Biological Conservation 247 (2020) 108592

Contents lists available at ScienceDirect

Biological Conservation

journal homepage: www.elsevier.com/locate/biocon

National Plans of Action (NPOAs) for reducing seabird bycatch: Developing best practice for assessing and managing fisheries impacts

S.D. Good[a,*], G.B. Baker[b], M. Gummery[c], S.C. Votier[a], R.A. Phillips[d]

[a] Centre for Ecology & Conservation, University of Exeter, Cornwall Campus, Penryn TR10 9EF, UK
[b] Institute for Marine and Antarctic Studies, University of Tasmania, Hobart, Tas 7005, Australia
[c] Marine Stewardship Council, Marine House, 1-3 Snow Hill, London EC1A 2DH, UK
[d] British Antarctic Survey, Natural Environment Research Council, High Cross, Madingley Road, Cambridge CB3 0ET, UK

ARTICLE INFO

Keywords:
Bycatch
Seabirds
Fisheries management
Incidental mortality
National Plan of Action (NPOA) - Seabirds

ABSTRACT

Fisheries bycatch is one of the biggest threats to seabird populations. Managers need to identify where and when bycatch occurs and ensure effective action. In 1999, the Food and Agriculture Organization of the United Nations released the International Plan of Action for Reducing Incidental Catch of Seabirds in Longline Fisheries (IPOA-s) encouraging states to voluntarily assess potential seabird bycatch problems and implement a National Plan of Action (NPOA) if needed. However, the IPOA-s is ambiguous about the steps and objectives, diminishing its value as a conservation tool.

We reviewed NPOAs to identify approaches taken to determine whether seabird bycatch is problematic, how bycatch minimisation and population objectives are set, and if thresholds are specified for managing impacts. Our aim was to recommend measures for improving consistency and effectiveness in future NPOAs and other management frameworks for seabirds, with relevance for other threatened marine vertebrates including sharks, turtles, pinnipeds and cetaceans. Globally, 16 NPOAs have been published, but few effectively linked seabird bycatch risk, objectives and management. However, we identified the following best-practice elements that could improve NPOA design: (1) defining explicit risk criteria and methods to assess bycatch problems; (2) setting specific and measurable objectives for minimising bycatch and achieving desired population status; and (3) defining fishery-specific thresholds to trigger management action linked to the population objective. Consistent adoption of NPOA best practice, particularly in states that have not already developed an NPOA, would help to mitigate bycatch threats and ensure fisheries do not reduce the viability of seabird populations.

1. Introduction

Incidental mortality (bycatch) in fisheries is one of the biggest threats to marine megafauna (Anderson et al., 2011; Moore et al., 2013; Phillips et al., 2016; Wallace et al., 2013). Minimising bycatch is therefore at the forefront of global marine conservation goals (FAO, 1995), including the development of reference points for estimating risk and managing impacts (Curtis and Moore, 2013; Moore et al., 2013; Zhou and Griffiths, 2008). Thresholds to trigger management action have been developed in some cases for marine mammals, but specific reference points or thresholds for seabirds have rarely been defined (Beggren et al., 2002; Geijer and Read, 2013; McDonald et al., 2015; Small et al., 2013).

To address the issue of seabird bycatch, the Food and Agriculture Organization (FAO) released the International Plan of Action for Reducing Incidental Catch of Seabirds in Longline Fisheries (IPOA-s) in 1999. The IPOA-s is a voluntary instrument that refers to objectives in the FAO code of conduct for responsible fisheries that aim to minimise negative impacts on non-target species, allowing sufficient selectivity of gear and the operational flexibility to do so (FAO, 1995, 1999). The 2009 release of the FAO Best Practice Technical Guidelines (BPTG) to support implementation extended the IPOA-s to other relevant fishing gear including trawls and gillnets (FAO, 2009). Although these documents highlight the importance of reducing impacts on seabirds or non-target species, none set objectives regarding population status of the affected species nor prescribe thresholds for impacts beyond which management action should be taken. The IPOA-s indicates that an assessment should determine the extent and nature of seabird bycatch but is not prescriptive about how this should be completed. The IPOA-s identifies that the assessment may include collection and analysis of: (1) the criteria used to evaluate the need for an NPOA; (2) data on fishing fleets, techniques, areas and effort; (3) status of seabird populations; (4)

* Corresponding author at: Environment and Sustainability Unit, University of Exeter, Cornwall Campus, Penryn TR10 9EF, UK.
E-mail address: sg606@exeter.ac.uk (S.D. Good).

https://doi.org/10.1016/j.biocon.2020.108592
Received 23 September 2019; Received in revised form 7 April 2020; Accepted 14 April 2020

annual bycatch of seabirds; (5) existing mitigation measures in use and an analysis of their effectiveness, and; (6) monitoring of seabird bycatch rates. The BPTG indicate that the criteria used to evaluate the need for an NPOA, whether qualitative or quantitative, should be explicitly defined. When deciding whether a NPOA for seabirds is necessary, states have taken different approaches, with some conducting an assessment before deciding whether to implement a plan and others conducting an assessment as part of their plan (Baker and Finley, 2010).

Setting out best practice allows relevant bodies, such as national governments, Regional Fisheries Management Organisations (RFMOs) and multilateral agreements to develop and implement effective seabird bycatch management. For example, regularly updated, best-practice mitigation methods for different gear types are available from the Agreement on Conservation of Albatross and Petrels (ACAP)(ACAP, 2017). In addition, risk assessments are used as a tool in some RFMOs, where the outputs have built momentum to implement bycatch mitigation (Tuck et al., 2011). An understanding of best practice is also important for organisations other than those that directly manage or assess fisheries impacts. For example, sustainability certification schemes, such as the Marine Stewardship Council, regularly review their standards to ensure that they reflect best practice in science and management (Agnew et al., 2014).

In this paper, we focus on three elements of a best-practice management framework that seeks to address seabird bycatch in fisheries: (1) identifying a problem, (2) setting objectives, and (3) establishing thresholds for management action. We reviewed NPOAs for reducing seabird bycatch to determine which countries or regions have developed and adopted such plans, and to identify how each defines a seabird bycatch problem, sets objectives and selects specific thresholds for managing fisheries impacts. Our aim was to develop recommendations that improve the consistency and effectiveness of NPOAs in order to achieve the joint objectives of minimising seabird bycatch and avoiding deleterious impacts of fisheries on seabird populations. Many of the recommendations are also relevant for ecological risk assessments for other threatened marine vertebrates impacted by fisheries, including sharks, marine turtles, pinnipeds and cetaceans.

2. Methods

In 2014, the FAO Committee on Fisheries (COFI) published results from a survey of their members on the development of NPOAs. We reviewed the responses to identify those fisheries involving gears that could interact with seabirds and those members which had undertaken an assessment to determine if they needed to implement a NPOA. Of those, we determined the number of members that had actually developed an NPOA.

NPOAs were obtained online from links at Cooper (2019). Unless indicated otherwise, the versions reviewed here were the latest published on or before 27 June 2019. Each NPOA was reviewed and information was extracted on the method used to identify if a seabird bycatch problem exists; the stated overarching objective; whether this or any sub-objectives related to the status of seabird populations or species; whether any thresholds were included and in what form, and; whether these thresholds were explicitly linked to a management response. The compiled results and current practices were considered in relation to specific criteria identified in the literature and described below (FAO, 1995, 1999, 2009; Moore et al., 2013; Small et al., 2013; Tear et al., 2005; Tuck, 2011).

2.1. Identifying the problem

Our assessment of how the compilers identified whether a seabird bycatch problem existed was based on the recommendation in the FAO BPTG that explicitly defined criteria should be used (FAO, 2009). We recorded whether qualitative, semi-quantitative, or fully quantitative approaches were used in the NPOA and whether there was a statement about the criteria used to determine if a problem existed. Qualitative approaches included collecting information (including quantitative data) to make an expert judgement on whether a problem existed, as well as qualitative ecological risk assessment methodologies like the Scale Intensity Consequence Analysis (SICA), which uses stakeholder input to identify the vulnerability of a species to impact in worst plausible scenarios (Hobday et al., 2011). Semi-quantitative approaches included risk assessments combining life-history characteristics and catchability attributes, such as the Productivity Susceptibility Analysis (PSA) (Hobday et al., 2011). Fully quantitative approaches involved numerical assessments including Potential Biological Removal (PBR) which uses demographic parameters to determine a mortality limit for a population (Wade, 1998), and population matrix models that assess the effects of fisheries mortality on seabird populations (e.g. Baker and Wise, 2005; Finkelstein et al., 2010; Tuck et al., 2001; Wiese and Smith, 2003).

We evaluated “explicitly defined” as criteria that are fully expressed, with nothing implied. Thus, if the stated criterion used to determine if a problem exists was the magnitude of seabird bycatch in terms of number of birds killed or bycatch rate, this was not considered to be explicitly defined unless quantified. For example, in Uruguay, a two-step process with a predefined, semi-quantitative Productivity Susceptibility Analysis was used alongside a predefined quantitative calculation of Potential Biological Removal to prioritise species for application of mitigation measures in the NPOA (Jiménez et al., 2012, 2015).

2.2. Setting management objectives

We recorded whether each NPOA included an objective to reduce, avoid or minimise bycatch based on the IPOA-s overall objective. We also recorded whether there were any specific objectives ensuring that seabird populations were not adversely impacted by fisheries specified within the NPOA. This is important because absolute numbers of birds bycaught mean little in the absence of an estimation of population-level effects (Tuck, 2011).

We also recorded whether the bycatch and population objectives were specific and measurable, based on principles for setting conservation goals and objectives outlined by Tear et al. (2005). Those include stating clear goals to direct the establishment and definition of quantifiable objectives, such that progress against those can be measured effectively. For example, the 2004 Falkland Island NPOA for longlines set an initial objective to minimise bycatch to a specific bycatch rate (0.05 birds/1000 hooks) within the lifetime of the NPOA. This goal was achieved in 2007–8 when no birds were caught. In the 2011 NPOA, the objective was to maintain the level of seabird bycatch at zero (Janzen et al., 2011).

2.3. Determining thresholds for management action

Finally, we recorded whether each NPOA specified thresholds and whether these were qualitative or quantitative. We also recorded whether the threshold was linked to a specific management response and whether this was allied to the population-specific objective. For example, the Australia Threat Abatement Plan uses a quantitative bycatch threshold of 0.05 birds/1000 hooks to trigger a management response for tuna and billfish fisheries (Commonwealth of Australia, 2014).

3. Results

3.1. Uptake of the IPOA-s by FAO Committee on Fisheries (COFI) Member States

The 2014 survey of COFI members reported 77 responses, including 67 that identified that longline fishing was conducted in waters under

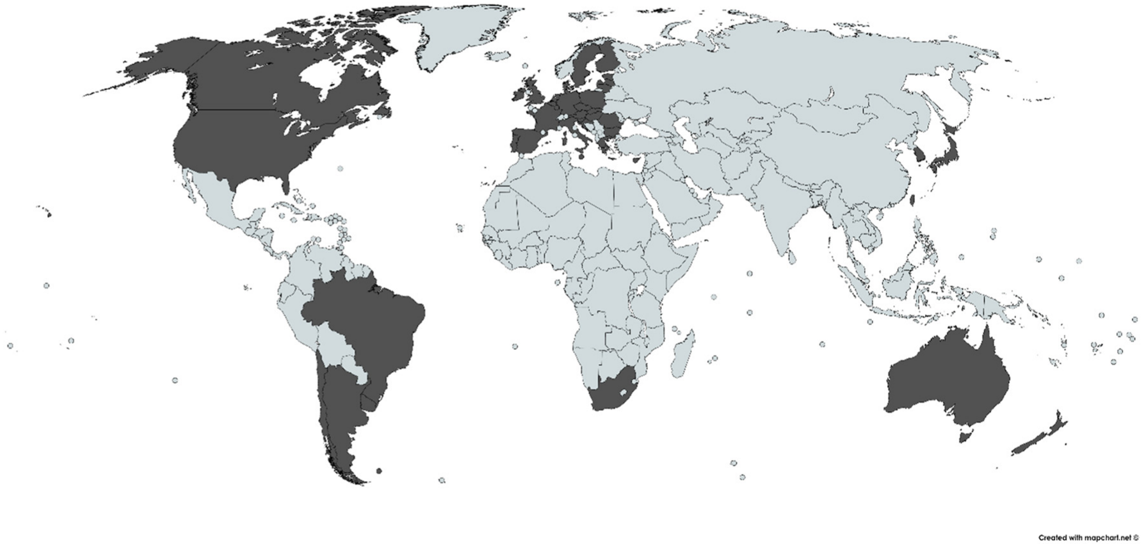

Fig. 1. States or other entities that have developed an NPOA (dark grey).

their jurisdiction. Of these, 24 completed an assessment to determine if they needed to implement an NPOA, of which 17 found they did (FAO, 2014). A further 25 countries reported that they were planning to conduct an assessment. Despite this recognition, at least 3 states identified the need to develop a NPOA but have not done so, and a further 43 have not yet conducted an assessment. The COFI survey only reviewed development of a NPOA in relation to longline fisheries in 2014, but 46 states also indicated they had trawl or gillnet fisheries. In this review, we consider the 16 NPOA or NPOA-like documents (hereafter NPOAs) available from 14 states or other entities: 11 countries, one overseas territory, one fishing entity and one political union which represents 28 countries (Fig. 1) (Chile, 2007; Commonwealth of Australia, 2014; Consejo Federal Pesquero, 2010; Cooper et al., 2008; Department of Agriculture and Water Resources, 2018; European Commission, 2012; Fisheries Agency, 2009, 2014; Government of Canada, 2007; Instituto Chico Mendes de Conservação da Biodiversidade (ICMBIO), 2018; Janzen et al., 2011; Jiménez et al., 2015; Kuepfer et al., 2018; Marques et al., 2017; Ministry for Primary Industries, 2013; Ministry of Oceans and Fisheries, 2014; National Marine Fisheries Service, 2001). There was more than one NPOA available for both Australia and the Falkland Islands.

3.2. Identifying the problem

States with NPOAs used a mix of approaches to identify if a seabird bycatch problem exists, either at a national or fishery-specific level. Most (88%) NPOA documents mentioned that expert workshops or a qualitative judgement (some based on quantitative information such as bycatch rates or numbers from logbooks or observer programs) were used to determine whether a problem existed in one or more fisheries (Table 1).

Three states indicated a semi-quantitative approach to assessment; in each of these three cases, this was in addition to qualitative approaches (Table 1). Three NPOA documents referenced the application of a fully quantitative approach for one or more species, involving population modelling or calculation of Potential Biological Removal. In these three cases, quantitative techniques were used together with a qualitative approach.

We recorded the use of explicit criteria for identification of a bycatch problem for four NPOAs (Table 1). Others indicated that they set out criteria, such as magnitude of bycatch or conservation status of species but were not specific in terms of how they were applied. These NPOAs had sometimes involved risk assessments to identify problems in specific fisheries or with specific seabird populations or species but did not refer to an explicitly-defined methodology.

3.3. Setting management objectives

Most (94%) of NPOAs included an overarching objective that related to reducing, avoiding or minimising seabird bycatch, though only 27% of these were specific and measurable (Table 1). The four NPOAs with specific, measurable objectives included linking the objective to a specific bycatch rate (number of bird mortalities per effort) or achieving zero bycatch.

Ten documents had specified an objective relating to fisheries impacts on a seabird population but only New Zealand's NPOA had a specific, measurable objective (Table 1). The latter was that "*The level of mortality of New Zealand seabirds in New Zealand commercial fisheries are reduced so that species currently categorised as at very high or high risk from fishing move to a lower category of risk*" (Ministry for Primary Industries, 2013). This is explicitly linked to an annual risk assessment.

3.4. Determining thresholds for management action

Some (19%) of NPOAs explicitly set out thresholds that would trigger a management response (Table 2). A bycatch rate (0.05 birds/1000 hooks for Chile, 0.05 birds/1000 hooks for Australian tuna and billfish fisheries and 0.01 birds/1000 hooks in all other Australian Commonwealth longlines) was used as such a threshold in two NPOAs — Chilean NPOA and the Australian Threat Abatement Plan — but neither specifically referred to an overall population objective (Chile, 2007; Commonwealth of Australia, 2014).

In the USA NPOA, a threshold may be set for fisheries where an advisory committee recommends that a management action is needed, such as for short-tailed albatross *Phoebastria albatrus* in the Alaska groundfish fisheries (Finkelstein et al., 2010; US FWS, 2015). This is the only example of a threshold linked to a population objective and was set using expert advice based on population modelling.

4. Discussion

Many states appear to be ignoring their responsibility to develop an NPOA. This includes states which identified they had a bycatch problem in the 2014 COFI survey. Moreover, several states without an implemented NPOA, including Angola, Namibia and Peru, manage fisheries identified by ACAP as high conservation priorities, i.e., where

Table 1
Methods for identifying seabird bycatch problem and types of objectives in NPOAs. "✓" indicates NPOA has used that method or objective. "ED" indicates both that the NPOA has used that method and that the criteria used in the method are explicitly defined. "SM" indicates objective used is specific and measurable.

NPOA (fishery or other detail)	Method type				Objective type		Reference
	Qualitative method	Semi-quantitative method	Quantitative method	Method not identified	Bycatch Reduction objective	Population objective	
Argentina	✓				✓		Consejo Federal Pesquero, 2010
Australia	✓				✓	✓	Department of Agriculture and Water Resources, 2018
Australia (TAP)	ED				SM		Commonwealth of Australia, 2014
Brazil	✓	ED			✓	✓	ICMBIO, 2018; Marques et al., 2017
Canada	✓		✓		✓		Government of Canada, 2007
Chile	✓				SM	✓	Chile, 2007
European Union	✓				✓	✓	European Commission, 2012
Falkland Islands (Longline)	✓				SM	✓	Janzen et al., 2011
Falkland Islands (Trawl)	✓				✓	✓	Kuepfer et al., 2018
Japan				✓	✓		Fisheries Agency, 2009
New Zealand	✓	ED	ED		✓	SM	Ministry for Primary Industries, 2013
South Africa	✓				SM	✓	Cooper et al., 2008
South Korea	✓				✓		Ministry of Oceans and Fisheries, 2014
Taiwan				✓		✓	Fisheries Agency, 2014
United States of America	✓				✓	✓	National Marine Fisheries Service, 2001
Uruguay	✓	ED	ED		✓		Jiménez et al., 2015

management needs to be improved in order to reduce impacts on globally important populations of albatrosses and petrels (Phillips et al., 2016). There are also high levels of bycatch in gillnet fisheries in other states without an NPOA, including Greenland, Iceland, Norway and Russia (Zydelis et al., 2013).

The main objective of this review was to identify a best-practice management framework for identifying and managing seabird bycatch. Although we did not identify one consistent best-practice framework adopted in all NPOAs, there were elements of common practice that could be applied more widely to improve fisheries management (Supplement Table S1). These are discussed below.

4.1. Identifying the problem

Most NPOAs used qualitative approaches and did not outline explicit criteria to identify what constitutes a bycatch problem at national level, or for particular species or fisheries. Where explicit criteria were outlined, they included use of a bycatch rate (Australia Threat Abatement Plan) or a semi-quantitative or fully quantitative risk assessment (New Zealand and Uruguay). However, in one case where a fully quantitative assessment was undertaken for a seabird species, the criteria for determining if the level of bycatch constituted a problem was not detailed in the NPOA itself (Canada).

Drawbacks to a qualitative approach include a lack of information to make an informed choice on the appropriate level of risk, e.g. little information on the consequence of fishery interactions for a particular species, or the potential lack of expertise of the participants. One potential solution is a systematic survey to collate population estimates from relevant scientific experts, e.g. a Delphi survey of experts, used to analyse and increase accuracy of population estimates for New Zealand seabirds and marine mammals (Abraham et al., 2016, 2017). When there is no defined methodology, it is much more difficult to achieve consistency across management approaches. This lack of consistency is also present among NPOAs for other marine megafauna, e.g. shark NPOAs independently resulting in binding regulations, non-binding measures and shark fin measures (Fischer et al., 2012). In general, NPOAs should be more explicit in identifying a bycatch problem by applying one or more risk assessment methodologies.

Ecological risk assessments are often defined in relation to the probability that an objective is not being achieved and can include a range of qualitative to quantitative methods (e.g. Hobday et al., 2011; Tuck et al., 2011). Small et al. (2013) reviewed risk assessments for fishery impacts on seabirds used by states as well as RFMOs. Each risk assessment method used slightly different approaches in terms of species selected, definition of risk, attributes selected for productivity and selectivity, and how uncertainty was incorporated into the assessment process. Despite these differences potentially leading to diverse outcomes, the authors identified many benefits of risk assessments, including the identification of seabird species or populations, regions, seasons and fisheries where risk of impact is higher.

In general, qualitative and semi-quantitative risk assessment approaches are less time-consuming, and hence more cost-effective than a fully quantitative assessment, and rely on fewer data. They are also flexible as attributes can be changed depending on the species or fishery, repeatable in that there is a clearly defined methodology, and iterative in that they can be updated when new information becomes available (Hobday et al., 2011). Hence, they are probably the most efficient tools for explicitly identifying if there is a risk that fisheries are negatively impacting seabird populations. However, as the risk outputs are relative rather than absolute, they cannot be used to track progress over time or establish thresholds or cut-offs for management response (Small et al., 2013).

Fully quantitative risk assessments require reliable data, particularly on biology and ecology of the non-target species. This may include demographic data such as estimates of adult survival (optimal, i.e. in the absence of fishing, rather than actual), population size, age at first

Table 2
Threshold types used to trigger management action and links to population objectives. "✓" indicates NPOA has link to population objective.

NPOA	Threshold type	Link to population objective	Reference
Australia (Threat Abatement Plan)	Bycatch rate		Commonwealth of Australia, 2014
Chile	Bycatch rate		Chile, 2007
United States of America	Incidental take allowance/expert advice	✓	National Marine Fisheries Service, 2001

breeding, breeding success, at-sea distribution (spatial and temporal), fishing effort or bycatch data (Jiménez et al., 2012; Sharp, 2017; Wiese and Smith, 2003). If some information is not available, substitutions are usually made from other ecologically similar or closely-related species. Advantages to fully quantitative approaches include that they provide absolute outcomes, allowing tracking of progress against management objectives. The models may also enable consideration of environmental stochasticity or demographic factors such as age or sex. Finally, uncertainty can be explicitly accounted for in models (e.g. Anderson et al., 2008; Caswell et al., 1998; Lewison and Crowder, 2003; Phillips et al., 2016 and references therein, Sharp, 2017; Veran et al., 2007; Wallace et al., 2013; Zador et al., 2008). Ensuring that any assumptions and uncertainties are explicitly defined is very important as the results are often assumed to be certain and definitive by managers wanting to use the information directly or stakeholders who may not appreciate the model limitations (Lonergan et al., 2017; Tuck et al., 2011).

Some applications of PBR do not explicitly account for uncertainty. Instead, precaution is built-in by selection of a conservative population size, e.g. 20% of population size, or the use of a recovery factor, which can be set at a lower value for species of higher conservation concern (Wade, 1998; Jiménez et al., 2012). The Spatially Explicit Fisheries Risk Assessment (SEFRA) developed by New Zealand is unique (compared with other PBR-like methods) in that it includes explicit treatment of uncertainty, so it is possible to distinguish between results that have high impact and low uncertainty from those where there is high uncertainty and unknown impact (Lonergan et al., 2017; Sharp, 2017).

Care may need to be taken with the application of PBR in a management setting where there are limited demographic data, as use of 'rule of thumb' multipliers for seabird species can have wide bounds (Dillingham and Fletcher, 2011). In addition, the PBR method contains some implicit assumptions, including about density dependence and population trajectory, that may not fit well with actual population dynamics (O'Brien et al., 2017). Indeed, a comparison of PBR and Leslie matrix models by O'Brien et al. (2017) showed that in some cases (e.g. population already declining, weak compensatory density-dependence) removing the number of seabirds that in theory was acceptable according to PBR could nevertheless lead to further population decline. An ICES Workshop to review and advise on seabird bycatch recommended that PBR be used only as an initial assessment tool to identify mortality levels that could be unsustainable, because the assumptions of PBR have not been widely tested in birds (ICES, 2013). The choice of recovery factor is arguably the most influential input in a PBR. A recent study found that changing the recovery factor from 0.5 to 1 led to an underestimate of the impact of fisheries bycatch by a factor of 2 (Bakker et al., 2018). In the case of the New Zealand SEFRA, the PBR has been modified and integrated into a Bayesian model that takes uncertainty into account and does not use a recovery factor, so results should provide a more accurate measure of risk (Sharp, 2017). Finally, with PBR, the results are based on the total additional mortality that can be sustained by the population; this is not just from fisheries of that nation, region or even in total. Although a PBR should allow managers to determine if a fishery in isolation is having an unsustainable impact, even if the level of that bycatch is within the limit, uncertainty associated with impacts of other fisheries or threats, and the potential for cumulative effects, are not taken into consideration.

Currently, most states or jurisdictions that developed an NPOA adopted their own approaches to identify what constitutes a seabird bycatch problem. This has allowed NPOAs to evolve independently and be applied adaptively but has the disadvantage that there are very different thresholds used to assess impacts, and expectations. As most seabirds are highly migratory, crossing multiple national jurisdictions, often spending extensive periods in the High Seas and interacting with many types of fishing activities (Phillips et al., 2016), there would clearly be many advantages to developing the framework for a more consistent approach.

4.2. Setting management objectives

Although most NPOAs include objectives to reduce, avoid or minimise bycatch of seabirds, only some were specific and measurable. Those that only specified reduction or minimisation objectives should make these more explicit by including a maximum acceptable bycatch rate or total, particularly in the short term, and an overall objective to minimise bycatch to below an agreed target level. Bycatch rates allow a practical target for reducing bycatch but may not be the most useful method for assessing whether management objectives are achieved because even low bycatch can still have an impact on a population, or the low rate could be the result of past declines that reduced the abundance of a population (Tuck, 2011). Hence, where bycatch rates are used, they should be in the context of population-specific targets or be based on modelling approaches that determine if reducing the bycatch rate to below a particular level would result in a favourable outcome for the population. Bycatch rates should also be adjustable over time, to account for changes in effort in the fishery, and fishing effort itself should be monitored.

A population-specific objective provides context and the ability to define specific actions to achieve that goal. Only the New Zealand NPOA contained a population objective that was specific and measurable. The other NPOAs that specified a population objective used qualitative expressions such as “not jeopardising viability,” “ensuring sustainability,” or “achieving a favourable conservation status.” It was noted for the Australia Threat Abatement Plan that a population objective was not specified in the document. However, its implementation is closely tied to the National recovery plan for threatened albatrosses and giant petrels, which does contain a population objective to ensure the long-term survival and recovery of albatross and giant petrel populations…by reducing or eliminating human related threats on sea and land, although it is not specific (DSEWPC, 2011). NPOAs for other states may also link to national policies that provide population objectives. However, in most cases, population objectives were not defined, and even where they were – Australia's NPOA defines favourable conservation status – they were not specific or measurable. This may be due to the lack of an agreed definition of the maximum sustainable level of impact on seabird populations, perhaps to allow for flexibility in approaches or because there is little political will to establish an allowable mortality for charismatic species. This lack of definition is also present in NPOAs for sharks (Fischer et al., 2012).

The New Zealand NPOA was also the only document reviewed that explicitly linked a population objective to the use of a risk assessment framework (the SEFRA), which has the advantage of allowing an absolute value of risk to be monitored to determine if the goal of moving a species from high to lower risk levels is achieved. The SEFRA also explicitly identifies a population target in its Population Sustainability Threshold (PST), defined as 95% probability that a species will recover to at least 50% carrying capacity in 200 years in the presence of ongoing human-caused mortalities, and environmental and demographic stochasticity (Sharp, 2017). This percentage of carrying capacity and timeframe selected were based on the approach used in the US for marine mammal bycatch and simulations undertaken for NZ seabird populations (Richard and Abraham, 2013). Further modelling to test the appropriateness of the percentage of carrying capacity and of the timeframe for recovery for long-lived, K-selected seabirds such as albatrosses and petrels in different management contexts would be useful. Also, it is important to ensure that the methodology for estimating risk remains the same over time so that such progress can be tracked.

The issue of setting a quantitative population objective has been more widely considered with regard to bycatch in fisheries of marine mammals. The US Marine Mammal Protection Act (MMPA) sets as its objective an 'Optimal Sustainable Population' with reference to population levels that are not depleted, and the term Maximum Net Productivity Level (MNPL) is often the lowest point of this range (Lonergan, 2011). Populations are considered depleted if estimated to be below MNPL, or below 50–70% of a historical population size representing carrying capacity (Gerrodette and DeMaster, 1990). The setting of quantitative population objectives in the US MMPA also allows the results of any measures implemented to be evaluated (McDonald et al., 2015).

The International Whaling Commission (IWC) Revised Management Procedure (RMP) sets a population goal that differs from the US MMPA, aiming to maintain populations of cetaceans at 72% of their carrying capacity (Lonergan, 2011). This was selected as a conservative value from simulations that showed that 'maximum sustainable yield', the amount that could be harvested sustainably, for large cetaceans occurs at 60% carrying capacity. Under the Agreement on the Conservation of Small Cetaceans of the Baltic, North East Atlantic, Irish and North Seas (ASCOBANS), the interim population objective for harbour porpoise *Phocoena phocoena* is to restore populations to, or maintain them at, 80% or more of carrying capacity (IWC, 2000). These differences in population goals reflect the political nature of setting thresholds and the balances that need to be struck. The population threshold in the NZ SEFRA is commensurate with the implicit population objective in PBR approaches as designed by Wade (1998) for marine mammals but has not been specifically evaluated to determine its appropriateness for seabirds.

There are other practical considerations when setting a population-level objective. Where there are many populations at risk, it may not be feasible to evaluate the status of each one. To ensure, however, that declines of less common species are not masked, risk-based assessments may be used to prioritise species for evaluation. Also, a population-specific objective may not be applicable in all situations – some states have no breeding populations of the seabird species (e.g. albatrosses or petrels) that are most impacted by their fisheries, or the provenance of the bycatch is unknown. In such cases, thresholds linked to ensuring that the fishery is not responsible for hindering population growth, e.g. through appropriate risk assessment, may be more appropriate, or regional approaches to setting objectives could be undertaken (Waugh et al., 2008). A specific threshold linked to population status will be different in different fisheries, so there is no one-size-fits-all approach. However, the potential for the fishery to impact a population should be considered when determining the need to take management action. Further examples of good practice are highlighted in Supplemental information (Table S1).

Setting quantifiable objectives requires adequate monitoring to be in place to determine if the objective is being met, monitoring performance in relation to thresholds and linking mortalities to impacts on populations (Phillips, 2013; Phillips et al., 2016). Bycatch of marine megafauna is often a rare event, meaning robust estimations of bycatch rates for many species is a challenge (Jiménez et al., 2012; Komoroske and Lewison, 2015; Rivalan et al., 2010). Bycatch rates depend on a complex interaction of temporal, spatial, operational, environmental and ecological factors, and as a consequence are highly variable (Delord et al., 2010; Gomez Laich et al., 2006; Klaer and Polacheck, 1998; Lewison et al., 2014). At-sea distribution of seabirds, for example, influences sex and age biases in the bycatch of some seabird species (Gianuca et al., 2017). In addition, many fisheries do not have a robust form of monitoring, such as observer coverage or electronic monitoring, or have a low sampling effort. For example, an analysis of the variability in precision of the bycatch estimate for the European tropical tuna purse-seine fleet operating in the Indian Ocean showed that observer coverage of < 5% resulted in large uncertainties in bycatch estimates by species (Amandè et al., 2012). Further, Amandè et al. (2012) determined that the current level of observer coverage was insufficient to give reliable bycatch estimates for species that are not frequently caught (e.g. marine turtles, pelagic sharks). Identification of bycatch to population or even species level is also a challenge that highlights the importance of dedicated seabird observers on board vessels, or electronic monitoring systems set up to capture such interaction and adequate analysis of the resulting footage (Bugoni et al., 2008; Pierre, 2018).

4.3. Determining thresholds for management action

Challenges to the successful implementation of the bycatch mitigation measures necessary to reduce seabird bycatch include lack of governance (especially on the high seas), lack of political will, lack of industry buy-in and support, insufficient resources and insufficient monitoring and enforcement (Dias et al., 2019; Gilman, 2011; Melvin et al., 2019; Phillips, 2013). The development of quantitative thresholds can enable prioritisation of action, provide evidence of impact, build stakeholder support and political will, and allow fisheries managers to evaluate if conservation goals are being met (Moore et al., 2013). Even if quantitative thresholds are not set, risk assessments can be used to trigger management action. In both cases, thresholds are important to ensure a management response is triggered when this is appropriate and necessary (Small et al., 2013).

As noted above, several NPOAs included reduction of bycatch below an identified rate as a specific objective. However, most were not explicit about management responses for fisheries that met or exceeded this rate. The two NPOAs with a bycatch rate threshold that triggered a management response were the Threat Abatement Plan of Australia and NPOA of Chile. The Australian Threat Abatement Plan is the most explicit about the management responses required by a fishery that exceeds the prescribed bycatch rate in one or successive seasons (Commonwealth of Australia, 2014). The Chilean NPOA states that mitigation measures agreed or to be developed will be applied in any fishery where the mortality of seabirds is > 0.05 birds/1000 hooks (Chile, 2007). In the Falkland Islands longline NPOA and South African NPOA, a bycatch threshold objective was stated, and management measures associated with exceeding that threshold were mentioned, but it was not clear what those measures would involve (Cooper et al., 2008; Janzen et al., 2011).

None of the NPOAs with bycatch thresholds as objectives established how the rates linked to the overarching population objectives. As noted above, even low levels of bycatch of some species could have severe negative consequences. However, approaches such as Management Strategy Evaluation or other simulation testing could be used to test population responses to the management action (Butterworth and Punt, 1999; Moore et al., 2013; Sainsbury et al., 2000). The US was the only state in this review where a threshold that triggered management action, e.g. closing an area or fishery; requiring additional mitigation measures, was linked to the population objective. The US NPOA requires relevant management authorities and fisheries representatives to work together to develop measures in fisheries where a bycatch problem has been identified. For short-tailed albatross, this involved experts comparing a population model with current estimated captures and quantifying the bycatch limit (number of birds over time) in the fishery (US FWS, 2015). This links to the population-specific objective of ensuring that the level of seabird take is below the level that would have a measurable negative effect on the population. There is thus a link between a threshold set and a population objective, both based on quantitative analysis.

The New Zealand SEFRA incorporates Bayesian approaches to modelling the absolute risk, and allows for adaptive management, including conservation measures adopted by New Zealand to minimise risk to species, such as prohibition on use of net-sonde cables (monitoring or “third wires”) in trawl fisheries, and deployment of seabird-scaring devices (Ministry for Primary Industries, 2013; Richard et al., 2017). Despite this framework, the NZ NPOA does not specifically link the absolute risk thresholds to explicit management responses. Outside the seabird context, thresholds have been estimated for marine mammals under the US MMPA, IWC and ASCOBANS (Lonergan, 2011; Moore et al., 2013; Wade, 1998). For example, PBR is used in the MMPA as a threshold that triggers management review. It is assumed that if bycatch is below PBR, then implicitly the goal of maintaining populations above MNPL will be achieved (Moore et al., 2013).

Finally, it is important when considering seabird bycatch thresholds to recall the need to minimise mortality of other non-target species, such as sea turtles, marine mammals or fish, as set out in the FAO Code of Conduct for Responsible Fisheries (FAO, 1995). So even where bycatch or population objectives are specified for seabirds, this should not prevent management authorities and fisheries operators from further minimising mortalities of other taxa. Any unintended consequences of reducing mortality of one taxon at expense of another should be considered, for example through holistic bycatch assessment and management (Gilman et al., 2019).

5. Conclusions

Based on a review of 16 NPOAs, we found no consistently adopted best practice for defining a bycatch problem, setting objectives or identifying specific thresholds for managing impacts of fisheries on seabirds. However, we identified the following elements of common practice – and some examples of their implementation that could be incorporated into a best-practice management framework for assessing and managing risks:

(1) defining explicit risk criteria and methods to determine whether a seabird bycatch problem exists (e.g. applying the SEFRA approach (Sharp, 2017) to identify populations at risk from fisheries interactions);
(2) setting specific and measurable objectives for minimising bycatch and achieving desired population status (e.g. setting objective that bycatch is reduced to a level that ensures that populations are maintained at low risk levels, as defined in the SEFRA, or moved from high risk categories to lower risk); and.
(3) defining fishery-specific thresholds to trigger agreed management action linked to the population objective (e.g. setting bycatch limit (x birds/year) based on modelling effects of these fishery removals on specific high-risk populations identified in the SEFRA and requiring application of additional mitigation measures when this threshold is reached).

Consistent adoption of NPOA best practice would help to mitigate bycatch threat and maintain seabird populations at a sustainable level. Development and implementation of an NPOA following our recommendations should be a priority in all countries with fisheries in which bycatch is a threat to seabirds, including as a minimum those which acknowledged this problem in the COFI survey, that manage fisheries identified by ACAP as high conservation-management priorities for safeguarding albatrosses and petrels (Phillips et al., 2016), or that are known to have high levels of seabird bycatch in gillnet fisheries (Zydelis et al., 2013). In addition, we recommend that a framework, including appropriate criteria, monitoring programmes, plans for analysis are in place to measure the success of the NPOA against its objectives.

A number of topics were identified in this review that would benefit from further consideration or case studies. For example, although having a population-specific objective is clearly important, there is no consensus on the level and timeframe at which this should be set, so work is therefore needed to identify appropriate levels and timeframes, bearing in mind that this is often a political or ethical decision. Another area that would benefit from additional investigation is in the choice and performance of different methods used as the basis of seabird risk assessments. Given the highly migratory nature of seabirds, global risk assessments of fisheries impacts should be prioritised (e.g. Baker et al., 2007; Clay et al., 2019). The FAO IPOA-s, and hence NPOAs focus only on fishery impacts, but there is a need for more all-encompassing approaches to estimate and mitigate cumulative impacts of bycatch on threatened species. These need to take better account of the many other threats to seabird populations, some of which – such as climate change – are considerably less tractable than fisheries bycatch (Dias et al., 2019; Phillips et al., 2016).

Role of the funding source

This work was supported in part by the Marine Stewardship Council (MSC). The MSC, through a co-author, Matt Gummery, provided expertise on non-seabird taxa and was involved in the design of the study and drafting of the manuscript.

CRediT authorship contribution statement

S.D. Good: Conceptualization, Methodology, Investigation, Writing - original draft, Writing - review & editing, Visualization. **G.B. Baker:** Methodology, Investigation, Writing - review & editing. **M. Gummery:** Conceptualization, Investigation, Writing - review & editing, Visualization. **S.C. Votier:** Conceptualization, Writing - review & editing, Supervision. **R.A. Phillips:** Conceptualization, Writing - review & editing, Supervision.

Declaration of competing interest

None of the authors have any actual or potential conflict of interest, including any financial, personal or other relationships with other people or organisations within three years of beginning the submitted work that could inappropriately influence, or be perceived to influence their work.

Acknowledgements

We are grateful for constructive comments and information provided by Patricia Pereira Serafini, Sebastian Jiménez, John Cooper, Nigel Brothers, Anton Wolfaardt, Gabriela Navarro, Johan De Goede and Jonathon Barrington. This work represents a contribution to the Ecosystems component of the British Antarctic Survey Polar Science for Planet Earth Programme, funded by the Natural Environment Research Council.

Appendix A. Supplementary information

Supplementary data to this article can be found online at https://doi.org/10.1016/j.biocon.2020.108592.

References

Abraham, E.R., Richard, Y., Clements, K., 2016. Evaluating threats to New Zealand seabirds. In: Report for the Department of Conservation, Available at. https://www.doc.govt.nz/about-us/science-publications/, Accessed date: 13 November 2018.

Abraham, E.R., Neubauer, P., Berkenbusch, K., Richard, Y., 2017. Assessment of the risk to New Zealand marine mammals from commercial fisheries. In: New Zealand Aquatic Environment and Biodiversity Report. 189.
ACAP, 2017. ACAP review and best practice advice for reducing the impact of pelagic longline fisheries on seabirds. In: Reviewed at the Tenth Meeting of the Advisory Committee Wellington, New Zealand 11–15 September 2017.
Agnew, D.J., Gutiérrez, N.L., Stern-Pirlot, A., Hoggarth, D.D., 2014. The MSC experience: developing an operational certification standard and a market incentive to improve fishery sustainability. ICES J. Mar. Sci. 71, 216–225.
Amandè, M.J., Chassot, E., Chavance, P., Murua, H., Delgado de Molina, A., Bez, N., 2012. Precision in bycatch estimates: the case of tuna purse-seine fisheries in the Indian Ocean. ICES J. Mar. Sci. 69 (8), 1501–1510.
Anderson, D.J., Huyvaert, K.P., Awkerman, J.A., Proano, C., Milstead, W.B., Jimenez-Uzcategui, G., Cruz, S., Grace, J.K., 2008. Population status of the critically endangered waved albatross Phoebastria irrorata, 1999 to 2007. Endanger. Species Res. 5 (2), 185–192.
Anderson, O.R.J., Small, C.J., Croxall, J.P., Dunn, E.K., Sullivan, B.J., Yates, O., Black, A., 2011. Global seabird bycatch in longline fisheries. Endanger. Species Res. 14, 91–106.
Baker, G.B., Finley, L.A., 2010. The 2008 National Assessment Report for Reducing the Incidental Catch of Seabirds in Longline Fisheries. Bureau of Rural Sciences, Canberra.
Baker, G.B., Wise, B., 2005. The impact of pelagic longline fishing on the flesh-footed shearwater *Puffinus carneipes* in eastern Australia. Biol. Conserv. 126, 306–316.
Baker, G.B., Double, M.C., Gales, R., Tuck, G.N., Abbott, C.L., Ryan, P.G., Petersen, S.L., Robertson, C.J.R., Alderman, R., 2007. A global assessment of the impact of fisheries-related mortality on shy and white-capped albatrosses: conservation implications. Biol. Conserv. 137, 319–333.
Bakker, V.J., Finkelstein, M.E., Doak, D.F., VanderWerf, E.A., Young, L.C., Arata, J.A., Sievert, P.R., Vanderlip, C., 2018. The albatross of assessing and managing risk for long-lived pelagic seabirds. Biol. Conserv. 217, 83–95.
Beggren, P., Wade, P.R., Carlstrom, J., Read, A., 2002. Potential limits to anthropogenic mortality for harbour porpoises in the Baltic region. Biol. Conserv. 103 (3), 313–322.
Bugoni, L., Mancini, P.L., Monteiro, D.S., Nascimento, L., Neves, T.S., 2008. Seabird bycatch in the Brazilian pelagic longline fishery and a review of capture rates in the southwestern Atlantic Ocean. Endangered Species Res 5, 137–147.
Butterworth, D.S., Punt, A.E., 1999. Experiences in the evaluation and implementation of management procedures. ICES J. Mar. Sci. 56, 985–998.
Caswell, H., Brault, S., Read, A.J., Smith, T.D., 1998. Harbour porpoise and fisheries: an uncertainty analysis of incidental mortality. Ecol. Appl. 8 (4), 1226–1238.
Chile, 2007. Plan de Acción Nacional de Chile para mitigar efectos de la pesca de palangre sobre Aves Marinas (PAN-AM) (FIP 2003–21: Informe Final). Fondo Investagacion Pesquera & Universidad de Austral de Chile.
Clay, T.A., Small, C., Tuck, G.N., Pardo, D., Carneiro, A.P.B., Wood, A.G., Croxall, J.P., Crossin, G.T., Phillips, R.A., 2019. A comprehensive large-scale assessment of fisheries bycatch risk to threatened seabird populations. J. Appl. Ecol. 56 (8), 1882–1893.
Commonwealth of Australia, 2014. Threat Abatement Plan 2014 for the Incidental Catch (or Bycatch) of Seabirds During Oceanic Longline Fishing Operations. Department of the Environment, Canberra.
Consejo Federal Pesquero, 2010. Plan Nacional Para Reducir la Interacción de Aves con Pesquerías en la República Argentina.
Cooper, J., 2019. National plans of action - seabirds. https://www.acap.aq/en/resources/management-plans/1690-npoa-seabirds, Accessed date: 27 June 2019.
Cooper, J., Petersen, S., Ryan, P.G., 2008. South African National Plan of Action for Reducing the Incidental Catch of Seabirds in Longline Fisheries. Department of Environmental Affairs & Tourism.
Curtis, K.A., Moore, J.E., 2013. Calculating reference points for anthropogenic mortality of marine turtles. Aquat. Conserv. Mar. Freshwat. Ecosyst. 23, 441–459.
Delord, K., Gasco, N., Barbraud, C., Weimerskirch, H., 2010. Multivariate effects on seabird bycatch in the legal Patagonian toothfish longline fishery around Crozet and Kerguelen Islands. Polar Biol. 33 (3), 367–378.
Department of Agriculture and Water Resources, 2018. National Plan of Action for Minimising the Incidental Catch of Seabirds in Australian Capture Fisheries. (Canberra).
Department of Sustainability, Environment, Water, Population and Communities (DSEWPC), 2011. National Recovery Plan for Threatened Albatrosses and Giant Petrels 2011–2016. Commonwealth of Australia, Hobart.
Dias, M.P., Martin, R., Pearmain, E.J., Burfield, I.J., Small, C., Phillips, R.A., Yates, O., Lascelles, B., Borboroglu, P.G., Croxall, J.P., 2019. Threats to seabirds: a global assessment. Biol. Conserv. 237, 525–537.
Dillingham, P.W., Fletcher, D., 2011. Potential biological removal of albatrosses and petrels with minimal demographic information. Biol. Conserv. 144 (6), 1885–1894.
European Commission, 2012. Communication From the Commission to the European Parliament and the Council. Action Plan for Reducing Incidental Catches of Seabirds in Fishing Gears COM/2012/0665.
FAO, 1995. Code of Conduct for Responsible Fisheries. FAO, Rome.
FAO, 1999. International Plan of Action for Reducing Incidental Catch of Seabirds in Longline Fisheries. FAO, Rome.
FAO, 2009. Fishing operations. 2. Best practices to reduce incidental catch of seabirds in capture fisheries. In: FAO Technical Guidelines for Responsible Fisheries: No. 1, Suppl. 2. FAO, Rome (49 pp.).
FAO, 2014. Progress in the implementation of the FAO code of conduct for responsible fisheries and related instruments. In: Committee on Fisheries (COFI) 31st Session. FAO, Rome (COFI/2014/Inf.15/Rev.1).
Finkelstein, M.E., Wolf, S., Doak, D.F., Sievert, P.R., Balogh, G., Hasegawa, H., 2010. The anatomy of a (potential) disaster: volcanoes, behaviour and population viability of the short-tailed albatross (*Phoebastria albatrus*). Biol. Conserv. 143, 321–333.
Fischer, J., Erikstein, K., D'Offay, B., Guggisberg, S., Barone, M., 2012. Review of the implementation of the international plan of action for the conservation and management of sharks. In: FAO Fisheries and Aquaculture Circular No. 1076.
Fisheries Agency, 2009. Japan's National Plan of Action for Reducing Incidental Catch of Seabirds in Longline Fisheries Revised Version. Fisheries Agency, Government of Japan 8 pp.
Fisheries Agency, 2014. National Plan of Action for Reducing Incidental Catch of Seabirds in Tuna Longline Fisheries. Fisheries Agency, Council of Agriculture, Taiwan (104 pp).
Geijer, C.K.A., Read, A.J., 2013. Mitigation of marine mammal bycatch in U. S. fisheries since 1994. Biol. Conserv. 159, 54–60.
Gerrodette, T., DeMaster, D.P., 1990. Quantitative determination of optimum sustainable population level. Marine Mammal Science 6, 1–16.
Gianuca, D., Phillips, R.A., Townley, S., Votier, S.C., 2017. Global patterns of sex- and age-specific variation in seabird bycatch. Biol. Conserv. 205, 60–76.
Gilman, E., 2011. Bycatch governance and best practice mitigation technology in global tuna fisheries. Mar. Policy 35, 590–609.
Gilman, E., Chaloupka, M., Dagorn, L., Hall, M., Hobday, A., Musyl, M., Pitcher, T., Poisson, F., Restrepo, V., Suuronen, P., 2019. Robbing Peter to pay Paul: replacing unintended cross-taxa conflicts with intentional tradeoffs by moving from piecemeal to integrated fisheries bycatch management. Rev. Fish Biol. Fish. 29 (1), 93–123.
Gomez Laich, A., Favero, M., Mariano-Jelicich, R., Blanco, G., Cañete, G., Arias, A., Silva Rodriguez, P., Brachetta, H., 2006. Environmental and operational variability affecting the mortality of black-browed albatrosses associated with long-liners in Argentina. Emu - Austral Ornithology 106 (1), 21–28.
Government of Canada, 2007. National Plan of Action for Reducing the Incidental Catch of Seabirds in Longline Fisheries. Fisheries and Oceans Canada, Ottawa.
Hobday, A.J., Smith, A.D.M., Stobutzki, I.C., Bulman, C., Daley, R., Dambacher, J.M., Deng, R.A., Dowdney, J., Fuller, M., Furlani, D., Griffiths, S.P., Johnson, D., Kenyon, R., Knuckey, I.A., Ling, S.D., Pitcher, R., Sainsbury, K.J., Sporcic, M., ... Zhou, S., 2011. Ecological risk assessment for the effects of fishing. Fisheries Research 108 (2–3), 372–384.
ICES, 2013. Report of the Workshop to Review and Advise on Seabird Bycatch. ICES, Copenhagen.
Instituto Chico Mendes de Conservação da Biodiversidade (ICMBIO), 2018. Plano de Ação Nacional para a Conservação dos Albatrozes e Petréis (PLANACAP) Ano 2018–2023 (3o ciclo). Instituto Chico Mendes de Conservação da Biodiversidade - ICMBio/MMA, Brasilia.
IWC, 2000. Report of the IWC-ASCBOANS working group on harbour porpoises. J. Cetacean Res. Manage 2 (Suppl), 297–305.
Janzen, K., Wolfaardt, A.C., Barton, J., Pompert, J., Brickle, P., 2011. Falkland Islands National Plan of Action for Reducing Incidental Catch of Seabirds in Longline Fisheries 2011–2015 an Update. Falkland Islands Government, Stanley (26 pp).
Jiménez, S., Domingo, A., Abreu, M., Brazeiro, A., 2012. Risk assessment and relative impact of Uruguayan pelagic longliners on seabirds. Aquat. Living Resour. 25 (4), 281–295.
Jiménez, S., Pin, O., Domingo, A., 2015. Plan de Acción Nacional para Reducir la Captura Incidental de Aves Marinas en las Pesquerías Uruguayas, 2015. In: Domingo, A., Forselledo, R., Jiménez, S. (Eds.), Revisión de Planes de Acción Nacional para la Conservación de Aves Marinas y Condrictios en las Pesquerías Uruguayas. Dirección Nacional de Recursos Acuáticos, Montevideo, pp. 11–79.
Klaer, N., Polacheck, T., 1998. Influence of environmental factors and mitigation measures on bycatch rates of seabirds by Japanese longline fishing vessels fishing in the Australian Region. Emu 98 (4), 305–316.
Komoroske, L.M., Lewison, R.L., 2015. Addressing fisheries bycatch in a changing world. Front. Mar. Sci. 2 (83).
Kuepfer, A., Crofts, S., Tierney, M., Blake, D., Goyot, L., 2018. Falkland Islands National Plan of Action for Reducing Incidental Catch of Seabirds in Trawl Fisheries, 2019 (FI NPOAS-T-2019). Fisheries Department, Directorate of Natural Resources, Falkland Islands Government, Stanley.
Lewison, R.L., Crowder, L.B., 2003. Estimating fishery bycatch and effects on a vulnerable seabird population. Ecol. Appl. 13 (3), 743–753.
Lewison, R.L., Crowder, L.B., Wallace, B.P., Moore, J.E., Cox, T., Zydelis, R., McDonald, S., DiMatteo, A., Dunn, D.C., Kot, C.Y., Bjorkland, R., Kelez, S., Soykan, C., Steward, K.R., Sims, M., Boustany, A., Read, A.J., 2014. Global patterns of marine mammal, seabird, and sea turtle bycatch reveal taxa-specific and cumulative megafauna hotspots. Proceedings of the National Academy of Sciences Apr 2014 111 (14), 5271–5276.
Lonergan, M., 2011. Potential biological removal and other currently used management rules for marine mammal populations: a comparison. Mar. Policy 35 (5), 584–589.
Lonergan, M.E., Phillips, R.A., Thomson, R.B., Zhou, S., 2017. Independent review of New Zealand's spatially explicit fisheries risk assessment approach – 2017. New Zealand Fisheries Science Review 2017, 2.
Marques, C., Sant-Ana, R., Gianuca, D., Neves, T., 2017. Ecological risk assessment of the Itaipava fleet, ES, Brazil, on albatrosses and petrels in the southwest Atlantic. In: Eighth Meeting of the Seabird Bycatch Working Group, Wellington, NZ 4–6 September 2017. SBWG8 Inf 28 Rev 1, (17 pp).
McDonald, S.L., Lewison, R.L., Read, A.J., 2015. Evaluating the efficacy of environmental legislation: a case study from the US marine mammal Take Reduction Planning process. Global Ecology and Conservation 5, 1–11.
Melvin, E.F., Dietrich, K.S., Suryan, R.M., Fitzgerald, S.M., 2019. Lessons from seabird conservation in Alaskan longline fisheries. Conserv. Biol. 33 (4), 842–852.
Ministry for Primary Industries, 2013. National Plan of Action – 2013 to Reduce the Incidental Catch of Seabirds in New Zealand Fisheries. Ministry for Primary

Industries, Wellington.
Ministry of Oceans and Fisheries, 2014. National Plan of Action for Reducing Incidental Catch of Seabirds in Longline Fisheries, Republic of Korea. (36 pp).
Moore, J.E., Curtis, K.A., Lewison, R.L., Dillingham, P.W., Cope, J.M., Fordham, S.V., Heppell, S.S., Pardo, S.A., Simpfendorfer, C.A., Tuck, G.N., Zhou, S., 2013. Evaluating sustainability of fisheries bycatch mortality for marine megafauna: a review of conservation reference points for data-limited populations. Environ. Conserv. 40 (4), 329–344.
National Marine Fisheries Service, 2001. Final United States National Plan of Action for Reducing the Incidental Catch of Seabirds in Longline Fisheries. National Marine Fisheries Service, Silver Spring.
O'Brien, S.H., Aonghais, S.C.P.C., Robinson, R.A., 2017. Implicit assumptions underlying simple harvest models of marine bird populations can mislead environmental management decisions. J. Environ. Manag. 201, 163–171.
Phillips, R.A., 2013. Requisite improvements to the estimation of seabird by-catch in pelagic longline fisheries. Anim. Conserv. 16, 157–158.
Phillips, R.A., Gales, R., Baker, G.B., Double, M.C., Favero, M., Quintana, F., Tasker, M.L., Weimerskirch, H., Uhart, M., Wolfaardt, A., 2016. The conservation status and priorities for albatrosses and large petrels. Biol. Conserv. 201, 169–183.
Pierre, J.P., 2018. Using Electronic Monitoring Imagery to Characterise Protected Species Interactions With Commercial Fisheries: A Primer and Review. Conservation Services Programme Project INT2017-02.
Richard, Y., Abraham, E.R., 2013. Application of potential biological removal methods to seabird populations. In: New Zealand Aquatic Environment and Biodiversity Report No. 108. Ministry of Primary Industries, Wellington.
Richard, Y., Abraham, E.R., Berkenbusch, K., 2017. Assessment of the risk of commercial fisheries to New Zealand seabirds 2006–07 to 2014–15. In: New Zealand Aquatic Environment and Biodiversity Report No. 191. MPI, Wellington.
Rivalan, P., Barbraud, C., Inchausti, P., Weimerskirch, H., 2010. Combined impacts of longline fisheries and climate on persistence of Amsterdam albatross *Diomedia amsterdamensis*. Ibis 152 (1), 6–18.
Sainsbury, K.J., Punt, A.E., Smith, A.D.M., 2000. Design of Operational management strategies for achieving fishery ecosystem objectives. ICES J. Mar. Sci. 57, 731–741.
Sharp, B.R., 2017. Spatially Explicit Fisheries Risk Assessment (SEFRA): a framework for quantifying and managing incidental commercial fisheries impacts on non-target species. In: Chapter 3 in: Aquatic Environment and Biodiversity Annual Review (AEBAR) 2017: A Summary of Environmental Interactions Between the Seafood Sector and the Aquatic Environment. Ministry for Primary Industries, New Zealand (724 pp).
Small, C., Waugh, S.M., Phillips, R.A., 2013. The justification, design and implementation of Ecological Risk Assessments of the effects of fishing on seabirds. Mar. Policy 37, 192–199.
Tear, T.H., Kareiva, Paul L., Angermeier, P.C., Czech, B., Kautz, R., Landon, L., Mehlman, D., Murphy, K., Ruckelshaus, M., Scott, J.M., Wilhere, G., 2005. How much is enough? The recurrent problem of setting measurable objectives in conservation. BioScience 55 (10), 835–849.
Tuck, G.N., 2011. Are bycatch rates sufficient as the principal fishery performance measure and method of assessment for seabirds? Aquatic Conservation Marine and Freshwater Ecosystems 21 (5), 412–422.
Tuck, G.N., Polacheck, T., Croxall, J.P., Weimerskirch, H., 2001. Modelling the impact of fishery by-catches on albatross populations. J. Appl. Ecol. 38, 1182–1196.
Tuck, G.N., Phillips, R.A., Small, C., Thomson, R.B., Klaer, N.L., Taylor, F., Wanless, R.M., Arrizabalaga, H., 2011. An assessment of seabird – fishery interactions in the Atlantic Ocean. ICES J. Mar. Sci. 68 (8), 1628–1637.
US FWS, 2015. Biological Opinion for the Effects of the Fishery Management Plans for the Gulf of Alaska and Bering Sea/Aleutian Islands Groundfish Fisheries and the State of Alaska Parallel Groundfish Fisheries. (Anchorage, AK. 49 pp).
Veran, S., Gimenez, O., Flint, E., Kendall, W.L., Doherty Jr., P.F., Lebreton, J.-D., 2007. Quantifying the impact of longline fisheries on adult survival in the black-footed albatross. J. Appl. Ecol. 44 (5), 942–952.
Wade, P.R., 1998. Calculating limits to the allowable human-caused mortality of cetaceans and pinnepeds. Marine Mammal Science 14 (1), 1–37.
Wallace, B.P., Kot, C.Y., DiMatteo, A.D., Lee, T., Crowder, L.B., Lewison, R.L., 2013. Impacts of fisheries bycatch on marine turtle populations worldwide: toward conservation and research priorities. Ecosphere 4 (3), 1–49.
Waugh, S.M., Baker, G.B., Gales, R., Croxall, J.P., 2008. CCAMLR process of risk assessment to minimise the effects of longline fishing mortality on seabirds. Mar. Policy 32, 442–454.
Wiese, F.K., Smith, J.L., 2003. Mortality Estimates and Population Effects of Canadian Pacific Longline Fisheries on Black-footed Albatross (*Phoebastria nigripes*): National and International Implications. Unpublished report for Environment Canada. Birdsmith Ecological Research, Victoria, B.C.
Zador, S.G., Punt, A.E., Parrish, J.K., 2008. Population impacts of endangered short-tailed albatross bycatch in the Alaskan trawl fishery. Biol. Conserv. 141, 872–882.
Zhou, S., Griffiths, S.P., 2008. Sustainability Assessment for Fishing Effects (SAFE): a new quantitative ecological risk assessment method and its application to elasmobranch bycatch in an Australian trawl fishery. Fish. Res. 91, 56–68.
Zydelis, R., Small, C., French, G., 2013. The incidental catch of seabirds in gillnet fisheries: a global review. Biol. Conserv. 162, 76–88.