SPRFMO

6th Meeting of the Scientific Committee

Puerto Varas, Chile, 9 - 14 September 2018

SC6-Doc30

Observer coverage to monitor seabird captures in fisheries

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South Pacific Regional Fisheries Management Organisation

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10 August 2018

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1. Purpose of paper

In response to requests from the SPRFMO Commission, this paper reviews observer coverage in place in longline and trawl fisheries internationally, identifies limitations inherent in low levels of coverage, and provides guidance on levels of observer coverage appropriate to developing bycatch estimates for seabirds in SPRFMO fisheries. Although this paper is focussed on seabirds, similar principles will apply to the consideration of observer coverage required to monitor the bycatch of other species of concern (e.g., marine mammals and reptiles).

2. Background

In 2014, the Roadmap for the Scientific Committee (Annex D of the Report on the Second Meeting of the Commission) requested that the Scientific Committee "*evaluate the level and type of observer coverage that is recommended for demersal longline and trawl fisheries to provide a statistically reliable estimate of seabird mortality associated with that fishery*". In 2018, Commission provided more explicit guidance on seabirds and observer coverage issues in its Workplan for the Scientific Committee 2018–2025:

- Analyse observer-collected seabird interaction data to inform risk assessment (by 2018)
- Progress southern hemisphere quantitative risk assessment (SEFRA) (by 2018)
- Provide a discussion paper on the interaction and tradeoffs between observer coverage levels and Commission management objectives for each major fishery (by 2018)
- Analyze observer coverage rates from simulation study for SPRFMO fisheries and recommend values to Commission (by 2019)
- Evaluate available observer data on seabird interaction rates (jack mackerel, different squid fisheries, demersal) and determine where estimates can be improved (by 2019)

This paper addresses the third of these bullet points using literature searches and information from New Zealand in-zone fisheries. This is essentially an update of a previous paper to SC-02 by Debski & Pierre (2014).

The deployment of independent fisheries observers is widely recognised as a key component of best practice fisheries management (e.g., FAO 1995, 2009, Lodge et al. 2007). In addition to supporting the management of target catch, observer data is fundamental to assessments of the effects of fishing on non-target species, including seabirds (e.g., Ministry for Primary Industries 2013a, b; Richard and Abraham 2013). The proportion of fishing events monitored by observers, the spread of observer coverage across vessels in a fleet, and the geographical and temporal spread of observer coverage across the fishing effort all have direct bearing on the robustness of any resultant data and understanding of bycatch patterns, including estimates of the extent of bycatch. Thus, the assessment and delivery of appropriate levels of coverage is critically important to ensuring that fishery managers' objectives and information needs can be addressed.

3. Observer coverage in other jurisdictions

Gilman et al. (2012) examined observer coverage across 12 regional fisheries management organisations (RFMOs)[1] in the context of the governance of fisheries bycatch and discards. Their review found that regional observer coverage rates varied from 0–87.5% on average, but that only about a quarter of the RFMO-managed fisheries had >5% observer coverage. Target or required percentages of coverage were typically stipulated in RFMO documentation (e.g., Western and Central Pacific Fisheries Commission[2]), with the data collected at sea sometimes being examined to assess whether the objectives of coverage were being met (e.g., Agnew et al. 2010). For one RFMO considering observer coverage, including to assess and monitor seabird bycatch, initial coverage levels of 25–30% across fleets have been recommended (Black et al. 2007).

As an alternative to achieving a prescribed proportion of coverage of fishing effort, some observer programmes are guided by the requirement to achieve a target level of precision for estimates of bycatch of seabirds or other taxa (e.g., coefficient of variation, CV). For example, the US Northeast Fisheries Science Center's National Working Group on Bycatch (Wigley et al. 2007) recommended that at-sea observation effort be tailored to reach a recommended precision goal of 20–30% CV for estimates of bycatch by species (or stock) in a fishery. Subsequently, a CV of 30% has been used for identifying the days of observer coverage required and for monitoring delivery of coverage (e.g., NOAA Fisheries 2011).

4. Efficacy of different levels of observer coverage

Observer coverage delivers the most complete and accurate suite of information when 100% of fishing effort is monitored. However, when full coverage is not achieved, limitations of the data collected must be recognised and information collected must be scaled up to fleet level using methods that, so far as possible, are unbiased. Given seabird bycatch is a statistically rare event, and often heterogeneous and patchy in both time and space, scaling up observer data creates mathematical challenges, as well as accuracy and precision issues. For example, captures of rare species are more likely to be missed when coverage levels are lower and confidence in the bycatch estimates generated is inherently lower. Observer coverage levels for seabird bycatch generally refer to the percentage of events or days fishing observed, not the percentage of vessels or trips observed. For example, on longline vessels, the haul may last several hours and, even when an observer is onboard, only a proportion of hooks hauled may actually be observed due to competing demands on the observer. Similarly, on trawl vessels that fish 24 hours a day it is possible that not all trawl hauls will be observed, even if an observer is onboard.

In general, observer coverage of 5% of fishing effort may be adequate to identify the existence of some bycatch issues, but is inadequate to estimate the frequency of bycatch species' interactions with fishing gear robustly (Gilman et al. 2012). In relatively homogenous fisheries, 5% coverage can provide sufficient information to support stock assessments (e.g., sufficient data on selectivity, fish size, and age structure), but such low coverage provides highly uncertain estimates of rare events like seabird or marine mammal bycatch. Exponential increases in the accuracy of bycatch estimates occur as observer coverage levels increase to around 20% of fishing effort (Lawson 2006). At that level of coverage, common fish species

[1] For this analysis, the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) was included alongside RMFOs.

[2] http://www.wcpfc.int/system/files/ROP%20Standards%20.pdf

comprising ~35% of the total catch will be estimated within 10% of their actual catch level 90% of the time (Babcock et al. 2003). For seabirds caught in CCAMLR demersal longline fisheries, 25% coverage has been considered broadly adequate to detect increases in bycatch when birds are captured at rates of around 0.2 birds/1000 hooks (Ashford 2002).

Beyond observer coverage of around 20% of fishing events, increases in the accuracy of bycatch estimates accrue more slowly (Lawson 2006). However, the need for higher rates of coverage to detect the capture of rare species (which, nonetheless may still be at risk from bycatch), and to estimate the levels of captures of species that rarely interact with fishing gear, is well recognised. In their simulation study, Babcock et al (2003) found that, for bocaccio rockfish captured in a trawl fishery (but comprising <0.1% of the catch), the proportion of simulations that gave estimates of within 10% of the true value increased only gradually with the sampling fraction because bycatch events are both rare and highly variable (as is the case with many seabirds and marine mammals). They estimated that more than 50% of fishing events had to be observed for 90% of estimates to be within10% of the true value. Where species and interactions are especially rare and/or highly aggregated, the need for coverage levels of close to 100% has been recognised (Lawson 2006).

Although general guidelines like these are well established, the level of coverage required to deliver a particular level of precision in bycatch estimates varies with a number of factors. The key factors and type of variation are summarised in Table 1. In addition to these variables, the relative occurrence of multiple capture events also influences the ability to accurately extrapolate observed bycatch data; if a seabird is captured in rare events that often have several or many individual birds, then higher levels of coverage will be required for a given desired level of precision compared with a species captured more frequently but in low numbers per event.

Table 1. Key factors influencing levels of observer coverage required to estimate seabird bycatch.

	Type of variation			
	Day/night	**Seasonal**	**Spatial**	**Vessel / skipper**
Fishing effort		✓	✓	✓
Seabird abundance		✓	✓	
Seabird behaviour	✓	✓	✓	
Vessel characteristics		✓		✓
Vessel behaviour	✓	✓	✓	✓
Use of mitigation	✓			✓

5. Examples from New Zealand longline and trawl fisheries

In New Zealand, government fisheries observers have monitored seabird bycatch in trawl and both surface and demersal longline fisheries for more than 20 years. Levels of observer coverage have varied through time and space as well as amongst fishing methods. Statistical models are used to estimate total observable[3] bycatch for a wide range of fisheries using observer data. Bycatch estimates based on data collected at varying levels of observer coverage

[3] Total observable captures is an estimate of the captures that would have been reported had all fishing events been observed

for selected fisheries are presented in Appendices 1 and 2[4], together with the uncertainty associated with the estimates (being the ratio of the width of the 95% confidence interval of the estimate to the estimated mean). It should be noted that the estimates of precision come from statistical models that can partition some of the observed variability to environmental or fishing-related factors. Ratio-based estimates using the same data would probably have lower precision (wider confidence limits) unless such estimates were appropriately stratified to account for known or suspected heterogeneity in capture rates. Full details of fishery definitions and the methods used to estimate bycatch are described by Abraham and Thompson (2011) and Abraham et al (2016).

As expected, the precision of estimates generally increases with increasing coverage (Figure 1), though absolute values vary greatly among fisheries and, for some fisheries, between years. Where observer coverage was less than 10%, the 95% confidence limits of estimates always spanned more than 1.5 times the mean value, making annual estimates of bycatch unreliable and providing very little power to monitor changes between years. Other factors such as the spread of observer coverage across seasons, locations, and vessels (i.e., representativeness of coverage), occurrence of bycatch events involving more than one (sometimes many) birds, and the information base to build appropriately stratified statistical models also influence the precision of these estimates. For instance, observations from 20–30% of events in New Zealand's hoki and squid trawl fisheries underpinned statistical models that generated quite precise estimates of historical seabird bycatch (95% C.I ~ 0.6 times the mean, all seabird species combined). Conversely, the same level of coverage in trawl fisheries for ling and southern blue whiting and the bottom longline fishery for ling generated models with very uncertain estimates (95% C.I ~ 1.5 times the mean or higher). Of course, estimates of the bycatch of individual seabird species or taxonomic groups like mollymawks, procellariad petrels, or great albatrosses will be of much lower precision than the estimates for all species combined. For this reason, New Zealand uses this type of statistical model to estimate the bycatch only for more commonly-caught species (see, for instance, a public online database available at: https://psc.dragonfly.co.nz/2017v1/released/explore/) and uses an integrated risk assessment to assess rare and less-commonly-caught species (see Section 6).

Bias is another issue that is related to the proportion of effort that is observed, but much harder to assess than precision and not often considered quantitatively (Babcock et al. 2003). Typically, the potential for bias decreases as the proportion of events observed increases. Bias can be introduced by non-random sampling whereby observers are allocated preferentially to vessels that volunteer to carry observers, or where certain classes of vessels find it difficult to carry an observer, or where, by chance, observed fishing occurs at different times, places, or for target species different than fishing in general. There is also the potential for an "observer effect" where fishers consciously or unconsciously change their behaviour in the presence of an observer (Benoît & Allard 2009). Some bias can be corrected using statistical models (for example by estimating factors for vessel characteristics, location, seasonality, time of day, moon phase, etc.), but robust correction for bias depends on sufficient data and a good understanding of the processes that can lead to bias. Benoît & Allard (2009) concluded that the nature of the effects they observed precluded correction of observer-collected catch data for possible biases and imprecision.

We do not explicitly consider the potential for bias here, but it is an important component of the overall uncertainty in bycatch estimates. It should be borne in mind that observation of a

[4] https://data.dragonfly.co.nz/psc/

low proportion of fishing events increases the risk of bias (which can be hard to detect and correct) as well as increasing the sampling error / imprecision of estimates.

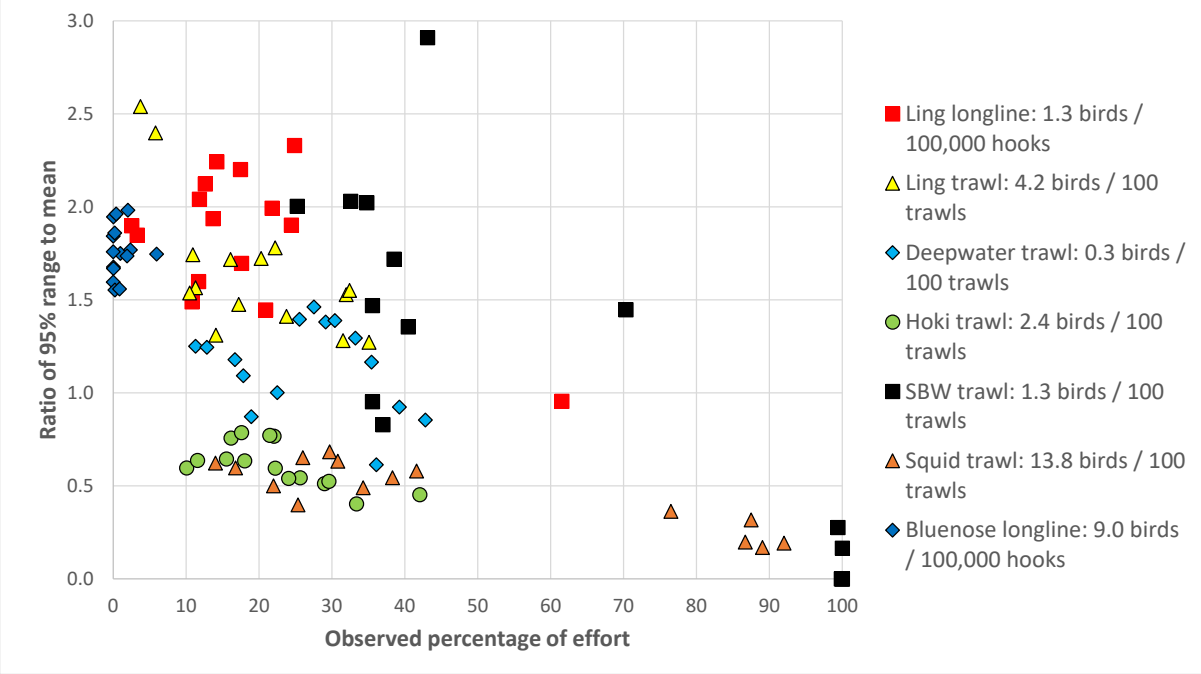

Figure 1: The ratio of the width of the 95% confidence interval to the mean of estimated seabird captures (all taxa combined) plotted against the percentage of fishing events observed for selected New Zealand in-zone fisheries 2003-2017. The data are summarised in Appendices 1 and 2.

6. The application of observer data to risk assessments

The use of risk assessments to explore the impacts of fisheries on non-target species such as seabirds is increasing globally (e.g., Small et al. 2013). In New Zealand, data on seabird bycatch collected by fisheries observers is one input into an integrated risk assessment using the SEFRA[5] framework for 71 seabird species. This risk assessment (Richard and Abraham 2013, Richard et al. 2017) assesses the extent to which estimated fatalities in commercial fisheries are higher than populations can sustain and still reach a defined population outcome. Allowance is made for cryptic, or unobserved, seabird mortality, such as aerial warp strikes in trawl fisheries, or loss of birds from longline hooks. Estimated mean multipliers were between 1.30 (C.I. 1.1–1.7) and 106.5 (C.I. 33.3–260.5) times observable mortality in trawl fisheries, for different types of trawlers and categories of seabird, and 2.08 (C.I. 1.79–2.43) times observable mortality in longline fisheries.

Specification and propagation of uncertainty in all input parameters makes this risk assessment a powerful tool for identifying and prioritising information needs. Figure 2 shows that, for 13 of the 16 seabird species at non-negligible risk from New Zealand commercial fisheries,

[5] Spatially-Explicit Fisheries Risk Assessment, see Ministry for Primary Industries 2017 (Chapter 3), available at: https://www.mpi.govt.nz/dmsdocument/27471-aquatic-environment-and-biodiversity-annual-review-aebar-2017-a-summary-of-environmental-interactions-between-the-seafood-sector-and-the-aquatic-environment

estimated risk was most sensitive to uncertainty in estimates of bycatch that, in turn, rely on observer records (as well as estimates of cryptic mortality which probably requires directed work as well as observer data). Estimates of risk were generally less sensitive to other inputs such as adult survival ("natural mortality") or the number of breeding pairs in each population.

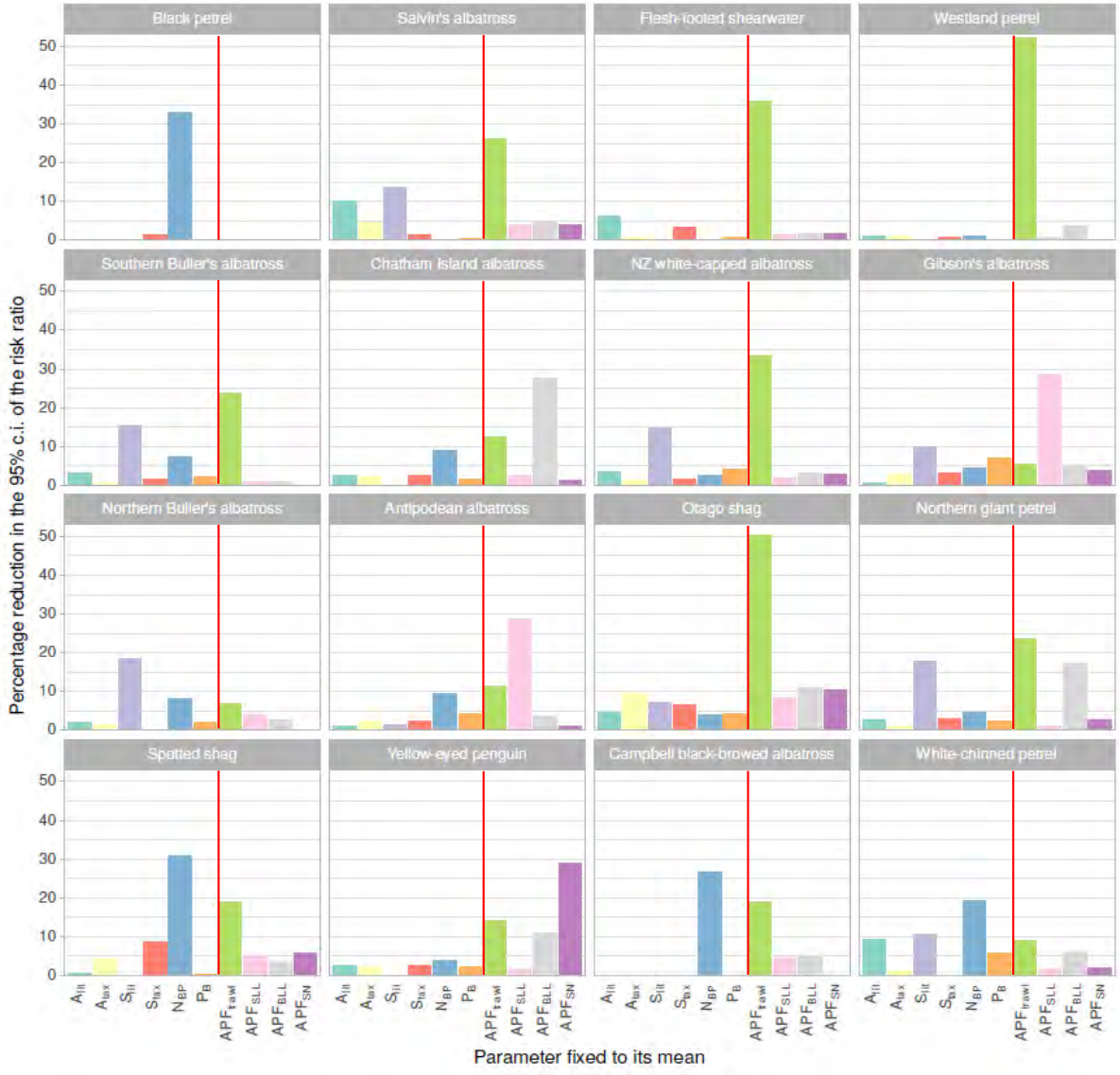

Figure 2 (from Richard et al. 2017, their Figure 7): Sources of the uncertainty in the risk ratio for the 16 most-at-risk seabird taxa. Values are percentage decrease in the 95% credible interval of the risk ratio for each parameter, when fixed to the mean independently of each other. Parameters include age at first reproduction A and adult survival rate S, the number of annual breeding pairs N_{BP}, the proportion of adults breeding in a year, P_B, and annual potential fatalities (APF) in trawl, surface-longline (SLL), bottom-longline (BLL), and set-net (SN) fisheries. Vertical red lines separates variance contributions from bycatch estimates (to the right of red lines) and from biological inputs (to the left).

7. Discussion

Information collected by fisheries observers is pivotal in quantitative assessment of the impacts of fisheries in terms of:

- The overall amount of bycatch (and any changes between years); and
- The risk that the bycatch poses to affected seabird populations, including the likelihood that each affected population can achieve explicit or implicit population goals or objectives

This review has highlighted that the level of observer coverage needed to obtain robust estimates of seabird bycatch can vary substantially according to managers' objectives and information needs as well as with characteristics of the fishery being monitored, species of interest, and bycatch patterns.

Where fisheries management objectives are developed to understand levels of bycatch, it is useful for those objectives to specify an acceptable or target level of certainty for the estimates (e.g., specifying a CV). In order to ascertain specific coverage levels appropriate for SPRFMO fisheries to address such objectives it will be necessary to examine existing data (or collect new data where none exists) from all SPRFMO fisheries. Ongoing review of observer coverage levels and the utility of the data generated in SPRFMO fisheries is also recommended to ensure coverage is appropriate to delivering on the Commission's information needs.

8. Recommendations

It is recommended that the Scientific Committee:

- **Notes** that the extent of observer coverage needed to generate robust estimates of the frequency and total number of interactions with seabirds varies with the characteristics of the fishery, the species of interest, and bycatch patterns, particularly patchiness and the prevalence of multiple captures; and
- **Notes** that observer coverage of ~5% may be adequate to identify some bycatch risks and issues but is unlikely to enable robust quantification of those issues; and
- **Notes** that ~20% observer coverage may be sufficient to robustly estimate total bycatch and bycatch of frequently-caught species in some (but not all) fisheries, and
- **Notes** that observer coverage levels of ~50% to ~100% may be necessary to robustly estimate bycatch of individual species that are caught infrequently but are nevertheless still at risk;
- **Notes** that, in addition to observable bycatch, there can also be unobservable mortality (i.e. "cryptic" mortality) that can vary substantially between fisheries;
- **Advises** the Commission that observer coverage of 20% or more may be required to robustly estimate the incidental mortality of Seabirds, Marine Mammals, and Other Species of Concern in some fisheries, and that multiple influencing factors must be considered in the placement of observer coverage;
- **Advises** the Commission that periodic review of observer coverage and the utility of the data generated should be used to fine-tune levels of observer coverage; and
- **Seeks guidance** from the Commission on the nature and certainty of its information needs on the bycatch of Seabirds, Marine Mammals, and Other Species of Concern, so that SC can more precisely advise on observer deployment requirements in SPRFMO fisheries.

9. References

Abraham, E. R., Richard, Y., Berkenbusch, K. & Thompson, F. (2016). Summary of the capture of seabirds, marine mammals, and turtles in New Zealand commercial fisheries, 2002–03 to 2012–13. *New Zealand Aquatic Environment and Biodiversity Report No. 169*. 206 p. Available at: http://mpi.govt.nz/document-vault/12180.

Abraham, E. R.; Thompson, F. N. 2011. Estimated capture of seabirds in New Zealand trawl and longline fisheries, 2002–03 to 2008–09. *New Zealand Aquatic Environment and Biodiversity Report No. 79*. Ministry of Fisheries, Wellington.

Agnew, D.J.; Grove, P.; Peatman, T.; Burn, R.; Edwards, C.T.T. 2010. Estimating optimal observer coverage in the Antarctic krill fishery. *CCAMLR Science* **17**: 139–154.

Ashford, J. 2002. Report of the WG-FSA intersessional subgroup on sampling catches from longliners. CCAMLR, WG-FSA-02/52.

Babcock, E.; Pikitch, E.K.; Hudson, C.G. 2003. How much observer coverage is enough to adequately estimate bycatch? Available at: http://oceana.org/sites/default/files/reports/BabcockPikitchGray2003FinalReport1.pdf.

Benoît H.; Allard J. 2009. Can the data from at-sea observer surveys be used to make general inferences about catch composition and discards? *Canadian Journal of Fisheries and Aquatic Science* **66**: 2025–2039

Black, A.; Small, C.; Sullivan, B. 2007. Recording seabird bycatch in longline observer programs. WCPFC-SC3-EB SWG/WP-6.

Debski I.; Pierre J. 2014. Observer coverage to monitor seabird captures in demersal longline and trawl fisheries. Paper SC-02-14 for the 2nd Meeting of the Scientific Committee, Honolulu, Hawaii, USA, 1–7 October 2014. 8 p. Available at http://www.sprfmo.int/assets/Meetings/Meetings-2013-plus/SC-Meetings/2nd-SC-Meeting-2014/Papers/SC-02-14-Observer-coverage-to-monitor-seabrid-captures-in-demersal-longline-and-trawl-fisheries.pdf.

Department of Conservation. 2013. Conservation Services Programme Annual Plan 2013/14. Department of Conservation, Wellington. Available at: http://www.doc.govt.nz/Documents/conservation/marine-andcoastal/marine-conservation-services/approved-csp-annual-plan-2013-14.pdf.

FAO. 1995. Code of Conduct for Responsible Fisheries. Food and Agriculture Organization of the United Nations, Rome. Available at: http://www.fao.org/3/a-v9878e.htm.

FAO. 2009. FAO Technical Guidelines for Responsible Fisheries 1. Supplement 2. Fishing Operations 2. Best practices to reduce incidental catch of seabirds in capture fisheries. Food and Agriculture Organization of the United Nations, Rome. Available at: http://www.fao.org/docrep/012/i1145e/i1145e00.pdf.

Gilman, E.; Passfield, K.; Nakamura, K. 2012. Performance assessment of bycatch and discards governance by Regional Fisheries Management Organizations. IUCN, Gland. Available at: https://www.researchgate.net/profile/Eric_Gilman2/publication/262261868_Performance_Assessment_of_Bycatch_and_Discards_Governance_by_Regional_Fisheries_Management_Organization/links/0c96053726e37a402b000000/Performance-Assessment-of-Bycatch-and-Discards-Governance-by-Regional-Fisheries-Management-Organization.pdf.

Lawson, T. 2006. Scientific aspects of observer programmes for tuna fisheries in the western and central Pacific Ocean. WCPFC-SC2-2006/ST WP-1.

Lodge M.W.; Anderson D.; Løbach T.; Munro G.; Sainsbury K.; Willock A. 2007. Recommended best practices for regional fisheries management organizations. Report of an independent panel to develop a model for improved governance by Regional Fisheries Management Organizations. Published by Chatham House, Royal Institute of International Affairs, London. 141 p. Available at: https://www.oecd.org/sd-roundtable/papersandpublications/39374297.pdf

Ministry for Primary Industries. 2013a. National Plan of Action for the Conservation and Management of Sharks 2013. Ministry for Primary Industries, Wellington. Available at: https://www.mpi.govt.nz/dmsdocument/1138-national-plan-of-action-for-the-conservation-and-management-of-sharks-2013.

Ministry for Primary Industries. 2013b. National Plan of Action – 2013 to reduce the incidental catch of seabirds in New Zealand fisheries. Ministry for Primary Industries, Wellington. Available at: https://www.mpi.govt.nz/dmsdocument/3962-national-plan-of-action-2013-to-reduce-the-incidental-catch-of-seabirds-in-new-zealand-fisheries.

NOAA Fisheries (Northeast Fisheries Science Center and Northeast Regional Office). 2011. Standardized bycatch reporting methodology: Sea day analysis and prioritization. Available at: http://www.nefsc.noaa.gov/femad/fsb/SBRM/2011/2011-SBRM-Sea-Day-Analysis-Prioritization.pdf.

Richard, Y.; Abraham, E.R. 2013. Risk of commercial fisheries to New Zealand seabird populations. *New Zealand Aquatic Environment and Biodiversity Report No. 109*. Ministry for Primary Industries, Wellington.

Richard, Y.; Abraham, E.; Berkenbusch, K. 2017. Assessment of the risk of commercial fisheries to New Zealand seabirds, 2006–07 to 2014–15. *New Zealand Aquatic Environment and Biodiversity Report 191*. Ministry for Primary Industries, Wellington. 104 p.

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. *Marine Policy* **37**: 192–199.

Wigley, S.E.; Rago, P.J.; Sosebee, K.A.; Palka, D.L. 2007. The analytic component to the Standardized Bycatch Reporting Methodology Omnibus Amendment: sampling design and estimation of precision and accuracy (2nd edition). US Department of Commerce, Northeast Fisheries Science Center Reference Document 07-09. Available at: http://www.nefsc.noaa.gov/publications/crd/crd0709/crd0709.pdf.

Appendix 1: Details of seabird bycatch observations for selected New Zealand in-zone bottom longline fisheries, 2003-2017. Definitions and estimation methods are described in Abraham et al. (2016).

Year	Total hooks	Observed hooks	Observed %	Observed captures	Estimated captures	Lower confidence limit	Upper confidence limit	95% range / mean
All birds, bottom longline, vessels >28 m targeting ling								
2002/03	17,928,519	11,031,896	61.5	254	620	428	1020	0.96
2003/04	23,339,252	4,875,415	20.9	46	356	193	707	1.45
2004/05	18,932,296	2,592,940	13.7	17	669	273	1568	1.94
2005/06	14,888,023	3,637,371	24.4	29	309	145	733	1.90
2006/07	12,759,288	1,813,382	14.2	15	522	183	1353	2.24
2007/08	14,127,896	3,079,011	21.8	22	410	175	992	1.99
2008/09	12,861,501	3,196,800	24.9	5	312	101	828	2.33
2009/10	13,602,940	1,717,425	12.6	10	348	134	874	2.12
2010/11	12,919,517	1,526,455	11.8	18	332	137	815	2.04
2011/12	11,571,447	2,019,501	17.5	4	208	74	531	2.20
2012/13	8,234,145	270,828	3.3	0	259	109	588	1.85
2013/14	16,459,721	1,925,347	11.7	47	682	332	1422	1.60
2014/15	14,060,072	356,650	2.5	11	482	210	1124	1.90
2015/16	18,604,396	2,010,313	10.8	80	607	319	1223	1.49
2016/17	22,157,051	3,899,101	17.6	13	567	255	1217	1.70
All birds, bottom longline, vessels <28 m targeting bluenose								
2002/03	1,718,544	513	0.0	0	350	148	735	1.68
2003/04	2,754,744	-	0.0	0	351	157	717	1.59
2004/05	4,643,687	10,800	0.2	0	473	214	948	1.55
2005/06	5,110,600	-	0.0	0	544	231	1234	1.84
2006/07	6,765,477	66,310	1.0	5	699	316	1539	1.75
2007/08	8,281,962	167,300	2.0	5	596	262	1442	1.98
2008/09	6,168,280	3,300	0.1	0	452	189	1068	1.95
2009/10	5,855,729	51,365	0.9	28	438	210	893	1.56
2010/11	4,908,170	116,100	2.4	2	387	167	852	1.77
2011/12	3,667,931	1,900	0.1	0	316	137	664	1.67
2012/13	2,184,138	8,800	0.4	0	177	73	420	1.96
2013/14	2,047,566	-	0.0	0	160	64	346	1.76
2014/15	2,413,820	45,729	1.9	2	175	74	377	1.74
2015/16	2,354,270	5,300	0.2	0	139	53	311	1.86
2016/17	1,909,775	113,946	6.0	11	149	64	324	1.75

Appendix 2: Details of seabird bycatch observations for selected New Zealand in-zone bottom trawl fisheries, 2003-2017. Definitions and estimation methods are described in Abraham et al. (2016).

Year	Total tows	Observed tows	Observed %	Observed captures	Estimated captures	Lower confidence limit	Upper confidence limit	95% range / mean
All birds, bottom trawl, vessels >28 m targeting ling								
2002/03	426	16	3.8	0	15	3	40	2.54
2003/04	379	22	5.8	0	13	3	34	2.40
2004/05	673	76	11.3	3	34	15	68	1.57
2005/06	1,033	113	10.9	3	52	22	112	1.74
2006/07	1,438	151	10.5	2	45	20	89	1.54
2007/08	1,711	241	14.1	7	74	39	136	1.31
2008/09	900	145	16.1	4	51	22	109	1.72
2009/10	547	192	35.1	12	29	16	53	1.27
2010/11	468	104	22.2	7	27	12	60	1.78
2011/12	435	139	32.0	6	18	8	35	1.53
2012/13	746	242	32.4	6	40	18	80	1.55
2013/14	610	105	17.2	11	44	22	87	1.48
2014/15	734	149	20.3	2	47	19	100	1.72
2015/16	639	152	23.8	7	33	16	62	1.41
2016/17	631	199	31.5	15	38	22	71	1.28
All birds, bottom trawl, vessels >28 m targeting deepwater species								
2002/03	7,789	1,301	16.7	0	22	11	37	1.18
2003/04	7,068	1,262	17.9	3	22	11	35	1.09
2004/05	7,188	1,619	22.5	7	40	24	64	1.00
2005/06	7,167	1,358	18.9	8	28	17	41	0.87
2006/07	6,944	2,307	33.2	1	13	6	23	1.29
2007/08	6,559	2,810	42.8	7	18	11	26	0.85
2008/09	5,922	2,325	39.3	7	18	11	28	0.92
2009/10	5,898	2,129	36.1	19	34	25	46	0.61
2010/11	4,136	1,206	29.2	1	12	5	22	1.38
2011/12	3,612	923	25.6	2	10	4	18	1.40
2012/13	3,050	345	11.3	2	13	6	22	1.25
2013/14	3,387	435	12.8	2	13	6	22	1.24
2014/15	3,549	977	27.5	0	11	4	20	1.46
2015/16	3,921	1,390	35.5	4	12	6	20	1.17
2016/17	3,751	1,141	30.4	2	10	4	18	1.39
All birds, bottom trawl, vessels >28 m targeting hoki								
2002/03	25,561	2,573	10.1	82	641	479	861	0.60
2003/04	19,957	2,309	11.6	32	383	280	524	0.64
2004/05	13,454	2,089	15.5	43	411	301	566	0.64
2005/06	10,665	1,723	16.2	52	304	212	442	0.76
2006/07	9,699	1,706	17.6	23	188	126	274	0.79
2007/08	8,060	1,777	22.0	28	172	119	251	0.77
2008/09	7,450	1,599	21.5	37	229	158	335	0.77
2009/10	8,898	1,977	22.2	53	257	192	345	0.60
2010/11	9,224	1,663	18.0	54	278	205	381	0.63
2011/12	10,223	2,622	25.6	56	239	185	315	0.54
2012/13	10,624	4,468	42.1	101	267	214	335	0.45
2013/14	11,749	3,922	33.4	156	377	310	462	0.40
2014/15	12,314	3,569	29.0	80	379	293	487	0.51
2015/16	11,162	3,303	29.6	46	217	167	281	0.52
2016/17	11,584	2,786	24.1	59	254	194	331	0.54

Appendix 2 contd.: Details of seabird bycatch observations for selected New Zealand in-zone bottom trawl fisheries, 2003-2017. Definitions and estimation methods are described in Abraham et al. (2016).

Year	Total tows	Observed tows	Observed %	Observed captures	Estimated captures	Lower confidence limit	Upper confidence limit	95% range / mean
All birds, bottom trawl, vessels >28 m targeting southern blue whiting								
2002/03	638	275	43.1	0	3	0	9	2.91
2003/04	740	241	32.6	1	6	1	13	2.03
2004/05	870	335	38.5	2	11	4	23	1.72
2005/06	624	217	34.8	1	5	1	11	2.02
2006/07	630	224	35.6	3	7	3	14	1.47
2007/08	818	331	40.5	3	8	4	15	1.35
2008/09	1,188	300	25.3	0	10	2	22	2.00
2009/10	1,114	396	35.5	11	29	18	46	0.95
2010/11	1,173	434	37.0	11	23	15	34	0.83
2011/12	950	668	70.3	3	6	3	12	1.45
2012/13	790	790	100.0	19	19	19	19	0.00
2013/14	806	805	99.9	16	16	16	16	0.00
2014/15	674	670	99.4	7	7	7	9	0.28
2015/16	444	444	100.0	6	6	6	6	0.00
2016/17	537	537	100.0	6	6	6	7	0.16
All birds, bottom trawl, vessels >28 m targeting squid								
2002/03	7,789	1,308	16.8	154	845	633	1137	0.60
2003/04	8,047	1,771	22.0	194	869	680	1114	0.50
2004/05	9,903	2,512	25.4	351	1278	1046	1554	0.40
2005/06	7,854	1,103	14.0	195	1136	843	1550	0.62
2006/07	4,934	1,283	26.0	126	495	362	684	0.65
2007/08	3,808	1,459	38.3	162	447	343	586	0.54
2008/09	3,783	1,297	34.3	259	635	506	817	0.49
2009/10	3,606	1,071	29.7	92	400	287	560	0.68
2010/11	4,097	1,263	30.8	142	542	402	745	0.63
2011/12	3,319	1,381	41.6	105	337	255	450	0.58
2012/13	2,619	2,271	86.7	444	501	466	565	0.20
2013/14	2,044	1,789	87.5	206	244	217	294	0.32
2014/15	1,841	1,694	92.0	384	411	387	466	0.19
2015/16	2,653	2,363	89.1	302	332	312	368	0.17
2016/17	2,517	1,926	76.5	261	344	298	423	0.36