Agreement on the Conservation of Albatrosses and Petrels

Seventh Meeting of the Seabird Bycatch Working Group

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Prioritising research and management of at-sea threats to New Zealand seabirds

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SUMMARY

A framework of tools is being developed by the New Zealand Department of Conservation to prioritise research and management of at-sea threats to seabirds. The framework aims to ensure the available knowledge on seabird biology and ecology is adequate to understand and manage at-sea threats to New Zealand seabirds. The approach builds on quantitative fisheries risk assessment approaches, but broadens the scope to all potential threats.

The prioritisation framework will collate existing information relevant to risk assessment in order to identify the greatest threats to seabirds. It will identify and prioritise gaps in current knowledge limiting our understanding of at-sea threats, so future research can be focussed on these areas. The framework will include the tools required to facilitate expert guidance to identify the full range of threats to seabirds, and seabird susceptibility.

Research gaps will be prioritised by assessing how the current uncertainty around each input parameter influences our ability to project population trajectories. This will allow the identification of research required to improve our understanding of population dynamics, and thus the potential effects of different threats on those populations.

Once the range of threats scenarios to any given seabird has been identified, they will be compared using a population modelling tool to quantify their effect on population trajectory. This will allow the prioritisation of threats requiring management.

We illustrate the development and potential application of this prioritisation framework using New Zealand breeding albatross taxa.

Priorizar la investigación y el manejo de amenazas en el mar para las aves marinas de Nueva Zelanda

RESUMEN

El Departamento de Conservación de Nueva Zelanda está elaborando un marco de herramientas para priorizar la investigación y el manejo de amenazas en el mar para las aves marinas. El marco apunta a garantizar que el conocimiento disponible sobre la biología y ecología de las aves marinas sea adecuado para entender y manejar las amenazas en el mar para las aves marinas de Nueva Zelanda. La estrategia se basa en diferentes abordajes sobre la evaluación cuantitativa de los riesgos en las pesquerías, pero amplía su alcance para abarcar todas las posibles amenazas.

El marco de priorización recopilará información existente de relevancia para la evaluación de riesgos a fin de identificar las principales amenazas para las aves marinas. Dicho marco permitirá identificar y priorizar vacíos en el estado actual de conocimiento que limitan nuestra comprensión sobre las amenazas en el mar, de modo que las investigaciones puedan centrarse en esas áreas. El marco incluirá las herramientas necesarias para facilitar el asesoramiento de expertos a fin de identificar el grado de susceptibilidad de las aves marinas y el total de amenazas que las afectan.

Se priorizarán los vacíos en materia de investigación evaluando la manera en que la incertidumbre existente sobre cada parámetro aportado incide en nuestra capacidad de proyectar las trayectorias de las poblaciones. Esta estrategia permitirá identificar qué investigación hace falta para mejorar nuestro conocimiento sobre las dinámicas de las poblaciones y, por ende, los posibles efectos de las diferentes amenazas sobre esas poblaciones.

Una vez que se haya identificado el abanico de amenazas posibles para cualquier tipo de ave marina, se compararán dichas amenazas usando una herramienta para crear modelos de poblaciones a fin de cuantificar sus efectos en la trayectoria de la población. De esta manera, se podrán priorizar las amenazas que requieran ordenación.

Demostramos la elaboración y posible aplicación de este marco de priorización utilizando los taxones de reproducción de albatros en Nueva Zelanda.

Privilégier la recherche et la gestion des menaces en mer pesant sur les oiseaux marins de Nouvelle-Zélande

RÉSUMÉ

Le département néo-zélandais pour la Conservation élabore un ensemble d'outils en vue de privilégier la recherche et la gestion des menaces en mer qui pèsent sur les oiseaux. Ce système vise à assurer que les connaissances disponibles en biologie et en écologie sont suffisantes pour comprendre et gérer les menaces en mer qui pèsent sur les oiseaux marins néo-zélandais. La méthode repose sur les approches d'évaluation quantitative des risques de la pêche, mais en prenant également en compte toutes les menaces potentielles.

Ce cadre de priorisation rassemble les informations existantes pertinentes quant à l'évaluation des risques afin d'identifier les activités qui menacent le plus les oiseaux de mer. Il permettra d'identifier et d'étudier en priorité les connaissances manquantes qui limitent notre compréhension des menaces en mer, et de focaliser ainsi les futures recherches sur ces points. Le cadre comprendra les outils nécessaires à faciliter la supervision spécialisée qui permettra d'identifier toutes les menaces pesant sur les oiseaux marins, ainsi que la vulnérabilité de ces derniers.

Les recherches prioritaires seront identifiées en évaluant l'incertitude actuelle autour de chaque paramètre d'entrée et son influence sur notre capacité à projeter les trajectoires de populations. Ceci permettra d'identifier les recherches nécessaires à une meilleure compréhension des dynamiques démographiques, et donc les effets possibles des différentes menaces sur ces populations.

Une fois les scénarios de menace identifiés, ils seront comparés à l'aide d'un outil de modélisation démographique afin de quantifier leur effet sur la trajectoire d'une population. Les menaces qui nécessitent d'être gérées seront ainsi traitées en priorité.

Nous illustrons l'élaboration et l'application potentielle de ce cadre de priorisation à l'aide du taxon de l'albatros reproducteur néo-zélandais.

1. INTRODUCTION

New Zealand has a particularly high seabird diversity, with 96 breeding taxa (following Robertson et al. 2013). A number of these taxa are critically endangered, with several in significant decline. Seabirds are protected species and the New Zealand Department of Conservation (DOC) has statutory responsibilities for their conservation.

Seabirds include many iconic species such as albatross and penguins. Such species have high societal and cultural values, with potential for far greater ecotourism. Seabirds also provide important ecosystem services, including transfer of nutrients from ocean to land. Our understanding of the biology, ecology, and threats is limited for many species. Existing data is dispersed amongst a range of sources.

Many seabirds forage widely, both within New Zealand waters and globally. They also tend to be long-lived and slow to reproduce and thus susceptible to any threats which may increase adult mortality. To ensure their conservation, it is vital not only to protect their breeding sites, but also to identify, understand and manage at-sea threats over their entire foraging range.

This paper describes a prioritisation framework that is being developed to collate existing information relevant to risk assessment in order to identify the greatest threats to seabirds. It will identify and prioritise gaps in current knowledge limiting our understanding of at-sea threats, so future research can be focussed on these areas. The framework will include the development of tools required to facilitate expert guidance on the full range of threats to seabirds, and seabird susceptibility. The ultimate purpose is to ensure the available knowledge on seabird biology and ecology is adequate to understand at-sea threats and to minimise their effects on seabirds.

2. FRAMEWORK COMPONENTS

The prioritisation framework currently consists of four components; a database, a spatial mapping tool, tools to facilitate expert review and input, and a risk assessment modelling tool. Figure 1 provides a schematic overview of the framework, and each element is briefly described below.

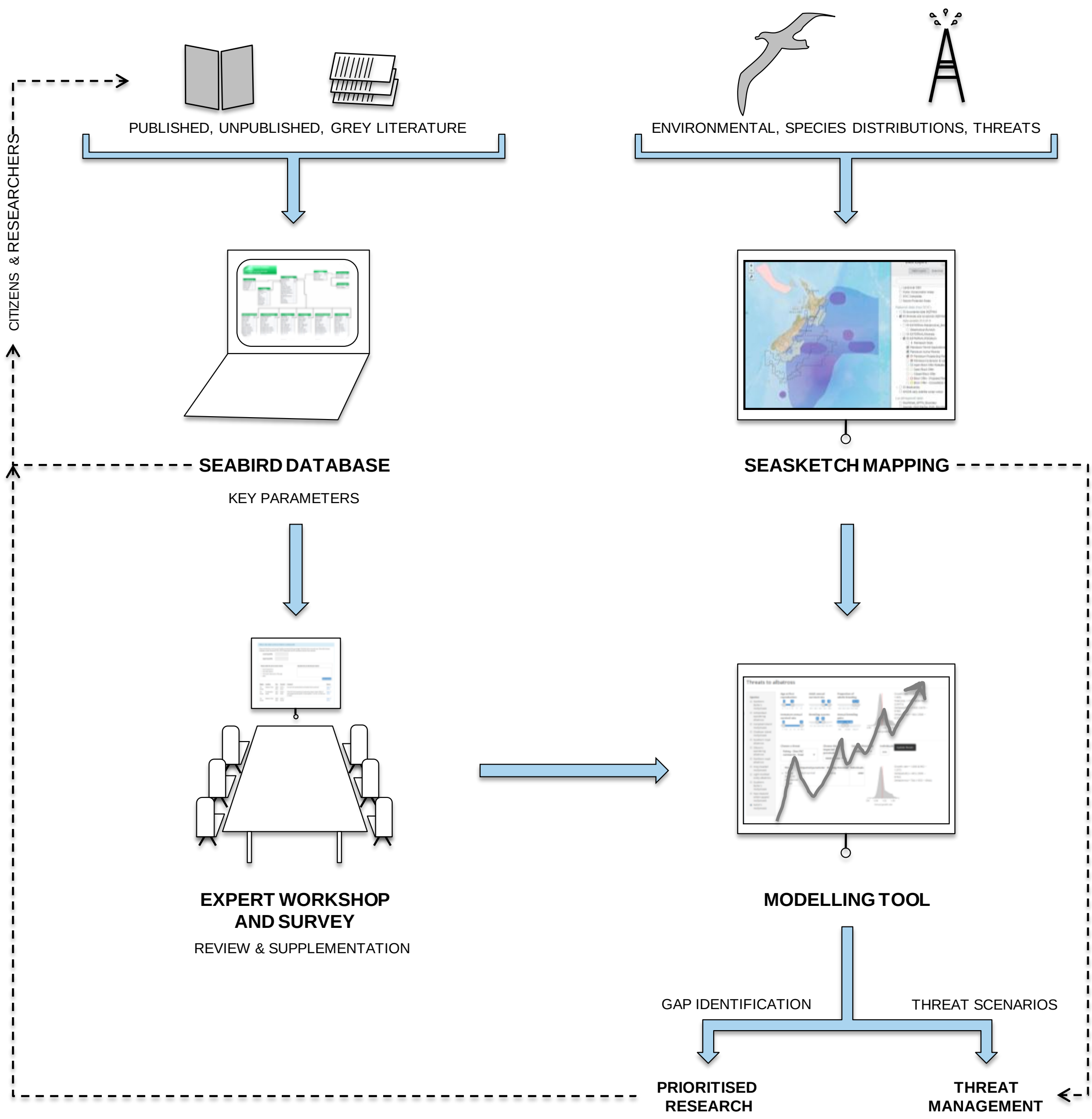

Figure 1. Proposed seabird prioritisation framework.

2.1. Seabird population and demographic database

This component will provide an inventory of pertinent population metric data, and records of at-sea and land-based threats to these seabirds identified to date. Building on historic reviews, the database will inform technical staff, and others, on the extent of information available on New Zealand seabirds and the threats to them. The resource is intended to be useful for various activities including conservation management planning and prioritisation, risk assessments, research and identifying critical data gaps. Currently the database can only be accessed within DOC, but options to allow a web-based interface are being investigated.

2.2. Spatial mapping tool for seabird distribution and at-sea threats

Visualising and assessing the foraging distribution of seabirds and their overlap with at-sea threats forms a central component of the framework. The participatory marine spatial planning tool SeaSketch (http://www.seasketch.org) is being used to develop an interactive mapping project as part of the framework. This will allow a range of spatial data to be displayed and overlaid.

A trial SeaSketch project (http://seabirds.seasketch.org) is available for registered users to view distribution data on New Zealand breeding albatrosses, together with a range of at-sea threat and environmental data. Work is continuing to identify potential at-sea threats, source data on the spatial extent of those threats, and assess their potential impact on seabirds. Note: this project is currently in the development stage, and is populated with data relevant to New Zealand breeding albatross species. The project is being provided to demonstrate the utility of such a mapping tool to better understand at-sea threats, and prioritise research and conservation management actions, and is not intended for other uses. Details on access are provided on the project "About" page.

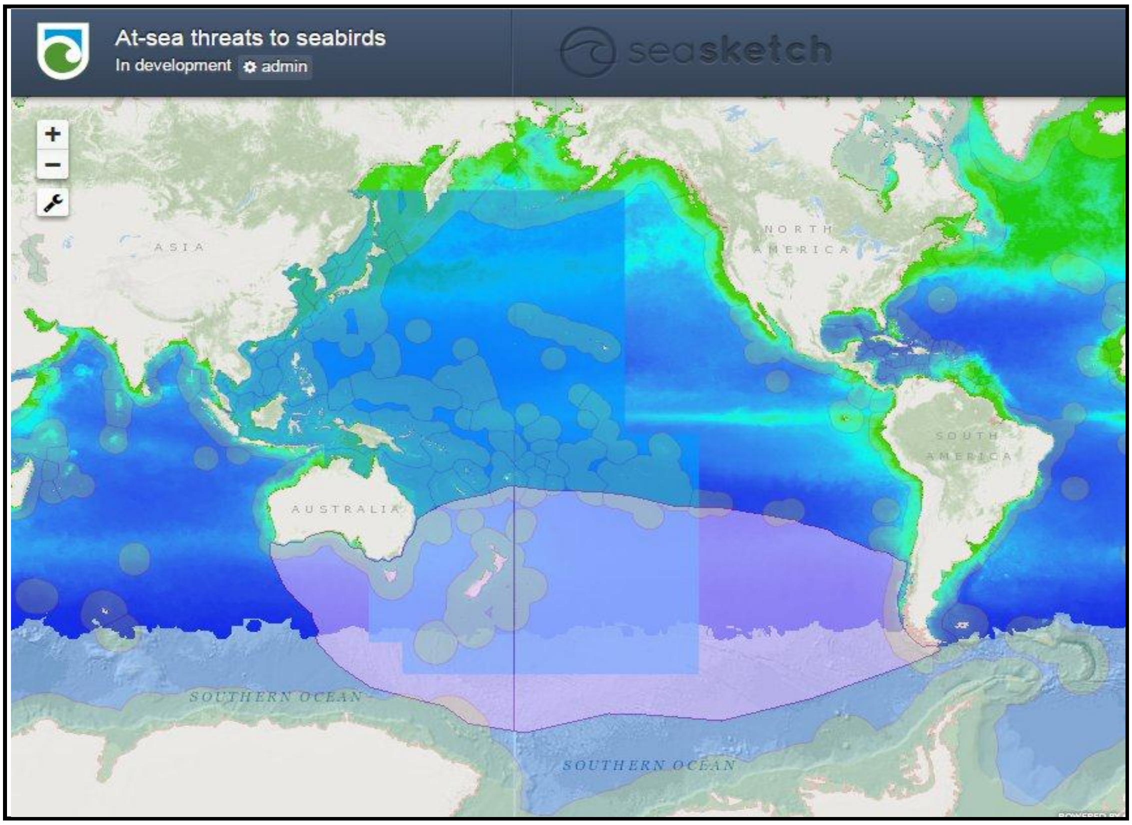

Figure 2. Illustrative screen shot of the SeaSketch spatial mapping tool, overlaying a seabird distribution with environmental and management layers.

2.3. Tools to facilitate expert review and input

The extent and quality of existing data on the biology and distribution of seabirds is highly variable. In order to conduct comparable risk assessment across all seabirds, it is necessary to establish an agreed set of inputs, such as estimates of demographic parameters and key foraging areas. To achieve this, existing data must be expert-reviewed, and in some cases supplemented with expert opinion.

We have developed a process to engage experts in the review of population data collated in the database and to reach consensus on a set of inputs for the risk assessment tool. We used an online Delphi survey (Figure 3). The Delphi method is a structured survey technique for gathering quantitative information and obtaining consensus estimates from a panel of experts. We used this method to review data on New Zealand breeding albatross taxa, and refine base case risk assessment model inputs. Abraham et al. (2015) describe the survey, and the findings, in more detail.

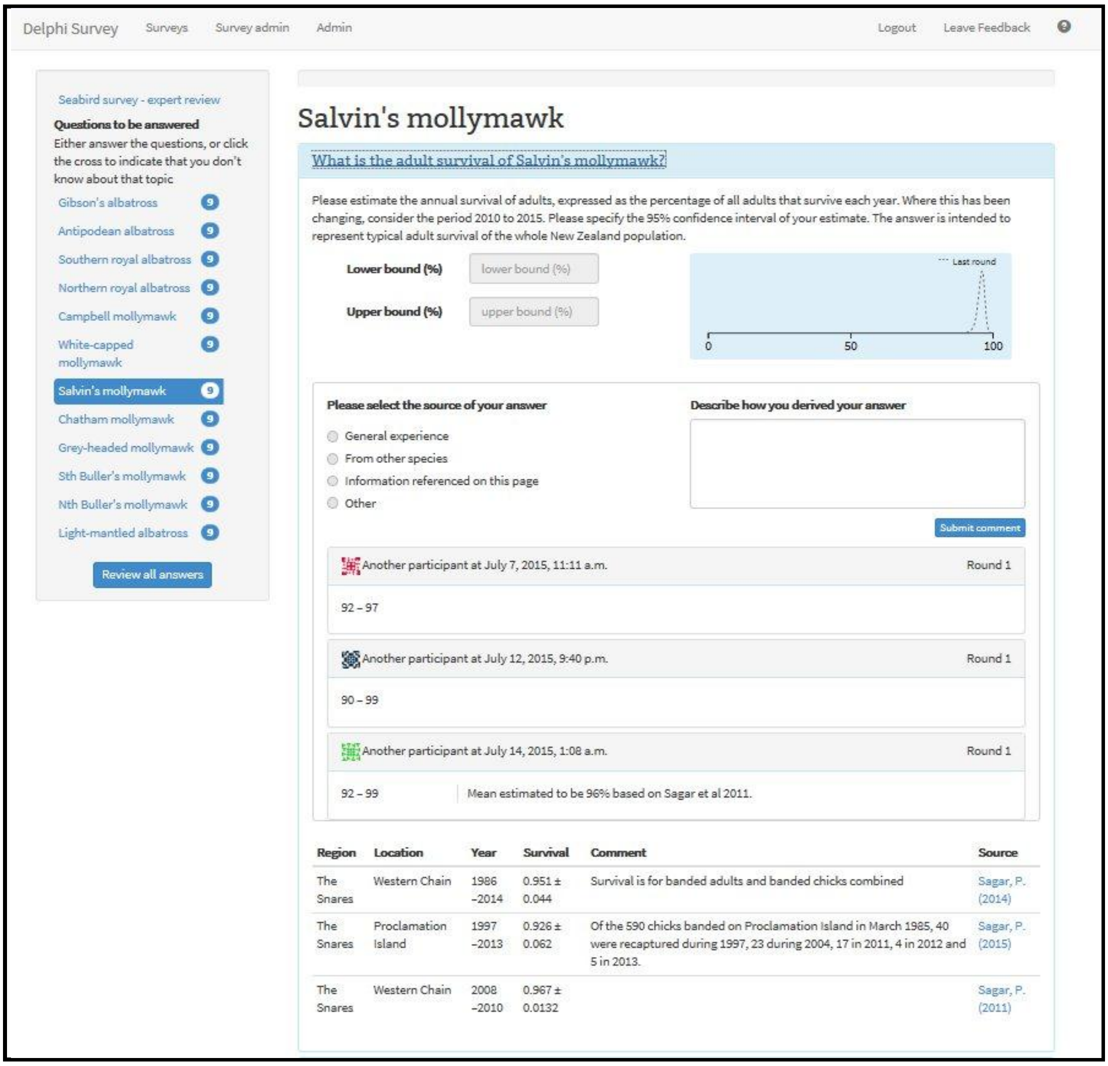

Figure 3. Illustrative screen shot of the Delphi Survey used to facilitate expert input to define risk assessment model input parameters.

We also plan to develop a process to allow relevant experts to review existing seabird distribution data and define key areas in which to assess the overlap and impact of at-sea threats. SeaSketch provides a platform to enable the input, sharing and review of spatial data, through the use of sketches. We envisage this technique can be used to reach expert consensus on core distribution areas, and the implementation of this technique in our SeaSketch project is an area of ongoing investigation.

2.4. Risk assessment modelling tool

A simple matrix model was developed to allow seabird population growth rates to be estimated for a wide range of species using the population parameters derived from the expert survey process. Six input parameters are used, each with a 95% quantile interval; age of first breeding (A), immature cohort survival (S_I), adult survival (S_A), breeding success (BS), proportion of adults breeding (P_B) and annual breeding pairs (N_{BP}). The tool is made available as a demographic modelling website (Figure 4). This online application allows users to assess how changes in demographic parameters affect changes in seabird populations.

In particular, the modelling tool may be used to assess how threats that impact on seabird demographic parameters affect the population trajectories of seabirds. To do this, each threat must be characterised to identify which of the model input parameters it acts upon (e.g. fisheries bycatch may act upon immature survival and adult survival, or food competition may act on breeding success). Scenarios of differing levels of threat intensity (e.g. number of adult birds killed, or percent decrease in breeding success) can then be created and tested with the tool.

Uncertainty in parameter estimates can also be investigated by manipulating the input parameters.

Abraham et al. (2015) describe the development of the model in more detail. The tool is available online for evaluation purposes, populated with input data for albatross taxa derived from the expert survey (https://docnewzealand.shinyapps.io/seabirdmodelling/).

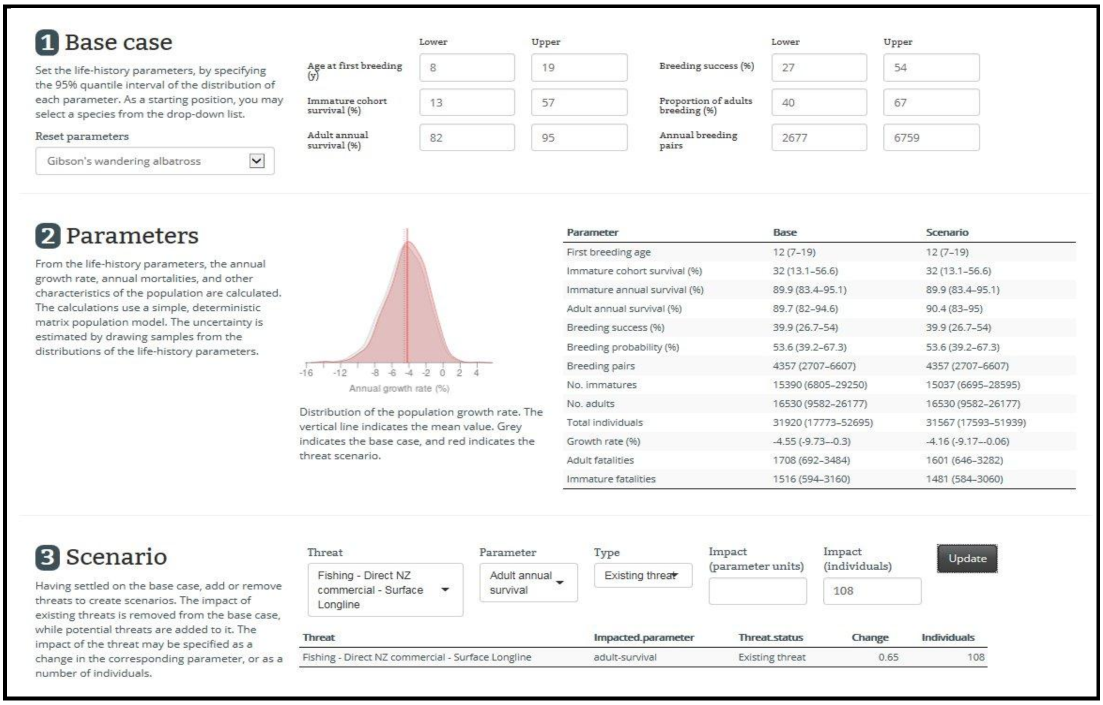

Figure 4. Illustrative screen shot of the risk assessment modelling tool, comparing the base case population growth rate with a scenario in which a current fisheries risk is removed.

3. ILLUSTRATIVE RESULTS

We used the risk assessment tool, populated with reviewed inputs on albatross biology (base case), to illustrate how we could prioritise both research gaps and known and potential threats.

Research gaps were prioritised by assessing how the current uncertainty around each input parameter influences our ability to estimate population growth rates. We ran two scenarios for each input parameter: a scenario where the confidence bound on the parameter estimate was reduced by one third, and the other scenario where the confidence bound was reduced by two thirds. These scenarios represent potential future states following successful completion of new research to obtain more precise estimates of the parameter (e.g. conducting a mark-resight study to obtain more precise estimates of adult survival).

Once the range of threats to any given seabird has been identified and characterised, a range of threat scenarios can be used prioritise the greatest threats.

To illustrate the effect of threats on model estimates of population growth rate we quantified upper and lower bounds of three threats across all New Zealand breeding albatross taxa: New Zealand commercial trawl fisheries, New Zealand commercial surface longline fisheries and New Zealand commercial bottom longline fisheries. The lower bound of the threat was the mean annual estimated captures, and the upper bound was the mean estimated potential fatalities (which includes an estimate of undetected mortality), for that fishery as used in the risk assessment approach of Richard & Abraham (2015). Scenario values used are provided in Annex 1.

To illustrate how all threats to a taxon can be prioritised, we conducted an indicative assessment of threats to Salvin’s mollymawk. A full range of threats were identified by the Delphi survey (Abraham et al. 2016). Plausible bounds for New Zealand commercial fisheries risks were derived as described above, and judgement was used to establish possible bounds for other threats. These bounds should be viewed purely as indicative, for the purpose of demonstrating the use of the process, and are provided in Annex 2. As we highlight in Section 4, a process to more robustly develop a full range of threat bounds is required.

The New Zealand breeding albatross taxa we used in this analysis are listed in Table 1. Note that the taxonomy and nomenclature follow Robertson et al. (2013), which differs slightly from that used by ACAP.

Table 1. New Zealand breeding albatross taxa, with New Zealand and IUCN Threat Status. Threat status: IUCN Red List 2014; NZ Threat status: T = Threatened, AR = At Risk, NT = Not Threatened (Robertson et al. 2013). * = assessed at species level.

Common name	Scientific name	Code	IUCN Threat status	NZ Threat status
Northern royal albatross	*Diomedea sanfordi*	NRA	Endangered	AR Uncommon
Southern royal albatross	*Diomedea epomophora epomophora*	SRA	Vulnerable	AR Uncommon
Antipodean wander albatross	*Diomedea antipodensis antipodensis*	AWA	Vulnerable*	T Critical
Gibson's wandering albatross	*Diomedea antipodensis gibsoni*	GWA	Vulnerable*	T Critical
Light-mantled sooty albatross	*Phoebetria palpebrata*	LMSA	Near Threatened	AR Declining
Grey-headed mollymawk	*Thalassarche chrysostoma*	GHM	Endangered	T Vulnerable
Campbell Island mollymawk	*Thalassarche impavida*	CAIM	Vulnerable	AR Uncommon
Northern Buller's mollymawk	*Thalassarche bulleri platei*	NBM	Near Threatened*	AR Uncommon
Southern Buller's mollymawk	*Thalassarche bulleri bulleri*	SBM	Near Threatened*	AR Uncommon
New Zealand white-capped mollymawk	*Thalassarche steadi*	WCM	Near Threatened	AR Declining
Chatham Island mollymawk	*Thalassarche eremite*	CHIM	Vulnerable	AR Uncommon
Salvin's mollymawk	*Thalassarche salvini*	SM	Vulnerable	T Critical

3.1. Prioritising seabird research

The prioritisation illustrated here is based on the size of the confidence interval of estimated population growth rate derived from the modelling tool. We have used this measure because ultimately threat management aims to maintain or improve the population growth rate. Thus, being able to accurately estimate population growth rate will allow outcome monitoring of threat management actions.

3.1.1. Priority species for research

The uncertainty around the base case model estimate of population growth rate provides a measure to prioritise which taxa to focus research effort. Figure 5 shows the size of the 95% confidence interval for each albatross taxon. This shows us that we have least certainty in estimating population growth rate for Chatham Island mollymawk, light-mantled sooty ablatross and Antipodean wandering albatross. Thus, these taxa would form the highest priority to obtain more precise population parameter estimates. Other factors that may influence the choice of priority species includes existing threat status classifications (e.g. see Table 1), or those species facing the greatest threats. Logistical and economic constraints will also need to be considered in designing and implementing research programmes to address the priority gaps identified.

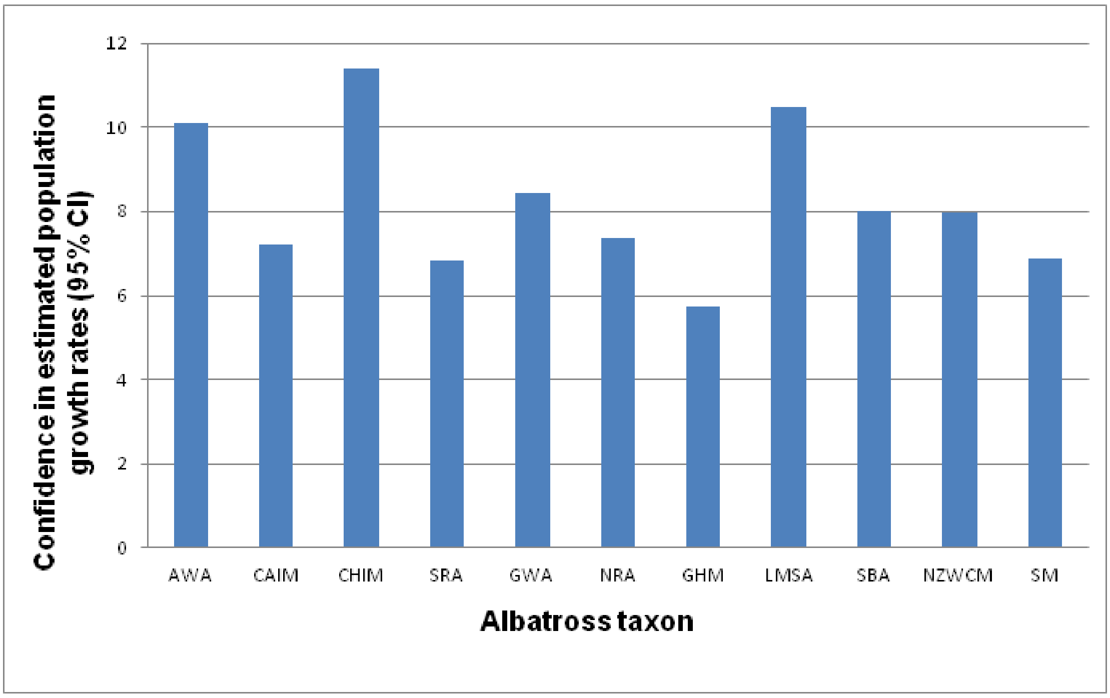

Figure 5. Uncertainty in population growth rate (95% CI) in base case model for New Zealand breeding albatross taxa. See Table 1 for taxa codes.

3.1.2. Priority research topics

Research programmes should be designed so as to provide the most useful information. In order to inform and monitor threat management we consider the ability to precisely estimate population growth rate to be the most useful information. On the assumption that new research will provide more precise estimates of input parameters, we tested scenarios under which the confidence interval of all six input parameters were reduced (by one third and by two thirds). Figure 6 summarises the influence of each of those scenarios as measured by the improvement in certainty of the model estimate of population growth rate.

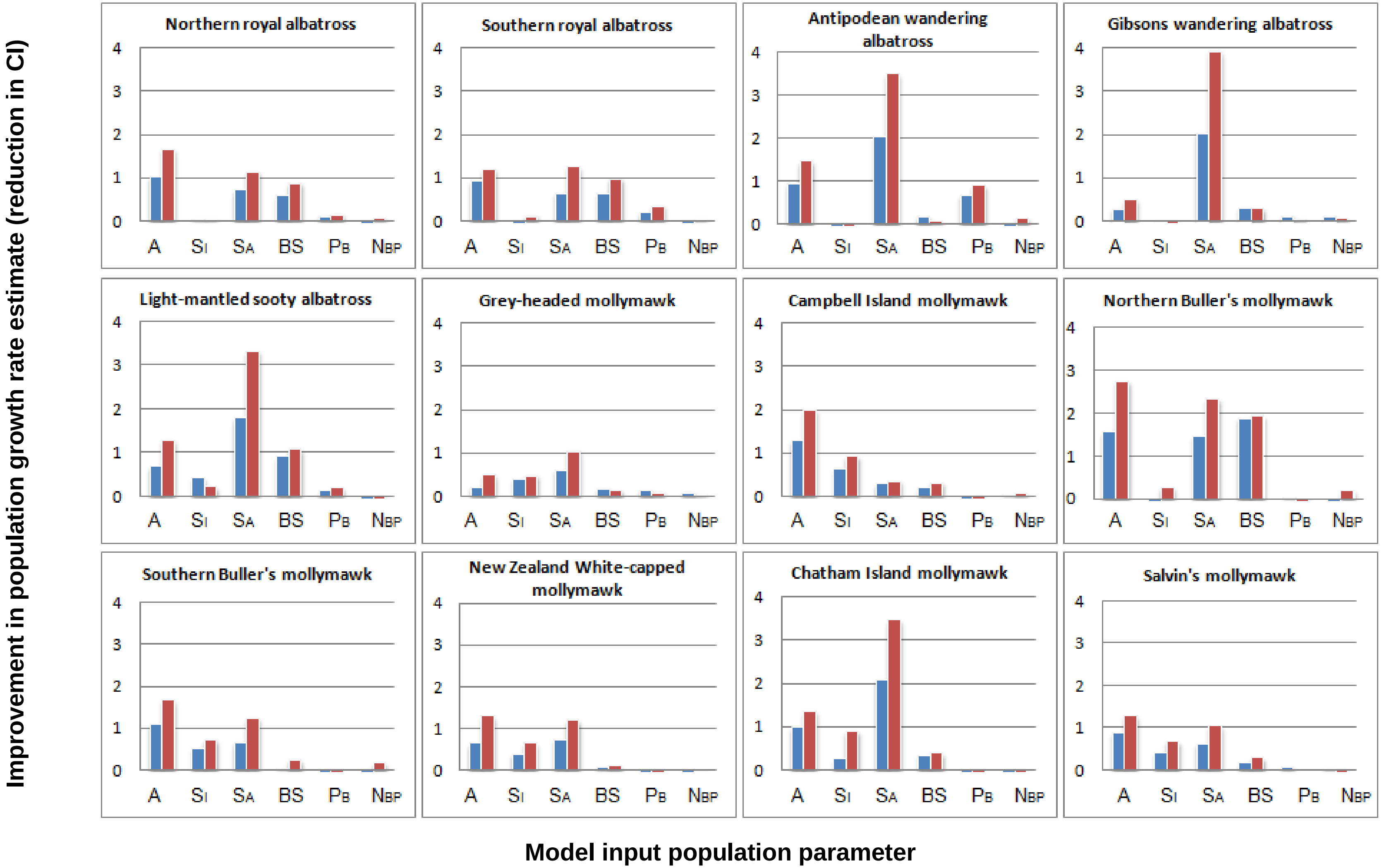

Figure 6. Improvement in estimated population growth rate (reduction in 95% CI) with improved estimates of model input parameters (blue bars = input parameter CI reduced by one third; red bars = input parameter CI reduced by two thirds). A = age of first breeding; SI = immature survival; SA = adult survival; BS = breeding success; PB = proportion breeding; NBP = number of breeding pairs.

For the three taxa identified as priorities in Section 3.1.1 (Chatham Island mollymawk, light-mantled sooty albatross and Antipodean wandering albatross) the greatest gains will come from more precise estimates of adult survival. Adult survival is typically investigated by mark-resight studies and appropriate modelling of the data collected. Such studies on these taxa would be a high priority.

Improving estimates of some input parameters, such as proportion of adults breeding, has minimal influence on resulting model estimates of population growth rate for any species. Conducting further research on this parameter would thus be a low priority.

For the purposes of completeness we included scenarios with increased confidence in the number of annual breeding pairs, though as expected this has little influence on the precision of model estimates of population growth rate. However, robust estimates of population size are important in quantifying population level risk posed by threats.

3.2. Comparing seabird threats

We use the effect of a threat on the estimated population growth rate as the key measure of risk posed by that threat, to allow prioritisation between threats. Current best estimates of input parameters, and thus base case model estimates, include the influence of existing threats (e.g. known direct fisheries bycatch). The risk assessment modelling tool can be used to run scenarios where such known threats are removed, and the resulting improvement in estimated population growth rate can be quantified. The modelling tool can also be used to run scenarios on potential future threats (e.g. new pest incursion), and the resulting drop in estimated population growth rate can be quantified. In this section we report both types of scenarios, using lower and upper bounds of plausible intensity, and present the resulting changes in population growth rate.

3.2.1. Assessing a threat across taxa

Figure 7 shows the resulting change in population growth rate for all New Zealand breeding albatross taxa under scenarios for three known existing fisheries threats; bycatch in the New Zealand commercial trawl, surface longline and bottom longline fisheries. It is clear that some taxa are at hgher risk to some threats that others. For example, this analysis indicates that management measures to reduce risk from trawl fisheries will be of most conservation benefit to Salvin's mollymawk, Southern Buller's mollymawk and New Zealand white-capped mollymawk. It should be noted that the bounds of risk uncertainty are particularly high for trawl, this being a reflection that the multiplier used for undetected mortalities in estimating the upper bound of the threat is higher than that used in longline fisheries (see Richard & Abraham 2015).

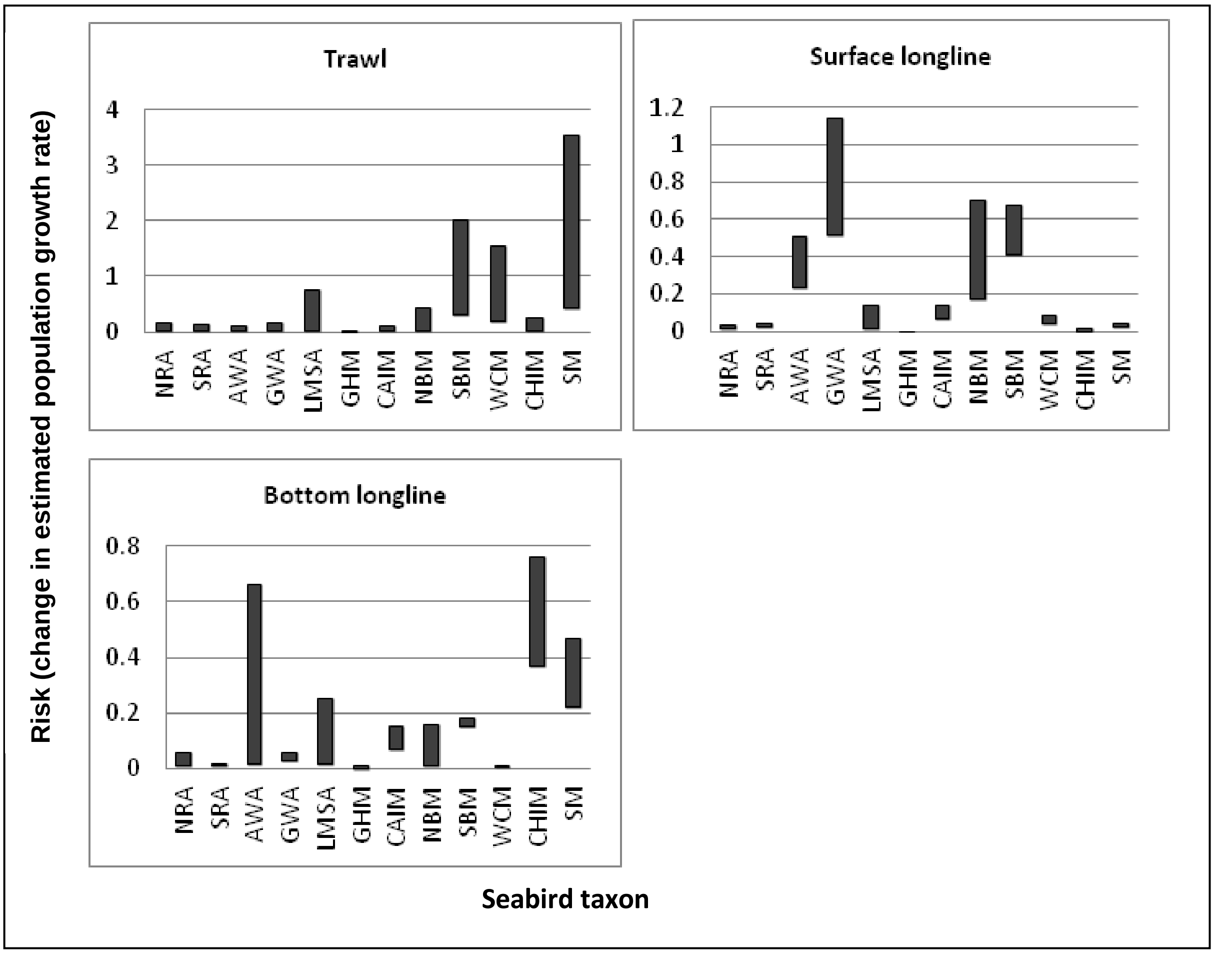

Figure 7. Plausible bounds of risk (as measured in a change to estimated population growth rate) for three fisheries bycatch threats to New Zealand breeding albatross taxa. The lower extent of the bars represent the lower bound of the threat, and the upper extent the upper bound of the threat. See Table 1 for taxa codes.

3.2.2. Assessing all threats to one taxon

Using the illustrative characterisation of all threats identified to Salvin's mollymawk (Annex 2), we ran scenarios using the upper and lower bounds of the cumulative impacts of each threat category (e.g. New Zealand commercial trawl, surface longline and bottom longline fisheries are all combined in this analysis). Threats vary from ongoing annual (e.g. fisheries bycatch) to rare events (e.g. natural disasters). Currently the modelling tool can only create scenarios using annualised threats. We considered any threat that was expected to impact the taxon at a frequency of less than once every five years to be a rare threat, and excluded that threat from this analysis. For cyclical threats, that may act once every two to five years, we took annualised estimate of the threat for the purposes of this analysis.

Figure 8 summarises the results for Salvin's mollymawk, showing the resulting change in population growth rate under the range of scenarios tested. These results are only indicative, for the purposes of demonstrating the utility of this approach, but illustrate in a directly comparable way the difference between the extent of risk posed by different threats. In this case, the direct effects of fishing (i.e. bycatch) pose by far the largest risk. The bounds of plausible risk are particularly high for direct fisheries effects due to the large degree of uncertainty around undetected mortality. Such an analysis also allows an assessment of how feasible the risk confidence bounds identified are. For example, the cumulative total of all upper bounds of all threats illustrated in Figure 8 equate to a change in population growth rate of over 12%. With a base case population growth rate in this case of 1.1%, removal of the upper bounds of all threats would result in a growth rate of over 13%, which is unlikely for an albatross taxon. This suggests the true extent of risk posed by these threats is less than the upper bounds identified.

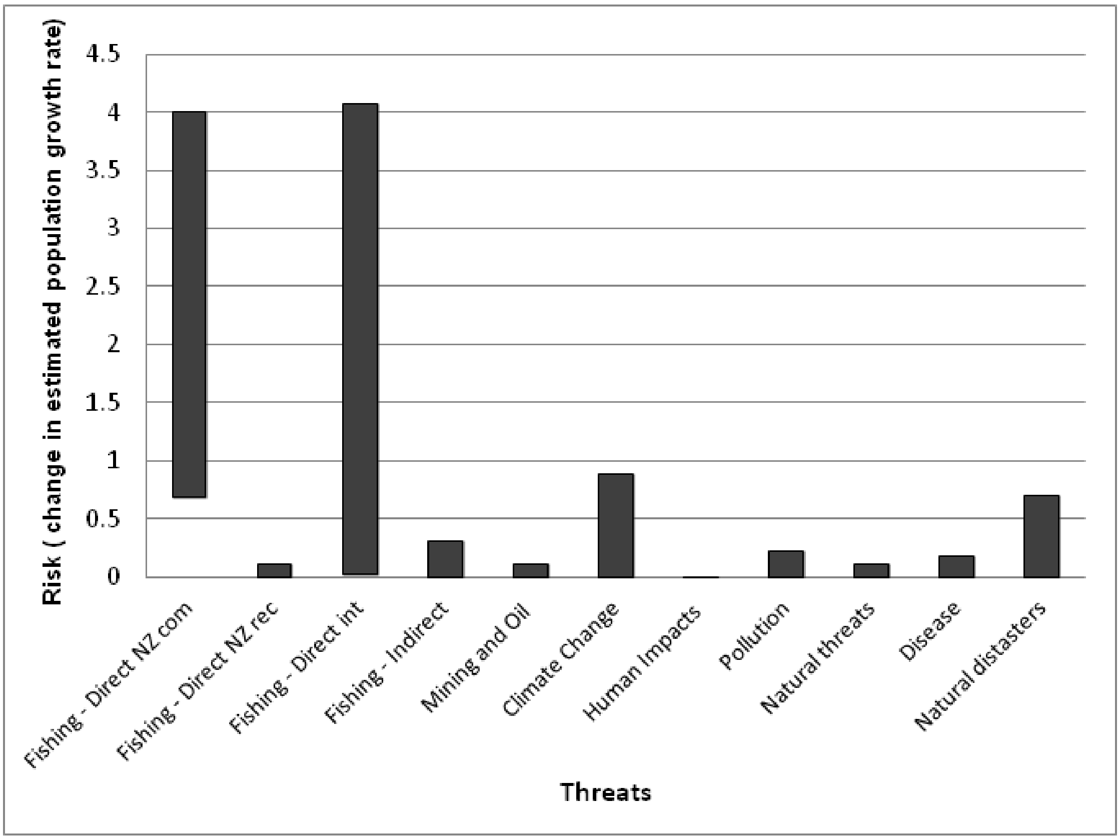

Figure 8. Possible bounds of risk (as measured in a change to estimated population growth rate) for all non-catastrophic threats identified for Salvin's mollymawk. The lower extent of the bars represent the lower bound of the threat, and the upper extent the upper bound of the threat.Com = commercial; rec = recreational.

4. FUTURE WORK

The work to develop this framework is ongoing, and it is envisaged that over time outputs will inform prioritisation decisions in seabird research and threat management actions at a national scale.

Some of the future challenges in developing this framework include:

1. Spatial discrepancies and uncertainty – both in terms of seabird distributional information, and threat spatial data. Threat/bird distribution overlap is an important element required to quantify at-sea threats, so robust spatial data layers must be developed. One process under development is the use of SeaSketch "sketches" to use expert judgement to define core areas based on a range of existing data.

2. Global threats. Many New Zealand seabird taxa forage over vast ranges and face a range of threats globally. Facilitating sufficient input at this scale is challenging with limited resources.
3. Quantifying poorly understood threats. We envisage a process will be necessary to seek guidance and expert input to identify, characterise and quantify the full range of threats facing New Zealand seabirds.
4. Modelling threats that are not easy to quantify in an annualised figure. Further development of the risk assessment modelling tool may accommodate the inclusion of risk from rare events.
5. Application to more data poor species. Albatross taxa are one of the better studied groups of New Zealand seabirds. We envisage application of this framework to other taxa groups could pose greater difficulties in gathering sufficient data.

We seek collaboration with others dealing with these and other challenges, and we hope that making the tools developed in our work freely available will be of use to both practitioners within New Zealand, other programmes outside of New Zealand.

ACKNOWLEDGEMENTS

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ANNEX 1. BOUNDS OF NEW ZEALAND COMMERCIAL FISHERIES RISK USED TO DEMONSTRATE THREAT SCENARIOS

Annual estimated captures (lower bound) and potential fatalities (upper bound) in New Zealand trawl, bottom longline and surface longline (see Richard & Abraham 2015).

		Trawl		Bottom longline		Surface longline	
Common name	Code	Lower	Upper	Lower	Upper	Lower	Upper
Northern royal albatross	NRA	3	33	2	6	3	11
Southern royal albatross	SRA	4	24	2	8	4	4
Antipodean wander albatross	AWA	2	20	4	93	44	10
Gibson’s wandering albatross	GWA	2	25	5	186	87	10
Light-mantled sooty albatross	LMSA	1	7	1	1	0	2
Grey-headed mollymawk	GHM	0	2	1	1	0	2
Campbell Island mollymawk	CAIM	7	53	38	77	36	82
Northern Buller’s mollymawk	NBM	3	184	2	296	71	68
Southern Buller’s mollymawk	SBM	102	647	49	215	132	57
New Zealand white-capped mollymawk	WCM	505	4160	21	211	97	38
Chatham Island mollymawk	CHIM	4	31	46	1	1	95
Salvin’s mollymawk	SM	377	3050	190	31	14	401

ANNEX 2. INDICATIVE BOUNDS OF GLOBAL THREATS TO SALVIN'S MOLLYMAWK USED TO DEMONSTRATE THREAT SCENARIOS

Threat characterisation of all threats identified for Salvin's mollymawk. Note: this is an indicative assessment for the purposes of demonstrating the utility of the modelling tool. Negligible threats and rare threats (periodicity less than one in five years) were excluded from the analysis but are shown here.

Threat class	Subcategory	Demographic parameter	Existing/ Potential	Unit	Lower	Upper	Periodicity	Comments
Fishing - Direct NZ com	Trawl	Adult survival	Existing	Individuals	377	3050	Annual	
Fishing - Direct NZ com	Surface Longline	Adult survival	Existing	Individuals	14	31	Annual	
Fishing - Direct NZ com	Bottom Longline	Adult survival	Existing	Individuals	190	401	Annual	
Fishing - Direct NZ com	Gillnet	Adult survival	Existing	Individuals	0	1	Annual	
Fishing - Direct NZ com	Other	Adult survival	Existing	Individuals	0	10	Annual	
Fishing - Direct NZ rec	Line	Adult survival	Existing	Individuals	0	100	Annual	
Fishing - Direct NZ rec	Setnet	Adult survival	Existing					Negligible
Fishing - Direct NZ rec	Other	Adult survival	Existing					Negligible
Fishing - Direct int		Adult survival	Existing	Individuals	10	3000		
Fishing - Direct int		Juvenile survival	Existing	Individuals	5	500		
Fishing - Indirect		Breeding success	Existing	breeding success	0.005	0.3		
Mining and oil	Pollution	Adult survival	Potential	Individuals	0	1000	1 in 20 yrs	Not included in analysis
Mining and oil	Pollution	Breeding success	Potential	breeding success	0.005	0.3	1 in 20 yrs	Not included in analysis
Mining and oil	Habitat degradation	Breeding success	Potential	breeding success	0	0.1	Annual	
Climate change	Temperature	Breeding success	Potential	breeding success	0	0.3	1 in 3 yrs	
Climate change	Sea level rise	Breeding success	Potential	breeding success	0	0.1	annual	
Climate change	Prey availability/ foraging displacement	Breeding success	Potential	breeding success	0	0.3	annual	

Table continued on next page.

Annex 2 table continued.

Threat class	Subcategory	Demographic parameter	Existing/ Potential	Unit	Lower	Upper	Periodicity	Comments
Climate change	Prey availability/ foraging displacement	Adult survival	Potential	survival rate	0	0.05	annual	
Climate change	Prey availability/ foraging displacement	Juvenile survival	Potential	survival rate	0	0.1	annual	
Climate change	Other	Breeding success	Potential	breeding success	0	0.7	1 in 3 yrs	Storm events associated with climate change
Human impacts at nest site	Research	Breeding success	Potential		0	10	Annual	
Pollution	Marine debris/entanglements	Adult survival	Existing	Failed breeding attempts	0	50	annual	
Pollution	Marine debris/entanglements	Juvenile survival	Existing	individuals	0	25	annual	
Pollution	Plastics	Breeding success	Potential	individuals	0	100	annual	
Natural animal threats	Mammal	Breeding success	Potential	dead chicks	0	0.1	Annual	
Disease	Avian cholera	Breeding success	Potential	breeding success	0	0.3	1 in 5 yrs	
Disease	Avian cholera	Adult survival	Potential	breeding success	0	0.05	1 in 5 yrs	
Disease	Avian pox virus	Breeding success	Potential	survival rate	0	0.1	Annual	
Natural disasters/events	Tsunami	Adult survival	Potential	breeding success				Negligible
Natural disasters/events	Tsunami	Breeding success	Potential		0	0.7	1 in 100 yrs	Not included in analysis
Natural disasters/events	Storms			breeding survival				Impact due to elevation in storm levels captured in "climate change - other" category