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ABUNDANCE OF SEAMOUNTS IN THE AZORES AND THEIR EFFECT ON AGGREGATING VISITING SPECIES

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ABSTRACT

It has been suggested that seamounts hold higher abundances of some "visiting" animals, such as tuna, sharks, billfishes, marine mammals, sea-turtles and even seabirds, but this has been based on sparse records, warranting further examination. In this paper we (1) characterized the seamount distribution of the Economic Exclusive Zone of the Azores and (2) examine whether the predicted higher abundances of tuna, marine mammals, sea turtles and seabirds actually occur around those mapped seamounts. Our algorithm showed that peaks and seamounts are common features in this region of the North Atlantic. Sixty three large and 398 small seamount-like features are mapped and described in the Azorean EEZ. Our results indicate that some marine predators (skipjack and bigeye tuna, common dolphin and Cory's shearwater) were significantly more abundant in the vicinity of some mapped shallow-water seamount summits. Our methodology, however, failed to demonstrate a seamount association for bottlenose dolphins, spotted dolphin, sperm whale, terns, yellow-legged gull, and loggerhead sea turtles. Not all seamounts, however, seemed to be equally important for these associations. Only seamounts shallower than 400 m depth showed significant aggregation effects. These seamounts may be considered hotspots of marine life in the Azores and a special effort should be made in order to ensure a sustainable management of these habitats. This paper describes the major findings of Morato *et al.* (2008a, b).

Keywords: Seamounts, locations, tuna, seabirds, marine mammals, sea turtles

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INTRODUCTION

Despite the fact that seamounts are highly important for fisheries and biodiversity (Pitcher et al. 2007), their exact numbers and locations are poorly known. Only a few seamount location datasets are available in the literature (e.g., Smith & Jordan 1988, Wessel 2001). Recently, Kitchingman et al. (2007) have conducted a global analysis aiming to generate a spatial dataset of points across the world's oceans that indicate large peaked bathymetric anomalies with a high probability of being seamounts. In that study 14,287 potential large seamounts were identified in the world's oceans. Seamounts are thought to be common topographic features in the Economic Exclusive Zone (EEZ) of the Azores archipelago (an irregular area within 33.5-43° N, 21-35.5° W) given the rugged volcanic and tectonically active seafloor that characterizes the region. However, as in the rest of the world's oceans their distribution has not yet been reasonably mapped warranting further examination.

Moreover, the importance of seamounts for some charismatic species such as marine mammals, sea turtles, seabirds and large pelagic fishes has been poorly examined can only be fully understood with a good knowledge of seamounts' locations and characteristics. It has been hypothesised that there are higher abundances of some "visiting" animals over seamounts but this has been based on sparse records and warrants further examination.

In this paper, we infer potential seamount locations in the Azores and used data from a fishery observer program to quantitatively investigate whether the abundances of tuna, marine mammals, sea turtles and seabirds observed at Azores seamounts are greater than in adjacent waters devoid of seamounts. This paper should contribute to the overall goal of better understanding the local distributions and abundance of marine organisms visiting seamounts and to infer their potential spatial dynamics, which has implications for conservation, management and monitoring.

METHODS

Seamount locations

In this study, seamounts are defined as any topographically distinct seafloor feature that is at least 200 meters higher than surrounding seafloor but which does not break the sea surface. We classify seamounts as being large or small, depending on whether the height exceeds 1000 meters (regardless of depth). This height separation is useful in isolating large seamounts, whose global distribution is well resolved by satellite altimetry, from small seamounts, the distribution of which must be derived from local acoustic mapping and therefore remain poorly sampled.

An automated methodology adapted from Kitchingman et al. (2007) was used to identify topographic structures with high probability of being seamounts. Two bathymetric datasets with different resolutions were used as the topographic bases: MOMAR (Monitoring the Mid Atlantic Ridge) mesoscale bathymetric map (Lourenço et al. 1998); and the "Global seafloor topography from satellite altimetry and ship depth soundings" database (Smith & Sandwell 1997). For details in the methodology used, see Morato et al. (2008a).

Visiting organisms

The Azores Fisheries Observer Program (POPA; http://www.Popaobserver.org) collected geo-referenced data onboard tuna fishing vessels including: fishing effort, tuna catch, sighting effort for different species, and sighting of named species of marine mammals, sea turtles, and seabirds. Fishing effort is estimated as the amount of time fishers spent looking for tuna schools. Sighting effort is defined as the time the observer spent searching for species other than tuna. Marine mammal, sea-turtle and seabird abundances were quantified by counting individuals (or estimation when in large groups) that were within 300 m of the vessel. Marine mammals were often counted within 2000 m of the vessel. The average speed of the boats when searching was 8 knots (~ 15 $km \cdot h^{-1}$). Observations occurring close to island shores (<30 km) were excluded from the analyses because they may be biased by the Island Mass Effect (Doty & Oguri 1956) and because we wanted to look at the effect of offshore seamounts.

We built grids of tuna catch, sighting effort, and sightings of different species by allocating each data point to a 0.05 x 0.05 degree cell (~5.5 x 5.5 km per side). This procedure produced two grids of tuna catch per 30.9 km^2, one grid of sighting effort in hours per 30.9 km^2, and several grids of numbers of individuals observed per 30.9 km^2. These later grids were then divided by the effort grid to produce grids of numbers of individuals per 30.9 km^2 per hour of search. These grids included cells with zero values, i.e., those cells with fishing or sighting effort but zero catch or observations. Null data cells were those with no fishing or sighting effort. Full details can be found in Morato et al., (2008b).

One-way analysis of variance (ANOVA) was used to test for significant differences between Log (x+1) transformed mean abundances (catch or sightings) at different distances from seamount summits. Dunnett's multiple comparison test was used to determine the significant differences between a control group mean and the treatment group means in the analysis of variance setting (Zar 1999).

RESULTS

Seamount locations

A total of 3177 peaks were identified yielding an average density of 3.3 peaks per 1000 km^2. The peaks dataset adequately identified topographic structures with heights larger than 100m (Figure 1). The exponential model adequately fitted the Azores peaks counts with ν_o= 4.31 peaks per 1000 km^2 and β= 2.89 km^{-1}, yielding a characteristic height (β^{-1}) of ~350 m. According to this exponential model there are about 4100 potential peaks in the Azores where 1000 km^2 contain an average of ~4 peaks of all sizes.

Figure 2 shows the location of 461 potential small and large seamount-like features in the Azores EEZ. Our methodology identified a total of 398 small features, which represents only 12% of the 3177 identified peaks. This discrepancy shows that our methodology successfully eliminated insignificant rises, peaks belonging to larger structures, or peaks that are part of ridges or island slopes. We have also detected 63 large potential seamounts, which is only 2% of the identified peaks. The mean abundance of small and large seamounts in the Azores EEZ is 0.42 and 0.07 per 1000 km^2, respectively.

Visiting organisms

Tuna catches per square kilometre per year (Figure 3) were significantly different at different distances from seamount summits (ANOVA $p << 0.001$ for skipjack and bigeye tuna). For skipjack (Figure 3a), catches occurring within 30 km from seamount summits were significantly higher than the overall mean (Dunnett tests for 10 km, 20 km and 30 km $p < 0.01$) with catches in all other areas being smaller. Bigeye tuna catches per square kilometre per year (Figure 3b) were significant higher within 20 km of the summits (Dunnett tests for 10 km and 20 km $p < 0.01$; Dunnett tests for 30 km $p > 0.05$).

Common dolphins were sighted at significantly higher frequencies in the vicinity of seamounts (ANOVA $p << 0.001$) whereas all other species showed no significant differences (ANOVAs bottlenose dolphin, $p = 0.278$; spotted dolphin, $p = 0.392$; sperm whale, $p = 0.233$). The common dolphin (Figure 4a) showed some association with seamounts. Highest observations per square kilometre per hour were recorded close to seamount summits (Dunnett (10 km) $p < 0.02$; Dunnett (20 km) $p < 0.01$; Dunnett (30 km) $p > 0.05$). On the other hand, bottlenose dolphins (Figure 4b), spotted dolphins (Figure 4c), and sperm whales (Figure 4d) showed no association with seamount and were not more abundant in the vicinity of these features.

The analyses of the number of loggerheads per square kilometre per hour (Figure 5) showed no differences with distance to seamount summits (ANOVA sea turtles, $p = 0.403$). As for seabirds, the distance to seamount summit influenced the abundance of Cory’s shearwater (ANOVA $p << 0.001$). The abundance of Cory's shearwater (Figure 6a) was higher in the first 20 km from the seamount summit. However, only the second distance bin (10-20 km) was significant higher than the overall mean (Dunnett 10 km $p > 0.05$; Dunnett (20km) $p < 0.01$; Dunnett (30 km) $p > 0.05$). Terns (Figure 6b) and yellow-legged gull (Figure 6c) abundances where not different at different distances from seamounts (ANOVA yellow-legged gull, $p = 0.364$; terns, $p = 0.998$).

DISCUSSION

In this study, we were able to map and describe 63 large and 398 small seamount-like features in the whole EEZ of the Azores. Our approach showed that peaks and seamounts are common features in the Azorean EEZ. A comparison with other topographical studies of the Mid Atlantic Ridge show that our average density of 3.3 peaks of all sizes per 1000 km^2 is in the same order of magnitude of that obtained by Batiza et al. (1989) but is an order of magnitude lower than obtained by Smith & Cann (1990) and by Jaroslow et al. (2000). The discrepancies observed in relation to the latter studies are probably due to the fact that they focused only in the immediate vicinity of the ridge, an area with exceptionally rugged topography (Smith & Cann 1990).

It must be emphasized, however, that there are some potential sources of uncertainty in this study. First, the bathymetry of the Azores EEZ is not perfectly known and most of its seafloor remains to be surveyed by ship-borne acoustic methods. Both bathymetry datasets used (Lourenço et al. 1999, Smith & Sandwell 1997) may lack resolution and thus preclude the identification of a significant number of small seamount-like features. For this reason, our references to seamounts should be interpreted as potential seamounts. A better but very costly solution would be to perform extensive multi-beam surveys that would provide not only excellent bathymetric data for mapping seamounts and estimating depths, areas and slopes but also backscatter data for mapping the nature of the seafloor.

This study has also demonstrated that some marine predators are associated with seamounts with quite shallow summits. This was the case of tuna species skipjack and bigeye, common dolphin and Cory's shearwater. These species were significantly more abundant in the vicinity of some seamount summits than in other locations further away from these features.

Seamounts probably localize pelagic prey and thus attract some species of pelagic fish, seabirds and marine mammals. That is, some seamounts in the Azores may act as feeding stations for some of these visitors. Tuna species such as skipjack and bigeye have previously been known to occur on seamounts but this study is the first to quantitatively demonstrate the spatial characteristics of these associations. Common dolphins are known to feed mostly on small pelagic fish and squids (Silva 1999) and may, therefore, take advantage of the localized abundance of these prey items on seamounts. As for seabirds, our results support the findings of Monteiro et al. (1996) who inferred from stomach contents data that Cory's shearwaters feed often in association with seamounts. Our methodology, however, failed to demonstrate a seamount association for bottlenose dolphins, spotted dolphin, sperm whale, terns, yellow-legged gull, and loggerhead sea turtles. Whereas for some species the lack of association with seamounts seems reasonable for others is more difficult to explain (see details in Morato et al., 2008b).

Some seamounts should be considered hotspots of marine life in the Azores and a special effort should be made in order to ensure a sustainable management of these habitats. These seamounts are also known to be heavily exploited by local fishermen and thus reconciling fisheries with conservation on these seamounts should be a priority for the local management authorities. Management strategies should recognize that the area of influence of the seamounts seemed to be about 20 to 30 km from the peak.

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FIGURES

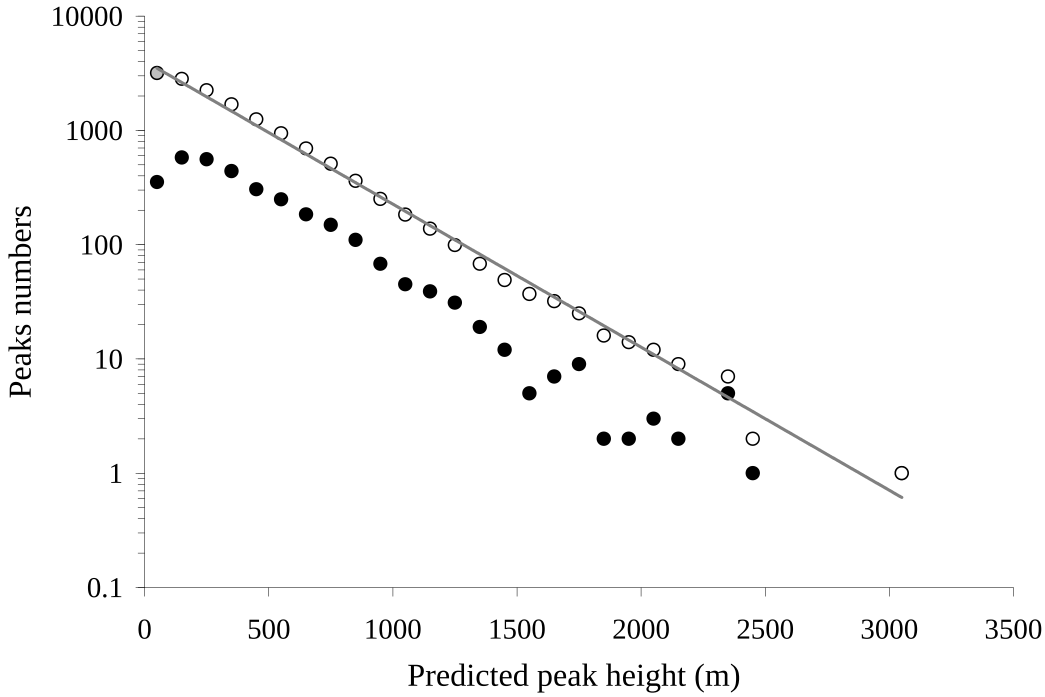

Figure 1 – Height (*h*) frequency distribution of all identified peaks. Solid circles are actual counts while open circles are the cumulative counts. The grey circle data point was excluded from the exponential model fit. The relationship can be expressed as $N = 4041.8 \cdot e^{-2.89 \cdot h}$, with *h* in km; $r^2 = 0.99$. If expressed by unit area (km^{-2}), $\nu(H) = 4.31 \cdot e^{-2.89 \cdot h}$.

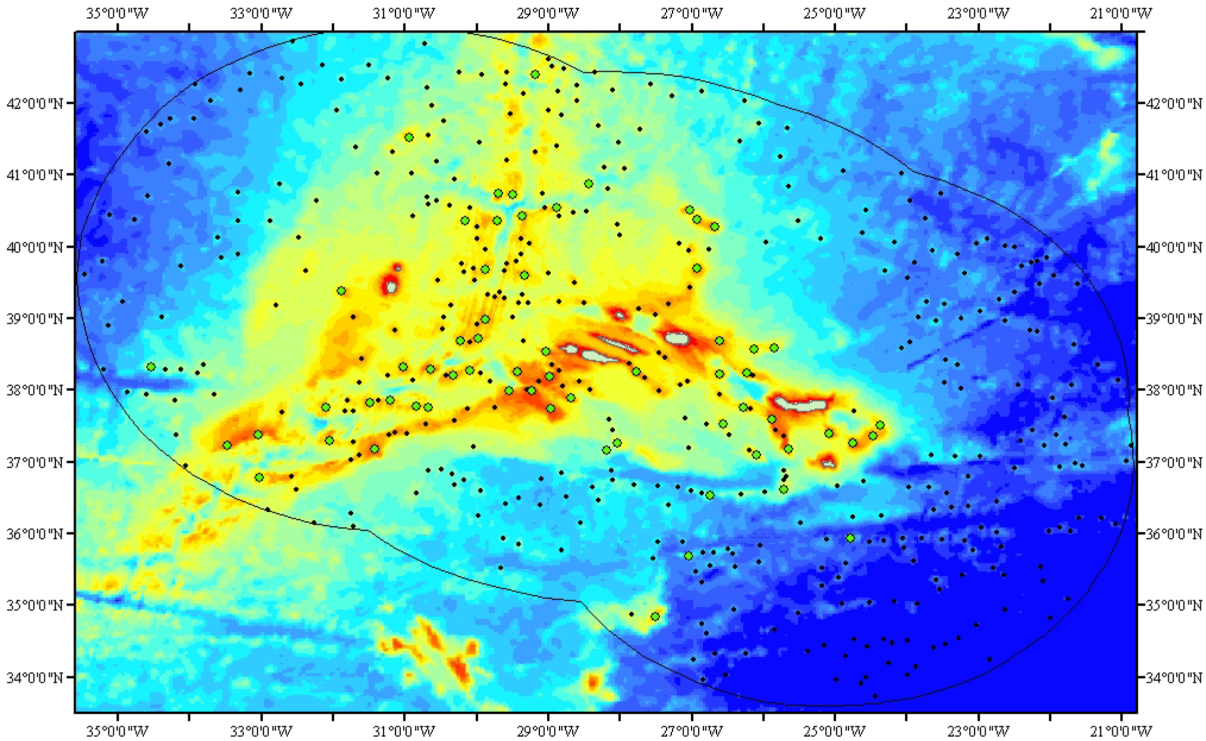

Figure 2 – Distribution of seamounts in the Azores Economic Exclusive Zone (black line). Green circles show large seamounts while black dots show small seamount-like features. Scale goes from dark blue (deep water; about 5000 m) to dark red (shallow water).

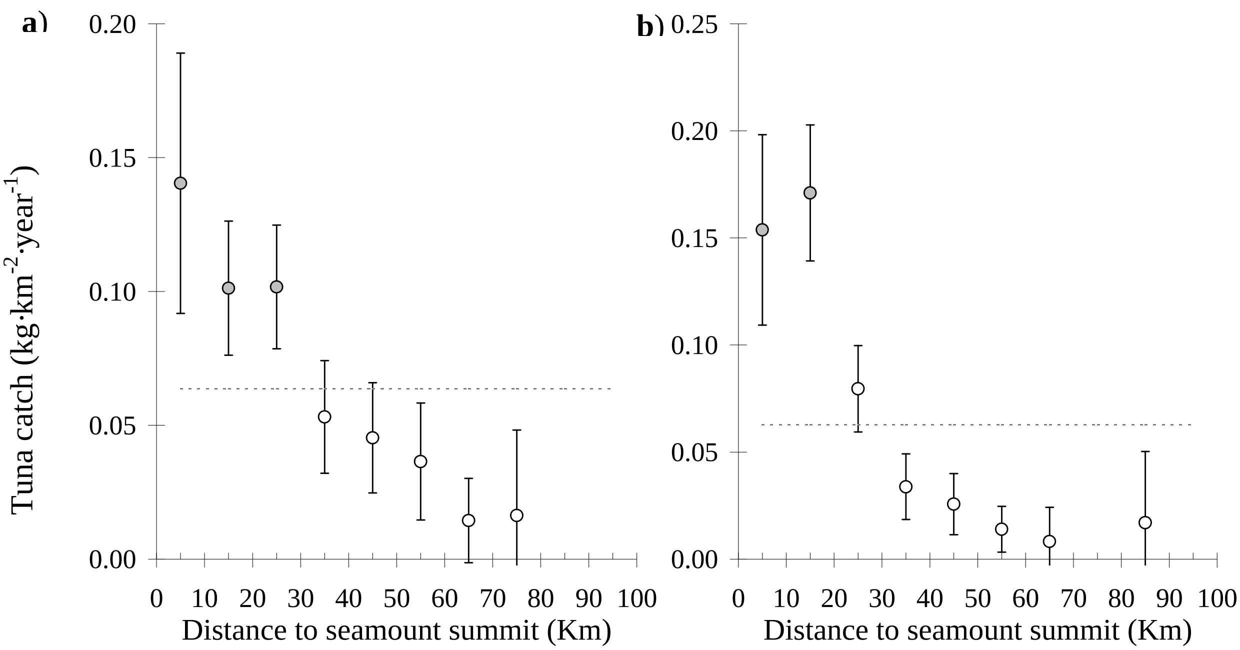

Fig. 3. Tuna catch per square kilometre per year (±95% CL) in relation to the distance to the nearest seamount summit in the Azores. a) skipjack, b) bigeye tuna. Bin size is 10 km. Light grey circles are significantly higher (Dunnett test) than the overall mean (light grey line).

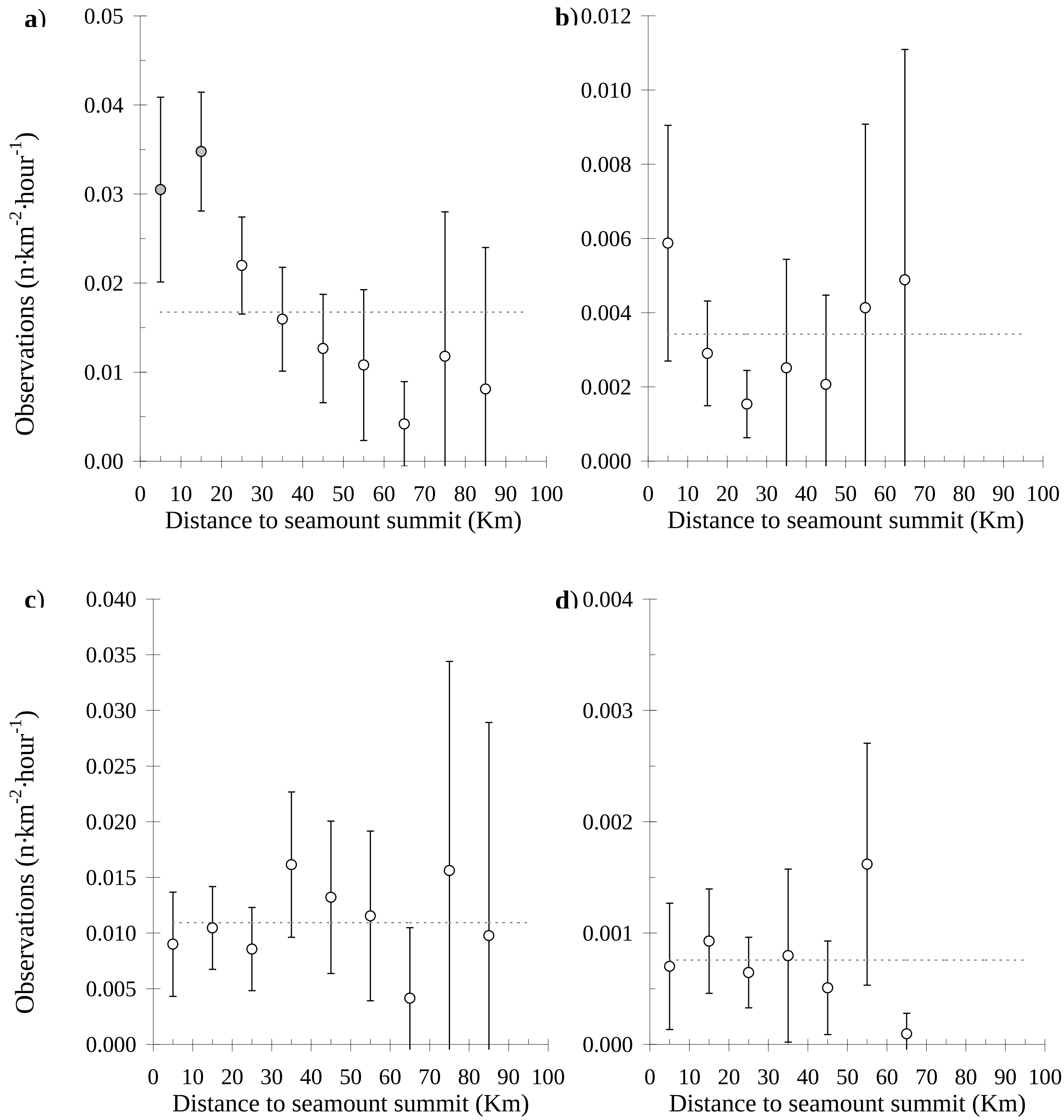

Fig. 4. Marine mammals sightings per square kilometre per hour (±95% CL) in relation to the distance to the nearest seamount summit in the Azores. a) common dolphin, b) bottlenose dolphins, c) spotted dolphin and d) sperm whale. Bin size is 10 km. Light grey circles are significantly higher (Dunnett test) than the overall mean (light grey line).

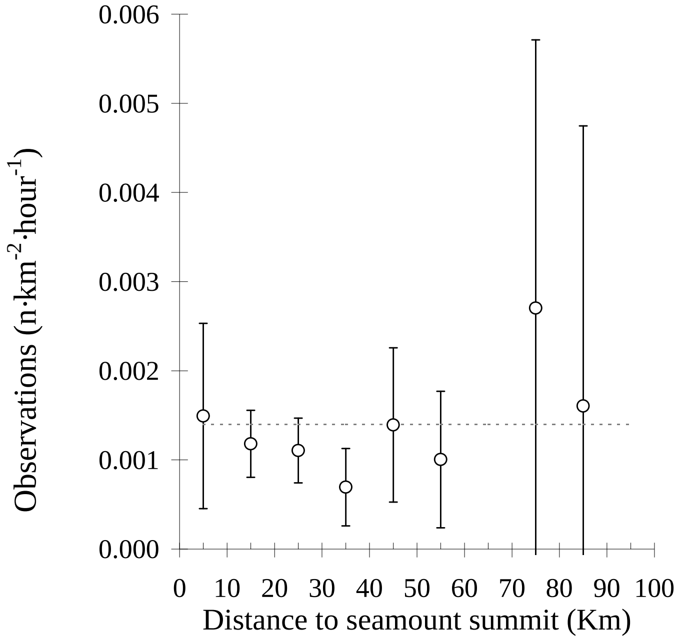

Fig. 5. Loggerhead turtles sightings per square kilometre per hour (±95% CL) in relation to the distance to the nearest seamount summit in the Azores. Bin size is 10 km.

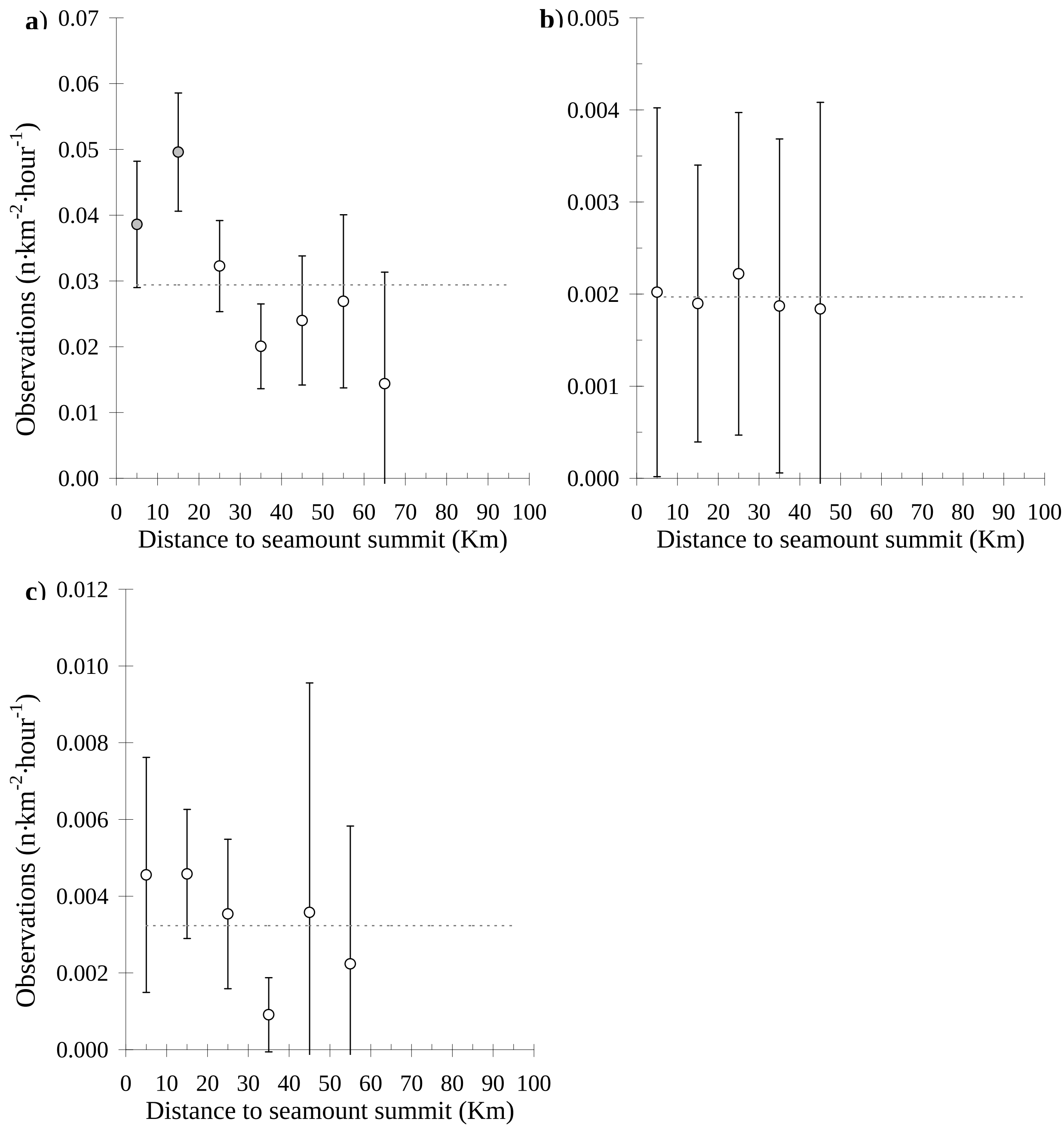

Fig. 6. Seabirds sightings per square kilometre per hour (±95% CL) in relation to the distance to the nearest seamount summit in the Azores. a) Cory's shearwater, b) terns, c) yellow-legged gull. Bin size is 10 km. Light grey circles are significantly higher (Dunnett test) than the overall mean (light grey line).