Agreement on the Conservation of Albatrosses and Petrels

**Fifth Meeting of the Seabird Bycatch Working Group**

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# Use of lethal and non-lethal approaches for testing seabird bycatch reduction methods

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## SUMMARY

Developing robust conclusions about the efficacy of mitigation measures requires experimental testing and the use of quantitative methods. However, such experiments have the potential to injure and kill birds. Given the role of ACAP in supporting favourable conservation status for albatrosses and petrels, conducting lethal experiments affecting these species is an ethical challenge. In addition to concerns at the population level, particularly for species classified as threatened, standard ethical issues relating to wildlife research apply. This paper proposes a framework in which to consider the need for lethal and non-lethal approaches to testing mitigation measures. Key components around which the framework is built are risk determination for seabirds affected by experiments and experimental outcomes, stakeholder considerations, and the practicalities of experimental work. Examples of lethal and non-lethal experiments that have effectively tested mitigation measures are also discussed. Many, but not all, testing situations can be addressed effectively using non-lethal approaches. When lethal approaches are employed, proactive measures through which seabird deaths can be minimised include a strong experimental design involving power analysis, and the *a priori* development of experimental catch limits.

## RECOMMENDATIONS

1. That the Seabird Bycatch Working Group endorses the proposed framework for considering lethal and non-lethal approaches to testing bycatch reduction measures.
2. That the Advisory Committee supports the proposed framework, and adopts it when considering applications to ACAP funding processes.
3. That applicants to ACAP funding processes are requested to justify their choice of approach to testing mitigation measures with respect to the framework proposed.
4. That the Advisory Committee considers and communicates the proposed framework when providing advice, as an expert body, on best practice and recommended approaches to mitigation testing (e.g., at meetings of Regional Fisheries Management Organisations and in best practice guidelines for mitigation research).

## Uso de enfoques letales y no letales para evaluar los métodos de reducción de la captura secundaria de aves marinas

Desarrollar conclusiones sólidas sobre la eficacia de las medidas de mitigación requiere de evaluaciones experimentales y el uso de métodos cuantitativos. Sin embargo, estos experimentos pueden lesionar y matar aves. Teniendo en cuenta el papel que cumple el ACAP para respaldar el estado de conservación favorable de albatros y petreles, la realización de experimentos letales que afecten estas especies constituye un desafío ético. Además de las inquietudes relativas a la población, en particular para las especies clasificadas como amenazadas, se aplican las cuestiones éticas estándar relacionadas con las investigaciones de la vida silvestre. Este documento propone un marco para considerar la necesidad de enfoques letales y no letales para evaluar las medidas de mitigación. Los componentes clave sobre los que se construye el marco son la determinación de riesgo para las aves marinas afectadas por los experimentos y los resultados de los experimentos, las consideraciones de las partes interesadas, y los aspectos prácticos del trabajo experimental. También se analizan ejemplos de los experimentos letales y no letales que han evaluado efectivamente las medidas de mitigación. Muchas de las situaciones de evaluación, aunque no todas, pueden abordarse efectivamente con enfoques no letales. Cuando se emplean enfoques letales, las medidas proactivas a través de las cuales se pueden reducir al mínimo las muertes de aves marinas incluyen un diseño experimental fuerte que incluya análisis de poder estadístico, y el desarrollo a priori de límites experimentales de captura.

### RECOMENDACIONES

1. Que el Grupo de Trabajo sobre Captura Secundaria de Aves Marinas avale el marco propuesto para considerar los enfoques letales y no letales para la evaluación de las medidas de reducción de la captura secundaria.
2. Que el Comité Asesor apoye el marco propuesto, y lo adopte cuando considere solicitudes para los procesos de financiamiento del ACAP.
3. Que aquellos que soliciten procesos de financiamiento del ACAP justifiquen su elección del enfoque para evaluar las medidas de mitigación con respecto al marco propuesto.
4. Que el Comité Asesor analice y comunique el marco propuesto cuando brinde asesoramiento, como organismo de expertos, sobre los enfoques con base en las mejores prácticas y enfoques recomendados para evaluar las medidas de mitigación (por ejemplo, en las reuniones de las Organizaciones Regionales de Ordenamiento Pesquero y en las directrices de mejores prácticas para las investigaciones para la mitigación).

## Adoption de techniques létales et non létales pour tester les méthodes d'atténuation de captures accidentelles d'oiseaux marins

Pour aboutir à des conclusions formelles sur l'efficacité des mesures d'atténuation, il convient de conduire des essais expérimentaux et d'adopter des méthodes quantitatives. Ces essais sont potentiellement dangereux pour les oiseaux : ils peuvent les tuer ou les blesser. Puisque l'ACAP soutient des statuts de conservation favorables pour les albatros et les pétrels, la mise en œuvre d'expériences létales représentant une menace pour ces espèces pose un problème éthique. En sus de ces inquiétudes démographiques, particulièrement pour les espèces menacées, se posent des questions éthiques liées à la recherche sur la faune et la flore. Ce document propose un cadre de réflexion sur l'éthique des pratiques létales et non létales adoptées pour tester des mesures d'atténuation. Ce cadre repose sur plusieurs piliers : détermination des risques pour les oiseaux marins concernés par les expériences et les résultats de ces expériences, avis des parties prenantes, aspects pratiques des expériences. Des exemples d'expériences létales et non létales ayant permis de tester avec succès des mesures d'atténuation sont également débattues. La plupart, mais non la totalité, des tests peuvent être menés de manière efficace sans recourir à des expériences létales. Lorsqu'on recourt à des méthodes létales, des mesures permettant de réduire le nombre de décès doivent reposer sur des méthodes expérimentales solides, une analyse de puissance et le développement en amont de mesures limitant les captures.

### RECOMMANDATIONS

1. Il est recommandé que le GTCA avalise le cadre de réflexion sur l'éthique des pratiques létales et non létales adoptées pour tester des mesures d'atténuation.
2. Que le Comité consultatif soutienne la proposition de cadre et l'applique lorsqu'elle examine les candidatures déposées en vue d’un financement.
3. Que les candidats à un financement de la part de l'ACAP justifient leur choix de test des mesures d'atténuation dans le respect du cadre proposé.
4. Que le Comité consultatif se réfère au cadre proposé lorsqu'il adresse des conseils, en tant qu'organisme spécialisé, sur les bonnes pratiques et les approches recommandées pour tester les mesures d'atténuation (p. ex. lors des réunions des ORGP, lignes de conduite pour la recherche sur les mesures d'atténuation).

## 1. INTRODUCTION

The Advisory Committee to the Agreement on the Conservation of Albatrosses and Petrels has agreed a series of research priorities as part of its advice on reducing seabird bycatch in trawl and longline fisheries (ACAP 2011a, b, c). In order to develop recommendations based on robust conclusions about the efficacy of mitigation measures, quality data must be available. Ideally, these data would be sourced from designed experiments conducted at sea, where the mitigation measures in question would be deployed. However, because mitigation measures are designed to reduce seabird captures, deaths, and injuries, assessing the efficacy of these measures invokes potentially lethal testing approaches (e.g., FAO 2009).

Experiments involving potentially lethal outcomes are ethically challenging and in many countries and institutions, require evaluation by a body monitoring research ethics (e.g., Australian Government 2004). Alongside experimental objectives, guidelines on the use of wildlife in research require consideration of the health and welfare of individual animals and also the species populations they represent (e.g., Canadian Council on Animal Care 2003). Coincident with this, Annex 1 of the Agreement on the Conservation of Albatrosses and Petrels lists 30 species, of which four are classified as Critically Endangered, 13 are Vulnerable, five are Endangered, six are Near Threatened, and the remaining two species are of Least Concern (IUCN 2012).

Lethal experiments can provide information about seabird captures under different operational scenarios at sea. Seabird captures are the most direct response to a mitigation approach. However, past work has shown that appropriately-selected indirect approaches can also be effective in assessing the performance of mitigation measures.

This paper is presented with the following objectives:

1. To propose a decision-making framework through which the appropriateness of lethal and non-lethal approaches to testing mitigation devices can be evaluated,
2. To outline approaches to limit impacts of lethal experiments where these are preferred, and,
3. To describe non-lethal metrics that can be effective for testing mitigation approaches.

Note that throughout this paper we use the following terminology:

- an ‘indirect’ metric quantifies seabird interactions other than deaths measured by landed seabird bodies, e.g., trawl warp strikes (for which some, but not all, strikes are expected to be fatal);
- a ‘lethal metric’ refers to an experimental response variable comprising the death, or potentially lethal injury, of seabirds, and ,
- a ‘lethal experiment’ is one utilising a lethal metric, which may elevate seabird deaths above the level of bycatch that would have occurred under normal fishing operations. Normally this involves a control treatment of no or less mitigation use compared to that used under normal fishing conditions (e.g. no tori line used when otherwise one would be used).

## 2. DECISION-MAKING FRAMEWORK

The proposed decision-making framework to guide the evaluation of lethal versus non-lethal methods for testing bycatch reduction measures is shown in Figure 1. Three key components of this framework are an assessment of the risk that trials represent to seabirds, stakeholder considerations, and the practicalities of executing trials at sea.

### 2.1. Risk determination

Characterising the risk of experiments to seabirds involves considering the location of testing and the fishing method involved. The combination of these two factors will highlight seabird species that may be at risk of capture during testing. Any risks of the methods to be tested (e.g. seabird strikes on mitigation devices) can also be considered here.

Conservation status of seabirds that may be caught is a critical consideration for assessing the value of lethal and non-lethal approaches. Mortalities should be considered in a precautionary and cumulative context. Therefore, where effects of mortalities on populations are unknown, lethal experiments would not be preferred. Noting that experimental mortalities are sustained in addition to those from other causes is also important – the cumulative effect of all sources of mortality on populations should be considered.

Obviously, species with more threatened status can sustain fewer losses at the population level. However, as well as global population, the status of local populations should be considered. For example, while it may have little numeric impact at a global population level, removing a significant part of a local population is still important for the long-term future of a species. In fact, local populations may be especially important if, for example, the local population occurs at the fringe of a species range, in a particularly well protected habitat, shows distinct morphological characteristics at the sub-specific level, etc.

The potential scale of the trial will be influenced by the objectives of the testing and the number of measures (and combinations of measures) being tested. For example, if one objective of the trial is to test a mitigation device in three different locations at sea, the scale (and magnitude of potential risk to seabirds) will obviously be greater than if the trial involves only one location. Consequently, the potential risk to, and impact on, seabird populations will also be greater. As a guideline, to be worth testing, a mitigation measure should be expected to save more birds in one year of deployment than are killed during the testing process.

### 2.2. Stakeholder considerations

Research on seabird bycatch reduction measures is conducted in a broader context, which is often politically-charged. For any research on fisheries-related seabird catches, scrutiny from stakeholders can be expected. For stakeholders with conservation interests, the impacts of mitigation trials on seabirds and their populations are likely to be paramount concerns. For members of the fishing industry, concerns about ‘unnecessary’ seabird deaths, public perceptions of the activity that caused them, and appropriately managing these deaths in the context of fisheries bycatch statistics (e.g., if experimental catches will inflate annual bycatch statistics for a fishery), may all be important issues. These factors can affect the landscapes surrounding trials to the extent that the support and participation of different stakeholders may be compromised. For environmental groups, perception issues may result in a lack of support for trials from a policy perspective, but also in-kind or fiscal support. For industry, funding may be less likely to be an issue but in-kind support may be compromised (e.g., lack of willingness to participate in trials and refusal of access to vessels).

## 2.3. Practicalities

The duration of experiments will affect the practicality of lethal compared to non-lethal approaches. Incidents of bycatch are generally rare from a statistical perspective. Consequently, unless bycatch rates are expected to be particularly high, trials using lethal metrics may need to run for relatively longer time periods in order to ensure sufficient data are collected to allow effective quantitative analysis. In contrast, data sufficient to engender statistical power can typically be collected more rapidly from non-lethal approaches.

In addition to time taken to achieve statistical power, factors affecting the desired duration of mitigation trials may include:

1. Seasonal constraints,
2. Vessel time available
3. Availability of data collectors (e.g., fisheries observers)
4. Project funding

## 2.4. Mitigating factors

When lethal methods are preferred, managing catch levels to minimise mortalities incurred is desirable. There are both *a priori* and *post-hoc* approaches to this.

### *2.4.1. Power analysis*

Determining the statistical power of the proposed approach, and so the number of samples or treatments likely to be required to deliver a result, is desirable as part of good experimental design. For lethal approaches, this means that where unacceptably high levels of captures will be required to achieve a statistically robust outcome, non-lethal methods can be selected before trials commence. Further, experiments can be terminated after the number of deaths required to achieve statistical power has occurred. (Note that power analysis is also recommended for non-lethal approaches, to maximise the efficiency of experimental effort).

### *2.4.2. Limits on seabird catch*

Where power is unknown (e.g., if information required to determine power is unavailable), and so predetermination of capture levels required to meet experimental objectives is not possible, setting catch limits is a practical way to limit mortalities and the impacts of research on seabird populations. Catch limits may be derived from some quantitative foundation (e.g., a catch limit derived from a population model, or a generic approach such as the Potential Biological Removal formula (Wade 1998)). Alternatively, catch limits may be based on a perceived level of acceptable mortalities (e.g., Middleton and Abraham 2007). Catch limits may be structured on a species by species basis, thereby allowing explicit management of risk to threatened species or those more susceptible to capture. Alternatively, limits may be developed on the basis of species groups and therefore less vulnerable to misidentifications of captured seabirds at sea.

### 2.5. Recommendations

Based on the decision framework presented here (Figure 1), we recommend that lethal experiments are not utilised in the following situations:

1. when seabird deaths due to testing, as a component of cumulative mortalities of any seabird species involved, have unknown impacts, or significant negative impacts on local or global populations, or,
2. when deaths due to testing are greater in number than birds saved in one year of deploying the mitigation measure in question, or,
3. when deaths will compromise stakeholder support for work undertaken, or,
4. when experimental objectives can be met using non-lethal metrics.

When lethal metrics are preferred, we recommend:

1. conducting a power analysis to identify the number of deaths that can be expected in the course of experiments, so deaths can be appropriately monitored at sea and work terminated in a timely fashion when statistical significance is achieved, and,
2. the *a priori* development of catch limits such that when these are reached at sea, the experiment is paused to allow the project team to consider an appropriate response to catches incurred in the context of future work required to achieve the desired results.

Examples of lethal experiments and alternatives to lethal metrics are discussed below.

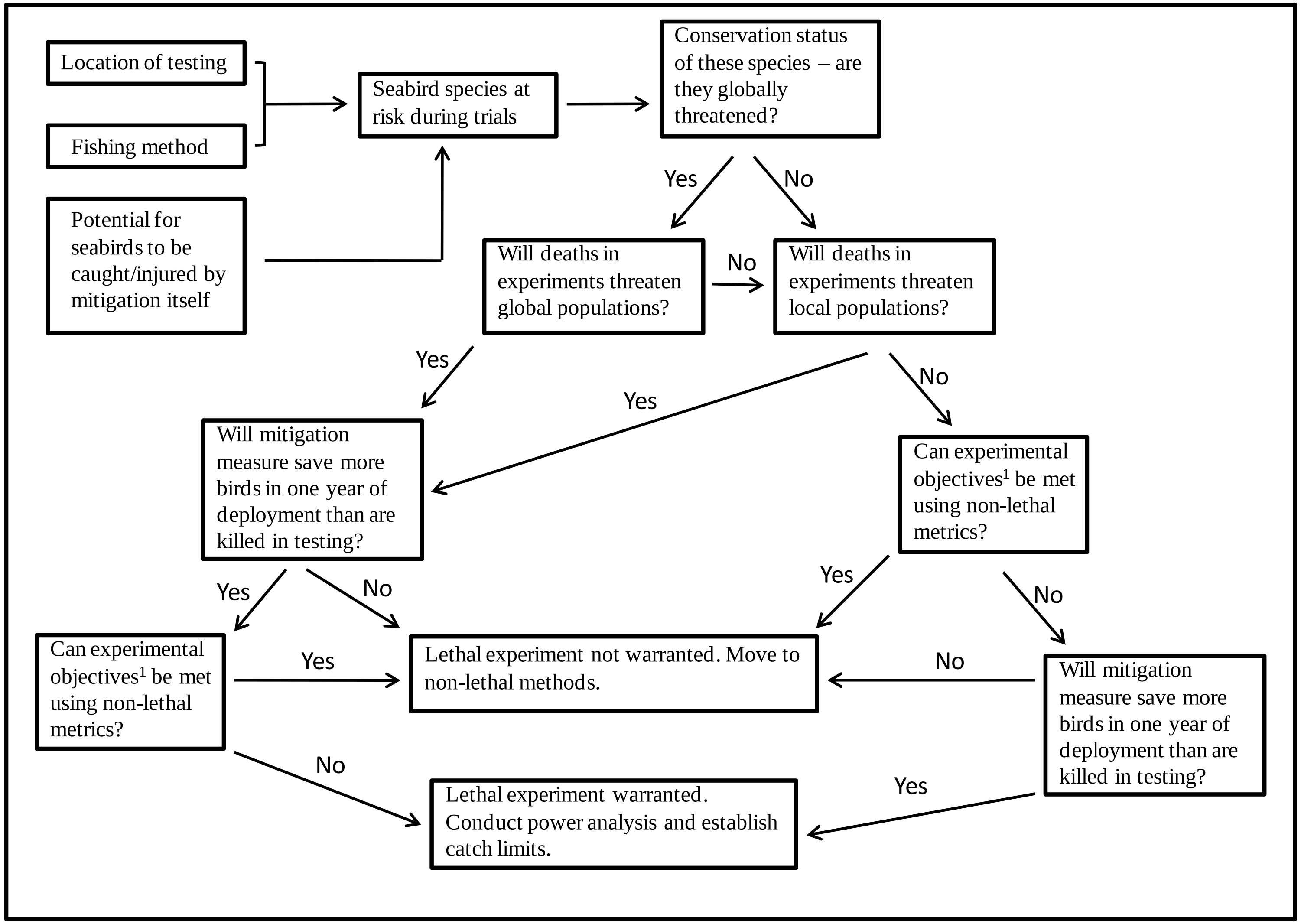


**Figure 1.** Proposed decision-making framework to guide the choice of lethal and non-lethal approaches to testing seabird bycatch mitigation measures. [1]Note that this invokes a broad consideration of all components of objectives, including relevant stakeholder views.

## 3. CONTEXTS FOR THE UTILISATION OF LETHAL METRICS

The biggest apparent advantage of lethal experiments is the unequivocal result gained from using a lethal metric: a captured and dead bird is clearly an instance of a negative interaction with fishing gear. From a scientific perspective, the directness of this result has some value - the identification and characterisation of bycatch problems is simplest with dead birds where the cause of death can be conclusively determined. Lack of ambiguity in the relationship between fishing and seabird deaths was an important feature of early work defining the bycatch problem (e.g., Brothers 1991) and estimating the extent of mortalities based on captures recorded continues to be important in monitoring fisheries globally (e.g., Abraham and Thompson 2009).

In an experimental context, the apparent clarity of direct results can also be appealing (e.g., Brothers et al. 1999; Bull 2007). In the absence of pre-existing knowledge, such clarity has value. Further, for some fishing gears and fishing environments, lethal metrics may be the only practical method currently available with which to effectively explore mitigation performance (e.g., gillnets). In such situations, as long as the proposed mitigation approach doesn't actually increase seabird deaths, the experimental situation created may be no worse than current fishing practice and would not be classed as a lethal experiment under our terminology. However, cryptic mortality may reduce the power and accuracy of lethal metrics, and is just starting to be explored (Gilman et al. in progress; Seabird Bycatch Advisory Committee 2012) and utilised in assessments of the risk fishing gear presents to seabirds (Richard et al. 2011). These aspects of research, and two examples of the use of lethal metrics, are discussed further below.

### 3.1. Experimental contexts

#### *3.1.1. Fishing methods*

For trawl and longline methods, the nature of seabird interactions with fishing gear are relatively well known, and indirect methods, including non-lethal methods, have been effectively used to assess bycatch reduction measures (see below). However, for some fishing gear types (e.g., gillnets), and some types of interactions (e.g., net captures), indirect approaches cannot feasibly be used to investigate the performance of mitigation measures.

Gillnets are deployed underwater, and for periods of hours. Monitoring the activity of diving seabirds around them will give an idea of bycatch risk by proximity. However, given that captures occur underwater and seabirds may swim into nets from a distance away, the efficacy of indirect measures in assessing the performance of any mitigation measure is questionable.

Similarly, investigating the efficacy of mitigation aiming to reduce captures in trawl nets is challenging. Again, monitoring seabird activity around nets astern vessels will give a coarse idea of bycatch risk given the presence of seabirds. However, captures can occur in meshes and through birds entering net mouths at distances astern that cannot be easily monitored. Further, when net mouths are below the waterline, seabird activity around them cannot be quantified (although the use of cameras can offer a solution to this). SBWG5_Doc_09 describes one such study, on mitigating net captures in the New Zealand scampi trawl fishery.

In such situations, conducting experiments over time within a robust experimental design is preferable to maximise the power of the approach implemented, while minimising the number of birds that will die.

#### *3.1.2. Environmental conditions*

Human visual abilities are seriously compromised at night, thereby limiting our ability to observe experimental proceedings at that time. When mitigation measures involving night time deployment of fishing gear are tested, lethal metrics may be effective and necessary. A mitigation measure that is widely considered to be part of best practice is night-setting (Bull 2007; ACAP 2011b). The efficacy of this measure could not have been tested conclusively using non-lethal metrics.

### 3.2. Contemporary examples

Here, we summarise two examples of work where the response variable was seabird mortality.

Robertson et al. (2006) describe the results of a particularly comprehensive suite of work examining the efficacy of line-weighting in reducing the catch of sooty shearwaters (*Puffinus griseus*) and white-chinned petrels (*Procellaria aequinoctialis*). They employed indirect, non-lethal, and lethal metrics to investigate the performance of integrated weight line in reducing seabird bycatch. Metrics included line sink rates, seabird diving activity, and seabird captures. At-sea trials compared longlines with no weight, and those with integrated weighting. Trials ran in three different years over more than 54 days at sea. (Testing effort in terms of hooks and lines was reported, rather than the number of sea days over which work occurred).

Significant reductions in the mortalities of the two focal species provided clear evidence of the efficacy of integrated weight backbone. Sink rates also reflected the altered bycatch risk. Robertson et al. (2006) reported significantly lower dive rates on integrated weight line by white-chinned petrels in one year of the study. Further, the distribution of diving activity astern the vessel changed for both species when integrated weight lines were set, compared to unweighted lines. Interspecific interactions were reported between the two focal species such that the numbers of dives per magazine, by species, were negatively correlated. The authors concluded that dive rates were not an appropriate measure of mortality potential for sooty shearwaters. However, while seabird captures provided an unambiguous answer to the questions posed at the outset of the experiment, behavioural metrics were not insensitive to the situation created. Had the lethal metric not been utilised, additional analyses on non-lethal metrics may have been useful for elucidating the results.

Given the pioneering nature of this research, the clarity of results afforded by field trials involving fishing, combined with the use of behavioural and lethal approaches, meant a very clear picture of the at-sea situation emerged. This may have facilitated uptake of the findings, and especially the use of a novel kind of longline gear by fishers at sea. The work is also important in providing a rare opportunity to compare the utility of different metrics in quantifying bycatch risk.

A very different quantitative challenge is reflected by the use of seasonal and area closures as bycatch reduction measures. For this situation, robust monitoring of seabird mortalities is the only method that will give unambiguous results. Mortalities when an area is closed can be compared to when an area is fished. Important considerations include spatial and temporal patterns of fishing effort. (For example, closures may displace fishing effort to another location, where bycatch risk may be higher. Therefore, a large-scale sampling approach is required). The best documented case of where closures of fishing grounds have reduced seabird mortality occurred in CCAMLR (Commission for the Conservation of Antarctic Marine Living Resources) waters. Extensive documentation of seabird bycatch in this Convention Area showed that when fishing was restricted in time and space, bycatch dropped from approximately 0.2 birds/1000 hooks (1995) to <0.025 birds/1000 hooks (1997) (SC-CAMLR 1995; SC-CAMLR 1998).

### 3.3. Recommendations

When lethal metrics are preferred, key considerations in selecting metrics and developing experiments include the following.

1. the mode of interaction between the focal seabirds and the fishing gear
2. the potential for (and extent of) cryptic mortality, and impact of that on detectability of interactions
3. the power of the approach proposed, to ensure objectives can be addressed by the experiment planned
4. developing an *a priori* catch limit with which to manage the experiment
5. clearly communicating to interested stakeholders why the experiment is being conducted with lethal metric(s), positive implications for seabirds if an effective mitigation measure is successfully identified, and precautions in place to manage impacts on seabirds in an ethically robust way.

## 4. ALTERNATIVES TO LETHAL METRICS

Where lethal approaches to testing mitigation methods are not acceptable or preferred, a range of indirect metrics are available. The relationship between some indirect metrics and seabird mortality has been tested quantitatively; these linkages are summarised below. In addition, examples of experiments that have successfully used metrics other than mortalities to test mitigation approaches are presented.

### 4.1. Confirming the representativeness of indirect metrics

#### *4.1.1. Seabird mortality and warp strikes*

In their pioneering study, Sullivan et al. (2006) were the first to report the use of trawl warp strikes as a proxy for seabird mortalities caused by trawl warps. Correlations between warp strikes and mortalities of black-browed albatrosses (*Thalassarche melanophris*) were reported with significance levels of $P = 0.01$ to $P < 0.001$. In New Zealand, the relationship between warp strikes and warp captures has also been quantitatively explored for large and small birds following warp strike monitoring across many of the trawl fleet of vessels $\geq$ 28 m in length, and a small number of vessels < 28 m. This exploration found that for every albatross landed dead from a warp capture, 244 (95% confidence interval: 190 – 330) struck the trawl warps. In contrast, for every small bird landed from a warp capture, 6440 (95% confidence interval: 3400 – 20000) struck the trawl warps (Abraham 2010).

While this analysis has not been repeated in other localities, the link between trawl warp strikes and mortalities is not disputed. Researchers have successfully used warp strikes to evaluate the risk of seabird captures in trawl fisheries, and to test the efficacy of mitigation measures designed to reduce them (e.g., Melvin et al. 2010).

#### *4.1.2. Seabird abundance and warp strikes*

The relationship between seabird abundance and warp strikes has been quantified in one experiment and one monitoring study, both conducted in New Zealand waters. The experimental dataset comprised a total of 1581 observation periods made of a defined area astern 18 trawl vessels (Middleton and Abraham 2007). While significant, the relationship between warp strikes and abundance was somewhat noisy, as shown in Figure 2.

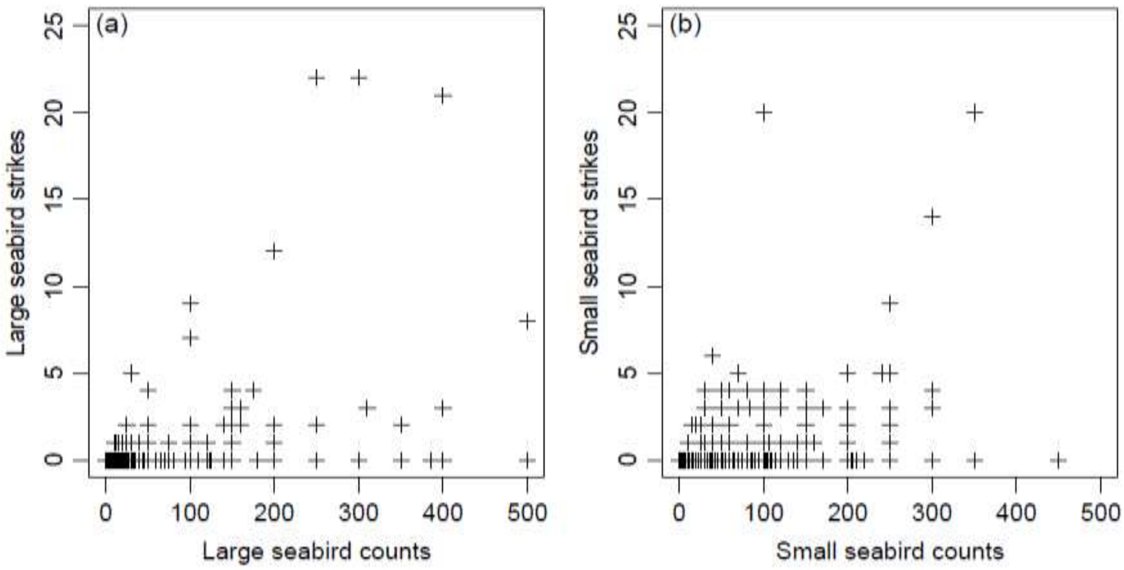


**Figure 2.** The relationship between seabird abundance and seabird warp strikes in the absence of warp strike mitigation measures. 'Large seabirds' are albatrosses and giants petrels. 'Small seabirds' are all other birds. (Source: Figure 17 in Middleton and Abraham (2007)).

Monitoring of seabird strikes on trawl warps over a five-year period has also produced a dataset allowing the exploration of the relationship between seabird abundance and trawl warp strikes (Abraham 2010). The dataset involved 2456 hours of observations of defined areas, conducted astern trawlers from 2004/05 to 2008/09. Figure 3 shows warp strike rate and seabird abundance for large (albatrosses and giant petrels) and small (all other seabirds) birds in a variety of locations fished around New Zealand.

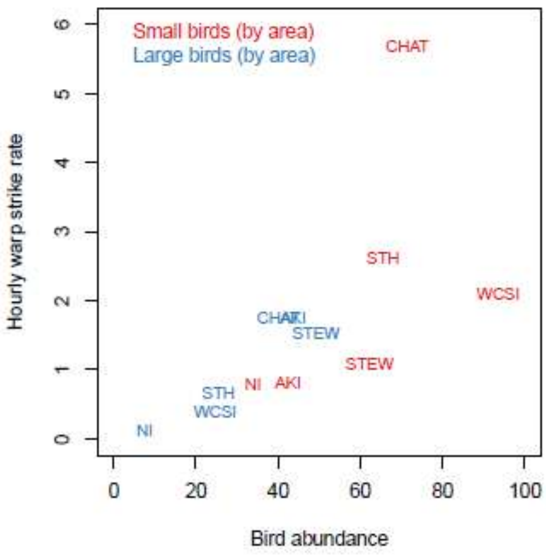


**Figure 3.** The relationship between warp strike and seabird abundance during a five year period of monitoring in New Zealand trawl fisheries. Letter codes represent different fishing areas. (Source: Figure 4a in Abraham (2010)).

These studies show that while the relationship is not necessarily simple or linear, seabird abundances in defined areas astern trawlers do relate statistically to warp strike rates, and therefore seabird mortalities.

## 4.2. Testing the efficacy of mitigation approaches using non-lethal metrics

### *4.2.1. Trawl fisheries: Seabird abundance and activity*

Drawing on the significant relationships identified between warp strikes and seabird abundance, a series of experiments was undertaken in New Zealand using abundance as the primary response variable. These experiments are summarised here.

In a single-vessel experiment conducted in New Zealand waters, researchers sought to test the efficacy of three different offal management regimes (mincing, mealing, and no offal control; Abraham et al. (2009)) in reducing the risk of seabird bycatch on trawl gear. The stakeholder context of the research did not allow for the use of lethal metrics. Consequently, paired streamer lines were utilised on the vessel throughout the experiment. The efficacy of streamer lines in reducing trawl warp strikes meant that few strikes occurred during the experiment, and warp strikes were insufficient to be used as a response variable to test experimental hypotheses. Further, while strikes on paired streamer lines did occur, they were also relatively few in number and did not yield statistically strong conclusions. Even if statistically possible to evaluate, small numbers of strike observations may lead to poor estimates of the underlying strike rates, and therefore conclusions that are not robust (Abraham et al. 2009).

Instead, seabird abundance in a defined area around trawl warps was used to elucidate treatment effects. Abundances were quantified across five seabird groups (large albatross (*Diomedea* spp.), small albatross (all other albatross), giant petrel (*Macronectes* spp.), Cape petrels (*Daption capense*), other petrels (all other petrels and shearwaters)) and three activity categories (flying, sitting, feeding). The effects of the three offal management regimes in question were clearly identified after 22 days at sea, as shown in Figure 4.

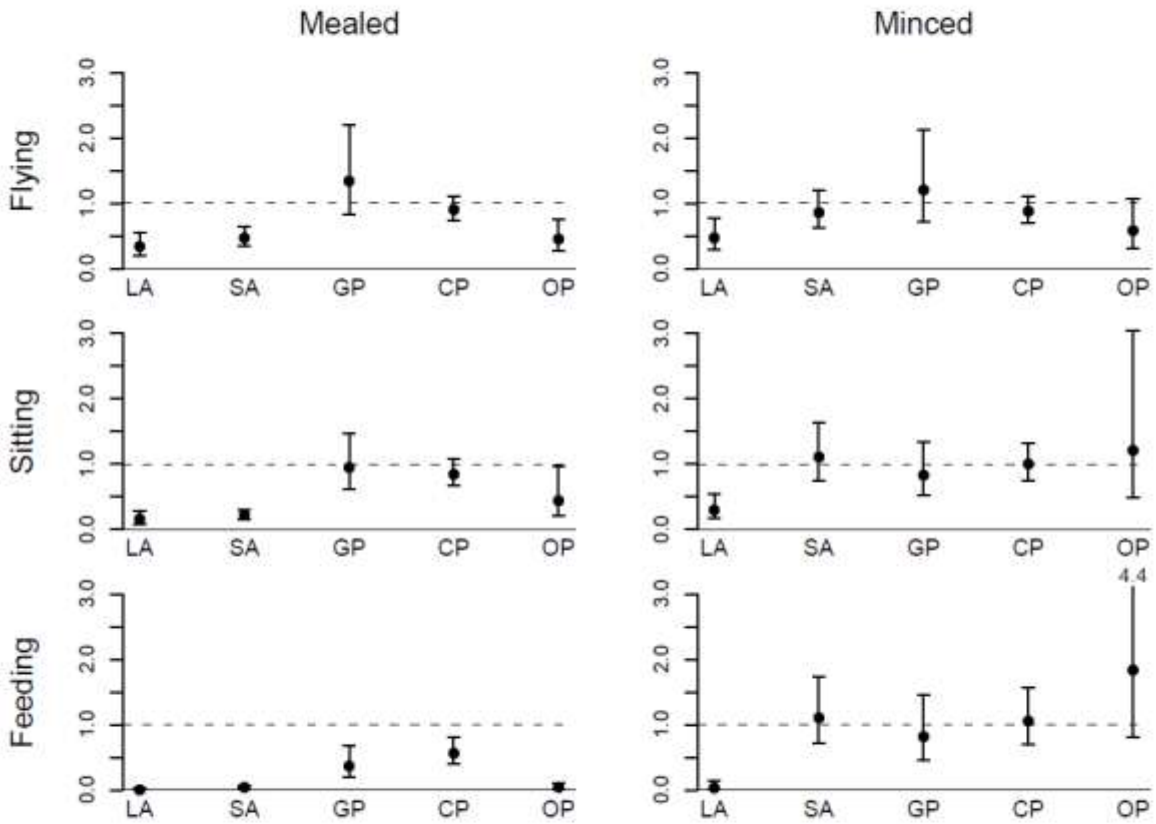


**Figure 4.** Summary of the effects of three offal management regimes deployed in a single-vessel experiment. Here, ratios of seabird abundances in a defined area astern the vessel are presented by species group during mealing and mincing treatments, compared to the discharge of unprocessed offal. The median of the posterior distribution (dot) and the 95% credible interval (bars) are shown for the coefficients of the mincing and mealing treatment effects. No effect of treatment is represented by a value of 1.0: confidence intervals falling below the dashed line reflect significant treatment effects. Seabird groups are: LA= large albatross, SA= small albatross, GP = giant petrel, CP = Cape petrel, OP = other petrels). (Source: Figure 4, Abraham et al. (2009)).

Following the analyses and conclusions of Abraham et al. (2009), subsequent experiments used simplified experimental protocols that delivered increased statistical power. For example, the number of seabird groups was reduced and activity metrics were replaced by abundance counts of seabirds in the air and on the water.

Pierre et al. (2010) examined seabird utilisation of discharge released from trawlers in batches after holding periods of four different durations. In this study, the abundances of the three seabird groups (large seabirds (albatross and giant petrel), small seabirds (all other birds except Cape petrels), and Cape petrels) were examined. Cape petrels were counted separately due to their different foraging style astern trawlers compared to other seabirds and the low incidence of bycatch of this species despite at times high abundances (Abraham and Thompson 2009).

Results after 36 days at sea clearly delineate treatment effects: holding periods of two hours duration were not sufficient to reduce seabird abundance astern the vessel. Holding periods of four and eight hours reduced the abundances of some species groups but not all (Figure 5).

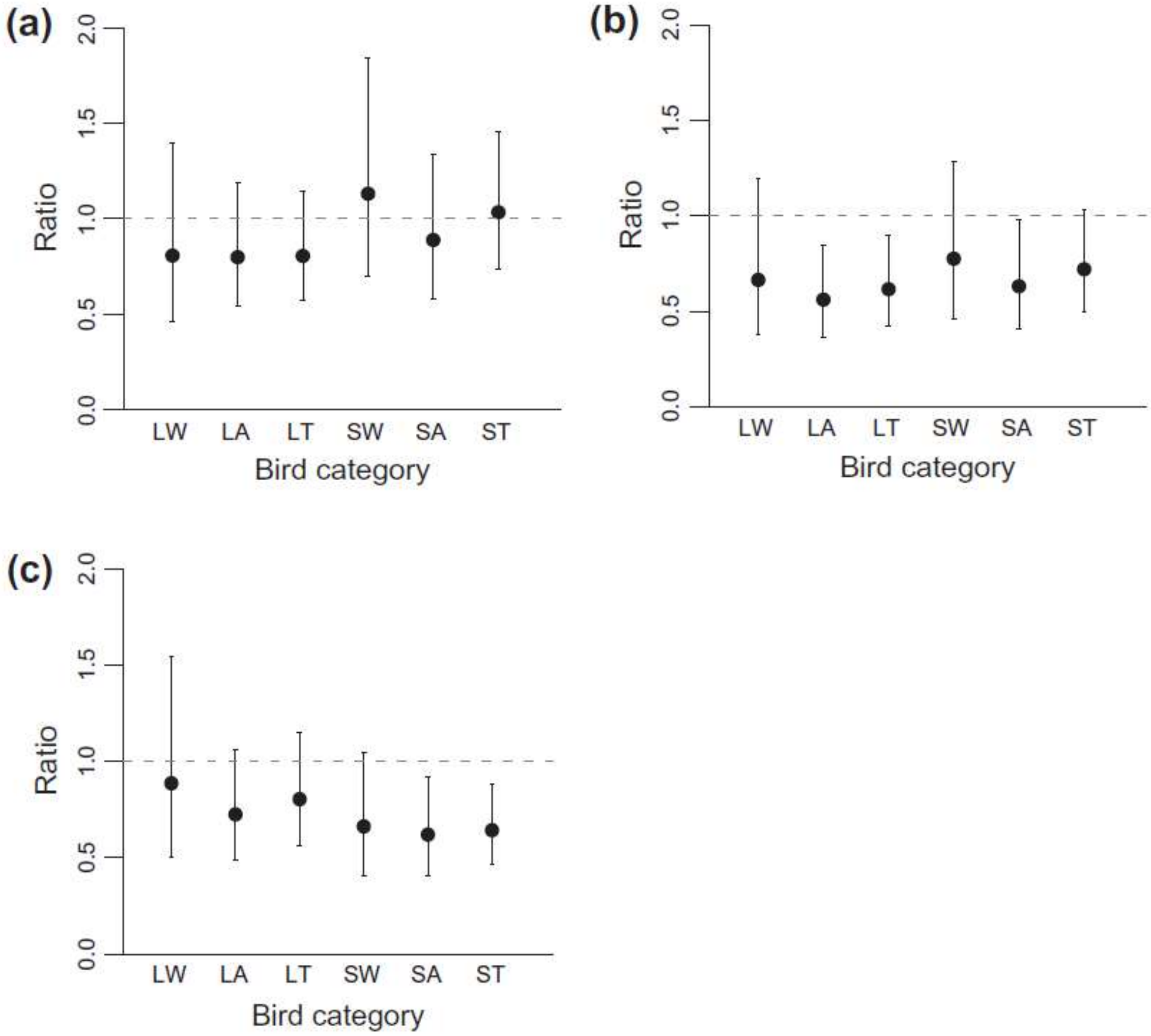


**Figure 5.** Ratio of seabird counts during 30 minute holding periods compared to (a) 2 hour, (b) 4 hour, and (c) 8 hour holding periods. As for Figure 4, the median of the posterior distribution (dot) and the 95% credible interval (bars) are shown. No effect of treatment is represented by a value of 1.0: confidence intervals falling below the dashed line reflect significant treatment effects. Seabird groups are: L=Large birds, S=small birds, A=birds in the air, W=birds on the water, T=total of birds in the air and on the water. (Source: Figure 6, Pierre et al. (2010)).

Using the same approach of three seabird groups (large seabirds, small seabirds, and Cape petrels), Pierre et al. (2012a) compared seabird attendance at a trawl vessel during two holding periods (30 minutes and 2 hours) with attendance during ad hoc discharge. As in Pierre et al. (2010), seabirds were counted in the air, and in the water. Significant results (Figure 6) were obtained after 31 days at sea.

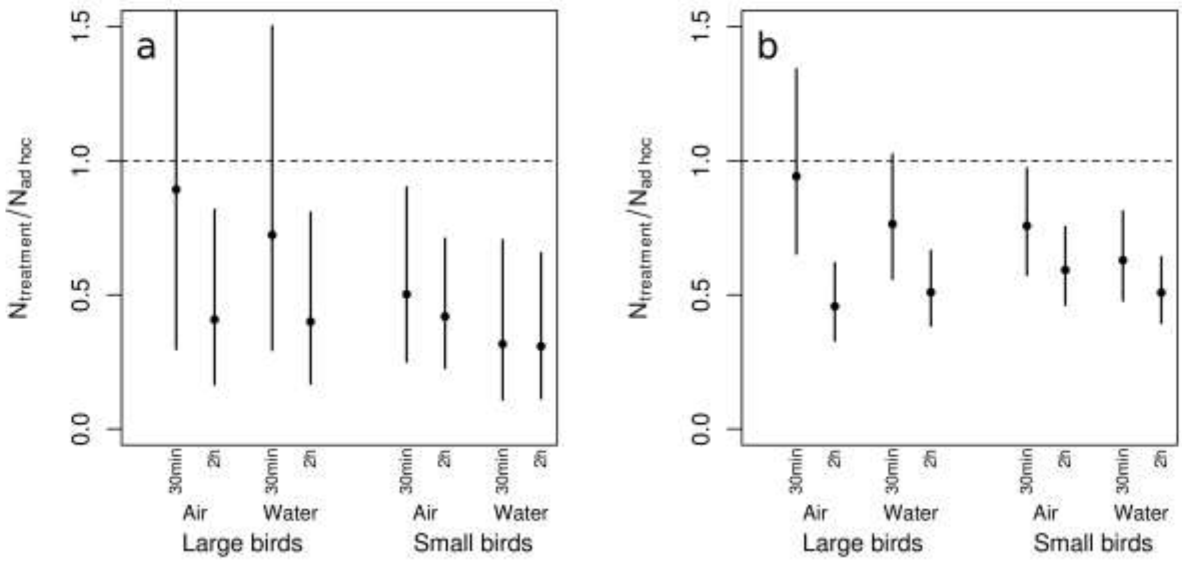


**Figure 6.** Ratio of seabird counts during 30 minute and 2 hour holding periods compared to ad hoc discharge, (a) 10 m astern and (b) 40 m astern the experimental vessel. The median of the posterior distribution (dot) and the 95% credible interval (bars) are shown. No effect of treatment is represented by a value of 1.0: confidence intervals falling below the dashed line reflect significant treatment effects. (Source: Figure 4, Pierre et al. (2012a)).

Implementing a simpler approach than was used in Abraham et al. (2009), but using additional seabirds groupings to Pierre et al. (2010, 2012a), Pierre et al. (2012b) quantified the abundances of four seabird groups on the water and in the air to investigate the effects of the particle size of minced discharge. Seabirds were split into large albatross (*Diomedea* spp.), small albatross (all other albatross) and giant petrel, Cape petrel, and other petrels. The albatross groups were split here given the different responses of large and small albatrosses to minced discharge found in previous work (Abraham et al. 2009). In this case, 27 days at sea yielded significant results showing that mincing attenuated the attendance of some groups of seabirds astern the vessel, relative to unprocessed discharge. However, abundances of small albatrosses and Cape petrels were not consistently reduced.

To complete this research programme using lethal metrics would have required the deaths of thousands of seabirds of conservation concern. Instead, non-lethal metrics produced relatively rapid results and the conclusions of the programme have been implemented in fishery management plans across the New Zealand deepwater trawl fleet (Deepwater Group 2009, 2011; Pierre et al. 2012c). From this series of experiments, we concluded that recording specific activities did not add information beyond a simple classification of seabird abundance in air versus on the water. We also note the importance of identifying appropriate seabird groupings (e.g., based on foraging styles, types of interactions with fishing gear, and experimental objectives).

#### *4.2.2. Longline fisheries: Seabird abundance and activity*

In 2003, SEO/BirdLife International hosted a competition that provided a financial incentive for submitting new ideas to mitigate seabird–fisheries interactions. The method that won the competition was dripping small amounts of fish liver oil on the surface of the ocean while setting longlines (Hansford 2004). Note that the use of this mitigation practice does not meet the latest waste management requirements of the International Maritime Organisation.

This win led to a series of experiments testing the efficacy of the oil method in deterring different seabird assemblages from attending fishing vessels (Pierre and Norden 2006; Norden and Pierre 2007). One of the winning competition entrants advocated use of the oil in areas occupied by black petrel (*Procellaria parkinsoni*) and the flesh-footed shearwater (*Puffinus carneipes*). The black petrel is of particular conservation concern, given that the population that may have declined by >20% between 2004/05 and 2009/10 (Bell et al. 2010). Further, estimates of potential incidental mortalities in commercial fisheries are beyond the species' sustainability limit (Richard et al. 2011). Both species are capable divers and can retrieve baits on hooks from significant depths (e.g., Thalmann et al. 2009; E. Bell, pers. comm.).

In these experiments, researchers used two metrics to describe seabird responses to oils deployed. Metrics were the number of seabirds, by species, attending vessels, and the number of 'dives' observed. Both metrics were recorded from an area 5 m across, and 75 m back from, the vessel stern. 'Dives' were described as the number of times birds dived below the sea surface of the sea or put their heads under the surface to look for baits. Experiments were undertaken with and without fishing gear in the water.

In northern waters where the seabird assemblage was dominated by black petrels and flesh-footed shearwaters, the use of these two metrics allowed the successful identification of oils effective in deterring seabirds from attending fishing vessels. Testing achieved significant results in four days. (Pierre and Norden 2006; Norden and Pierre 2007, Figure 7).

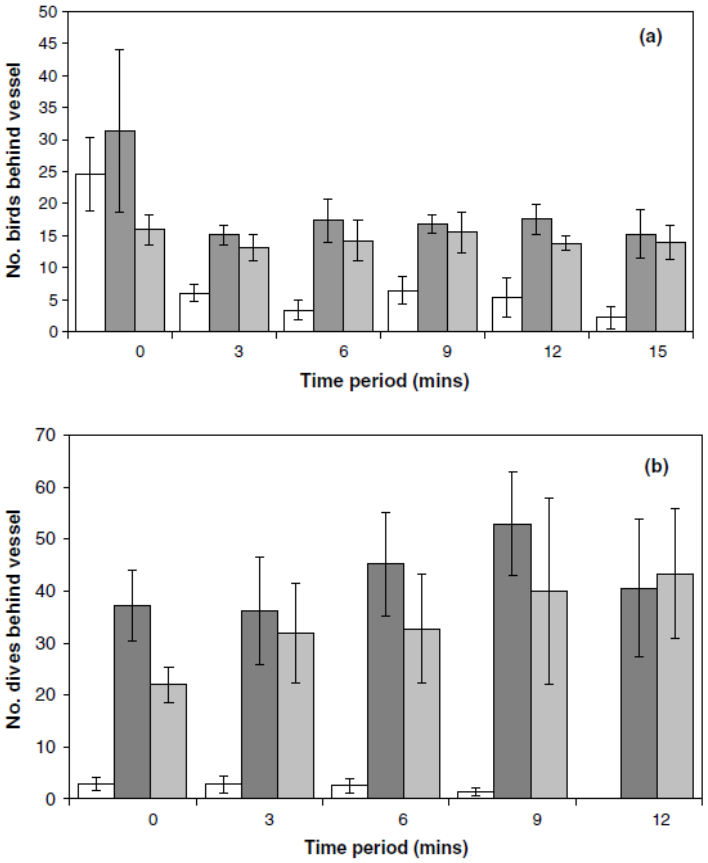


**Figure 7.** Number (mean ± standard error) of seabirds (predominantly petrels and shearwaters) (a) attending the vessel, and (b) diving during each sampling period of preliminary trials using shark liver oil (open bars), vegetable oil (dark grey bars) and seawater (light grey bars). (Source: Figure 2 in Pierre and Norden (2006)).

To test the effect of oils on other seabird assemblages, and specifically an assemblage dominated by albatrosses, researchers moved to a new area off the east coast of New Zealand's South Island (Norden and Pierre 2007). For the assemblage dominated by albatrosses, the 'dive' metric was not effective. However, examining the abundance of albatross species in a defined area astern the vessel still delivered clear results – oil had no effect on these birds' attendance astern (Figure 8).

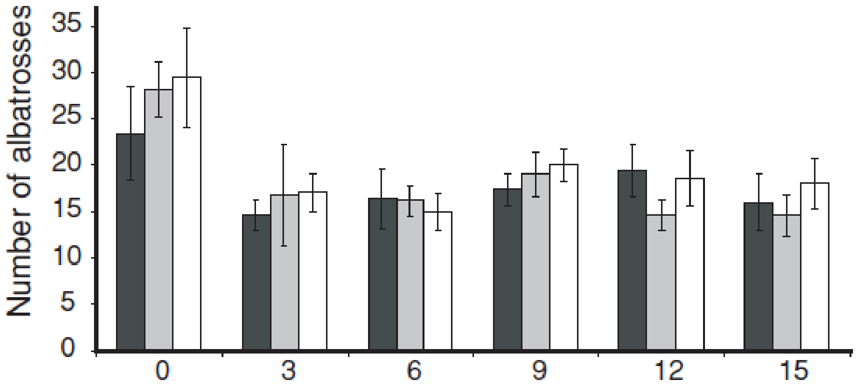


**Figure 8.** Number (mean ± standard error) of albatrosses astern during deployment of two types of fish oils (dark and light grey bars) and sea water (open bars). (Source: Figure 2, Norden and Pierre (2007)).

In both studies, the conservation status of the seabird species involved, and the efficacy of the indirect metrics in detecting responses to experimental treatments, rendered the use of direct metrics unnecessary. However, ensuring the appropriateness of the metric in relation to the behaviour of the focal species was paramount.

#### *4.2.3. Work underway*

Current work underway in northern New Zealand waters is also focused on identifying suites of fishing practices that may reduce the risk of incidental capture of the black petrel in bottom longline fisheries (Conservation Services Programme 2012; Pierre 2013). Given the conservation status of the species, sensitivity of stakeholders (including industry) to captures, and the large number of captures that would be required to obtain results, indirect measures are in use in this study. Methods include the use of time depth recorders to determine longline sink rate and quantification of seabird abundance and diving behaviour under various operational conditions. While the specific forms of the quantitative relationships are unknown between these individual variables and bycatch events *per se*, all do reflect the risk of petrel bycatch.

### 4.3. Comparisons across studies using indirect measures of seabird mortality

Significant relationships between indirect and direct measures of seabird interactions have been found in a number of experiments, both in New Zealand (e.g., Middleton and Abraham 2007; Abraham 2010) and elsewhere (Sullivan et al. 2006). However, confirming these relationships in additional localities, and when experiments are conducted across multiple vessels, has value.

Following Sullivan et al. (2006), Melvin et al. (2010) used trawl warp strikes as a proxy for mortality in their work examining mitigation measures on two trawlers in the Bering Sea. Melvin et al.'s (2010) results suggest that the shape of the relationship between interactions and abundance was somewhat vessel-specific. That is, the ‘multiplier’ linking warp strikes to seabird abundance varies. Causes of that variation were not formally tested, but Melvin et al. (2010) suggested that warp aerial extent (which differed by a factor of two between the two vessels used in the study) and discharge types (mince versus rendered; both vessels also discharged surimi wash water and occasional whole discards) may have been important. To our knowledge, the effect of different warp extents has not been tested elsewhere. However, other studies demonstrate the importance of discharge types in affecting seabird abundance around groups of vessels, and also over time around the same vessel (Middleton and Abraham 2007; Abraham et al. 2009; Pierre et al. 2012a, b).

In contrast with Melvin et al. (2010), studies reporting relationships between seabird abundance and mortalities involved eight vessels (Sullivan et al. 2006), 18 vessels (Middleton and Abraham 2007), and > 25 vessels (overall total number of vessels not reported, Abraham 2010). In addition, there was considerable diversity in the vessels included in the Middleton and Abraham (2007) and Abraham (2010) work. Including a larger number of vessels has likely increased the power of the analyses conducted in these studies, such that relationships between seabird abundance and warp strikes emerged more clearly despite variation inherent in the character of the relationship and the diversity of vessel gear and operational practices.

An additional and potentially important difference between the Melvin et al. (2010) study and others which have statistically linked indirect and direct measures of mortality is seabird assemblage. Melvin et al. (2010) worked in an area where seabird assemblages are dominated by small birds: fulmars and shearwaters. In contrast, other studies have occurred amongst assemblages dominated by albatrosses of the genus *Thalassarche* (Sullivan et al. 2006; Middleton and Abraham 2007; work reviewed in Pierre et al. 2012a). Melvin et al. (2010) reported that they could not establish a clear link between trawl warp strikes and mortalities of small-winged birds. This result appears coincident with other work, given the scale of the Melvin et al. (2010) experiment. Abraham (2010) found that the relationship between trawl warps strikes and the detected mortalities of large birds was characterised by greater precision than the same relationship for small birds. In addition, a larger number of mortalities was detected. For every albatross landed dead from a warp capture, 244 (95% confidence interval: 190 – 330) struck the trawl warps. Mortalities were recorded at a rate of 0.006 per hour. In contrast, for every small bird landed from a warp capture, 6440 (95% confidence interval: 3400 – 20000) struck the trawl warps. Mortalities were reported at a rate of 0.00025 per hour (Abraham 2010). Further, Middleton and Abraham (2007) report on the significance, but statistical noisiness, of the relationship between warp strikes and seabird abundance (see above).

The discussion above highlights the need to use indirect metrics carefully, and where possible, use metrics that have a demonstrated relationship with mortalities. However, common sense and knowledge of species biology and behaviour are also important in determining metrics to sample, especially when species are of particular conservation concern.

### 4.4. Recommendations

When non-lethal metrics are preferred, key considerations in selecting metrics and developing experiments include the following.

1. the mode of interaction between the focal seabirds, the fishing gear, and the mitigation to be tested
2. the composition of seabird groups, i.e., grouping species that interact with gear similarly
3. whether the metric has been used effectively in previous work
4. whether the existence of a relationship between the metric and seabird mortality has been confirmed
5. the complexity of the experiment: is the most parsimonious set of metrics being used?
6. the power of the approach proposed, to ensure objectives can be addressed by the experiment planned

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