Ecological Risk Assessment for seabird interactions in surface longline fisheries managed under the Convention for the Conservation of Southern Bluefin Tuna

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Abstract

An analysis of risk of seabird interactions with surface longline fisheries was undertaken using fishing data from the Commission for the Conservation of Southern Bluefin Tuna (Commission), and biological and spatial data indicative of the distributions of a suite of albatross and petrel species known to be caught in the Convention for the Conservation of Southern Bluefin Tuna (CCSBT) fisheries. The analysis adapted methods developed in other regions and applied to assess risk of incidental mortality of highly migratory top predator species in other Regional Fisheries Management Organisations. Seabird species included in the analysis include rare species, such as Amsterdam Albatross, listed as Critical by the IUCN, and common species which are globally distributed, such as white-chinned petrels. Simple representations of species spatial distributions were used in the first instance, with hotspots of activity defined around breeding localities for each species. These distributions were combined with spatial fishing effort data to define risk as a function of spatial overlap between these distributions on a seasonal quarterly basis. Risk is then a function of spatial overlap, species vulnerability to capture in longline fisheries, and species biological productivity. Results indicate that species at highest risk are primarily large albatrosses at temperate latitudes, followed by smaller albatrosses. Geographical areas of highest risk include the Tasman Sea and the area around New Zealand, primarily in the Austral autumn and winter, and to a lesser extent areas to the south of southern Africa and southwest of Australia. The analysis could be improved by utilising improved species spatial distribution information derived from satellite telemetry, and by collecting fishery-specific information indicative of species capture rates to inform estimates of species vulnerability to CCSBT longline fisheries.

Keywords: Seabird, Ecological Risk Assessment, Fisheries, CCSBT, surface longline fisheries, Productivity-Susceptibility Analyses.

1. Introduction

1.1 Seabird fishery interactions

Seabird interactions with fisheries are a high-profile issue in many jurisdictions and for many Regional Fisheries Management Organisations (RFMOs) (FAO 2010). During fishing with longlines, seabirds may be caught on baited hooks or entangled in fishing lines, resulting in mortality. Three billion longline hooks are set annually around the globe, and it is estimated that 300,000 or more seabirds may be killed annually (Anderson et al. 2011). International agreements assert the need to reduce adverse effects of fishing mortality on non-target catch and seabird populations, and to safeguard populations during migrations. These include the Convention on the Conservation of Migratory Species of Wild Animals (2003), the Fish Stocks Agreement (UNGA 1995), the Code of Conduct for Responsible Fisheries (FAO 1995), the Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR 2007), the Western and Central Pacific Fisheries Commission (WCPFC 2007), the Indian Ocean Tuna Commission (IOTC 2006) and the Agreement for the Conservation of Albatrosses and Petrels (ACAP 2009).

To assist RFMOs in the aim of minimising impacts on non-target species, the Food and Agriculture Organisation of the United Nations has published best-practice guidelines for domestic fisheries and RFMOs (FAO 2008), detailing effective methods and processes for reduction of seabird bycatch as recommended by the FAO International Plan of Action for Reducing Incidental Catch of Seabirds in Longline Fisheries established 10 years earlier (FAO 1999). Defining the spatial and temporal aspects of incidental seabird catch is an important aspect of these guidelines. Specialised Ecological Risk Assessment (ERA) methods have potential to assist RFMOs in prioritising actions to species, locations and seasons where impacts may be highest (Small et al. 2011).

Defining the extent and significance of incidental seabird catch is an issue for the Commission to address, and is the subject of discussions under the Ecologically Related Species Working Group (CCSBT 2012a). Longline fishing activity reported to the Commission operates globally, with a major concentration of activity in the Indian Ocean, but also in the temperate Pacific, and southern Atlantic Ocean (Figure 1). Required seabird mitigation measures to reduce incidental capture of seabirds are limited to streamer lines, while research into other forms of effective mitigation is strongly encouraged (CCSBT 2012a). Non-binding mitigation measures, such as use of thawed baits, and offal management are described (CCSBT 2012a).

The area in which CCSBT fisheries operate overlaps with areas under the jurisdiction of several other fishery commissions. Non-binding measures on Members of CCSBT include the need to comply with the mitigation measures in force under the IOTC, WCPFC and ICCAT agreements when CCSBT fisheries operate in the areas of competency of these commissions (Table 1). The Commission encourages information exchange and fisher education to improve seabird bycatch reduction efforts (CCSBT 2012b).

This study focuses on CCSBT surface longline fisheries, and addresses the questions is the methodology for ERA applied to WCPFC fisheries appropriate for CCSBT fisheries to:

- assess which species are most likely to be adversely affected by surface longline fishing mortality from CCSBT fisheries; and,
- identify in which areas and seasons is risk of seabird mortality highest?

1.2 Species of conservation concern

Twenty-eight percent of seabird species are threatened with extinction according to the International Union for the Conservation of Nature (IUCN 2011), and there is a potential for seabird-fishery interactions to further threaten at-risk seabird populations. BirdLife International (2006) noted that several species of seabird spend more than 70% of their time in the areas of operation of CCSBT fisheries, as follows: Amsterdam albatross *Diomedea amsterdamensis* (100% of their time), Buller's albatross (97%), Chatham albatross *Thalassarche eremite* (71%), Indian Yellow-noted albatross *Thalassarche carteri* (100%), northern royal albatross *Diomedea sanfordi (92%),* shy albatross *Thalassarche cauta* (73%) , southern royal albatross (72%), Tristan albatross (69%) and Westland petrel *Procellaria westlandica (*100%). All of these species are listed by the IUCN as threatened with extinction, including two species listed with the most severe threat ranking possible, "Critical": the Amsterdam and Tristan albatrosses (IUCN 2011).

Albatrosses are particularly vulnerable to adverse population effects of fishing mortality, partly due to their long-ranging foraging habits which expose them to fishing activity over large areas of ocean, and partly because of their extreme low-productivity life-history traits (Rivalan 2010). For example, some albatross species breed at most once every two years, and take up to one year to raise a chick, and have an age at maturity of over 10 years. Should one adult die during its breeding period, the chick will most likely not survive, and the widowed mate may take several years to find another mate. Due to this low reproductive output, even occasional captures in fisheries can put pressure on seabird populations and contribute, long term, to declines in numbers of birds at breeding colonies (Weimerskirch et al 2011). Significant declines have been observed in most albatross populations, the most threatened family of birds globally, of which 18 of the 22 species are threatened with extinction (IUCN 2011).

1.3 Ecological Risk Assessment (ERA)

To implement the management required to reduce the environmental effects of fishing called for under international agreements, such as the United Nations' Fish Stocks Agreement (UNGA 1995) and Code of Conduct for Responsible Fisheries (FAO 1995), fishery managers are required to consider which of a suite of non-target species populations may be adversely affected by fishing mortality. To make best use of patchy and at times highly uncertain information, Ecological Risk Assessment (ERA) approaches have been developed (e.g. Hobday et al. 2006, Kirby 2006, Tuck et al. In press). Productivity-Susceptibility Analysis (PSA) is a semi-quantitative ERA methodology, developed to identify the fishery-associated risks of adverse population effects on non-target species, and to help prioritize management across a broad suite of non-target taxa, such as turtles, sharks, non-target fish, and marine birds or mammals, exposed to different fishing methods (Hobday et al. 2006). The need for detailed analysis which considers a suite of population factors along with catch estimation is reinforced by recent research showing that for highly fishery-impacted species population collapse may occur even where fishery catch rates are closely monitored (Tuck 2012).

In this study, a spatially-explicit PSA methodology was used to estimate the relative impacts of seabird-fisheries interactions and the potential for adverse effects of fisheries mortality on seabird populations (Waugh et al. 2008a, Kirby et al. 2009, Waugh et al. 2012). The ‘risk' in this analysis refers to the probability of adverse effects on seabird populations arising from fishing mortality.

In many bycatch-management contexts, data characterising the frequency of capture and species identity of discarded, non-target catch is highly unreliable. Our approach maximises the use of robust available data, and can be applied wherever data is available to characterise the spatial and/or temporal distributions of both seabirds and fishing effort. The species information we use to characterise species productivity includes parameters which can be easily and robustly estimated even in the absence of long-term research programmes, i.e. constraints on demographic parameters such as breeding frequency (annual or biennial) and clutch size (one-, two- or multiple-egg clutches depending on the family).

PSAs are a semi-quantitative method of characterising population-level risk on two axes: one which describes the biological productivity of the species, the other its susceptibility to adverse impacts. On the productivity axis those species with highest fecundity are considered better able to withstand and recover from fisheries removals than slower-breeding species. Susceptibility (i.e. exposure to impact) represents the frequency or probability of fishery-related mortality events for a particular species or population. Susceptibility is characterised by the spatio-temporal overlap between the species distribution and the distribution of fishing effort, multiplied by species ‘vulnerability’, i.e. a species-specific coefficient representing the relative likelihood that a bird will be caught in an encounter with fishing effort of a certain method (i.e. ‘vulnerability’ equates to ‘catchability’ in fisheries terms). By combining information on both productivity and susceptibility, the species-level risk can be characterised, and the differential effects of removals by a particular fishery on a species population can be assessed.

PSA studies sit in a suite of ERA methods that range from qualitative, such as assessments based on expert knowledge, to fully age-structured population models. Each method has its limitations. For example, expert workshop-based assessments, sometimes termed Level 1 Risk Assessment, such as that undertaken for CCAMLR fisheries (Waugh et al. 2008b, Rowe 2010), may be constrained by the inherent biases of participants, and may not provide reproducible results. More complex (Level 3) modelling approaches, such as those undertaken for some species in the Atlantic Ocean, require high quality (and often long-term) datasets to estimate parameters necessary for population modelling (Tuck et al. 2004, Lewison & Crowther 2003, Inchausti et al. 2001), and hence may be applicable to only a small subset of the species potentially affected by fishery interactions. Semi-quantitative (or Level 2) ERA methods, such as those explored here, enable assessment of risk for a broad suite of species or systems including in data-poor settings, incorporating biological or environmental data as available. Representations of uncertainty in the risk calculations can be used to highlight where better quality information is needed. Estimates of risk can be updated and improved as new information becomes available over time. Management responses in relation to ERA findings can inform the development and application of effective mitigation measures, and the prioritisation of fisheries observer programmes or data collection to more accurately characterise fisheries risks.

2. Methods

We analysed fishing effort data sourced from the Commission. Only surface longline fishing effort was included. Seabird species data were collated from literature review and through compilations of data on species demography and ecology. Seabird range data from multi-research information holdings were accessed to describe the distribution of species globally. Species-specific risk scores were calculated as a function of the spatial overlap between seabirds and fishing effort, and of species demographic parameters and behavioural susceptibility to capture in longline fisheries, using methods adapted from a similar analysis of seabird interactions in longline fisheries in the Western and Central Pacific Fisheries Commission (Waugh et al. 2012) and in previous analyses (for example, see Kirby et al. (2009) and Filippi et al. (2010)). Spatial overlap and risk score estimates were generated for annual and quarterly periods, to examine the effects of seasonally variable fishing effort and species distributions. Spatially resolved risk maps summed across all species in the analysis are summarized as seasonal (quarterly) and total annual risk as indicated below.

2.1 Fishing effort seasonal and spatial distribution

Fishing effort data for surface longline vessels were extracted from databases held by the Commission Secretariat, and available for download from the internet (CCSBT 2012c). Fishing effort was summarized for each five-degree longitude by five-degree latitude square over the period 2007 to 2010, averaging over four years of data to account for inter-annual variability. These years were selected to most appropriately represent current fishing effort patterns as this was a period over which relatively consistent regulations and homogenous fishery operations were in place. On the advice of the Commission Secretariat, we used total SBT catch (in tonnes) as the most effective proxy for the spatio-temporal intensity of CCSBT fishing effort; (Figure 1). For quarterly fishing activity plots, data were presented in a negatively lagged-quarters of the year (Q1 = Dec – Feb / Austral summer; Q2 = Mar – May / Austral autumn, etc), as for species distributions (see below). During the development of the analysis, we also explored alternative proxy representations of fishing effort, including the reported total number of hooks deployed; in future this or other proxies for fishing effort intensity could be used as appropriate.

2.2 Seabird species seasonal and spatial distribution

We analysed data for 34 seabird species occurring in tropical or temperate oceanic systems known to interact with CCSBT longline fisheries (Table 2). We included all albatrosses and *Procellaria* petrels, only some of which have been documented as catch in CCSBT fisheries. These two groups were included due to the strong propensity for species from these groups to interact with longline fisheries. Including different species with contrasting capture rates, i.e. species with both high and low probabilities of capture in the fishery concerned, provides contrast in the analyses. Our low-probability species include Cape Petrel *Daption capense* and Light-mantled Albatross *Phoebetria palpebrata*. We chose also to include North Pacific albatrosses, as some Commission datasets include fishing effort reported in this region. However, for the final data selection, effort for this region was not included because actual catches of SBT were zero (see above). Nonetheless retention of this group of species serves as a reference, with the expectation that they rank lowest in the analysis, due to lack of spatial overlap with fishing effort retained in the analysis.

We used BirdLife International's Range Maps as a basis for the species global distributions (BirdLife International 2010). These represent the likely maximum range of a species throughout all seasons. They provide presence/absence information at a global scale by species. Species richness was highest in the Tasman Sea – eastern New Zealand area when all seasons were considered together (Figure 2).

We established seasonal (quarterly) estimated distribution maps for each species using four quarters of the year that aligned with the breeding time-tables of most seabird species, with a 'negatively lagged-quarter' defined as Q1 - Austral summer (Dec – Feb); Q2 - Austral autumn (Mar – May); Q3 - Austral winter (Jun – Aug); Q4 - Austral spring (Sep – Nov). Many of the species considered in the analysis are highly aggregated near their breeding sites in Q4 and Q1, and more dispersed during Q2 and Q3 (Figure 3). We established the quarterly distributions by taking into account the known breeding colonies at a global scale and numbers of breeders at each, the breeding period (by month), and using an estimate of distribution of breeding distribution as follows: For each of the 34 species, birds were assigned to either the breeding or the non-breeding distribution on a monthly basis based on the breeding timetable for each species; monthly distributions were subsequently aggregated into quarterly distributions. We assumed that the breeder component of the population in any year was 0.4 of the whole population for biennial breeding species, or 0.5 for annual breeding species. The non-breeder component of the population includes pre-breeders and juveniles.   We assumed that the non-breeder birds occupy the full species' range for the entire year, while the breeder birds are constrained to the areas around their breeding colonies during the breeding season and occupy the full range during the non-breeding season.

We used an exponential decay function to describe the rate at which breeding bird densities are expected to decline with distance from the colony during the breeding season, due to their central-place foraging pattern, extending up to their maximum foraging range radius (see Waugh et al. 2012 for further details; unpublished data compilation).

The density of birds at a distance *r* from the colony following an exponential decay is defined with *r* representing the distance at the colony, thus, if *r* > range_max then breeder_density(*r*) = 0, where range_max is the maximum range for a species foraging from its breeding site, and breeder_density (*r*) is the density of breeding birds at a point location.

For *r* < = range_max:

$$breeder\_density(r) = e^{\frac{\ln(0.01)\times r}{range\_max}} \quad \text{(Eq. 1)}$$

Distribution layers for each species (i.e. combined for breeders and non-breeders, separately for each quarter) were normalized such that the sum total of all cells in each layer equals one. In this way each layer represents a global probability distribution per bird, i.e. the probability that an individual bird drawn at random from the population will be found in that cell. Multiplying the layer by the appropriate population estimate and dividing by cell area then yields an actual density estimate of birds per km^2. Estimated total density for all 34 species combined is shown in Figure 4.

2.3 Productivity-Susceptibility Analyses (PSA)

We used the distributions of fishing effort and species distributions to calculate seasonal and average annual risk scores based on (a) the *Susceptibility* index and (b) the *Productivity* index.

2.3.1 Susceptibility

The *Susceptibility* index was calculated as the product of fishing effort and normalised species distributions (i.e. *spatial overlap* on a quarterly basis) multiplied by the *Vulnerability* of the different species to longline fishing gear:

$$susceptibility(sp, se) = \frac{Vulnerability(sp) \times \int_{CCSBT} bird\_density(sp, se) \times effort\_density(se)}{bird\_population(sp)}$$

(Eq. 2)

with *sp* and *se* representing respectively the species and the season.

Conceptually the *spatial overlap* is a proxy for the frequency or probability that an individual bird of a particular species will encounter a fishing event in the fishery in question; *Vulnerability* then represents the likelihood of the bird being caught in a particular encounter.

2.3.2 Vulnerability

Vulnerability is a function of behavioural and physical characteristics, and differs among species (or species groups), i.e. different species will experience different mortality rates per fishing event for the same seabird density. In the New Zealand EEZ V has been estimated empirically for a large number of seabird species, including for albatrosses and petrels included in the CCSBT fisheries analysis, using observed capture rates of seabirds of particular species (or species groups) at different densities of those birds (Richard et al. 2011). For each species *Vulnerability* (V) relates the density of birds present at a fishing event (D) to the likelihood or number of fatal interactions associated with that event (K). This provides an instantaneous rate of capture as a function of seabird density. The average number of birds killed K per fishing event is then:

$$K = V\,D \qquad \text{(Eq. 3)}$$

Units of V are probability of capture per 1000 longline sets.

The New Zealand Ministry of Agriculture and Forestry observer data provides a consistent data source that has been used in similar ERA studies to estimate the number of birds caught as a function of spatial overlap with fishing effort in the New Zealand EEZ (Filippi et al. 2010, Richard et al. 2011). In this CCSBT risk analysis, we use estimates of V derived from observed capture rate data from the New Zealand EEZ studies for vessels similar to those operating in CCSBT fisheries (i.e. longline vessels in excess of 28 m in fishing years 2004-05, 2005-06 and 2006-07). The species were first grouped together in the following guilds based on similar behavioural and physical characteristics affecting susceptibility to capture in longline fisheries (in descending order of V): large albatrosses, small albatrosses, giant petrels, *Procellaria* petrels, large *Pterodroma* petrels, dark shearwaters and southern petrels. Grouping species into guilds was necessary in order to achieve sufficient observed captures in each group to allow statistically robust estimation of capture rates. V was then estimated for each species group by fitting a generalized linear model to the captures and density data (after Filippi et al. 2010).

It is likely that capture rates derived from the New Zealand EEZ study do not accurately represent the actual likelihood of capture in CCSBT fisheries in ***absolute*** terms, because variable fisher behaviour or differential use of mitigation between vessels will affect capture rates by altering *V*. Instead the purpose of incorporating a variable *V* in this analysis is to approximate the effect of differential behavioural or physiological characteristics affecting susceptibility to longline capture between different seabird species, even while we lack the necessary data to quantify the differential effect of mitigation uptake or fisher behaviour between different vessels. Refinement of the estimates of *V* used in this and future analyses to incorporate the latter consideration would require robust observations of actual capture rates aboard vessels operating in CCSBT fisheries, e.g. by deploying independent observers. This is one of the areas where significant improvement in the data underpinning this and similar analyses can be made, informing improved understanding of fishery-associated risks to seabirds by region, flag, and in relation to mitigation deployed.

For three species, the Grey-headed albatross and Light-mantled albatross we used a value of *V* that was 0.1 *V* for the small albatross group. This is because these species are very infrequently observed in fisheries bycatch relative to other species even when they are known to be present in similar densities; this lower V effectively represents a known behavioural difference whereby these three species are less attracted to fishing vessels. A similar approach, i.e. subjectively assigning relative vulnerabilities to reflect known behavioural tendencies, was used by Phillips and Small (2007).

2.3.3 Productivity

The *Productivity* risk factor is an inverted index of species reproductive potential. A ‘Fecundity Factors Index’ (FFI) was generated which provides a relative measure between species of the fecundity, here based on a normalised ‘Life History Strategy’ (annual breeding, multiple-egg clutches = 1; annual-breeding, single-egg clutches = 2; biennial-breeding, single-egg clutches = 3) added to the normalised Average age of first breeding, divided by 2, to give a range of values that fell between 0 and 1. This method relies on relatively easily-estimated parameters, and few assumptions, yet provides a robust method of differentiating between species in terms of their ability to recover from increased mortality. More complex methods relying on increased numbers of assumptions have been shown to produce comparable results (e.g. in Waugh et al. 2012 the Pearson’s *r* comparing FFI and alternate methods was 0.91). Hence here we use FFI here for reasons of parsimony.

2.3.4 PSA risk scores

Season-specific fishery-associated risk to seabird populations were calculated by combining both *Productivity* and *Susceptibility* factors. We defined risk as the product of these two indices, noting that the inverse of the *Productivity* score is used so that the axes move intuitively from lowest risk near the origin to higher risk at higher values. In this way, birds with low productivity, but very little exposure to fisheries interactions could not achieve a high risk score:

$$risk\_score(sp, se) = \frac{susceptibility(sp,se)}{productivity(sp)} \quad \text{(Eq. 4)}$$

Risk maps per species/quarter represent total species-level risk spread in space proportional to the *spatial overlap* (i.e. bird density map multiplied by effort_density_map) in that quarter (Eq 5); annual species risk maps are the average of the four quarters:

$$risk\_map(se, sp) = \frac{vulnerability(sp)}{productivity(sp)} \times \sqrt[4]{\frac{bird\_density\_map(sp, se) \otimes effort\_density\_map(se)}{bird\_population(sp)}} \quad \text{(Eq. 5)}$$

In the estimation of total species-level risk the units for both *Productivity* and *Susceptibility* were normalized between species so that values for each range 0 to 1 prior to combining both factors to generate the species risk score. See Table 3.

Risk maps by 5 degree square for all species combined were calculated as:

$$Risk\_map(se) = \sum\nolimits_{all\ species} risk\ map(se, sp) \qquad \text{(Eq. 6)}$$

By summing un-normalized cell values across multiple species maps, species are weighted in the combined maps proportional to their species risk score; in this way the combined output assigns higher risk to high-risk cells for high-risk species than to high-risk cells for low-risk species. Species-combined risk maps of this kind were produced for annual average risk, seasonal risk for each individual quarter, and maximum quarterly risk across all four quarters. We also summarize species risk scores and the parameters by which they are calculated in a series of tables.

3. Results

We discuss the results of what we consider our 'base-case' analysis first in each section. This is the outputs produced by analyses which used variable *V*, and used tonnes of SBT reported as an index of fishing effort. Secondary outputs were tested as a sensitivity, in which we assigned a uniform *V* parameter across all species, but the spatial results were similar and are not reported here. We note that the outputs of this analysis should be considered as preliminary, and are primarily intended to demonstrate the use of the spatially explicit PSA method applied to fisheries data from the Commission. It is possible that species risk scores and spatial results will change as the analysis is updated using better data, e.g. by utilising satellite tracking information (where available) rather than range maps to represent species spatial distributions (see below).

3.1 Biological parameters

Seabird species included in this study and biological parameters contributing to estimation of risk are summarized in Table 2 (see Waugh et al. 2012 for references). *Species group* denotes guild membership within which the *Vulnerability* parameter is assumed to be constant. *Age at maturity* and *life history strategy (LHS*) combine to yield the *fecundity factors index (FFI)* which in turn affects estimation of the *Productivity* index. Mean foraging distance and timing of seasonal breeding affect the quarterly species distribution maps. World population size is used in the empirical estimation of *Vulnerability*; note however that in the absence of fishery observer data to enable direct estimation of capture rates, this study uses *Vulnerability* estimates derived elsewhere (from Waugh et al. 2010, see Table 3) such that population estimates are not used directly in this analysis and (like IUCN threat status) are provided here for information purposes only.

3.2 Species-specific seasonal and average annual risk maps

Spatially explicit risk maps (per quarter and combined annual total) were produced for each of the 34 species in this analysis. The means by which season-specific species distributions and fishing effort distributions were used to generate maps of species-level risk are illustrated here with reference to a single species (the Westland Petrel[1]) in Figure 5. The seasonal *spatial overlap* is the product of the

[1] This species nests in the March – November period (Q2 – 4) in western central South Island, New Zealand, during which time its range is restricted to near the breeding areas. Relatively high concentrations of CCSBT fishing effort in the same time and place result in a high *spatial overlap* and thus a moderate species risk score despite low species *Vulnerability* (Table 3).

seasonal bird distribution (Fig 5 column 1) and the seasonal effort distribution (Fig 5 column 2) maps; seasonal *Risk* (Fig 5 column 3) maps are a function of the seasonal *spatial overlap* maps multiplied by the species *Vulnerability* scores (yielding *Susceptibility*, Eq 2) and by the inverse *Productivity* index (equation 4). Maps of total annual risk per cell (e.g. Figure 5, final panel) combine the outputs of the four seasons-specific risk maps.

3.3 Species-level risk scores

Species-level *Vulnerability, spatial overlap*, *Susceptibility*, and *Productivity* index values and the corresponding risk scores are summarized in Table 3. *Productivity* is calculated from biological parameters in Table 2; *Susceptibility* is calculated as the product of species *Vulnerability* and *spatial overlap* as in Eq 2, this time using values summed across all cells in the spatial domain rather than calculated on a per-cell basis. Species risk is the product of the species-level *Susceptibility* and inverse *Productivity* indices as shown in Figure 6. In the species-level risk scores both *Susceptibility* and inverse *Productivity* are normalized between species so that values range 0 to 1; the resulting species risk scores range 0 to 0.75.

These analyses indicate that the seabird species most at risk from CCSBT longline fisheries are primarily large albatrosses at temperate and sub-Antarctic latitudes: Amsterdam albatross, wandering albatross, Gibson's albatross and Tristan albatross are the four highest risk species (risk score > 0.25), reflecting low biological productivity, high *Vulnerability* to capture by longline fisheries and high *spatial overlap* with recent CCSBT fishing effort patterns (Table 3 and Figure 6). Species at moderate to high risk (risk score ranges 0.1 – 0.25) include the large albatrosses with lower *spatial overlap* (e.g. Antipodean albatross, northern royal albatross) as well as smaller albatrosses with highest *spatial overlap* (e.g. sooty albatross, Indian yellow-nosed albatross) but lower *Vulnerability* relative to large albatrosses. Species at low to moderate risk (range 0.02 – 0.1) are mostly small albatrosses, but also include petrel species for which very high *spatial overlap* contributes to higher risk scores despite their lower *Vulnerability* and relatively higher biological *Productivity* (e.g. Westland petrel, Parkinson's petrel). Species at low risk (range 0.001 - 0.02) include several small petrels for which lower risk scores reflect relatively low species *Vulnerability* combined with higher *Productivity*, and also albatrosses at low risk despite low *Productivity*, due to very low species *Vulnerability* (i.e. grey-headed albatross, and light-mantled sooty albatross, which do not aggressively target fishing vessels to feed). Lowest risk species (risk < 0.001) include abundant species for which *Vulnerability* is very low (e.g. shearwaters, cape pigeons) and northern hemisphere albatrosses for which *spatial overlap* is zero.

3.4 Species-combined seasonal and total annual risk maps

Combined seabird risk across all 34 species is represented by summing the untransformed species-specific risk maps by season, as shown in Figure 7. The effect of using the untransformed species-level risk layers is that species are weighted in the combined maps proportional to their species *risk* score in Table 3; in this way the combined output assigns higher risk to highest-risk cells for high-risk species than it does to highest-risk cells for low-risk species. In Figure 7 lower seasonal risk in spring and summer (Q4 and Q1) reflects both the lower absolute level of fishing effort in these seasons and also the dispersed spatial distributions of many bird species outside of their breeding season. Conversely, highest risk in autumn and winter (Q2 and Q3) reflects the increased concentrations of at-risk seabirds around breeding sites, in locations that coincide with seasonally high CCSBT fishing effort, primarily in the Tasman Sea and around New Zealand. Other locations of elevated risk include the waters off southern Africa in autumn and winter, and southeast of Australia in winter and spring. These same areas are reflected also in Figure 8 which depicts total annual risk across all 34 species for each spatial cell.

4. Discussion

During this study we applied methods developed for assessing the risk to populations of seabirds of incidental mortality to longline fishing activity conducted under the management of the CCSBT Commission. We adapted the methods applied elsewhere in Pacific regions (Waugh et al. 2012) using alternate datasets for species and fishing effort, and applying a different risk estimation approach using a quantitative *spatial overlap* metric yielding semi-quantitative estimates of species risk, in which risk scores can be expected to indicate the relative magnitude of fisheries associated risk to different seabird populations, rather than merely ranking species in order of decreasing risk. The same method can also be used to track changing risk to particular species or groups of species over time in a given fishery or area, or alternately for global populations affected by fisheries in different areas, to compare the relative magnitude of risks arising from fisheries in different areas or under different jurisdictions. However in the absence of fishery-specific data indicative of species capture rates to inform estimates of species Vulnerability (as in Filippi et al 2010 and Richard et al. 2011) it is not possible to estimate actual numbers of captures using this method.

The results reported here are preliminary, and can be updated as better data become available. In particular it is likely that substantial improvements are possible by utilising species distribution data based on satellite telemetry studies, instead of the maximum range maps and breeding colony proximity distributions used here. Telemetry-based distribution data is available for many albatross and petrel species, and have been requested for use in 2012 to update this analysis, but were not available in the timeframe in which this study was completed.

4.1 Species and areas of greatest risk of seabird-fishery interactions

The study suggests that the seabird species at highest risk from CCSBT longline fisheries include several species of temperate-distributed large albatrosses, that risk is highest in the austral autumn and winter, and that geographical areas of highest risk include the Tasman Sea and the area around New Zealand, and to a lesser extent to the south of southern Africa and southwest of Australia. All of these areas have previously been identified as potential problem areas for seabird bycatch (e.g. Abraham et al. 2010, Abraham and Thompson. 2011, Watkins et al. 2008, Tuck et al 2003, Glass et al. 2000). This analysis suggests that in addition to being areas of high density of individual birds, and corresponding increased numbers of seabird-fishery interactions, fishing activities in these areas also poses risks to rare species' populations and vulnerable populations likely to be adversely affected by fisheries-associated mortality.

The study stops short of exploring to what extent the incidental mortality of particular seabird species is likely to deplete their populations, instead assigning risk in a relative sense between species and between seasons/locations. The large albatrosses are shown to be at highest risk of adverse population effects compared with small albatrosses and petrels, due to the combination of their low-productivity life-histories, high spatial and temporal overlap with fishing activity, and high likelihood of capture when and where they do co-occur with surface longline fishing.

Here we examine the results with reference one rare species and high-risk species, the Amsterdam albatross, and two common lower-risk species, the flesh-footed shearwater and Westland petrel, and discuss to what extent we expect that the analysis may be improved by use of alternate spatial distribution data layers as these become available.

The Amsterdam albatross, the species with the highest identified risk score in this analysis (0.75), has a breeding population of 29 pairs occurring at Amsterdam Island; the estimated annual distribution and associated risk map is shown in Figure 9. However, an extensive dataset of seasonal satellite tracking data has been collected, and we hope to use this for upcoming analyses. The main foraging areas for both adult and juvenile Amsterdam Albatross coincide with areas of high fishing effort density under the IOTC as well as CCSBT fisheries, as identified also in the current analysis.

Understanding risks to this species by area and season is vital, due to the current critical status of the species' population. Weimerskirch et al. (2011) and Rivalan et al. (2010) note that as few as 6 individuals removed from the population due to bycatch or other anthropogenic effects would be sufficient to result in extinction of the species within 10 years.

In contrast the flesh-footed shearwater, ranked 29th in the current analysis (risk score = 0.00005), is numerous (65,000 breeding individuals) and has a wide-spread breeding distribution (Figure 10), including the Australian, New Zealand and French jurisdictions in sub-tropical waters (Brooke 2004, Baker et al 2010). It is sometimes captured in longline fisheries (Baker & Wise 2005, Richard et al 2011), with the ability to dive to great depths, but its vulnerability in CCSBT longline fisheries is thought to be low. For this species, current remote tracking studies suggest some areas of concentrated feeding activity (Thompson, Taylor & Waugh et al. unpublished data), which will allow its likely overlap with CCSBT other fisheries to be examined in greater detail. It is likely that this species is at greater risk from other fisheries utilising methods other those used by CCSBT longline vessels (e.g. see Richard et al. 2011).

The Westland petrel breeds only in New Zealand and feeds in proximity to the South Island of New Zealand during its breeding season, i.e. Q2-Q4 (austral autumn, winter and spring). During the austral summer, a proportion of birds remain in New Zealand waters while the remaining birds migrate to South American waters (ACAP 2012). See Figure 8. This species occurs infrequently in longline bycatch, but its small population size (c. 4000 breeding pairs; Baker et al. 2008) mean that probability of detection in longline catch by scientific observers will be small. Consistent with the pattern for all species combined (Figure 7) highest seasonal risk occurs around New Zealand's mid-latitudes in Q2 and Q3, during the breeding season. Seasonal migrations have been described recently, showing the extent of inter-breeding migration ranges (Landers et al. 2011). Remote tracking work has been undertaken in 2011 and in 2012 and will allow provide improved spatial distribution data to better characterise species risk during the breeding season (Waugh et al., unpublished data).

4.2 Study limitations and next steps

The risk assessment described here is currently limited by available datasets, in particular the use of species range maps rather than satellite telemetry data to characterise breeding and non-breeding seabird distributions. A key strength of the risk assessment method is that it is designed to be easily updated as new data becomes available. We recommend that the research be revised to improve the species distributions with satellite tracking data available for most of the albatross species and some petrels, and managed by BirdLife International. In addition it may be beneficial to explore datasets indicative of capture rates from the fisheries of several members of the Commission, to better estimate the *Vulnerability* estimates by fishery and region, and hence improve on the estimation of risk. Finally it may be useful to examine the use of alternate metrics of fishing effort distribution (total SBT catch was used here).

This analysis did not attempt to characterise uncertainty in the risk estimates; rather we have used what we consider 'best estimates' for each parameter used to estimate risk, rather than plausible ranges or prior distributions. More sophisticated and data-hungry approaches (e.g. Tuck et al. 2004, Inchausti et al. 2001, Richard et al. 2011) are required to examine the extent to which uncertainty in species and fishery distributions and in other input parameters combine to generate uncertainty in the output estimate of species risk. Our previous experience in the field indicates that the two variables for which uncertainty is likely to be high are the species distribution layers (a factor generally poorly explored in analyses of risk, and for which it is difficult to characterise uncertainty using quantitative methods) and behavioural or physiological factors influencing the *Vulnerability* parameter used here, the estimation of which relies on both improved species distribution and fishery-specific capture rate information. These data require independent fisheries observer coverage, deployed at appropriate times and in appropriate areas, to improve our understanding of the ways that seabird species interact with different fisheries in different areas.

5. Acknowledgements

We are grateful to our respective organisations and funders for enabling these studies to be undertaken, in particular the Ministry of Agriculture and Forestry (Contract SEA2011/14), Museum of New Zealand Te Papa Tongarewa and Centre Nationale d'Etudes Scientifiques. Thanks to the CCSBT Secretariat who assisted with data. Thanks to the staff at BirdLife International who assisted with data extracts of these and other data, in particular Cleo Small, Phil Taylor, and Mark Balman. We acknowledge the contribution of BirdLife International in supplying data in a timely manner.

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Figure 1. Spatial distribution and intensity of fishing effort (2007-2010) in CCSBT surface longline fisheries by 5-degree cell. The index of fishing effort intensity is average annual total reported catch of SBT. (tonnes).

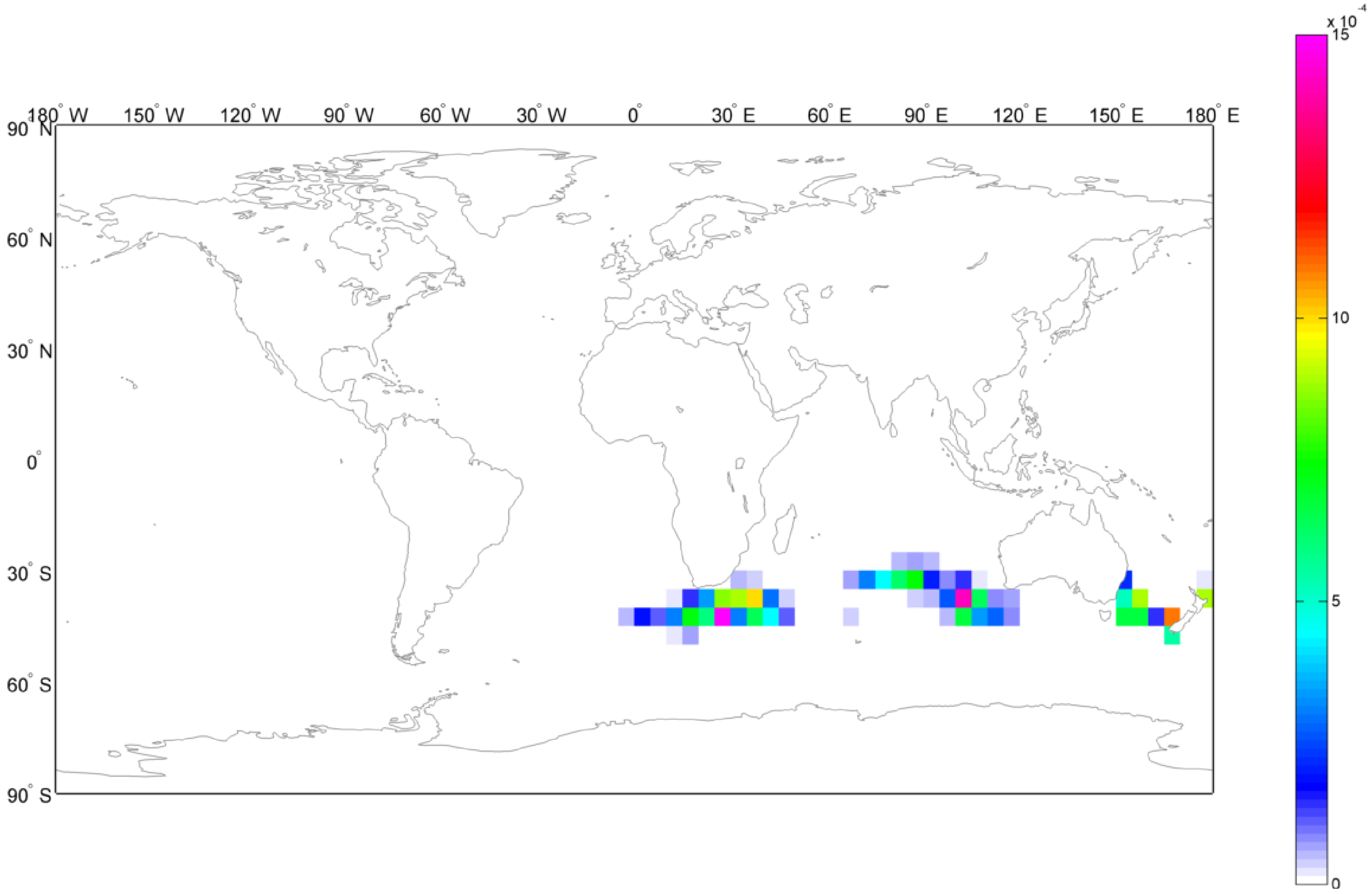


Figure 2. Plot of seabird diversity (number of species per 5×5 degree area) for the 34 species of albatross and petrel included in the analysis. These distributions were generated by combining BirdLife International Species Range Maps (BirdLife International 2010) with colony locations and other literature-based information indicative of foraging distances.

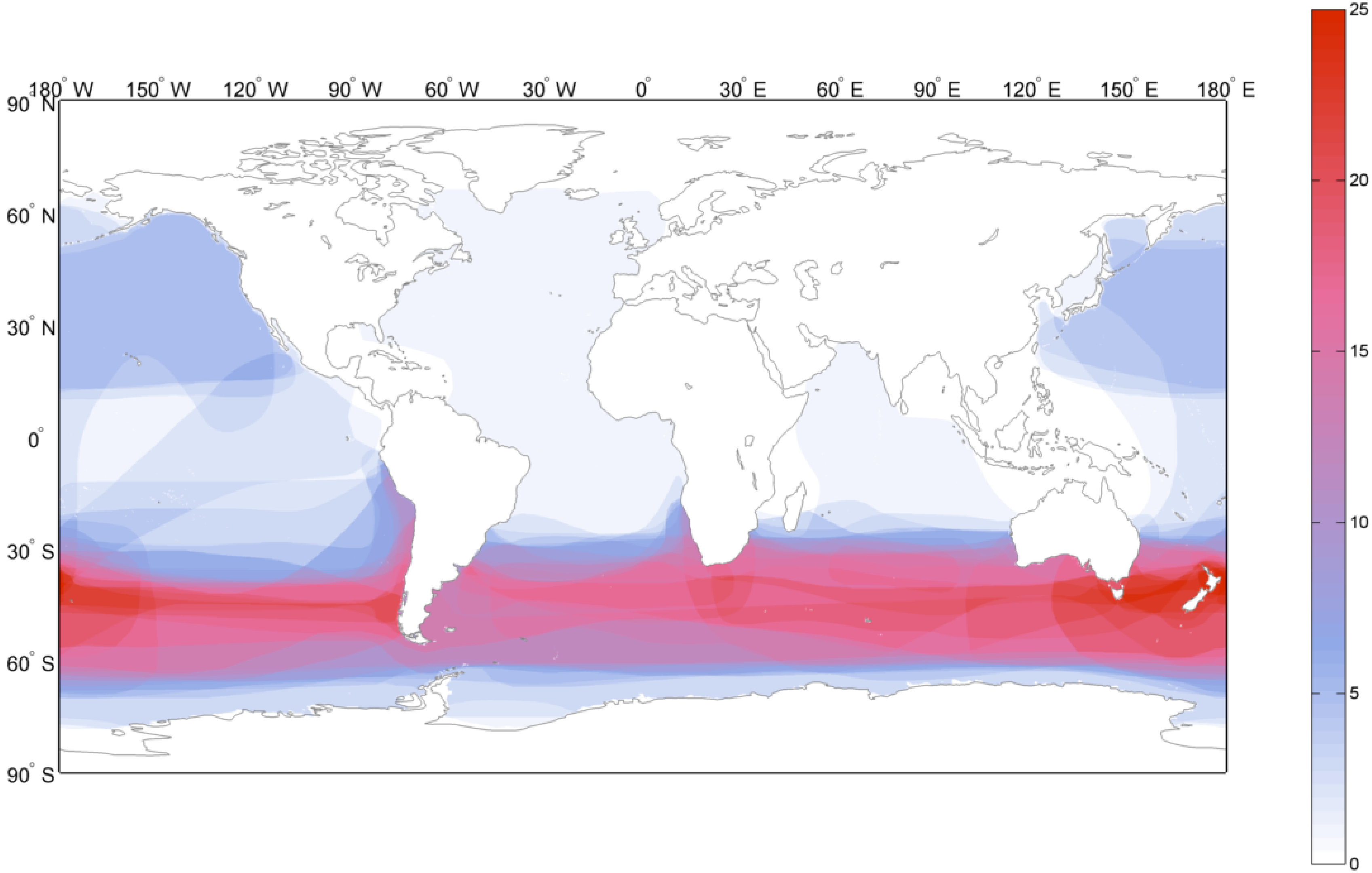
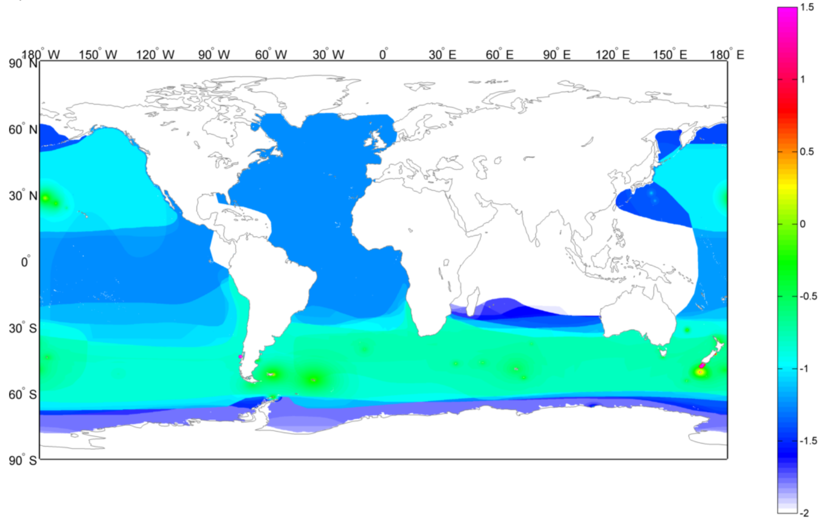
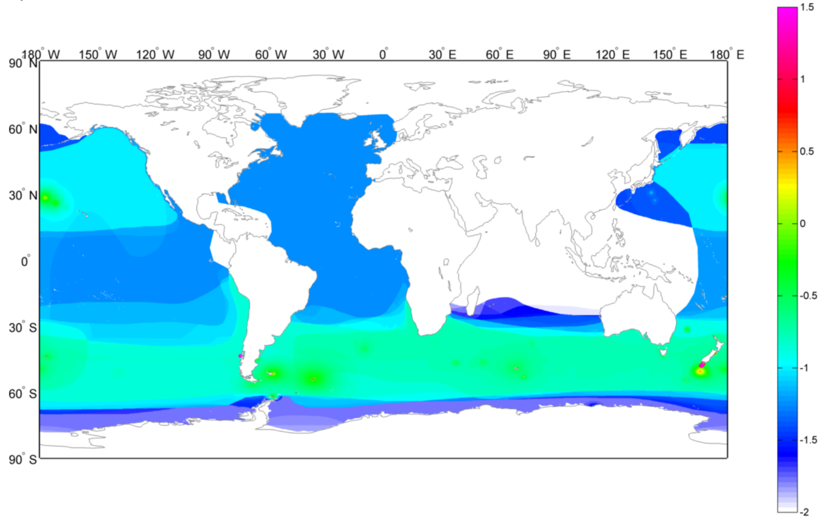


Figure 3. Estimated density of seabirds [$\log_{10}$(birds/km2)] combined for all 34 species of albatross and petrel included in the analysis per 5×5 degree cell during four seasonal quarters: (a) Q1- Austral summer; b) Q2 - Austral autumn; c) Q3 – Austral winter, and d) Q4 - Austral spring. Season-specific densities are estimated for each species by proportionally assigning birds to either breeding or non-breeding season distributions on a monthly basis and subsequently aggregating into quarters. Breeding birds are constrained within their maximum foraging distance from known colony locations. Transformed values are displayed here to aid visual interpretation, but not used in calculations.

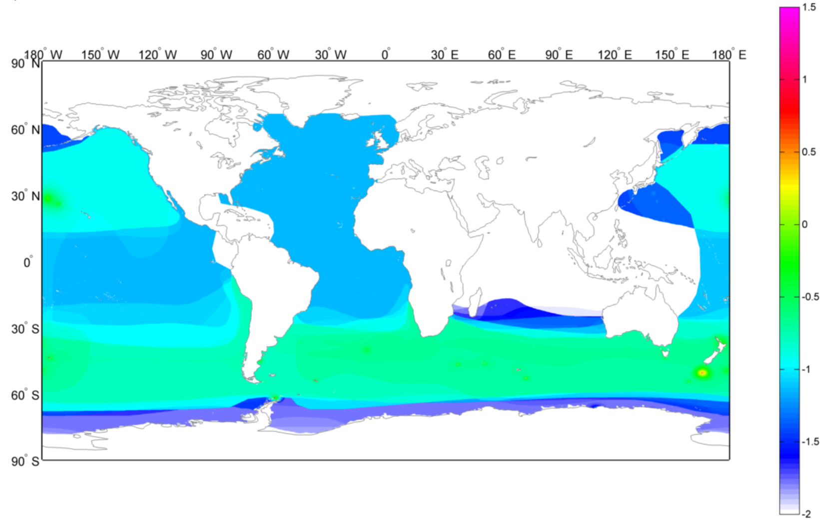
a) Q1 – summer



b) Q2 - autumn



c) Q3 - winter



d) Q4 - spring

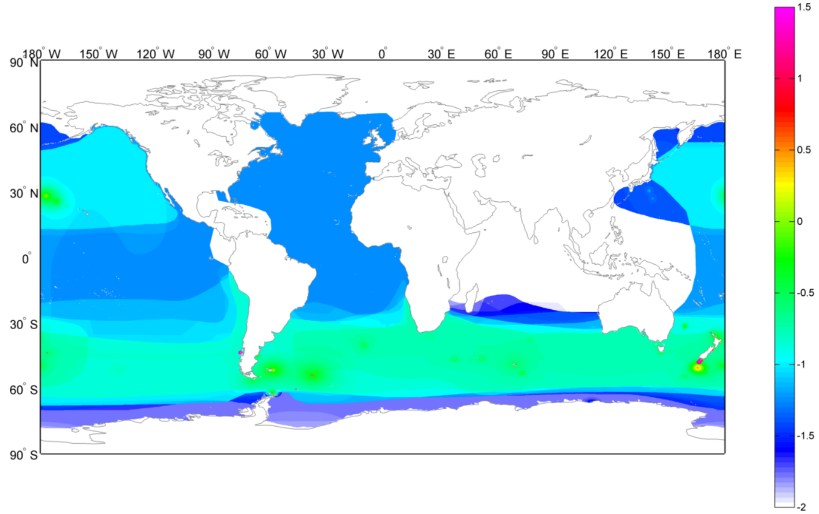


Figure 4. Estimated density of seabirds [log10(birds/km2)] of all species combined per 5×5 degree cell averaged across all four seasonal quarters. Note that this figure and Figure 3 depict total bird densities, such that abundant species dominate the graphic, whereas rare species are under-emphasised. Log_{10} transformed data are displayed here to aid visual interpretation, but are not used in calculations.

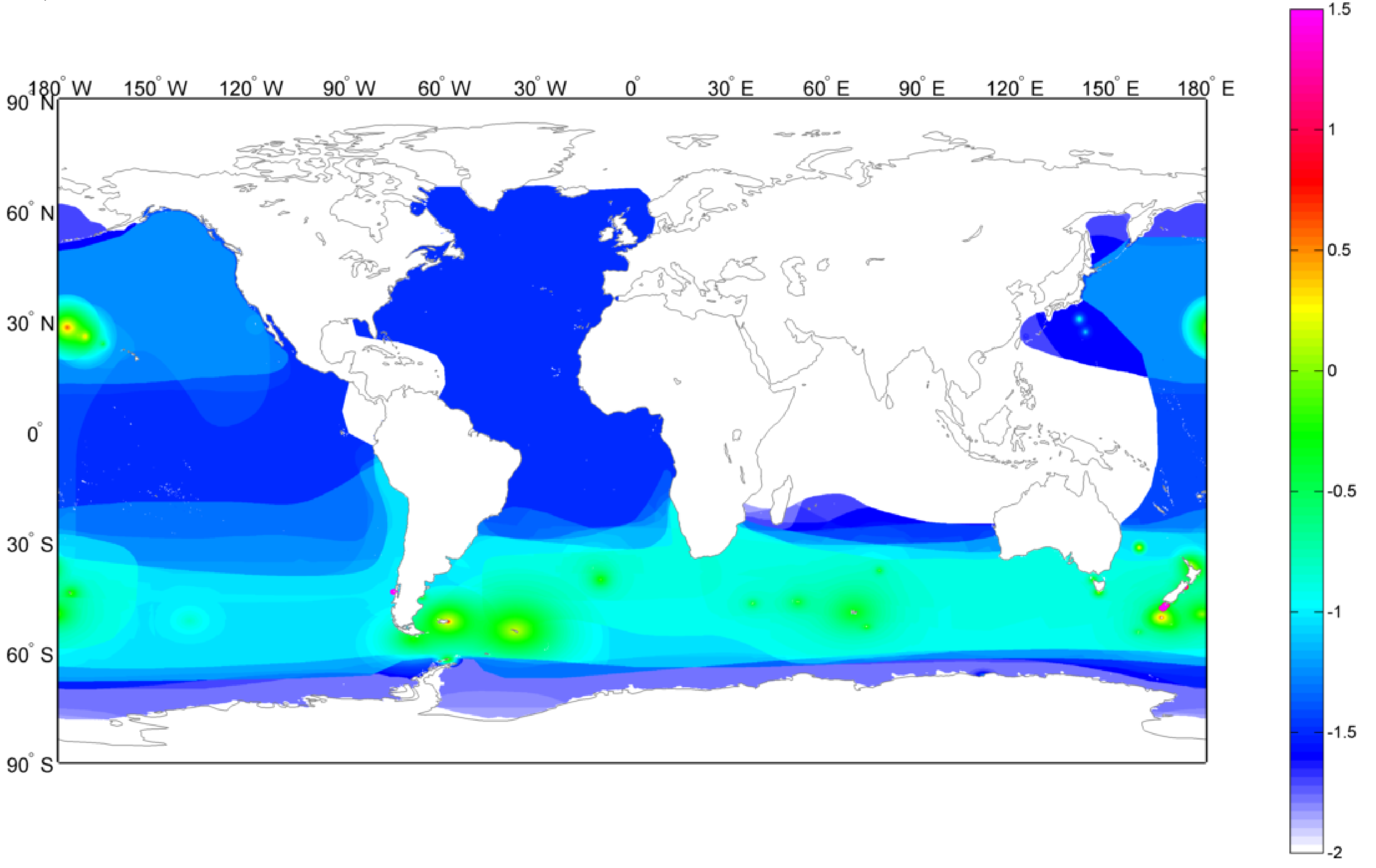


Figure 5. Seasonal spatial bird distribution, effort distribution and seasonal risk map for Westland petrels, to illustrate the means by which spatial input data layers combine to yield the species risk map. The first column contains the bird spatial distribution for each quarter, the second column is the seasonal distribution of fishing effort using catch of SBT as the index of effort; the third column contains the risk scores for Westland Petrel only. The final image (labelled Max) contains the maximum risk scores for each cell where fishing effort overlaps with Westland petrel distribution for the four seasons combined.

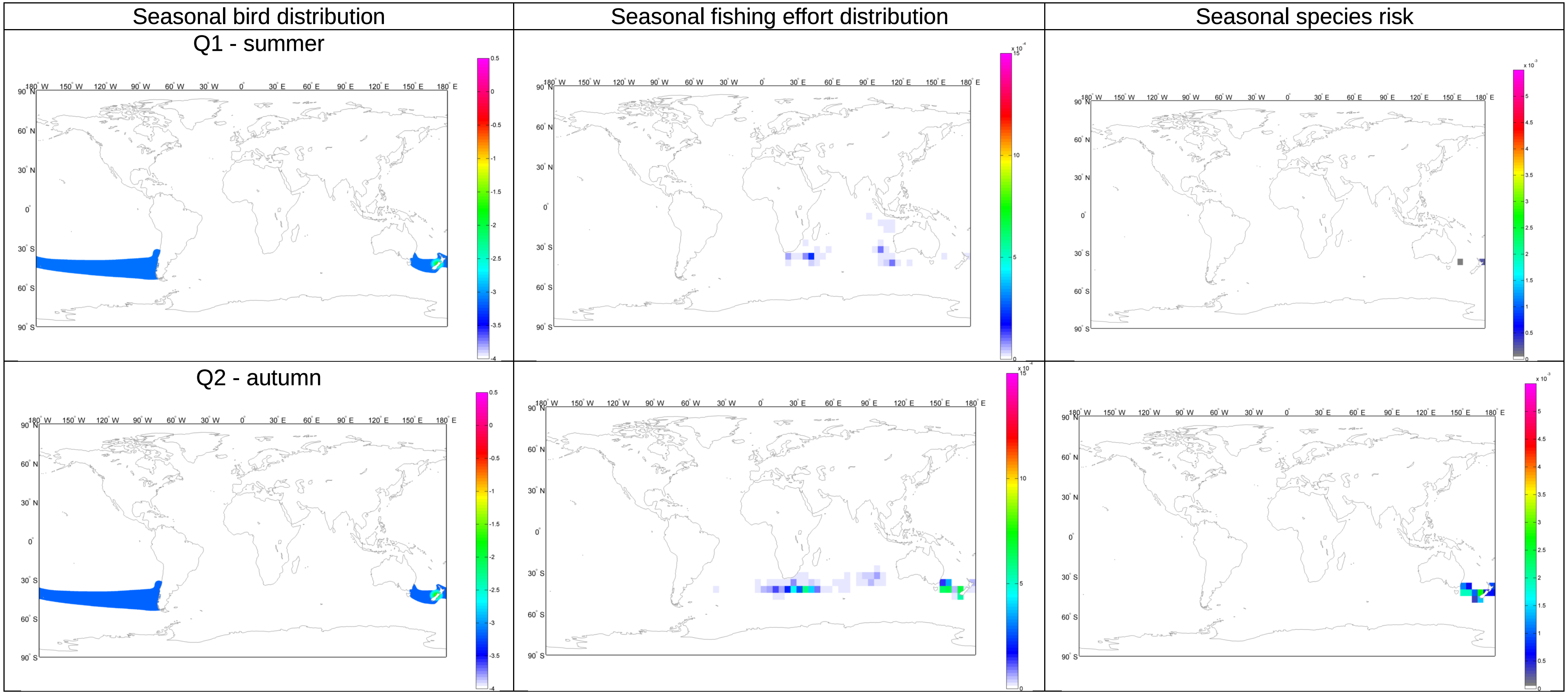


Figure 5 continued

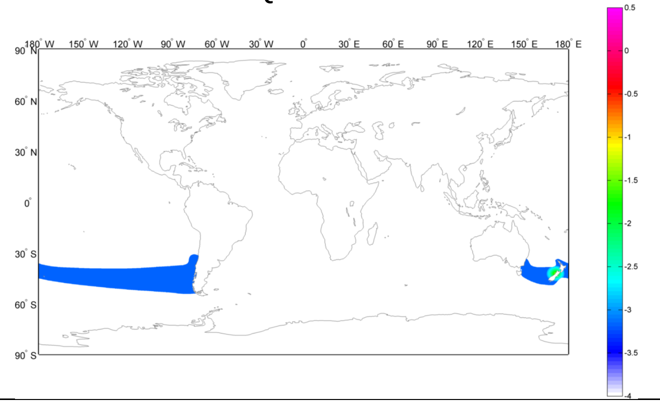
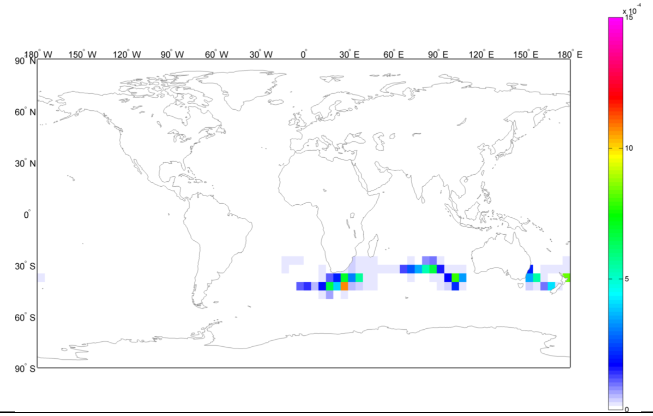
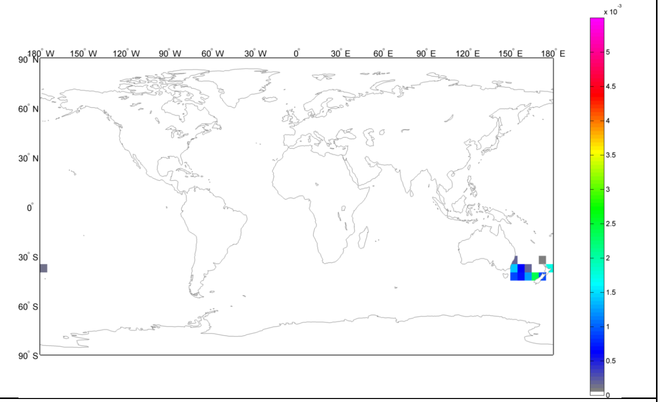
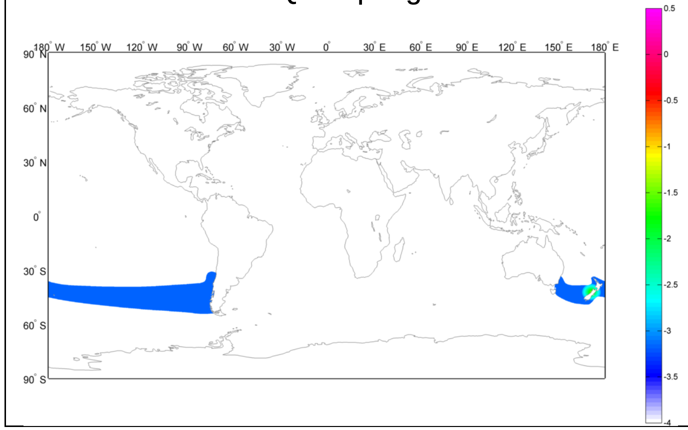
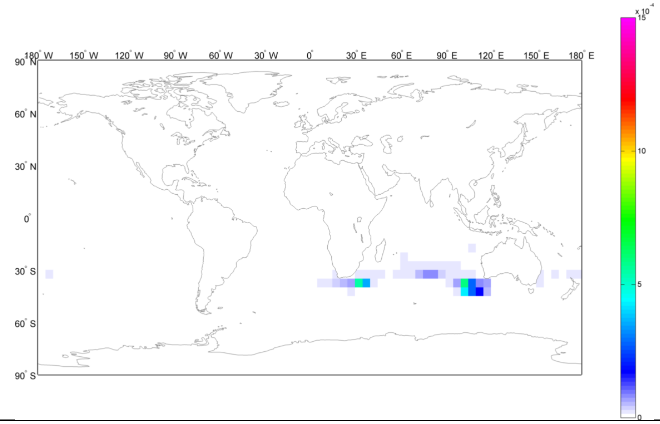
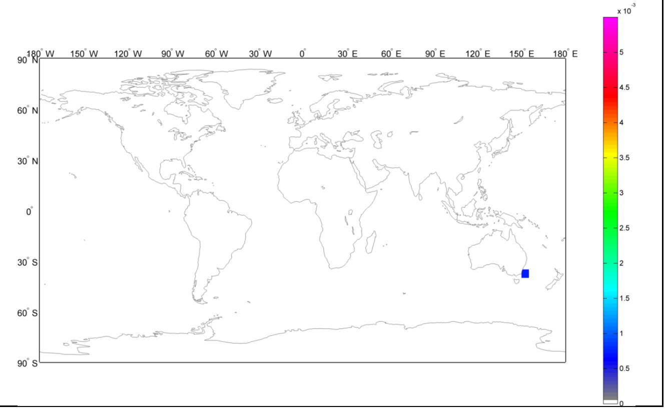
Seasonal bird distribution	Seasonal fishing effort distribution	Seasonal species risk
Q3 - winter 		
Q4 - spring 		

Figure 5 continued

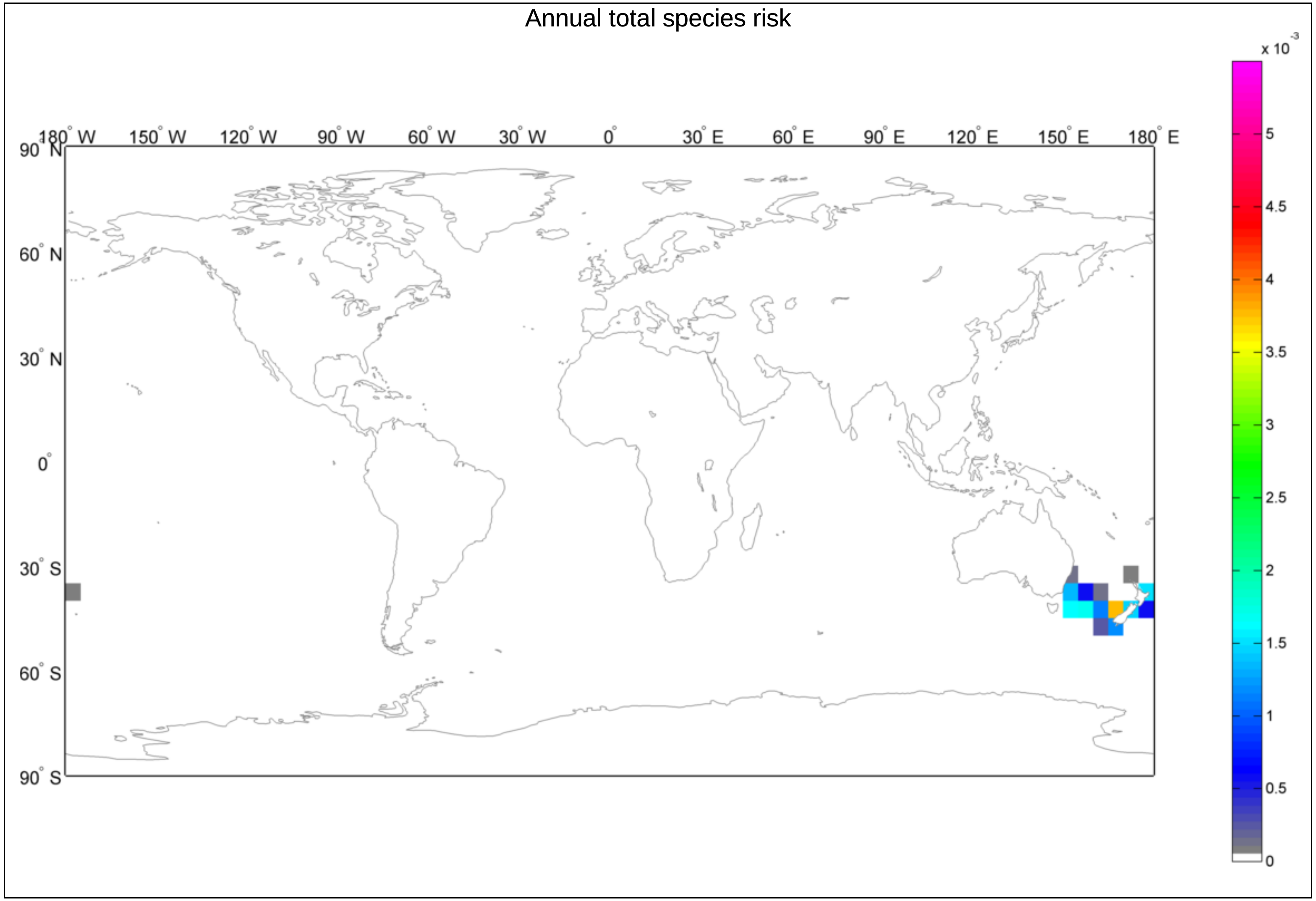


Figure 6. PSA plot showing total annual fisheries-associated risk for each seabird species as a product of their *Susceptibility* index and their inverse *Productivity* index. *Susceptibility* is estimated as a function of *spatial overlap* and species *Vulnerability (V)*; *Productivity* is a function of the *Fecundity Factor Index* and age at reproduction as described in the text. *Risk* is proportional to the area of the rectangle formed by plotting the species on these normalized axes (see Table 3 for species codes and index values). Bird species are colour-coded by guild as follows: Large albatrosses = red; small albatrosses = green; giant petrels = magenta; large shearwaters = black; miscellaneous small petrels = blue.

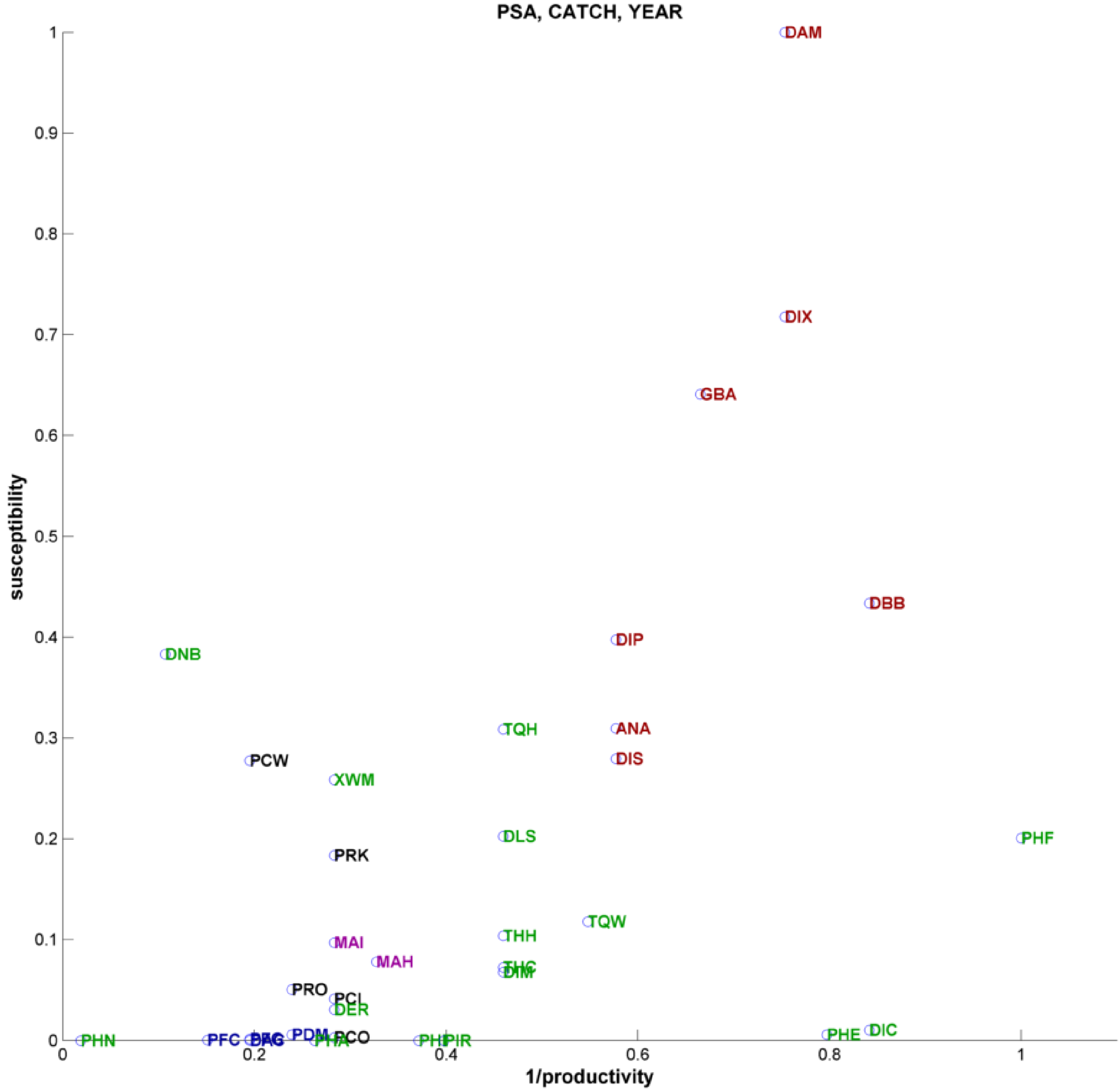
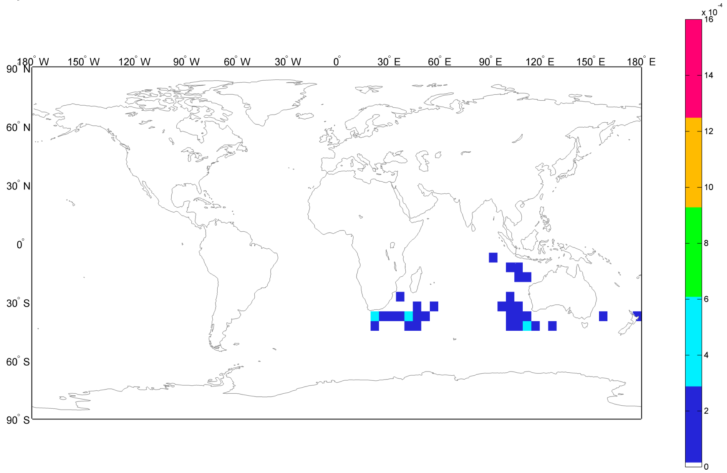
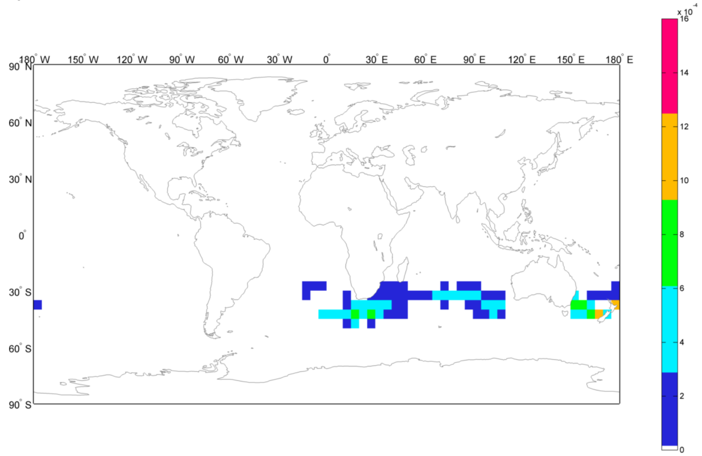


Figure 7. Seasonal risk in each 5 x 5 cell per seasonal quarter, combined for all 34 bird species included in this analysis: a) Q1 - Austral summer, b) Q2 – Austral autumn, c) Q3 - Austral winter, d) Q4 - Austral spring. By summing the untransformed cell values of the species-specific risk maps, the weighted contribution of each species to the combined map is in proportion to the species risk score in Table 3.

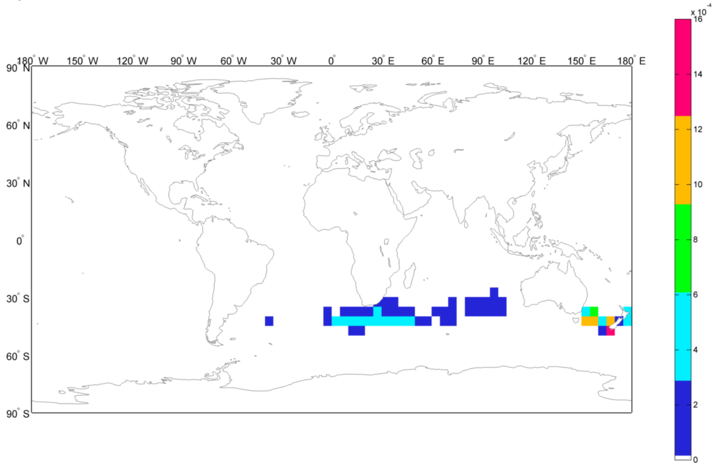
a) Q1 - summer



c) Q3 - winter



b) Q2 - autumn



d) Q4 - spring

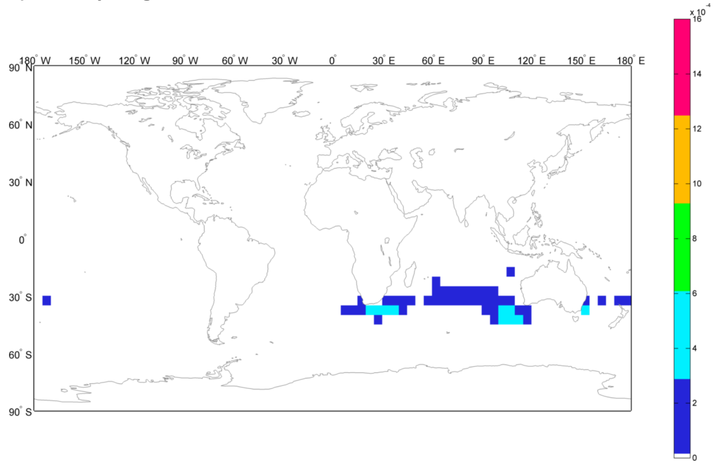


Figure 8. Total annual risk in each 5 x 5 square combined for all 34 species in this analysis, summed across all four seasonal quarters in Figure 7.

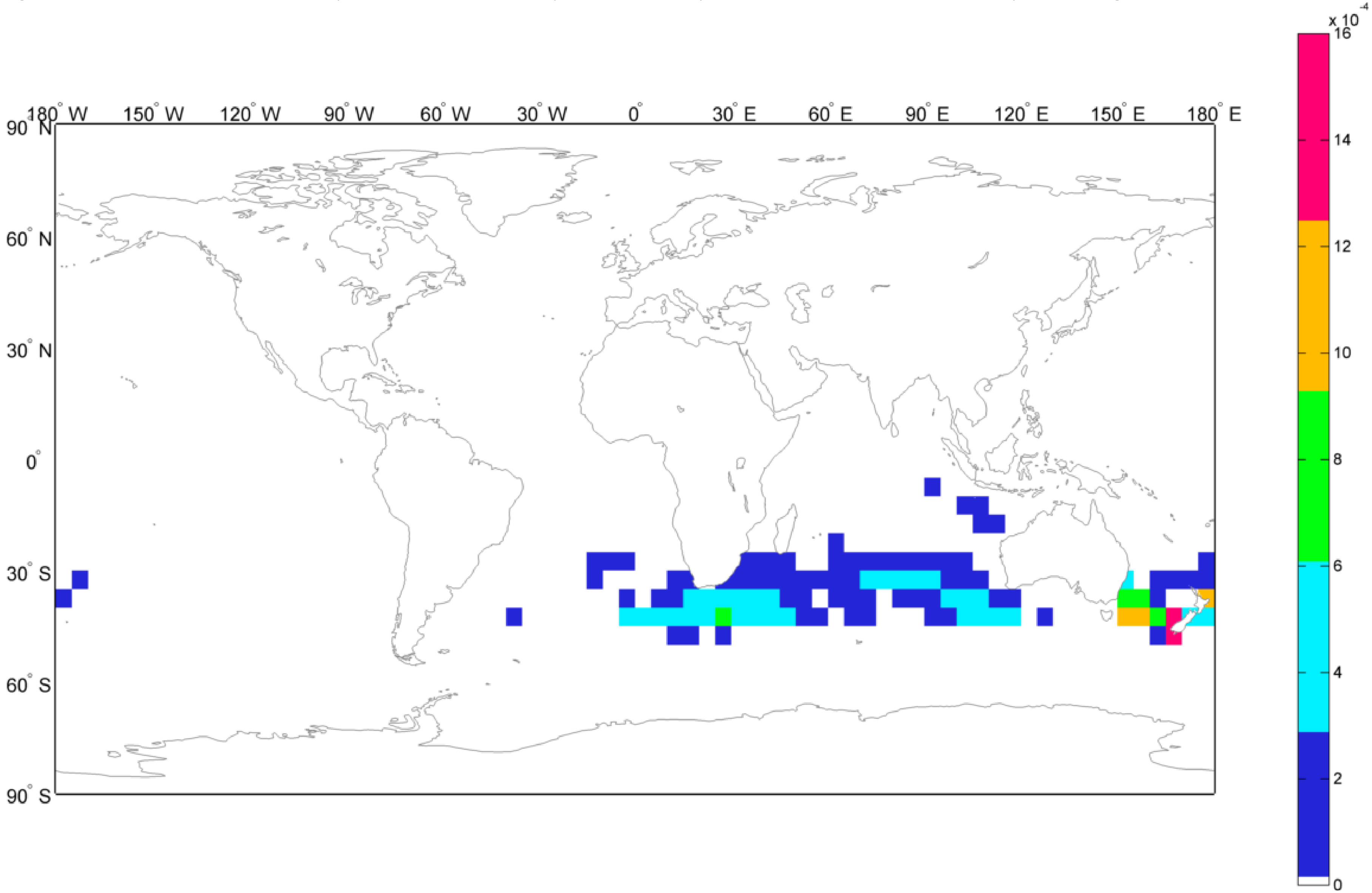


Figure 9. Amsterdam albatross spatial distribution (log10(birds / km^2) and corresponding annual species risk map. In this analysis the spatial distribution remains constant for all four seasonal quarters, as the species has a 12 month breeding cycle.

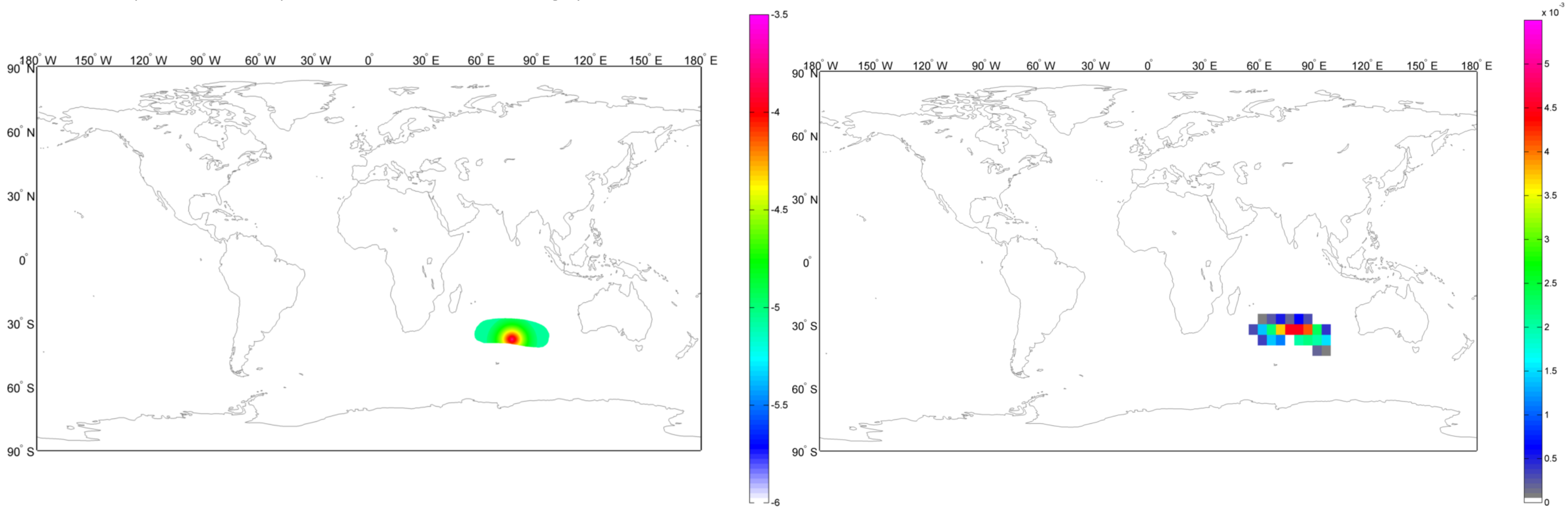


Figure 10. Seasonal spatial distributions of Flesh-footed shearwaters in during non-breeding (Q1 – Austral summer, left) and breeding (Q2, 3, 4 – Austral autumn, winter, spring, right) seasons. The scale bar figures represent log10(birds / km^2).

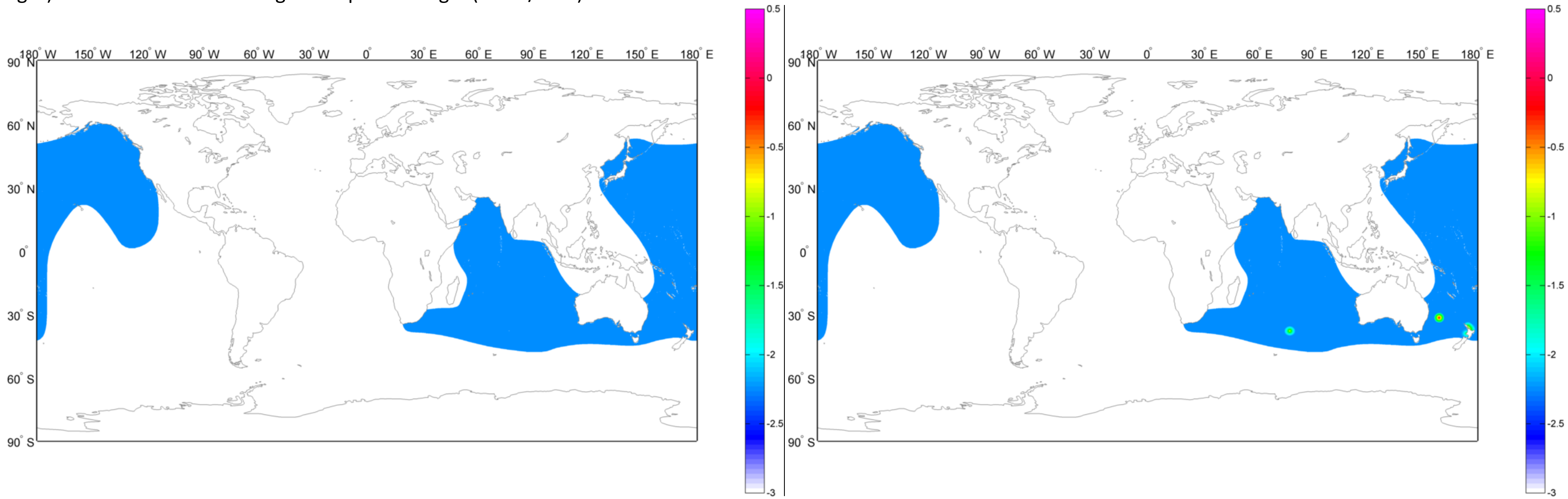


Table 1: Mitigation measures in force in selected fishery Commissions aimed at avoiding incidental capture of seabirds. Symbols ○ = voluntary deployment; ● = mandatory deployment. Note that these measures apply to restricted areas of each Convention area only, not detailed here. ( ) Measures indicated as required due to the mandatory nature of their use in other fisheries commissions. * At least two of the measures indicated with this symbol must be used in WCPFC, and either Streamer lines or a combination of line weighting and night setting in ICCAT for Swordfish fishing, and for IOTC at least one of the items marked * must be deployed.

Fishery Commission	Mitigation measures in force									
	Streamer lines / tori pole	**Night setting**	**Weighted branch lines / minimum line sink rate**	**Side-setting and weighted lines**	**Offal management**	**Thawed baits**	**Blue-dyed bait**	**Underwater setting chute / line shooting device**	**Bird exclusion device for hauling**	**Conservation measure(s) referring to mitigation measures**
CCSBT	●	( ) *	( ) *	( ) *	( ) *	○	( ) *	( ) *		CCSBT-ERS Recommendation 2011
IOTC	●*	●*	●*		○		○ (squid only)	○		IOTC Recommendation 10/06
WCPFC	●*	●*	●*	●*	●*		●*	●*		WCPFC Conservation and Management Measure 2007-04
CCAMLR	●	●	●		●				●	CCAMLR Conservation Measure 24-02 (2008) CCAMLR Conservation Measure 25-02 (2009)
ICCAT	●*	●*	●*							ICCAT Recommendation 2007-07 ICCAT Recommendation 2011-09

Table 2: Species characteristics for 34 seabird species included in the analysis, including species identifiers (common name, scientific name, species code in analysis); species group by which species *Vulnerability* was assigned; Average age at maturity; Life-history strategy: 3 = biennial breeder, single-clutch egg; 2 = annual breeder, single-clutch egg; FFI – *Fecundity factors index*, calculated by multiplying a normalised LHS and normalised Average age at maturity, and taking the average value of the product. IUCN threat ranking: CR – Critical, EN – Endangered, VU – Vulnerable, NT – Near Threatened, LC – Least concern. World population size used in the analysis; Mean maximum foraging range from breeding colony; Breeding dates (start and end).

Common name	Scientific name	Species group	CODE	Average age at maturity	LHS	FFI	IUCN 3.1	World Population (pairs)	Mean maximum foraging radius from the colony (km)	Breeding start (month)	Breeding end (month)
Amsterdam Albatross	*Diomedea amsterdamensis*	Large albatrosses	DAM	9	3	0.95	CR	26	1200	2	2
Antipodean Albatross	*Diomedea antipodensis*	Large albatrosses	ANA	7	3	0.85	VU	6286	2000	1	1
Atlantic Yellow-nosed Albatross	*Thalassarche chlororhynchos*	Small albatrosses	THH	9	2	0.78	EN	69100	2600	8	4
Black-browed Albatross	*Thalassarche melanophrys*	Small albatrosses	DIM	9	2	0.78	EN	601686	1100	9	5
Black-footed Albatross	*Phoebastria nigripes*	Small albatrosses	PHN	4	2	0.53	EN	61307	250	10	6
Buller's Albatross	*Thalassarche bulleri*	Small albatrosses	DNB	5	2	0.58	NT	30460	450	12	9
Campbell Albatross	*Thalassarche impavida*	Small albatrosses	TQW	10	2	0.83	VU	21000	650	8	5
Cape Pigeon	*Daption capense*	Southern petrels	DAC	6	2	0.63	LC	666000	360	10	1
Chatham Albatross	*Thalassarche eremita*	Small albatrosses	DER	7	2	0.68	VU	4575	600	7	4
Flesh-footed Shearwater	*Puffinus carneipes*	Dark shearwaters	PFC	5.5	2	0.61	LC	216000	250	9	5
Gibson's Albatross	*Diomedea gibsoni*	Large albatrosses	GBA	8	3	0.90	VU	5271	2000	12	12
Great-winged Petrel	*Pterodroma macroptera*	Large Pterodromas	PDM	6.5	2	0.66	LC	500000	600	6	1
Grey Petrel	*Procellaria cinerea*	Procellaria petrels	PCI	7	2	0.68	NT	111684	600	2	12
Grey-Headed Albatross	*Thalassarche chrysostoma*	Small albatrosses	DIC	10	3	1.00	VU	95748	1600	9	5
Indian Yellow-nosed Albatross	*Thalassarche carteri*	Small albatrosses	TQH	9	2	0.78	EN	65000	2600	8	4
Laysan Albatross	*Phoebastria immutabilis*	Small albatrosses	PHI	8	2	0.73	NT	591356	1000	9	7
Light-mantled Sooty Albatross	*Phoebetria palpebrata*	Small albatrosses	PHE	9.5	3	0.98	NT	22611	1550	9	5
Northern Giant Petrel	*Macronectes halli*	Giant petrels	MAH	7.5	2	0.71	LC	11800	550	8	5
Northern Royal Albatross	*Diomedea sanfordi*	Large albatrosses	DIS	7	3	0.85	EN	5832	1250	1	1
Parkinson's Petrel	*Procellaria parkinsoni*	Procellaria petrels	PRK	7	2	0.68	VU	3333	550	10	6

Common name	*Scientific name*	Species group	CODE	Average age at maturity	LHS	0.78	IUCN 3.1	World Population (pairs)	Mean maximum foraging radius from the colony (km)	Breeding start (month)	Breeding end (month)
Salvin's Albatross	*Thalassarche salvini*	Small albatrosses	DLS	9	2	0.67	VU	31947	1500	8	4
Short-tailed Albatross	*Phoebastria albatrus*	Small albatrosses	PHA	6.77	2	0.78	VU	470	1500	10	6
Shy Albatross	*Thalassarche cauta*	Small albatrosses	THC	9	2	1.09	NT	12585	250	6	4
Sooty Albatross	*Phoebetria fusca*	Small albatrosses	PHF	11.8	3	0.63	EN	13890	2000	7	5
Sooty Shearwater	*Puffinus griseus*	Dark shearwaters	PFG	6	2	0.68	NT	6000000	100	9	5
Southern Giant Petrel	*Macronectes giganteus*	Giant petrels	MAI	7	2	0.85	LC	50170	250	6	6
Southern Royal Albatross	*Diomedea epomophora*	Large albatrosses	DIP	7	3	0.68	VU	7900	1000	10	10
Spectacled Petrel	*Procellaria conspicillata*	Procellaria petrels	PCO	7	2	1.00	VU	10000	1900	9	3
Tristan Albatross	*Diomedea dabbenena*	Large albatrosses	DBB	10	3	0.95	CR	1700	2500	1	1
Wandering Albatross	*Diomedea exulans*	Large albatrosses	DIX	9	3	0.75	VU	8050	1800	1	1
Waved Albatross	*Phoebastria irrorata*	Small albatrosses	PIR	8.3	2	0.63	CR	9620	200	3	12
Westland Petrel	*Procellaria westlandica*	Procellaria petrels	PCW	6	2	0.68	VU	4000	500	2	12
White-capped Albatross	*Thalassarche steadi*	Small albatrosses	XWM	7	2	0.66	NT	97111	450	11	11
White-chinned Petrel	*Procellaria aequinoctialis*	Procellaria petrels	PRO	6.5	2	FFI	VU	1241000	1900	10	5

Table 3: Species parameters and indices contributing to the estimate of total species risk (final column) for each of 34 seabird species included in this analysis. Species risk is the product of the normalized *Susceptibility* and inverse *Productivity* indices as illustrated in Figure 6; mathematical derivation of the Susceptibility and Productivity indices as a function of the other parameters is as described in the text.

Common_name	**Code**	*Vulnerability*	*spatial overlap* **($*10^{-7}$)**	*Susceptibility* **($*10^{-7}$)**	**Normalised** *Susceptibility*	**Normalised 1/***Productivity*	**Risk score**
Amsterdam Albatross	DAM	1	12.251	12.2506	1.0000	0.7532	0.7532
Wandering Albatross	DIX	1	8.794	8.7939	0.7178	0.7532	0.5407
Gibson's Albatross	GBA	1	7.850	7.8499	0.6408	0.6651	0.4262
Tristan Albatross	DBB	1	5.311	5.3112	0.4336	0.8414	0.3648
Southern Royal Albatross	DIP	1	4.869	4.8695	0.3975	0.5770	0.2293
Sooty Albatross	PHF	0.3079	7.980	2.4571	0.2006	1.0000	0.2006
Antipodean Albatross	ANA	1	3.790	3.7904	0.3094	0.5770	0.1785
Northern Royal Albatross	DIS	1	3.422	3.4223	0.2794	0.5770	0.1612
Indian Yellow-nosed Albatross	TQH	0.3079	12.273	3.7787	0.3085	0.4595	0.1417
Salvin Albatross	DLS	0.3079	8.059	2.4814	0.2026	0.4595	0.0931
White-capped Albatross	XWM	0.3079	10.294	3.1696	0.2587	0.2832	0.0733
Campbell Albatross	TQW	0.3079	4.696	1.4459	0.1180	0.5476	0.0646
Westland Petrel	PCW	0.1512	22.493	3.4010	0.2776	0.1951	0.0542
Parkinson's Petrel	PRK	0.1512	14.870	2.2483	0.1835	0.2832	0.0520
Atlantic Yellow-nosed Albatross	THH	0.3079	4.132	1.2723	0.1039	0.4595	0.0477
Buller's Albatross	DNB	0.3079	15.245	4.6940	0.3832	0.1069	0.0410
Shy Albatross	THC	0.3079	2.888	0.8893	0.0726	0.4595	0.0334
Black-browed Albatross	DIM	0.3079	2.690	0.8282	0.0676	0.4595	0.0311
Southern Giant Petrel	MAI	0.3079	3.857	1.1875	0.0969	0.2832	0.0275
Northern Giant Petrel	MAH	0.3079	3.100	0.9543	0.0779	0.3273	0.0255
White-chinned Petrel	PRO	0.1512	4.088	0.6181	0.0505	0.2391	0.0121
Grey Petrel	PCI	0.1512	3.342	0.5053	0.0412	0.2832	0.0117
Chatham Albatross	DER	0.3079	1.208	0.3721	0.0304	0.2832	0.0086
Grey-Headed Albatross	DIC	0.0308	4.035	0.1243	0.0101	0.8414	0.0085
Light-mantled Sooty Albatross	PHE	0.0308	2.262	0.0697	0.0057	0.7973	0.0045
Great-winged Petrel	PDM	0.0063	11.145	0.0702	0.0057	0.2391	0.0014
Spectacled Petrel	PCO	0.1512	0.228	0.0344	0.0028	0.2832	0.0008
Sooty Shearwater	PFG	0.0011	15.846	0.0174	0.0014	0.1951	0.0003
Flesh-footed Shearwater	PFC	0.0011	3.541	0.0039	0.0003	0.1510	0.0000
Cape Pigeon	DAC	0.0003	3.981	0.0012	0.0001	0.1951	0.0000
Short-tailed Albatross	PHA	0.3079	0	0	0	0.2629	0
Laysan Albatross	PHI	0.3079	0	0	0	0.3713	0
Black-footed Albatross	PHN	0.3079	0	0	0	0.0188	0
Waved Albatross	PIR	1	0	0	0	0.3978	0