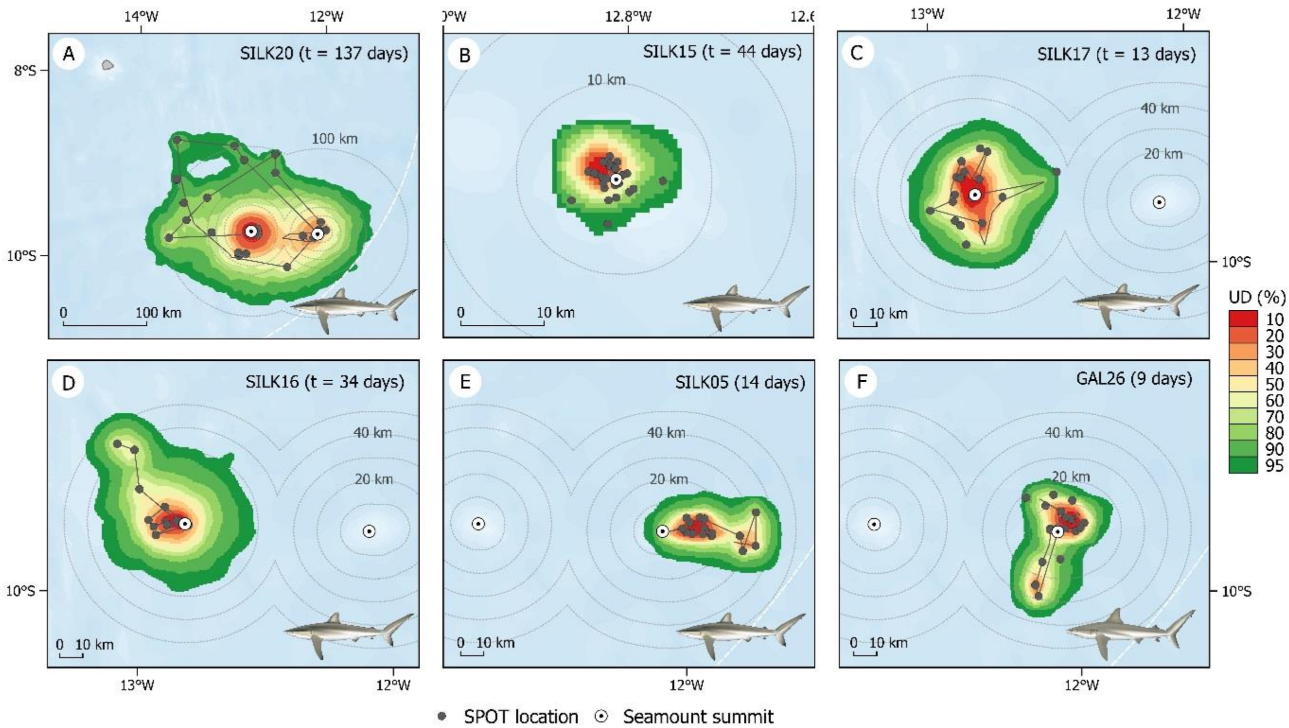


Figure 5.4. Utilisation distributions (UDs) of SPOT-tagged Galapagos and silky sharks during periods of residency on the Grattan and Young seamounts. UDs represent the smallest area in which each individual had a given probability of occurring and are derived from the posterior distributions of continuous time correlated random walk models fitted to track segments consisting of more than 10 locations separated by intervals < 20 days. Distance buffers from the summit (200m isobath) of each feature are also included for reference; note the different scales. UDs for individuals C-F are based on clusters of locations received during short periods of potentially atypical, post-tagging behaviour and should be treated with caution. Shark illustrations © Marc

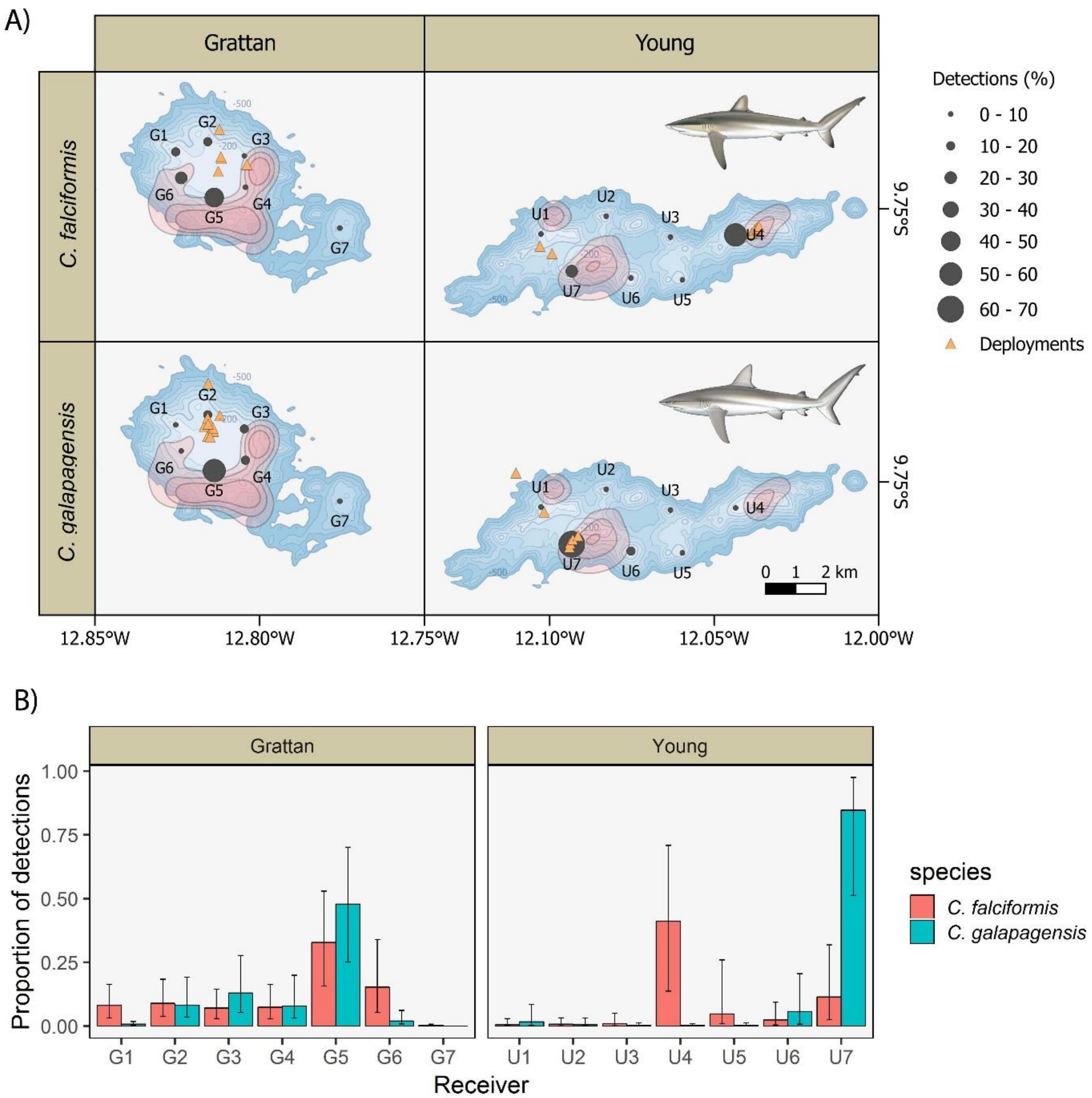


Figure 5.5. Fine-scale habitat use by acoustically-tagged Galapagos and silky sharks on the Grattan and Young seamounts. A) Spatial distribution of detections on summit receiver arrays expressed as the mean percentage of total detections for each individual. For comparison, approximate hotspots of fish/shark biomass from bioacoustic surveys are also shown (red filled contours; see Section 2). Hotspots were mapped by β-spline interpolation of total water column NASC recorded across all surveys on a 100 x 100 m grid. B) Mean proportion of detections recorded for each species by receiver with bootstrapped 95% confidence intervals. Shark illustrations © Marc Dando.

residency. Only in two cases (both silky sharks) were SPOT transmissions sufficiently frequent and temporally resolved to allow reliable home range estimates to be derived (Fig 5.4 A and B). Interestingly, these individuals exhibited very different spatial behaviours: one maintained a very restricted home range, spending 95% of its time within 8 km of the Grattan seamount (Figure 5.4B), while the other ranged over a sizable geographic area, travelling > 100 km from the southern seamounts and making several return visits to the summits of both Grattan and Young over a 137-day period. Unfortunately, this latter individual was not carrying an acoustic tag meaning it is not possible to compare attendance metrics with the rest of the tagged population. However, it appears to have been more loosely associated with the southern seamounts than the majority of other silky sharks tracked (Figure 5.2).

5.2.4 Fine scale habitat use

Acoustically-tagged Galapagos and silky sharks did not utilise all areas of the southern seamounts equally. Localised hotspots of activity were apparent in acoustic detection patterns on both the Grattan and Young seamounts and the strength and location of these differed between species. On Grattan, detections of both species were most frequent along the southernmost edge of the summit plateau (receiver G5, Figure 5.5), although this spatial bias was only statistically significant for Galapagos sharks. Both species were also detected significantly less frequently over an outlying sub-peak to the south east of the main summit plateau (G7) than on any other part of the array. On the Young Seamount, detections of Galapagos sharks were overwhelmingly centred on the south western sub-peak (station U7, Figure 5.5) – the shallowest point of the seamount – while silky sharks were detected most frequently at the easternmost tip of the summit ridge (station U4). Unlike on Grattan, these distributions closely correspond to the locations in which the animals were originally tagged suggesting more localised site fidelity on the topographically complex Young seamount. Interestingly, on both seamounts, detection hotspots broadly coincide with hotspots of total fish and shark biomass estimated from bioacoustic data (Figure 3.3), suggesting that they are biologically-relevant and not artefacts of receiver placement or topography.

5.3 Tuna

5.3.1 Tag deployments

Between 22nd May 2017 and 17th February 2018, 12 yellowfin tuna and 11 bigeye tuna were fitted with PSATs at Ascension's seamounts (see Annex table 2). Study animals were captured using baited vertical longlines (at Harris-Stewart) or by lure trolling (at Southern seamounts). Yellowfin tuna were only encountered and tagged around the southern seamounts (Young: n = 8; Grattan: n =3), whereas bigeye were tagged on all three seamounts (Harris-Stewart: n = 4; Young: n = 4; Grattan: n = 3). Fork lengths of tagged individuals ranged from 85 – 134 cm for yellowfin and from 97 – 165 cm for bigeye. Tags were programmed to release after an interval of 365 days; however all were shed prematurely (Table S5.2). Two individuals - one yellowfin and one bigeye - appear to have died shortly following release (tag release triggered by depth 1-2 days post-deployment) and are excluded from further analyses. Median retention times for the remaining animals were 22.4 days for yellowfin tuna (range = 5 – 87 days) and 42.2 days for bigeye (range = 4 – 211 days).

5.3.2 Residency and home range size

All tuna tagged with PSATs at the seamounts remained either within or in the vicinity of the Ascension Island EEZ for the duration of their deployments and many were still located close to the seamount summits at the time their tags released (Figure 5.6). Core use areas of bigeye and yellowfin tagged at the southern seamounts were strongly centred on the seamounts themselves indicating a degree of residency around these features over the short to medium term (Figure 5.6, A & C). Similar periods of residency have been reported for yellowfin tuna tagged in inshore waters around Ascension Island [Richardson et al. 2018], although a comparison of estimated utilisation distributions suggest that seamount-associated individuals may range more widely than their island-associated counterparts (Figure 5.6 C&D). Richardson et al. [2018] estimated that a ca. 90 km buffer around Ascension Island would be needed to incorporate 95% of the movements of resident inshore yellowfin, whereas a 250 – 300 km buffer would be needed to achieve a similar level of certainty around the southern seamounts. This is largely due to long, looping trips that appear to have occurred in both species, in some cases approaching Ascension Island itself. However, caution is required when interpreting processed PSAT tracks at finer scales, particularly for species such as bigeye tuna that spend much of their time at depth where light geolocation and positional corrections using sea surface temperature are less reliable. Tag release locations provide the only reliable

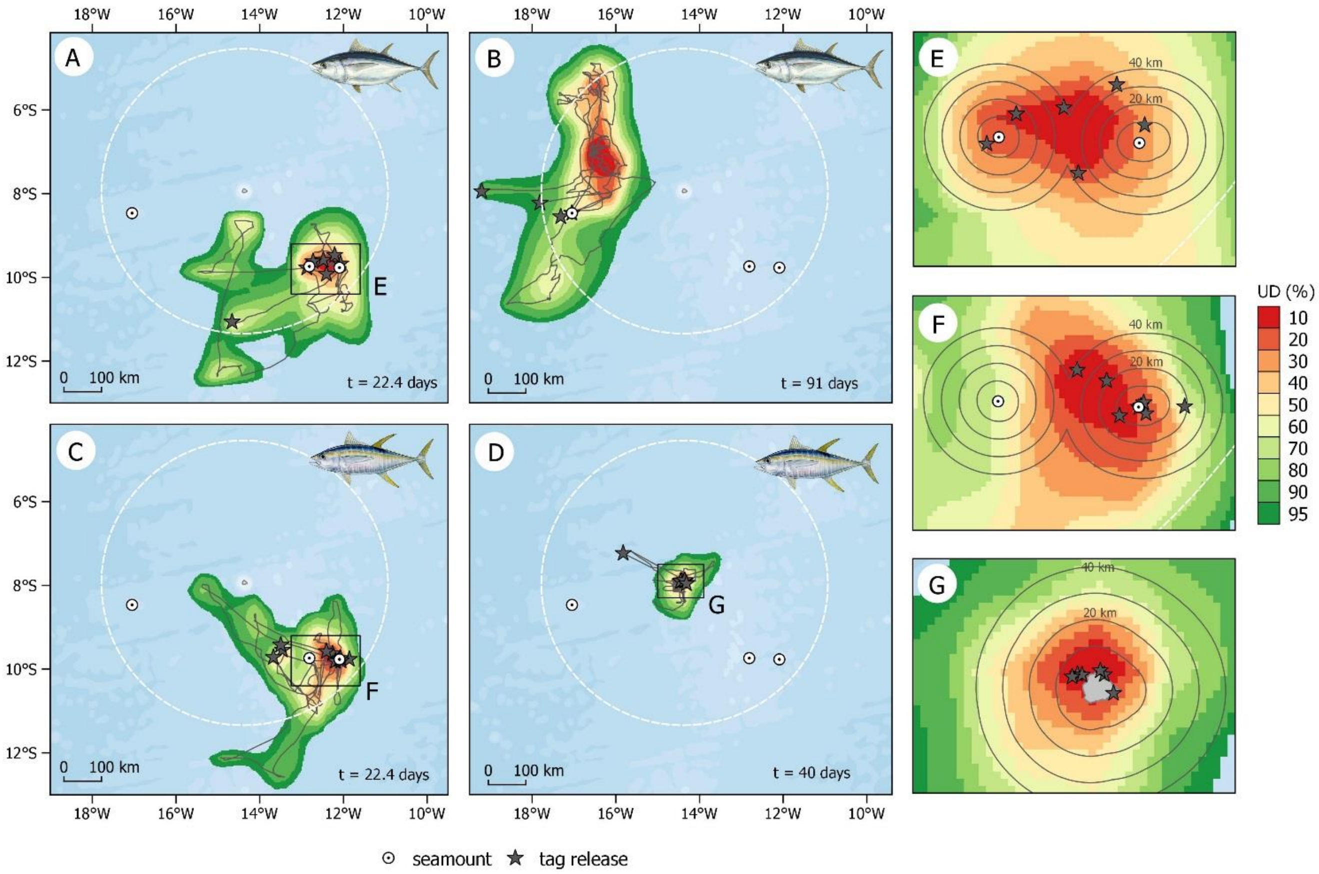


Figure 5.6 Probability density plots showing areas of high utilization by yellowfin and bigeye tuna tagged with PSATs at the Young, Grattan and Harris-Stewart seamounts. A) Bigeye tuna tagged at the southern seamounts; B) Bigeye tuna tagged at Harris-Stewart seamount; C) Yellowfin tuna tagged at the southern seamounts; D) For comparative purposes, UDs for yellowfin tuna tagged previously at Ascension Island are also shown [Richardson et al. 2018]. Utilisation distributions (UDs) correspond to the smallest area within which each tagged cohort had a given probability of being located across their respective deployment periods and are based on a weighted average that gives greater influence to individuals with longer tracking windows. Inset boxes in A, C and D are enlarged in panels E – G, respectively, to provide finer detail of tag release locations. Illustrations © Diane Roam Peebles.

positional data at this spatial scale and indicate that the majority of tuna tagged on the Southern seamounts were still located within 40km of the summits at the end of their respective deployment periods (Figure 5.6). Indeed, median distance from the summit (weighted by deployment duration) at the point of release was 2.8 km for yellowfin tuna and 19.5 km for bigeye (Figure 5.6 E&F). The former is similar to the 3.5 km median distance from shore estimated for yellowfin tagged at Ascension Island.

Bigeye tuna tagged at the Harris-Stewart seamount are also predicted to have ranged over a sizeable portion of the Ascension EEZ, although unlike cohorts tracked around the southern seamounts, core use areas were located in oceanic waters to the northwest of Ascension rather than on the seamount itself. All four of the individuals tracked are estimated to have spent time foraging in this north-western region, which is where the commercial bigeye fishery has historically focussed its effort. However, of these, three appear to have returned towards the Harris-Stewart seamount in the latter stages of their tracking periods and two were still located within 30km of its summit when their tags released after 50 – 211 days at liberty. The fact that all bigeye tagged on the Harris-Stewart seamount are predicted to have spent time in an area known to support a productive fishery for this species provides some confidence in the fitted tracks. Nevertheless, it is clear that some individuals showed fidelity to Harris-Stewart over long timescales. Given the considerable location error inherent in PSAT tracks, a closer association with this feature cannot therefore be ruled out.

5.4 Other oceanic species

In addition to the tunas and sharks that were the principle focus of the tagging study, small numbers of four other oceanic species were also opportunistically captured and tagged with PSATs in the vicinity of Ascension's seamounts (< 20 km from summit). This included two oceanic whitetip sharks (*Carcharhinus longimanus*) captured over the summit of the Harris-Stewart seamount, three blue sharks (*Prionace glauca*) captured in the vicinity of Harris-Stewart (n = 2) and Young (n = 1), five wahoo (*Acanthocybium solandri*) tagged on Young (n = 4) and Grattan (n = 1) and a single large swordfish (*Xiphias gladius;* fork length = 2.65 m) captured in the deep water channel separating the southern seamounts. Small sample sizes limit the conclusions that can be drawn regarding the space use of these species; however, all oceanic sharks and billfish tagged quickly migrated away from the seamounts around which they were captured and most were located well outside of the Ascension Island EEZ at the time their tags released (5.7 D & E). The two oceanic whitetips travelled in a westerly direction after leaving Harris-Stewart and were located 810 – 1830 km from the Ascension EEZ when their tags released 51 – 54 days later. One appears to have travelled close to the island of Fernando do Noronha (Brazil) seamount chain which is a known hotspot for this species [Tolotti et al 2015.]. The single swordfish tagged also embarked on an extensive migration after leaving the southern seamounts and was located 1700 km to the north east in the Gulf of Guinea region when its tag was shed 58 days later. Blue sharks tagged at the seamounts travelled shorter distances by comparison; however, two individuals were located 380 and 450 km outside of the Ascension EEZ when their tags released (Figure 5.7E). The third remained within the EEZ for 28 days after leaving Harris-Stewart seamount and was last located 40 km from the summit of the Grattan Seamount. Tag retention times on wahoo were extremely poor (range = 4 – 6 days), although it is noteworthy that during these short periods tagged fish travelled an average of 65 km from their capture locations (range = 21 – 125 km), predominantly in a westerly to north-westerly direction, and four out of five were located more than 20 km from the seamount summits when their tags released (Figure 5.7C).

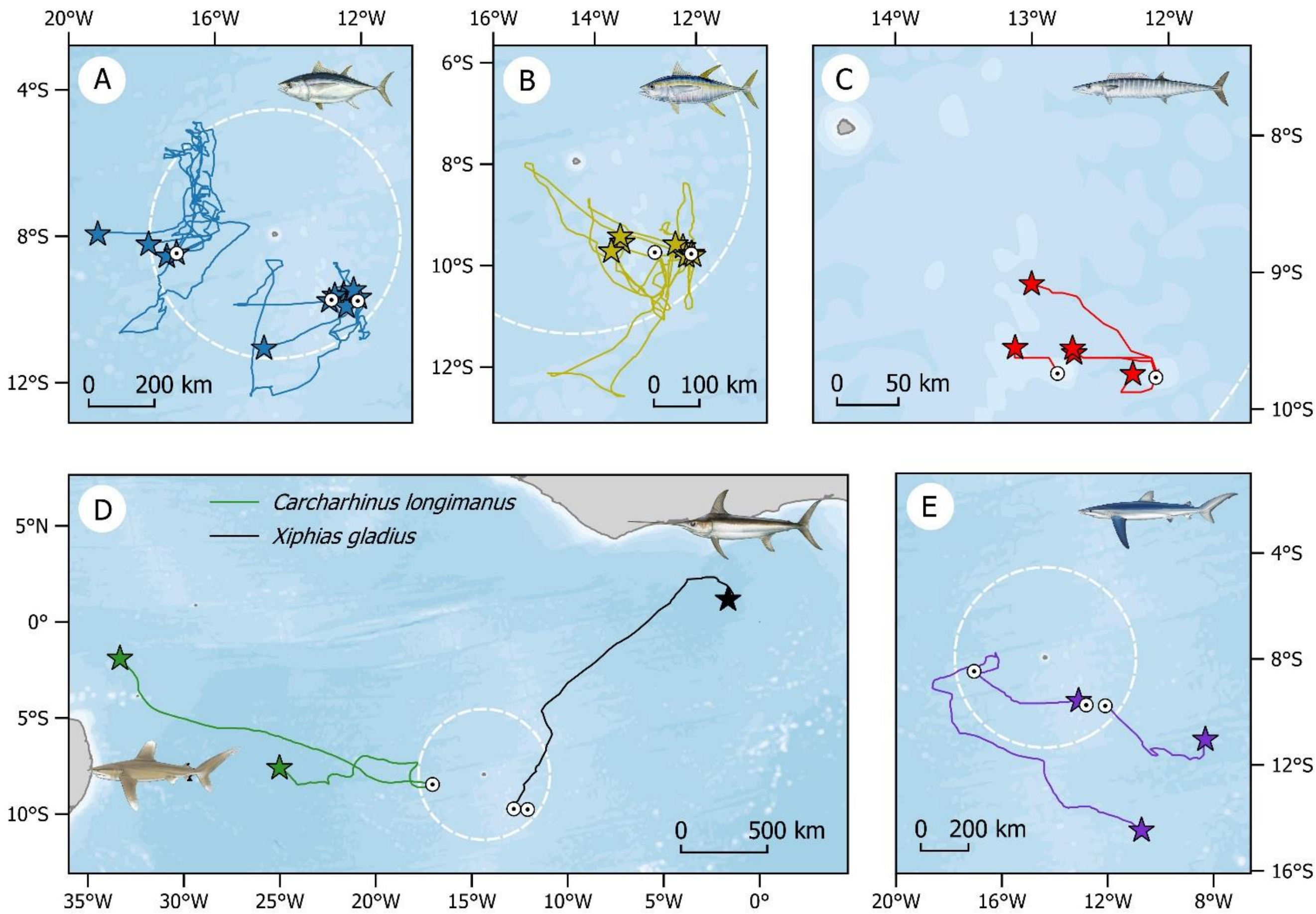


Figure 5.7. **Most probable tracks of 32 pelagic fish and sharks equipped with pop-up satellite archival tags (PSATs) at the Harris-Stewart, Grattan and Young seamounts.** A) Bigeye tuna (*Thunnus obsesus*); B) Yellowfin tuna (*Thunnus albacares*); C) Wahoo (*Acanthocybium solandri*); D) Oceanic whitetip shark (*Carcharhinus longimanus*) and swordfish (*Xiphias gladius*); E) Blue shark (*Prionace glauca*). Tag release locations are marked with stars. Fish illustrations © Diane Roam Peebles; shark illustrations © Marc Dando.

SECTION 6: CONCLUSIONS

6. CONCLUSIONS

This project represents the first detailed scientific study of the pelagic megafauna communities of Ascension Island's shallow water seamounts and outlines a strong case for their protection. The Southern Seamounts in particular could well be regarded as the 'jewels in the crown' of Ascension's offshore ecosystem. Here we summarise the main findings as they relate to the three principle research questions that motivated the work and offer recommendations for the inclusion of seamounts within a large-scale marine protected area planned for the Territory.

6.1 *Do Ascension's seamounts support higher abundance and diversity of marine megafauna than surrounding open-ocean habitats?*

Clear evidence of a bio-aggregating effect was apparent for the Grattan and Young seamounts. Both of these features support significantly elevated biomass and species richness of epipelagic fish and sharks when compared to surrounding, deeper water habitats. Large predatory species such as yellowfin tuna, wahoo, rainbow runner, Atlantic sailfish, Galapagos sharks and silky sharks were all encountered more frequently and at significantly higher abundances when compared to pelagic baselines. We also found some evidence that Ascension frigatebirds and sooty terns – species known to feed in association with schools of large, predatory fish – were locally more abundant over the southern seamounts, although it does not appear that these features are critical foraging habitat for seabirds at a regional scale.

The Southern Seamounts are similar geophysical environments with characteristics that would be expected to promote biological productivity. Both have shallow summits lying in the sunlit euphotic zone that approximately intersecting the deep chlorophyll maximum (~ 80 - 90 m depth). Both also showed evidence of tidally-induced upwelling and significantly elevated zooplankton biomass in surface water. In contrast, the Harris-Stewart Seamount lies entirely below the euphotic zone and was comparatively depauperate in terms of epipelagic megafauna. Many of the dominant shark and fish species encountered in the southern seamounts were apparently absent from this feature and those that were encountered were not significantly more common than would be expected in offshore areas more generally. However, hydroacoustic surveys did provide limited evidence of a biomass accumulation immediately over the summit of Harris-Stewart and it would be premature to rule out a bio-aggregating effect deeper in the water column.

6.2 *What is the sphere of influence of these features in terms of any zone of enhanced biological activity?*

Precisely defining the zone of influence of a seamount is extremely challenging due to temporal variability and the low densities at which many species occur. Previous attempts to do this have leveraged extensive, multiyear fishery catch-effort datasets and sightings data derived from long-term observer programmes (e.g. Morato et al. 2010), neither of which are available for Ascension Island. Nevertheless, the survey methodology used along with information on the ranging behaviour of tagged animals do permit an initial assessment for the Southern Seamounts. Based on observed gradients in total epipelagic biomass, species abundance and species richness, the biodiversity footprint of these features extends at least as far as 5 km from the summits and probably as far as 10 km (Figures 4.3, 4.5-4.9). As expected, the most abrupt transition occurs close to the peaks themselves. Aggregations of yellowfin tuna, rainbow runner and Galapagos sharks were only observed by BRUVs deployed within 2 km of the summits and total biomass of fish and sharks also increased sharply within this radius. In comparison, silky sharks appear to range more widely around the southern seamounts and were significantly more abundant up to 5 km from the summits while Atlantic sailfish were detected more frequently as far as 10 km away (Figures 4.6 & 4.8). Further sampling at intermediate distances from these features (i.e. 5 – 20 km) is needed to refine abundance gradients and may yet reveal a more extensive biodiversity footprint. Indeed, tracking data from sharks and tuna tagged on the southern seamounts suggest that some individuals may range extensively throughout the south-eastern quadrant of the Ascension Island EEZ between periods of residency.

6.3. *How long do individual sharks, tuna and billfish reside around seamounts and how extensive are their movements and onward migrations?*

Acoustic tracking of Galapagos and silky sharks tagged on the Grattan and Young seamount provided evidence of very high levels residency, with many individuals still present at the end of the 235 day study period. Galapagos sharks in particular appear to be almost permanently resident, being detected over the summits of the southern summits on an average of 97% of days tracked and for over 16 hours per day. This is consistent with their highly localised distribution within 2 km of the summits in BRUV surveys. Silky sharks also showed high levels of residency, with minimum mean residence times of >140 days, although around half of the individuals tagged had apparently migrated away within 90 days. Unfortunately, GPS tags deployed to track fine-scale habitat use of these species around the seamounts provided limited insight as sharks rarely spent sufficient time at the surface to transmit locations and those positions that were received often fell within a period of apparently atypical behaviour immediately following tagging. Based on the available data it seems likely that silky sharks spent the majority of their time within 30 - 40 km of summits during periods of residency, although more extensive forays to > 100 km were apparent for one individual. Both Galapagos and silky sharks also intermittently moved between Grattan and Young over the course of the study, demonstrating a level of connectivity within the southern seamount system.

6.4 The need for seamount Marine Protected Areas

Ascension Island's southern seamounts are unquestionably of high importance for pelagic megafauna. However, they are also demonstrably fragile ecosystems that are likely to be quickly eroded by fisheries encroachment. A prescient warning can be found in the St Paul's Rocks archipelago, a remote seamount system situated 1600 km to the northwest of the Ascension Island EEZ. Following the commencement of a fishery targeting yellowfin tuna, rainbow runner and wahoo in the 1980s, Galapagos and silky sharks that had previously been highly abundant suffered dramatic population collapses from which neither species has recovered (Luiz & Edwards 2011). Indeed, Galapagos sharks now appear to be locally extinct, likely due to a combination of high residency and geographic isolation as described here for Ascension's seamounts. Both silky and Galapagos sharks are protected under local law on Ascension Island and silky shark is also listed on Appendix II of the Convention for International

Trade in Endangered Species (CITES). Given the risk to these species alone we argue that it would never be sustainable to operate a fishery within vicinity of the southern seamounts.

The majority of the pelagic fish species that occur in elevated abundances on the southern seamounts are widespread, pan-tropical species that are not individually considered to be of high conservation concern. However, seamounts are predictable and spatially well-defined hotspots of abundance for these species, which is rare in tropical, oceanic waters. Importantly, we have barely begun to understand the complex relationships that connect the pelagic and benthic ecosystems of seamounts meaning it is vital that they are managed holistically in order to protect their overall ecological integrity.

Based on the combined results of this study we suggest that a minimum protection buffer of 20 km would be needed around Ascension's southern seamounts to include all key conservation features, and that extending this to at least 40 km would be a sensible precautionary measure given remaining uncertainties surrounding their radii of influence and clear evidence of connectivity between them. The scientific case for protecting the Harris-Stewart is far less compelling; however, this feature was sampled less intensively than southern seamounts and much of it lies deeper than the detection limits of the research methods used. As such it is impossible to rule out the possibility of deep-water fish aggregations that might be impacted by commercial longline gears targeting bigeye tuna. Indeed, there was evidence of a localised biomass accumulation in the limited area of the summit that could be surveyed using hydroacoustics (Figure 4.2A) and the small numbers of bigeye tuna tagged clearly show some level of fidelity to it (Figure 5.6B). Extending the minimum 40 km buffer to Harris-Stewart while further ecological studies take place would therefore be strongly advisable.

It is important to recognise that establishing MPAs on seamounts may not in itself be enough to ensure their meaningful protection. Historically, licensed tuna long liners have not specifically targeted seamounts and fishing effort in the vicinity of the southern seamounts in particular has been relatively low at an EEZ level. Of perhaps greater concern is the potential for IUU vessels originating from the African continent targeting their abundant shark and fish populations. Illegal shark finning has been documented previously in the Ascension Island EEZ despite historically low levels of monitoring. During the principle research expedition for this project a fishing vessel was also encountered in vicinity of southern seamounts that was not transmitting on normal maritime AIS channels and failed to respond or stop when hailed by fisheries officers from AIG. Although the intentions of this vessel were not clear and there was no direct evidence of illegality, it serves to highlight the potential vulnerability of these remote and inconspicuous places at the periphery of the EEZ. The delivery of an effective surveillance and enforcement package should therefore be considered a high priority to accompany designation of any seamount MPAs.

REFERENCES

Barnes D.K.A, Morley, S.A., Bell, J., Brewin, P., Brigden, K., Collins, M., Glass, T., Goodall-Copestake W.P., Henry, L., Laptikovsky, V., Piechaud, N., Richardson, A., Rose, P., Sands, C.J., Schofield, A., Shreeve, R., Small, A., Stamford, T. & Taylor, B. (2018) Marine plastics threaten giant Atlantic Marine Protected Areas. Current Biology 28, R1121-R1142.

Carvalho, F.C., Murie, D.J., Hazin, F.H.V., Hazin, H.G., Leite-Mourato, B. and Burgess, G.H. (2011) Spatial predictions of blue shark (*Prionace glauca*) catch rate and catch probability of juveniles in the Southwest Atlantic. *ICES Journal of Marine Science*, 68(5): 890-900

Camphuysen C.J., Fox A.D., Leopold M.F., & Petersen I.K. (2004). Towards standardised seabirds at sea census techniques in connection with environmental impact assessments for offshore wind farms in the U.K.: a comparison of ship and aerial sampling methods for marine birds, and their applicability to offshore wind farm assessments, NIOZ report to COWRIE (BAM – 02-2002), Texel, 37pp. Available from: http://jncc.defra.gov.uk/PDF/Camphuysenetal2004_COWRIEmethods.PDF

Clark, M. R., Vinnichenko, V. I., Gordon, J. D. M., Beck-Bulat, G. Z., Kukharev, N. N., and Kakora, A. F. (2007). "Large-scale distant-water trawl fisheries on seamounts," in *Seamounts Ecology Fisheries Conservation and Management. Fish and Aquatic Resources Series*, eds T. J. Pitcher, T. Morato, P. J. B. Hart, M. R. Clark, N. Haggan, and R. S. Santos (Oxford: Blackwell), 361–399.

Kim, S.S and Wessel, P. (2011) New global seamount census from altimetry-derived gravity data. Geophysical Journal International, 186(2): 615:631

Kvile, K., Taranto, G. H., Pitchner, T.J. & Morato, T. (2014) A global assessment of seamount ecosystems knowledge using an ecosystem evaluation framework. Biological Conservation, 173, 108-120

Luiz, O.J. and Edwards, A.J. (2011) Extinction of a shark population in the Archipelago of Saint Paul's Rocks (equatorial Atlantic) inferred from historical records. Biological Conservation 144: 2873-2881

Morato, T., Varkey, D.A., Damaso, C., Machete, M., Santos, M., Prieto, R., Santos, R.S. & Pitcher, T.J. (2008) Evidence of a seamount effect on aggregating visitors. MEPS 357: 23-32.

Morato, T., Hoyle, S.D., Allain, V. and Nicol, S.J. (2010) Seamounts are hotpost of pelagic biodiversity in the open ocean. PNAS, 107: 9707-9711.

Oppel, S., Beard, A. Fox, D., Mackley, E., Leat, E., Henry, L., Clingham, E., Fowler, N., Sim, J., Sommerfeld, J., Weber, N., Weber, S. and Bolton, M. (2015) Foraging distribution of a tropical seabird supports Ashmole's hypothesis of population regulation. *Behav. Ecol. Sociobiol.* 69: 915-926.

Oppel,S., Weber, S. Weber, N., Fox, D., Leat, E., Sim, J., Sommerfeld, J., Bolton, M., Broderick, A.C. & Godley, B.J. (2017) Seasonal shifts in foraging distribution due to individual flexibility in a tropical pelagic forager. MEPS 585: 199-212

Oxenford, H.A., Mahon, R. and Hunte, W. (1995) Distribution and relative abundance of flying (Exocoetidae) in the eastern Caribbean. I. Adults. *Marine Ecology Progress Series*, 117: 11 – 23.

Pitcher, T.J., Clark, M.R., Morato, T. and Watson, R. (2010) Seamount fisheries: do they have a future? *Oceanography*, 23: 135-144.

Richardson, A.J., Downes, K.J., Nolan, E.T., Brickle, P., Brown, J., Weber, N. and Weber, S. (2018) Residency and reproductive status of yellowfin tuna in a proposed large-scale pelagic marine protected area. Aquatic Conservation,

Totlotti, M.T., Bach, P., Hazin, F. Travassos, P. & Dagorn, L. (2015) Vulnerability of the oceanic whitetip shark to pelagic longline fisheries. PLoS One, https://doi.org/10.1371/journal.pone.0141396

Vitorero, L., Watling, L., Deng Palomares, M.L. & Nouvian, C. (2018) Out of sight, but within reach: a global history of bottom-trawled deep-sea fisheries from > 400m depth. Frontiers in marine science, 5:98. doi: 10.3389/fmars.2018.00098

Yesson, C., Clark, M. Taylor, M.L. & Rogers, A.D (2011). The global distribution of seamounts based on 30-arc second bathymetry data. Deep Sea Res. Part 1, 58(4): 442-453

ANNEXES

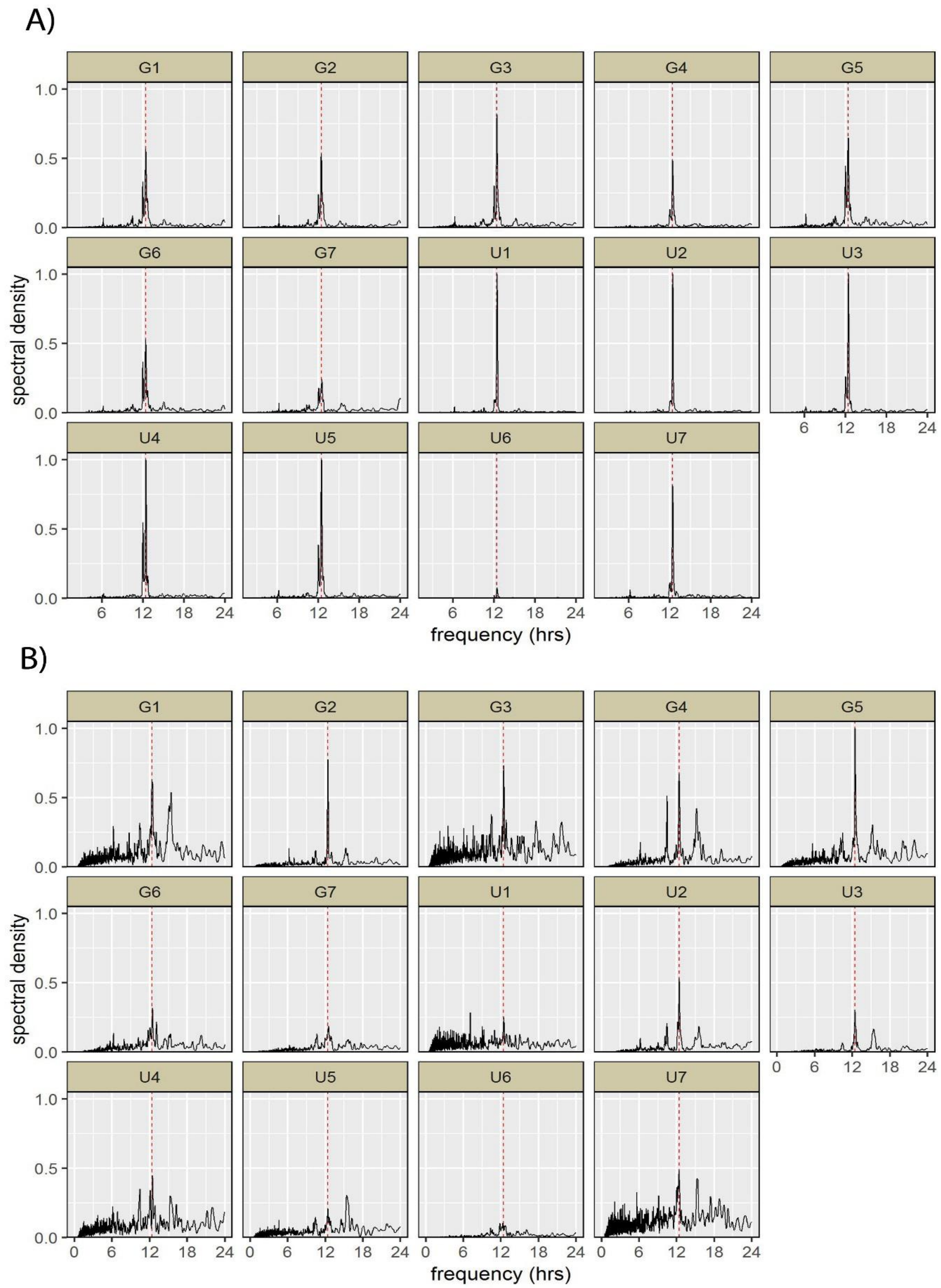


Figure S3.1 Density spectra showing dominant periodicity in A) temperature and B) current strength (tilt) time series recorded over a 235 day period by 14 VR2AR receiver stations deployed on the summits of the Grattan and Young seamounts. Broken red lines correspond to the frequency of the principle semi-diurnal lunar tide (12.4 hours). Spectra are truncated at 24 hours for clarity

Table S4.1. Maximum abundance (Max N) and probability of occurrence (P) of pelagic fish, shark and cetacean species recorded during baited remote underwater video (BRUV) surveys of the Harris-Stewart, Grattan and Young seamounts. Grattan and Young are situated approximately 80 km apart and are jointly referred to as the 'southern seamounts'. Max N is the maximum number of individuals simultaneously recorded in any BRUV deployment and P is the proportion of deployments where at least one individual was detected. See Figures S4.1 - S4.3 for a detailed breakdown of the spatial distribution of detections.

				Max N		P	
	Family	**Species**		**Harris**	**Southern**	**Harris**	**Southern**
	Delphinidae	*Stenella sp*	(Oceanic dolphin)	1	0	0.08	0.00
Elasmobranchs	Carcharhinidae	*Carcharhinus falciformis*	(Silky shark)	0	14	0.00	0.42
		Carcharhinus galapagensis	(Galapagos shark)	0	14	0.00	0.18
		Carcharhinus longimanus	(Oceanic whitetip)	1	0	0.08	0.00
		Prionace glauca	(Blue shark)	1	2	0.50	0.18
	Lamnidae	*Isurus oxyrinchus*	(Shortfin mako)	0	1	0.00	0.03
	Sphyrnidae	*Sphyrna zygaena*	(Smooth hammerhead)	1	0	0.08	0.00
Teleost	Balistidae	*Balistes capriscus*	(Grey triggerfish)	0	1	0.00	0.03
		Canthidermis maculata	(Rough triggerfish)	0	1	0.00	0.05
	Carangidae	*Carangidae sp*		0	1	0.00	0.03
		Caranx crysos	(Blue runner)	1	0	0.08	0.00
		Caranx hippos	(Crevalle jack)	0	1	0.00	0.03
		Decapterus sp	(Mackerel scad)	0	1	0.00	0.03
		Elagatis bipinnulata	(Rainbow runner)	0	15	0.00	0.21
		Naucrates ductor	(Pilot fish)	1	2	0.08	0.16
	Coryphaenidae	*Coryphaena equiselis*	(Pompano dolphinfish)	1	5	0.08	0.08
		Coryphaena hippurus	(Common dolphinfish)	3	5	0.17	0.08
	Echeneidae	*Echeneis naucrates*	(Live sharksucker)	0	3	0.00	0.13
		Remora remora	(Common remora)	2	4	0.42	0.50
	Istiophoridae	*Istiophorus albicans*	(Atlantic sailfish)	1	1	0.08	0.21
		Makaira nigricans	(Atlantic blue marlin)	0	1	0.00	0.08
	Monacanthidae	*Aluterus scriptus*	(Scrawled filefish)	1	1	0.08	0.03
		Cantherhines macrocerus	(Whitespotted filefish)	1	0	0.08	0.00
	Nomeidae	*Psenes sp*	(Driftfish)	4	7	0.83	0.79
	Scombridae	*Acanthocybium solandri*	(Wahoo)	2	13	0.17	0.16
		Katsuwonus pelamis	(Skipjack tuna)	0	159	0.00	0.05
		Scombridae sp		0	5	0.00	0.03
		Thunnus albacares	(Yellowfin tuna)	0	94	0.00	0.13
		Thunnus obesus	(Bigeye tuna)	0	1	0.00	0.03

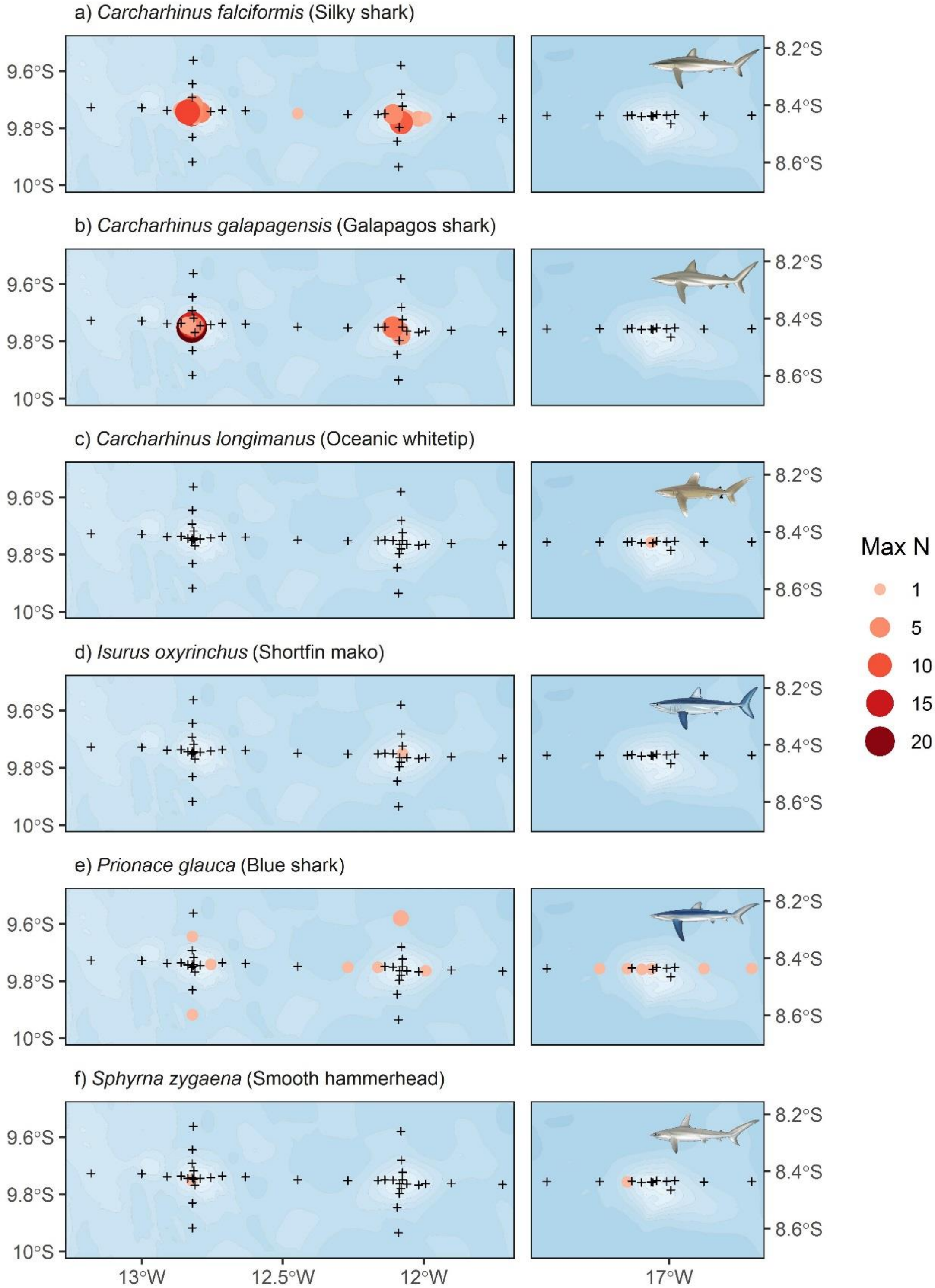


Figure S4.1. Distribution of pelagic sharks recorded during baited remote underwater video (BRUV) surveys of the Grattan, Young and Harris-Stewart seamounts. Plotting symbols are scaled according to the maximum number of individuals counted simultaneously in each deployment (Max N). Locations where no individuals were recorded are marked with a +.

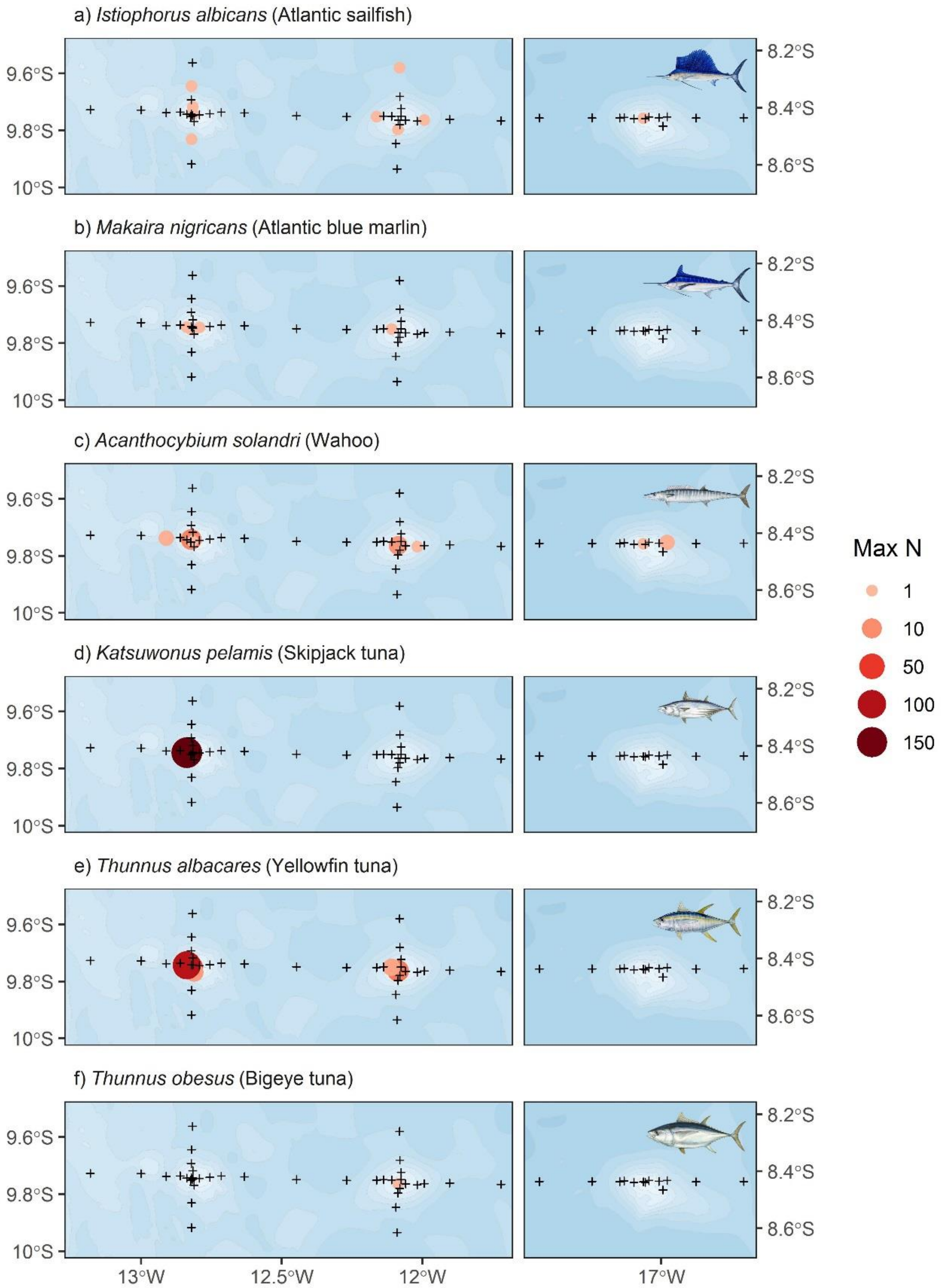


Figure S4.2 Distribution of billfish (Istiophoridae) and scombrids (tuna and wahoo) recorded during BRUV surveys of the Grattan, Young and Harris-Stewart seamounts. Plotting symbols are scaled according to the maximum number of individuals counted simultaneously in each deployment (Max N). Locations where no individuals were recorded are marked with a +.

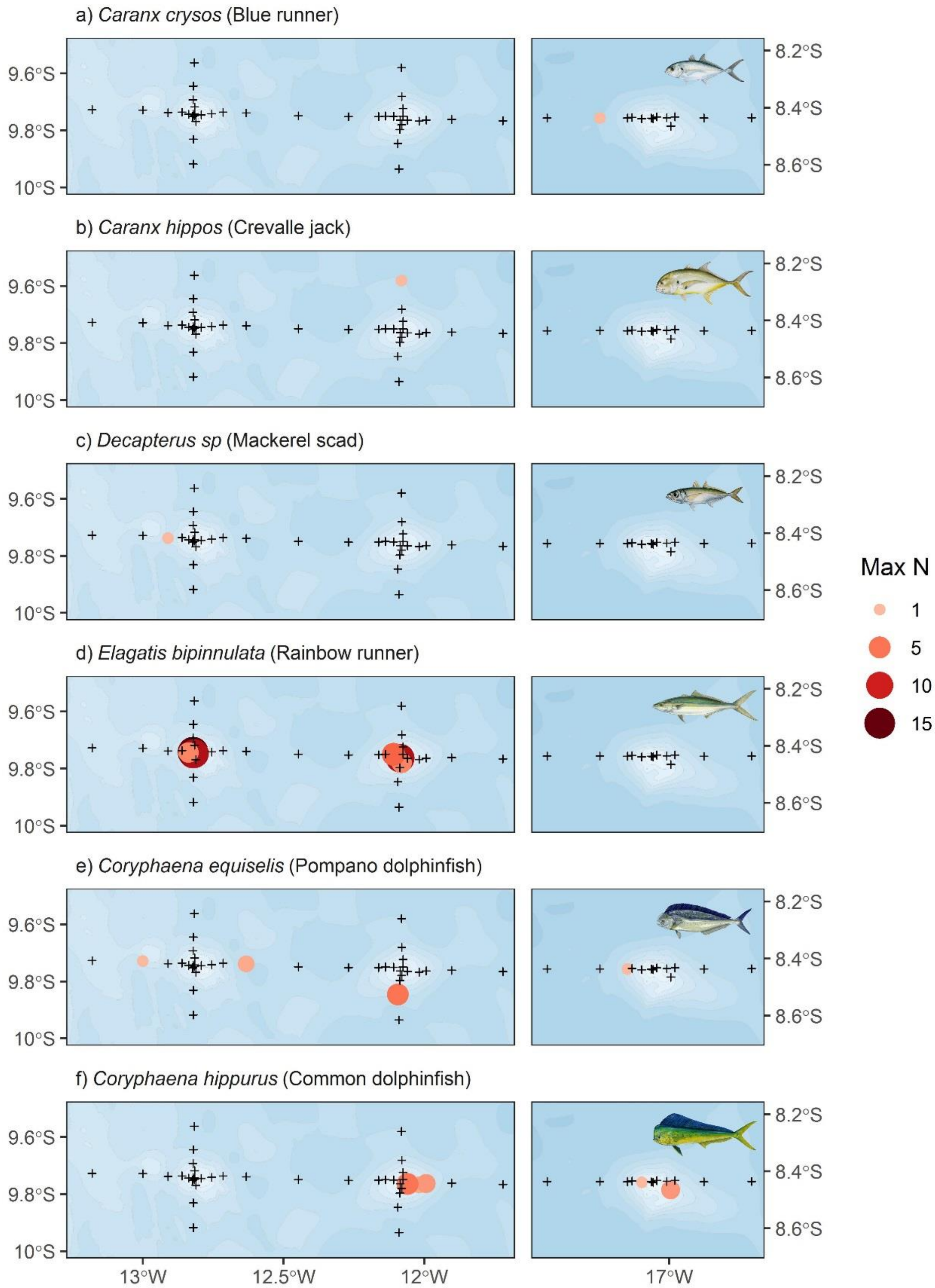


Figure S4.3 Distribution of carangids (jacks) and dolphinfish (family Coryphaenidae) recorded during BRUV surveys of the Grattan, Young and Harris-Stewart seamounts. Plotting symbols are scaled according to the maximum number of individuals counted simultaneously in each deployment (Max N). Locations where no individuals were recorded are marked with a +.

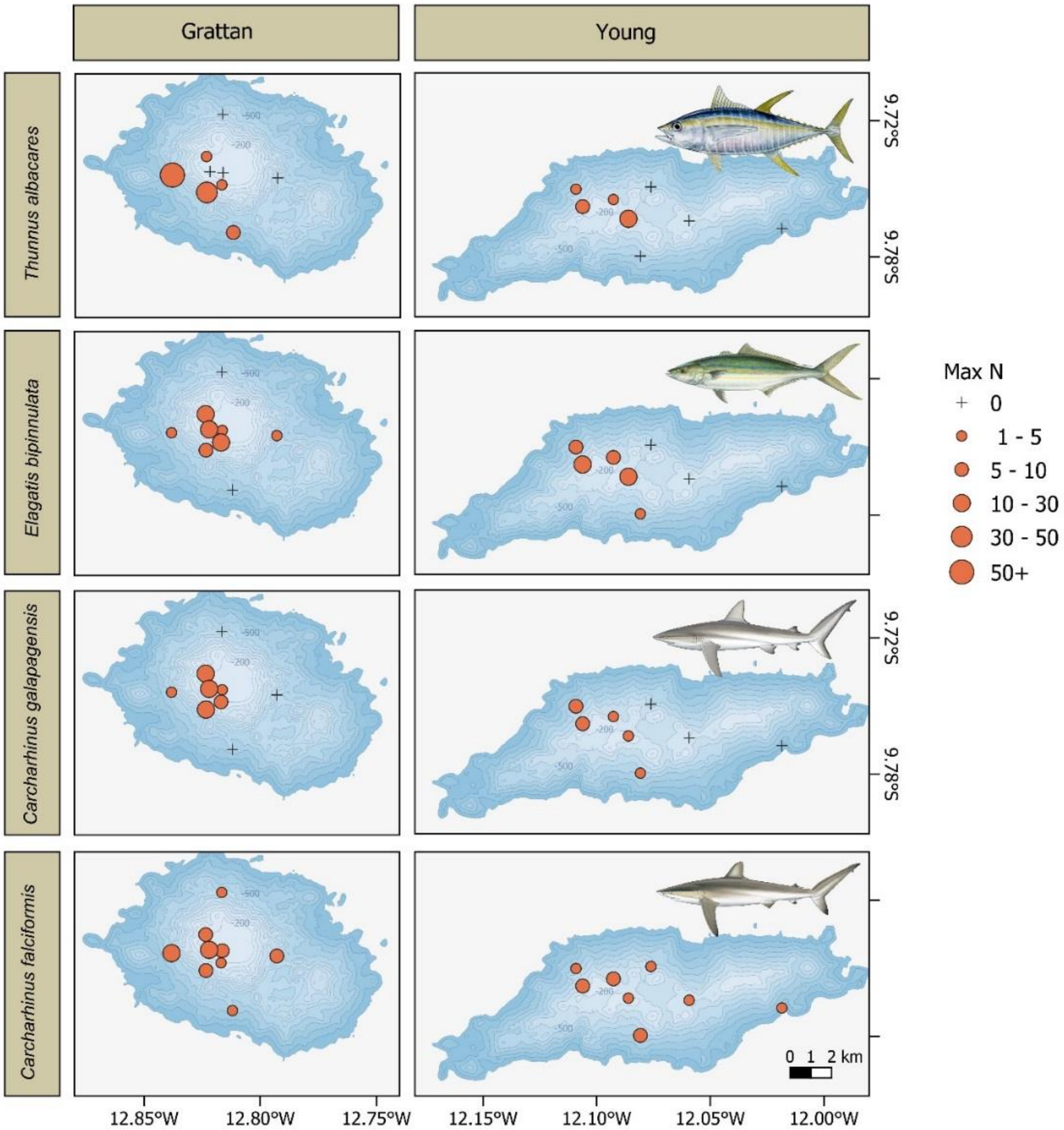


Figure S4.4. Localised distribution of four commonly-encounted pelagic species recorded by mid-water BRUVs deployed around the summits of Ascension' southern seamounts. Symbols are placed at the centroid of each drift track and are scaled according to the maximum number of individuals recorded simultaneously on each deployment. Note the more extensive area of occurrence of the silky shark *Carcharhinus falciformis*.

Table S5.1. Summary of telemetry tag deployments on 36 Galapagos and silky sharks at the Grattan and Young Seamounts.

	ID	Seamount	Tag date	Sex	Length (cm)		Tags		Residence time (days)	Residency index	SPOT locations	Max. range (km)
					Total	Fork	Acoustic	SPOT				
C. galapagensis	GAL23	Young	30 May 2017	M	170		TRUE	TRUE	>237	1	3	0.1
	GAL24	Young	30 May 2017	M	163		TRUE	TRUE	>237	0.94	0	-
	GAL25	Young	31 May 2017	M	145		TRUE	TRUE	>236	1	0	-
	GAL26	Young	31 May 2017	F	161		TRUE	TRUE	>236	0.94	18	28.8
	GAL27	Young	31 May 2017	M	204		TRUE	TRUE	>236	0.97	4	15.7
	GAL28	Young	31 May 2017	M	170		TRUE	TRUE	>235	0.89	0	-
	GAL29	Grattan	01 Jun 2017	F	168		TRUE	TRUE	0	0	0	-
	GAL30	Grattan	01 Jun 2017	M	245		TRUE	TRUE	>235	0.93	3	237.8
	GAL31	Grattan	01 Jun 2017	M	120		TRUE	FALSE	0	0	-	-
	GAL32	Grattan	02 Jun 2017	M	161		TRUE	TRUE	>234	1	0	-
	GAL33	Grattan	02 Jun 2017	M	130		TRUE	FALSE	>234	1	-	-
	GAL34	Grattan	02 Jun 2017	M	157		TRUE	FALSE	>234	1	-	-
	GAL35	Grattan	02 Jun 2017	M	156		TRUE	FALSE	>234	1	-	-
	GAL36	Grattan	02 Jun 2017	M	148		TRUE	FALSE	>234	1	-	-
	GAL37	Grattan	02 Jun 2017	M	126		TRUE	FALSE	>234	1	-	-
	GAL38	Grattan	02 Jun 2017	M	155		TRUE	FALSE	>234	1	-	-
	GAL39	Grattan	02 Jun 2017	M	135		TRUE	FALSE	>234	1	-	-
C. falciformis	SILK02	Young	30 May 2017	M	142		TRUE	FALSE	4	0.01	-	-
	SILK03	Young	30 May 2017	M	180		TRUE	FALSE	>237	1	-	-
	SILK04	Young	30 May 2017	M	136		TRUE	TRUE	0	0	0	-
	SILK05	Young	31 May 2017	M	175		TRUE	TRUE	95	0.29	15	33.4
	SILK06	Young	01 Jun 2017	F	168		TRUE	FALSE	>235	1	-	-
	SILK07	Young	01 Jun 2017	M	153		TRUE	FALSE	72	0.23	-	-
	SILK08	Young	01 Jun 2017	M	160		TRUE	FALSE	>235	1	-	-
	SILK09	Young	01 Jun 2017	M	147		TRUE	FALSE	>235	0.97	-	-
	SILK10	Grattan	01 Jun 2017	F	156		TRUE	FALSE	44	0.18	-	-
	SILK11	Grattan	01 Jun 2017	F	181		TRUE	TRUE	29	0.11	14	8
	SILK12	Grattan	02 Jun 2017	M	123		TRUE	FALSE	>234	0.99	-	-
	SILK13	Grattan	02 Jun 2017	M	141		TRUE	TRUE	37	0.04	9	42.6
	SILK14	Grattan	02 Jun 2017	M	126		TRUE	FALSE	0	0	-	-
	SILK15	Grattan	02 Jun 2017	M	167		TRUE	TRUE	>234	1	31	4.3
	SILK16	Grattan	02 Jun 2017	F	155		TRUE	TRUE	>234	0.96	13	43.2
	SILK17	Grattan	02 Jun 2017	M	200		TRUE	TRUE	45	0.16	17	34.9
	SILK18	Grattan	02 Jun 2017	F	178		TRUE	TRUE	0	0	0	-
	SILK19	Grattan	02 Jun 2017	M	148		TRUE	TRUE	0	0	0	-
	SILK20	Grattan	02 Jun 2017	M	141		FALSE	TRUE	-	-	41	138.6

Table S5.2. Summary of popup satellite archival tag (PSAT) deployments on seamount-associated sharks, billfish and tuna.

Species	ID	PTT	Deployment				Fork length (cm)	Sex	Release				Duration (days)
			Location	Date	Lat	Lon			Date	Lon	Lat	Type	
Acanthocybium solandri	WAH01	169033	Young	2017-06-04	-9.762	-12.095	153		2017-06-26	-39.176	-23.393	Premature	21.8
	WAH02	169045	Young	2018-01-22	-9.762	-12.091	144		2018-01-27	-13.002	-9.085	Premature	5.3
	WAH03	169041	Young	2018-01-22	-9.713	-12.075	137		2018-01-28	-12.262	-9.744	Premature	6.5
	WAH04	169020	Grattan	2018-01-24	-9.728	-12.815	150		2018-01-28	-13.123	-9.551	Premature	3.9
	WAH05	169051	Young	2018-02-17	-9.767	-12.092	149		2018-02-22	-12.704	-9.556	Floater	5.0
	WAH06	169047	Young	2018-02-17	-9.771	-12.075	148		2018-02-23	-12.691	-9.591	Premature	6.3
Carcharhinus falciformis	SILK21	169023	Young	2018-01-23	-9.765	-12.097	126	M	2018-01-24	-12.733	-9.746	Too Deep	1.1
	SILK22	169019	Grattan	2018-01-25	-9.741	-12.816	100	M	2018-02-07	-12.901	-8.815	Premature	13.4
Carcharhinus galapagensis	GAL26	169035	Young	2017-05-31	-9.768	-12.094	125	F	2017-07-11	-12.095	-9.758	Premature	41.2
	GAL27	169027	Young	2017-05-31	-9.767	-12.093	164	M	2017-07-21	-12.095	-9.760	Premature	50.9
	GAL29	169040	Grattan	2017-06-01	-9.728	-12.810	123	F	2017-06-02	-12.826	-9.669	Too Deep	0.4
Carcharhinus longimanus	OCE01	165730	Harris-Stewart	2017-05-19	-8.431	-17.071	146	M	2017-07-10	-33.341	-1.913	Too Deep	51.4
	OCE02	165733	Harris-Stewart	2017-05-21	-8.429	-17.073	137	F	2017-07-14	-25.023	-7.608	Too Deep	53.7
Prionace glauca	BLUE04	165728	Harris-Stewart	2017-02-11	-8.520	-16.784	210	F	2017-05-08	-10.722	-14.468	Too Deep	85.7
	BLUE07	165740	Harris-Stewart	2017-05-20	-8.420	-17.086	181	F	2017-06-17	-13.101	-9.578	Too Deep	27.5
	BLUE08	169031	Young	2018-01-22	-9.659	-12.093	210	M	2018-02-19	-8.310	-11.042	Floater	27.4
Thunnus albacares	YFT014	169032	Young	2017-05-31	-9.764	-12.111	135		2017-06-01	-11.858	-9.765	Too Deep	0.9
	YFT016	169046	Young	2017-06-01	-9.771	-12.075	93		2017-06-06	-12.068	-9.745	Premature	5.4
	YFT103	169018	Young	2018-01-22	-9.771	-12.075	85		2018-01-30	-12.408	-9.579	Premature	7.8
	YFT104	169048	Young	2018-01-22	-9.770	-12.075	100		2018-01-27	-16.315	-8.716	Premature	4.7
	YFT105	169030	Grattan	2018-01-24	-9.730	-12.817	113		2018-02-23	-13.496	-9.424	Premature	30.5

			Deployment				Fork length (cm)		Release				
Species	ID	PTT	Location	Date	Lat	Lon		Sex	Date	Lon	Lat	Type	Duration (days)
	YFT106	169037	Grattan	2018-01-24	-9.732	-12.816	115		2018-02-15	-13.672	-9.720	Premature	22.4
	YFT108	169009	Grattan	2018-01-25	-9.740	-12.821	120		2018-03-17	-12.258	-9.633	Floater	51.2
	YFT112	169044	Young	2018-02-17	-9.772	-12.075	93		2018-05-15	-12.056	-9.801	Pin Broke	86.6
	YFT114	169025	Young	2018-02-17	-9.771	-12.072	93		2018-03-26	-12.093	-9.770	Pin Broke	37.4
	YFT113	169015	Young	2018-02-17	-9.770	-12.072	115		2018-02-22	-13.456	-9.545	Too Deep	5.1
	YFT115	169013	Young	2018-02-17	-9.770	-12.070	134		2018-03-13	-12.191	-9.813	Floater	24.5
	YFT117	169007	Young	2018-02-17	-9.769	-12.074	96		2018-03-30	-12.082	-9.762	Pin Broke	41.4
	BET01	165738	Harris-Stewart	2017-05-22	-8.449	-17.052	120		2017-07-09	-17.053	-8.468	Pin Broke	48.7
	BET02	165721	Harris-Stewart	2017-05-23	-8.436	-17.065	118		2017-06-28	-19.206	-7.946	Premature	35.7
	BET03	165729	Harris-Stewart	2017-05-23	-8.435	-17.066	115		2017-12-20	-17.318	-8.550	Premature	210.7
	BET04	165739	Harris-Stewart	2017-05-23	-8.435	-17.066	115		2017-10-05	-17.816	-8.223	Floater	135.3
	BET05	169036	Young	2017-06-01	-9.757	-12.105	113		2017-07-03	-12.407	-9.924	Premature	32.0
Thunnus obesus	BET06	169049	Grattan	2017-06-02	-9.730	-12.812	144		2017-06-04	-12.874	-9.773	Too Deep	2.4
	BET07	169042	Young	2018-01-22	-9.772	-12.076	120		2018-04-11	-12.210	-9.470	Premature	78.7
	BET08	165724	Young	2018-01-23	-9.766	-12.098	129		2018-01-26	-12.480	-9.588	Premature	3.5
	BET09	169029	Grattan	2018-01-24	-9.732	-12.815	97		2018-02-04	-12.724	-9.620	Floater	11.5
	BET10	169024	Grattan	2018-01-24	-9.730	-12.817	120		2018-04-15	-12.066	-9.677	Premature	80.7
	BET11	169011	Young	2018-02-17	-9.768	-12.078	165		2018-03-05	-14.660	-11.063	Floater	15.8
Xiphias gladius	SWO01	169012	Young	2018-01-23	-9.727	-12.290	265		2018-03-22	-1.647	1.165	Premature	57.5