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Distribution of seabird bycatch at WCPFC and the neighboring area of the southern Hemisphere

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Abstract

Incidental mortality of bycatch of seabirds, congregating around tuna longline fishery vessel and hooked branch lines seems one of the major risks for conservation of Procellariiforme species. Our study described distribution of the bycatch CPUEs of those species in the ocean of southern hemisphere, and examined their spatial and seasonal patterns. The distribution and the occurrence were compared with those in other area. Then, the area where mitigation measure should be introduced was discussed. Data from scientific observer programs, data from fishing boats for high school training and chartered research boats were used for the analyses. Bycatch CPUE (number of seabirds/ 1000 hooks) was calculated by species or species groups by 5x5 degree blocks, and its spatial distribution was presented. Operation data in the southern hemisphere were obtained mostly off South African water, off Chile water, southeast Indian Ocean and the Tasman Sea. By-catch CPUEs of seabirds were the highest in the Tasman Sea in WCPFC conventional area but the value was smaller than that in high interaction area out of the WCPFC area. In the southern WCPFC area, bycatch CPUE of albatrosses was observed more than that of petrels. Albatross species, mostly wandering albatrosses, black-browed albatrosses, Buller's albatrosses, and shy albatrosses, were caught in the Tasman Sea. On the other hand, white-chinned petrels and flesh-footed shearwaters, which are thought to dive deeper than albatrosses and by-caught frequently in the Atlantic and Indian Oceans, were not caught in the Tasman Sea. Albatrosses of higher conservational risks were exclusively caught in the area south of 25S, which indicates effective mitigation measures need to be introduced in the area. With the data from the WCPFC area, capture of white-chinned petrels did not statistically accounted for simultaneous capture of albatrosses and giant petrels in our data. A previous study showed that attack of white-chinned petrels against baited hooks lead bycatch of albatrosses in pelagic longline off south African water (Melvin et al. 2009), and relatively lower CPUEs of total albatrosses in the WCPFC area than the others could also be at least partially attributed to this fact. However, in the case of the Tasman Sea, albatrosses of higher conservation risks such as wandering albatrosses were by-caught without diving petrels. It is likely that the bycatch mechanism in the Tasman Sea differ from that off South Africa. To clarify the mechanism, more data and researches are needed in the Tasman Sea.

Introduction

The problems of seabird bycatch in longline fisheries are thought one of the risks of the seabird conservation (Brothers 1994). From now, necessity to conserve the seabird has been led to develop several kind of bycatch mitigation technologies and those have been deployed by many pelagic longliners (Kiyota 2002, Yokota & Kiyota 2008).

Community, abundance and aggressiveness toward pelagic longline operation of seabirds are geographically varied. Around off South African water, it is reported that huge number of seabirds aggregate operating pelagic longline vessels and intensely attack toward baited hooks, which has been made mainly by diving seabirds (Melvin et al. 2009). In the case of North Pacific, the situation is very different that the number of species aggregated and their attacking rate during pelagic longline operation is quite less than those of the off South African water and that there are no deep divers (Sato et al. 2010). Thus, seabird aggressiveness and the bycatch risk would differ among regions. To apply appropriate mitigation measures onto such area, we have to made a risk analysis about distribution of incidental mortality by pelagic longline and determine hotspots of seabird bycatch.

Kirby et al. (2009) and Filippi et al. (2010) presented spatial risk assessment about Pacific seabird community, based on the data of seabird distribution collected by the remote tracking, estimation from literature and distribution of fishing effort of pelagic longline fisheries. These analysis demonstrated the risk index by calculating the overlaps between seabirds and fishing effort distributions. However, these analyses depended on some insufficient data of the seabird distribution and probability of bycatch for each species would depend on the behavioral traits of each species or interaction with other seabirds. Therefore, it is likely that some species defined as high risk species may not be caught even in the overlap area.

At-sea distribution or foraging effort of seabirds seems to change seasonally according to phenology; laying an egg, rearing a chick and migrating. For example, some petrels migrate between wide range, which should change their habitat seasonally. Also, during chick-rearing period, a parent would be restricted their foraging range in order to return to its colony for a chick provisioning and would increase foraging effort in order to feed for a chick. Thus, it is important to closely examine seasonal distribution of each seabird species.

In our study, distributions of seabird bycatch were presented using data collected by Japanese observers, fishing boat for high school training and chartered research boats in 1992-2010 in the southern part of the WCPFC area. For the fragile species of which population decreased into the concerned level, or of which CPUEs were high around WCPFC area of southern hemisphere, distribution patterns of the bycatch CPUEs were described by season and the hotspots to introduce bycatch mitigation measure was discussed.

Methods

We used bycatch data of seabirds collected by science observers for commercial longliners, training vessels of high schools as well as, chartered research boats. Majority of data was collected by first two data sources as volunteer bases. The data from observer programs in the southern bluefin tuna operation were obtained during 1997-2010 and the data from high school fishing boat for training and chartered research boats were obtained during 1992-2010. In majority of cases, quality of data of seabirds were maintained by giving special lectures on each observers and species identification were conducted using photos taken by observers in the designated from described in the species identification guide (Nakano 2002). In this study, the older classification system for the species identification of albatrosses was used because of the difficulty to identify some newly described albatross species in the most recent year.

Using these data, the number of bycatch seabirds and number of hooks were collected into a grid of 5°x5° respectively. And the catch numbers of seabirds were divided by number of hooks and made 1000 times to obtain average CPUE values of seabirds at each 5°x5° grid. The mitigation measures of seabirds were changed by year, area, season and even by vessels and this should give some large influences on the degree of bycatch of seabirds, but these effects were not accounted for the calculation of average CPUEs of each 5°x5° grid. For the species with higher occurrence around WCPFC of south hemisphere, the quarterly CPUE distributions (January-March, April-June, July-September and October-November) were presented.

To examine the number of bycatch of albatrosses would increase when white-chinned petrels exist, we applied generalized linear model analyses (GLMs) with Poisson error distribution. We assumed the number of bycatch of all albatrosses and giant petrels as a dependent variable, the number of bycatch of white-chinned petrels as an independent variable with one operation as one unit as follows;

$$ALB+MAC=WHI+\varepsilon$$

where ALB+MAC; the number of bycatch of all albatrosses and giant petrels at the operation, WHI; the number of bycatch of white-chinned petrels at the operation, ε; normal error term. The analyses were done in the WCPFC area and out ofWCPFC area of south hemisphere. Analysis was made through the GLM procedure of computer software R (R Development Core Team 2011).

Results

The data of total 2,328 operation and 5,567,941 hooks were obtained in the southern part of the WCPFC area (Table 1). Bycatches of 3 genus, 8 species and 231 individuals of albatrosses, 1 genus, 2 species and 13 individuals of giant petrels, 4 genus, 5 species and 6 individuals of petrels by the longline sets were observed during 1992-2010 (Table 1). Total number of by-caught seabirds was 321 individuals (Table 1). In the WCPFC area, the number of bycatch of giant petrels and petrels were very low compared with the number of albatrosses.

Bycatch CPUEs of total seabirds around the WCPFC area in the southern hemisphere were the highest in the Tasman Sea from April to September but the level is lower than other area out of the WCPFC area (e.g. in off South Africa, the southeastern Indian Ocean, and off Chile water; Fig. 1). The CPUE was quite low around New Guinea Island and Melanesia in south of equator within the WCPFC area (Fig. 1). In total, levels of bycatch CPUE in the WCPFC area was also lower than that in other area (Fig. 1).

Unidentified albatrosses were caught in the Tasman Sea from April to September within the WCPFC area but the value was the highest in off the South African water from April to June and in the southeastern Indian Ocean (Fig. 2). Unidentified petrels were not caught within the WCPFC area (Fig. 3).

Bycatch of wandering albatrosses was observed in the Tasman Sea from April to September (Fig. 4). Black-browed albatrosses were the most by-caught seabirds in the WCPFC area and they were caught in Tasman Sea from April to September and in the southeastern Indian Ocean from July to December (Fig. 5). Bycatch of yellow-nosed albatrosses was rarely observed in the Tasman Sea but substantial number of the species observed in the southeastern Indian Ocean from July to December (Fig. 6). Shy albatrosses were also caught both in the Tasman Sea from April to September and in the southeastern Indian Ocean from July to December (Fig. 7). Bycatch of Grey-headed albatrosses was observed at 175-180W, 50-55S of open sea area from January to March, in the southeastern Indian Ocean in July to December, but not much observed in the Tasman Sea (Fig. 8). Buller's albatrosses were caught in the Tasman Sea from April to September and were not caught much in the southeastern Indian Ocean, only at two blocks from July to September (Fig. 9).

Northern giant-petrels were caught both in the southeastern Indian Ocean from July to December and in the Tasman Sea from April to June but they did not appear in the Tasman Sea from July to September (Fig. 10).

White-chinned petrels were not caught at the Tasman Sea from April to December, but were caught in 135-140W 45-50S from January to March, in the south African water from April to December, in the southeastern Indian Ocean from October to December and off Chile water from July to December (Fig. 11). Flesh-footed shearwaters were not caught in the Tasman Sea during all season but were caught in the southeastern Indian Ocean from July to December (Fig. 12).

To examine whether bycatch number of albatrosses and giant-petrels increased with the number of by-caught white-chinned petrels, we tested GLM analysis. And the analysis indicated that the number of bycatch of white-chinned petrels did not affect the number of bycatch of albatrosses and giant-petrels in the WCPFC area of south hemisphere (GLM; χ^2= 0.418, *P*=N.S., Table 2-1, Table 2-2) but affected out of WCPFC area of south hemisphere (GLM; χ^2= 225.98, $P<0.0001$, Table 2-3) and bycatch number of albatrosses and giant-petrels increased with the bycatch number of white-chinned petrels out of WCPFC area (Table 2-4).

Discussion

Distribution pattern of CPUEs of seabirds

The CPUE distribution pattern of total seabirds (Fig. 1) slightly differed from integration of CPUE distribution pattern of each identified species, because some albatrosses and petrels could not be identified down to species level (Figs. 2 and 3). Old data include more unidentified albatrosses and petrels than recent data and recent data seems to be more accurately identified. This should be considered in the detailed interpretation of the results of this study.

Seabird life phenology, such as a cycle of breeding and migration, seems to affect seabird's distribution or foraging behaviour. In our study, wandering albatrosses were caught in the southeastern Indian Ocean from April to September in 2nd and 3rd quarters(Fig. 3), which supports the reference describing that some individuals come to eastern area from the Iles Clozet and stay in the southeastern Indian Ocean (Brooke 2002). The individuals caught from October to December 4th quater can be ones returning from southeastern Indian Ocean to Iles Clozet. Shy albatrosses have colonies around the Tasman Sea (ACAP 2011, Brooke 2002) so concentration of their bycatch around the colony may indicates capture of the breeding individuals in April which is chick-rearing period, or September which is egg-laying period. (Fig. 7).

Distribution patterns of bycatch in some species were also supported by the existing reference but in the other species were not. For example, grey-headed albatrosses, highly pelagic seabirds, were caught only in open ocean and south of 40S, which corresponds with the reference that their distribution is more south than other albatrosses (Brooke 2002, Fig. 8). Also, distribution pattern of CPUE of northern giant-petrels seems to reflect their habitat (Fig. 10). In the other case, yellow-nosed albatrosses of which bycatch was observed in north of 35S of the southeastern Indian Ocean has not been considered to distribute in that area (Fig. 6). It is the same in the case of Buller's albatrosses of which bycatch was observed in the southeastern Indian Ocean (Fig. 9). The results of this study indicates that the CPUE distributions of some albatrosses and petrels were not exactly coinciding with the their distribution pattern estimated by satellite or electric tagging studies. Further analysis should be necessary to clarify the reasons of these observed differences.

Our result also indicates that nature of pelagic seabird distribution can be changed by longline fishery activity. The results of this study showed that substantial number of black-browed albatrosses which is thought to distribute mostly continental shelf or shelf-break areas (Brooke 2002) was even caught out of such area (Fig. 5). They might exploit fishery-originated food sources around Australia or have the habit to make feeding excursions to the pelagic area.

Compared with the case of albatrosses, petrels were rarely caught in the Tasman Sea(Table 1). Although white-chinned petrels are previously reported to distribute in the Tasman Sea during April to September (ACAP 2011, Brooke 2002), they did not caught there (Fig. 11). It is unclear why they were not caught only in the Tasman Sea but they might distribute to other areas because food availability in Tasman Sea was poor for them. Flesh-footed shearwaters migrate to north hemisphere during April to September, when the most of longliners operate in Tasman Sea (Fig. 12), thus consequently they could avoid interaction to pelagic longline vessels in the Tasman Sea.

A factor affecting seabird bycatch

In the previous study in the South African water, albatross bycatch was caused that albatrosses attack baits brought upon the sea surface by diving seabirds from sinking (Melvin et al. 2009). We predict that more albatrosses would be caught at the area where more white-chinned petrels are caught and the prediction was supported out of WCPFC area but was not supported in the WCPFC area. Melvin et al. (2009) recommended to use a combination of three mitigation measures, weighted blanch lines, night setting and a tori-line, in the effect of diving seabirds such as white-chinned petrels dominated system. Although this result spatially and seasonally lacks data especially in eastern area of New Zealand, it seems that the situation of the Tasman Sea is not the situation in the diving seabird dominated system as Melvin et al. (2009) referred. Therefore, seabird bycatch could mitigate without immersing baited hooks in deep depth during hooks setting in the Tasman Sea, and it should be investigated there. Also, bycatch data in other area and seasons must be collected and the triple combination of mitigation measures should be introduced when we find hotspots where diving seabirds closely related pelagic longline operations.

The area of bycatch mitigation and measures

The total bycatch CPUEs were low around New Guinea Island and Melanesia in south of equator within the WCPFC area in all season while bycatch of albatrosses was observed much in the south of 25S with a focus on Tasman Sea. And also, because CPUE in the WCPFC area is relatively low compared with other region, and this supposed to be due to the almost zero catches of diving petrels in this area. This should be considered when one think about seabird mitigation measures in this area.

Comparison with previous analysis

According to the result of Filippi et al. (2010), though the data in the southeastern Indian Ocean was absent in this study, risk area in the Tasman Sea and around New Zealand slightly differ from our result. Because last result was based on SPC and New Zealand observer data, which did not cover pelagic ocean where our observer data covered, the risk area would differ from our result. And also, because tracking data was obtained in restricted species, that might not reflect actual distribution well. Thus, the result of risk assessment based on actual bycatch data and tracking data should be considered for the consideration of seabird mitigation in the southern hemisphere of the WCPFC area.

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Table 1 Albatrosses and petrels observed in WCPFC area of south hemisphere

Wandering albatross	*Diomedea exulans*	44
Black-browed albatross	*Thalassarche melanophrys*	70
Buller's albatross	*T. bulleri*	55
Shy albatross	*T. cauta*	36
Salvin's albatross	*T. salvini*	2
Yellow-nosed albatross	*T. chlororhynchos*	3
Grey-headed albatross	*T. chrysostoma*	2
Light-mantled albatross	*Phoebetria palpebrata*	3
Other albatrosses		16
Northern giant-petrel	*Macronectes halli*	9
Southern giant-petrel	*M. giganteus*	4
Cape petrel	*Daption capense*	1
Great-winged petrel	*Pterodroma macroptera*	1
Grey petrel	*Procellaria aequinoctialis*	1
White-chinned petrel	*P. cinerea*	2
Flesh-footed shearwater	*Puffinus carneipes*	0
other petrels		1
South polar skua	*Catharacta maccormicki*	5
Unknown birds		66
Albatrosses		231
Macronectes		13
Petrels		6
Total Seabirds		321
Observed hooks		5568941
Observed operation		2328

Table 2-1 The result of the likelihood ratio test with step-down procedure method of GLM in the WCPFC area

	Residual Df	Residual Deviance	Df	Deviance	*P*
Model 1	2326	1241.6			
Model 2	2327	1242	1	0.418	0.518

Table 2-2 Summary of GLM(Model1) in the WCPFC area

	Coefficient	Std.Error	*Z*	*P*
(Intercept)	-2.259	0.064	-35.212	<0.0001
WHI	-11.044	331.862	-0.033	0.973

Table 2-3The result of the likelihood ratio test with step-down procedure method of GLM in no-WCPFC area

	Residual Df	Residual Deviance	Df	Deviance	*P*
Model 1	8212	9196.7			
Model 2	8213	9422.7	1	225.98	<0.0001

Table 2-4 Summary of GLM(Model1) in no-WCPFC area

	Coefficient	Std.Error	*Z*	*P*
(Intercept)	-1.298	0.021	-61.35	<0.0001
WHI	0.885	0.044	20.12	<0.0001

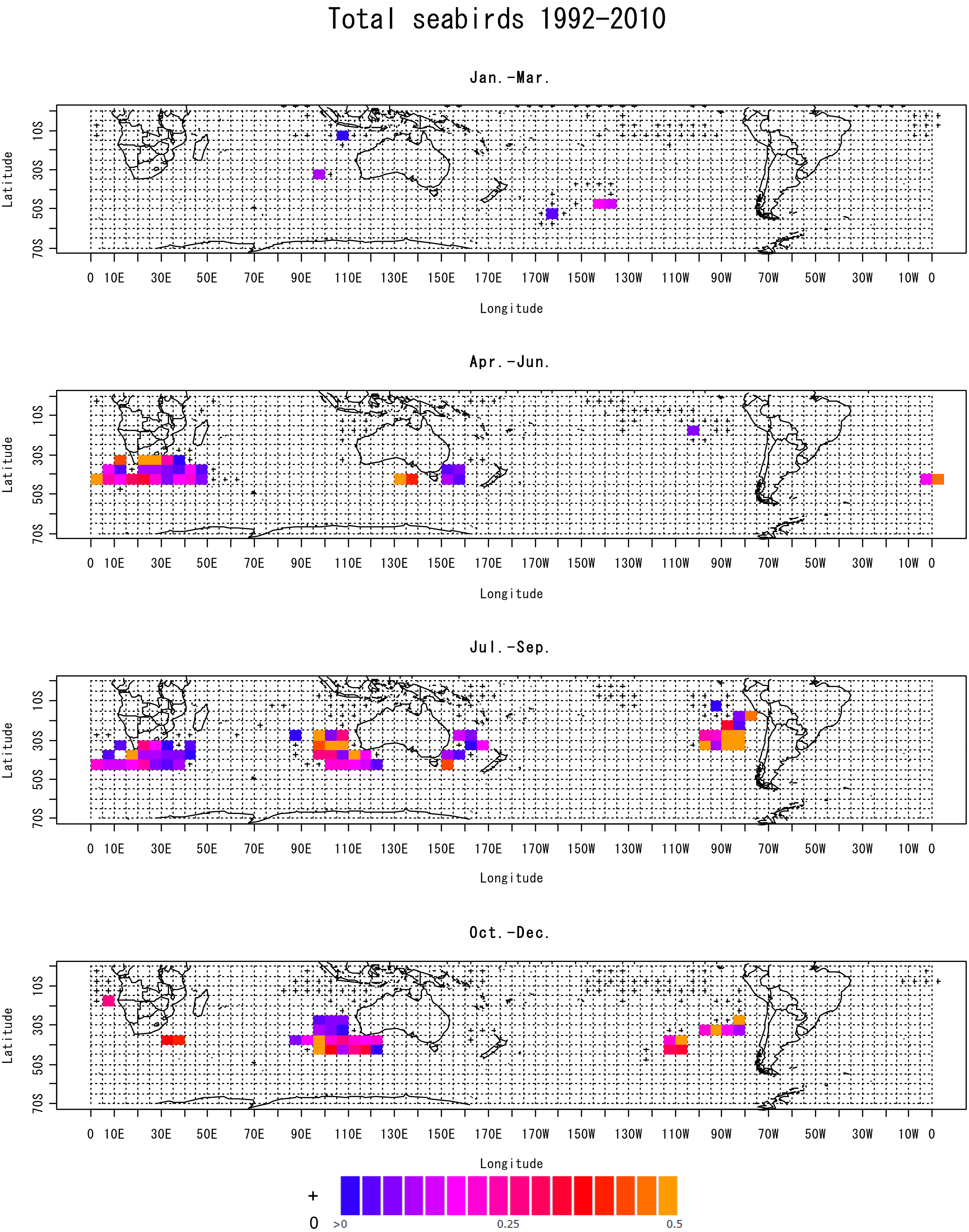

Figure 1 Effort (number of hooks) distribution in Southern hemisphere of observer data of total birds used in this study by quarter of year during 1992-2010

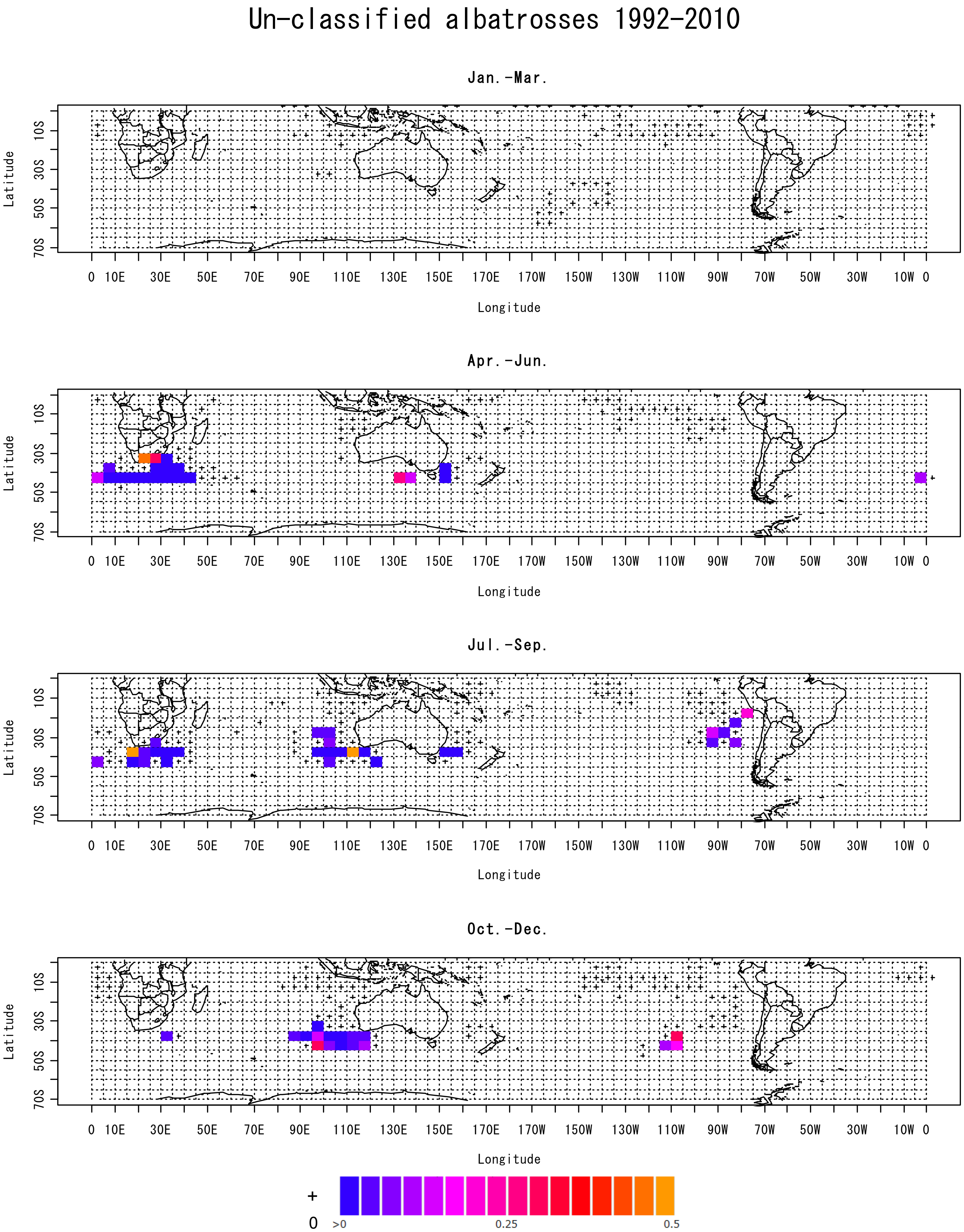

Figure 2 Effort (number of hooks) distribution in the Southern hemisphere of observer data of un-classified albatrosses used in this study by quarter of year during 1992-2010

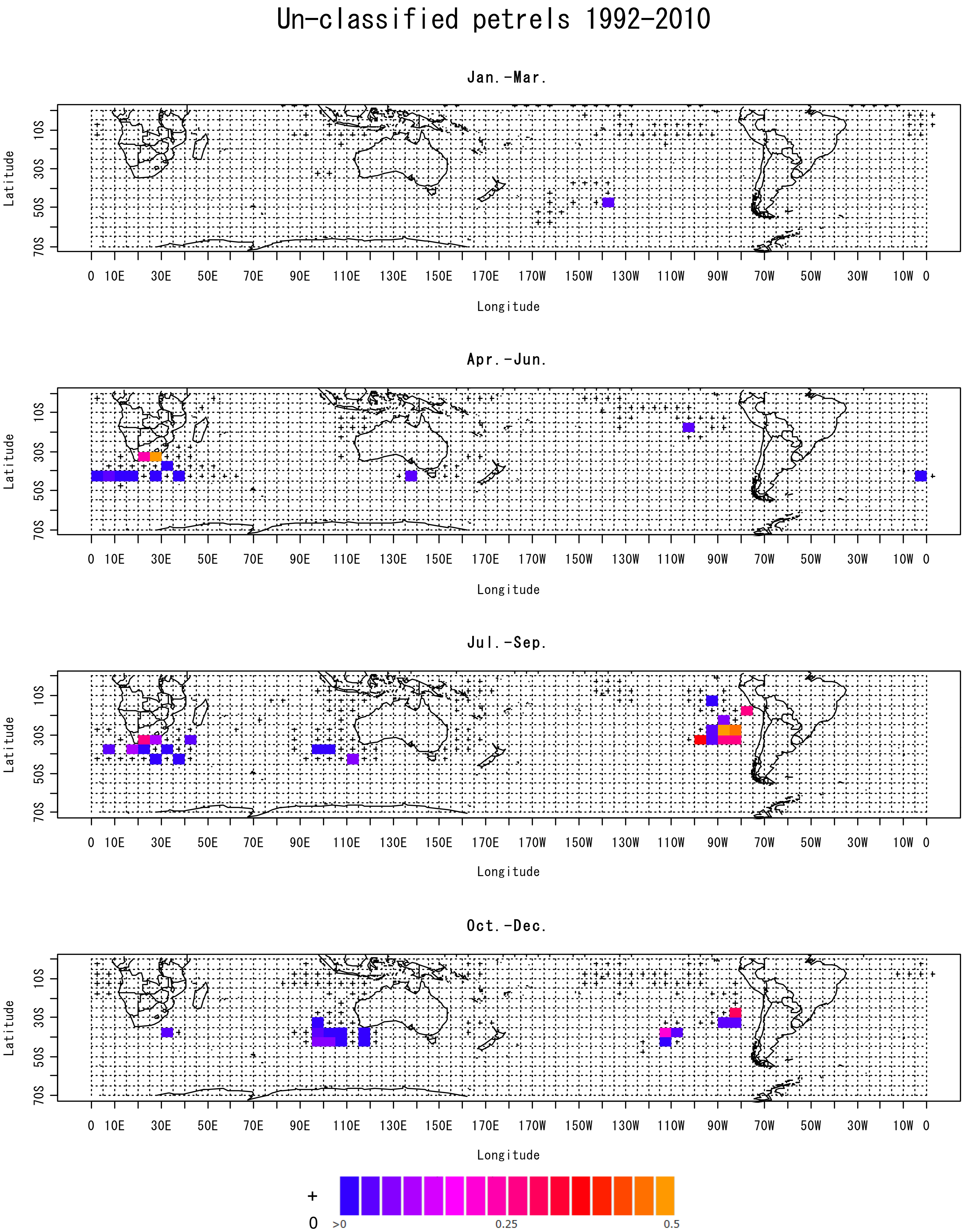

Figure 3 Effort (number of hooks) distribution in the Southern hemisphere of observer data of un-classified petrels used in this study by quarter of year during 1992-2010

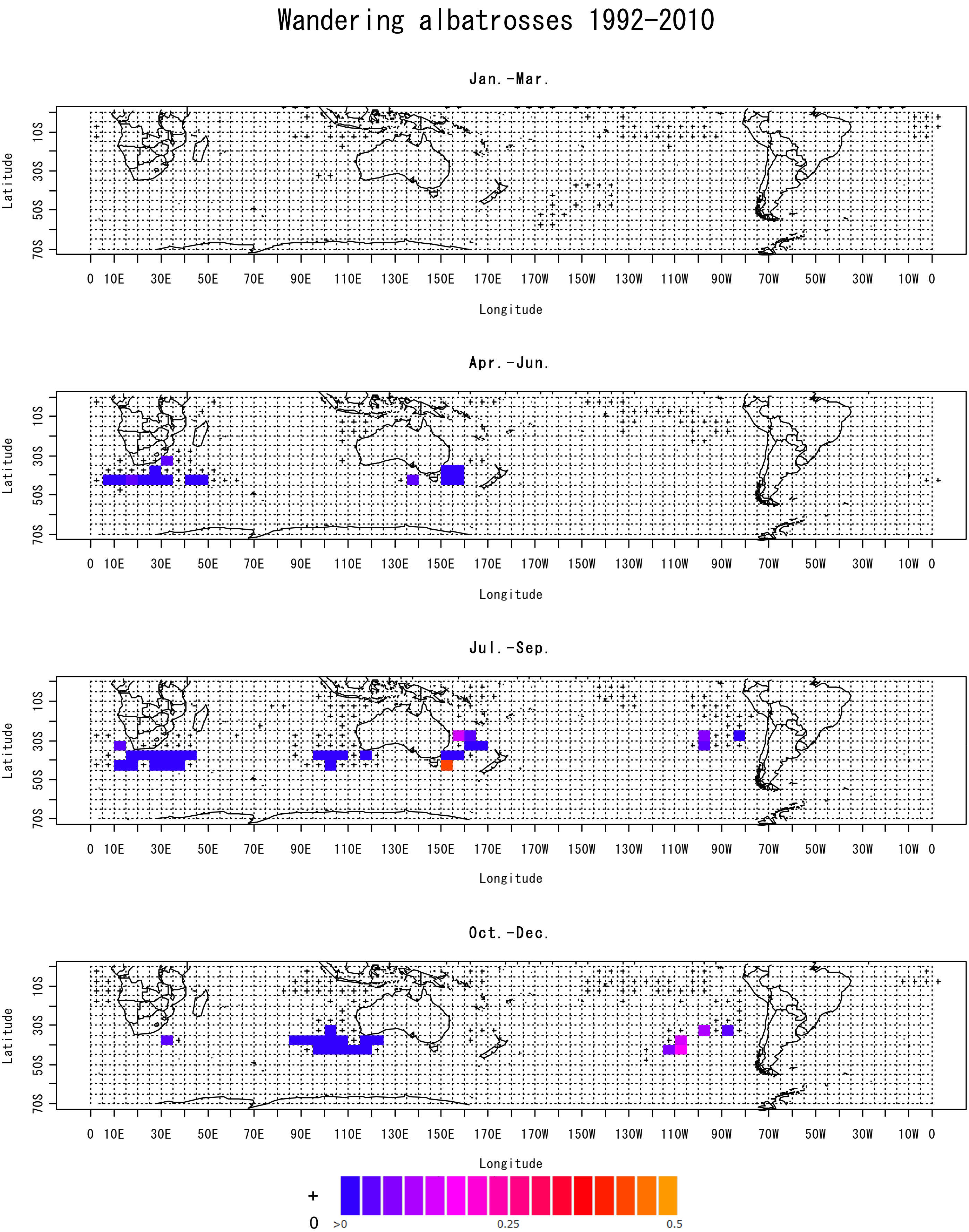

Figure 4 Effort (number of hooks) distribution in the Southern hemisphere of observer data of Wandering albatrosses used in this study by quarter of year during 1992-2010

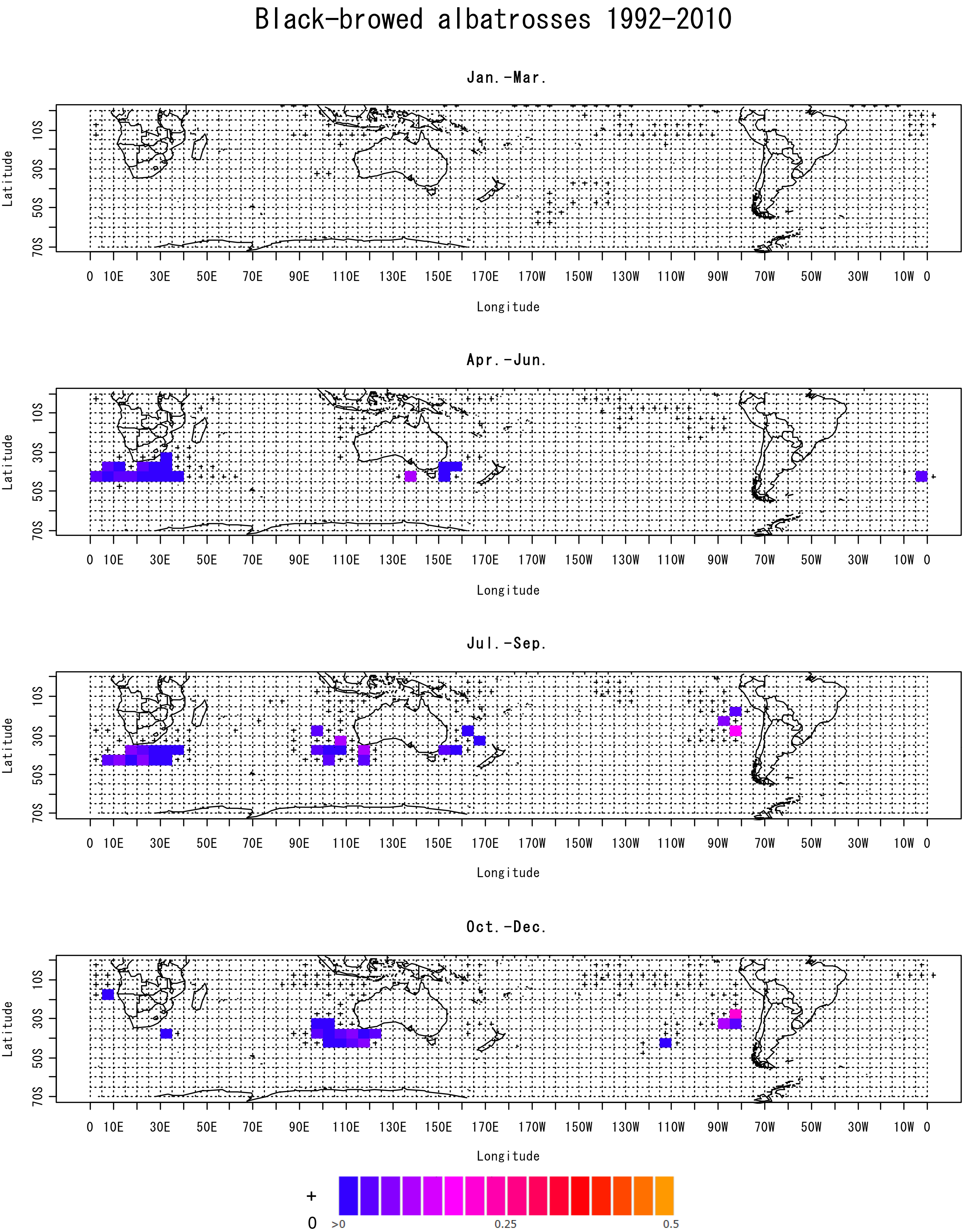

Figure 5 Effort (number of hooks) distribution in the Southern hemisphere of observer data of Black-browed albatrosses used in this study by quarter of year during 1992-2010

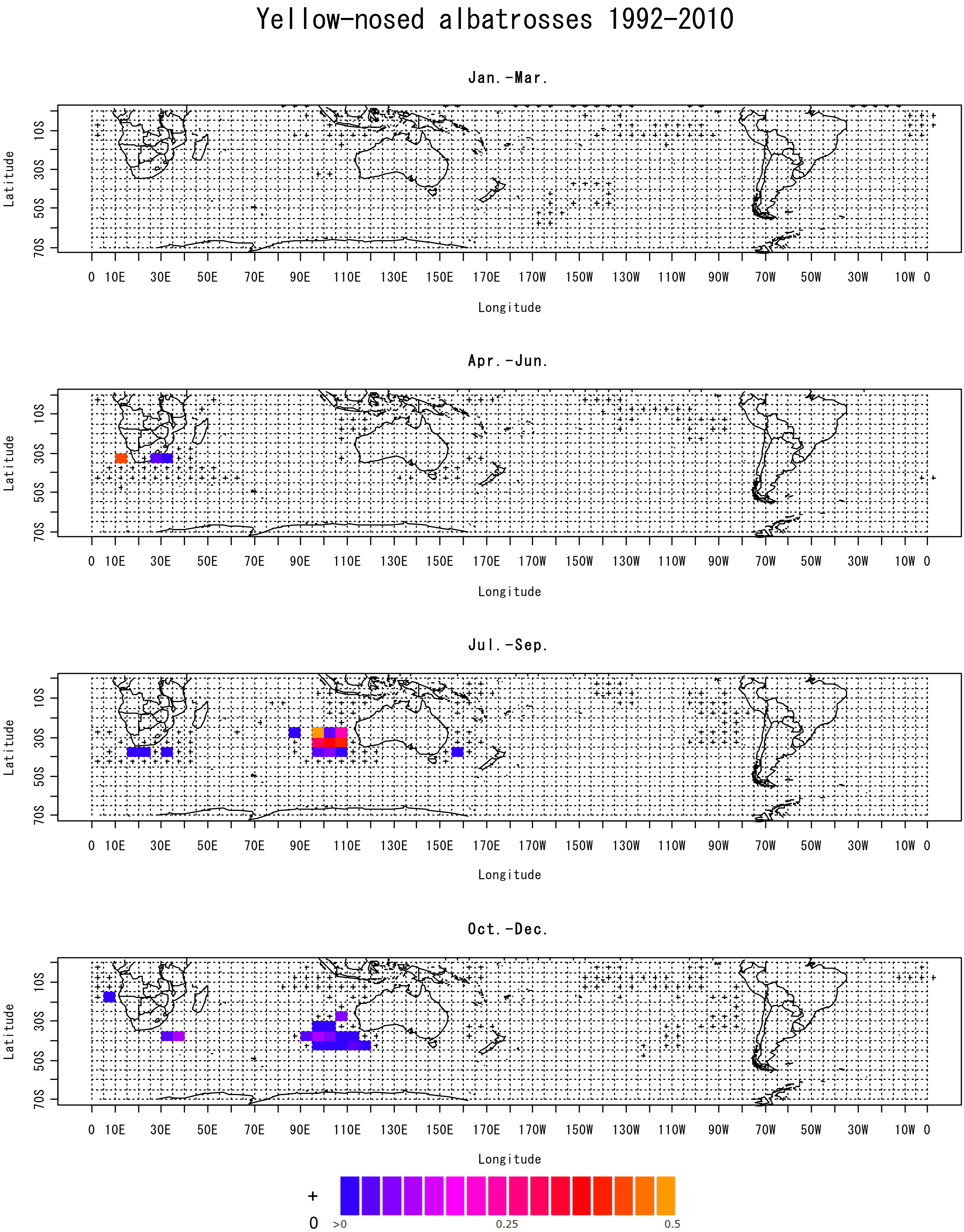

Figure 6 Effort (number of hooks) distribution in the Southern hemisphere of observer data of Yellow-nosed albatrosses used in this study by quarter of year during 1992-2010

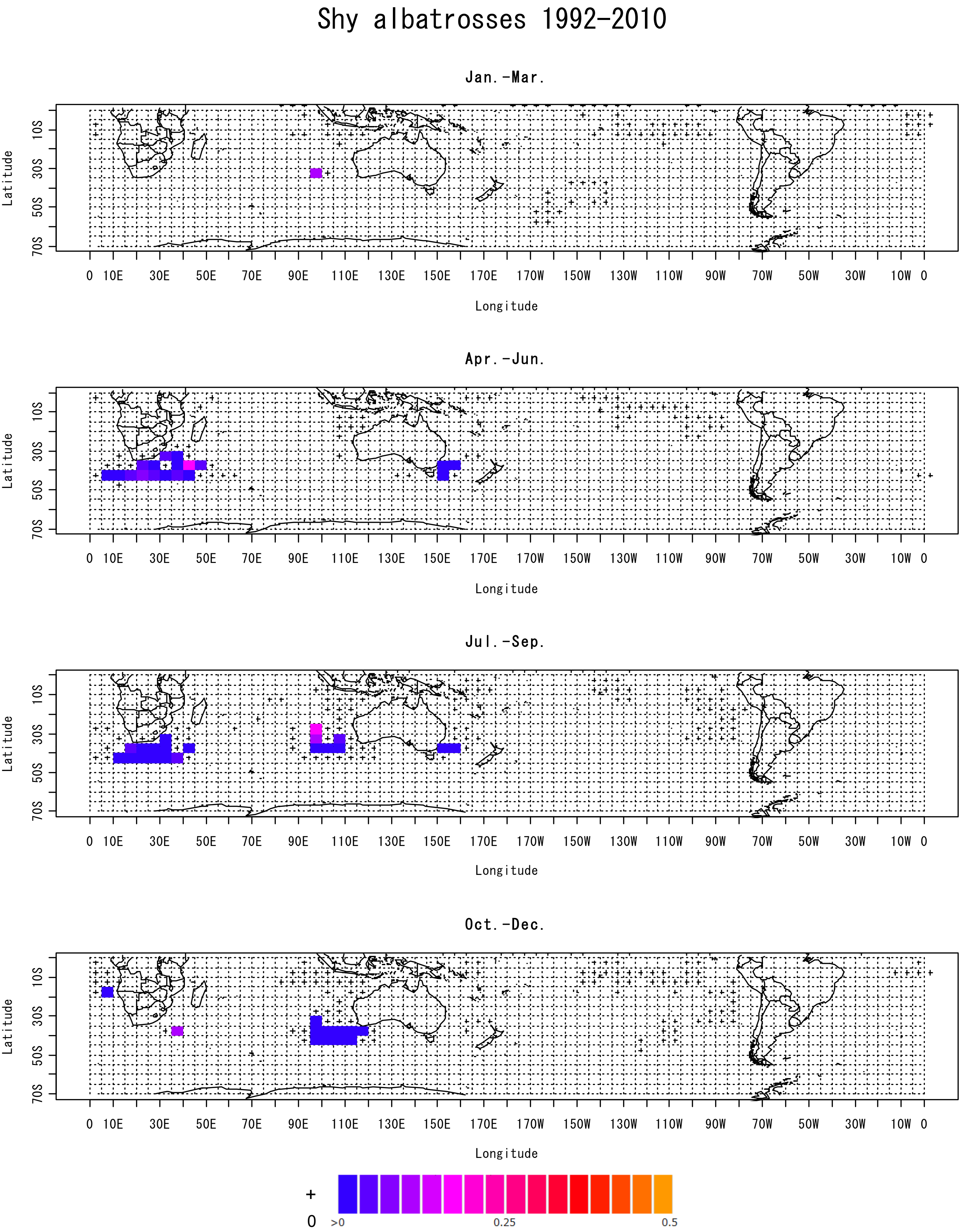

Figure 7 Effort (number of hooks) distribution in the Southern hemisphere of observer data of Shy albatrosses used in this study by quarter of year during 1992-2010

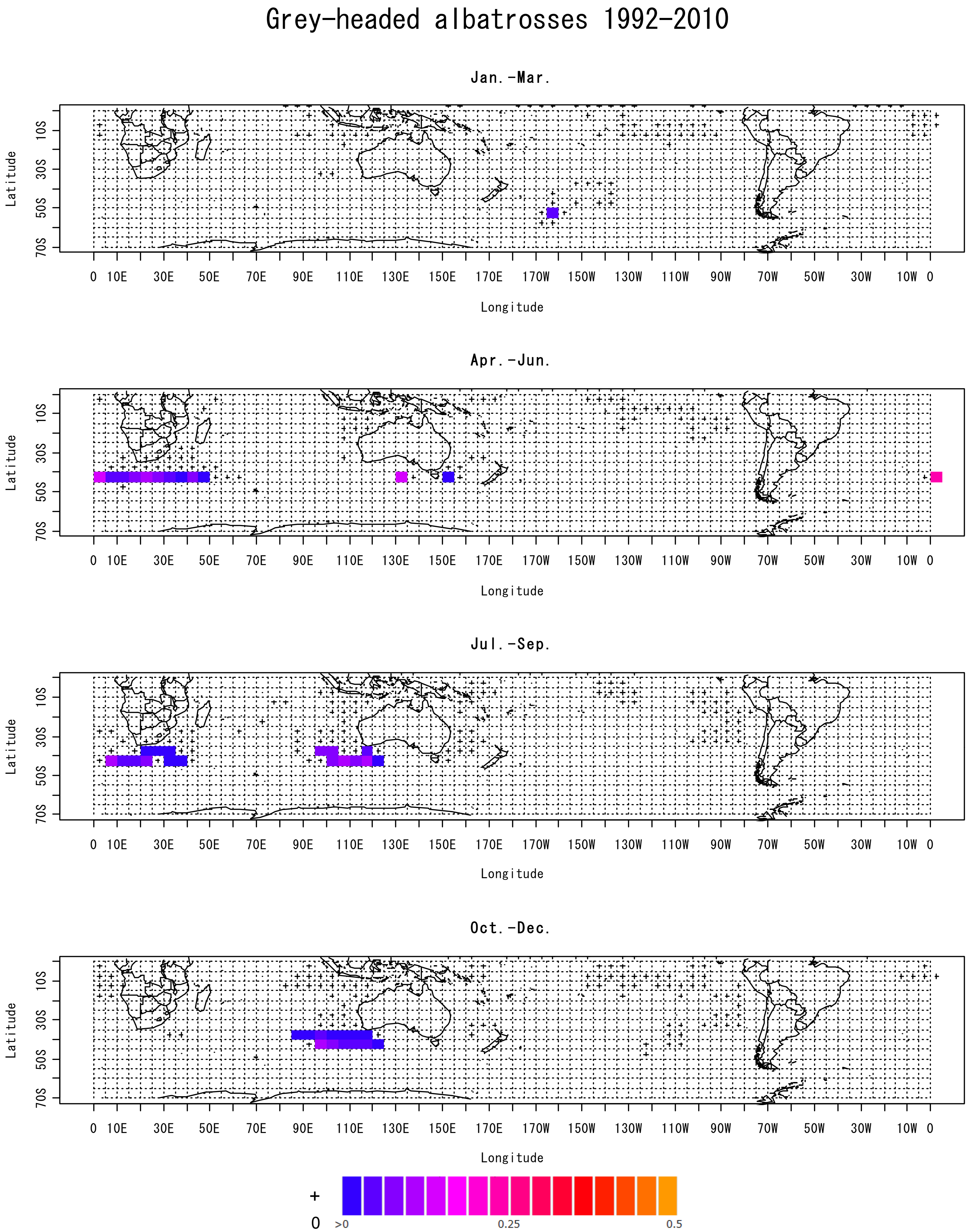

Figure 8 Effort (number of hooks) distribution in the Southern hemisphere of observer data of Grey-headed albatrosses used in this study by quarter of year during 1992-2010

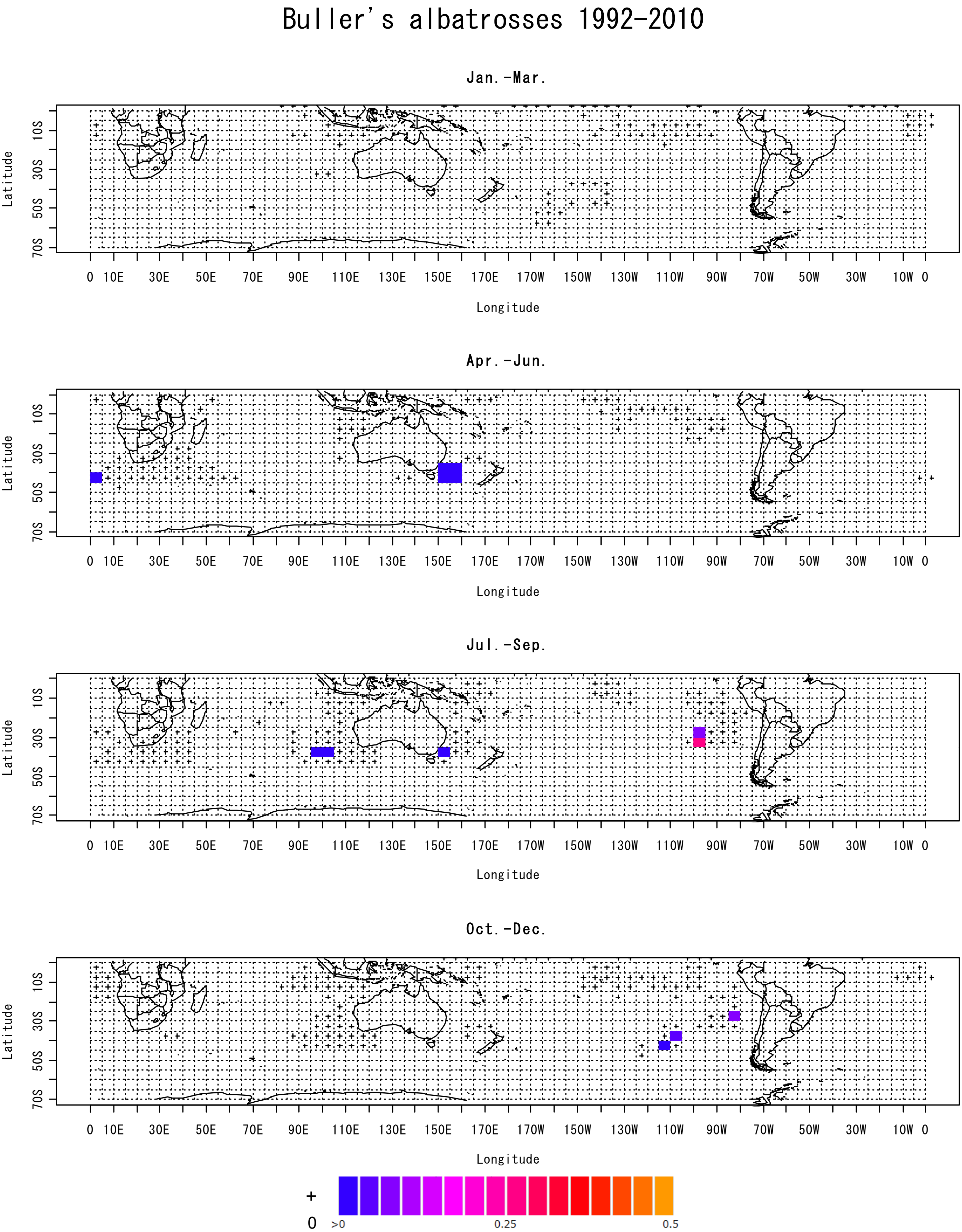

Figure 9 Effort (number of hooks) distribution in the Southern hemisphere of observer data of Buller's albatrosses used in this study by quarter of year during 1992-2010

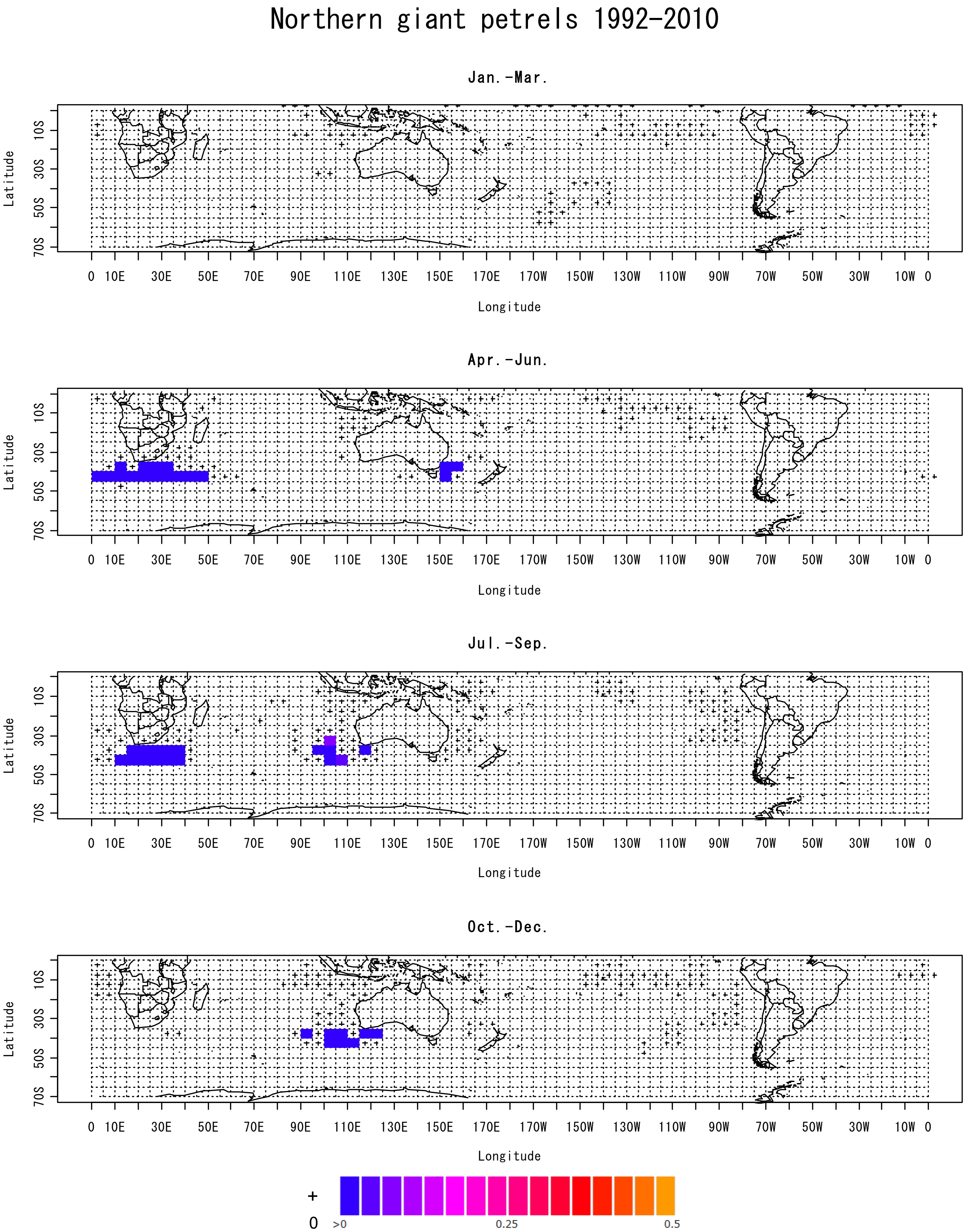

Figure 10 Effort (number of hooks) distribution in the Southern hemisphere of observer data of Northern giant-petrels used in this study by quarter of year during 1992-2010

White-chinned petrels 1992-2010

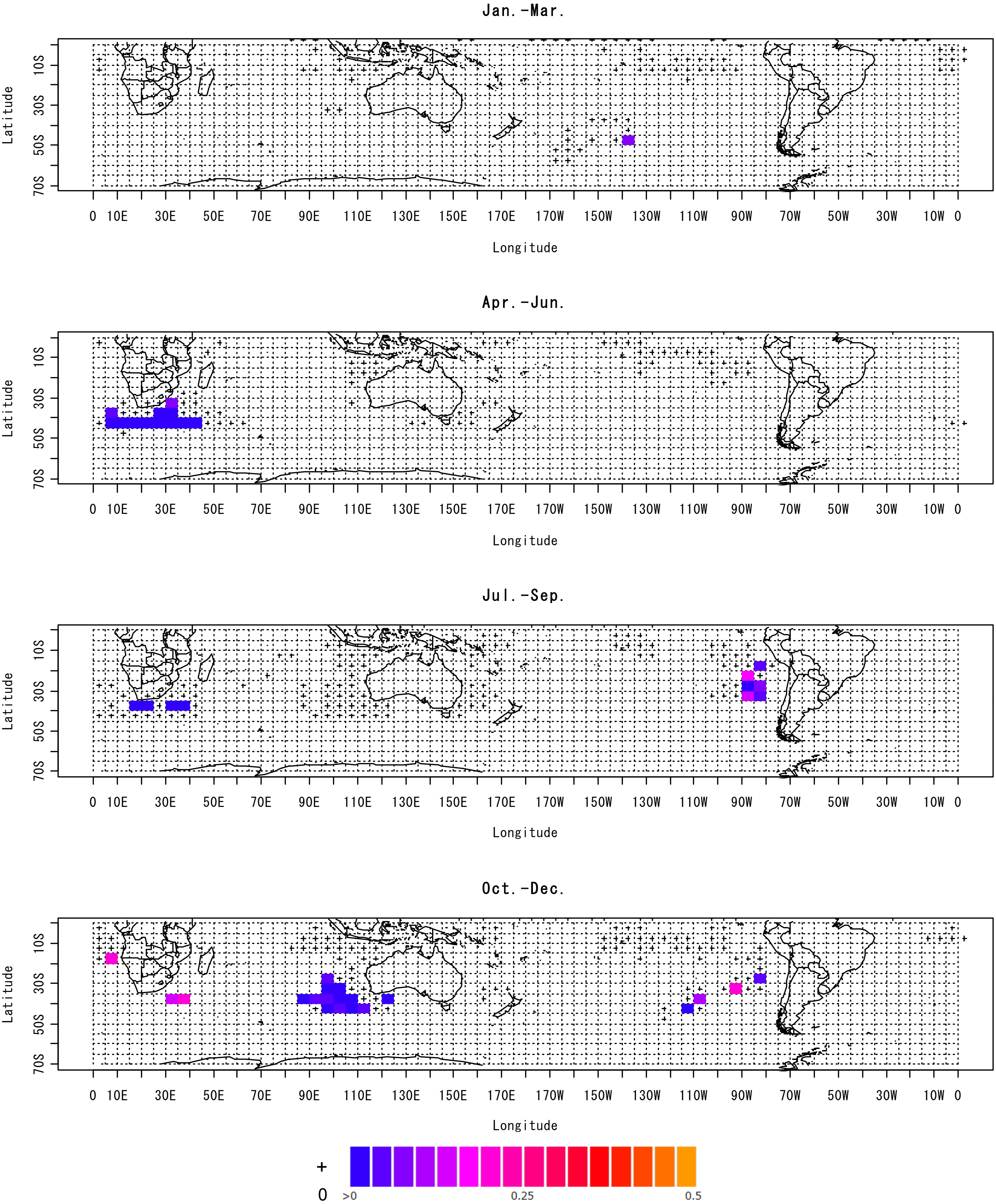

Figure 11 Effort (number of hooks) distribution in the Southern hemisphere of observer data of White-chinned petrels used in this study by quarter of year during 1992-2010

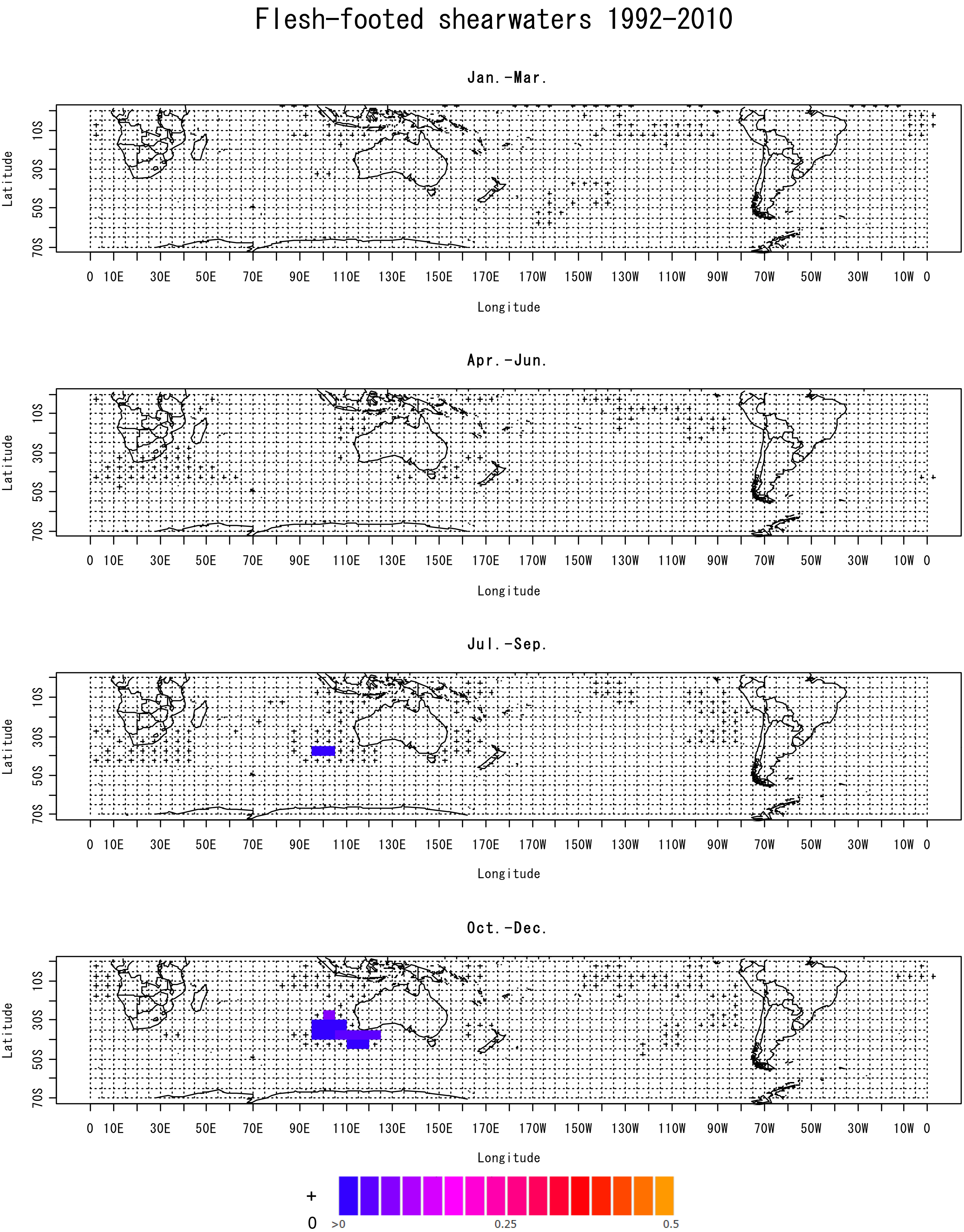

Figure 12 Effort (number of hooks) distribution in the Southern hemisphere of observer data of Fresh-footed shearwaters used in this study by quarter of year during 1992-2010