PRELIMINARY IDENTIFICATION OF MINIMUM ELEMENTS TO REVIEW THE EFFECTIVENESS OF SEABIRD BY-CATCH MITIGATION REGULATIONS IN TUNA RFMOs

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SUMMARY

The five tuna regional fishery management organizations (RFMOs) require their longline vessels to use seabird by-catch mitigation measures in areas overlapping with albatrosses, and plan to review the effectiveness of these measures. However, methodologies for undertaking such reviews haven't been defined. This paper summarizes views of an ACAP (Agreement on the Conservation of Albatrosses and Petrels) intersessional group to discuss what minimum elements may be reviewed. Four elements are recommended to monitor the seabird conservation measures adopted by ICCAT [Rec. 11-09]:

1. The extent to which the tuna RFMO seabird conservation and management measure(s) reflects 'best practice' for pelagic longline fisheries, and has appropriate spatial, temporal and vessel application.
2. The availability and quality of data available for review.
3. The degree of implementation by vessels (compliance).
4. Analysis and monitoring of seabird by-catch levels over time, including
    a) Reported by-catch rates (birds/1000 hooks)
    b) Total number of birds killed per tuna RFMO per year
The paper recommends adoption of harmonized review methods across tuna RFMOs, and ongoing efforts to harmonize tuna RFMO by-catch data collection, reporting and storage mechanisms.

RÉSUMÉ

Les cinq organisations régionales de gestion des pêches thonières (ORGP thonières) exigent que leurs palangriers appliquent des mesures d'atténuation des prises accessoires d'oiseaux de mer dans les zones de chevauchement avec les albatros, et ont l'intention d'étudier l'efficacité de ces mesures. Ceci dit, les méthodologies de réalisation de ces vérifications n'ont pas encore été définies. Ce document résume les conclusions d'un groupe intersession de l'ACAP (Accord sur la conservation des albatros et des pétrels) dans le but de discuter des éléments minimum à vérifier. On a recommandé quatre éléments pour effectuer le suivi des mesures de conservation des oiseaux de mer adoptées par l'ICCAT (Rec. 11-09) :

1. La mesure dans laquelle les mesures de conservation et de gestion des oiseaux de mer des ORGP thonières reflètent les "meilleures pratiques" pour les pêcheries palangrières pélagiques et ont une application adéquate au niveau spatio-temporel et des navires.
2. La disponibilité et qualité des données disponibles pour la vérification.
3. Le niveau de mise en œuvre des navires (application).
4. L'analyse et le suivi des niveaux de prise accessoire des oiseaux de mer au cours du temps, incluant :
    a) taux de prise accessoire déclarée (oiseaux/1000 hameçons) et
    b) nombre total d'oiseaux morts par ORGP thonière par année.
Le document recommande l'adoption de méthodes harmonisées de vérification entre les ORGP thonières et la poursuite des efforts actuellement déployés en vue d'harmoniser les mécanismes de collecte, de déclaration et de stockage de données sur les prises accessoires par les ORGP thonières.

RESUMEN

Las cinco Organizaciones regionales de ordenación pesquera de túnidos (OROP) requieren que sus palangreros utilicen medidas de mitigación de la captura fortuita de aves marinas en las zonas en que se solapan con los albatros y prevén examinar la eficacia de dichas medidas. Sin embargo, no se han definido aún las metodologías para llevar a cabo dichas revisiones. Este documento resume las opiniones preliminares de un grupo intersesiones de ACAP (Acuerdo sobre la Conservación de albatros y petreles) que se ha establecido para debatir cuales deben ser los elementos mínimos para dicha revisión. Se recomiendan cuatro elementos para hacer un seguimiento de las medidas de conservación de aves marinas adoptadas por ICCAT [Rec. 11-09]:

1. La medida en la que las medidas de conservación y ordenación de aves marinas de las OROP de túnidos reflejan las "mejores prácticas" para las pesquerías de palangre pelágico, y cuentan con una adecuada aplicación espacial, temporal y de los buques.
2. La disponibilidad y cualidad de los datos disponibles para la revisión.
3. El grado de implementación por parte de los buques (cumplimiento).
4. Análisis y seguimiento de los niveles de captura fortuita de aves marinas a lo largo del tiempo, lo que incluye:
  a) Tasas de captura fortuita declaradas (aves por 1000 anzuelos)
  b) Número total de aves muertas por OROP de túnidos por año
El documento recomienda la adopción de métodos de revisión armonizados entre las OROP de túnidos, además de continuar los esfuerzos en curso para armonizar los mecanismos de recopilación, comunicación y almacenamiento de datos de captura fortuita las OROP de túnidos.

KEYWORDS

By-catch, Seabirds, Longline, Mitigation, Monitoring

1. Background

All five tuna commissions have established seabird by-catch mitigation requirements for longline vessels in most areas overlapping with the distribution of albatrosses and petrels, although with some variation in the specific mitigation measures required (**Table 1**). All seabird by-catch conservation and management measures adopted by tuna RFMOs have provisions for reviewing the effectiveness of these measures. In ICCAT and IOTC there are specific commitments to reviews in 2015 and 2016, respectively, whereas in the others there are commitments to review regularly, but with unspecified time frames (**Table 1**). The methods or criteria for such reviews have not yet been formally established.

The review of ICCAT's seabird by-catch mitigation Recommendation (Rec. 11-09) is on the agenda for the 2014 meeting of the ICCAT Sub-Committee on Ecosystems (Agenda item 8). The ICCAT Sub-Committee on Ecosystems had on its July 2012 meeting agenda the following item '*Define the strategy to evaluate the efficacy of the seabird by-catch mitigation measures defined under Rec. [11-09]*', but a lack of proposed methodology meant that this agenda item was not addressed at this time. In April 2013, at the seventh meeting of the Advisory Committee of the Agreement for the Conservation of Albatrosses and Petrels, an intersessional group was formed to discuss what methods might be most appropriate, and to identify minimum elements that it believes should be considered in reviewing and monitoring the effectiveness of seabird by-catch mitigation measures in tuna RFMOs (ACAP 2013). The ACAP intersessional group prepared a paper on this work that was presented to the August 2013 meeting of the Commission for the Conservation of Southern Bluefin Tuna (CCSBT) Ecologically Related Species Working Group (ERSWG). On the basis of the paper, and discussions at the ERSWG meeting, a Technical Group has been established and a workshop has been organised for November 2014 to progress this work and to provide advice to ERSWG on optimal approaches for measuring and monitoring the effectiveness of seabird by-catch mitigation measures in Southern bluefin tuna longline fisheries.

The seabird conservation and management measures adopted by tuna RFMOs are currently largely focused on addressing the seabird by-catch issue in relation to albatrosses and petrels, and this document therefore focuses on these species, but the elements presented below are intended to be applicable for all seabird species affected by by-catch in ICCAT fisheries.

2. Minimum elements for reviews of seabird conservation and management measures in tuna RFMOs

Below is a preliminary summary on views collected during ACAP intersessional discussion. These discussions have also drawn from previous papers submitted to ACAP (including Wolfaardt 2011, Anderson and Small 2012, Small 2013, Turner & Papworth 2013). At the ACAP Advisory Committee meeting in April 2013, the group recognized that methods proposed must take into account the availability of data (quantity of data and level of detail), as well as realistic capacity of tuna RFMOs to analyze and review data. It is also important that RFMOs have effective formal mechanisms to monitor and ensure implementation of the required by-catch mitigation measures. It is recommended that the following four elements be part of monitoring the effectiveness of tuna RFMO seabird measures.

2.1 Content of tuna RFMO seabird conservation measures

This element is most closely linked to the process of review that is already ongoing in the ecosystem and by-catch working groups of most tuna RFMOs, has been underway for several years, and has led to the establishment of the existing tuna RFMO seabird by-catch conservation measures. However, it is important to maintain (and formalize where not yet formalized) the existing process by which the tuna RFMOs regularly consider updated information on by-catch mitigation best practice. We recommend that this must include:

- Assessment of the extent to which the current tuna RFMO seabird conservation and management measures reflect best practice (by-catch mitigation requirements and their technical specifications), including the advice developed and updated by the ACAP Seabird By-catch Working Group.
- Assessment of the spatial and temporal application of the by-catch mitigation requirements.
- Assessment of the range of vessels to which the by-catch mitigation requirements applies.
- Assessment of new scientific work to test and develop seabird by-catch mitigation measures. This could be achieved by making use of advice provided by scientific review groups, such as the ACAP Seabird By-catch Working Group.

Currently, each tuna RFMO conducts this review independently of the other tuna RFMOs, but other options could be considered, such as the use of the joint tuna by-catch expert group, or use of the best practice advice that is developed by the ACAP Seabird By-catch Working Group.

An additional factor that could be considered within 'best practice' is the extent to which a by-catch mitigation requirement can be easily monitored for compliance by flag or port states, and the results reported to the RFMO for inclusion in their review process.

2.2 Data collected and reported by tuna RFMO longline fleets

The results and usefulness of any review will depend on the quantity and quality of data available. The data collection and reporting requirements therefore need to be clearly outlined and monitored. Data availability will also determine the methods that can be used for a review.

2.2.1 By-catch data collection

All tuna RFMOs have established requirements for their longline fleets to have at least 5% observer coverage, with CCSBT having a recommendation of 10% observer coverage since 2001. CCSBT, IOTC and WCPFC have established data collection standards for their longline observer programs and the process is underway in IATTC. There remains a need for harmonization of minimum observer data standards for longline vessels across tuna RFMOs, and ICCAT has offered to lead this (ICCAT 2013). Comparisons of existing tuna RFMO observer data collection methods have been undertaken in, for example, Wolfaardt 2011, Anderson and Small 2012, Turner and Papworth 2013.

Minimum observer data collection standards for by-catch have been discussed in a variety of fora, with ACAP recommendations for tuna RFMOs in Wolfaardt (2011). These suggest that the key elements that should be assessed in relation to availability of data include:

- Quantity of observer coverage (% total effort observed), and its spatial and temporal representivity.
- The proportion of national reports (or % total effort these fleet represent) that report the number of birds caught as by-catch, recorded to species level if possible.
- Data on the use of mitigation measures, and on other factors that affect by-catch rates.

In addition, it is widely recognised that 5% coverage is unlikely to be enough to accurately monitor rare catch events such as those for seabird and turtles, and that the current 5% target is the result of a pragmatic approach to increase observer coverage from current very low levels. However, attention needs to be given to how to monitor by-catch when observer coverage rates remain low, and how coverage levels could be increased to 20% and above. This may be achieved, for example, by supplementing observer data collection with the use of electronic monitoring. Compliance procedures to enforce data collection standards and reporting should also be elements of the review.

2.2.2 By-catch and fishing effort data reporting

Given the variable nature of by-catch and fishing effort, both in space and time, by-catch and fishing effort data collected through observer programmes, will need to be reported in a spatially and temporally stratified manner in order for meaningful analysis and comparisons of seabird by-catch rates to be conducted. Seabird work to date within the tuna RFMOs has mostly used a resolution of analysis of 5x5 degrees and year quarters. This reflects striking a balance between the need to incorporate spatial and temporal variability in seabird distribution and by-catch rates, and the realities of the amount and resolution of data available (by-catch data, fishing effort data and seabird distribution data). Work undertaken by ICCAT and IOTC Secretariats to fill effort data gaps has been important in facilitating seabird risk assessments to date. Reporting is needed on all elements identified in the section above.

Currently, WCPFC requires member states to submit raw observer data to the WCPFC Secretariat (WCPFC CMM 07-01), and IOTC also has agreed detailed reporting protocols, which include spatial (5x5°) and temporal stratification of observer data (IOTC Resolution 11-04). In 2012, CCSBT refined its reporting requirements for national reports submitted to the Ecologically Related Species Working Group (CCSBT 2012). ICCAT and IATTC have not yet agreed their reporting requirements, although these are under discussion. The CCSBT ERSWG and the ICCAT Sub-Committee on Ecosystems have noted that it would be highly beneficial for reporting requirements to be harmonized across the tuna commissions in order to be able to assess cumulative impacts on non-target species (CCSBT 2012, Anon. 2013). The IOTC has agreed data confidentiality and data sharing provisions which could be useful in relation to the other tuna RFMOs.

2.3 Degree of implementation

Measurement of the degree of implementation of by-catch mitigation measures at (i) the fleet level and (ii) set by set level is central to understanding whether seabird conservation measures have been effective. However, methods to monitor compliance with by-catch mitigation measure requirements have not yet been substantially discussed within tuna RFMOs' compliance committees.

In order to assess the degree of implementation, the following four elements could be measured:

- The proportion of sets in which the required by-catch mitigation measures were used, when fishing in the specified areas of application (self reporting via log books). The flag states would report this proportion to the Ecosystem and By-catch working group of the relevant tuna RFMO.
- The proportion of sets in which the required by-catch mitigation measures were used, when fishing in the specified areas of application, verified by an independent source. This independent source could be (i) data recorded by observers, though recognizing that required observer coverage is only 5% (ii) port inspection, though recognizing presence of mitigation measure devices in port does not necessitate that they were used on all required sets (iii) data reported to the flag state from vessel VMS or electronic monitoring data to establish whether mitigation measures were used (for example, night setting, bird scaring lines or line weights).

- The proportion of vessels (or captains/crew) that have received education and outreach on by-catch mitigation within the last 1 or 2 years. This information could be provided as part of the annual reporting requirements.
- Similarly, the extent to which the observers are receiving training on recording by-catch (the key training elements in seabird by-catch monitoring could be defined).

Such systems and arrangements for reporting the use of mitigation measures are not yet widely in place. ICCAT has not yet established minimum requirements for reporting of observer data. Therefore data for the 2015 ICCAT seabird by-catch review may be limited. However, CCSBT's new Template for the Annual Report to the Ecologically Related Species Working Group, agreed at the ERSWG 9 meeting in 2012, includes the request for member states to report data on compliance with seabird by-catch mitigation requirements (CCSBT 2012 Attachment 4). Both the IOTC and WCPFC regional observer program data collection forms also require information on the seabird by-catch mitigation measures used in each set (including night setting, line weights, bird scaring line) (IOTC 2013, WCPFC 2013a). In addition, WCPFC requires member states to report data in logbooks on start time of each set (WCPFC 2012), and the WCPFC seabird measure has a general requirement for member states to report on mitigation used (paragraph 9, WCPFC CMM 2012-07), although there is not a specific part of the Annual Report template that addresses this (WCPFC 2013b). As noted above, ICCAT is currently in the process of developing their longline observer program data collection and reporting protocols. However, both Rec 10-10 and 11-09 require observers to record the use of by-catch mitigation measures, and details regarding the fishing operations. It is necessary to translate these requirements into reporting templates and protocols.

Across the tuna RFMOs, work is ongoing to elaborate monitoring, control and surveillance systems, with developments across all tuna RFMO Compliance Committees. If by-catch conservation measures are to be effective, and if their effectiveness is to be monitored, the assessment of compliance with non-target species requirements (specifically relating to by-catch mitigation) will need to form part of the work of these Compliance Committees. This should include when port inspection, at-sea inspection, electronic monitoring or observer program protocols are developed.

2.4 Assessment and monitoring of seabird by-catch

There are a range of methods that might be used to monitor levels of tuna RFMO seabird by-catch, or seabird by-catch impacts, ranging from simple to more complex. Examples of possible approaches are shown in **Table 2.**

A decision on the most appropriate method will be guided by factors such as data availability, available capacity and resources to undertake the review and review objectives. The influence of data availability on analytical methods was discussed at the ACAP Seabird By-catch Working Group in April 2012, and a summary is provided in **Table 3.**

Based on the level of data that are likely to be available to tuna RFMOs in the near future, we recommend that the most feasible approaches to monitor the effect of tuna RFMO seabird conservation measures on seabird by-catch rates/levels/impacts are:

- Measuring seabird by-catch rates (birds per 1000 hooks), tracked over time, with information on spatial and temporal distribution of data (see recommendation in 2.2 above regarding spatial and temporal resolution of reported data), and a measure of robustness of the estimates.
- Estimating the total number of birds killed per tuna RFMO per year, tracked over time, and including measures of error. On the basis of the recommendation in 2.2 above regarding the resolution of the data that should be reported (5x5 grid squares and per quarter), it will be possible to provide this information at a finer scale (e.g. per fleet, or areas).

By-catch rates (birds per 1000 hooks) are included because these should become readily available from tuna RFMO observer programs. It will be important to monitor by-catch rates adjusted for spatial and temporal stratification (as outlined in 2.2), and for estimates of by-catch to include error estimates, with information on how the by-catch rates were estimated.

Because a reduction in by-catch rates does not necessarily mean that the total number of birds killed is reduced (for example if the total fishing effort in areas overlapping with albatrosses and petrels increases), and vica versa (a reduction in the total number of birds killed does not necessarily imply a reduction in by-catch rates) there is also a need to monitor the total number of birds estimated killed per year, which can be tracked over time. A request for WCPFC and IOTC Scientific Committees to estimate total number of seabirds killed per year is included in the current WCPFC seabird measure (CMM 2012-07), and was in IOTC Resolution 10-06, although is not in the current IOTC Resolution 12-06.

Ecological Risk Assessments (ERAs) have been used increasingly to assess the impacts of fishing activities on seabirds (and other taxa) (e.g. Tuck *et al.* 2011; Jiménez *et al.* 2012; Waugh *et al.* 2012; Richard and Abraham 2013; Richard *et al.* 2013; Small *et al.* 2013). Indeed, the previous ICCAT seabird assessment adopted an ERA framework (Tuck *et al.* 2011). As with other methods, ERAs range from basic (largely qualitative) to very complex, highly quantitative, approaches. It is also possible, as was the case in the ICCAT seabird assessment, to use a multilevel framework, in which the species considered of lower risk are subject to lower level assessment, while the more intensive analyses are limited to the higher risk species. In very simple terms, data on seabird distribution and fishing effort are combined with a species' vulnerability to by-catch, where *vulnerability* is derived from a detailed observer data set in which by-catch rates by species are compared to estimates of their distribution. By weighting seabird distribution by population size, an estimate of the number of birds caught can be developed, and this can be compared to estimates of Potential Biological Removal, if the necessary seabird demographic data are available. Given the data requirements for this type of analysis, it may not the most feasible monitoring tool at the RFMO level.

More sophisticated methods of monitoring by-catch levels and the consequent population-level or conservation impacts, such as the inclusion of population modeling, may be possible for some species or colonies. However, several factors restrict the circumstances in which population modeling is possible: (i) few observer programs are currently able to identify seabird by-catch to species level (ii) population models to date have focused on a colony rather than an entire population, but by-catch cannot yet be attributed to colony in most cases (iii) the time lag between by-catch reductions and population/demographic data response makes it more difficult to determine impacts (iv) tuna fleets are just one part of seabird by-catch (v) other factors affecting demographic parameters, including climate change, will make it more difficult to detect an effect. However, population modeling can contribute important additional insights into understanding impacts of by-catch, including identification of (i) life-history or breeding stages most vulnerable to fishing impacts (by fleet/area/time) (ii) whether current levels of predicted by-catch are sustainable (iii) identifying other measures that may be effective e.g. spatial management. In addition, some seabird species may be more amenable to population modeling, for example through being more spatially restricted, which would allow more confident assignment of provenance of each bycaught bird. Further, it may be necessary that a review of effectiveness of seabird by-catch mitigation measure includes some evaluation of population level impacts.

Use of seabird population status (e.g. species' population trend) as an indicator of effectiveness of tuna RFMO seabird measures is also complicated because of factors such as (i) assumption that tuna fleets have an impact that is large relative to other fleets, i.e. sufficiently large to detect an impact (ii) the impact of other fleets and non-fishing factors on the population (iii) time lag between management measure effectiveness and demographic response (iv) the difficulty in assigning management effectiveness in one area to specific colonies. However, improved population trend and status is clearly an ultimate objective of seabird by-catch mitigation efforts.

3. Harmonization of review across tuna RFMOs

Given that many albatross and petrel species migrate between the areas of more than one tuna RFMO, having a harmonized tuna RFMO system for monitoring overall seabird by-catch and conservation measure effectiveness is necessary in order that cumulative impacts on each species can be assessed. In order to undertake a wider-scale assessment of by-catch and thus consider the cumulative impacts, data collection and reporting protocols also need to be standardised across tuna RFMOs.

In addition, assessment of the effectiveness of the tuna RFMO seabird measures would benefit from a centralised approach to by-catch data management at the tuna RFMO level (or even joint tuna RFMO level). It could provide a useful gap analysis in terms of low levels of observer coverage and/or data accessibility. This would require a centralised database, managed by one or more RFMO Secretariats.

4. Conclusion

Given that all five tuna RFMOs have now established seabird by-catch mitigation requirements, it is a useful time to consider how the effectiveness of these measures might best be monitored, or at least to identify minimum essential elements that reviews should include, and to consider the data collection and reporting that would be needed in order to facilitate this analysis. We recommend four elements that we consider important to include in such reviews. In addition, if review methods were harmonized across the tuna RFMOs, this would facilitate seabird by-catch comparisons between tuna RFMOs. For those seabird species that are distributed across multiple tuna RFMO areas, this is necessary in order to assess cumulative impacts on these species.

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Table 1. Currently active tuna RFMO seabird conservation and management measures and plans to review the effectiveness of these measures.

Tuna RFMO seabird measure	Seabird by-catch mitigation requirements	Intent to review
ICCAT Recommendation 11-09	Use at least two of the following mitigation measures: night setting with minimum deck lighting, bird-scaring lines, or line weighting in area south of 25˚S with minimum technical standards. Use bird-scaring lines in area between 20˚S to 25˚S (swordfish vessels can set lines at night and use line weights of >=60g within 3 m of the hook). Vessels in the Mediterranean encouraged to use mitigation measures on voluntary basis.	Paragraph 8. In 2015, the SCRS shall conduct another fishery impact assessment to evaluate the efficacy of these mitigation measures. Based on this fishery impact assessment, the SCRS shall make appropriate recommendations, if necessary, to the Commission on any modifications.
IOTC Resolution 12-06	Use at least two of the following measures: night setting with minimum deck lighting, bird-scaring lines (tori lines) or line weighting in the area south of 25˚S with the minimum technical standards	Paragraph 6. The Scientific Committee, based notably on the work of the WPEB and information from CPCs, will analyse the impact of this Resolution on seabird by-catch no later than for the 2016 meeting of the Commission. It shall advise the Commission on any modifications that are required, based on experience to date of the operation of the Resolution and/or further international studies, research or advice on best practice on the issue, in order to make the Resolution more effective
WCPFC CMM 2012-07	Use two of weighted branch lines, night setting or tori lines, in the area south of 30˚S; use at least two of bird streamer line, line weights, night setting, side setting with a bird curtain, blue-dyed bait, line shooter, offal management, including at least one of the first four of these, in the area north of 23˚N. CCMs are required to report annually on mitigation used, by-catch rates and total number of birds killed; vessels encouraged to undertake research and ensure safe handling and release;	Paragraph 6. The SC and TCC will annually review any new information on new or existing mitigation measures or on seabird interactions from observer or other monitoring programmes. Where necessary, an updated suite of mitigation measures, specifications for mitigation measures, or recommendations for areas of application will then be provided to the Commission. Paragraph 8: The intersessional working group for the regional observer programme will take into account the need to obtain detailed information on seabird interactions to allow analysis of the effects of fisheries on seabirds and evaluation of the effectiveness of by-catch mitigation measures.
IATTC Resolution C-11-08	Use at least two of the following mitigation measures: bird scaring line, line weights, night setting, side setting with a bird curtain, blue-dyed bait, line shooter, offal management, underwater setting chute, including at least one the first four of these, in the area north of 23˚N and south of 30˚S, plus the area bounded by the coastline at 2˚N, west to 2˚N-95˚W, south to 15˚S-95˚W, east to 15˚S-85˚W, and south to 30˚S, with minimum technical standards.	Paragraph 11: The effectiveness of this resolution to reduce seabird by-catch in the EPO, including the mitigation measures in Table 1, the area of application, and the minimum technical specifications adopted pursuant to this resolution, shall be subject to review and possible modification, taking into account the scientific advice from the Working Group on By-catch, the SAC, and the IATTC scientific staff.
CCSBT ERS Recommendation 2011	Comply with all IOTC, WCPFC and ICCAT measures; report data on interactions to the Commission which is authorized to exchange it with other tuna RFMOs	Paragraph 6: The Extended Commission will review the operation of this Recommendation with a view to enhancing the protection of ecologically related species from the impacts of fishing for southern bluefin tuna.

Table 2. Examples of methods that could be used to measure seabird by-catch rates, levels or impacts over time in tuna RFMOs as part of a review of the effectiveness of the tuna RFMO seabird conservation measures.

Method	Description	Examples of use
Track reported seabird by-catch rates	Tuna RFMOs could monitor reported seabird by-catch rates (birds caught/1000 hooks) over time, with expectations that rates would decrease as mitigation measures are implemented, and with the potential to make comparisons between different fleets. However, this approach would need to be able to account of non-reporting fleets, as well as account for bias that may occur from data reported from low or non-representative observer coverage. In addition, given that by-catch rates vary spatially and temporally, it may be that the by-catch rate needs to be standardised to take into account variations in fishing effort distribution. However, currently, ICCAT and IATTC do not require fleets to report their raw or spatially and temporally stratified observer data to RFMO Secretariats, so standardisation would not be feasible. IOTC and WCPFC do have requirements to submit stratified observer data, but very few data have been submitted to date. An additional factor is that impact on seabirds could increase if fishing effort goes up, even if by-catch rates go down: this issue can be overcome by also tracking fishing effort. In some cases decreases/increases in by-catch rates could reflect declining/increasing populations, although this will be a problem for a number of these methods.	Widespread
Estimate number of birds killed per year	Use best available seabird by-catch rate data together with estimates of fishing effort in order to estimate the number of birds killed per year. Spatial and temporal stratification can be used (e.g. best available by-catch rate for each 5x5 degree square and year quarter, multiplied by fishing effort). By-catch rates may be estimated for non-reporting fleets using the nearest by-catch rate estimate. Estimates of the number of each species killed could be made if reliable species level data were available. The 2012 meeting of the CCSBT Ecologically Related Species Working Group recommended that data be reported in such a stratified way that CCSBT could estimate total seabird mortality, and that such reporting be harmonized with other tuna RFMOs as far as possible (paras 32 and 56, CCSBT 2012).	Klaer 2012, Yeh *et al.* 2013.
Risk assessment	Estimate and monitor by-catch risk using data on seabird distribution and fishing effort combined with a measure of a species' vulnerability to by-catch, where *vulnerability* is derived from a detailed observer data set in which by-catch rates by species are compared to estimated species distribution. An estimate of the number of birds caught can be created by weighting seabird distribution by population size, and this can be compared to estimates of Potential Biological Removal, if demographic parameters are available. *Vulnerability* will be affected by the degree of implementation of seabird by-catch mitigation measures, therefore to track the effectiveness of tuna RFMO seabird measures, the *vulnerability* measure (or at least degree of by-catch mitigation measure implementation) would need to be tracked for each fleet. Given the data requirements for this type of analysis, this may not be a feasible monitoring tool at the RFMO level.	Waugh *et al.* 2012 Richard and Abraham 2013 Richard *et al.* 2013
Population modelling	For those species for which sufficient demographic and population data are available, population models can be constructed which model impact of tuna pelagic longline fisheries at a colony or population level. However, given levels of background noise in such analyses, and impacts of non-tuna fleets, it may not be possible to use this to monitor impacts of seabird by-catch mitigation measures in the tuna pelagic longline fleets.	Tuck *et al.* 2011
Population status	Monitor population trends and responses of relevant albatross and petrel colonies. Colonies will be impacted by factors other than tuna pelagic longline fleets.	

Table 3. Types of approaches possible in assessing the impact of fisheries on seabird by-catch depending on the spatial/temporal resolution of the data available. The purpose of this information is to provide an indication of how the available data influence the type of assessments that can be carried out (Annex 8, ACAP 2013).

Type 1: Fleet footprint data only	- Summaries of change in the fishing footprint over time. - Low quality risk assessment (possible only if seabird distribution information is available)
Type 2: Fleet wide effort data only	- Annual summary of fishery effort. - Only provides a good indicator of trends in fishing effort if the fishery is stable by season and area through time (not normally the case). Determining the impact on seabirds requires data on seabird by-catch (and distribution of that by-catch)
Type 3: Spatial and temporal effort data (e.g. 5x5 degrees, quarterly)	- Annual spatial and temporal summaries of fishery effort data. - Improved description of fishery effort that accounts for major spatial and/or temporal shifts common in fisheries. - Impact on seabirds requires data on seabird by-catch (and distribution of that by-catch).
Type 4: Spatial and temporal effort data + spatial foraging distributions of interacting birds by species	- An overlap index could be calculated and tracked over time. - While not providing a direct measure of by-catch, an overlap index can give a relative indication of potential interaction. For example, if a fishery relocated to another area beyond the normal range of previously impacted seabirds, the level of by-catch as well as the overlap index would be expected to decline.
Type 5: By-catch rate data for fleet only	- Annual trends in by-catch rate for fleets could be tracked. - Integration of fleets not examined.
Type 6: By-catch rate analysis + spatial and temporal effort data available	- Matching corresponding (in space and time) by-catch rates with effort, allowing an estimate of total by-catch (total and by area, time and fleet). - This is what is recommended for ACAP
Type 7: By-catch rate analysis with seabird species composition + spatial and temporal effort data available	As above but by species/population
Type 8: By-catch rate analysis by seabird species + spatial and temporal effort data available + demography parameters	A population level impact assessment could be conducted; this would enable the estimated by-catch totals (e.g. from 7 above) to be related to the consequent population impact. This can be important as tracking by-catch totals alone may not be giving an indication of population impact.