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**Spatial risk indicators for seabird interactions with longline fisheries  
in the western and central Pacific**

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**WCPFC-SC5-2009/EB-WP-06**

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## **Abstract**

In this paper we assess the risk of interactions between longline fisheries and seabirds in the Western and Central Pacific Fisheries Commission (WCPFC) Convention Area. Efforts to reduce fishing-induced mortality are especially important for Procellariiform seabirds, particularly albatrosses and gadfly petrels, which are at particularly high risk of species extinction. We use a spatially explicit *Productivity-Susceptibility Analysis* (PSA) to determine (a) the probability of seabird-fisheries interactions occurring, by comparison of fishing effort and species range distributions, and (b) the risk of adverse effects of fishing-induced mortality on populations of seabirds. We also identify areas of high seabird diversity as well as areas with the potential for fisheries interactions if fishing effort were to increase in those areas. On the basis of the analysis we make recommendations for future research and for future refinement of management measures.

## ***Introduction***

In this paper we assess the risk of interactions between longline fisheries and seabirds in the Western and Central Pacific Fisheries Commission (WCPFC) Convention Area. We further develop and apply methods discussed by Kirby and Hobday (2006) and examined in more detail for seabirds by Waugh et al (2008) for a suite of seabird species known to be vulnerable to capture in longline fisheries. We use a spatially explicit version of a *Productivity-Susceptibility Analysis* (PSA) to determine the probability of seabird-fisheries interactions and the potential for adverse effects of fisheries mortality on populations of seabirds. We step through the development of the *Susceptibility* axis, mapping the results at each stage back onto a 5×5 degree grid across the entire Convention Area, thereby incorporating multiple perspectives on ‘risk’, i.e. to particular species, from particular flags and in particular areas. This allows the monitoring and management implications by species/flag/area to be easily understood.

‘Risk’ in this analysis refers to the probability of adverse effects on seabirds as a result of fishing mortality. We relate this, firstly, to the probability that a species is subject to fishing-induced mortality, under the general assumption that this risk is proportional to the overlap between distributions of fishing effort and of the seabird species concerned. This overlap index is used to define the *Susceptibility* score.

Additional indicators are then developed for the number of species and the number of individuals potentially affected by fishing-induced mortality in any particular area. This allows consideration of ‘biodiversity hotspots’ as well as areas where the potential for fisheries interactions with seabirds of any species is highest.

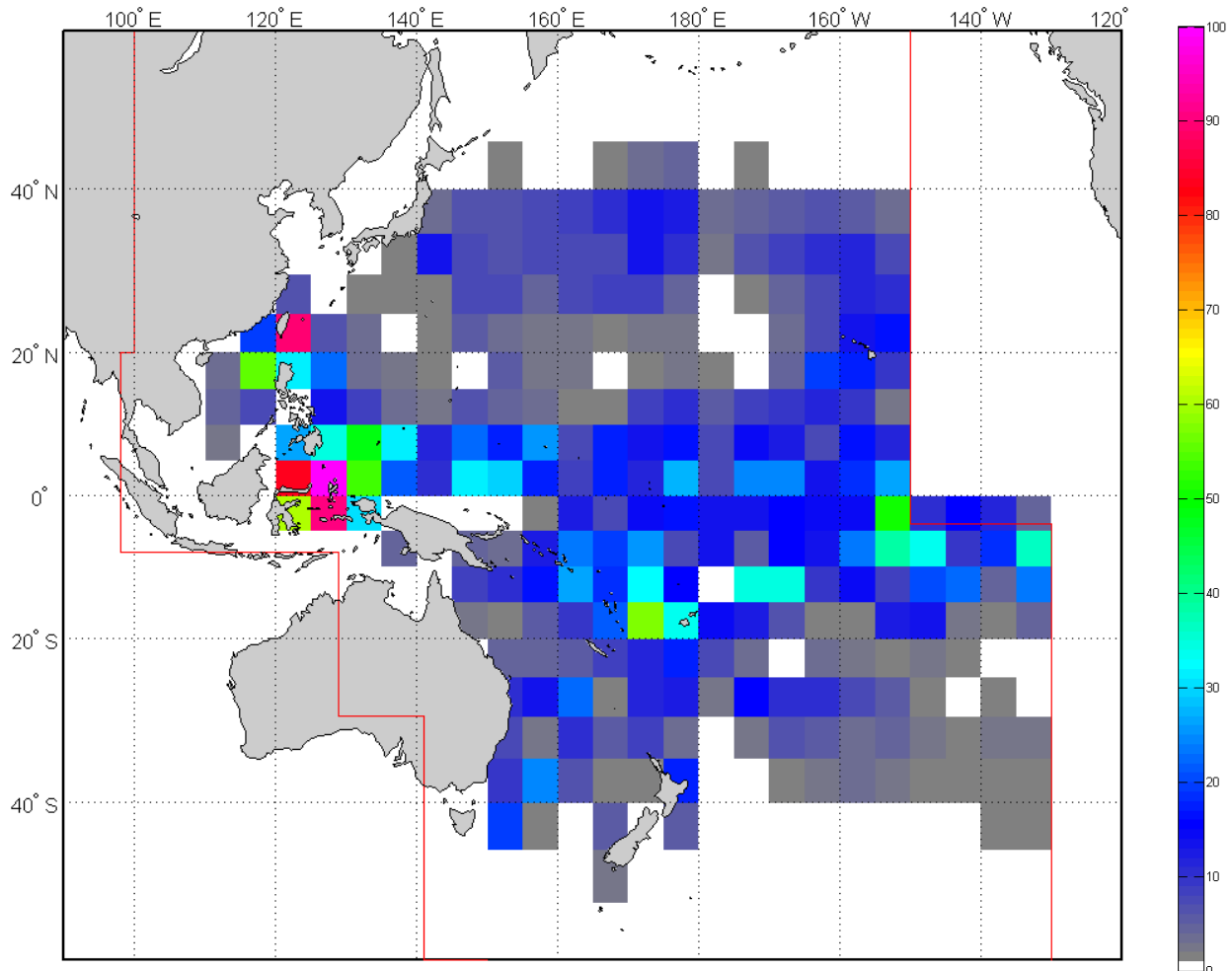
Finally, we determine areas where fisheries pose the most risk of population-level effects. To assess the risk of population-level effects we carry out an analysis including a measure of the population growth rate for each species and re-define ‘risk’ as the anticipated consequences at a population level of the probable fishing-induced mortality incurred. This therefore includes the *Productivity* axis of the PSA in addition to the *Susceptibility* as derived from the spatial overlap.

## Methods

### *Longline fishing effort and its distribution*

Longline fishing effort data for vessels targeting tunas and swordfish was extracted from SPC databases. These data were number of hooks stratified by flag state per 5 degree square per month for the period 2002 to 2007. We plotted fishing effort density, within 5-degree squares of latitude and longitude, as thousands of hooks per square km and summed the fishing effort within each square across the 6 years of data (Fig. 1). We did not attempt to account for monthly, seasonal or inter-annual variability in the distribution of effort, as bird distribution data were not available to describe corresponding changes in range.

**Figure 1. Fishing effort density for WCPFC longline fisheries by 5-degree square (2002-2007) (thousand hooks/km<sup>2</sup>)**



## *Study species and their distributions*

We examined the range of seabird species occurring in the WCPFC Convention Area, whose families or genera are known to be captured in longline fishing. In order to reduce the scope of the study to a manageable size, we excluded 192 other seabird species outside the order Procellariiformes, despite information to suggest that some level of incidental mortality may also occur for some of these species (Gales et al. 1999, Waugh et al. 2008, Huang et al. 2008). We excluded several species of diving petrel and storm petrel due to lack of detailed data on their population ecology, as well as expert opinion that indicated lower likelihood of fisheries interactions with this group. We also excluded species for which there was no information about their distribution at sea. We therefore analysed data for a group of 74 species, which included albatrosses, petrels, and shearwaters occurring in both tropical and temperate oceanic systems. See Table 1 for the species list, including biological attributes used to calculate *Productivity* (see below).

Of the 74 species included, 23 have previously been recorded captured in western Pacific longline fisheries by fisheries observers during the entire history of the national and regional observer programmes contributing to the SPC database (mostly mid-1990s onwards; Table 1). This list is the best available data but is nonetheless unlikely to be comprehensive for two main reasons: firstly not all species included in this analysis would have been recorded by fisheries observers even if they had been caught, because of the difficulties in correctly identifying hooked seabirds, and especially those that have been soaking underwater for several hours. The observer data therefore include a large number of “unidentified seabirds”, around 1/3 of the total records held by SPC. Secondly, the representativeness of the observer data is compromised by the low overall coverage of Pacific longline fleets by scientific observers, which is <1% for all fleets combined. The fact that in many parts of the region seabird bycatch is a statistically rare event implies that a much higher percentage of observer coverage is needed in order to reliably estimate catches, by comparison to target or bycatch fish species (Lawson 2006).

The range data available were limited to average annual distributions for all species. We mapped species distributions on a global scale (i.e. including outside the WCPFC Convention Area) assuming that 100% of the population of the species was distributed within the BirdLife Range Map (Appendix 1 for species examples). We estimated the proportion of the global population that is within the WCPFC Convention Area based on the proportion of a species' total range within this zone.

We then defined areas within the global range of a species where a higher proportion of birds from each species could be found relative to the surrounding area (Hotspots; See Appendix 1 for species level details), using either:

- a. Remote-tracking data layers, with 50, 75, 90, 95% utility distribution for 12 species (see BirdLife 2005 for methods in determining kernel distributions of birds on the basis of these data for 16 species), for breeding and non-breeding ranges. In order to represent average annual probability distributions we attributed 40% of each population to the breeding season range, and 60% to the non-breeding range<sup>1</sup> each comprised of up to three kernel layers; or
- b. Species foraging radius approach – for 18 species where remote-tracking data were unavailable, colony locations and average foraging radius of the birds were used based on published estimates of foraging activity. We estimated the density of birds from individual populations within the WCPFC Convention Area, attributing 50% of the individual populations to these zones, defined by the radius of the average foraging trip from a colony.
- c. Where data on concentrations of foraging activity were not available, we only used the BirdLife Range Maps to describe the species ranges, with an even distribution of the species attributed to its range within the Convention Area.

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<sup>1</sup>Weightings based on previous work in ICCAT fisheries: 70% of species population is presumed to be breeding adults, occupying the breeding range during 6 months of the year, as do 10% of the non-breeding adult population, therefore on average 40% of total population occupies the breeding range during the year; 20% of the population is attributed to the juvenile stage, which occupies the non-breeding range throughout the year, and is joined by the breeding and non-breeding adults during half of the year.

## Productivity-Susceptibility Analyses (PSAs)

We used the maps of longline fishing effort in the WCPFC Convention Area and those of species distributions to calculate risk scores based on (a) *Susceptibility* indicators, calculated as the product of fishing effort and normalised species distributions (i.e. proportion of a species' range) (Eq. 1):

$$susceptibility(species, flag) = \int_{pacific} normal\_bird\_density(species) \times effort\_density(flag)$$

and (b) a *Productivity* indicator, defined as the maximum reproductive rate.

In previous PSA analyses, *Productivity* estimates have been generated using a collection of variables that determine reproductive output, standardised and averaged in order to provide a scale-free indicator that approximates the intrinsic rate of population increase. This methodology was developed to deal with information across a wide range of taxon groups, including fish, turtles, mammals and seabirds, where population parameters that are not directly measurable are unknown.

For this study, where all study species are within a single taxonomic order, we were able to use a more harmonious set of life-history parameters to approximate  $R_{max}$ , the maximum rate of increase of a population with no resource limitation, predation or competition (Sibly & Hone 2003). Niel & Lebreton (2005) demonstrated that for birds there is a constant relationship between generation length and population growth rate. They established that maximum annual growth rate  $\lambda_{max}$  can be estimated for long-lived species using estimates of age at first reproduction ( $\alpha$ ) and adult annual survival ( $s$ ).

We solved for  $\lambda_{max}$ , to derive the index of *Productivity*, based on the relationship between this parameter and age at first breeding and annual adult survival, (Eq. 2):

$$\lambda_{max} = \exp \left[ \left( \alpha + \frac{s}{\lambda_{max} - s} \right)^{-1} \right]$$

$R_{max}$  was calculated from  $\lambda_{max}$  thus:  $R_{max} = \lambda_{max} - 1$

We estimated  $\alpha$  and  $s$  values for each species based on parameter values found in the scientific literature. Where more than one value was available for a species, the value from the study likely to provide the most robust estimation of  $R_{max}$  was used, i.e.. that with the largest sample size, or a longer-term study. Where severe colony-based threats (i.e. from factors other than fishing mortality) were apparent, which are likely to result in



depressed  $s$  values, we excluded these values from the study. For species where data were absent, we substituted a value from a closely-related species.  $R_{\max}$  values were normalized, with a maximum value set at 1.

Overall risks of adverse effects on seabird populations are then calculated by combining both *Productivity* and *Susceptibility* indicators (Eq. 3).

$$risk = (Productivity^2 + Susceptibility^2)^{1/2}$$

We normalized outputs of the overall PSA, combining both *Susceptibility* and *Productivity* indicators, so that values fell between 0 and 1. After the PSA outputs had been generated, we re-created maps without the results for Fiji petrel as the extremely high values generated for this species made interpretation of mapping outputs difficult. Values plotted were square-root transformed to normalize the distribution of the data. Five levels were attributed to the outputs based on the actual frequency distribution of the PSA scores, in order to ease interpretation. Negligible levels of risk (0 – 0.001): white; Low (0.001 – 0.2): royal blue; Low to Medium (0.2 – 0.4): pale blue; Medium (0.4 – 0.6): green; Medium to High (0.6 – 0.8): orange; High (0.8 – 1.0): pink. Risk scores by 5×5 degree area were calculated as (Eq. 4):

$$Risk(area) = \sum_{all\_species} \sum_{all\_flags} Risk(species, flag)$$

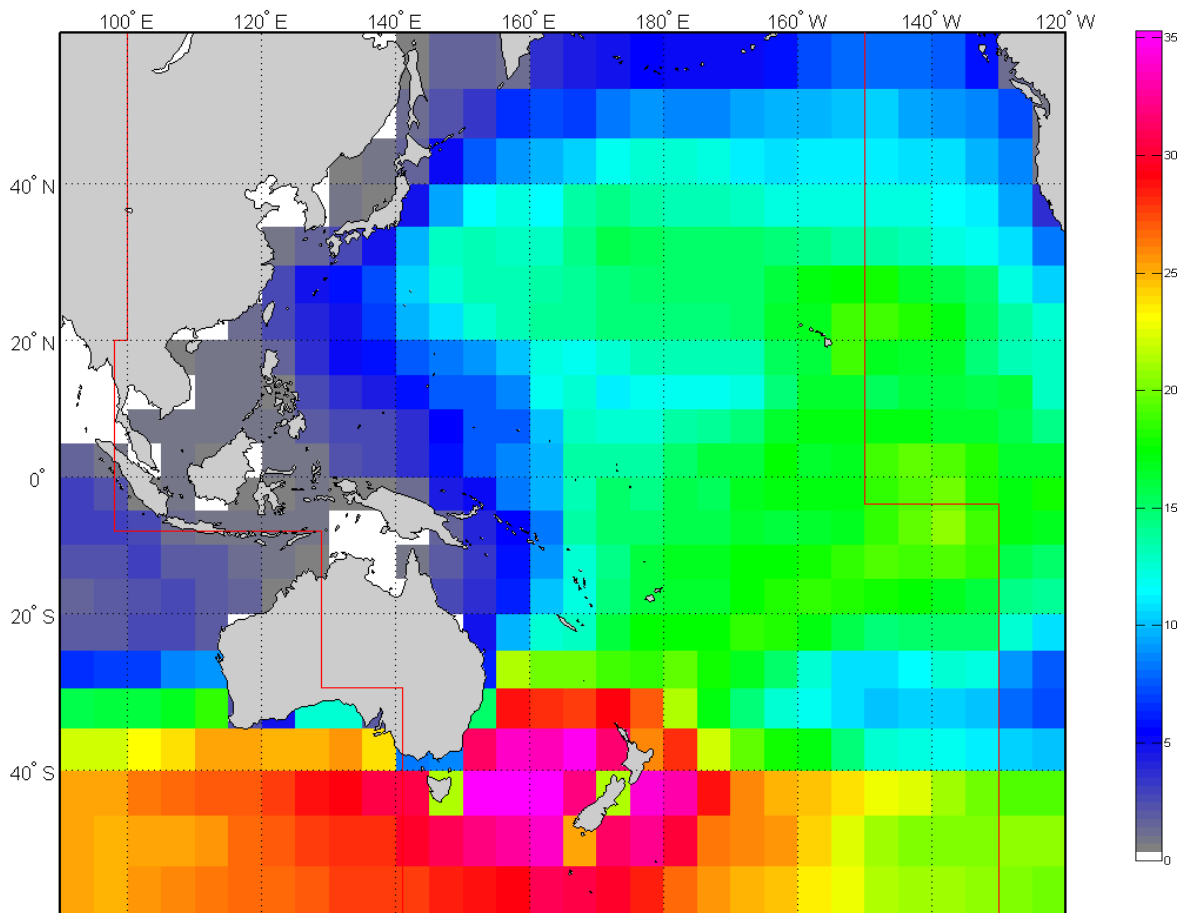
## Results

### *Risk indicators for seabird-fisheries interactions based on spatial overlap*

The maps for risk indicators for seabird-fisheries interactions based on spatial overlap can be seen in Figs. 2, 3 & 4. We have included Figs. 2 & 3 for information in their own right, while Fig. 4 is also used as the *Susceptibility* indicator in the subsequent *Productivity-Susceptibility Analysis* (PSA).

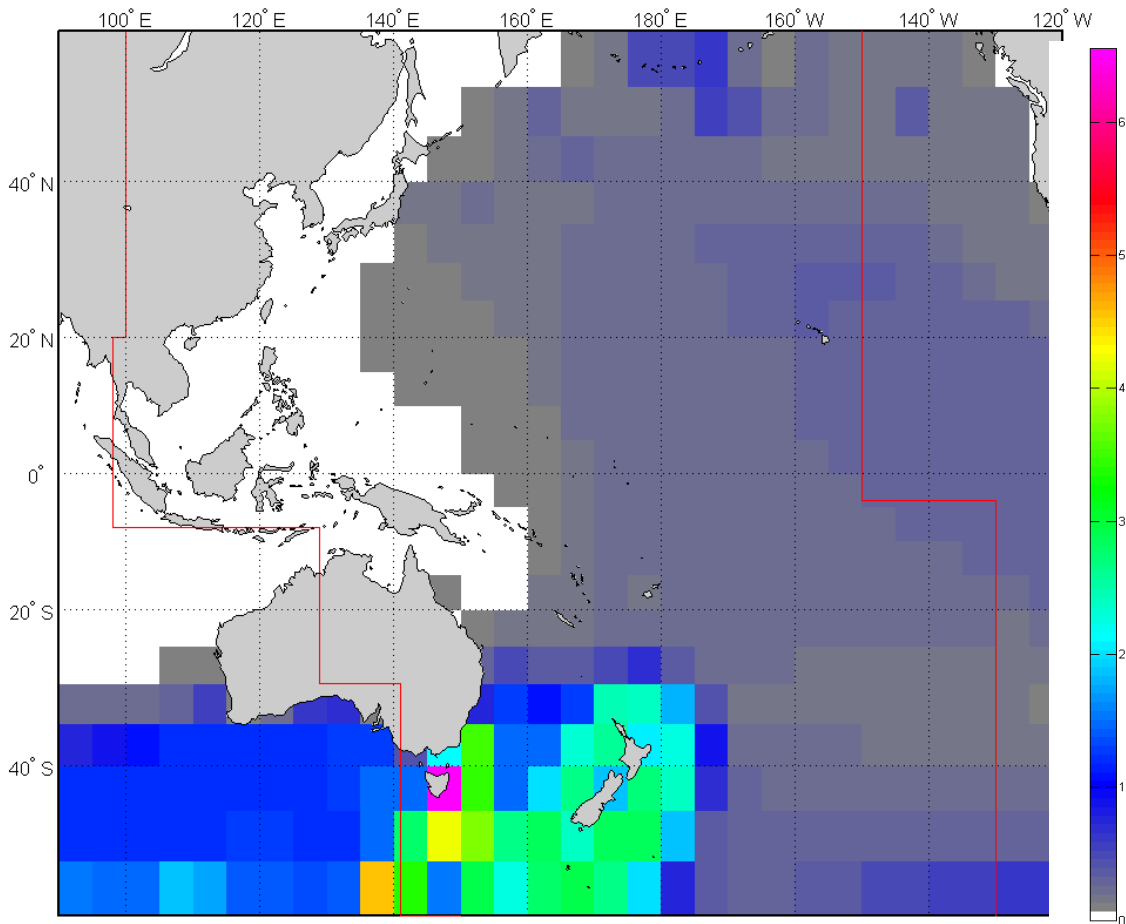
In Fig. 2 we can see which areas are frequented by more/less species of seabird. This tells us what areas might be considered ‘biodiversity hotspots’ for seabirds and which other areas are frequented by only one or two species. This information is useful as it illustrates, for example, the extent to which scientific observers must be trained in identifying numbers of different species depending on the area in which they are working. The results show that highest seabird diversity occurs in the Tasman Sea, temperate areas north, south, west and east of the Tasman Sea, and in an arc spreading north-east to the central Pacific and back to the north-west Pacific.

**Figure 2. Plot of seabird diversity (number of species per 5×5 degree area) for 74 species of albatross and petrel found in the WCPFC Convention Area**



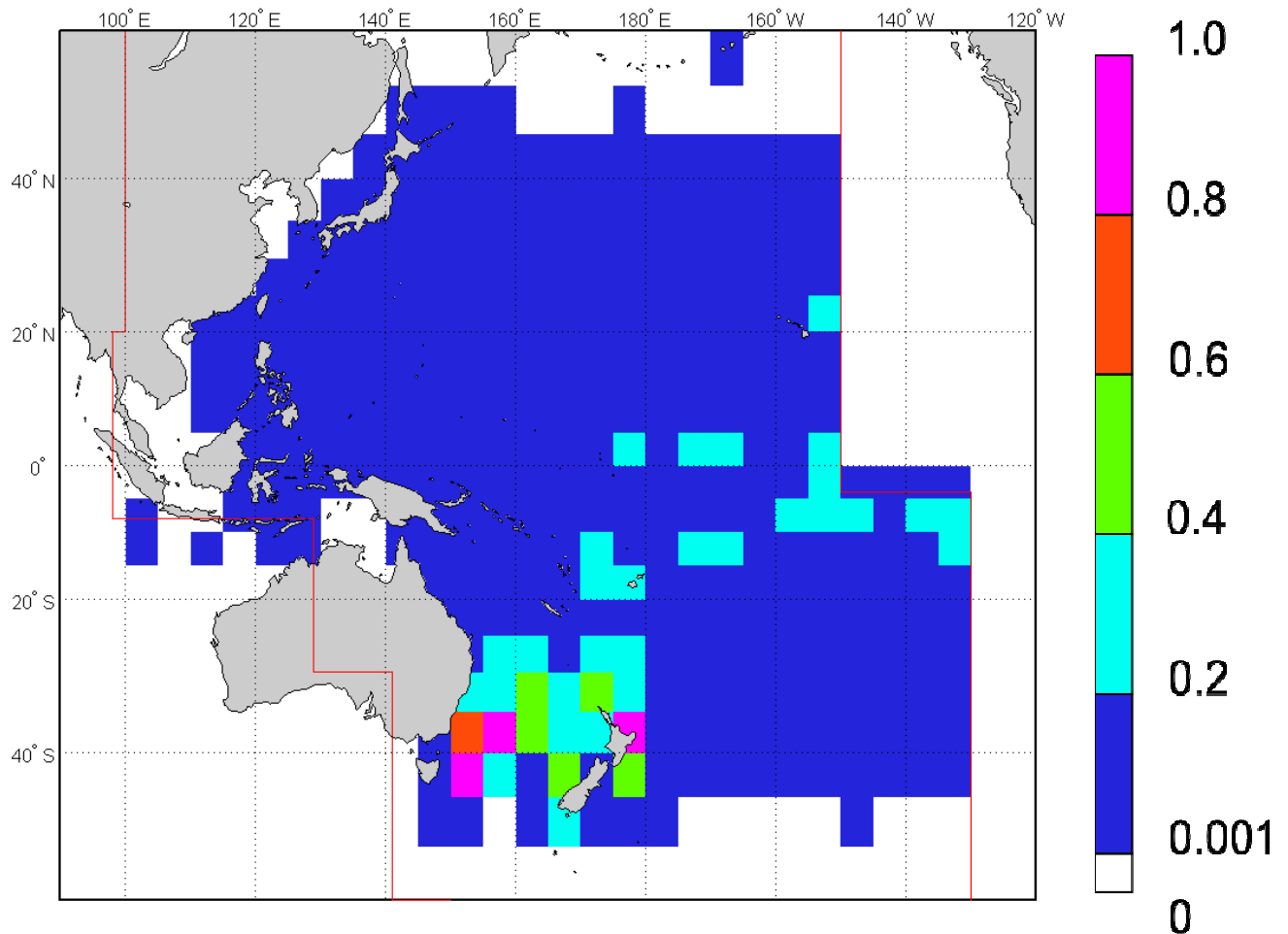
In Fig. 3. we have scaled the number of species present (Fig. 2) by their respective population sizes to give the expected numbers of seabirds in each area. The results show that waters around New Zealand and west into the Tasman Sea and Southern Ocean have the highest absolute numbers of seabirds. While this is an intermediate step, as it is the combined presence of fishing effort and seabirds that results in risk of capture, it does suggest areas where use of mitigation measures would be necessary in order to minimize the number of seabird interactions if these areas are actually fished now or in the future.

**Figure 3. Plot of seabird numbers (individuals per 5×5 degree area) for 74 species of albatross and petrel found in the WCPFC Convention Area (birds/km<sup>2</sup>)**



In Fig. 4. we have combined the estimate of absolute number of seabirds (Fig. 3) with fishing effort (Fig. 1), in order to plot where fishing-induced mortality of seabirds is most likely to have been occurring over the study period (2002–2007). These values are used as the *Susceptibility* index in the PSA described below. The results show the highest risk of seabird interactions to be in the Tasman Sea and east of New Zealand, but the risk landscape extends again through an arc into the central tropical Pacific and back to the north-east Pacific. There are also some localized 5×5 areas within this arc and north of 20°S where higher than average interactions are expected. These areas are certainly worthy of increased monitoring and possible application of mitigation measures.

**Figure 4. Zones of greatest likelihood of capture of seabirds, based on distributions of fishing effort (Fig. 1) and seabird numbers (Fig. 3). Highest risk areas: pink; Medium to high: orange; Medium: green; Medium to low: pale blue; Low: dark blue; Negligible: white**



## *Productivity-Susceptibility Analyses (PSAs) for risk of species-level effects*

We calculated Productivity-Susceptibility (PSA) scores for all species included in the analysis (Fig. 5). Values expressed in maps and in tables are generated on the basis of the distance from the origin of this plot.

Species were spread along the *Productivity* axis in relation to their  $R_{max}$  value, a measure of their ability to rebuild populations. The grouping of species along this axis that is apparent in Fig. 5. indicates where species-specific values were lacking, and substitute values were used for several species from the same genus. Values ranged from near to 0.9 for species that are common and rapidly-breeding (e.g. Bulwers' petrel, Cape petrel) to close to 0.05 for the slowest-breeding species (e.g. some long-lived and biennially-breeding albatrosses). The  $R_{max}$  values used for this study are in Table 1.

The results of the PSA, combining Fig. 4 as the *Susceptibility* indicator on the *y*-axis with values of  $R_{max}$  as the *Productivity* indicator on the *x*-axis, are shown in Fig. 5. We have tabulated the outputs of the PSAs to examine them in more detail in relation to the likely effect of combined fishing effort (i.e. aggregated across areas and flags) for each species (Table 2), and the proportion of risk at a species level attributed to each flag (see outputs for each species in Table 3). We have then mapped the PSA results back to the 5×5 grid across the WCPFC Convention Area (Fig. 6). Thus the outputs are defined in relation to three questions, discussed in more detail below:

*Q1. Which species are most at risk of adverse effects from WCPFC longline fishing?*

*Q2. In which areas is there greatest risk of adverse effects on seabird species?*

*Q3. Which flags are posing the greatest risk of adverse effects on seabird species?*

***Which species are most at risk of adverse effects from WCPFC longline fishing?***

The top ranked (most at risk) ten species includes six gadfly petrels<sup>2</sup>, one shearwater, and three albatross species. The petrel and shearwater species concerned occur in tropical waters, while the albatrosses are mainly temperate in distribution.

The next highest risk species (ranked 11–25) include a range of petrels and albatrosses from tropical and temperate regions. Twenty three of the top 25 species are listed as threatened with extinction, including two species listed as *Critically Endangered* and two as *Endangered*. Three species had extremely small population sizes of a few dozen individuals each.

The medium risk species (ranked 26–50) contains nine albatrosses species, all of which are threatened with extinction, including 4 which are classified as *Endangered* or *Critically Endangered*. Of the remaining 16 petrel species, six are threatened with extinction including four *Endangered* species.

The lowest ranked species included 10 species for which there is no overlap in the WCPFC Convention Area with the fishing effort used in the analysis (2002–2007), or where these birds ranges abuts, but does not enter the WCPFC Convention Area. These species include three *Critically Endangered* and one *Endangered* species. They are listed at the bottom of Table 2.

The analysis shows that species likely to be at risk from fishing include many species which are poorly known. Species likely to be exposed to high levels of risk include some with small population sizes, and with severe conservation threat status, from a range of tropical and temperate environments.

Some of the *Pterodroma* and *Pseudobulweria* species may not in fact be susceptible to fishing mortality, due to their small size; however, very small storm petrels are occasionally caught in longlining operations in temperate and sub-Antarctic regions (Waugh et al. 2008). Therefore without specific information that allows us to eliminate the possibility of fisheries effects, we must consider that there is some likelihood of catch for these species.

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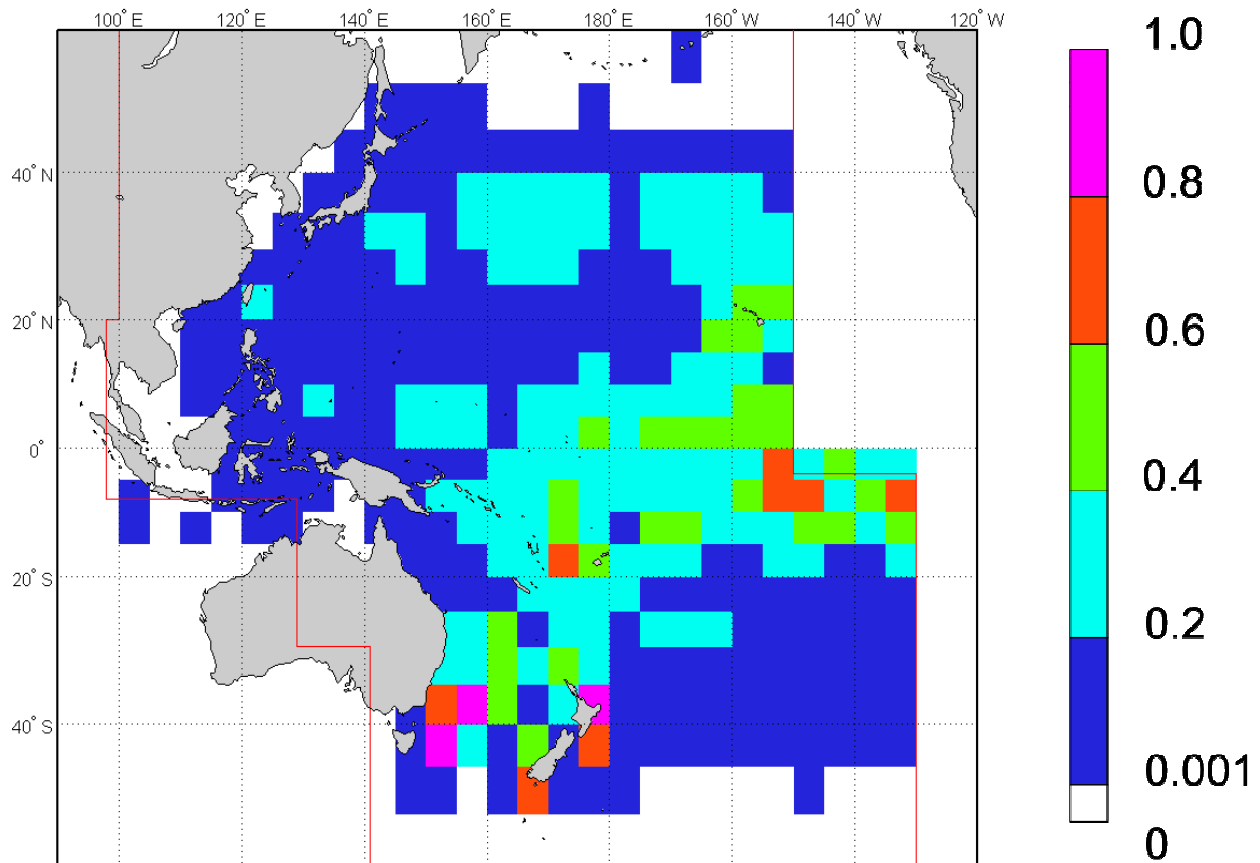
<sup>2</sup> Petrels from the genera *Pterodroma* and *Pseudobulweria*



***In which areas is there most risk of adverse effects on seabird species?***

The areas with highest likelihood of species-level population effects occur in the Tasman Sea, east of New Zealand, around Fiji and at the equator at 165 °W (Fig. 6, pink areas<sup>3</sup>). Moderate-to-high risk levels (red) occur in an arc from Australasia, through the Vanuatu-Fiji area, finishing in the east of the WCPFC Convention Area in French Polynesia. Medium risk areas (green) are most prevalent through the central Pacific to around 20 °S, but with areas in temperate regions around Hawaii, and eastern and southern New Zealand. Lowest levels of risk occur in the south-eastern and north western parts of the Convention Area, including waters north of Australia and Papua New Guinea.

**Figure 6. Areas of likely species-level effects of fishing in the WCPFC Convention Area. Highest risk areas - pink, Medium-high - orange; Medium – green; Medium-low – pale blue; Low – dark blue; Negligible risk – White.**



<sup>3</sup> Note that the highest risk area was the 5-degree square around the island of Gau, Fiji. This was removed from the plots as its extremely high risk score made it difficult to interpret results for other areas.

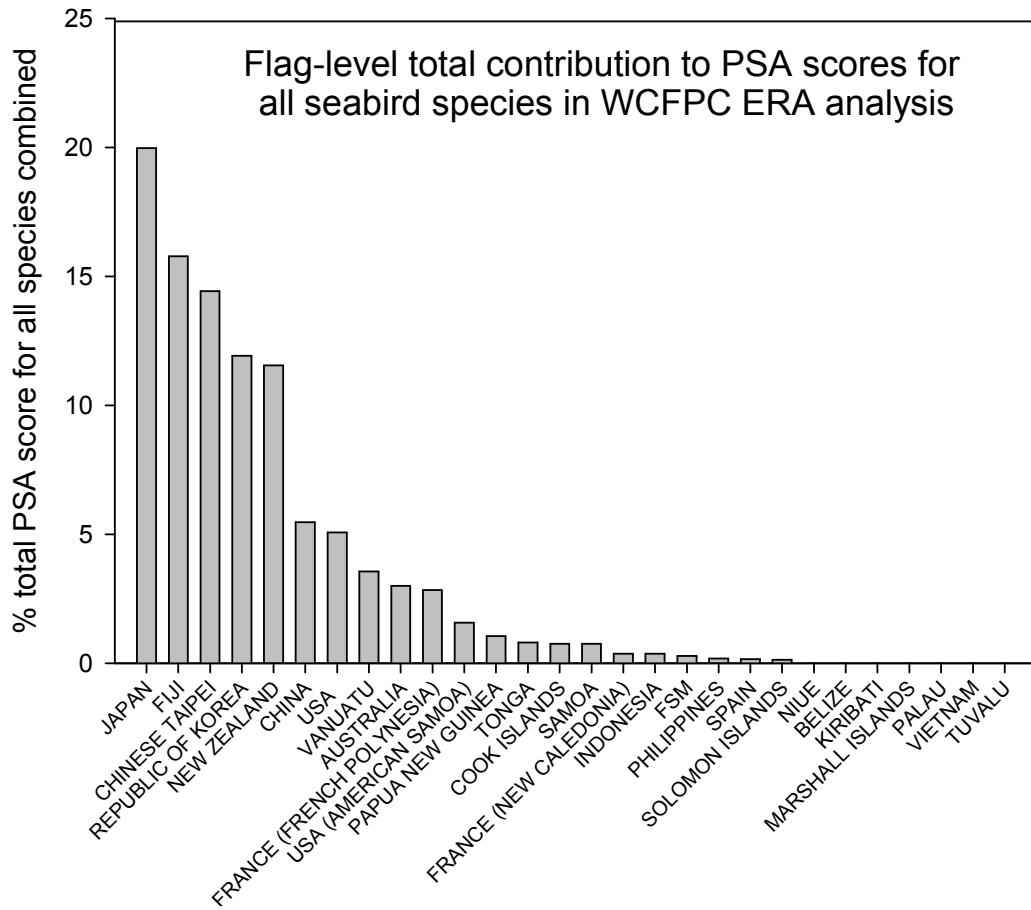


***Which flags are posing the most risk of adverse effects on seabird species?***

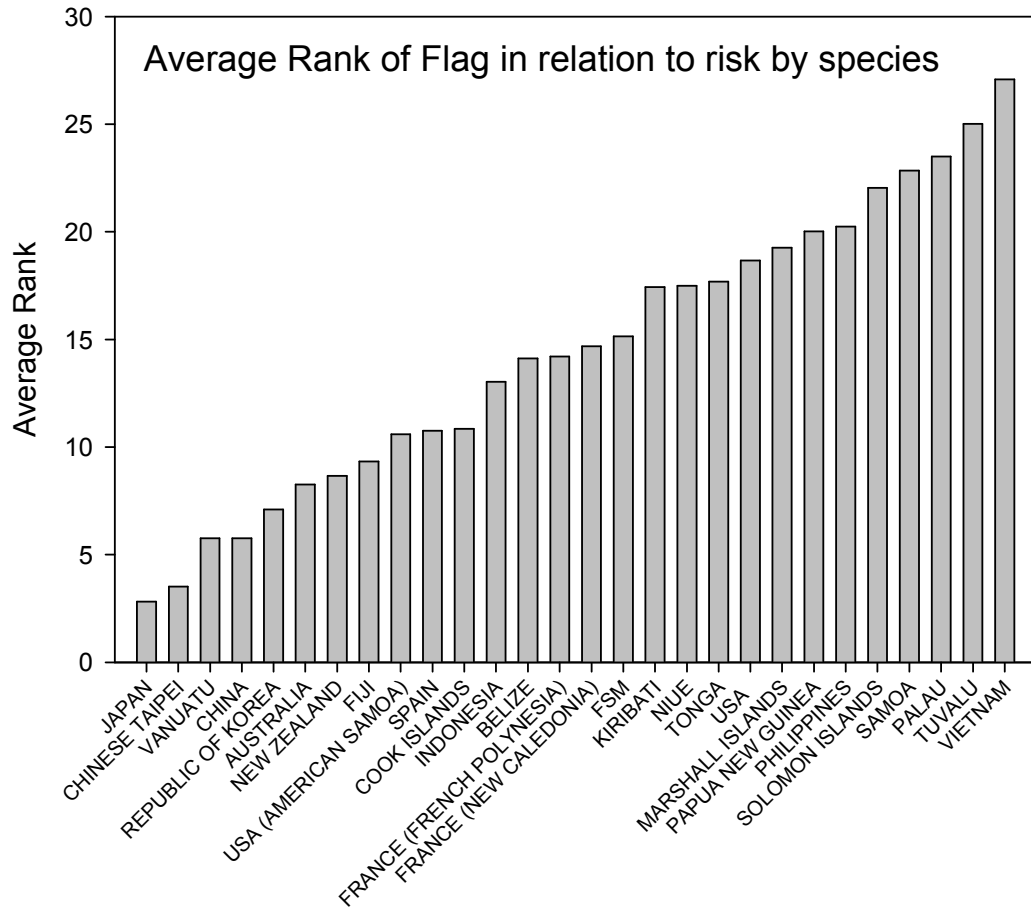
Nine flags contribute over 90% of the combined risk to seabirds in the WCPFC (Fig. 7). Of these, only 5 contribute over 50% of the total risk. These are, in descending order: Japan (20%), Fiji (17%), Chinese Taipei (14%), Republic of Korea (12%), and New Zealand (12%). Other flags contribute less than 5% of the total risk each. This outcome is due to the distribution of fishing effort in relation to the highest risk species, which contains many tropical petrels, and several species which have low productivity.

Similarly, when we examined what was the ranking of flag states in relation to effects on individual species, we found that the probability of adverse effects was not evenly spread among flags. The five flags with the highest likelihood of population effects on species, in descending order, were Japan, Chinese Taipei, Vanuatu, China, Republic of Korea, and Australia. The PSA scores for each flag by species is set out in Table 3, as are the contributions of each flag to the risk score for each species.

**Figure 7. Sum of PSA scores for all species in the analysis, attributed to flag**



**Figure 8. Average rank of flags in relation to risk by species. Flags with highest average ranks (smaller number) are most likely to have adverse effects on viability of a number of seabird species**



## ***Discussion***

The WCPFC Convention Area is host to a range of seabird species, including a number of threatened species. Minimizing seabird interactions in terms of total mortality is an objective of the WCPFC Convention and WCPFC Conservation and Management Measure CMM2007-04, as is the aim of alleviating pressure on fragile populations.

A key finding of the study is that the risk of seabird population effects is spread over a far greater extent than previously acknowledged, and potentially affects a wider range of species, some of which are highly vulnerable to extinction. Efforts to reduce fishing-induced mortality are especially important for Procellariiform seabirds, particularly albatrosses and gadfly petrels, which are at particularly high risk of species extinction. Albatrosses are the most threatened group of birds in the world with 19 out of 22 species threatened with extinction (BirdLife International 2008). Of the 74 seabird species examined in the study, 41 (55%) are threatened with extinction (IUCN 2009).

The two highest ranked petrels are little-known species in the risk assessment were Fiji petrel and Beck's petrel, which have recently been rediscovered after a period when they were thought to be extinct. They are both listed as *Critically Endangered* and are estimated to have extremely small global population sizes, at fewer than 50 and 300 individuals, respectively (BirdLife 2008). Fishing-induced mortality for these species would be of great concern with regard to their global population status.

Wandering albatrosses (ranked 2nd) have been shown to suffer population effects of fishing mortality (Weimerskirch et al. 1997, Tuck et al. 2001.). Recent incidental mortality of 51 Antipodean albatrosses (ranked 5<sup>th</sup>) in one swordfish fishing trip shows that this species is highly susceptible to capture in surface longline fisheries (New Zealand Ministry of Fisheries 2006).

The findings of this study do not contradict previous information, that suggested that highest risk area occurs south of 30°S and north of 23°N. Instead, they identify a finer-scaled landscape of risk, in a relative sense, across both tropical and temperate environments. A high probability of capturing seabirds, as well as an associated risk of population effects, may still exist outside the medium- to high-risk zones identified here, but may be more localized or affecting single species (e.g. Laysan or short-tailed albatrosses) in a way that this analysis is not designed to detect.

This study has identified areas of seabird biodiversity, areas of higher potential for and probability of fishing-induced seabird mortality, species at risk of population-level effects of fishing-induced mortality, areas where this risk is highest summed across species, the contribution of individual flag states to the risk of species-level effects, and the contribution of individual species to total risk posed by flag.

Areas in which fishing is most likely to result in captures of considerable numbers of seabirds were identified in the Tasman Sea and surrounding ocean, and east of New Zealand. These known bycatch areas have rich assemblages of both albatrosses and petrels (see Fig. 2), many of which are threatened with extinction.

One short coming of this type of analysis is that risk to particular species is not examined in great detail, even if additional information is actually available. Future analyses would be strengthened by examining well documented case studies for species of particular conservation concern. This could lead to the upgrading of risk classifications for particular areas based on additional risk already established for these species.

The PSA approach used here allowed us to use all available information about species for the WCPFC Convention Area, and include different data types describing the species ranges. In this study, the scarcity of independently derived information on seabird catch from the WCPFC fisheries precluded using actual bycatch information in the study; such data have been used elsewhere, either semi-quantitatively (Klaer & Black 2008), or to define species catchability (New Zealand Ministry of Fisheries, unpublished report).

The key assumption that risk is proportional to spatial overlap of species with fishing effort is logical enough for species that are known to attempt to take baited hooks if they are available. There may be some inter-species variation in this tendency, in addition to temporal and spatial variability in this tendency for any particular species, but this is very difficult to quantify and the data necessary to do so are not presently available.

It will be useful, as more observer data becomes available in WCPFC fisheries, to include indices of catchability for different species. In other contexts (e.g. ICCAT), expert opinion has been used to assign a catchability coefficient to susceptibility scores. In the current analysis, after prior exclusion of some species known not to take baited hooks, catchability is treated as equal among all species, with *Susceptibility* described only by the degree of spatial overlap with longline effort. It is therefore possible that

some species have been attributed medium-to-high risk scores when little or no risk is occurring. Small petrels, particularly from the Gadfly petrel family have only rarely been reported in fishing bycatch. However, the number of these species occurring within the WCPFC, from small and fragile populations, makes it nonetheless imperative to examine possible risk, even if observer data are lacking to verify whether this risk is realized.

Although it would be interesting to carry out fine-scaled analysis of the relative ranking of species along the *Productivity* axis this is not possible at this stage, due to the large number of substitutions employed in the analysis: ca. 50% of survival or age-at-first breeding scores were from substitute species. Thus, while it is useful to regard the *Productivity* score as an index of relative productivity among all the species, the score should only really be regarded as being *high*, *medium* or *low*.

## **Conclusions**

The areas defined as high and medium risk need particular monitoring and mitigation measures in order to reduce incidental mortality of seabirds. Firstly, there are areas where large numbers of seabirds are likely to be captured – running in an axis from Australasia to Hawaii, with a few isolated outlying areas (Fig. 4). Secondly, there are areas where population effects of incidental mortality are likely to be disproportionately large compared to the absolute number of bycatch events occurring (Fig. 6). These include temperate areas but also many tropical areas such as those around Fiji, Vanuatu and the central to eastern tropical Pacific. The analysis has demonstrated a far broader area where species may be adversely affected by fishing mortality than previously thought, in particular in tropical waters where bycatch of species is rare and has therefore been considered to be insignificant in terms of population effects (see Watling 2002).

The disaggregation of risk posed to individual species by individual flag states has demonstrated that the likely effects of fishing are not spread evenly between the different flags. We hope that this analysis helps fisheries managers from the flag states posing the highest risk in justifying the need for better monitoring and management of their fleets. If effective mitigation measures are already in place on these fleets then the risk rankings given here will of course change. We therefore hope that better monitoring of those fishing fleets most likely to have adverse effects on seabird species will be carried out and that the results of such monitoring will be shared with the WCPFC Scientific

Committee, so that all flag states can come to understand their relative success in minimizing the risk of adverse effects of longline fisheries on seabirds.

There is a need to consider whether the current seabird measure (CMM2007-04) should be applied in areas than are not currently covered and to a wider range of vessels. For example, some tropical areas that are currently outside the zone of application of the CMM are shown as high risk by these analyses. Vessels <24m length fishing north of 23°N, which includes some higher risk areas, are currently exempt from the requirements of the CMM, despite the lack of evidence for vessel-size-related differences in catch rates.

The current analysis provides a useful overview and broad scale representation of the relative risk that longline fishing poses to seabirds in the Convention Area, given the constraints of variable data quality. Experience from similar analyses in other international and national fisheries shows that more complex models are likely to result in relatively minor adjustment of risk rankings by area, species or flag, providing diminishing returns in terms of understanding fisheries impacts on seabirds. In specific cases, where high risk classification is accompanied by availability of high quality data sets on population ecology, age-structured population modeling can be used to examine scenarios for minimizing risk of adverse population effects. However, these opportunities will be limited in number because they are time consuming and costly to pursue.

We would therefore recommend that the results presented form a basis for future decision making in terms of defining areas where longline fisheries pose a risk of adverse effects on seabird populations.

The process of determining such areas should be iterative, in that new seabird and fisheries data will become available through time, and these can be incorporated into subsequent analyses. This should be seen as a natural evolution of the best available science, rather than invalidating the logic of the current analysis, with management able to become less precautionary and more evidence-based as the quality of datasets and sophistication of analyses both improve. For now, however, a precautionary approach is justified by the limited observational data. More detailed information about species propensity to be caught on longline sets, along with refinement to our knowledge of fishery specific catch rates and species distributions will greatly build on our knowledge of where risk of seabird mortality is most acute across the WCPFC area.

## ***Future work***

Noting the discussion above, we recommend that in future analyses of the likelihood and effects of seabird interactions in WCPFC longline fisheries:

- a) Additional data on seabird distributions should be incorporate as they become available over the next 2–3 years, e.g. by 2010 over 1000 seabird colony records will be available for the Australasia region via new BirdLife International databases.
- b) The potential effect of spatio-temporal variability on the results should be analyzed as it is possible that seasonal and interannual variability in fishing effort distribution may result in different risk rankings to those presented here.
- c) Estimate any differences in catchability among seabird species, using observer data from areas where several species overlap with longline fisheries at the same time, as this may significantly influence the outcome of the analyses. Behavioural aspects, such as whether seabirds are foraging in or migrating through particular areas, should also be examined and incorporated in future risk assessments.
- d) Carry out analyses in relation to fishing targeting strategies, as it is possible that, for example, 1000 hooks of swordfish fishing effort poses a different risk of seabird capture compared to 1000 hooks of albacore effort, depending on the time of fishing, gear configuration etc. Data on fishing gear configuration (e.g. hooks per basket, float line length), on deployment of mitigation methods and on actual catch of seabirds will of course be required to examine this aspect.
- e) Examine whether the outcomes, by comparison with global seabird assessments, adequately deal with risk to particular species, via case-studies on seabird species of established conservation concern.

## ***Recommendations***

On the basis this analyses we recommend that the WCPFC:

1. Define areas of risk throughout the Convention Area, on a graded scale from lowest to highest risk, at the level of 5 degree squares rather than latitudinal bands, based on the analysis of species-level effects of seabird-fisheries overlaps (Fig. 6) as well as those areas that have the highest potential interaction rates (Figs. 3 & 4). These areas should be revised as new information becomes available for analysis.
2. Develop more detailed data collection at the operational level, particularly for fisheries operating in medium to high risk areas, in relation to gear configuration, use of mitigation measures and catch of seabirds. These data need to be provided across the Convention Area and made available to the Scientific Committee for analysis and review.
3. Continue to develop spatially stratified analyses of fisheries interactions with bycatch species in the WCPFC Convention Area, particularly threatened species, building on the approach developed and results obtained in this study.
4. Consider revising its mitigation requirements in the future in light of risk areas identified by this type of analysis; improved data on seabird distribution and on catchability will improve the analyses, giving managers confidence in the results..



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**Table 1. Estimated Productivity ( $R_{max}$ ) values, derived from Age-at-maturity and Annual Adult Survival rates, for 75 species of albatrosses and petrels found in the WCPFC Convention Area and which are vulnerable to capture on longline fisheries. Scientific name follows BirdLife International taxonomy ([www.birdlife.org](http://www.birdlife.org)). ‘Code’ is generally FAO Code but may include other national standard codes. Whether a species has been observed captured in the region is noted (Y: yes), as is threat status for species as defined by the International Union for the Conservation Nature (IUCN; [www.iucnredlist.org](http://www.iucnredlist.org)). World population (number of individuals) estimated by BirdLife International. Where a population size range was provided, we have taken the mid-point of that range to use in analyses). Species are listed in alphabetical order of their scientific name.**

| Code | BLI Scientific name            | BLI Common name          | Rmax  | Age-at-maturity average | Survival average | Threat status | Global population | BLI tracking data | Recorded bycatch |
|------|--------------------------------|--------------------------|-------|-------------------------|------------------|---------------|-------------------|-------------------|------------------|
| BUB  | <i>Bulweria bulwerii</i>       | Bulwer's Petrel          | 0.898 | 5                       | 94.7             | LC            | 750000            |                   |                  |
| DAC  | <i>Diaption capense</i>        | Cape Petrel              | 0.827 | 6                       | 94               | LC            | 2000000           |                   |                  |
| GBA  | <i>Diomedea antipodensis</i>   | Antipodean Albatross     | 0.564 | 7                       | 97               | VU            | 25000             | Y                 |                  |
| DIP  | <i>Diomedea epomophora</i>     | Southern Royal Albatross | 0.056 | 7                       | 97               | VU            | 28750             | Y                 | Y                |
| DIX  | <i>Diomedea exulans</i>        | Wandering Albatross      | 0.053 | 9                       | 96               | VU            | 26000             | Y                 | Y                |
| DIS  | <i>Diomedea sanfordi</i>       | Northern Royal Albatross | 0.071 | 7                       | 94.6             | EN            | 17000             | Y                 |                  |
| FUG  | <i>Fulmarus glacialisoides</i> | Southern Fulmar          | 0.084 | 5                       | 95.5             | LC            | 4000000           |                   |                  |
| HBE  | <i>Halobaena caerulea</i>      | Blue Petrel              | 0.127 | 5.4                     | 84               | LC            | 3000000           |                   |                  |
| LUB  | <i>Lugensa brevirostris</i>    | Kerguelen Petrel         | 0.107 | 5.5                     | 90               | LC            | 1000000           |                   |                  |
| MAI  | <i>Macronectes giganteus</i>   | Southern Giant-petrel    | 0.078 | 7                       | 93               | LC            | 97000             |                   | Y                |
| MAH  | <i>Macronectes halli</i>       | Northern Giant-petrel    | 0.074 | 7.5                     | 93               | LC            | 19000             |                   | Y                |
| PAB  | <i>Pachyptila belcheri</i>     | Thin-billed Prion        | 0.107 | 6.7                     | 84               | LC            | 7000000           |                   |                  |
| PWD  | <i>Pachyptila desolata</i>     | Antarctic Prion          | 0.136 | 5                       | 84               | LC            | 50000000          |                   |                  |
| XFP  | <i>Pachyptila turtur</i>       | Fairy Prion              | 0.149 | 4.5                     | 84               | LC            | 5000000           |                   |                  |
| XPV  | <i>Pachyptila vittata</i>      | Broad-billed Prion       | 0.128 | 5.4                     | 84               | LC            | 15000000          |                   |                  |
| PAN  | <i>Pagodroma nivea</i>         | Snow Petrel              | 0.107 | 5.5                     | 90               | LC            | 4000000           |                   |                  |
| PHA  | <i>Phoebastria albatrus</i>    | Short-tailed Albatross   | 0.071 | 6.7666667               | 95               | VU            | 2350              |                   | Y                |
| PHI  | <i>Phoebastria immutabilis</i> | Laysan Albatross         | 0.063 | 8                       | 95               | VU            | 1200000           | Y                 |                  |
| PIR  | <i>Phoebastria irrorata</i>    | Waved Albatross          | 0.061 | 8.3                     | 95               | CR            | 35000             | Y                 |                  |
| PHN  | <i>Phoebastria nigripes</i>    | Black-footed Albatross   | 0.103 | 4                       | 95               | EN            | 120000            | Y                 | Y                |

| Code | BLI Scientific name                 | BLI Common name         | Rmax  | Age-at-maturity average | Survival average | Threat status | Global population | BLI tracking data | Recorded bycatch |
|------|-------------------------------------|-------------------------|-------|-------------------------|------------------|---------------|-------------------|-------------------|------------------|
| PHF  | <i>Phoebastria fusca</i>            | Sooty Albatross         | 0.054 | 7                       | 97.3             | EN            | 42000             |                   |                  |
| PHE  | <i>Phoebastria palpebrata</i>       | Light-mantled Albatross | 0.054 | 7                       | 97.3             | NT            | 58000             |                   | Y                |
| PRO  | <i>Procellaria aequinoctialis</i>   | White-chinned Petrel    | 0.097 | 6.5                     | 89               | VU            | 7000000           |                   |                  |
| PCI  | <i>Procellaria cinerea</i>          | Grey Petrel             | 0.079 | 7                       | 93               | NT            | 400000            |                   | Y                |
| PRK  | <i>Procellaria parkinsoni</i>       | Parkinson's Petrel      | 0.094 | 7                       | 88               | VU            | 10000             | Y                 | Y                |
| PCW  | <i>Procellaria westlandica</i>      | Westland Petrel         | 0.106 | 6                       | 88               | VU            | 20000             | Y                 | Y                |
| PSB  | <i>Pseudobulweria becki</i>         | Beck's Petrel           | 0.094 | 5.5                     | 93               | CR            | 149.5             |                   |                  |
| PSM  | <i>Pseudobulweria macgillivrayi</i> | Fiji Petrel             | 0.094 | 5.5                     | 93               | CR            | 25.5              |                   |                  |
| PSR  | <i>Pseudobulweria rostrata</i>      | Tahiti Petrel           | 0.094 | 5.5                     | 93               | NT            | 20000             |                   |                  |
| PTA  | <i>Pterodroma alba</i>              | Phoenix Petrel          | 0.094 | 5.5                     | 93               | EN            | 30000             |                   |                  |
| PTT  | <i>Pterodroma atrata</i>            | Henderson Petrel        | 0.094 | 5.5                     | 93               | EN            | 74999.5           |                   |                  |
| PTX  | <i>Pterodroma axillaris</i>         | Chatham Petrel          | 0.094 | 5.5                     | 93               | EN            | 500               |                   |                  |
| PTB  | <i>Pterodroma brevipes</i>          | Collared Petrel         | 0.094 | 5.5                     | 93               | NT            | 5500              |                   |                  |
| WNP  | <i>Pterodroma cervicalis</i>        | White-necked Petrel     | 0.094 | 5.5                     | 93               | VU            | 100000            |                   |                  |
| PTC  | <i>Pterodroma cookii</i>            | Cook's Petrel           | 0.094 | 5.5                     | 93               | VU            | 1258000           |                   |                  |
| PTD  | <i>Pterodroma defilippiana</i>      | De Filippi's Petrel     | 0.094 | 5.5                     | 93               | VU            | 14999.5           |                   |                  |
| PTE  | <i>Pterodroma externa</i>           | Juan Fernandez Petrel   | 0.094 | 5.5                     | 93               | VU            | 3000000           |                   |                  |
| XMP  | <i>Pterodroma inexpectata</i>       | Mottled Petrel          | 0.094 | 5.5                     | 93               | NT            | 1500000           |                   |                  |
| XWH  | <i>Pterodroma lessonii</i>          | White-headed Petrel     | 0.094 | 5.5                     | 93               | LC            | 600000            |                   |                  |
| PTL  | <i>Pterodroma leucoptera</i>        | Gould's Petrel          | 0.094 | 5.5                     | 93               | VU            | 12000             |                   |                  |
| PTO  | <i>Pterodroma longirostris</i>      | Stejneger's Petrel      | 0.094 | 5.5                     | 93               | VU            | 400000            |                   |                  |
| PDM  | <i>Pterodroma macroptera</i>        | Great-winged Petrel     | 0.083 | 6.5                     | 93               | LC            | 150000            |                   | Y                |
| PTM  | <i>Pterodroma magentae</i>          | Magenta Petrel          | 0.094 | 5.5                     | 93               | CR            | 135               |                   |                  |
| PTS  | <i>Pterodroma mollis</i>            | Soft-plumaged Petrel    | 0.094 | 5.5                     | 93               | LC            | 5000000           |                   |                  |
| PVB  | <i>Pterodroma neglecta</i>          | Kermadec Petrel         | 0.094 | 5.5                     | 93               | LC            | 175000            |                   |                  |
| PTG  | <i>Pterodroma phaeopygia</i>        | Galapagos Petrel        | 0.1   | 5                       | 93               | CR            | 14999.5           |                   |                  |

| Code | BLI Scientific name                | BLI Common name                 | Rmax  | Age-at-maturity average | Survival average | Threat status | Global population | BLI tracking data | Recorded bycatch |
|------|------------------------------------|---------------------------------|-------|-------------------------|------------------|---------------|-------------------|-------------------|------------------|
| PTP  | <i>Pterodroma pycrofti</i>         | Pycroft's Petrel                | 0.087 | 5.5                     | 72               | VU            | 6500              |                   |                  |
| PTW  | <i>Pterodroma sandwichensis</i>    | Hawaiian Petrel                 | 0.094 | 5.5                     | 93               | VU            | 12800             |                   |                  |
| PTI  | <i>Pterodroma solandri</i>         | Providence Petrel               | 0.094 | 5.5                     | 93               | VU            | 100000            |                   |                  |
| PTU  | <i>Pterodroma ultima</i>           | Murphy's Petrel                 | 0.094 | 5.5                     | 93               | NT            | 900000            |                   |                  |
| PUA  | <i>Puffinus assimilis</i>          | Little Shearwater               | 0.107 | 5.5                     | 90               | LC            | 900000            |                   |                  |
| PUU  | <i>Puffinus auricularis</i>        | Townsend's Shearwater           | 0.107 | 5.5                     | 90               | CR            | 624.5             |                   |                  |
| PBU  | <i>Puffinus bulleri</i>            | Buller's Shearwater             | 0.107 | 5.5                     | 90               | VU            | 2500000           |                   |                  |
| PFC  | <i>Puffinus carneipes</i>          | Flesh-footed Shearwater         | 0.094 | 5.5                     | 93               | LC            | 650000            |                   | Y                |
| PUC  | <i>Puffinus creatopus</i>          | Pink-footed Shearwater          | 0.094 | 5.5                     | 93               | VU            | 40000             |                   |                  |
| PFG  | <i>Puffinus griseus</i>            | Sooty Shearwater                | 0.088 | 6                       | 93               | NT            | 20000000          | Y                 | Y                |
| PUN  | <i>Puffinus heinrothi</i>          | Heinroth's Shearwater           | 0.094 | 5.5                     | 93               | VU            | 624.5             |                   |                  |
| HSW  | <i>Puffinus huttoni</i>            | Hutton's Shearwater             | 0.115 | 5                       | 90               | EN            | 325000            |                   |                  |
| PUL  | <i>Puffinus lherminieri</i>        | Audubon's Shearwater            | 0.08  | 8                       | 90               | LC            | 500000            |                   |                  |
| PUW  | <i>Puffinus newelli</i>            | Newell's Shearwater             | 0.107 | 5.5                     | 90               | EN            | 35800             |                   |                  |
| PUB  | <i>Puffinus pacificus</i>          | Wedge-tailed Shearwater         | 0.118 | 4                       | 93               | LC            | 5200000           |                   | Y                |
| PUP  | <i>Puffinus puffinus</i>           | Manx Shearwater                 | 0.085 | 6                       | 93.5             | LC            | 1150000           |                   |                  |
| PUT  | <i>Puffinus tenuirostris</i>       | Short-tailed Shearwater         | 0.088 | 6                       | 93               | LC            | 23000000          |                   | Y                |
| DNB  | <i>Thalassarche bulleri</i>        | Buller's Albatross              | 0.109 | 5                       | 91.3             | NT            | 64000             | Y                 | Y                |
| TQH  | <i>Thalassarche carteri</i>        | Indian Yellow-nosed Albatross   | 0.063 | 9                       | 93.5             | EN            | 65000             |                   | Y                |
| THC  | <i>Thalassarche cauta</i>          | Shy Albatross                   | 0.063 | 9                       | 93.5             | NT            | 26000             | Y                 |                  |
| THH  | <i>Thalassarche chlororhynchos</i> | Atlantic Yellow-nosed Albatross | 0.063 | 9                       | 93.5             | EN            | 69100             |                   | Y                |
| DIC  | <i>Thalassarche chrysostroma</i>   | Grey-headed Albatross           | 0.052 | 10                      | 95.3             | VU            | 250000            | Y                 | Y                |
| DER  | <i>Thalassarche eremita</i>        | Chatham Albatross               | 0.076 | 7                       | 93.5             | CR            | 11000             | Y                 | Y                |
| TQW  | <i>Thalassarche impavida</i>       | Campbell Albatross              | 0.055 | 10                      | 94.5             | VU            | 49000             | Y                 | Y                |
| DIM  | <i>Thalassarche melanophrys</i>    | Black-browed Albatross          | 0.068 | 9                       | 92               | EN            | 1200000           | Y                 | Y                |

| Code | BLI Scientific name           | BLI Common name        | Rmax  | Age-at-maturity average | Survival average | Threat status | Global population | BLI tracking data | Recorded bycatch |
|------|-------------------------------|------------------------|-------|-------------------------|------------------|---------------|-------------------|-------------------|------------------|
| DLS  | <i>Thalassarche salvini</i>   | Salvin's Albatross     | 0.063 | 9                       | 93.5             | VU            | 62000             |                   | Y                |
| XWM  | <i>Thalassarche steadi</i>    | White-capped Albatross | 0.063 | 9                       | 93.5             | NT            | 299999.5          |                   | Y                |
| THA  | <i>Thalassoica antarctica</i> | Antarctic Petrel       | 0.087 | 6                       | 93               | LC            | 15000000          |                   |                  |

**Table 2. Species rankings in relation to PSA score. Species are listed in descending order of PSA score, and are listed with their common and scientific name and IUCN threat status, and with the mid-point of the estimated population size in numbers of individuals. The listed species are split into four groups: Highest risk (red) for the top 10 species, High Risk for those ranked 11- 25, (orange) Medium Risk (yellow) for those ranked 26-50, and Lowest Risk (green) for those ranked 51-74. The lowest ranked species (indicated “-“) are 10 species which had ranges which did not overlap with WCPFC fishing effort in the current analysis.**

| <b>BLI Scientific name</b>          | <b>BLI Common name</b>        | <b>Species</b> | <b>IUCN Threat status</b> | <b>Estimated Population mid point (individuals)</b> | <b>Rank in this analysis</b> |
|-------------------------------------|-------------------------------|----------------|---------------------------|-----------------------------------------------------|------------------------------|
| <i>Pseudobulweria macgillivrayi</i> | Fiji Petrel                   | PSM            | CR                        | 25                                                  | 1                            |
| <i>Diomedea exulans</i>             | Wandering Albatross           | DIX            | VU                        | 26000                                               | 2                            |
| <i>Pseudobulweria becki</i>         | Beck's Petrel                 | PSB            | CR                        | 150                                                 | 3                            |
| <i>Pterodroma alba</i>              | Phoenix Petrel                | PTA            | EN                        | 30000                                               | 4                            |
| <i>Diomedea antipodensis</i>        | Antipodean Albatross          | GBA            | VU                        | 25000                                               | 5                            |
| <i>Puffinus lherminieri</i>         | Audubon's Shearwater          | PUL            | LC                        | 500000                                              | 6                            |
| <i>Pterodroma solandri</i>          | Providence Petrel             | PTI            | VU                        | 100000                                              | 7                            |
| <i>Pterodroma brevipes</i>          | Collared Petrel               | PTB            | NT                        | 5500                                                | 8                            |
| <i>Phoebastria albatrus</i>         | Short-tailed Albatross        | PHA            | VU                        | 2350                                                | 9                            |
| <i>Pterodroma cervicalis</i>        | White-necked Petrel           | WNP            | VU                        | 100000                                              | 10                           |
| <i>Procellaria parkinsoni</i>       | Parkinson's Petrel            | PRK            | VU                        | 10000                                               | 11                           |
| <i>Pseudobulweria rostrata</i>      | Tahiti Petrel                 | PSR            | NT                        | 20000                                               | 12                           |
| <i>Pterodroma leucoptera</i>        | Gould's Petrel                | PTL            | VU                        | 12000                                               | 13                           |
| <i>Bulweria bulwerii</i>            | Bulwer's Petrel               | BUB            | LC                        | 750000                                              | 14                           |
| <i>Diomedea epomophora</i>          | Southern Royal Albatross      | DIP            | VU                        | 28750                                               | 15                           |
| <i>Pterodroma neglecta</i>          | Kermadec Petrel               | PVB            | LC                        | 175000                                              | 16                           |
| <i>Pterodroma longirostris</i>      | Stejneger's Petrel            | PTO            | VU                        | 400000                                              | 17                           |
| <i>Pterodroma inexpectata</i>       | Mottled Petrel                | XMP            | NT                        | 1500000                                             | 18                           |
| <i>Pterodroma cookii</i>            | Cook's Petrel                 | PTC            | VU                        | 1258000                                             | 19                           |
| <i>Pterodroma atrata</i>            | Henderson Petrel              | PTT            | EN                        | 75000                                               | 20                           |
| <i>Phoebastria immutabilis</i>      | Laysan Albatross              | PHI            | VU                        | 1200000                                             | 21                           |
| <i>Pterodroma sandwichensis</i>     | Hawaiian Petrel               | PTW            | VU                        | 12800                                               | 22                           |
| <i>Puffinus bulleri</i>             | Buller's Shearwater           | PBU            | VU                        | 2500000                                             | 23                           |
| <i>Puffinus heinrothi</i>           | Heinroth's Shearwater         | PUN            | VU                        | 625                                                 | 24                           |
| <i>Pterodroma ultima</i>            | Murphy's Petrel               | PTU            | NT                        | 900000                                              | 25                           |
| <i>Puffinus huttoni</i>             | Hutton's Shearwater           | HSW            | EN                        | 325000                                              | 26                           |
| <i>Puffinus carneipes</i>           | Flesh-footed Shearwater       | PFC            | LC                        | 650000                                              | 27                           |
| <i>Puffinus newelli</i>             | Newell's Shearwater           | PUW            | EN                        | 35800                                               | 28                           |
| <i>Phoebastria nigripes</i>         | Black-footed Albatross        | PHN            | EN                        | 120000                                              | 29                           |
| <i>Puffinus griseus</i>             | Sooty Shearwater              | PFG            | NT                        | 20000000                                            | 30                           |
| <i>Thalassarche bulleri</i>         | Buller's Albatross            | DNB            | NT                        | 64000                                               | 31                           |
| <i>Thalassarche carteri</i>         | Indian Yellow-nosed Albatross | TQH            | EN                        | 65000                                               | 32                           |
| <i>Puffinus pacificus</i>           | Wedge-tailed Shearwater       | PUB            | LC                        | 5200000                                             | 33                           |
| <i>Thalassarche impavida</i>        | Campbell Albatross            | TQW            | VU                        | 49000                                               | 34                           |
| <i>Thalassarche salvini</i>         | Salvin's Albatross            | DLS            | VU                        | 62000                                               | 35                           |
| <i>Pterodroma externa</i>           | Juan Fernandez Petrel         | PTE            | VU                        | 3000000                                             | 36                           |
| <i>Pterodroma axillaris</i>         | Chatham Petrel                | PTX            | EN                        | 500                                                 | 37                           |
| <i>Procellaria westlandica</i>      | Westland Petrel               | PCW            | VU                        | 20000                                               | 38                           |

| <b>BLI Scientific name</b>         | <b>BLI Common name</b>          | <b>Species</b> | <b>IUCN Threat status</b> | <b>Estimated Population mid point (individuals)</b> | <b>Rank in this analysis</b> |
|------------------------------------|---------------------------------|----------------|---------------------------|-----------------------------------------------------|------------------------------|
| <i>Daption capense</i>             | Cape Petrel                     | DAC            | LC                        | 2000000                                             | 39                           |
| <i>Thalassarche steadi</i>         | White-capped Albatross          | XWM            | NT                        | 300000                                              | 40                           |
| <i>Pterodroma macroptera</i>       | Great-winged Petrel             | PDM            | LC                        | 150000                                              | 41                           |
| <i>Puffinus tenuirostris</i>       | Short-tailed Shearwater         | PUT            | LC                        | 23000000                                            | 42                           |
| <i>Diomedea sanfordi</i>           | Northern Royal Albatross        | DIS            | EN                        | 17000                                               | 43                           |
| <i>Thalassarche eremita</i>        | Chatham Albatross               | DER            | CR                        | 11000                                               | 44                           |
| <i>Macronectes halli</i>           | Northern Giant-petrel           | MAH            | LC                        | 19000                                               | 45                           |
| <i>Puffinus assimilis</i>          | Little Shearwater               | PUA            | LC                        | 900000                                              | 46                           |
| <i>Macronectes giganteus</i>       | Southern Giant-petrel           | MAI            | LC                        | 97000                                               | 47                           |
| <i>Phoebastria palpebrata</i>      | Light-mantled Albatross         | PHE            | NT                        | 58000                                               | 48                           |
| <i>Pterodroma lessonii</i>         | White-headed Petrel             | XWH            | LC                        | 600000                                              | 49                           |
| <i>Pachyptila belcheri</i>         | Thin-billed Prion               | PAB            | LC                        | 7000000                                             | 50                           |
| <i>Thalassarche cauta</i>          | Shy Albatross                   | THC            | NT                        | 26000                                               | 51                           |
| <i>Fulmarus glacialoides</i>       | Southern Fulmar                 | FUG            | LC                        | 4000000                                             | 52                           |
| <i>Pachyptila vittata</i>          | Broad-billed Prion              | XPV            | LC                        | 15000000                                            | 53                           |
| <i>Procellaria aequinoctialis</i>  | White-chinned Petrel            | PRO            | VU                        | 7000000                                             | 54                           |
| <i>Procellaria cinerea</i>         | Grey Petrel                     | PCI            | NT                        | 400000                                              | 55                           |
| <i>Pterodroma mollis</i>           | Soft-plumaged Petrel            | PTS            | LC                        | 5000000                                             | 56                           |
| <i>Lugensa brevirostris</i>        | Kerguelen Petrel                | LUB            | LC                        | 1000000                                             | 57                           |
| <i>Thalassarche chrysostoma</i>    | Grey-headed Albatross           | DIC            | VU                        | 250000                                              | 58                           |
| <i>Halobaena caerulea</i>          | Blue Petrel                     | HBE            | LC                        | 3000000                                             | 59                           |
| <i>Pachyptila desolata</i>         | Antarctic Prion                 | PWD            | LC                        | 50000000                                            | 60                           |
| <i>Thalassarche melanophrys</i>    | Black-browed Albatross          | DIM            | EN                        | 1200000                                             | 61                           |
| <i>Pterodroma magentae</i>         | Magenta Petrel                  | PTM            | CR                        | 135                                                 | 62                           |
| <i>Pachyptila turtur</i>           | Fairy Prion                     | XFP            | LC                        | 5000000                                             | 63                           |
| <i>Phoebastria fusca</i>           | Sooty Albatross                 | PHF            | EN                        | 42000                                               | 64                           |
| <i>Pterodroma defilippiana</i>     | De Filippi's Petrel             | PTD            | VU                        | 15000                                               | -                            |
| <i>Pterodroma pycrofti</i>         | Pycroft's Petrel                | PTP            | VU                        | 6500                                                | -                            |
| <i>Puffinus creatopus</i>          | Pink-footed Shearwater          | PUC            | VU                        | 40000                                               | -                            |
| <i>Pagodroma nivea</i>             | Snow Petrel                     | PAN            | LC                        | 4000000                                             | -                            |
| <i>Puffinus puffinus</i>           | Manx Shearwater                 | PUP            | LC                        | 1150000                                             | -                            |
| <i>Thalassoica antarctica</i>      | Antarctic Petrel                | THA            | LC                        | 15000000                                            | -                            |
| <i>Thalassarche chlororhynchos</i> | Atlantic Yellow-nosed Albatross | THH            | EN                        | 69100                                               | -                            |
| <i>Phoebastria irrorata</i>        | Waved Albatross                 | PIR            | CR                        | 35000                                               | -                            |
| <i>Pterodroma phaeopygia</i>       | Galapagos Petrel                | PTG            | CR                        | 15000                                               | -                            |
| <i>Puffinus auricularis</i>        | Townsend's Shearwater           | PUU            | CR                        | 625                                                 | -                            |



Table 3. Species level information on risk posed to species in the Ecological Risk Assessment, assigned to the flag state of vessels which fish in regions overlapping the distribution of the species. Flags are listed in descending order of their contribution to risk for the species, with flags contributing the first 90% of risk for each species listed. The overall rank of the species in the PSA is indicated as “rank of species in analysis”. Those ranked with smaller numbers had highest overall risk levels. Species are listed by alphabetical order in relation to their scientific name.

| Scientific name              | Common Name              | Flag              | Flag contribution to species risk | Rank of species in analysis |
|------------------------------|--------------------------|-------------------|-----------------------------------|-----------------------------|
| <i>Bulweria bulwerii</i>     | Bulwer's Petrel          | CHINESE TAIPEI    | 31%                               | 14                          |
| <i>Bulweria bulwerii</i>     | Bulwer's Petrel          | REPUBLIC OF KOREA | 16%                               | 14                          |
| <i>Bulweria bulwerii</i>     | Bulwer's Petrel          | JAPAN             | 14%                               | 14                          |
| <i>Bulweria bulwerii</i>     | Bulwer's Petrel          | INDONESIA         | 12%                               | 14                          |
| <i>Bulweria bulwerii</i>     | Bulwer's Petrel          | CHINA             | 7%                                | 14                          |
| <i>Bulweria bulwerii</i>     | Bulwer's Petrel          | USA               | 5%                                | 14                          |
| <i>Bulweria bulwerii</i>     | Bulwer's Petrel          | PHILIPPINES       | 5%                                | 14                          |
| <i>Daption capense</i>       | Cape Petrel              | CHINESE TAIPEI    | 21%                               | 39                          |
| <i>Daption capense</i>       | Cape Petrel              | JAPAN             | 13%                               | 39                          |
| <i>Daption capense</i>       | Cape Petrel              | FRENCH POLYNESIA  | 11%                               | 39                          |
| <i>Daption capense</i>       | Cape Petrel              | FIJI              | 10%                               | 39                          |
| <i>Daption capense</i>       | Cape Petrel              | VANUATU           | 8%                                | 39                          |
| <i>Daption capense</i>       | Cape Petrel              | NEW ZEALAND       | 7%                                | 39                          |
| <i>Daption capense</i>       | Cape Petrel              | AMERICAN SAMOA    | 6%                                | 39                          |
| <i>Daption capense</i>       | Cape Petrel              | AUSTRALIA         | 6%                                | 39                          |
| <i>Daption capense</i>       | Cape Petrel              | CHINA             | 4%                                | 39                          |
| <i>Daption capense</i>       | Cape Petrel              | REPUBLIC OF KOREA | 4%                                | 39                          |
| <i>Diomedea antipodensis</i> | Antipodean Albatross     | JAPAN             | 56%                               | 5                           |
| <i>Diomedea antipodensis</i> | Antipodean Albatross     | NEW ZEALAND       | 25%                               | 5                           |
| <i>Diomedea antipodensis</i> | Antipodean Albatross     | CHINESE TAIPEI    | 9%                                | 5                           |
| <i>Diomedea epomophora</i>   | Southern Royal Albatross | NEW ZEALAND       | 99%                               | 15                          |
| <i>Diomedea exulans</i>      | Wandering Albatross      | JAPAN             | 76%                               | 2                           |
| <i>Diomedea exulans</i>      | Wandering Albatross      | AUSTRALIA         | 15%                               | 2                           |
| <i>Diomedea sanfordi</i>     | Northern Royal Albatross | NEW ZEALAND       | 97%                               | 43                          |
| <i>Halobaena caerulea</i>    | Blue Petrel              | JAPAN             | 49%                               | 59                          |
| <i>Halobaena caerulea</i>    | Blue Petrel              | NEW ZEALAND       | 40%                               | 59                          |
| <i>Halobaena caerulea</i>    | Blue Petrel              | CHINESE TAIPEI    | 6%                                | 59                          |
| <i>Lugensa brevirostris</i>  | Kerguelen Petrel         | JAPAN             | 54%                               | 57                          |
| <i>Lugensa brevirostris</i>  | Kerguelen Petrel         | NEW ZEALAND       | 35%                               | 57                          |
| <i>Lugensa brevirostris</i>  | Kerguelen Petrel         | CHINESE TAIPEI    | 6%                                | 57                          |
| <i>Macronectes giganteus</i> | Southern Giant-petrel    | JAPAN             | 37%                               | 47                          |
| <i>Macronectes giganteus</i> | Southern Giant-petrel    | NEW ZEALAND       | 24%                               | 47                          |
| <i>Macronectes giganteus</i> | Southern Giant-petrel    | AUSTRALIA         | 18%                               | 47                          |
| <i>Macronectes giganteus</i> | Southern Giant-petrel    | CHINESE TAIPEI    | 13%                               | 47                          |

| Scientific name                   | Common Name             | Flag             | Flag contribution to species risk | Rank of species in analysis |
|-----------------------------------|-------------------------|------------------|-----------------------------------|-----------------------------|
| <i>Macronectes halli</i>          | Northern Giant-petrel   | JAPAN            | 37%                               | 45                          |
| <i>Macronectes halli</i>          | Northern Giant-petrel   | NEW ZEALAND      | 23%                               | 45                          |
| <i>Macronectes halli</i>          | Northern Giant-petrel   | AUSTRALIA        | 20%                               | 45                          |
| <i>Macronectes halli</i>          | Northern Giant-petrel   | CHINESE TAIPEI   | 13%                               | 45                          |
| <i>Pachyptila belcheri</i>        | Thin-billed Prion       | JAPAN            | 44%                               | 50                          |
| <i>Pachyptila belcheri</i>        | Thin-billed Prion       | NEW ZEALAND      | 26%                               | 50                          |
| <i>Pachyptila belcheri</i>        | Thin-billed Prion       | AUSTRALIA        | 20%                               | 50                          |
| <i>Pachyptila desolata</i>        | Antarctic Prion         | JAPAN            | 43%                               | 60                          |
| <i>Pachyptila desolata</i>        | Antarctic Prion         | NEW ZEALAND      | 31%                               | 60                          |
| <i>Pachyptila desolata</i>        | Antarctic Prion         | AUSTRALIA        | 15%                               | 60                          |
| <i>Pachyptila turtur</i>          | Fairy Prion             | JAPAN            | 37%                               | 63                          |
| <i>Pachyptila turtur</i>          | Fairy Prion             | NEW ZEALAND      | 23%                               | 63                          |
| <i>Pachyptila turtur</i>          | Fairy Prion             | AUSTRALIA        | 21%                               | 63                          |
| <i>Pachyptila turtur</i>          | Fairy Prion             | CHINESE TAIPEI   | 12%                               | 63                          |
| <i>Pachyptila vittata</i>         | Broad-billed Prion      | NEW ZEALAND      | 83%                               | 53                          |
| <i>Pachyptila vittata</i>         | Broad-billed Prion      | JAPAN            | 6%                                | 53                          |
| <i>Pachyptila vittata</i>         | Broad-billed Prion      | CHINESE TAIPEI   | 5%                                | 53                          |
| <i>Phoebastria albatrus</i>       | Short-tailed Albatross  | CHINESE TAIPEI   | 46%                               | 9                           |
| <i>Phoebastria albatrus</i>       | Short-tailed Albatross  | JAPAN            | 32%                               | 9                           |
| <i>Phoebastria albatrus</i>       | Short-tailed Albatross  | USA              | 15%                               | 9                           |
| <i>Phoebastria immutabilis</i>    | Laysan Albatross        | USA              | 35%                               | 21                          |
| <i>Phoebastria immutabilis</i>    | Laysan Albatross        | JAPAN            | 31%                               | 21                          |
| <i>Phoebastria immutabilis</i>    | Laysan Albatross        | CHINESE TAIPEI   | 21%                               | 21                          |
| <i>Phoebastria immutabilis</i>    | Laysan Albatross        | VANUATU          | 11%                               | 21                          |
| <i>Phoebastria nigripes</i>       | Black-footed Albatross  | USA              | 31%                               | 29                          |
| <i>Phoebastria nigripes</i>       | Black-footed Albatross  | CHINESE TAIPEI   | 26%                               | 29                          |
| <i>Phoebastria nigripes</i>       | Black-footed Albatross  | JAPAN            | 25%                               | 29                          |
| <i>Phoebastria nigripes</i>       | Black-footed Albatross  | VANUATU          | 15%                               | 29                          |
| <i>Phoebetria fusca</i>           | Sooty Albatross         | AUSTRALIA        | 100%                              | 64                          |
| <i>Phoebetria palpebrata</i>      | Light-mantled Albatross | NEW ZEALAND      | 48%                               | 48                          |
| <i>Phoebetria palpebrata</i>      | Light-mantled Albatross | JAPAN            | 42%                               | 48                          |
| <i>Phoebetria palpebrata</i>      | Light-mantled Albatross | CHINESE TAIPEI   | 5%                                | 48                          |
| <i>Procellaria aequinoctialis</i> | White-chinned Petrel    | JAPAN            | 45%                               | 54                          |
| <i>Procellaria aequinoctialis</i> | White-chinned Petrel    | NEW ZEALAND      | 29%                               | 54                          |
| <i>Procellaria aequinoctialis</i> | White-chinned Petrel    | CHINESE TAIPEI   | 11%                               | 54                          |
| <i>Procellaria aequinoctialis</i> | White-chinned Petrel    | AUSTRALIA        | 7%                                | 54                          |
| <i>Procellaria cinerea</i>        | Grey Petrel             | NEW ZEALAND      | 69%                               | 55                          |
| <i>Procellaria cinerea</i>        | Grey Petrel             | JAPAN            | 25%                               | 55                          |
| <i>Procellaria parkinsoni</i>     | Parkinson's Petrel      | NEW ZEALAND      | 79%                               | 11                          |
| <i>Procellaria parkinsoni</i>     | Parkinson's Petrel      | JAPAN            | 6%                                | 11                          |
| <i>Procellaria parkinsoni</i>     | Parkinson's Petrel      | FRENCH POLYNESIA | 5%                                | 11                          |
| <i>Procellaria parkinsoni</i>     | Parkinson's Petrel      | CHINESE TAIPEI   | 4%                                | 11                          |

| Scientific name                     | Common Name      | Flag              | Flag contribution to species risk | Rank of species in analysis |
|-------------------------------------|------------------|-------------------|-----------------------------------|-----------------------------|
| <i>Procellaria westlandica</i>      | Westland Petrel  | NEW ZEALAND       | 97%                               | 38                          |
| <i>Pseudobulweria becki</i>         | Beck's Petrel    | REPUBLIC OF KOREA | 24%                               | 3                           |
| <i>Pseudobulweria becki</i>         | Beck's Petrel    | CHINESE TAIPEI    | 19%                               | 3                           |
| <i>Pseudobulweria becki</i>         | Beck's Petrel    | FIJI              | 11%                               | 3                           |
| <i>Pseudobulweria becki</i>         | Beck's Petrel    | CHINA             | 11%                               | 3                           |
| <i>Pseudobulweria becki</i>         | Beck's Petrel    | JAPAN             | 11%                               | 3                           |
| <i>Pseudobulweria becki</i>         | Beck's Petrel    | FRENCH POLYNESIA  | 5%                                | 3                           |
| <i>Pseudobulweria becki</i>         | Beck's Petrel    | VANUATU           | 4%                                | 3                           |
| <i>Pseudobulweria becki</i>         | Beck's Petrel    | AMERICAN SAMOA    | 3%                                | 3                           |
| <i>Pseudobulweria becki</i>         | Beck's Petrel    | AUSTRALIA         | 2%                                | 3                           |
| <i>Pseudobulweria macgillivrayi</i> | Fiji Petrel      | FIJI              | 96%                               | 1                           |
| <i>Pseudobulweria rostrata</i>      | Tahiti Petrel    | CHINESE TAIPEI    | 23%                               | 12                          |
| <i>Pseudobulweria rostrata</i>      | Tahiti Petrel    | REPUBLIC OF KOREA | 20%                               | 12                          |
| <i>Pseudobulweria rostrata</i>      | Tahiti Petrel    | JAPAN             | 12%                               | 12                          |
| <i>Pseudobulweria rostrata</i>      | Tahiti Petrel    | FIJI              | 11%                               | 12                          |
| <i>Pseudobulweria rostrata</i>      | Tahiti Petrel    | CHINA             | 10%                               | 12                          |
| <i>Pseudobulweria rostrata</i>      | Tahiti Petrel    | FRENCH POLYNESIA  | 5%                                | 12                          |
| <i>Pseudobulweria rostrata</i>      | Tahiti Petrel    | VANUATU           | 4%                                | 12                          |
| <i>Pseudobulweria rostrata</i>      | Tahiti Petrel    | AMERICAN SAMOA    | 3%                                | 12                          |
| <i>Pseudobulweria rostrata</i>      | Tahiti Petrel    | AUSTRALIA         | 2%                                | 12                          |
| <i>Pterodroma alba</i>              | Phoenix Petrel   | REPUBLIC OF KOREA | 26%                               | 4                           |
| <i>Pterodroma alba</i>              | Phoenix Petrel   | CHINESE TAIPEI    | 18%                               | 4                           |
| <i>Pterodroma alba</i>              | Phoenix Petrel   | CHINA             | 13%                               | 4                           |
| <i>Pterodroma alba</i>              | Phoenix Petrel   | FIJI              | 9%                                | 4                           |
| <i>Pterodroma alba</i>              | Phoenix Petrel   | FRENCH POLYNESIA  | 9%                                | 4                           |
| <i>Pterodroma alba</i>              | Phoenix Petrel   | AMERICAN SAMOA    | 6%                                | 4                           |
| <i>Pterodroma alba</i>              | Phoenix Petrel   | JAPAN             | 5%                                | 4                           |
| <i>Pterodroma alba</i>              | Phoenix Petrel   | VANUATU           | 3%                                | 4                           |
| <i>Pterodroma alba</i>              | Phoenix Petrel   | SAMOA             | 3%                                | 4                           |
| <i>Pterodroma atrata</i>            | Henderson Petrel | REPUBLIC OF KOREA | 33%                               | 20                          |
| <i>Pterodroma atrata</i>            | Henderson Petrel | CHINESE TAIPEI    | 22%                               | 20                          |
| <i>Pterodroma atrata</i>            | Henderson Petrel | FRENCH POLYNESIA  | 22%                               | 20                          |
| <i>Pterodroma atrata</i>            | Henderson Petrel | JAPAN             | 14%                               | 20                          |
| <i>Pterodroma axillaris</i>         | Chatham Petrel   | NEW ZEALAND       | 99%                               | 37                          |

| Scientific name              | Common Name           | Flag              | Flag contribution to species risk | Rank of species in analysis |
|------------------------------|-----------------------|-------------------|-----------------------------------|-----------------------------|
| <i>Pterodroma brevipes</i>   | Collared Petrel       | REPUBLIC OF KOREA | 28%                               | 8                           |
| <i>Pterodroma brevipes</i>   | Collared Petrel       | CHINESE TAIPEI    | 17%                               | 8                           |
| <i>Pterodroma brevipes</i>   | Collared Petrel       | FIJI              | 14%                               | 8                           |
| <i>Pterodroma brevipes</i>   | Collared Petrel       | CHINA             | 11%                               | 8                           |
| <i>Pterodroma brevipes</i>   | Collared Petrel       | FRENCH POLYNESIA  | 7%                                | 8                           |
| <i>Pterodroma brevipes</i>   | Collared Petrel       | JAPAN             | 6%                                | 8                           |
| <i>Pterodroma brevipes</i>   | Collared Petrel       | AMERICAN SAMOA    | 5%                                | 8                           |
| <i>Pterodroma brevipes</i>   | Collared Petrel       | VANUATU           | 4%                                | 8                           |
| <i>Pterodroma cervicalis</i> | White-necked Petrel   | REPUBLIC OF KOREA | 21%                               | 10                          |
| <i>Pterodroma cervicalis</i> | White-necked Petrel   | JAPAN             | 18%                               | 10                          |
| <i>Pterodroma cervicalis</i> | White-necked Petrel   | CHINESE TAIPEI    | 18%                               | 10                          |
| <i>Pterodroma cervicalis</i> | White-necked Petrel   | CHINA             | 10%                               | 10                          |
| <i>Pterodroma cervicalis</i> | White-necked Petrel   | FIJI              | 8%                                | 10                          |
| <i>Pterodroma cervicalis</i> | White-necked Petrel   | USA               | 7%                                | 10                          |
| <i>Pterodroma cervicalis</i> | White-necked Petrel   | VANUATU           | 4%                                | 10                          |
| <i>Pterodroma cervicalis</i> | White-necked Petrel   | FRENCH POLYNESIA  | 4%                                | 10                          |
| <i>Pterodroma cookii</i>     | Cook's Petrel         | REPUBLIC OF KOREA | 22%                               | 19                          |
| <i>Pterodroma cookii</i>     | Cook's Petrel         | CHINESE TAIPEI    | 19%                               | 19                          |
| <i>Pterodroma cookii</i>     | Cook's Petrel         | JAPAN             | 16%                               | 19                          |
| <i>Pterodroma cookii</i>     | Cook's Petrel         | USA               | 10%                               | 19                          |
| <i>Pterodroma cookii</i>     | Cook's Petrel         | CHINA             | 9%                                | 19                          |
| <i>Pterodroma cookii</i>     | Cook's Petrel         | FRENCH POLYNESIA  | 6%                                | 19                          |
| <i>Pterodroma cookii</i>     | Cook's Petrel         | VANUATU           | 5%                                | 19                          |
| <i>Pterodroma cookii</i>     | Cook's Petrel         | AMERICAN SAMOA    | 4%                                | 19                          |
| <i>Pterodroma externa</i>    | Juan Fernandez Petrel | USA               | 35%                               | 36                          |
| <i>Pterodroma externa</i>    | Juan Fernandez Petrel | REPUBLIC OF KOREA | 25%                               | 36                          |
| <i>Pterodroma externa</i>    | Juan Fernandez Petrel | JAPAN             | 17%                               | 36                          |
| <i>Pterodroma externa</i>    | Juan Fernandez Petrel | CHINESE TAIPEI    | 13%                               | 36                          |
| <i>Pterodroma externa</i>    | Juan Fernandez Petrel | CHINA             | 7%                                | 36                          |

| Scientific name                | Common Name         | Flag              | Flag contribution to species risk | Rank of species in analysis |
|--------------------------------|---------------------|-------------------|-----------------------------------|-----------------------------|
| <i>Pterodroma inexpectata</i>  | Mottled Petrel      | REPUBLIC OF KOREA | 20%                               | 18                          |
| <i>Pterodroma inexpectata</i>  | Mottled Petrel      | CHINESE TAIPEI    | 18%                               | 18                          |
| <i>Pterodroma inexpectata</i>  | Mottled Petrel      | JAPAN             | 15%                               | 18                          |
| <i>Pterodroma inexpectata</i>  | Mottled Petrel      | CHINA             | 9%                                | 18                          |
| <i>Pterodroma inexpectata</i>  | Mottled Petrel      | FIJI              | 8%                                | 18                          |
| <i>Pterodroma inexpectata</i>  | Mottled Petrel      | USA               | 7%                                | 18                          |
| <i>Pterodroma inexpectata</i>  | Mottled Petrel      | VANUATU           | 6%                                | 18                          |
| <i>Pterodroma inexpectata</i>  | Mottled Petrel      | FRENCH POLYNESIA  | 4%                                | 18                          |
| <i>Pterodroma inexpectata</i>  | Mottled Petrel      | AMERICAN SAMOA    | 3%                                | 18                          |
| <i>Pterodroma lessonii</i>     | White-headed Petrel | JAPAN             | 39%                               | 49                          |
| <i>Pterodroma lessonii</i>     | White-headed Petrel | NEW ZEALAND       | 29%                               | 49                          |
| <i>Pterodroma lessonii</i>     | White-headed Petrel | AUSTRALIA         | 14%                               | 49                          |
| <i>Pterodroma lessonii</i>     | White-headed Petrel | CHINESE TAIPEI    | 11%                               | 49                          |
| <i>Pterodroma leucoptera</i>   | Gould's Petrel      | CHINESE TAIPEI    | 18%                               | 13                          |
| <i>Pterodroma leucoptera</i>   | Gould's Petrel      | REPUBLIC OF KOREA | 14%                               | 13                          |
| <i>Pterodroma leucoptera</i>   | Gould's Petrel      | FIJI              | 13%                               | 13                          |
| <i>Pterodroma leucoptera</i>   | Gould's Petrel      | JAPAN             | 12%                               | 13                          |
| <i>Pterodroma leucoptera</i>   | Gould's Petrel      | CHINA             | 12%                               | 13                          |
| <i>Pterodroma leucoptera</i>   | Gould's Petrel      | FRENCH POLYNESIA  | 8%                                | 13                          |
| <i>Pterodroma leucoptera</i>   | Gould's Petrel      | AMERICAN SAMOA    | 6%                                | 13                          |
| <i>Pterodroma leucoptera</i>   | Gould's Petrel      | VANUATU           | 4%                                | 13                          |
| <i>Pterodroma leucoptera</i>   | Gould's Petrel      | AUSTRALIA         | 4%                                | 13                          |
| <i>Pterodroma leucoptera</i>   | Gould's Petrel      | SAMOA             | 3%                                | 13                          |
| <i>Pterodroma longirostris</i> | Stejneger's Petrel  | REPUBLIC OF KOREA | 28%                               | 17                          |
| <i>Pterodroma longirostris</i> | Stejneger's Petrel  | JAPAN             | 26%                               | 17                          |
| <i>Pterodroma longirostris</i> | Stejneger's Petrel  | CHINESE TAIPEI    | 22%                               | 17                          |
| <i>Pterodroma longirostris</i> | Stejneger's Petrel  | CHINA             | 12%                               | 17                          |
| <i>Pterodroma longirostris</i> | Stejneger's Petrel  | USA               | 7%                                | 17                          |
| <i>Pterodroma macroptera</i>   | Great-winged Petrel | JAPAN             | 34%                               | 41                          |
| <i>Pterodroma macroptera</i>   | Great-winged Petrel | NEW ZEALAND       | 22%                               | 41                          |
| <i>Pterodroma macroptera</i>   | Great-winged Petrel | CHINESE TAIPEI    | 18%                               | 41                          |
| <i>Pterodroma macroptera</i>   | Great-winged Petrel | AUSTRALIA         | 14%                               | 41                          |
| <i>Pterodroma macroptera</i>   | Great-winged Petrel | VANUATU           | 9%                                | 41                          |

| Scientific name                 | Common Name          | Flag                      | Flag contribution to species risk | Rank of species in analysis |
|---------------------------------|----------------------|---------------------------|-----------------------------------|-----------------------------|
| <i>Pterodroma magentae</i>      | Magenta Petrel       | INDONESIA                 | 35%                               | <b>62</b>                   |
| <i>Pterodroma magentae</i>      | Magenta Petrel       | SPAIN                     | 29%                               | <b>62</b>                   |
| <i>Pterodroma magentae</i>      | Magenta Petrel       | NEW ZEALAND               | 13%                               | <b>62</b>                   |
| <i>Pterodroma magentae</i>      | Magenta Petrel       | VANUATU                   | 10%                               | <b>62</b>                   |
| <i>Pterodroma magentae</i>      | Magenta Petrel       | CHINESE TAIPEI            | 9%                                | <b>62</b>                   |
| <i>Pterodroma mollis</i>        | Soft-plumaged Petrel | NEW ZEALAND               | 58%                               | 56                          |
| <i>Pterodroma mollis</i>        | Soft-plumaged Petrel | JAPAN                     | 37%                               | 56                          |
| <i>Pterodroma neglecta</i>      | Kermadec Petrel      | CHINESE TAIPEI            | 20%                               | 16                          |
| <i>Pterodroma neglecta</i>      | Kermadec Petrel      | REPUBLIC OF KOREA         | 20%                               | 16                          |
| <i>Pterodroma neglecta</i>      | Kermadec Petrel      | JAPAN                     | 18%                               | 16                          |
| <i>Pterodroma neglecta</i>      | Kermadec Petrel      | CHINA                     | 9%                                | 16                          |
| <i>Pterodroma neglecta</i>      | Kermadec Petrel      | FIJI                      | 8%                                | 16                          |
| <i>Pterodroma neglecta</i>      | Kermadec Petrel      | USA                       | 6%                                | 16                          |
| <i>Pterodroma neglecta</i>      | Kermadec Petrel      | VANUATU                   | 4%                                | 16                          |
| <i>Pterodroma neglecta</i>      | Kermadec Petrel      | FRANCE (FRENCH POLYNESIA) | 4%                                | 16                          |
| <i>Pterodroma neglecta</i>      | Kermadec Petrel      | USA (AMERICAN SAMOA)      | 2%                                | 16                          |
| <i>Pterodroma sandwichensis</i> | Hawaiian Petrel      | USA                       | 56%                               | 22                          |
| <i>Pterodroma sandwichensis</i> | Hawaiian Petrel      | REPUBLIC OF KOREA         | 18%                               | 22                          |
| <i>Pterodroma sandwichensis</i> | Hawaiian Petrel      | JAPAN                     | 13%                               | 22                          |
| <i>Pterodroma sandwichensis</i> | Hawaiian Petrel      | CHINA                     | 6%                                | 22                          |
| <i>Pterodroma solandri</i>      | Providence Petrel    | JAPAN                     | 23%                               | 7                           |
| <i>Pterodroma solandri</i>      | Providence Petrel    | REPUBLIC OF KOREA         | 21%                               | 7                           |
| <i>Pterodroma solandri</i>      | Providence Petrel    | CHINESE TAIPEI            | 15%                               | 7                           |
| <i>Pterodroma solandri</i>      | Providence Petrel    | FIJI                      | 11%                               | 7                           |
| <i>Pterodroma solandri</i>      | Providence Petrel    | USA                       | 10%                               | 7                           |
| <i>Pterodroma solandri</i>      | Providence Petrel    | CHINA                     | 6%                                | 7                           |
| <i>Pterodroma solandri</i>      | Providence Petrel    | VANUATU                   | 5%                                | 7                           |

| Scientific name           | Common Name             | Flag                      | Flag contribution to species risk | Rank of species in analysis |
|---------------------------|-------------------------|---------------------------|-----------------------------------|-----------------------------|
| <i>Pterodroma ultima</i>  | Murphy's Petrel         | CHINESE TAIPEI            | 25%                               | 25                          |
| <i>Pterodroma ultima</i>  | Murphy's Petrel         | REPUBLIC OF KOREA         | 24%                               | 25                          |
| <i>Pterodroma ultima</i>  | Murphy's Petrel         | CHINA                     | 14%                               | 25                          |
| <i>Pterodroma ultima</i>  | Murphy's Petrel         | FRANCE (FRENCH POLYNESIA) | 10%                               | 25                          |
| <i>Pterodroma ultima</i>  | Murphy's Petrel         | JAPAN                     | 7%                                | 25                          |
| <i>Pterodroma ultima</i>  | Murphy's Petrel         | USA (AMERICAN SAMOA)      | 6%                                | 25                          |
| <i>Pterodroma ultima</i>  | Murphy's Petrel         | VANUATU                   | 5%                                | 25                          |
| <i>Puffinus assimilis</i> | Little Shearwater       | CHINESE TAIPEI            | 31%                               | 46                          |
| <i>Puffinus assimilis</i> | Little Shearwater       | JAPAN                     | 24%                               | 46                          |
| <i>Puffinus assimilis</i> | Little Shearwater       | NEW ZEALAND               | 15%                               | 46                          |
| <i>Puffinus assimilis</i> | Little Shearwater       | VANUATU                   | 15%                               | 46                          |
| <i>Puffinus assimilis</i> | Little Shearwater       | AUSTRALIA                 | 9%                                | 46                          |
| <i>Puffinus bulleri</i>   | Buller's Shearwater     | REPUBLIC OF KOREA         | 21%                               | 23                          |
| <i>Puffinus bulleri</i>   | Buller's Shearwater     | CHINESE TAIPEI            | 18%                               | 23                          |
| <i>Puffinus bulleri</i>   | Buller's Shearwater     | JAPAN                     | 17%                               | 23                          |
| <i>Puffinus bulleri</i>   | Buller's Shearwater     | CHINA                     | 9%                                | 23                          |
| <i>Puffinus bulleri</i>   | Buller's Shearwater     | FIJI                      | 9%                                | 23                          |
| <i>Puffinus bulleri</i>   | Buller's Shearwater     | USA                       | 7%                                | 23                          |
| <i>Puffinus bulleri</i>   | Buller's Shearwater     | VANUATU                   | 5%                                | 23                          |
| <i>Puffinus bulleri</i>   | Buller's Shearwater     | USA (AMERICAN SAMOA)      | 3%                                | 23                          |
| <i>Puffinus bulleri</i>   | Buller's Shearwater     | NEW ZEALAND               | 2%                                | 23                          |
| <i>Puffinus carneipes</i> | Flesh-footed Shearwater | JAPAN                     | 28%                               | 27                          |
| <i>Puffinus carneipes</i> | Flesh-footed Shearwater | CHINESE TAIPEI            | 18%                               | 27                          |
| <i>Puffinus carneipes</i> | Flesh-footed Shearwater | FIJI                      | 13%                               | 27                          |
| <i>Puffinus carneipes</i> | Flesh-footed Shearwater | REPUBLIC OF KOREA         | 11%                               | 27                          |
| <i>Puffinus carneipes</i> | Flesh-footed Shearwater | CHINA                     | 7%                                | 27                          |
| <i>Puffinus carneipes</i> | Flesh-footed Shearwater | USA                       | 7%                                | 27                          |
| <i>Puffinus carneipes</i> | Flesh-footed Shearwater | VANUATU                   | 6%                                | 27                          |
| <i>Puffinus carneipes</i> | Flesh-footed Shearwater | AUSTRALIA                 | 3%                                | 27                          |



| Scientific name             | Common Name           | Flag                      | Flag contribution to species risk | Rank of species in analysis |
|-----------------------------|-----------------------|---------------------------|-----------------------------------|-----------------------------|
| <i>Puffinus griseus</i>     | Sooty Shearwater      | REPUBLIC OF KOREA         | 19%                               | 30                          |
| <i>Puffinus griseus</i>     | Sooty Shearwater      | CHINESE TAIPEI            | 19%                               | 30                          |
| <i>Puffinus griseus</i>     | Sooty Shearwater      | JAPAN                     | 17%                               | 30                          |
| <i>Puffinus griseus</i>     | Sooty Shearwater      | CHINA                     | 9%                                | 30                          |
| <i>Puffinus griseus</i>     | Sooty Shearwater      | FIJI                      | 8%                                | 30                          |
| <i>Puffinus griseus</i>     | Sooty Shearwater      | USA                       | 7%                                | 30                          |
| <i>Puffinus griseus</i>     | Sooty Shearwater      | VANUATU                   | 6%                                | 30                          |
| <i>Puffinus griseus</i>     | Sooty Shearwater      | FRANCE (FRENCH POLYNESIA) | 4%                                | 30                          |
| <i>Puffinus griseus</i>     | Sooty Shearwater      | USA (AMERICAN SAMOA)      | 3%                                | 30                          |
| <i>Puffinus heinrothi</i>   | Heinroth's Shearwater | PAPUA NEW GUINEA          | 63%                               | 24                          |
| <i>Puffinus heinrothi</i>   | Heinroth's Shearwater | JAPAN                     | 25%                               | 24                          |
| <i>Puffinus heinrothi</i>   | Heinroth's Shearwater | CHINESE TAIPEI            | 6%                                | 24                          |
| <i>Puffinus huttoni</i>     | Hutton's Shearwater   | JAPAN                     | 35%                               | 26                          |
| <i>Puffinus huttoni</i>     | Hutton's Shearwater   | AUSTRALIA                 | 30%                               | 26                          |
| <i>Puffinus huttoni</i>     | Hutton's Shearwater   | NEW ZEALAND               | 25%                               | 26                          |
| <i>Puffinus huttoni</i>     | Hutton's Shearwater   | CHINESE TAIPEI            | 7%                                | 26                          |
| <i>Puffinus lherminieri</i> | Audubon's Shearwater  | CHINESE TAIPEI            | 25%                               | 6                           |
| <i>Puffinus lherminieri</i> | Audubon's Shearwater  | REPUBLIC OF KOREA         | 25%                               | 6                           |
| <i>Puffinus lherminieri</i> | Audubon's Shearwater  | JAPAN                     | 12%                               | 6                           |
| <i>Puffinus lherminieri</i> | Audubon's Shearwater  | CHINA                     | 11%                               | 6                           |
| <i>Puffinus lherminieri</i> | Audubon's Shearwater  | FIJI                      | 9%                                | 6                           |
| <i>Puffinus lherminieri</i> | Audubon's Shearwater  | FRANCE (FRENCH POLYNESIA) | 5%                                | 6                           |
| <i>Puffinus lherminieri</i> | Audubon's Shearwater  | VANUATU                   | 3%                                | 6                           |
| <i>Puffinus lherminieri</i> | Audubon's Shearwater  | USA (AMERICAN SAMOA)      | 3%                                | 6                           |
| <i>Puffinus newelli</i>     | Newell's Shearwater   | USA                       | 40%                               | 28                          |
| <i>Puffinus newelli</i>     | Newell's Shearwater   | REPUBLIC OF KOREA         | 31%                               | 28                          |
| <i>Puffinus newelli</i>     | Newell's Shearwater   | JAPAN                     | 13%                               | 28                          |
| <i>Puffinus newelli</i>     | Newell's Shearwater   | CHINESE TAIPEI            | 9%                                | 28                          |



| Scientific name              | Common Name                   | Flag                      | Flag contribution to species risk | Rank of species in analysis |
|------------------------------|-------------------------------|---------------------------|-----------------------------------|-----------------------------|
| <i>Puffinus pacificus</i>    | Wedge-tailed Shearwater       | CHINESE TAIPEI            | 29%                               | 33                          |
| <i>Puffinus pacificus</i>    | Wedge-tailed Shearwater       | REPUBLIC OF KOREA         | 17%                               | 33                          |
| <i>Puffinus pacificus</i>    | Wedge-tailed Shearwater       | JAPAN                     | 16%                               | 33                          |
| <i>Puffinus pacificus</i>    | Wedge-tailed Shearwater       | CHINA                     | 8%                                | 33                          |
| <i>Puffinus pacificus</i>    | Wedge-tailed Shearwater       | FIJI                      | 7%                                | 33                          |
| <i>Puffinus pacificus</i>    | Wedge-tailed Shearwater       | USA                       | 5%                                | 33                          |
| <i>Puffinus pacificus</i>    | Wedge-tailed Shearwater       | VANUATU                   | 3%                                | 33                          |
| <i>Puffinus pacificus</i>    | Wedge-tailed Shearwater       | FRANCE (FRENCH POLYNESIA) | 3%                                | 33                          |
| <i>Puffinus pacificus</i>    | Wedge-tailed Shearwater       | USA (AMERICAN SAMOA)      | 2%                                | 33                          |
| <i>Puffinus pacificus</i>    | Wedge-tailed Shearwater       | AUSTRALIA                 | 2%                                | 33                          |
| <i>Puffinus tenuirostris</i> | Short-tailed Shearwater       | JAPAN                     | 67%                               | 42                          |
| <i>Puffinus tenuirostris</i> | Short-tailed Shearwater       | AUSTRALIA                 | 11%                               | 42                          |
| <i>Puffinus tenuirostris</i> | Short-tailed Shearwater       | CHINESE TAIPEI            | 6%                                | 42                          |
| <i>Puffinus tenuirostris</i> | Short-tailed Shearwater       | REPUBLIC OF KOREA         | 5%                                | 42                          |
| <i>Puffinus tenuirostris</i> | Short-tailed Shearwater       | CHINA                     | 2%                                | 42                          |
| <i>Thalassarche bulleri</i>  | Buller's Albatross            | NEW ZEALAND               | 51%                               | 31                          |
| <i>Thalassarche bulleri</i>  | Buller's Albatross            | JAPAN                     | 48%                               | 52                          |
| <i>Thalassarche bulleri</i>  | Buller's Albatross            | JAPAN                     | 46%                               | 31                          |
| <i>Thalassarche bulleri</i>  | Buller's Albatross            | NEW ZEALAND               | 31%                               | 52                          |
| <i>Thalassarche bulleri</i>  | Buller's Albatross            | AUSTRALIA                 | 10%                               | 52                          |
| <i>Thalassarche bulleri</i>  | Buller's Albatross            | CHINESE TAIPEI            | 8%                                | 52                          |
| <i>Thalassarche carteri</i>  | Indian Yellow-nosed Albatross | JAPAN                     | 47%                               | 32                          |
| <i>Thalassarche carteri</i>  | Indian Yellow-nosed Albatross | AUSTRALIA                 | 17%                               | 32                          |
| <i>Thalassarche carteri</i>  | Indian Yellow-nosed Albatross | NEW ZEALAND               | 17%                               | 32                          |
| <i>Thalassarche carteri</i>  | Indian Yellow-nosed Albatross | CHINESE TAIPEI            | 12%                               | 32                          |
| <i>Thalassarche cauta</i>    | Shy Albatross                 | JAPAN                     | 50%                               | 51                          |
| <i>Thalassarche cauta</i>    | Shy Albatross                 | AUSTRALIA                 | 42%                               | 51                          |

| Scientific name                 | Common Name            | Flag           | Flag contribution to species risk | Rank of species in analysis |
|---------------------------------|------------------------|----------------|-----------------------------------|-----------------------------|
| <i>Thalassarche chrysostoma</i> | Grey-headed Albatross  | CHINESE TAIPEI | 32%                               | 58                          |
| <i>Thalassarche chrysostoma</i> | Grey-headed Albatross  | JAPAN          | 24%                               | 58                          |
| <i>Thalassarche chrysostoma</i> | Grey-headed Albatross  | VANUATU        | 20%                               | 58                          |
| <i>Thalassarche chrysostoma</i> | Grey-headed Albatross  | NEW ZEALAND    | 17%                               | 58                          |
| <i>Thalassarche eremita</i>     | Chatham Albatross      | NEW ZEALAND    | 66%                               | 44                          |
| <i>Thalassarche eremita</i>     | Chatham Albatross      | CHINESE TAIPEI | 10%                               | 44                          |
| <i>Thalassarche eremita</i>     | Chatham Albatross      | VANUATU        | 5%                                | 44                          |
| <i>Thalassarche eremita</i>     | Chatham Albatross      | JAPAN          | 4%                                | 44                          |
| <i>Thalassarche eremita</i>     | Chatham Albatross      | FIJI           | 3%                                | 44                          |
| <i>Thalassarche impavida</i>    | Campbell Albatross     | NEW ZEALAND    | 68%                               | 34                          |
| <i>Thalassarche impavida</i>    | Campbell Albatross     | JAPAN          | 20%                               | 34                          |
| <i>Thalassarche impavida</i>    | Campbell Albatross     | CHINESE TAIPEI | 5%                                | 34                          |
| <i>Thalassarche melanophrys</i> | Black-browed Albatross | JAPAN          | 27%                               | 61                          |
| <i>Thalassarche melanophrys</i> | Black-browed Albatross | CHINESE TAIPEI | 25%                               | 61                          |
| <i>Thalassarche melanophrys</i> | Black-browed Albatross | NEW ZEALAND    | 17%                               | 61                          |
| <i>Thalassarche melanophrys</i> | Black-browed Albatross | AUSTRALIA      | 13%                               | 61                          |
| <i>Thalassarche melanophrys</i> | Black-browed Albatross | VANUATU        | 13%                               | 61                          |
| <i>Thalassarche salvini</i>     | Salvin's Albatross     | JAPAN          | 40%                               | 35                          |
| <i>Thalassarche salvini</i>     | Salvin's Albatross     | NEW ZEALAND    | 28%                               | 35                          |
| <i>Thalassarche salvini</i>     | Salvin's Albatross     | CHINESE TAIPEI | 15%                               | 35                          |
| <i>Thalassarche salvini</i>     | Salvin's Albatross     | VANUATU        | 9%                                | 35                          |
| <i>Thalassarche steadi</i>      | White-capped Albatross | JAPAN          | 38%                               | 40                          |
| <i>Thalassarche steadi</i>      | White-capped Albatross | NEW ZEALAND    | 25%                               | 40                          |
| <i>Thalassarche steadi</i>      | White-capped Albatross | AUSTRALIA      | 17%                               | 40                          |
| <i>Thalassarche steadi</i>      | White-capped Albatross | CHINESE TAIPEI | 13%                               | 40                          |