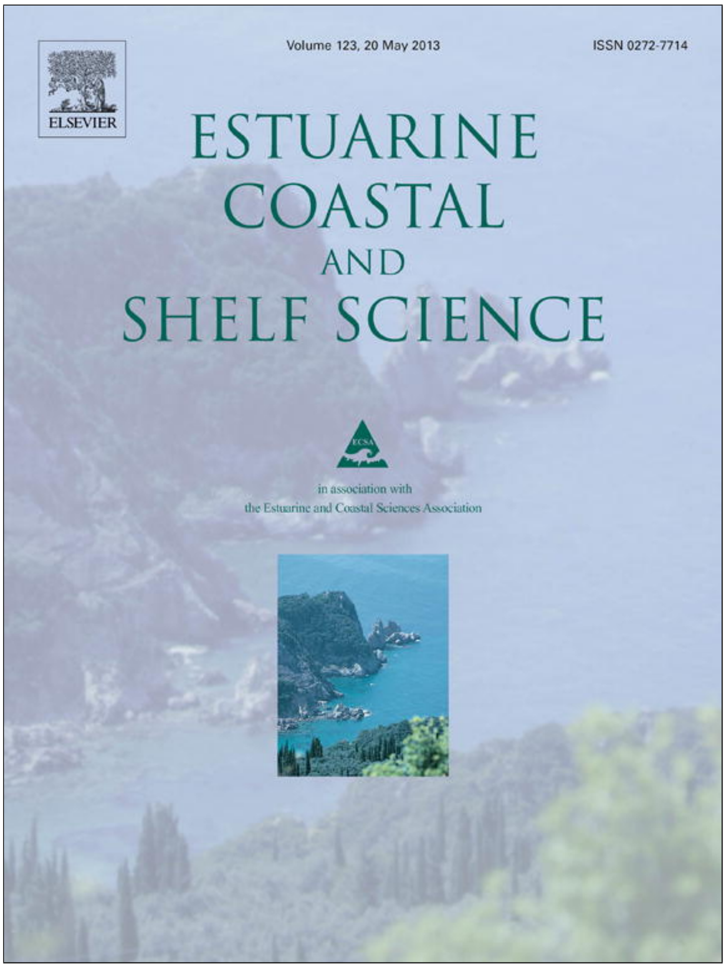
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Use of marine space by Black-browed albatrosses during the non-breeding season in the Southwest Atlantic Ocean

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ABSTRACT

Marine birds like albatrosses have shown a profound deterioration of their conservation status in recent years. The Black-browed albatross (*Thalassarche melanophris*) is the most abundant threatened albatross species in the Southwest Atlantic continental shelf. Declines in their breeding populations have been largely attributed to the impact of incidental mortality in fisheries. Data on at-sea distribution for the species during breeding is abundant, but movements of individuals during winter are poorly known. Here, we investigate the at-sea distribution of Black-browed albatrosses during the non-breeding seasons 2011 and 2012. Eleven adult individuals were captured at-sea and equipped with satellite tags. Distribution of tracked Black-browed albatrosses was mostly restricted to waters within the continental shelf of Argentina, Uruguay and southern Brazil; from 29° to 51°S. Two large marine areas, comprising the ca. 90% of the core area (50% utilization distribution) were identified; one from the mouth of Rio de la Plata toward the E and SE reaching the shelfbreak, and another in El Rincón estuary and waters to the South. Tracked birds were distributed over nine oceanographic regimes in the SW Atlantic continental shelf, spending between 5 and 34% of their time at sea in marine fronts of high productivity such as Río de la Plata, Los Patos lagoon estuary front, the shelfbreak and the mixed front. The identified core areas could be considered as proxy indicators of priority areas at the time of implementing conservation measures for the species. The analysis of overlapping with fisheries on the Argentinean Continental Shelf will provide further insights about critical areas where those measures should be more stringent.

1. Introduction

In recent years albatrosses and large petrels have shown a profound deterioration of their conservation status (Croxall et al., 2012). A large proportion (c. 80%) of the 22 albatross species are threatened with extinction (BirdLife International, 2012a). The Black-browed albatross (*Thalassarche melanophris*, herein BBA), is listed by the International Union for the Conservation of Nature as Endangered due to the steep decline observed at the large breeding colonies in the Southwest Atlantic (BirdLife International, 2012b), largely attributed to the impact of incidental mortality in longline and trawl fisheries (Croxall et al., 2012). Because of its conservation status, this species has also being listed in the CMS Appendix II (Convention on Migratory Species, 2000) and in Annex 1 of the Agreement on the Conservation of Albatrosses and Petrels (ACAP, 2012a). The total breeding population is estimated in 600,000 pairs, 70% of which breed in the Malvinas/Falkland Islands, 20% in Chile and 10% in South Georgia Islands (ACAP, 2012b and references therein). Given that threats to BBA are predominately at-sea based (i.e. mortality in fisheries), there is an urgent need to better understand its spatial distribution, mainly for the Southwest Atlantic Ocean where the species is more abundant and largely attend a range of fisheries (Favero and Silva Rodriguez, 2005; Arata et al., 2009; Consejo Federal Pesquero, 2010). For many albatross species the at-sea distribution during the breeding and non-breeding periods show marked differences (BirdLife International, 2004). For the BBA, data on the at-sea distribution of adults during the breeding period is well known for populations in Malvinas/Falkland (Huin, 2002; Granadeiro et al., 2011), South Georgia (Phillips et al., 2008), Macquarie (Terauds et al., 2006) and Diego Ramirez islands (BirdLife International, 2004). However, for the non-breeding period the information is more scarce and mostly coming from Diego Ramirez in the SE Pacific (BirdLife International, 2004) and South Georgia populations (Phillips et al., 2005; Petersen et al.,

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2008), with an important asymmetry with what is known in the SW Atlantic. To our knowledge, there are only two published studies from late 90's, using remote sensing technologies to assess the distribution of BBA from Malvinas/Falkland colonies during the time off breeding (Grémillet et al., 2000; BirdLife International, 2004). Grémillet et al. (2000) used geolocator (GLS) tags, technology that provides geographic locations of low spatio-temporal resolution, with just two fixes per day with and an average error of c. 200 km (Phillips et al., 2004). These devices can be used to obtain broad-scale habitat preferences of animals, but in order to identify important marine areas or characterize interaction with fisheries a higher spatio-temporal resolution is needed. Meanwhile data from the Tracking Ocean Wanderers (BirdLife International, 2004) combined platform terminal transmitters (PTT) and GLS data and identified broad-scale density areas. In this paper we present the at-sea distribution of BBAs during the non-breeding season by means of satellite telemetry (PTTs), identifying important marine areas of high density in the SW Atlantic continental shelf and broadly characterizing the oceanographic features of those areas in compliance with objectives defined in the Argentinean National Plan of Action – Seabirds.

2. Methods

A total of 11 satellite transmitters was deployed (battery-powered PTTs, K3H 179A KiwiSat303 Sirtrack® and TAV-2656 Telonics Inc.) on adult birds (age inferred by bill color, (Bugoni and Furness, 2009) during the wintering period 2011 and 2012 (June–September, Table 1). The tags weighted 63 and 55 g, respectively, representing less than 1.6% of the adult body mass (mean = 4 kg, $n = 31$, Seco Pon unpubl. data), well under the maximum 3% recommended to avoid any adverse effects on bird behavior (Phillips et al., 2003). Albatrosses were captured at sea from fishing vessels using hoop nets and released approximately at 42°S near the shelfbreak in 2011 and at 38°S some 30 nm offshore in 2012 (Fig. 1B). The tags were attached to the back feathers with Tesa® tape and zip ties. The gender of birds was determined by DNA techniques, with blood samples taken by pricking a vein in the foot and absorbing a small droplet of blood onto a commercial filter paper (Quintana et al., 2008).

Tags were programmed to transmit with a duty cycle of 8 h on (0900–1700 h local time, -3 GMT) and 16 h off in 2011, and 12 h on (0600–1800 h local time) and 12 h off in 2012. On average, 7.1 positions (range: 3–18) were obtained per duty cycle in 2011 and 12.5 locations (range: 3–16) per duty cycle in 2012. Position fixes for satellite-tagged albatrosses were received from the Argos System (CLS America, Inc., Largo, Maryland, USA) using the Satellite Tracking and Analysis Tool to download the data (Coyne and Godley, 2005). We used all Argos locations (accuracy classes A, B, Z, 0, 1–3), after filtering positions accordingthe bird's flight speed (maximum velocity was set at 100 km h^{-1}) (BirdLife International, 2004). This speed filter removed 9% of the received positions (425 out of 5288). Standard locations (classes 3 to 0) accounted for the most (82%) of gathered fixes. Tracks were re-sampled at 30 min intervals, assuming that the bird moved along a straight line between positions (no assumptions were made about the bird's locations along the track during the "off" cycle for PTTs).

Density maps were generated with kernel home-range utilization distributions (UD, based on Worton, 1989). Kernel density analyses have been used successfully to quantify habitat use in several studies concerning albatrosses and petrels (BirdLife International, 2004). The UDs provides a probability indicating the relative proportion of the distribution within a particular area. The smoothing parameter (h) was 50 km and contour levels were estimated for 50% (core area), 75% (focal region) and 95% of the locations (Hyrenbach et al., 2006). Core areas were used as a proxy for the definition of important marine areas. Oceanographic regimes were characterized based on properties of surface waters, vertical stratification, ocean fronts and marine circulation following Piola (2009); and tidal fronts were mapped according to Rivas et al. (2006). Nine oceanographic regimes (including tidal fronts) were considered: (1) Patos (i.e. Los Patos lagoon estuary front), (2) Plata (Río de la Plata estuary), (3) Subtropical, (4) Mixed, (5) Sub polar, (6) Shelf Break, (7) Open Shelf, (8) Magellan and (9) Tidal fronts. The percentage of time that birds spent in each oceanographic regime was calculated following Copello et al. (2011). These analyses were

Table 1
Summary of the tracking procedures.

PTT Id	Sex	Tracking device	Deploy location	Start/end tracking[a]	Days	Number of analyzed locations
41132	F	K3H179AKiwisat303	41°37′57.4″S 58°32′30.9″W	19/06/2011 22/06/2011	4	31
41120	F	K3H179AKiwisat303	42°00′35.2″S 58°27′46.5″W	20/06/2011 21/06/2011	1	14
41128	F	K3H179AKiwisat303	42°02′33.5″S 58°26′53.8″W	20/06/2011 26/06/2011	6	53
41134	F	K3H179AKiwisat303	42°12′28.0″S 58°30′04.4″W	20/06/2011 30/09/2011	100	942
41133	F	K3H179AKiwisat303	42°14′17.9″S 58°31′16.2″W	20/06/2011 30/09/2011	100	931
41130	M	K3H179AKiwisat303	42°15′45.5″S 58°32′48.4″W	20/06/2011 08/09/2011	78	728
41135	F	K3H179AKiwisat303	42°15′32.9″S 57°35′45.6″W	20/06/2011 21/06/2011	1	14
114010	F	TAV-2656	38°15′16.8″S 56°57′44.4″W	13/06/2012 15/06/2012	3	33
114013	M	TAV-2656	38°15′16.8″S 56°57′44.4″W	13/06/2012 19/07/2012	36	501
114017	F	TAV-2656	38°15′16.8″S 56°57′44.4″W	13/06/2012 15/06/2012	3	25
114018	F	TAV-2656	38°15′16.8″S 56°57′44.4″W	13/06/2012 30/09/2012	107	1591
Total						4863

[a] PTTs 41134, 41135 and 114018 transmitted until October but we only included data from June to September in our data analysis.

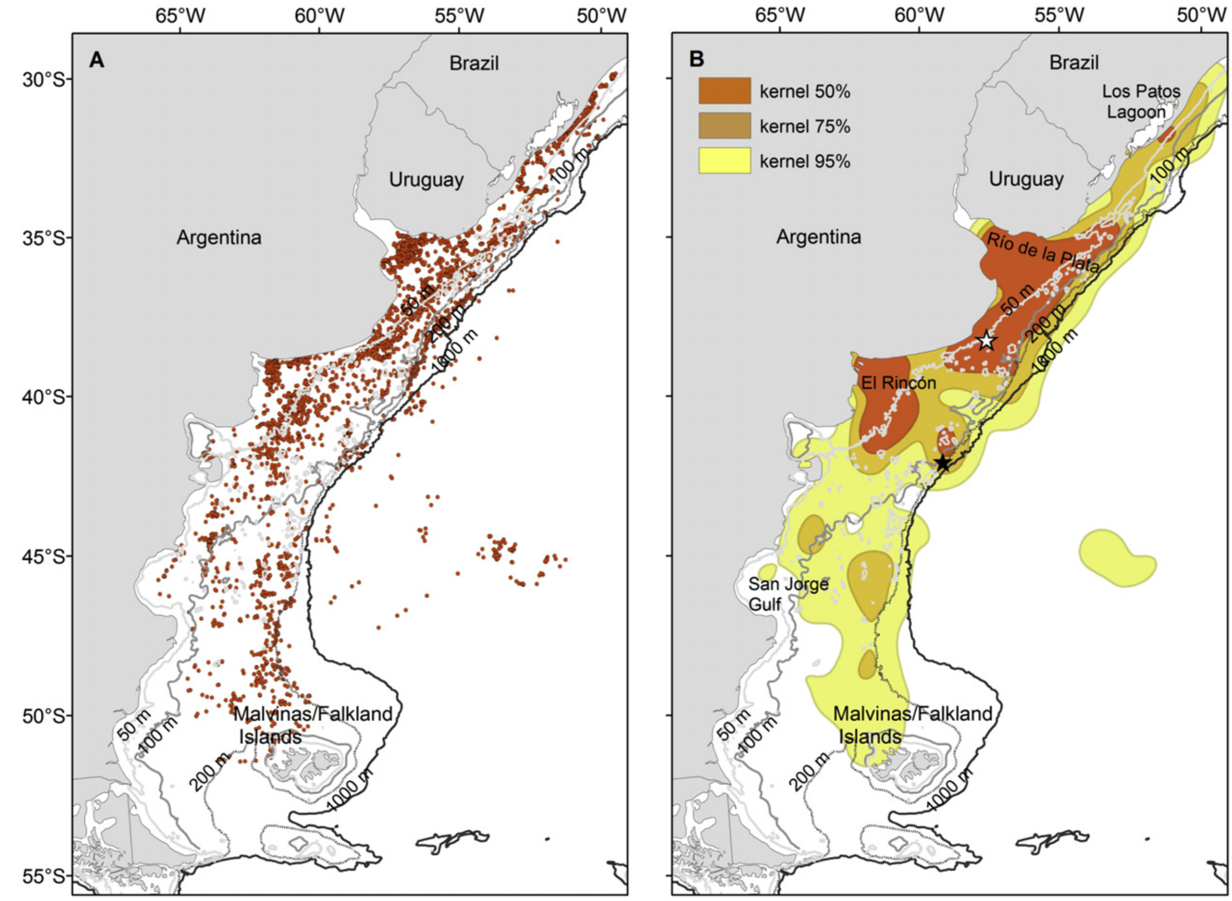

Fig. 1. (A) At-sea distribution (filtered locations) of Black-browed albatrosses during the non breeding period 2011–2012; (B) utilization distributions for 50% (core area, dark orange), 75% (focal region, mustard yellow) and 95% (light orange) of locations. Stars symbol show locations of capture and release of BBA in 2011 (black star) and 2012 (white star). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

only performed with individuals transmitting for more than 30 days ($n = 5$; 6629 fixes).

Spatial analysis (package *adehabitat*) (Calenge et al., 2009) and statistical analysis were perform using R 2.15 and ArcGIS 10.

3. Results

A total of 4863 BBA fixes were obtained during the study period. Birds were tracked for an average of 40 days (SD = 46.2, maximum 107 days) with six BBAs transmitted for less than seven days (Table 1). Distribution of BBAs was mostly restricted to waters within the continental shelf of Argentina, Uruguay and southern Brazil. Only one individual explored waters beyond the shelf break at about 44°S 50°W. Birds ranged from about 29° to 51°S and from the high seas (48°W) to neritic waters (66°W) (95% UD), covering a foraging area of c. 1,100,000 km^2 (95% UD), while the core area (50% UD) was just one fifth of the total area (c. 220,000 km^2). Four core areas of distribution were identified, two small located in southern Brazil and above the shelf break at 41°S 58°W, and two large, one from the mouth of the Rio de la Plata to the shelf break including waters off Southern Uruguay, and another located in El Rincón area and waters to the South. Focal areas (75% UD) included three additional areas of Southern Patagonian Shelf, one coastal in the north of San Jorge Gulf between 44° and 45°S, and two pelagic along the shelf break between 45°–47°S and 48°–49°S (Fig. 1a, b).

The analysis of distribution in relation of pre-defined oceanographic regimes (see methods, $n = 5$; 6629 fixes) indicated that the Open Shelf was widely used by all birds analyzed, spending between 55 and 89% of their time in this area. Tracked birds also explored the oceanographic regime of Río de la Plata estuary during 18% (SD = 14%) of the time at sea. Only one bird spent 34% of its time at sea in the Patos estuary regime. Some 60% of tracked birds used the shelf break and the mixed regime during the non breeding period (7%, SD = 6.7% and 5%, SD = 6.2%, respectively). In less than 5% of their time at sea, BBAs used the subtropical, sub polar and Magellan regimes and Tidal fronts (Fig. 2).

4. Discussion

Although based on a limited sample size this study on at-sea distribution of Black browed albatrosses during the non-breeding period showed novel and important information about the species' habitat use. We assume that tags transmitting for a short period of time simply detached from birds due to failures occasioned by non-optimum weather conditions (i.e. moisture) at the time of attachment (Wilson et al., 1997). Future studies will likely consider the possibility of using harnesses to secure the PTT.

While most of the time, tracked BBAs (assumed to breed in Malvinas/Falkland Islands) explored marine areas within the continental shelf and reaching north up waters of southern of Brazil, non-breeding BBAs tracked in South African (and likely breeding in Sough Georgia Islands) waters have used not only the continental shelf (Phillips et al., 2005) but also frequently performed trips into oceanic waters (Petersen et al., 2008). This contrasting foraging behavior within the same species could be attributed to differences in the oceanographic landscapes of both continental shelves,

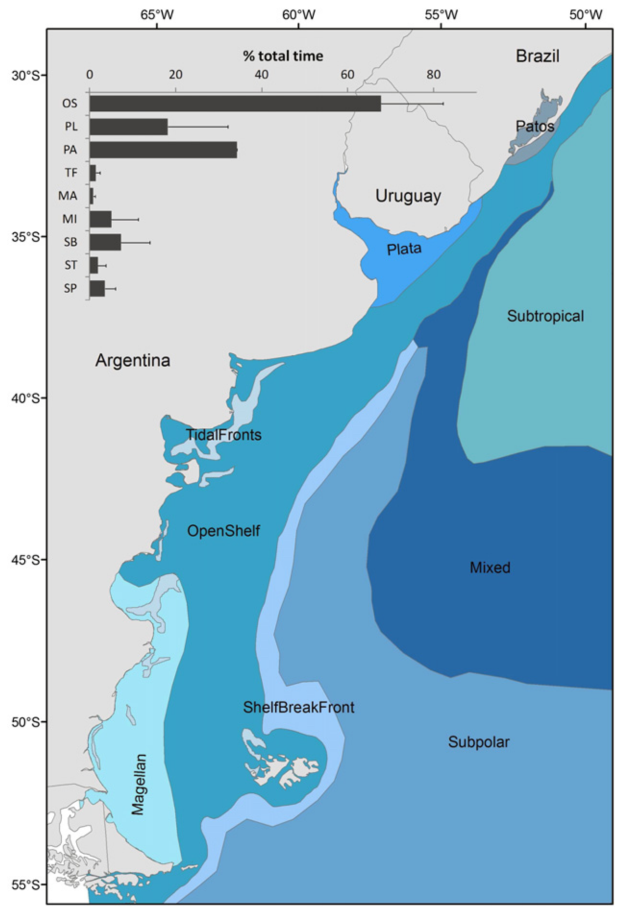

Fig. 2. Oceanographic regimes in the Southwest Atlantic continental shelf, and the proportion of time spent by Black-browed albatrosses in these regimes during the non-breeding period 2011–2012 (inset). OS: Open shelf, PL: Plata (Río de la Plata estuary), PA: Patos (Los Patos lagoon estuary front), TF: Tidal fronts, MA: Magellan, MI: Mixed, SB: Shelf break front, ST: Subtropical and SP: Sub polar. TF adapted from (Rivas et al., 2006), all other oceanographic regimes from (Piola, 2009).

variations in the composition of seabird assemblages in these areas leading to differences in inter-specific competition, differences in the distribution of prey, or a combination of them. Moreover, during the breeding period BBAs from Malvinas/Falkland Islands also were distributed over the continental shelf but only restricted to waters south 41°S (Huin, 2002).

Important marine areas for BBAs (defined by 50% UD core areas) were located within the continental shelf. Two important marine areas, comprising the 88% of the core area were identified in this study, one at the mouth of Rio de la Plata toward the East and covering c. 150,000 km^2 and another in El Rincón estuary and waters to the South covering an area of c. 60,000 km^2. These core areas don't match those previously reported for non-breeding tracked BBAs from Malvinas/Falkland Islands, located further south on the continental shelf between 45° and 50°S (Grémillet et al., 2000). Despite different accuracies of fixes from both datasets (i.e. GLS vs. PTTs), differences in the location of core areas are most likely due to the time of the year reported (start of transmission on April for GLS data vs. June for PTT data), and/or changes in the distribution of food sources (i.e. natural prey and/or fishery discards).

Core areas were located in marine areas of high productivity and weak seasonality. Particularly, the Río de la Plata estuary and marine neighboring waters is one of the most important estuarine environments in South America (Acha et al., 2008). Many top predators breeding in South America or coming from distant regions use those marine areas, namely the Southern Sea Lion *Otaria flavescens* (Rodríguez et al., 2012), sea turtles (López-Mendilaharsu et al., 2009; González-Carman et al., 2012), penguins (Pütz et al., 2000; Boersma, 2008) and a number of albatross and petrel species (BirdLife International, 2004; Nicholls et al., 2005). Although there exist an Argentinean-Uruguayan Commission dedicated to the management of resources in these waters (Comisión Técnica Mixta del Frente Maritimo, www.ctmfm.org), neither specific management measures for the protection of top predators have being developed nor implemented so far. Incidental mortality of BBAs has been reported in longliners and trawlers in the above-mentioned marine areas (Favero et al., 2010, 2013), hence these core areas could be considered, at least on a provisional basis, of high priority at the time of implementing conservation measures to mitigate incidental mortality in fisheries (among other threats seabirds might be facing). On the other hand, BBA bycatch has been reported in pelagic longliners operating in offshore areas in Southern Brazil and Uruguay (Bugoni et al., 2008; Jiménez et al., 2009). Most of the reported captured birds were juveniles; consequently, age-class segregation on the habitat use could be occurring during the winter period as was reported for other albatrosses species (BirdLife International, 2004).

All the oceanographic regimes of the Southwest Atlantic continental shelf considered in this study were used by tracked BBAs, varying from 1 to 68% of the time spent at-sea. Such differences could be linked to a combination of the relative size and productivity within each area (Acha et al., 2004, 2008) and the distribution of the fishing effort (Louzao et al., 2011), among others. As it was previously mentioned, knowing the important interactions between BBAs and longline and trawl fisheries in the Southern Ocean (Watkins et al., 2008; Favero et al., 2010, 2013) differences in the time spent in marine fronts might also be, at least partially, driven by the distribution of the fishing effort by fleet in either area. For example, changes in the foraging behavior due to association with vessels have been reported for the white-capped albatross *Thalassarche steadi* breeding in the Auckland Islands archipelago in the New Zealand sub-Antarctic (Torres et al., 2011). Only in the Argentine continental shelf, some 800 vessels operate throughout the year including demersal longliners, ice and freezer trawlers and jiggers (Consejo Federal Pesquero, 2010) and their distribution largely varies within the year (S. Copello unpubl. data), hence likely affecting the intra and interannual variability in the distribution of seabirds.

Further information about the at-sea distribution of BBAs during winter is needed in order to broaden the database and the understanding factors driving such distribution. Data on more adults as well as juveniles during the non-breeding season will allow a more comprehensive spatial modeling of this species in the SW Atlantic continental shelf, gender and age differences included. It will be also crucial to include in further studies information about the spatial distribution of fishing effort in order to address threats at sea and also take into account the availability of fishery discards as another factor driving the distribution at-sea.

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