**Agreement on the Conservation of Albatrosses and Petrels**

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# Ecological Risk Assessments for the effects of fishing: considerations for using ERAs to assess risks to albatrosses and petrels

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**Summary**
This paper reviews for ACAP the benefits of undertaking Ecological Risk Assessments of the effects of fishing (hereafter, ERAs) on albatross and petrel species.

In particular, it:
- Considers the benefits of undertaking ERAs as a means to address the threats to albatross and petrel populations posed by interactions with fisheries
- Briefly summarises the methods that have been used to undertake ERAs for seabirds (notably those undertaken by CCAMLR, New Zealand, WCPFC, and ICCAT)
- Identifies 10 points to consider when undertaking or promoting the use of ERAs in relation to seabirds

Methodologies for ERAs for seabirds are still under discussion. We suggest that the issues identified in this paper could be explored further by ACAP's Seabird Bycatch Working Group and, if considered appropriate, developed into recommendations to pass to AC6. A revised version of this document and these recommendations could potentially constitute the next in the series of ACAP Conservation Guidelines.

## 1. Do we need Ecological Risk Assessments in order to reduce the threats to albatross and petrel populations posed by interactions with fisheries?

The FAO Code of Conduct for Responsible Fisheries and the UN Fish Stocks Agreement established the 'Ecosystem Approach' and the 'Precautionary Approach' as key approaches necessary to achieve sustainable management of the world's fisheries, as well as establishing the duty of fishery management to minimize impacts on non-target species such as albatrosses and petrels (e.g., amongst others, Article 5(f) of the UN Fish Stocks Agreement[1], and Article 6.6. of the Code of Conduct for Responsible Fisheries[2]).

While progress to address seabird bycatch should be possible solely through invoking the obligations of fisheries managers to minimize bycatch, the incentive to do so may be increased if

[1] *Article 5(f) of the UN Fish Stocks Agreement requires States to "minimize pollution, waste, discards, catch by lost or abandoned gear, catch of non-target species, both fish and non-fish species, (hereinafter referred to as non-target species) and impacts on associated or dependent species, in particular endangered species, through measures including, to the extent practicable, the development and use of selective, environmentally safe and cost-effective fishing gear and techniques".*
[2] *Article 6.6 of the Code of Conduct for Responsible Fisheries states that "Selective and environmentally safe fishing gear and practices should be further developed and applied, to the extent practicable, in order to maintain biodiversity and to conserve the population structure and aquatic ecosystems and protect fish quality. Where proper selective and environmentally safe fishing gear and practices exist, they should be recognized and accorded a priority in establishing conservation and management measures for fisheries. States and users of aquatic ecosystems should minimize waste, catch of non-target species, both fish and non-fish species, and impacts on associated or dependent species."*

an ERA highlights that a bycatch problem exists for particular species, operational areas and fishing practices. An ERA is also demonstrable evidence that ecosystem and precautionary approaches have been applied to assess and address bycatch issues.

Fisheries management organisations around the world have struggled to embed the ecosystem and precautionary approaches into their management decision-making in a meaningful and practical way. However, ERAs offer a framework through which fisheries managers can address this, by identifying the species and/or habitats most at risk from interaction with fisheries, taking data scarcity and uncertainty into consideration, and linking the risk assessment process to pre-determined rules that trigger management decision-making. ERAs are currently being undertaken in many fisheries worldwide. The Marine Stewardship Council has also adopted an ERA-based framework for assessing certification of fisheries (www.msc.org).

Therefore, while seabird bycatch can be, and has been, addressed in the absence of formal risk assessment, a number of benefits may derive from a dedicated ERA process.

Firstly, ERAs can be used to refine understanding of the:

- Seabird species at risk from bycatch
- Key areas, fisheries and seasons in which bycatch may be occurring
- Data gaps and research priorities, including the need for higher levels of observer program coverage

Furthermore, from a strategic perspective:

- If fishery management organisations are undertaking ERAs, it is important to ensure that seabirds are included in such assessments
- Similarly, if no progress is being made to address seabird bycatch through other routes, then an ERA may be a means to stimulate action
- ERAs will present risk in terms that are familiar to those involved in fisheries management.
- Ideally, ERAs will enable a precautionary approach to fisheries management if linked to pre-determined rules for decision making (e.g. CCAMLR).
- ERAs can also be a means to embed decision-making on bycatch into the long-term fisheries management framework, i.e. to ensure that bycatch is considered as a central rather than a peripheral issue

Nevertheless, there are a number of factors to consider in order to ensure that ERAs for seabirds enhance the prospect of effective management responses:

- It is conceivable that ERAs could undermine the focus of fishery managers on their duty to minimize bycatch *per se*, since a dedicated seabird ERA focuses attention on those taxa areas where there is highest risk of impacts of fisheries on seabirds. This risk may increase if, at the outset, the use of mitigation or other management response is predicated on proof through the ERA process that population-level impacts are occurring.
- ERA methodologies for seabirds are still in development. When selecting an approach, the right balance needs to be struck between desired outputs, data availability (which is almost invariably limited), and complexity of the process. Although the ideal output would be for an ERA to quantify absolute impact from fisheries in a way that can be monitored in relation to management response, in the great majority of cases, there will be insufficient data to do so, and determining the relative risk is a more realistic goal.
- For this reason, and in order to ensure a precautionary approach, it is important that data gaps and uncertainties are dealt with in an appropriate way

- Currently, few examples exist of ERAs linked to pre-determined management decision rules. Further exploration of this is needed.

In this document, we make suggestions on approaches that help to minimise the above risks.

## 2. What methods have been used to undertake ERAs for seabirds?

Four key examples currently exist of the application of ERA to seabirds. These are CCAMLR (summarised in Waugh et al. 2008), WCPFC (Kirby et al. 2009), New Zealand (Sharp 2009, Waugh & Filippi 2009), and ICCAT (Phillips et al. 2007; Phillips & Small 2007). Each uses a different approach, and the reader is referred to the original sources for full details. However, **Box 1** attempts to summarise key aspects.

Although each of the four has used a different approach, all fall broadly within the ERA framework that was developed by the Commonwealth Scientific and Industrial Research Organisation of Australia (CSIRO) in 2002-2006 for the Australian Fisheries Management Authority (Hobday et al. 2007, CSIRO, 2010). This method elaborated on a framework proposed by Sainsbury and Sumaila (2001) of using three progressive stages in an ERA, with assessment moving from one stage to the next depending on the level of risk identified, the data available, and the management response.

Under the CSIRO framework, ERA involves a comprehensive but largely qualitative 'Scale, Intensity, Consequence' analysis at Level 1 (envisaged as stakeholder and expert-led scoring developed in a workshop situation); a more focused and semi-quantitative 'Productivity-Susceptibility' analysis at Level 2 (in which risk score is the square root of Productivity$^2$ + Susceptiblity$^2$); and a highly quantitative model-based analysis at Level 3. The latter is focused on species identified by the previous levels as being at high risk. Importantly, the framework envisages management responses at each level, and a precautionary approach encompassed through assigning high-risk scores to data gaps (Hobday et al. 2007). Within this CSIRO framework, the CCAMLR method is similar to a Level 1 analysis, the WCPFC ERA for seabirds corresponds largely to Level 2, the New Zealand ERA for seabirds corresponds to Level 2-3, and the ICCAT seabird assessment corresponds to Levels 1-3 depending on the species in question. There are additional examples of a 'Level 3' type analysis in the peer-reviewed literature, but these are generally of single species (Baker and Wise 2005, Lewison and Crowder 2003, Rolland et al. 2009, Tuck et al. 2001).

## 3. Issues to consider when undertaking or promoting the use of ERAs in relation to seabirds

Based on an initial review of the existing fisheries-wide ERAs for seabirds, we have identified 10 key issues for consideration. All of these would benefit from further exploration in order to maximise the usefulness of future ERAs, both in terms of improving the process, and ensuring appropriate management responses.

### (i) Defining 'risk' and establishing the burden of proof

> *"When our Society for Risk Analysis was brand new, one of the first things it did was establish a committee to define the word 'risk'. This committee labored for 4 years and then gave up, saying in its final report, that maybe it's better not to define risk. Let each author define it in his own way, only please each should explain clearly what that way is." Kaplan 1997.*

Although difficult, the definition of 'risk' is important as it will determine the burden of proof required of an ERA. In recent years, Regional Fisheries Management Organisations including IOTC, ICCAT and IATTC have passed seabird measures with text along the following lines:

*"When feasible and appropriate, the Scientific Committee should present to the Commission an assessment of the impact of incidental catch of seabirds resulting from the activities of all the vessels fishing for tunas and tuna-like species, in the ICCAT/IOTC/IATTC Area."*

Such text could be interpreted as requiring proof of population-level impacts in order to prompt management decisions. Indeed, absolute measures of impact are considered desirable for fishery managers, much as they aim for robust, quantitative stock assessments in order to assign fishing quotas: an absolute measure of risk or impact enables managers to monitor the effect of different management options (e.g. bycatch mitigation) such that changes in risk scores can be analysed in relation to the management actions implemented (Sharp 2009).

However, there are also reasons to avoid a definition of 'risk' in terms of population impact, including:

(1) The Code of Conduct and UN Fish Stocks Agreement establish the duty to minimize bycatch *per se*
(2) For threatened species, any additional sources of mortality may be detrimental to population levels, even if population-level impacts of fisheries cannot be proven.
(3) Assessment of population-level impacts require large amounts of census, demographic, distribution and/or bycatch data; and the reality is that for the vast majority of species, sufficient data are not available. For many ACAP species, and *Procellaria* petrels in particular, population size and status are unknown. Similarly, many fisheries world-wide have insufficient levels of observer coverage to be able to adequately estimate total, or spatio-temporal variability in bycatch. Such uncertainties will often mean that population level effects cannot be proven. Under a precautionary approach to fisheries management, risk assessment and decision-making should ensure that data-deficient species are not put at risk. In the context of data gaps, it is worth noting that a lack of density-dependence in historical time-series also means that future population levels under scenarios involving reduced bycatch levels are, ultimately, impossible to predict.

A Level 2-type Productivity-Susceptibility Analysis incorporates measures of likely impact on populations, but the outputs are restricted to relative, not absolute, risk. Within the existing examples for ERAs for seabirds, the CCAMLR, WCPFC and ICCAT risk prioritisation (Phillips Small 2007) approaches focus on relative risk, whereas the approach used in New Zealand and in the four detailed case studies undertaken for ICCAT estimated absolute risk.

Bearing these issues in mind, an appropriate aim for an ERA in relation to seabirds may be as follows: *"An assessment of the risk of incidental mortality of seabirds resulting from interactions with fisheries, in particular the risk of incidental mortality of threatened species, or mortality known or likely to be impacting on populations"*

**(ii) Focus on risk prioritisation and productivity-susceptibility analysis**

Although there would clearly be benefits to fishery managers if risk to seabirds could be quantified in absolute terms, given the general inadequacy of available data, the complexity and time required to carry out such an analysis, and the risk that the burden of proof is placed on the ERA outcome before action can be taken, we suggest that priority is given to Level 1 and Level 2 type analyses that focus on the relative risk ranking of species or populations. Level 3 type analyses may provide useful and powerful case studies that support the results from Level 2, but will only be appropriate for the very limited number of species for which sufficient data are available.

**(iii) Which species or populations to include in the ERA?**

The CCAMLR risk assessment restricts itself to albatrosses and petrels, on the basis that these are the species caught in longline and trawl fisheries. In the WCPFC and New Zealand risk assessments, if one species of a genus had been recorded as bycatch then all species in that genus were included. In the New Zealand analysis, a 'vulnerability' measure was then assigned to each species based on analysis of bycatch data, and this was used in the estimation of impact of fisheries. A similar measure of 'vulnerability' will be incorporated in a revised version of the WCPFC seabird ERA, to be finalised in August 2010. In a slightly different approach, the ICCAT risk prioritisation included all species that had been recorded as caught in ICCAT fisheries, and five additional species that were known to suffer bycatch in other regions, the inclusion of which needed to be justified to the ICCAT Sub-Committee on Ecosystems on a case by case basis. Hence, small gadly petrels *Pterodroma* were not included in the ICCAT assessment.

Having an inclusive approach entails more work, but has the advantage of not overlooking rare species which may be caught so infrequently that they are not recorded in observer data. However, the disadvantage is that in practical terms, the problem of missing population data is often more acute for example for small, burrow-nesting species such as gadly petrels. Hence, if adopting the precautionary approach, these species may as a consequence be designated as relatively high risk, when the lack of observed bycatch may indeed reflect the reality. Moreover, fishermen or fishery managers are unlikely to welcome the introduction of mitigation to protect species for which there is no concrete evidence that fisheries pose any threat. It is therefore also important that at some stage the ERA identifies those species most susceptible to bycatch. The most appropriate method for selecting species will reflect the types of fisheries involved: longline fisheries with smaller hooks (e.g. for Ling), are likely to present risks to a broader range of seabird species than those with large hooks (e.g. for tuna). Frigatebirds and boobies were excluded from the ERA conducted by WCPFC for their longline fisheries, but were included in the analysis for purse seine fisheries. Species selection should therefore be guided by expert opinion. This would be assisted by the establishment of a readily-accessible, searchable database that identifies which species have been recorded as caught within different fisheries.

In ICCAT, the unit of assessment was at the level of seabird breeding population (island group or region) rather than entire species. The advantage of this is that different populations may differ in relative risk, in terms of overlap with fisheries, or show a different population trend. Examples of this are Cory's shearwater *Calonectris diomedea* breeding in the Mediteranean compared with the Atlantic, and black-browed albatrosses *Thalassarche melanophris* breeding at different islands groups in the south-west Atlantic. Ideally, methods should be flexible enough to allow inclusion of both species and populations in the ERA, and if data are available to incorporate different parameter values for different populations. The disadvantage of working at the level of breeding population is that it is impossible to assign bycatch or determine relative overlap with fisheries of a particular population without independent information on bird distribution (e.g. from tracking data, ring recoveries or morphology).

**(iv) Data parameters for *productivity* in the PSA**

In this context, the term *productivity* is considered to reflect the natural growth rate of the population in the absence of fisheries mortality. In the ICCAT seabird assessment, productivity was measured by a single ternary variable *(life history strategy*, see Box 1*)*. Initial feedback from some experts was that more than one variable was required; therefore, age at first breeding was added to a revised version (categorised into low, medium, high because of the variability in data quality and necessary substitutions when values were unavailable). However, subsequent discussion at the sub-committee concluded that there was little advantage in doing so, because the initial variable, life history strategy, captured the key differences among species in natural population growth rate.

In the risk assessments for New Zealand and WCPFC, a more quantitative approach was used, and *RMax* was calculated for each species. This created a greater spread of data points across the productivity axis. However, the drawback of using *Rmax* is that reliable data on age of first breeding and adult survival are unavailable for many species, and burrow-nesting seabirds in particular. Hence the use of *Rmax* introduces a false sense of accuracy. In addition, there are very few estimates of adult survival prior to the advent of large-scale industrial fishing, yet the productivity parameter is supposed to reflect mortality in the absence of fishing impacts; hence, the risk of some circularity in the wider analysis. For these reasons, we suggest that a simple measure for productivity (such as that used in ICCAT) provides sufficient discrimination among species in their capacity to buffer impacts of fisheries, and ise a more appropriate reflection of available datas.

**(v) Data parameters for *susceptibility* in the PSA: measures of seabird distribution**
As above, when devising the method for estimating the overlap between seabird distribution and fisheries, there is a need to strike a pragmatic balance between a simplistic "back-of-the-envelope" calculation and a more detailed estimate that could introduce false impressions of accuracy.

Options for methods to estimate seabird distribution include:

- Expert opinion (low, medium, high)
- Range map (assume homogeneous distribution throughout range)
- Use a range map to represent non-breeding distribution and foraging radius to represent breeding distribution
- Refine foraging radius based on simple habitat preference
- Use a combination of range map, foraging radius and tracking data, as available
- Use only tracking data, and limit the assessment to those species for which data are available.
- Develop a model of distribution, including for areas and populations for which data are lacking, based on analysis of habitat preference (from tracking data or at-sea observations) and availability (accessibility), limiting the assessment to a minority of species.

There are clear benefits to attempting to quantify seabird density-distribution and overlap with fisheries. Without this detailed information, it is impossible to identify the areas and seasons of highest overlap with fisheries (and hence highest risk of bycatch).

In the CCAMLR approach, all available distribution data are considered and then used to create the qualitative risk score (1-5) for each of seventeen areas. In the initial ICCAT risk prioritisation, the seabird-fishery overlap variable was simply 'low/medium/high', scored by expert opinion based on knowledge of each species/population, tracking data, and an estimate of the time spent in areas overlapping with ICCAT longline fishing effort. A later stage of the ICCAT seabird assessment attempted calculations of overlap based on an estimate of seabird distribution derived from maps of species range, estimates of foraging radius during breeding, breeding season duration, and estimates of population structure (70% breeding adults, 20% pre-breeders, 10% juveniles), and then calculating overlap with ICCAT longline fishing effort (available at a resolution of 5x5 degree grid squares) (Box 1). However, the difficulty in applying this method led to the conclusion that results were not necessarily more reliable than original 'low/medium/high' score (although they had the advantage of indicating spatial and temporal distribution). The WCPFC and New Zealand analyses also used a mix of range, foraging radii and tracking data in order to estimate seabird distribution, and used similar assumptions of population structure and calculations of overlap (Box 1).

However, the use of range maps, foraging radii and tracking data to estimate seabird distribution raises a number of issues:

- Sufficient tracking data are available for a limited number of species (e.g. 5 of the 40 seabird populations in the ICCAT analysis); for many species the best available distribution data will be a range map and an estimate of foraging radius during the breeding season
- Range maps tend to be for an entire species rather than a population: if the analysis is based on populations, the species range map is likely to be an overestimate
- Foraging pattern usually varies greatly with breeding stage; hence, the use of a single radius is often unrealistic
- Foraging areas are not likely to be circular; however, one partial solution is to exclude particular sectors based on knowledge of habitat preference
- Population age structure is rarely known with any confidence, and likely to vary with species

Many of these issues are difficult to resolve, and clearly warrant further investigation. Nevertheless, it is possible to offer the following general advice:

If using range and foraging radius data, the best available measure of foraging radius is likely to be the mean maximum of all trips. This is preferable to the mean of all fixes, or the absolute maximum in the dataset (the latter is often far greater than average maximum). For species for which no tracking data exist, data substitutions from similar species may be an appropriate solution. Both the ICCAT and WCPFC analyses assumed a homogeneous distribution of birds throughout the range/foraging radius. It would be valuable to test whether this assumption is the most appropriate, or whether it would be better to assume some other density distribution.

It is important for experts to look at the map created for each species and refine this as necessary. It would also be valuable for the ERA to test sensitivity to assumptions (e.g. foraging radius) to assess uncertainty in overlap estimates. Ultimately, the ERA should aim to match the resolution of the bird distribution data to the fishing effort data – if the fishing effort data are at 5x5 degree resolution, then some of the finer scale inaccuracies in estimating bird distribution may be inconsequential. The scale of the fishery may also be important in relation to the appropriateness of the method: in smaller scale fisheries, it may be difficult to find sufficient expert opinion.

**(vi) Data parameters for *susceptibility* in the PSA: calculating overlap with fishing effort**

The ICCAT seabird assessment used three measures of overlap and calculated overlap by month (Box 1), whereas the New Zealand and WCPFC assessments calculated an overlap as annual percent distribution in each 5x5 grid square multiplied by number of hooks per year. A useful general measure of overlap appears to be the percent bird distribution in 5x5 square (or finer resolution) multiplied by the number of longline hooks, where the fishing effort data are based on an average of 3-5 years of recent data. An alternative is for the distribution of each species to be weighted by population size, which will then reflect likely numbers of birds caught. However, the percent distribution provides a better impression of potential impact of fisheries on individual species, the population sizes of which vary greatly.

**(vii) Including seasonality**

Where possible, analyses should take account of seasonal changes in seabird distribution and fishing effort (and hence seasonal changes in seabird-fishery overlap). It may be most appropriate to consider this in terms of year quarters, as in many cases monthly estimates of seabird distribution will introduce a false impression of data accuracy.

**(viii) Role of bycatch data**

Data on seabird bycatch are often sparse and biased in relation to geographical and seasonal spread. As such, they can be used to confirm where bycatch is occurring, but for most fisheries/areas/seasons it is problematic to use seabird bycatch data to indicate species/areas/seasons in which bycatch is not occurring. In the New Zealand ERA, bycatch data were used to calculate *Vulnerability* for each of 11 species groups. This measure was then applied to estimates of seabird-fishery overlap in order to estimate the number of birds killed per year. However, for most fisheries, bycatch data may be better applied in a qualitative assessment of species susceptibility to bycatch in Level 1 of an ERA, but are unlikely to be sufficiently comprehensive for inclusion in Level 2 of the ERA PSA analysis.

**(ix) Appropriate risk scoring for data gaps**

It is important that data scarcity and uncertainty are dealt with appropriately within the ERA. Within a productivity-sensitivity analysis, parameters for which no data exist should be given a high score, equivalent to a high risk category. This is necessary to ensure a precautionary approach to risk, and to avoid bias towards fisheries and areas in which there are seabird bycatch data. There may be cases in which it is considered more appropriate to fill data gaps using a substitute value from a species that is considered comparable. If the latter approach is taken, clearly care is needed not to underestimate risk. In the WCPFC and New Zealand analyses, a high proportion of seabird species were excluded from the analysis on the basis of lack of data, which is clearly undesirable.

**(x) Links to decision making**

Under the CSIRO framework for ERAs, each of the three levels of analysis are linked to management responses. Within CCAMLR, each of the risk scores are linked to pre-determined management decisions. However, within the ICCAT and WCPFC risk assessments, the management response was not predicated by the ERA outputs. Before an ERA is undertaken, it would be beneficial to plan in advance how the outputs of the risk assessment will be linked to decision-making. We need to define, if possible, what kind of recommendations are 'appropriate' following a Level 2 (semi-quantitative) type of analysis, and the limitations in terms of inference. . For RFMOs, there are clear benefits to having the ERA requested and overseen by the relevant sub-committee or working group, in order to ensure buy-in to the process. This does not overcome the problem that any decisions or recommendations by a specialist working group will not necessarily result in management decisions at higher (e.g. Commission) level.

## 4. Conclusions

There are a number of benefits that can be derived from undertaking Ecological Risk Assessments for seabirds, including refined understanding of the species/areas/seasons in which seabirds are at risk, and that ERAs may be a means for bycatch to be ‘embedded’ centrally in fishery management decisions, rather than treated as a peripheral issue. However, we identify several issues for further consideration, including several relating to methodology, the importance of dealing with data gaps in a precautionary manner, the need to balance the detail and aims of the analysis with the data available, the benefits of establishing links between ERA outputs and management decisions before undertaking the ERA, and caution to avoid undermining the duty of fishery managers to minimise bycatch per se.

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**Box 1. A summary of four examples of the application of ERA to seabirds. The reader is referred to the original sources for full details.**

**CCAMLR (Waugh et al. 2008)**
The Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) was a pioneer in incorporating the ecosystem and precautionary approaches into fisheries management, and in developing risk assessments for seabirds in fisheries: the first risk assessments for seabirds were carried out in 1997. Within CCAMLR, it was decided that adopting an approach of 'sustainable catch' of seabirds was neither appropriate nor possible given the requirements of such an approach for data on seabird distribution, ecology and demography, together with an understanding of all sources of mortality. To do this at a species level for such a wide geographical area was not considered feasible, and the aim was therefore to identify the relative risk of capture of seabirds in fishing operations. The CCAMLR risk assessment approach uses areas as units of analysis, not species. Each year, each of seventeen areas is assigned a risk rating of 1-5, based on expert-led consideration of seabird distribution within each area (using data from satellite tracking, at-sea surveys and band returns). The assessment is restricted to albatross and petrel species, on the basis of these being known to be the species vulnerable to incidental catch. CCAMLR's Working Group on Incidental Mortality Associated with Fishing (IMAF) then considers the risk ratings in relation to seabird bycatch data (which are available from high levels of observer coverage). IMAF makes recommendations on the Conservation Measures, which are applied by risk rating.

**WCPFC (Kirby et al. 2009)**
In 2006, WCPFC established a program of multi-taxa ecological risk assessment. In the first year, results for seabirds were presented alongside other taxa. Later, the seabird risk assessment was developed separately, and will be finalised in 2010. The seabird ERA focused on a productivity-sensitivity analysis, corresponding to Level 2 under the CSIRO framework. Seabird species were included in the analysis if any of the family or genus had been recorded as bycatch. However, 192 species were subsequently excluded on the basis of (1) excluding storm petrels and diving petrels as they were considered unlikely to be caught, (2) excluding species for which no distribution data were available. In total, 74 species of albatross, petrel and shearwater were considered, of which 23 had been recorded as captured. Rmax was selected as the measure for productivity, derived from age at first breeding and adult survival. Since data were missing for many species, substitutions were made from similar species. Seabird distribution was estimated from range maps, foraging radii and remote tracking data. Where there were tracking data, 60% birds were assumed to be in a non-breeding distribution, and 40% in a breeding distribution to produce a map to summarise distribution over the year (the analysis did not attempt to calculate seasonal variations in overlap). Where range maps and foraging radii were used, 50% of the population was assumed to be distributed evenly in the range, corresponding to non-breeding birds, and 50% was assumed to be distributed evenly within the foraging radius, corresponding to breeding birds during the breeding season. Where foraging radii data weren't available, an estimate of radius was made using species genus and weight. Susceptibility was calculated as % distribution x longline fishing effort per 5x5 grid square, with fishing effort averaged across six years (2002-2007). By also calculating risk scores for each 5x5 grid square, maps were created to show the areas of highest risk of species level effects.

**ICCAT (Phillips & Small 2008, Tuck refs..)**
In the ICCAT seabird assessment, a six stage methodology was developed: (i) identify seabird species most at risk from fishing in the ICCAT Convention Area, (ii) collate available data on at-sea distribution of these species, (iii) analyze the spatial and temporal overlap between species distribution and ICCAT longline fishing effort, (iv) review existing bycatch rate estimates for ICCAT longline fisheries, (v) estimate total annual seabird bycatch (number of birds) in the ICCAT Convention Area, (vi) assess the likely impact of this bycatch on seabird populations. Stage 1 (Phillips & Small 2007), which corresponded to a Level 1 and Level 2 type analysis, used a mix of populations and species as the unit of assessment (68 populations representing 41 species), based on these species having been recorded as bycatch within ICCAT longline fisheries, or, in the case of 5 species, having been caught in similar fisheries elsewhere. The inclusion of the 5 additional species needed to be justified on a case by case basis. The risk prioritisation used life history strategy (1=multiple eggs, 2=single egg, 3=biennial) as the measure for productivity, and the average of degree of overlap with fisheries (low, medium, high) and behavioural susceptibility to bycatch (low, medium, high) as the measure for susceptibility, both based on expert opinion.

**Box 1 continued.**

Under stage (iii) of the assessment (calculation of overlap with fisheries), for 4 populations, sufficient tracking data were available to create detailed monthly distribution maps. A 'simpler' method was used to estimate distribution of all species, based on range maps (to estimate non-breeding distribution), an estimate of foraging radius during breeding, breeding season duration, and an assumed population structure of 70% breeding adults, 20% pre-breeders and 10% juveniles. Juveniles assumed to be homogeneously distributed within range map throughout the year, breeding adults and immatures assumed to be distributed homogeneously within the foraging range during the breeding season, and within the range map in the non-breeding season. Three calculations of overlap were used: (1) % distribution within area of ICCAT longline fishing effort, by month, (2) % distribution in each 5x5 grid square by month, multiplied by number of hooks, and (3) % fishing effort within seabird distribution, by month. While stage (iii) was valuable in that it enabled identification of areas and seasons of likely high overlap between fishing effort and seabirds, the number of assumptions that had to be adopted meant that the results were not necessarily considered more robust than the simplistic 'low, medium, high' estimates of overlap in stage (i). Stage (v) of the assessment attempted to estimate the total number of seabirds being caught per year in ICCAT longline fisheries. Stage (vi) developed population models for 4 populations for which detailed demographic and distribution data existed, seeking to identify impacts of ICCAT longline fisheries on these populations.

**New Zealand method (Sharp 2009, Waugh & Filippi 2009)**
The New Zealand ERA for seabirds differs from the others described above in that it estimated absolute risk for all the species under consideration. An absolute- as opposed to relative-risk score was considered beneficial in terms of enabling managers to monitor the performance of different management options (e.g. bycatch mitigation) in relation to changing risk score. Of the 120 seabirds species found in New Zealand waters, c. 60 species excluded due to lack of data on distribution (though most of these were Pterodromas and gulls and thought unlikely to interact with fisheries). Sixty-three species were included in the analysis with, although the final analysis reported on the 39 species that interact with longline and trawl fisheries, the remainder being excluded due to lack of data in the relevant fisheries (e.g. pot and gillnet). The assessment looked at risk and impact of fisheries with reference to the *New Zealand population* of the species in question.  For each species, an estimate was made of the number of birds killed per year, based on seabird distribution x fishing effort x *Vulnerability*, where the vulnerability criterion was calculated on the basis of observer data and seabird densities for each of 11 groups: 1) gannets; 2) gulls and terns; 3) large albatrosses; 4) large *Pterodroma* petrels; 5) mollymawks & small albatrosses; 6) other species; 7) penguins; 8) *Procellaria* petrels; 9) shags; 10) shearwaters; 11) small shearwaters.. For seabird distribution, only a range map was available for half the species.

Impact ratios were then calculated for each species, on the basis of the estimated number of birds killed in New Zealand fisheries, divided by an index of population productivity. The latter was calculated as 0.5* Rmax * F (where F is between 0-1, based on IUCN Red List status), in an approach analogous Potential Biological Removal (PBR).

One of the benefits of the above approach to calculate absolute risk is that it can respond to changes in seabird catch in different fisheries through time. However, problems were recognised in relation to data availability: many species were excluded from the analysis, and frequently data substitutions were necessary. The authors felt that the PBR index was best used to indicate the relative vulnerability of each of the species in the study to fisheries effects, and was unlikely to be an accurate measure of the number of individuals that can be removed from a population before population effects would ensue.