The development of the seabird component of the IOTC ecosystem report card

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SUMMARY

This paper serves as a contribution to the development of the IOTC Ecosystem Report Card by outlining the context and providing proposals for the seabird bycatch component of the report card. We highlight that bycatch is considered one of the main impacts of IOTC fisheries on seabirds and emphasise the importance of monitoring seabird bycatch associated with IOTC fisheries. We note that IOTC fisheries may also have indirect impacts on seabirds through overexploitation of large subsurface predators (e.g. tuna and billfish), leading to reductions in the accessibility of seabird prey. Although this aspect is not considered further in the document, we highlight the need to develop appropriate indicators. Following the format adopted at WPEB14, we propose conceptual and operational objectives, and a list of candidate indicators. These include two high-level indicators (bycatch rates per unit effort, and an estimate of the total number of seabirds killed), together with a third indicator (use and effectiveness of bycatch mitigation measures) to facilitate the interpretation of trends in the other two, and to help inform an adaptive approach to the management of seabird bycatch in IOTC fisheries. We also underline the need to include an indicator measuring the risks, or population-level impacts, of bycatch for seabirds. We outline the uncertainties and limitations associated with the suite of indicators, most of which relate to the availability of appropriately collected and reported data. It is imperative that efforts are directed to improving the data available for these indicators. However, this should not hold back the process to monitor the impacts of IOTC fisheries on seabirds, and to help inform and support efforts to minimise these impacts. Improvements in the quantity and quality of data will lead to enhancements in the indicator system and its usefulness for informing management decisions. Even with imperfect data, the indicators and ecosystem report card will help highlight data gaps and priorities for further monitoring, and thus strengthen the report card tool over time.

KEYWORDS

Seabirds, bycatch, bycatch rates, indicators

1. Introduction

In order to help support an Ecosystem Approach to Fisheries Management in the IOTC Convention Area, IOTC's Working Party on Ecosystem and Bycatch (WPEB) has recommended the development and use of an indicator-based ecosystem report card (Juan-Jordá et al. 2018). The main purpose of the report card is to help facilitate a stronger link between ecosystem considerations and fisheries management in the IOTC area of jurisdiction, in support of a move towards an ecosystem approach to fisheries

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management. It is intended that the ecosystem report card system will be used, *inter alia*, as a tool to improve communication between scientists and managers on the state of the range of ecosystem components within the IOTC region, and the fishing pressures that impact the state of these components. Consequently, it can be used as a framework for monitoring important ecosystem components, including measuring the success of a particular regulation or management action, to identify areas or issues of concern, and to help inform and direct in a timely manner management actions required to address issues of concern (Juan-Jordá et al. 2018). The development of an indicator-based ecosystem report card for the IOTC has been included in the WPEB Programme of Work (2019-2023). (IOTC 2018b).

Juan-Jordá et al. (2018) provided an initial outline of the work involved in developing an ecosystem report card for IOTC, including identifying what ecosystem components should be included in the initiative, and monitored as part of the process. Seabirds were identified as one of the ecosystem components that should be included in the monitoring and assessment framework of the report card system.

A major impact of IOTC fisheries on seabirds is through incidental mortality associated with pelagic longline fishing operations (bycatch). Bycatch of seabirds in longline fisheries occurs when birds attack baited hooks and become hooked and drowned as the line sinks. Birds can also become hooked when the lines are hauled. Due to their foraging behaviour and ecology, albatrosses and large petrels are the seabirds that are most susceptible to being caught in pelagic longline fisheries. Albatrosses and large petrels are amongst the most threatened groups of birds in the world, due in a large part to the impacts of bycatch, which, for many species, remains the most serious threat and continues to drive ongoing population declines (Phillips et al. 2016; Clay et al. 2019; Dias et al. 2019).

Within the Indian Ocean, bycatch of seabirds is most problematic in waters south of 25°S, which coincides with the greatest densities of albatrosses and large petrels, which consequently leads to the highest degree of overlap between these bycatch-susceptible seabirds and IOTC pelagic longline fishing effort.

The IOTC has recognised the adverse impact of pelagic longline fishing activities on seabirds, and the need to implement measures to reduce levels of seabird bycatch in its fisheries. IOTC Resolution 12/06 prescribes bycatch mitigation measures that longline vessels fishing south of 25°S are required to implement to help reduce levels of seabird bycatch, noting that the ultimate aim of the IOTC and CPCs is "*to achieve a zero bycatch of seabirds for fisheries under the purview of IOTC*". One of the actions specified in Resolution 12/06 is for the IOTC Scientific Committee, through the WPEB, to analyse the impact of Resolution 12/06 on seabird bycatch no later than the 2016 meeting of the Commission. There have been some efforts to respond to this requirement. However, given the paucity of data made available, it has not been possible to assess the extent to which the IOTC seabird conservation measure has influenced levels of seabird bycatch, and indeed to monitor levels of seabird bycatch associated with IOTC pelagic longline fishing operations (IOTC 2016).

IOTC fisheries may also indirectly impact seabirds through overexploitation of target species (e.g. tuna and billfish) that are associated with seabird prey. Some tropical seabirds associate with large subsurface predators (such as tuna and billfish) that drive smaller prey to the surface, where they become accessible to the seabirds; reductions in the biomass of these predators may lead to reduced accessibility of the seabird prey and consequent impacts on seabird populations (Danckwerts et al. 2014). We do not consider this aspect further here but highlight the importance of developing appropriate objectives and indicators as part of the broader process.

In support of the development of the IOTC ecosystem report card, this paper provides proposals for the seabird bycatch component of the report card. We highlight why this component is important to monitor and propose conceptual and operational objectives to measure progress towards monitoring the impacts of IOTC fisheries on seabirds. We propose a list of candidate indicators, highlighting the requirements and challenges associated with measuring these.

2. The seabird component of the report card and objectives to measure progress

Bycatch is one of the primary threats to seabirds globally, and is especially problematic for albatrosses and large petrels, which are considered to be amongst the most threatened groups of seabirds (Phillips et al. 2016; Dias et al. 2019). A recent assessment of seabird bycatch associated with pelagic longline fishing in the Southern Hemisphere estimated that approximately 30,000-40,000 seabirds were killed annually between 2012 and 2016 (BirdLife South Africa 2019), with seabird bycatch predicted across the South Indian Ocean.

A range of operational and technical bycatch mitigation measures and approaches have been developed to reduce the interaction of seabirds with fishing gear, and therefore the frequency and magnitude of bycatch (Agreement on the Conservation of Albatrosses 2019). IOTC adopted Res 12/06 in 2012, which prescribes bycatch mitigation measures to reduce the level of bycatch associated with pelagic longline fishing vessels operating south of 25°S in the Indian Ocean. Res 12/06 also requires an assessment of the effectiveness of these measures and the Resolution in reducing seabird bycatch. However, this requirement remains outstanding, due to the lack of sufficient data - both in terms of quantity and quality - to undertake such an assessment.

The candidate indicators proposed for the seabird component of the IOTC ecosystem report card are intended to help monitor levels of seabird bycatch in IOTC fisheries and to assess the effectiveness of management measures adopted by IOTC to minimise bycatch. Successful implementation of these objectives will help support an informed and adaptive approach to the management of bycatch. There are many challenges associated with measuring and monitoring bycatch and its impact on seabird populations, the most fundamental of which relates to the data available for this purpose. These challenges are outlined below and highlight the urgency of improving data collection practices.

In order to measure progress towards monitoring the impacts of IOTC fisheries on seabirds, and the state of seabirds overlapping with IOTC fisheries, we propose the following conceptual and operational objectives:

Conceptual objective:

- Ensure that IOTC fisheries minimise catch of seabirds and minimise impacts on seabird populations with which they overlap.

Operational objectives:

- Ensure that IOTC fisheries reduce bycatch of seabirds in fishing operations.

- Work towards a robust method of assessing the impacts of IOTC fisheries on seabird populations.

3. Proposed seabird candidate indicators, their development, requirements and limitations

3.1 Proposed indicators

In order to monitor the extent to which the conceptual and operational objectives are being met, it is necessary to develop a suite of indicators that serve to describe the state of seabird bycatch in IOTC fisheries and how, and ideally why, it changes over time. Requirements for use of bycatch mitigation measures have been adopted by the IOTC, and there is an expectation that proper use of these measures will contribute to reductions in bycatch. However, there is a need to measure and monitor these changes to assess the performance of the IOTC in achieving its ultimate aim of *"achieving a zero bycatch of seabirds for fisheries under the purview of the IOTC, especially threatened albatross and petrel species in longline fisheries."* It is also important to understand the factors contributing to these changes (or why the anticipated level of change did not eventuate).

There is a range of methods that may be used to estimate and monitor levels of seabird bycatch in fisheries. Inevitably, the assessment methods are dependent on the quantity and quality of data available, as well as the specific objectives of the exercise. In most situations, only a portion of the total fishing effort is formally observed for bycatch events. Consequently, extrapolation of bycatch figures from observed fishing effort to total fishing effort is required to estimate the bycatch associated with an entire fleet (i.e. including the unobserved fishing effort). In the case of the IOTC, and most other tuna RFMOs, a minimum of 5% of the total fishing effort is required to be observed. Even if this requirement is met, the low level of observer coverage makes it very difficult rigorously to quantify the levels of bycatch occurring, especially of rarely caught, but highly threatened, species (Pierre 2019).

The Agreement on the Conservation of Albatrosses and Petrels (ACAP) has recommended that assessment and monitoring of seabird bycatch levels over time should include estimates of a) bycatch rates (i.e. number of birds killed per a given unit effort, for example birds per 1000 hooks set for longline fisheries) and b) the total number of birds killed per fleet (Jiménez et al. 2019). The reason it is important to include both of these metrics as indicators is that although bycatch rates are suitable for direct comparisons over time or across strata or fisheries, they do not account for differences in fishing effort. Even if bycatch rates decline, impacts on seabird populations could increase if fishing effort increases. In some cases, changes in bycatch rates might also reflect declining/increasing seabird populations or shifts in fishing areas and seasons. Consequently, bycatch rates should be used in combination with estimates of the total number of birds killed per fleet as an overall indicator to monitor bycatch trends over time. These two indicators are recognised by the FAO as the primary approaches for monitoring seabird bycatch reduction goals (FAO 2009), and have previously been presented to the IOTC WPEB (Wolfaardt and Debski 2015; Wolfaardt et al. 2016). The IOTC WPEB agreed that these proposed indicators (bycatch rates and total number of birds killed) would be useful candidate indicators for the review of Resolution 12/06 (IOTC 2016).

Therefore, we propose that these serve as the two main candidate seabird indicators for the IOTC ecosystem report card:

- the bycatch rate, expressed as the number of seabirds killed per 1000 hooks set;
- the total number of seabirds caught, ideally at a species specific, or generic seabird level.

One of the actions within Resolution 12/06 is for the IOTC Scientific Committee to assess the impact of the Resolution in achieving its goal of reducing seabird bycatch. In order to do this properly it is necessary to obtain information on the use of the prescribed mitigation measures, both in terms of the combinations of measures that are used, and through an assessment of how effectively the mitigation measures are being used. Without this information, it is difficult to assess the effectiveness of the Resolution - and the prescribed conservation measures - especially considering that the prescribed measures are likely not being adequately or fully implemented across the fleets. Therefore, we propose the inclusion of a third indicator that serves to measure the implementation and effectiveness of prescribed bycatch mitigation measures:

- Use and effectiveness of prescribed bycatch mitigation measures.

This third indicator will help interpret the trends in the first two indicators - what combinations of mitigation measures have been most effective and could also help to identify implementation problems and direct efforts to address these.

All three of these indicators are influenced by the quantity and quality of data available, by how the data are collected, and are best served if these data are collected in a standardised manner.

We acknowledge that there are a number of limitations and critical issues to consider when estimating and interpreting these three indicators, which are discussed further below.

3.1.1 Indicator 1: Bycatch rates per unit fishing effort

One of the commonest ways to measure and report levels of seabird bycatch is to express the number of birds caught per unit fishing effort (e.g. per 1000 hooks set for longline fisheries). Even for these simple and well-understood measures, there are challenges and limitations regarding representativeness and bias when dealing with low levels of observer coverage. In addition to the limitations associated with data gaps, bycatch rates do not account for changes in fishing effort, and therefore should be used as part of a broader indicator, in combination with estimates of the total numbers of seabirds killed. The calculation of bycatch rates should be conducted in a stratified manner and tracking changes in bycatch rates over time should be done by stratum, rather than the average rate across all strata (as different strata will likely have different background rates of bycatch). Ideally, estimates of bycatch rates should be provided for each species caught. However, data limitations will often preclude such an approach, and CPCs should aim to provide estimates at the finest level possible. Annex 1 provides a classification for birds unidentified to species level using ACAP species as an example.

3.1.2 Indicator 2: The total number of seabirds killed

Given the situation in most fisheries, in which bycatch data are available for only a portion of the overall fishing effort, some sort of extrapolation is required to derive estimates for the total number of birds killed annually in a fishery. The usefulness of this metric is that it integrates the bycatch rate estimate with fishing effort, hence the proposed approach of including both in the overall Seabird Bycatch Indicator. Generally, estimating total captures relies on the observed effort being representative of the total effort. In many fisheries, this may not be the case. For example, the observations may be biased towards a particular time of year when captures of seabirds are more or less frequent, or observers may be placed on vessels that are not representative of the fleet as a whole. Model-based approaches can be used to deal with these issues (unobserved fishing effort, quantifying uncertainty or error), but also have their limitations. The calculation of the total number of seabirds killed should be conducted in a stratified manner, and tracking changes in mortality over time should be done by stratum, rather than the average estimate across all strata (as different strata will likely have different background levels of bycatch). Ideally, estimates of the total numbers of seabirds killed should be provided for each species caught. However, data limitations will often preclude such an approach, and CPCs should aim to provide estimates at the finest level possible (see Annex 1). In addition to representative bycatch data, this indicator relies on comprehensive and accurate fishing effort data. CPCs are required to report these data to the IOTC Secretariat, and so they should, in theory, be available for this purpose. However, there remain major gaps in fishing effort data held by the IOTC Secretariat, which need urgently to be addressed to enable bycatch estimates to be reliably scaled up to the extent of the entire fleets.

3.1.3 Indicator 3: Use and effectiveness of prescribed mitigation measures

In order for IOTC to evaluate the impact of its conservation measure in reducing seabird bycatch (Res 12/06), it is important to ensure that data on the use of these mitigation measures is collected and made available for assessment processes. The mitigation measures prescribed by the IOTC and other tuna RFMOs have been demonstrated to be effective at reducing seabird bycatch, mostly in experimental studies. Consequently, these data should be incorporated into bycatch estimation models to improve estimates. Although there is clearly a compliance-monitoring aspect to such data, the IOTC WPEB has acknowledged that although it is important to keep these issues separate, there are links between the two (IOTC 2018a). For example, the degree of proper use (or non-use) of bycatch mitigation measures in high risk areas will influence the rates of bycatch measured, and should be accounted for, or at least acknowledged. A number of studies have highlighted vessel-specific bycatch rates, even amongst vessels fishing in the same time and space strata, which is likely due, at least in part, to differences in the use of mitigation measures. Although challenging, efforts should be directed towards facilitating the standardised collection and reporting of information on mitigation measure use so that it can be incorporated into the assessment process and as an explanatory indicator in the ecosystem report card.

3.2 Issues to consider when measuring the indicators

3.2.1 Undetected mortality

Seabird mortality estimates in longline fisheries are generally based on the number of dead birds brought aboard vessels on hooks. However, in many cases a proportion of birds that are caught on longlines during line setting may drop off hooks prior to hauling, and so will not be retrieved and recorded. This undetected mortality is sometimes referred to as "cryptic mortality", and the proportion in some longline fisheries has been estimated at 50% (Brothers et al. 2010). This undetected mortality has the potential to significantly underestimate actual mortality. Ideally, the undetected mortality should be accounted for in bycatch estimates, but this is not necessarily a simple task. Some studies have been undertaken to derive correction factors. However, such a relationship is influenced by a number of variables, making it difficult to apply broadly. Indeed, a recent experimental study using dead ducks as surrogates for hooked seabirds reported much lower levels of undetected mortality (Baker et al. 2019).

3.2.2 Uncertainty in estimation

Where there is 100% observer coverage of hooks hauled within a fishery, bycatch should be completely observed, and apart from cryptic mortality, there is no need for estimation. However, in most situations, observer coverage is substantially lower, and extrapolation of bycatch from observed hooks to total fishing effort is required. Data collection and extrapolation should also include data on factors that affect the seabird bycatch rates and numbers, including a range of environmental, ecological and operational factors, all of which vary in space and time, as well as variation in fishing gear, including technical mitigation measures, and fishing techniques used within a fishery, and the different modes of bycatch. For example, in longline fisheries birds may be killed during the line setting process, but also during the haul, and it is useful to differentiate between these sources of mortality.

It is inappropriate to assume that bycatch and associated data collected for a small sample of the overall fishing effort is necessarily representative of the whole fleet. Applying a bycatch rate from a particular area/time across a whole fleet, part of which may not be interacting with seabirds, will result in biases. With this in mind, every effort should be made to ensure that observer programmes sample a representative portion of the fishing effort of each fleet, spatially, temporally and across the full range of vessels and gear types. Ideally estimates should be reported with some measure of representativeness, but given the complexity of issues affecting representativeness a simpler approach is to simply collect and report metadata including the level of observer coverage and the factors used in the estimation (e.g. factors used to stratify data or co-variables in model-derived estimates).

The representativeness of the observer coverage can be assessed in simple terms by determining the proportion of the total fishing effort that was observed for each strata, and how these compare with the target level of observer coverage required. However, in some cases information on the overall fishing effort may be lacking, thus hampering efforts to determine how representative the observer coverage is. Spatial and temporal representativeness should be based on appropriate stratification. Temporal stratification is relatively straightforward and could simply comprise year quarters. Spatial stratification should ideally be meaningful to the distribution of seabirds and fishing effort, dividing the area in question into units that are similar in respect of these properties, but are not necessarily the same size and shape. This will not always be possible or practical. In such cases, which would generally apply to RFMOs, spatial stratification should be based on a resolution of 5x5 degree grid squares or a finer grid-arranged stratification. Figures 1 and 2 provide an example of how representativeness and bycatch events and estimates can be usefully presented for a fishery. It is important to note that sampling should also be representative of other factors, such as vessel type, target fish and gear set up. Representativeness is less important when using a modelling approach to extrapolate bycatch estimates, provided the appropriate factors have been included.

Given generally low levels of observer coverage for many fisheries, including for the IOTC, there will inevitably be some level of uncertainty associated with bycatch estimates. In order to reflect this uncertainty and to understand the bounds of the estimates, confidence intervals should be calculated and reported together with the estimates of bycatch.

3.2.3 Uncertainty in species identification

An important consideration for bycatch estimation is whether it is possible to estimate bycatch by species or some species groupings. The ability to provide estimates for each species is dependent on the accurate identification of bycaught seabirds by observers, or the use of programmes to analyse samples collected, or photographs taken at sea. In order to understand the conservation implications of bycatch, it is preferable that estimates are derived for each species, which can also then be aggregated to groupings of species, and for all birds combined. Consequently, efforts should be directed towards encouraging the identification of all bycaught birds to species level, by for example retaining carcasses, biological samples, and taking photographs for later identification. The ACAP Seabird Bycatch Identification Guide provides a useful tool to help identify bycaught seabirds. However, it may not always be possible to identify a bycaught bird to species level. In these cases, the identification of a bycaught bird at a coarser level (e.g. large/great albatross), or even unidentified birds, still contribute to the estimate of the total number of birds caught. A proposed standard set of nested groupings for birds unidentified to species level is provided in Annex 1, the use of which would allow estimates to be summed at different taxonomic levels.

4. Lessons learnt from Common Oceans Tuna Project process to derive a global estimate of seabird bycatch in Southern Hemisphere pelagic longline fisheries (BirdLife South Africa 2019)

It is instructive to consider the outcomes of the recently completed (February 2019) process to assess seabird bycatch in pelagic longline fisheries operating south of 20°S (BirdLife South Africa, 2019). The main aims of the process were to derive a global estimate of seabird bycatch associated with these fisheries, to assess the population-level impacts of this bycatch on some well-studied species, and to provide a toolbox of methods for estimating seabird bycatch. The analytical approach used in this process included a focus on estimating the total number of seabirds killed per year. The overall assessment approach comprised a number of stages, starting with an estimation of bird bycatch rates. These were then scaled to the total fishing effort to derive the total number of seabirds caught per year. Four modelling approaches were used to estimate seabird bycatch in these fisheries:

- Stratified Ratio-based Estimate (SRBE)
- Integrated Nested Laplace Algorithm (INLA)
- Generalized Additive Models (GAM)
- Spatially Explicit Fisheries Risk Assessment (SEFRA)

The variability in the way that seabird bycatch mitigation use was recorded and reported over the period under consideration (2012 – 2016) meant that data on the proper use of bycatch mitigation measures were not used as factors in any of the models. Consequently, it was not possible to assess the effectiveness of mitigation measures adopted by tuna RFMOs, as initially planned for the project. The workshop highlighted the importance of this information and of working towards incorporating such information in the future.

In addition, a Population Viability Analysis (PVA) model was used to investigate the impacts of bycatch on key albatross species/populations.

The availability of data, and challenges associated with available data, were the greatest constraints faced during the workshop. Despite these limitations, the wide range of modelling approaches used were relatively consistent in their estimates of seabird bycatch, at approximately 30,000-40,000 birds per year. This suggests that, despite their limitations, even simple methods may produce reasonably robust estimates, albeit at a coarse level.

One of the data inputs that emerged as an important predictor of bycatch in all of the model-based estimates were seabird density surfaces, using data from the Global Seabird Tracking Database, which is curated by BirdLife International. However, like other datasets, there are also limitations with the seabird-density surfaces, due in part to populations and/or life stages of seabirds that remain poorly tracked or untracked. As with the other data sets, it is important that critical gaps in the seabird density surfaces are addressed, so that these data can be used with increased reliability for future assessments.

The importance of the seabird distribution data set also highlights another issue for the IOTC report card process: the need to collaborate with external data owners/curators. While the fisheries and bycatch data should, in theory, be provided through the IOTC structures, use of future updates of seabird distribution data will need to be requested via data requests to owners of data in the Global Seabird Tracking Database.

PVA models were used to assess the impacts of the estimated bycatch on five selected seabird species. Species-specific estimates were derived from the SEFRA models and used as inputs to the PVA models. The analysis was limited to five species/populations for which sufficient demographic data were available. Some species, such as the White-chinned Petrel, which is bycaught in larger numbers than many others, were not included due to the lack of robust demographic data. This highlights that while it is clearly important to try and assess the impacts of bycatch on affected populations, the ability to do so is constrained by the available demographic data. As with the seabird density data, use of these 'external' data sets in the future will require a collaborative approach between IOTC and external organisations such as ACAP. ACAP maintains species assessments for albatrosses and large petrels, which contain *inter alia* best current estimates of key metrics such as population size and adult survival. These species assessments are in the process of being updated.

One of the intended outcomes of the workshop was to provide guidance on seabird bycatch assessment methodologies in the form of a toolbox of methods appropriate for different data availability scenarios. However, given the similarity of results from the different modelling approaches used at the workshop, a methodological toolbox was not developed, but instead model scripts have been compiled and made available as a resource at:

https://github.com/seabird-risk-assessment/abnj-seabird-bycatch-analysis

5. Establishing thresholds for management action and linking the seabird bycatch reduction goal to measurable bycatch reduction and seabird population objectives

The main purpose of the IOTC ecosystem report card is to improve the link between ecosystem science and fisheries management in support of an ecosystem approach to fisheries management (Juan Jordá et al. 2018). An indicator-based system is likely to be most effective if explicit links are established at the outset between the indicator outputs (bycatch rates and numbers) and specified management responses (Small et al. 2013). Moreover, bycatch reduction goals and targets should ideally be linked to measurable bycatch reduction and (seabird) population objectives (Good et al. 2019).

Although seabird population objectives are captured broadly within our proposed conceptual and operational objectives (re-stated below), they are not defined in a manner that is easily measurable.

Conceptual objective:

- Ensure that IOTC fisheries minimise catch of seabirds and minimise impacts on seabird populations with which they overlap.

Operational objectives:

- Ensure that IOTC fisheries reduce and, where practicable, eliminate bycatch of seabirds in fishing operations.

- Work towards a robust method of assessing the impacts of IOTC fisheries on seabird populations.

It is challenging to define a bycatch target in a manner that links directly and in a quantifiable way to seabird population metrics. This is due to a number of factors: seabird bycatch thresholds will vary between species and even populations; bycatch rates and estimates are usually a mix of multiple species and populations, including unidentified species, and in terms of their impact on seabird populations are influenced by fishing effort; in terms of the biological relevance, bycatch impacts need to be considered together with all the other sources of mortality (for each species), which we are generally unable to fully quantify.

For this reason, attempts to assess and monitor seabird bycatch reduction efforts have generally set targets based on attainable objectives that lead to ongoing reductions in seabird mortality, rather than on thresholds in respect of seabird population metrics. For longline fisheries, these have broadly, and informally, been categorized as follows:

- *< 0.05 birds/1000 hooks = acceptable;*
- *0.05 – 0.1 birds/1000 hooks = needs further implementation of mitigation measures to further reduce bycatch rates;*
- *> 0.1 birds/1000 hooks = alarm bell for immediate action, by improving rates of implementation of existing bycatch measures and/or strengthening the mitigation requirements.*

We acknowledge that these categories are not explicitly linked to seabird population metrics, and that there are inherent limitations of using bycatch rates with low levels of observer coverage. However, it would be useful to have some means of gauging how well bycatch reduction efforts are progressing, apart from, or in addition to, the trajectory of the trends of the indicators.

Notwithstanding the difficulties of assessing the impacts of bycatch on seabird populations, this is clearly an important component of the overall objectives and should be addressed. The SEFRA and PVA approaches have both been used to assess the relative impacts of bycatch on seabird populations (see Section 4). The SEFRA approach, in particular, is still under development, and the application of this approach has produced varying results. However, work is underway to develop the methodology further, and may in the future provide a robust mechanism for monitoring the impacts of IOTC fisheries on seabirds. It would be useful to work towards including some candidate seabird species to incorporate in the indicator system of monitoring. These would be species that interact with IOTC fisheries, are considered to be adversely impacted by bycatch and for which good demographic data are available.

6. Data

Arguably the greatest constraint to progressing the seabird component of the IOTC ecosystem report card is the availability of the data required for the process. Notwithstanding the substantial challenges associated with low levels of observer coverage and associated bias, much of the bycatch and fishing effort data needed to measure the indicators is already required to be collected by IOTC CPCs. It is important that these data are properly collected (in a standardised manner) and made available for use in the ecosystem report card process. Efforts to improve data collection, including expanding observer coverage levels through electronic monitoring, will help improve the reliability of the indicators.

As outlined in Section 4, assessment and monitoring of the seabird indicators will likely benefit from the use of external data sets, such as the seabird distribution densities and ACAP species assessments, and ongoing engagement with the key organisations to facilitate such a collaboration.

Given the importance of the quantity and quality of data available to calculate and interpret the indicators, we suggest that it would be useful to include some 'data availability' indicators to help track progress in this important requirement. Such indicators would presumably be relevant to other ecosystem components, and so could be discussed by the wider group at WPEB15 as a cross-cutting issue.

7. Conclusions

In order to achieve the conceptual and operational objectives, we propose a list of candidate indicators. These include two high-level indicators (bycatch rates per unit effort, and an estimate of the total number of seabirds killed), together with a third indicator (use and effectiveness of bycatch mitigation measures) to facilitate the interpretation of trends in the other two, and to help inform an adaptive approach to the management of seabird bycatch in IOTC fisheries. We also highlight the need to include an indicator measuring the risks, or population-level impacts, of bycatch for seabirds. We have outlined a number of uncertainties and gaps in data and knowledge that need to be addressed to calculate and monitor the proposed seabird indicators in a robust manner. It is imperative to improve the data available for these indicators. However, this should not hold back the process to monitor the impact of IOTC fisheries on seabirds, and to help inform and support efforts to minimise these impacts. Improvements in the quantity and quality of data will lead to enhancements in the indicator system and its usefulness for informing management decisions. Indeed, even with imperfect data, the indicators and ecosystem report card will help highlight data gaps and priorities for further monitoring, and thus strengthen the report card tool over time.

The establishment of an IOTC process to monitor seabird bycatch indicators in its area of jurisdiction will also help ensure that it can feed into wider scale assessments, such as a future iteration of the Southern Hemisphere seabird bycatch assessment workshop discussed in Section 4. Participants at this workshop recommended that the assessment should be repeated in the future in order to monitor progress from 2016 onwards, and that ongoing monitoring by RFMOs on a regional basis will help support these efforts (BirdLife South Africa, 2019).

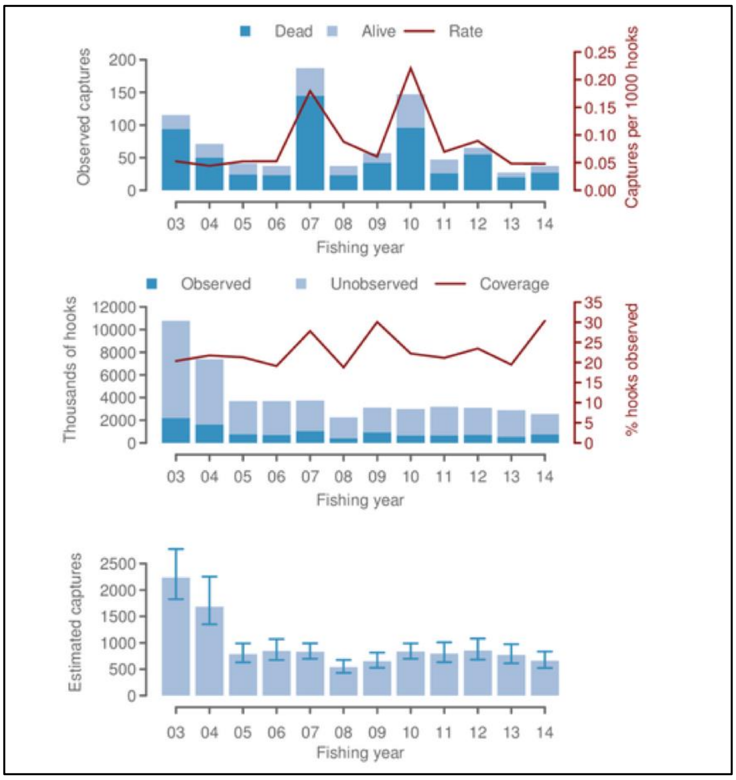

Figure 1: Observed captures, fishing effort, and estimated captures for all surface longline fisheries in New Zealand from 2002-03 to 2013-14 (from Walker and Abraham 2016).

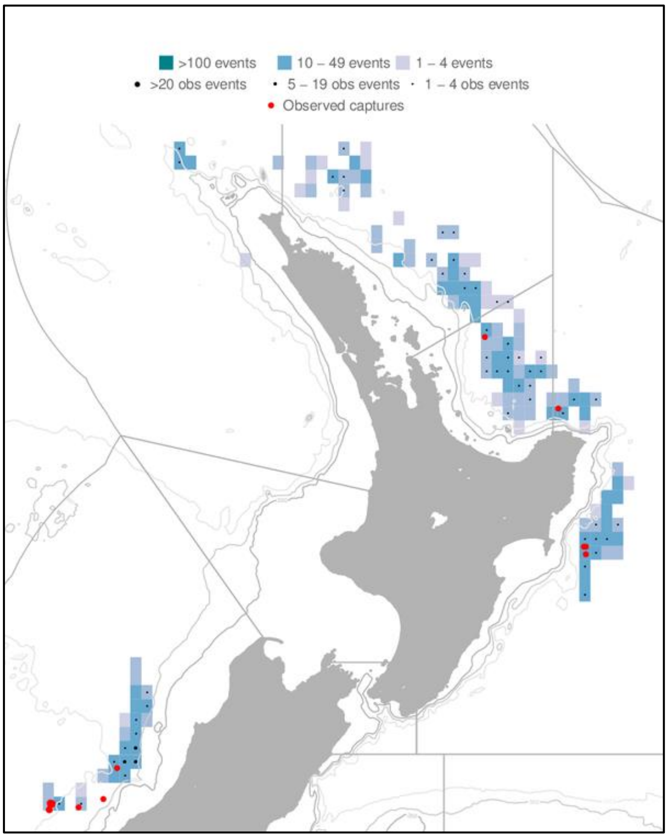

Figure 2: Standardised map showing the spatial strata and distribution of total fishing effort, observed effort and seabird bycatch for all surface longline fisheries in New Zealand

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ANNEX 1: PROPOSED CATEGORISATION FOR BIRDS UNIDENTIFIED TO SPECIES LEVEL - USING ACAP SPECIES AS AN EXAMPLE

Every effort should be made to identify birds to species level, or failing that to the lowest level of taxonomic classification

Seabird sp	Large albatross sp	*Diomedea sp*	*Diomedea sanfordi*	Northern Royal Albatross
			Diomedea epomophora	Southern Royal Albatross
			Diomedea exulans	Wandering Albatross
			Diomedea antipodensis	Antipodean Albatross
			Diomedea amsterdamensis	Amsterdam Albatross
			Diomedea dabbenena	Tristan Albatross
	Smaller albatross sp	*Phoebetria sp*	*Phoebetria fusca*	Sooty Albatross
			Phoebetria palpebrata	Light-mantled Albatross
		Phoebastria sp	*Phoebastria irrorata*	Waved Albatross
			Phoebastria nigripes	Black-footed Albatross
			Phoebastria immutabilis	Laysan Albatross
			Phoebastria albatrus	Short-tailed Albatross
		Thalassarche sp	*Thalassarche chlororhynchos*	Atlantic Yellow-nosed Albatross
			Thalassarche carteri	Indian Yellow-nosed Albatross
			Thalassarche chrysostoma	Grey-headed Albatross
			Thalassarche melanophris	Black-browed Albatross
			Thalassarche impavida	Campbell Albatross
			Thalassarche bulleri	Buller's Albatross
			Thalassarche cauta	Shy Albatross
			Thalassarche steadi	White-capped Albatross
			Thalassarche eremita	Chatham Albatross
			Thalassarche salvini	Salvin's Albatross
	Petrel sp	*Macronectes sp*	*Macronectes giganteus*	Southern Giant Petrel
			Macronectes halli	Northern Giant Petrel
		Procellaria sp	*Procellaria aequinoctialis*	White-chinned Petrel
			Procellaria conspicillata	Spectacled Petrel
			Procellaria parkinsoni	Black Petrel
			Procellaria westlandica	Westland Petrel
			Procellaria cinerea	Grey Petrel
		Shearwater *sp*	*Ardenna creatopus*	Pink-footed Shearwater
			Puffinus mauretanicus	Balearic Shearwater

Highest (general) level of taxonomic classification → Lowest (specific) level of taxonomic classification (preferred)