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Observer coverage to monitor seabird captures in pelagic longline fisheries

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Igor Debski[1], Johanna Pierre[2] and Kirstie Knowles[1]

[1]Department of Conservation, [2]JPEC Ltd

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Abstract

This review aims to provide guidance on levels of observer coverage appropriate to developing seabird bycatch estimates in pelagic longline fisheries. We review observer coverage in place in pelagic longline fisheries internationally and the extent to which these enable the estimation of seabird bycatch. We identify key factors influencing the levels of observer coverage required to estimate seabird bycatch, and the limitations inherent in suboptimal levels of coverage. We also discuss the extent to which observed bycatch reflects true levels of mortality taking into consideration unobserved, or cryptic, mortality. Whilst this paper is focused 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).

Introduction

Independent observer monitoring of target and non-target fisheries catch is a well-recognized component of best-practice fisheries management (e.g., FAO 1995, 2009; Lutchman 2014). Observer information provides for verification of fishers' catch-reporting, as well as an independent quantification (and identification) of catch landed. Observer monitoring information also adds value to fisheries in terms of building credibility and stakeholder confidence in management regimes (e.g. Ceo et al. 2012; Clark et al. 2015).

Typically, observer coverage is considered as a component of monitoring, control and surveillance (MCS) frameworks. MCS activities are fundamental to ensuring the integrity of fisheries management regimes, and encompass objectives with much broader scope than catch characterization alone. For example, assessing compliance with mandatory fishery management measures is a key focus (Ceo et al. 2012). Therefore, observer programs are designed to span objectives that have inherently different demands in terms of the level of coverage required.

Amongst fisheries managed under multilateral agreements, the amount of fishing effort that is monitored by observers ranges broadly. For example, Gilman et al. (2012) reports that on average, fisheries observers monitor 18.5% of fishing activities amongst 13 Regional Fisheries Management Organizations (RFMOs)[1]. However, coverage rates varied widely (SD$\pm$37%) and approaches to bycatch data collection were often not consistent amongst fisheries. More specifically, where coverage was required by RFMOs, this was not above 5% in most cases, and the extent of coverage

[1] The Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) is also included in Gilman et al.'s (2012) analysis.

was defined differently as a percentage of catch, or fishing days, sets, or trips (Gilman 2012; Turner and Papworth 2013). At coverage levels of 5%, observer information is likely to capture the existence of bycatch in a fishery, but cannot be expected to support robust estimation of bycatch rates (Gilman 2012). The variable approaches to bycatch data collection by observers, and limitations of the data collected at low levels of coverage, have resulted in the promulgation of recommendations for best practice observer data collection. Such recommendations have captured observer data requirements necessary to deliver a robust understanding of the nature and extent of seabird bycatch (e.g. Black et al. 2007; ACAP 2012).

This paper considers observer coverage of pelagic longline fisheries. Specifically, we examine coverage in place internationally and consider how this can support the quantitative estimation of seabird bycatch rates. We identify factors affecting the development of seabird bycatch estimates and how observer program design can facilitate robust seabird bycatch estimation. We also consider unobserved, or cryptic, mortality and the relationship of this to estimates based on observed bycatch.

Observer coverage for monitoring seabird bycatch

Naturally, having fisheries observers monitor 100% of fishing effort provides the most complete information on catch composition and the extent of seabird interactions with fishing gear. However, in most cases, 100% coverage is neither achieved nor sought. For pelagic longline fisheries in which seabird captures are monitored, broad ranges of observer coverage have been reported in recent years (Table 1).

Table 1. Examples of the levels of observer coverage recently reported from pelagic longline fisheries in which seabird captures are recorded.

Location	Primary target species	Coverage level (% of hooks)	Source
Hawaii	Bigeye tuna (*Thunnus obesus*)	21 – 100	NOAA 2014
South Atlantic	Yellowfin tuna (*Thunnus albacares)* Bigeye tuna Albacore (*Thunnus alalunga*)	0.2 – 5.3	Huang 2011 Yeh et al. 2012
Southwest Atlantic	Swordfish (*Xiphias gladius*) Yellowfin tuna Bigeye tuna Albacore Sharks	26 – 100	Jiménez et al. 2014
Australia	Swordfish Yellowfin tuna Bigeye tuna Albacore Striped marlin (*Kajikia audax*)	3.6 – 10.4	Patterson et al. 2012
New Zealand	Swordfish Bigeye tuna Albacore Southern bluefin tuna (*Thunnus maccoyii*)	0.4 – 22 1.6 – 6.4 0 – 52 32 – 57	https://data.dragonfly.co.nz/psc/

When 100% of fishing effort cannot be monitored by observers, limitations of the available dataset must be recognised when information collected is scaled up to the fleet level. Seabird bycatch is a statistically rare event. Therefore, scaling up observer data creates mathematical challenges, as well as giving rise to issues around accuracy and precision. For example, captures of rare species are more likely to be missed when coverage levels are lower. Further, at lower levels of monitoring, the precision of bycatch estimates is lower (i.e. confidence intervals are larger, with less certainty about where the true value lies), where estimates can be calculated at all. It must also be considered that observers being present onboard does not necessarily mean fishing effort is being monitored. For instance, on pelagic longline vessels the haul may commonly last several hours, and an observer may only directly observe a proportion of hooks hauled (due to other duties or rest breaks).

In general, observer coverage of 5% of fishing effort may be adequate to identify the existence of some level of seabird bycatch. However, monitoring at this level is inadequate to document the frequency of particular species' interactions with fishing gear (Gilman et al. 2012). As observer coverage levels increase to around 20% of fishing effort, the accuracy of bycatch estimates increases exponentially (Lawson 2006). At 20% coverage, species comprising 35% of the catch will be estimated within 10% of their actual catch level 90% of the time (Babcock et al. 2003).

Above around 20% observer coverage of fishing effort, 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, and to estimate the levels of captures of species that rarely interact with fishing gear, is well recognised. Where species comprising <0.1% of the catch interact with fishing gear, more than 50% observer coverage is required to estimate captures within 10% of true levels 90% of the time (Babcock et al. 2003). Where species and interactions are especially rare, the need for coverage levels of close to 100% has been recognised (Lawson 2006).

Factors affecting the accuracy and precision of bycatch estimates

While the indicative coverage levels above provide useful guidance for planning observer deployments, the level of coverage required to deliver a particular level of precision in bycatch estimates varies in accordance with a number of factors. These factors affect the adequacy of all catch monitoring undertaken by observers (i.e. non-target and target species catch) and apply across fishing methods (e.g., Karp and McElderry 1999; Rago et al. 2005; Amande et al. 2012).

The key factors and type of variation relevant to seabird captures that should be considered when planning observer coverage of pelagic longline fisheries are summarised in Table 2. In addition to these variables, the relative occurrence of multiple capture events also influences the ability to effectively extrapolate observed bycatch data. Specifically, if a seabird is infrequently captured but caught in large numbers at those times, then higher levels of coverage may be required to achieve a specified level of precision. In contrast, a species most frequently captured in low numbers per fishing event will require relatively less coverage to deliver the same level of precision.

Table 2. Key factors that influence the accuracy and precision of seabird bycatch estimates based on observer data collected from pelagic longline fisheries.

Factor	Type of variation				
	Target fish species	Day/night	Annual/Seasonal	Spatial	Vessel to vessel
Fishing effort	✓		✓	✓	✓
Seabird abundance	✓		✓	✓	
Seabird behaviour	✓	✓	✓	✓	
Vessel characteristics	✓		✓		✓
Vessel behaviour	✓	✓	✓	✓	✓
Mitigation use	✓	✓			✓

Cryptic mortality of seabirds

Cryptic seabird mortality encompasses those captures that are undetected or not readily detectable. For example, cryptic mortality includes when a seabird that is released alive following capture on a longline hook subsequently dies due to being captured (and this death is undetected) (e.g., Gilman et al. 2013). Discussion of cryptic mortality of seabirds follows decades of consideration of "unaccounted" fishing mortality amongst fish (ICES 1995, 2005). While extremely difficult to quantify, cryptic mortality is important because it affects our understanding of the true extent of seabird bycatch.

For pelagic longline fisheries, seminal work to quantify cryptic mortality was conducted by Brothers et al. (2010). They found that amongst 11 pelagic longline vessels fishing in four geographic regions over 15 years, 85 carcasses were landed on hauling from 176 seabirds observed captured on hooks on setting. These figures resulted from detailed observations conducted over more than 2,000 hours at sea.

In New Zealand, work undertaken to assess the risk that commercial fishing vessels present to seabirds has included consideration of cryptic mortality. Richard and Abraham (2013) used Brothers et al.'s (2010) work to inform their estimation of overall seabird bycatch risk, that is, the risk that observed seabird captures and cryptic mortalities in New Zealand's commercial fisheries have negative impacts on seabird populations. Using a multiplier approach developed by Richard and Abraham (2013), Pierre et al. (2015) showed that when combined with information on observed captures, considering cryptic mortality increased the risk that pelagic longline fisheries were considered to present to New Zealand seabirds (Table 3).

Table 3. Effect of cryptic mortality (CM) on the relative risk (assessed by Richard and Abraham 2013) that New Zealand pelagic longline fishing vessels < 45 m long present to selected seabirds. Median relative risk is shown when cryptic mortality is both excluded and included, with 95% confidence intervals (Pierre et al. 2015).

Target species	Seabird species	Relative risk without CM		Relative risk with CM	
		Median	95% CI	Median	95% CI
Tunas	Black petrel (*Procellaria parkinsoni*)	0.43	0.19 – 0.85	0.92	0.40 – 1.80
	Southern Buller's albatross (*Diomedea bulleri bulleri*)	0.29	0.15 – 0.60	0.61	0.31 – 1.27
	Gibson's albatross (*D. antipodensis gibsoni*)	0.28	0.15 – 0.58	0.59	0.31 – 1.23
	Antipodean albatross (*D. a. antipodensis*)	0.21	0.12 – 0.36	0.44	0.26 – 0.76
	Norther Buller's albatross (*D. b. platei*)	0.13	0.06 – 0.26	0.27	0.13 – 0.56
Swordfish	Gibson's albatross	0.20	0.10 – 0.42	0.44	0.22 – 0.93
	Antipodean albatross	0.11	0.06 – 0.19	0.23	0.13 – 0.40

For observer programmes, cryptic mortalities present a difficult problem. The amount of observer effort required to improve estimates of cryptic mortality for New Zealand pelagic longline fisheries is explored in Table 4. (For a more detailed documentation of methods, see Pierre et al. 2015). Existing observer data were insufficient to conduct estimations in some sectors of the pelagic fleet, and simplistic assumptions underpinning these analyses present a best-case scenario (e.g. cryptic mortality is the same across sectors of the pelagic longline fleet and every cryptic mortality is detected by observation) (Pierre et al. 2015). Despite these limitations, it is evident that to improve estimation of cryptic mortality would require the observation of hundreds of fishing events.

Table 4. Approximate number of fishing events that must be observed to estimate the cryptic mortality scalar with a coefficient of variation of 0.2 and 0.4. The cryptic mortality scalar is defined as the ratio of all seabird captures to the number of carcasses recovered on deck. (Missing values reflect where available data were insufficient to support simulations). For more detail, see Pierre et al. 2015.

Seabirds	**Pelagic longline vessel length**	**Number of observed fishing events required for:**	
		CV = 0.2	**CV = 0.4**
Albatross	< 45 m	250	-
	≥ 45 m	300	-
Other seabirds	< 45 m	430	90

Accuracy and precision of seabird bycatch estimates from New Zealand pelagic longline fisheries

In New Zealand, government fisheries observers have monitored seabird bycatch in pelagic longline fisheries for approximately 20 years. Levels of observer coverage have varied temporally and spatially, as well as amongst species targeted by pelagic longline fishers. Bycatch estimates based on data collected at varying levels of observer coverage are summarised below, together with the uncertainty associated with the estimates (presented as the ratio of the width of the 95% confidence interval of the estimate to the estimated mean, Tables 5 – 8). As expected, the precision of estimates generally increases with increasing coverage (Figure 1). However, there is significant variation around this broader trend, and differences amongst the target fisheries introduce other (non-statistical) sources of variation such as fishing gear, location of activity and timing of sets (Table 2) and the occurrence of multiple capture events. The least precise bycatch estimates are focused where observer coverage levels are less than 10%.

These estimates also do not consider cryptic mortality. Based on the work of Brothers et al. (2010), true estimates of total bycatch (i.e. observed and cryptic mortality) could be double those presented below.

Table 5. Pelagic longline vessels targeting southern bluefin tuna in New Zealand waters: seabird bycatch rates observed 2003-2014. Definitions and estimation methods are described in Abraham and Thompson (2011). (Source: https://data.dragonfly.co.nz/psc/).

Fishing year ended	Fishing effort (hooks)	Observed capture rate (captures/1000 hooks)	% effort observed	Estimated captures	95% confidence interval (CI) width	95% CI width/ mean
2003	3,513,361.00	0.038	32	484	276	0.57
2004	3,195,171.00	0.048	46	487	249	0.51
2005	1,661,979.00	0.049	44	185	96	0.52
2006	1,493,418.00	0.044	44	165	92	0.56
2007	1,938,111.00	0.121	47	238	80	0.34
2008	1,104,825.00	0.080	34	155	95	0.61
2009	1,484,438.00	0.057	57	174	96	0.55
2010	1,559,858.00	0.193	37	299	118	0.39
2011	1,330,265.00	0.056	43	195	114	0.58
2012	1,593,754.00	0.079	41	385	259	0.67
2013	1,516,397.00	0.047	32	316	210	0.66
2014	1,587,220.00	0.047	47	289	191	0.66

Table 6. Pelagic longline vessels targeting bigeye tuna in New Zealand waters: seabird bycatch rates observed 2003-2014. Definitions and estimation methods are described in Abraham and Thompson (2011). (Source: https://data.dragonfly.co.nz/psc/).

Fishing year ended	Fishing effort (hooks)	Observed capture rate (captures/1000 hooks)	% effort observed	Estimated captures	95% confidence interval (CI) width	95% CI width/ mean
2003	5,188,307	0.000	2	1,223	644	0.53
2004	3,507,507	0.008	3	829	448	0.54
2005	1,648,381	0.060	2	384	232	0.60
2006	1,868,306	0.133	2	521	300	0.58
2007	1,532,071	0.059	5	404	240	0.59
2008	967,829	0.247	3	331	214	0.65
2009	1,565,517	0.099	6	454	261	0.57
2010	1,247,437	0.400	6	455	259	0.57
2011	1,646,956	0.171	5	527	341	0.65
2012	1,291,923	0.179	3	410	290	0.71
2013	994,535	0.050	6	344	246	0.72
2014	743,381	0.097	3	289	219	0.76

Table 7. Pelagic longline vessels targeting albacore in New Zealand waters: seabird bycatch rates observed 2003-2014. Definitions and estimation methods are described in Abraham and Thompson (2011). (Source: https://data.dragonfly.co.nz/psc/).

Fishing year ended	Fishing effort (hooks)	Observed capture rate (captures/1000 hooks)	% effort observed	Estimated captures	95% confidence interval (CI) width	95% CI width/ mean
2003	1,893,010	0.073	52	493	489	0.99
2004	463,419	0	0	330	680	2.06
2005	136,812	0.232	3	77	112	1.45
2006	60,360	0	1	50	148	2.96
2007						
2008						
2009	7,800	0	27	5	16	3.20
2010	23,329	0	21	12	26	2.17
2011	13,610	0	7	7	18	2.57
2012	0				0	
2013				4	13	3.25
2014				2	9	4.50

Table 8. Pelagic longline vessels targeting swordfish in New Zealand waters: seabird bycatch rates observed 2005-2014. Definitions and estimation methods are described in Abraham and Thompson (2011). (Source: https://data.dragonfly.co.nz/psc/).

Fishing year ended	Fishing effort (hooks)	Observed capture rate (captures/1000 hooks)	% effort observed	Estimated captures	95% confidence interval (CI) width	95% CI width/ mean
2005	132,503	0.173	9	52	78	1.50
2006	228,305	0.417	2	96	127	1.32
2007	210,175	1.769	19	163	127	0.78
2008	125,330	0.046	17	41	69	1.68
2009	41,700	0.000	10	12	28	2.33
2010	137,840	6.000	0	58	86	1.48
2011	177,248	0.000	11	59	84	1.42
2012	195,400	0.161	22	54	68	1.26
2013	316,390	0.121	3	95	118	1.24
2014	192,963	0.000	3	75	96	1.28

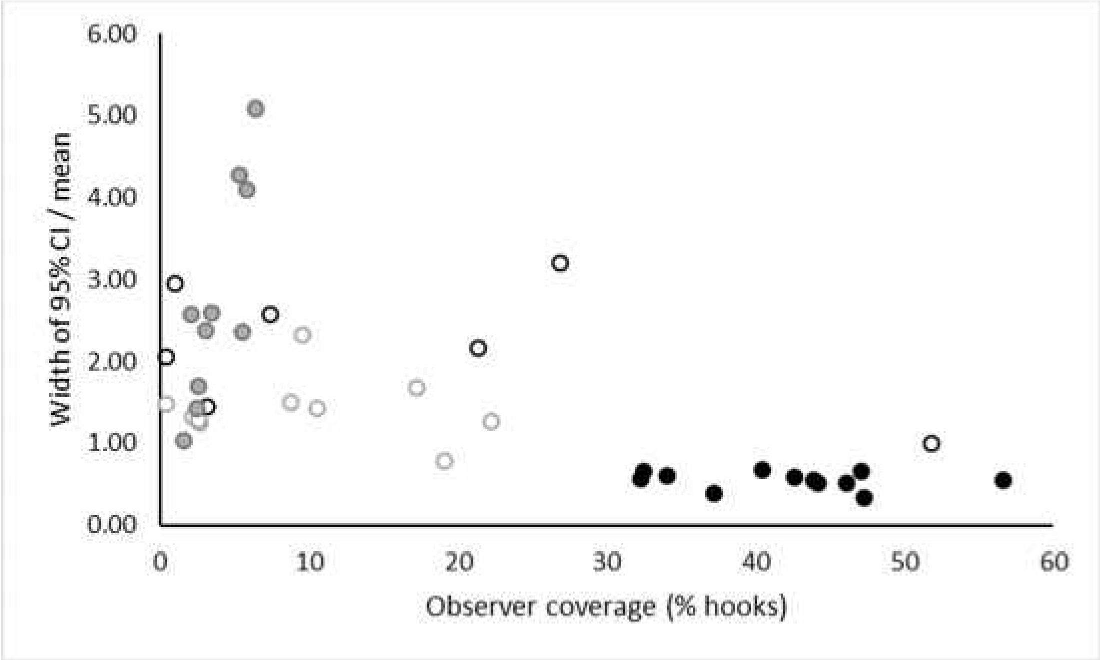

Figure 1. The ratio of the width of the 95% confidence interval to the mean of estimated seabird captures plotted against the percentage of observer coverage for New Zealand pelagic longline fisheries 2003-2014. Symbols relate to target species: Solid black = southern bluefin tuna, open black = albacore, solid grey = bigeye tuna, open grey = swordfish. (See Tables 5 – 8 for raw data).

Conclusions

Fisheries observers collect information that is essential for robust and best practice fisheries management, including understanding the extent of seabird interactions with fishing gear. Broad guidelines exist on the levels of observer coverage that are adequate to quantitatively estimate seabird captures. To establish reasonably precise estimates of observed seabird bycatch, coverage of 20% is required. However, levels of observer coverage more than 2.5 times that will be required to detect captures of species that are rare, or that rarely interact with fishing gear. Levels of coverage of 5% are called for by some management bodies. While that level of coverage will detect some capture events, it is insufficient for effectively quantifying seabird bycatch. Further, observed seabird bycatch is also only one component of total bycatch, with cryptic mortalities adding to observed capture events.

In addition to developing observer coverage as a percentage of fishing effort, fishery characteristics must be considered to ensure coverage is maximally representative. Factors that can affect both the accuracy and precision of capture estimates developed using observer data include seasonality of fishing, between-vessel variation within a fishery, timing of sets, and location of fishing activities. Observer coverage is seldom, if ever, truly representative (except when 100% coverage of hooks is achieved). However, applying coverage to 20% of hooks over all definable longline fishing sectors would significantly improve the accuracy and precision of seabird bycatch estimates currently available. Alternatively, where a particular level of precision is sought for bycatch estimates, the amount of observer coverage required to deliver this in a particular fishery can be identified.

Using observer coverage to quantify captures of other species of particular concern (e.g. marine reptiles and mammals) requires similar considerations as those described above for seabirds. As for seabirds, bycatch patterns for those species are also statistically rare events that vary in similar ways to seabirds in space and time.

Recommendations

We recommend that the Scientific Committee recognise that:

- the extent of observer coverage needed to generate robust bycatch estimates varies with the characteristics of the fishery being monitored, species of interest, and bycatch patterns;
- observer coverage levels of 5% may be adequate to collect information identifying some bycatch risks and issues but is likely insufficient for effectively quantifying seabird bycatch;
- in general, to robustly estimate bycatch levels of more frequently caught species, observer coverage levels of 20% or more may be necessary, whereas to estimate bycatch of species caught infrequently, coverage levels of 50% to almost 100% may be necessary;
- observer coverage should aim to be maximally representative, taking into consideration factors such as seasonality of fishing, between-vessel variation within a fishery, timing of sets, and location of fishing activities;
- even with high levels of observer coverage there can be unobserved bycatch (i.e. “cryptic” mortality), and this can form a high proportion of total bycatch and can vary substantially between fisheries.

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