Seabird bycatch reduction in scampi trawl fisheries

JOHANNA P. PIERRE
JOHN CLEAL
FINLAY N. THOMPSON
EDWARD R. ABRAHAM

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www.dragonfly.co.nz

Dragonfly Science
PO Box 27535
Wellington 6141
New Zealand

www.fishinfo.co.nz

Clement & Associates Limited
Postal Box 1460
Nelson
New Zealand

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EXECUTIVE SUMMARY

Seabird bycatch rates in the scampi fishery are estimated to be the second highest amongst New Zealand trawl fisheries. Seabirds have been reported caught on trawl warps, and also in trawl nets during shooting and hauling. Seabird captures in this fishery are exacerbated by characteristics of the fishing operation: the gear is at or near the sea-surface for extended periods during shooting and hauling, and the catch typically comprises over 80% fish and invertebrate bycatch, which is discharged at the fishing grounds. A substantial body of work exists on seabird bycatch reduction measures for trawl fisheries. However, characteristics of scampi trawl gear and the prevalence of net captures amongst bycaught birds (for which no deployment-ready mitigation measures are available) present challenges for reducing seabird catch in this fishery. This project sought to identify potential methods with which to mitigate seabird captures in the New Zealand scampi fishery, test the feasibility and effectiveness of these methods, and make recommendations on future work on seabird bycatch in this fishery.

Through reviewing available information and holding an expert workshop (including representatives from the scampi fishing industry), we identified three areas for work: improving batch discharge regimes to ensure discharge is held on-board during shooting and hauling; improving the design and construction of paired streamer lines; and testing the "restrictor" – a novel approach to reducing seabird captures in scampi nets. The first two areas of work will be addressed on an ongoing basis through working with skippers and crews, and utilising observer coverage of scampi vessels.

Deployment of the restrictor prevents the mouth of the net from becoming wide open during shooting and hauling. First, we examined the operational feasibility of the restrictor in the centre net of a triple-rig targeting scampi. Then, we designed an experiment to test the efficacy of the restrictor in reducing seabird catch. Constraints on government observer coverage prevented the implementation of this experiment during the course of the project. However, implementing data collection protocols in future years on observed trips where vessels are using restrictors will allow the assessment of the efficacy of the restrictor in reducing seabird catch.

Video collected using underwater cameras confirmed that the height of the centre net in triple-rig scampi gear was reduced by approximately 75% during hauling when restrictor ropes were in place. Video also showed that the headline and some of the body of mesh around the headline sat lower in the water column with restrictors in place than without. Although not a substitute for a designed experiment, this footage is a preliminary indication that the restrictor may be effective in reducing the risk of seabird bycatch in centre nets at shooting and hauling. We recommend empirical testing of the efficacy of restrictors in the scampi fishery. The method may also warrant exploring in other demersal fisheries in which seabirds are caught in trawl nets.

1. INTRODUCTION

Scampi (*Metanephrops challengeri*) is a small, benthic crustacean fished by demersal trawling in New Zealand waters. In 2012–13, the Total Allowable Commercial Catch (TACC) was 1190 tons. Annually, the scampi fishery produces 600–750 tonnes of product. The majority of the catch is taken from Quota Management Areas (QMAs) SCI1, SCI2, SCI3 and SCI6A (Figure 1), in Bay of Plenty, Wairarapa Coast, Chatham Rise and around Auckland Islands, respectively (Ministry for Primary Industries 2012). Scampi typically represents less than 20% of the catch landed in the double- or triple-rigged nets deployed. Fish and invertebrate bycatch make up the remainder of the catch. Vessels normally process and freeze their catch at sea, and discharge unwanted non-quota bycatch at the fishing grounds (Ministry for Primary Industries 2012).

Seabird captures in the scampi fishery are exacerbated by a number of characteristics of fishing operations. The gear, consisting of multiple adjacent trawl nets, can be at or close to the water surface for extended periods during shooting and hauling. Codend mesh sizes are much smaller than finfish trawl nets (e.g., as small as 50 mm), and nets retain stickers (whole or parts of dead catch remaining after the net is emptied) particularly effectively due to a combination of small mesh size and because nets are not cleaned between shots. Further, the netted catch and discharge of non-target bycatch from each haul attracts birds to vessels. Estimated total seabird captures for tows targeting scampi ranged from 67 to 443 birds annually for the fishing years 2002–03 to 2010–11 (95% c.i.; Abraham et al. 2013). Observed capture rates ranged from 1.44 to 16.04 birds per 100 tows over the 2002–03 to 2010–11 period (Abraham et al. 2013). The average observed capture rate of seabirds in this fishery for the years 2002–03 to 2010–11 was 4.92 birds per 100 tows, which is the second highest seabird capture rate for New Zealand trawl fisheries. Seabird species that have been reported caught have included southern Buller's albatross (*Thalassarche bulleri*), Salvin's albatross (*Thalassarche salvini*), Campbell albatross (*Thalassarche impavida*), white-capped albatross (*Thalassarche steadi*), Cape petrel (*Daption capense*), black petrel (*Procellaria parkinsoni*), giant petrel (*Macronectes* spp.), white-chinned petrel (*Procellaria aequinoctialis*), flesh-footed shearwater (*Puffinus carneipes*), and sooty shearwater (*Puffinus griseus*) (Abraham et al. 2013). Of these species, black petrel, flesh-footed shearwater, Salvin's albatross, and white-capped albatross have been identified as species that are potentially at risk of population-level impacts as a result of fatalities in New Zealand commercial fisheries (Richard & Abraham 2013).

A substantial body of research exists on methods to reduce seabird bycatch in trawl fisheries. Nets, warp cables, and net monitoring cables are the components of fishing gear that may capture or kill seabirds during trawl fishing (Bull 2007, 2009, Lokkeborg 2011). However, despite common elements, the form and configuration of gear components differ between conventional finfish trawl fisheries and shrimp trawl fisheries. Although seabird bycatch has been recorded in shrimp fisheries internationally (González-Zevallos et al. 2011, Marinao & Yorio 2011), mitigation measures have not been deployed to reduce these incidental captures. Similarly, in New Zealand, scampi fishing involves gear and operational practices that are unlike other trawl fisheries, and mitigation approaches beyond discharge management are not well developed as yet.

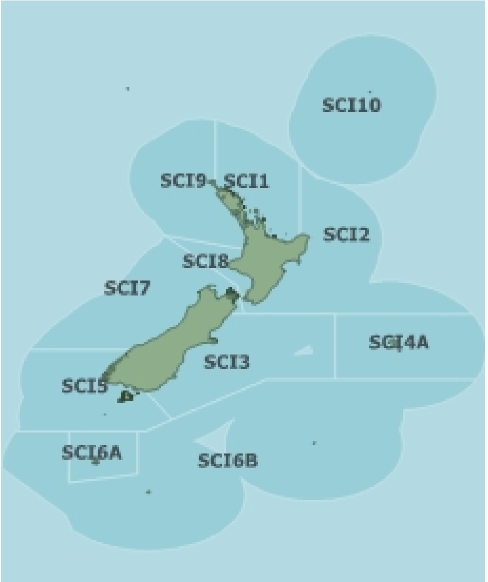


Figure 1: Scampi Quota Management Areas. Source: http://fs.fish.govt.nz/Page.aspx?pk=7&tk=38&sc=SCI.

Due to the high seabird bycatch rates observed in the scampi trawl fishery, this project (Conservation Services Programme project MIT2011–02) aimed to develop methods to mitigate the capture of seabirds in this fishery. The specific objectives were:

1. To identify methods to mitigate the capture of seabirds in the commercial scampi trawl fishery,
2. To test the feasibility, and to the extent possible the effectiveness, of methods to mitigate the capture of seabirds in the commercial scampi trawl fishery, and,
3. To make recommendations for future work to develop and/or test the effectiveness of methods to mitigate the capture of seabirds in the commercial scampi trawl fishery.

2. METHODS

2.1 Methods to mitigate seabird captures in trawl fisheries

Our approach to identifying measures that may reduce seabird captures during scampi fishing operations was threefold:

- conduct a review of previous research on seabird bycatch reduction measures in trawl fisheries,
- review existing data collected by New Zealand government fisheries observers deployed in scampi fisheries and reported by fishers, and,
- hold a workshop with scampi fishers, scientists, fishery managers, and fisheries observers.

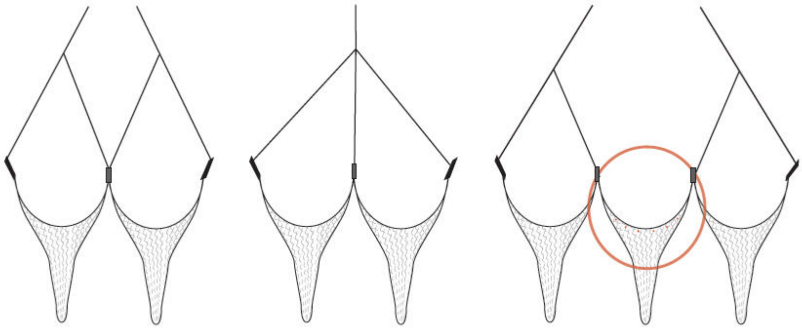


Figure 2: Gear types used in New Zealand scampi trawl fisheries. Left: Two adjacent nets with two warp cables. Centre: Two adjacent nets with one warp cable. Right: Three adjacent nets with two warp cables. The centre net which is the focus of this project, is circled. Diagram: Ros Wells.

2.1.1 Review of mitigation measures

Measures to reduce the incidental capture of seabirds in trawl gear have focused on finfish and squid fisheries to date (Bull 2007, 2009, Lokkeborg 2011). However, the attraction of seabirds to shrimp fisheries has been documented (Wickliffe & Jodice 2010) and seabird mortalities have been reported in shrimp trawl nets internationally (González-Zevallos et al. 2011, Marinao & Yorio 2011).

Consistent with shrimp fisheries in other locales (e.g., North and South America, (González-Zevallos et al. 2011, Marinao & Yorio 2011)), gear configuration used in the New Zealand scampi fishery is very different to trawl fisheries targeting finfish and squid. In New Zealand, two or three adjacent nets are used. Rigs with two nets may have one or two warps. Triple-rigs have two warps (Figure 2).

Despite gear differences, the same two components present the risk to seabirds in the scampi and other trawl fisheries, i.e., trawl warps and the trawl net. In New Zealand, seabird captures have been reported to involve both. In reviewing past research on methods intended to reduce seabird catch in trawl operations, we considered both warp and net captures. However, our focus was on net captures, given their relative prevalence during scampi fishing (Abraham et al. 2013, Pierre et al. 2012b). Further, while reported but not incorporated into bycatch estimates, another cause of fatal interactions is seabirds colliding with fishing vessels (Rowe 2010, Ramm 2012).

There are three recent comprehensive reviews of measures designed to reduce seabird bycatch in trawl fisheries (Bull 2007, 2009, Lokkeborg 2011). Here, we consider these reviews and additional published reports to identify mitigation measures that might effectively reduce seabird bycatch on trawl warps and in trawl nets in the New Zealand scampi fishery.

Warp strikes

Currently, paired streamer lines (PSLs) are recognised internationally as the best practice device for reducing warp strikes (Agreement on the Conservation of Albatrosses and Petrels (ACAP) 2011). Streamer lines are also known as tori lines. Other measures have been investigated as possible mitigants of warp strikes, for example, bird bafflers, warp scarers, cones on warp cables and warp booms (summarised in Agreement on the Conservation of Albatrosses and Petrels (ACAP) (2011), and reviewed in detail in Bull (2007, 2009)). These measures have not been effective in consistently delivering reductions in warp strikes.

The efficacy of PSLs in reducing warp strikes has been demonstrated in a variety of fisheries, including off New Zealand (Middleton & Abraham 2007), the Falkland Islands (Reid & Edwards 2005, Sullivan et al. 2006a), and in the east Bering Sea (Melvin et al. 2011). The basic approach for trawlers is to attach one line to both the port and starboard stern quarters of a vessel, above and outside of the trawl blocks. Lines must have sufficient length and aerial extent to protect the length of the exposed trawl warp. Streamers should be long enough to reach the water surface, and ideally brightly coloured. While PSLs are the best practice measure for reducing warp strikes, their effectiveness is reduced in some circumstances, e.g., in strong cross-winds and when the vessel is turning. In such situations, the lines may not effectively track the location of the warps, and so seabird exposure to the warps can increase. A towed object at the end of the lines reduces this issue, but does not eliminate it (Sullivan et al. 2006b). Further, seabirds can strike the PSLs themselves (Middleton & Abraham 2007).

Net captures

Measures for reducing seabird catches in trawl nets are much less developed than those reducing warp strikes. Currently, no methods have been widely tested and demonstrated to be effective in reducing net captures on shooting and hauling trawl nets. However, net binding and net weighting are methods which may reduce seabird captures during net shooting (Hooper et al. 2003, Sullivan et al. 2004, Clement and Associates 2009).

Two operational measures are widely, and intuitively, considered to reduce the risk of net captures. These are minimising the period of time over which the trawl net is on the water surface (and within the diving range of seabirds), and removing stuck fish and fish parts from the net prior to shooting (Hooper et al. 2003). The efficacy of these measures has not been tested quantitatively. However, the intuitive appeal of these measures has led to their incorporation into a Conservation Measure used by the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) (CCAMLR Conservation Measure 25-03). The package of measures used in the CAMLR Convention Area is widely recognised as international best practice for seabird bycatch reduction.

Offal and discard management

Physically keeping birds away from fishing gear that potentially causes injury is desirable, for example, by PSLs reducing the exposure of seabirds to trawl warps. However, the underlying reason seabirds attend vessels is due to the attraction of food, i.e., the trawled catch and discharged processing waste. Offal and discard management is a critical part of best practice for reducing seabird bycatch, which works by reducing the abundance of seabirds around vessels, consequently reducing the likelihood of captures.

Pierre et al. (2012a) summarised experimentally tested measures for offal and discard management. The preferred waste management option, i.e., the most effective approach for reducing the risk of bycatch is to retain all processing waste, and discharge it when the trawl gear is out of the water (Abraham et al. 2009). If waste cannot be retained for the duration of trawl tows, discharging waste as quickly as possible (in as large batches and as infrequent as possible) is the recommended practice for the reduction of seabird interactions with trawl warps (Pierre et al. 2010). Holding waste for periods as short as 30 minutes may reduce the numbers of petrels and shearwaters (excluding Cape petrels) attending vessels. However, longer holding periods of up to 8 hours may be required. Holding waste for periods of 2 - 4 hours can reduce vessel attendance by albatrosses and giant petrels (Pierre et al. 2012a).

Mincing processing waste can also reduce the abundance of some species of seabirds at vessels. Mincing is most effective in reducing vessel attendance by great albatrosses (*Diomedea* spp.), but less effective in reducing attendance by smaller albatrosses (e.g., *Thalassarche* spp.). Further, limitations of mincing machinery mean that not all processing waste can be minced. Retrofitting vessels with mincers is costly and difficult when space is limited.

Discharging waste as it becomes available during processing is the least desirable waste management option (Pierre et al. 2012a).

Another intuitive element of best practice is not discharging fish processing waste prior to shooting or hauling of the trawl net. Retaining waste at these times is considered to reduce seabird captures both on trawl warps and in nets. This reduction is linked to the lower likelihood of seabirds attending vessels in the absence of discharge (Abraham et al. 2009). Consequently, they will not be available to be caught on trawl gear.

Seabird collisions with vessels

Although not a focus for this project, seabird collisions with vessels are reported by observers at sea and result in some seabird fatalities in the scampi fishery (Rowe 2010, Ramm 2012). These collisions can result from different factors, e.g., extreme weather conditions (which may drive birds into vessels through wind gusts) and birds becoming confused in deck lights at night. Across fisheries, best practice to manage this issue is to use deck lighting such that crew safety is ensured but seabird risk is minimised (Black 2005).

2.1.2 Review of existing data collected by New Zealand government fisheries observers and reported by fishers

Information extracted from Ministry for Primary Industries databases was explored in order to characterise the scampi fishery, including fishing effort, vessels involved, and seabird captures. Fisher-reported seabird captures were also examined. Seabird capture data were used to estimate catch rates per unit of fishing effort, as well as seasonality of captures and gear factors potentially increasing capture risk. Observer comments were also considered in identifying risk factors that may have contributed to bycatch events.

Fishing capacity and effort distribution in space and time

Fishing vessel and effort data were extracted from the Ministry for Primary Industries' (MPI) Warehou database. Since the 2000–01 fishing year, 8 - 19 vessels have targeted scampi in QMAs SCI1 - SCI9 (Table 1). There was no fishing in SCI8 or SCI10, where TACCs have been 5 t and 0 t, respectively since 2003–04 (Clement and Associates 2011). Scampi was introduced into the Quota Management System (QMS) on 1 October 2004. Prior to that date, a catch limit existed (Clement and Associates 2011). Also on 1 October 2004, QMAs were given their current boundaries. Specifically, the boundary was shifted between SCI3 and SCI4A, and the area of SCI6A was adjusted from a circular to a trapezoid configuration. After introduction into the QMS, TACCs and reported catch did not change greatly (Clement and Associates 2011) although the fleet almost halved in size between the 2003–04 and 2004–05 fishing years (Table 1). In recent years, the fleet has comprised 8-9 vessels and the number of vessels targeting scampi has been approximately proportional to each QMA's TACC, i.e., most vessels fished where TACCs were highest (SCI3 and SCI6A). (See Tuck (2013) for a more detailed characterisation of SCI1 - SCI3.)

Table 1: Fishing vessels targeting scampi, by fishing year (1 October - 30 September) and area. The total value refers to the total number of vessels fishing in New Zealand's Exclusive Economic Zone each year.

	Quota management areas									Total
	SCI1	SCI2	SCI3	SCI4A	SCI5	SCI6A	SCI6B	SCI7	SCI9	
2000–01	9	9	10		2	10				12
2001–02	10	14	12	1		10	2	2		15
2002–03	9	12	16	6	4	9	2	2		19
2003–04	7	7	15	4	2	10				17
2004–05	5	8	8	8	2	6	1	1	1	9
2005–06	3	8	8	5	1	6	1	1		9
2006–07	3	6	7	5		6				10
2007–08	4	6	7	2	1	7				11
2008–09	3	5	9		1	5				9
2009–10	5	6	6	1		6	1			8
2010–11	3	4	7	4		7				8

Between 2000-01 and 2010-11, 4000 to 5000 trawl tows targeting scampi were conducted annually (Figure 3). Since introduction into the QMS, annual effort (number of trawl tows) has been most variable in SCI3 and SCI4A, and most consistent in SCI1 and SCI6A. Most fishing effort occurred between October and January, in QMAs SCI3, SCI1, and SCI2 (Figure 4). Least effort occurred between April and September. On average, the number of trawl tows targeting scampi in October was almost double that conducted in July (Figure 4).

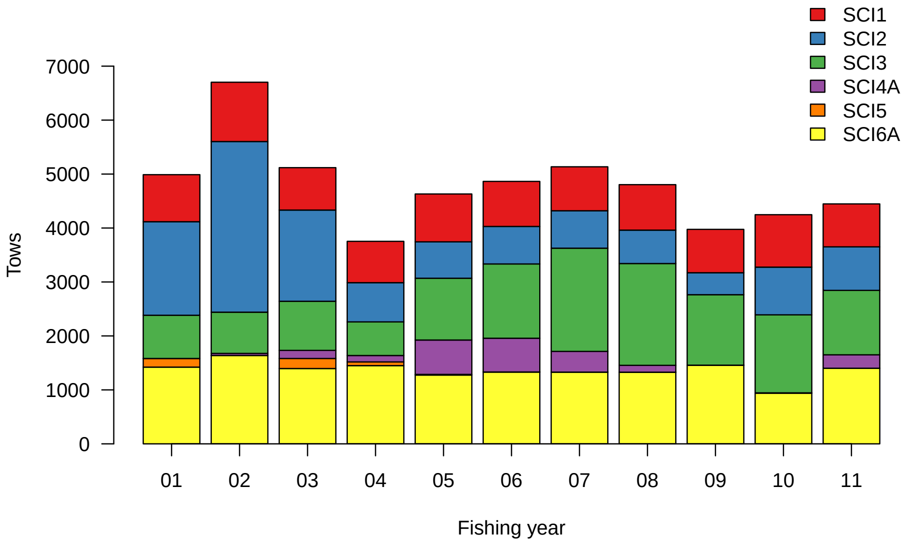


Figure 3: Annual fishing effort (number of trawl tows targeting scampi) from the 2000–01 to the 2010–11 fishing years in different Quota Management Areas (QMAs) in New Zealand's Exclusive Economic Zone. Effort is delineated according to current QMA boundaries.

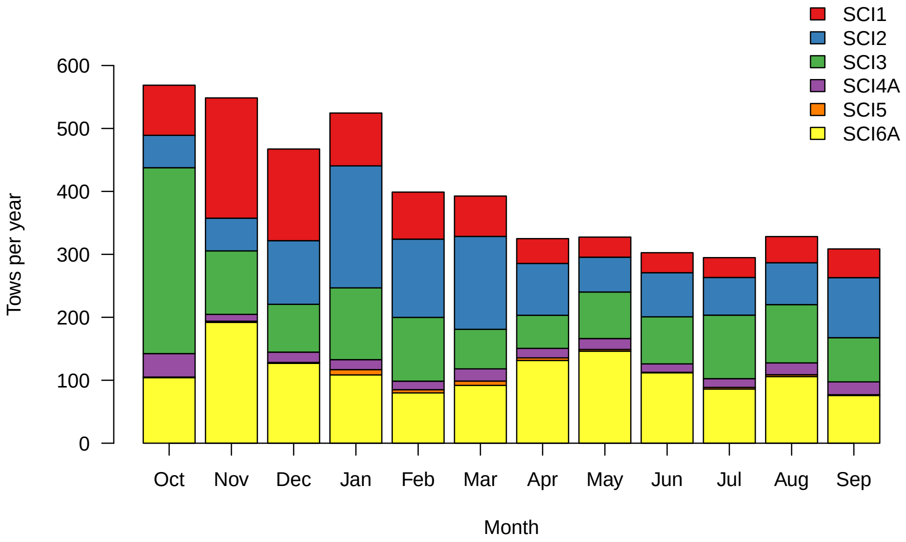


Figure 4: Monthly distribution of the fishing effort targeting scampi in different Quota Management Areas (QMAs), for the fishing years 2000–01 to 20010–11. Effort is delineated according to current QMA boundaries.

Table 2: Fisher-reported seabird captures in the scampi fishery, by fishing year for the period between 2001-2011. Common names and codes listed are those used on the Non-fish Protected Species Catch Return.

Species	Code	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total
Albatrosses	XAL	3	3	5		20	16	15	22	13	14	15	129
Antipodean and Gibson's albatrosses	XAG										1		1
Black-browed albatrosses	XKM										1	1	2
Campbell black-browed albatross	XCM									2			2
Salvin's albatross	XSA							1	4	1		4	10
Southern Buller's albatross	XBM						3						3
Buller's albatrosses	XPB									7		7	14
White-capped albatrosses	XSY						2	2		1	8		13
New Zealand white-capped albatross	XWM									2	6		8
Petrels	XPE		1		2	11	1	9	4				28
Black petrel	XBP									2	3	2	7
White-chinned petrel	XWC							1				8	9
Flesh-footed shearwater	XFS								3	5	7	2	17
Common diving petrel	XDP										1		1
Sooty shearwater	XSH						5	3	13		5	32	58
Petrels, prions, and shearwaters	XXP									13	12	33	58
Seabirds	XSB		3							2			5
Small seabirds	XSS	2	1	3	2	14	13	9	1				50
Large seabirds	XSL	6	3	5	7	22	16	8	6	1			75
	Total	11	11	13	11	67	56	48	53	49	58	104	481
Reported capture rate, %		0.22	0.16	0.25	0.29	1.44	1.15	0.93	1.10	1.23	1.37	2.34	0.91

Fisher- and observer reported seabird captures

Under the Fisheries Act (1996), incidental captures of protected species in commercial fisheries must be reported. Prior to 1 October 2008, fishers could use the Non-fish Incidental Catch Return form to report captures. These data are administered by the National Institude of Water and Atmospheric Research (NIWA) under contract to the MPI. After 1 October 2008, this form was discontinued and the Non-fish/Protected Species Catch Return form was used. Data from these forms are stored in the Warehou database. Table 2 summarises seabird captures reported by fishers from 2001 to 2011, as extracted from the databases capturing data from these two forms.

Government observers deployed in scampi fisheries also record seabird captures that occur while they are on-board vessels. The data collected by observers are entered into the MPI Centralised Observer Database (COD). Although observer coverage rates have been low in most years (3 - 12% of trawl tows monitored annually since 2000–01), observers have reported capture events (Table 3) and potential risk factors associated with them. Modelling methods are used to develop fleet-wide estimates of seabird captures from these raw data (Table 3; Abraham et al. (2013)).

The range of species reported by fishers has increased signficantly between 2000-01 (three codes used) to 2010–11 (nine codes used). Species reported have included albatrosses, petrels, and shearwaters. Species captured reported by government observers have included the same species groups (Table 4).

The seabird capture rate reported by fishers has increased ten-fold from 0.22 in 2000–01, to 2.34 in 2010–11 (Table 2). Although greatly increased, it is still well below the capture rate reported by observers. For example, in the 2010–11 fishing year, observers reported a capture rate of 16.04 birds per 100 tows (Table 3). Estimated total annual captures based on observer data have ranged from 114 to 307 on average. Confidence intervals (95%) vary from 67 to 433 captures (Table 3), highlighting the effects of low levels of observer coverage.

Observers have reported captures both on the trawl warps and in the trawl net. The majority of captures (albatrosses and petrels) have been detected in the trawl net. Albatrosses have also been captured on trawl warps/doors (five reported instances since 2007). In addition, two albatrosses have been reported caught on mitigation devices deployed (Department of Conservation (DOC) and MPI, unpubl.).

Table 3: Seabird captures reported by government fisheries observers in the scampi fishery, by fishing year for the period between 2000-01 and 2010-11. Presented are total fishing effort, percentage of effort observed, number of captures, capture rate per 100 tows, and estimated total captures (mean value with 95% confidence interval) (data from Abraham et al. (2013).

		Observed			Est. captures	
	Effort	% obs.	Cap.	Rate	Mean	95% c.i.
2000/01	4978	5.3	9	3.38	139	104–178
2001/02	6719	8.8	6	1.02	167	123–216
2002/03	5130	9.98	8	1.56	158	93–271
2003/04	3753	10.98	8	1.94	114	67–191
2004/05	4648	3.08	9	6.29	212	135–330
2005/06	4867	6.8	13	3.93	225	142–351
2006/07	5135	7.58	24	6.17	157	106–227
2007/08	4804	10.91	11	2.1	163	102–251
2008/09	3975	9.96	19	4.8	209	137–316
2009/10	4248	8.19	5	1.44	180	112–285
2010/11	4447	12.05	86	16.04	307	225–433

Table 4: Seabird species reported as bycatch by government fisheries observers in the scampi fishery in the period between 2000-01 and 2010-11. Names of species and species groupings are those used on the reporting forms.

Fishing year	Species captured
2000–01	New Zealand white-capped albatross, Salvin’s albatross, Seabirds, white-capped albatrosses
2001–02	Black-browed albatross, Cape petrels, New Zealand white-capped albatross, Salvin’s albatross
2002–03	Albatrosses, common diving petrel, New Zealand white-capped albatross, Salvin’s albatross, sooty shearwater
2003–04	Albatrosses, Cape Petrel, New Zealand white-capped albatross, Salvin’s albatross, sooty shearwater, white-chinned petrel
2004–05	Chatham Island albatross, New Zealand white-capped albatross, Salvin’s albatross, southern Buller’s albatross, white-chinned petrel
2005–06	Albatrosses, black-browed albatrosses, flesh-footed shearwater, New Zealand white-capped albatross, petrels, southern Buller’s albatross
2006–07	Albatrosses, flesh-footed shearwater, New Zealand white-capped albatross, northern giant petrel, petrels, sooty shearwater
2007–08	Black petrel, flesh-footed shearwater, Salvin’s albatross, sooty shearwater
2008–09	Albatrosses, Cape Petrel, Cape petrels, flesh-footed shearwater, New Zealand white-capped albatross, Salvin’s albatross, southern Buller’s albatross
2009–10	Campbell black-browed albatross, flesh-footed shearwater, New Zealand white-capped albatross
2010–11	Flesh-footed shearwater, New Zealand white-capped albatross, Salvin’s albatross, sooty shearwater, white-chinned petrel

Observer data entered in COD may under-represent the number of seabirds captured in this fishery. A negative bias of the number of seabirds bycaught is possible because when multiple capture events occur, individual records have not been consistently completed for individual seabirds. This became apparent through the identification of bycaught seabirds that were returned for necropsy (Bell 2012). Identification work involves examination of bird carcasses as well as photos provided by observers. Two occasions were identified where multiple capture events (15 and 10 birds) were observed in scampi trawl fisheries. In both cases the observer reported captures using a single entry on the Non-fish Bycatch Form, and all captures were of white-chinned petrels. Records associated to these events were rectified in the database. Where possible, and particularly for older records, verification of capture details is warranted using the forms on which these events were originally reported.

Observer comments on factors relevant to seabird bycatch risks

Observer comments relating to seabird captures were focused on the management of processing waste and the use of mitigation devices. In 2007–08, one observer reported particularly high bird activity at full moon, and that a crew member actively shielded the net from birds using a plastic spade. Collection of offal and discards for batch discharge occurred on some vessels whereas others were equipped with a tank or hopper for storage of discharge but did not use it. There was some *ad hoc* discharging during shooting and towing. Streamer lines, bafflers and a buoy on a rope were all reported as being used with the intent of reducing seabird interactions with trawl warps (Rowe 2010). Observers also reported that seabirds were consistently attracted to the net. Similar observations were reported in the 2008–09 and 2009–10 fishing years (Ramm 2010, 2012).

These observations suggest that improving batch discharge practices would reduce the risk of seabird bycatch. The design and construction of mitigation measures in use (e.g., streamer lines) could also be improved.

Exploratory analysis of gear characteristics that may influence bycatch risk

There have been 78 observed trawl scampi trips, on 15 different vessels, during the fishing years 2000–01 to 2010–11. Approximately a third of observed trips occurred on the east coast of the South Island (SCI3), 28% around the Auckland Islands (SCI6A), and the remainder were split across SCI1, SCI2, and SCI4A. There was very little observer coverage in SCI5 or SCI7.

In the 2007–08 fishing year, observers commenced reporting on gear configuration in detail using the MPI Trawl Gear Details Form. Information collected on this form was used to explore gear characteristics that may influence bycatch risk. In the four years 2007–08 to 2010–11, there were 19 trips on seven vessels for which gear configuration data were reported. Of those 19 trips, all but two had the use of tori lines reported. These two trips without tori lines occurred in the 2010–11 fishing year.

A step analysis (Akaike 1974, Venables & Ripley 2002) was applied to the observer records that included gear configuration data, encompassing 950 tows. Factors considered by the step analysis included QMA, month, the use of tori lines, and a series of fields describing the trawl gear (Table 5). A negative binomial link function was used in this analysis. Step analyses were used to explore the relationships between gear characteristics and the likelihood of captures of all seabirds, albatrosses, and shearwaters and petrels.

All bird captures:

When all bird captures were considered, the most important factors included in the analysis (Table 5) were month and QMA in which fishing occurred, followed by the number of nets and presence of a tori line. Codend mesh size was of marginal significance (Table 6).

Month of the year accounted for most variation in the data. Significantly fewer captures than expected were reported in August, November, and December. Captures increased in October, but this increase was not significant. Fewer captures than expected were reported in QMAs SCI2, 3 and 6A.

Significantly more captures were reported when three nets were deployed, compared with two nets. Increasing codend mesh size was related to a trend (of marginal significance) of increased captures.

Use of paired streamer lines reduced total seabird captures significantly, presumably through reducing warp strikes although strikes themselves were not monitored.

Albatross captures:

Fewer albatrosses were captured in gear comprised of three nets compared with two. Headline length was of marginal significance, with a trend for more albatross captures in gear with longer headlines (Table 7).

Captures of small seabirds including petrels and shearwaters:

For small seabirds, month, QMA, number of nets and codend mesh size were all significant in accounting for captures. August and December showed significantly lower captures than expected. Also, fewer captures than expected were reported in QMAs SCI2, SCI3 and SCI6A.

Significantly more captures occurred during deployments of three nets compared with two, and increased captures occurred with increasing mesh size.

Interactions between factors were offered to the step analyses, and the first order effects were stronger in all cases. Further analysis was not attempted given the small sample size of the data set. We recommend that this analysis is repeated when observer records for future fishing years are available.

The results of the step analyses should be interpreted cautiously given the limited amount of data available overall, as well as spatial and temporal constraints on data collected. Despite this limitation, the analysis identified factors relating to gear deployment that may affect captures, i.e., the number of nets used, use of tori lines, and codend mesh size. Of these factors, codend mesh size was not previously identified by observers as a possible risk factor. However, it has been explored to a limited extent by mitigation practitioners as a possible correlate of seabird captures in other fisheries (pelagic icefish trawl (*Champsocephalus gunnari*), Roe (2005)). Roe (2005) reduced mesh size from 200 mm to 140 mm in this fishery, but did not report on the efficacy of this measure in reducing seabird captures. Investigating codend mesh size was not supported as an avenue of further mitigation research for this project as it would involve significant changes to trawl gear.

Table 5: Factors used in the step analysis. Codes used follow Sanders & Fisher (2010). Gear events: Z - No events, F - Haul, turn, reshoot - during a tow the vessel partially hauls the net, completes a turn, then reshoots the net, A, B - Net damage - where observer reported torn nets and nets that came fast, G, I - Gear breakage - where observer reported twisted warps, crossed doors, warp breakages, and lost gear, D - Winch failure at set, O, Y - Other - includes where observer has listed more than three, U - Unknown; Door type: H - High aspect, L - Low aspect, O - Other; Headline tag: (describes the source of headline height information) 1 - from net sonde measurements, 2 - a standard figure e.g., taken from net plans, 3 - from skipper.

QMA	SCI1 - 9
Number of codends	1, 2 or 3
Gear events	Mostly Z, but also A, AB, AIB, AO, B, BA, BG, D, F, G, GO, O, U, Y
Door spread	Range from 24 to 105 m
Lengthener mesh size	Range from 50 to 115 mm
Door type	H, L, or O
Month	Calendar month of fishing
Headline length	18 to 150 m
Headline tag	1, 2, or 3
Codend mesh size	Range from 50 to 115 mm
Trawl wingless	Yes or No
Number of warps	1 or 2
Tori lines used	Yes or no (No bafflers were reported in use on the vessels used in this analysis)
Vessel key	One of 7 vessels

Table 6: Summary of step analysis of all bird captures in scampi tows conducted during 19 trips on seven vessels in fishing years 2007–08 to 2010–11.

	Degrees of freedom	Deviance		
		Residual	Explained	Explained (%)
		356.85		
Month	10	213.76	143.09	40.1
Quota management area	3	176.13	37.63	17.6
Number of codends	2	158.49	17.64	10.0
Tori line present	1	148.36	10.12	6.4
Codend mesh size	1	144.86	3.50	2.4

Table 7: Summary of step analysis of albatross captures in scampi tows conducted during 19 trips on seven vessels in fishing years 2007–08 to 2010–11.

	Degrees of freedom	Deviance		
		Residual	Explained	Explained (%)
		76.34		
Number of codends	2	72.16	4.18	5.5
Headline length	1	68.98	3.18	4.4

Table 8: Summary of step analysis of small bird captures in scampi tows conducted during 19 trips on seven vessels in fishing years 2007–08 to 2010–11.

	Degrees of freedom	Deviance		
		Residual	Explained	Explained (%)
		336.71		
Month	10	183.92	152.78	45.4
Quota management area	3	141.48	42.45	23.1
Number of codends	2	121.42	20.06	14.2
Codend mesh size	1	117.64	3.77	3.1

2.1.3 Expert workshop

Although the observer-collected information that is available is of high quality, the limited coverage of the scampi fleet by government observers means that knowledge of this fishery is less developed than for most other deepwater trawl fisheries. To complement the information extracted from available databases, and to progress the project from desktop work to at-sea information collection and trials, we held a workshop involving vessel management, skippers, crew, scientists, the MPI fishery manager, seabird bycatch reduction practitioners, and government fisheries observers. This workshop included discussion of mitigation measures currently in use, issues around current measures, best practice measures used in other trawl fisheries, and potential new measures that could be explored (Pierre et al. 2012b).

The objectives of the workshop were:

- to seek feedback on factors identified as increasing the risk of seabird bycatch in the scampi fishery;
- to identify possible solutions to the risk factors identified;
- to discuss potential mitigation measures identified, and,
- to identify key information for observers to collect, relating to fishing practices and events that increase seabird bycatch risk.

The workshop covered the following areas:

- a characterisation of the scampi fleet,
- fishing gear used,
- vessel operations,
- current practices in the fleet that relate to seabird bycatch reduction,
- nature and extent of seabird captures,
- observer comments,
- possible mitigation measures, and,
- next steps.

Discussion at the workshop was wide-ranging and constructive, and is reported in detail in Pierre et al. (2012b) and reflected below.

3. RESULTS

3.0.4 Application of mitigation measures to the scampi fishery

Given the extent of knowledge on the efficacy of batch discharge in reducing seabird bycatch risk (Pierre et al. 2012a), and the presence of holding tanks on scampi vessels, ensuring effective discharge management is recommended to minimise capture risk. Batch discharge approaches could be refined to ensure robust regimes are implemented consistently on vessels. This consistency can be achieved through crew education and coordination. Discharge has been reported during shooting and hauling. Refining operations such that discharging is avoided during these times should be relatively straightforward, but requires ongoing diligence from skippers and crew. Future observer coverage could also be used to monitor discharge practices.

The deployment of well-designed PSLs as warp strike mitigation measures has potential in the scampi fishery. Key considerations include the design of the PSLs and the identification of safe and effective locations on-board from which PSLs can be deployed and retrieved. Designs of PSLs deployed must be targeted to scampi gear, i.e., exposed warp length and location astern. The design of PSLs is expected to improve following consideration of recommendations and outputs of Conservation Services Programme project MIT2011–07 which examined the design of streamer lines used on trawl vessels ≥ 28 m in overall length (Conservation Services Programme 2011). Although this project focused on larger vessels, its recommendations provide for the development of streamer lines suitable for different sized vessels (Cleal et al. 2013).

Net capture mitigation measures are not so easily transferred from other fisheries to scampi, and development of these measures is limited across trawl fisheries. The net is typically not brought onboard in its entirety during scampi fishing. Nets can also be on the surface for relatively extended periods, as the rig is comprised of multiple nets which are emptied asynchronously. Net mouths being open and closing during shooting and hauling is expected to be a key source of bycatch risk. Measures used in other trawl fisheries such as net binding and weighting may be worth investigating further. The most promising avenue for further work was the net "restrictor", mooted at the expert workshop.

To test the feasibility of the restrictor at sea, restrictor ropes were deployed by one vessel using a triple-rig over a period of several months. These ropes were fitted across the mouth of the centre trawl net (Figure 5, Figure 6). In that time, skippers and crew monitored the performance of the restrictor ropes. Ropes did not tangle, and were readily attached to the headline and groundrope of the net. While not evaluated quantitatively, crew considered that the handling of the centre net improved with restrictors fitted. In addition, although not tested empirically, crews felt that fish and invertebrate bycatch was lower in the net when the restrictor ropes were in place. Given the feasibility of the method from an operational perspective, moving to a trial of the restrictor's efficacy in reducing seabird bycatch was warranted.

3.1 At-sea testing of the net restrictor

3.1.1 Experimental design for testing the restrictor at sea

At the outset of this project, government observer coverage was the platform expected to support testing of potential mitigation measures at sea, should new measures be identified (Conservation Services Programme 2011, Pierre et al. 2012b). Planned observer coverage for the year from 1 July 2011 to 30 June 2012 was 450 observer days (Conservation Services Programme 2011). Once the operational feasibility of the restrictor was confirmed, we designed an experimental approach using observer coverage to test the efficacy of the restrictor in reducing seabird captures in the centre net of triple-

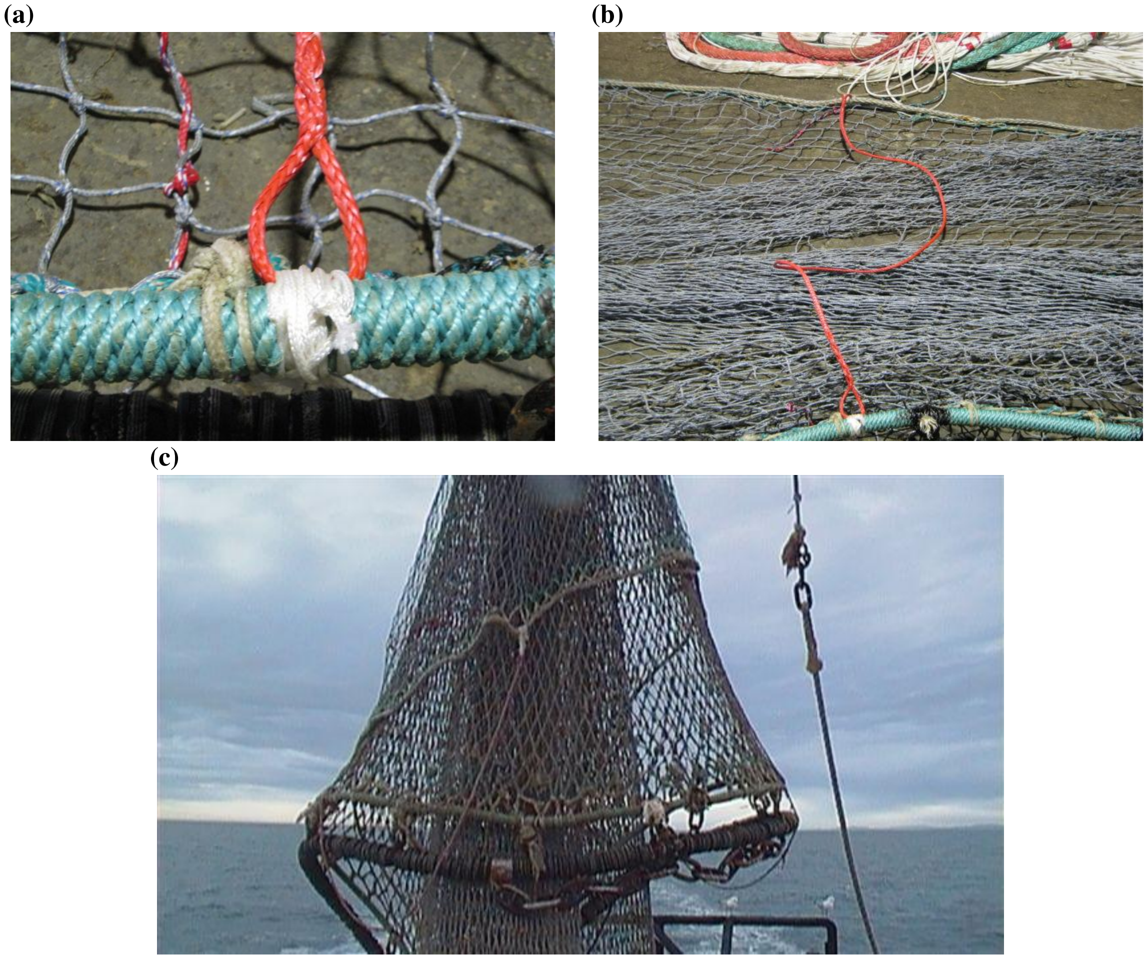


Figure 5: Photos from the at-sea feasibility trial of the net restrictor showing a restrictor rope (red in colour) deployed across a trawl net. (a) the restrictor affixed to the net rope, (b) the restrictor spanning the mouth of the trawl net, (c) the restrictor attached to the headline and groundrope, and spanning the mouth of the net.

rig scampi trawl gear. However, observer coverage was not implemented as planned and the experiment could not be completed.

The experimental design specified the deployment of restrictors on the centre net of triple-rigged vessels, in accordance with a pre-defined randomised schedule. The centre net was selected for restrictor deployment as this net is thought to comprise a greater bycatch risk for seabirds, compared with the port or starboard nets. Restrictors were to be deployed randomly for blocks of two to four consecutive treatment days, with treatment days starting and ending at midnight. If operational reasons (e.g., bad weather or fishing occurring on muddy substrates) required the removal of the centre net, the treatment days were to be paused, and then resumed when fishing using the centre net recommenced. For example, if muddy substrates were fished two days into a four-day block when restrictors were to be deployed, the centre net was removed. After that fishing activity concluded, the centre net was to be redeployed with restrictors in place, and the second two days of the four-day block were to be fished.

The restrictor arrangement consisted of six ropes that were to be fitted across the mouth of the centre net, i.e., from the headline to the groundrope. One restrictor rope was to be fitted 1 m to each side of the headline centre. Another two restrictor ropes were to be fitted to each side of the net mouth, 2 m

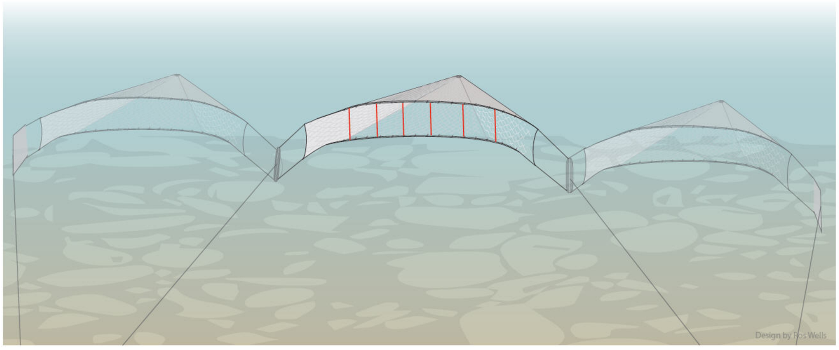


Figure 6: Net restrictors across the mouth of the centre net of a triple rig shown at fishing depth during scampi trawling. Diagram: Ros Wells.

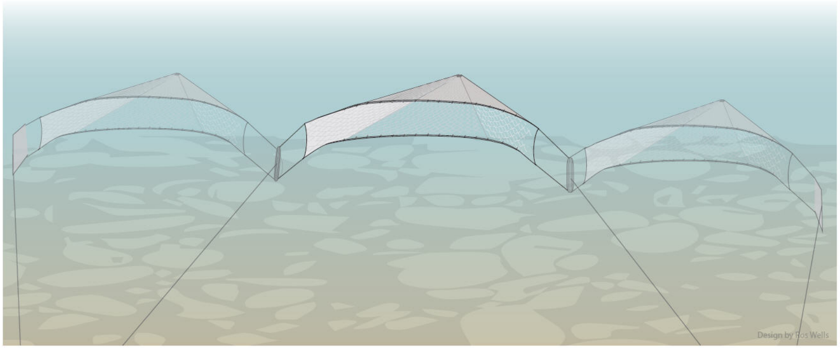
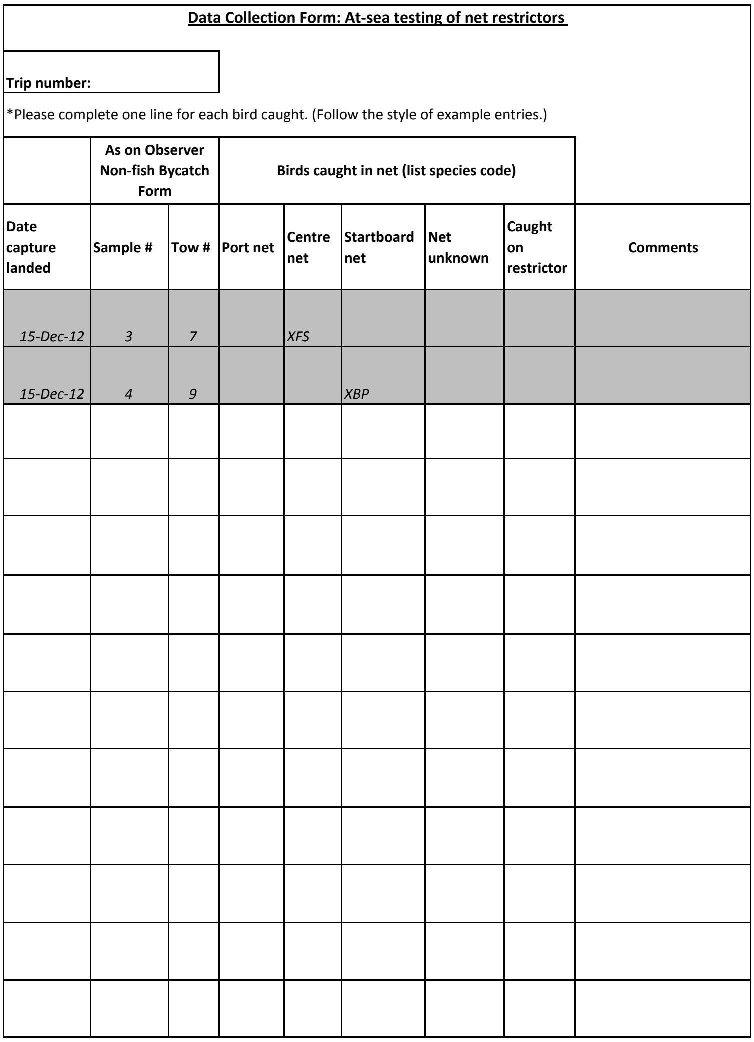


Figure 7: A triple rig shown at fishing depth during scampi trawling, without restrictors in place. Diagram: Ros Wells.

apart (Figure 6). Restrictor ropes were made of 6–10 mm nylon braid and were either attached using non-slip knots, or using an alternative attachment method which facilitated their removal during the experiment. The length of restrictor ropes matched the headline height of the net, allowing the net to keep its intended shape during fishing (Figure 7). Observers were tasked with checking the placement of the restrictor ropes prior to each tow, and confirming that the experimental treatment days were followed in the random order prescribed prior to sailing.

In lieu of a non-lethal metric with which the efficacy of the restrictor at reducing seabird bycatch could be determined, the response variable for the experiment was to be seabird captures. As part of their normal duties, observers record seabird captures and associated metadata on a series of forms. An additional form was designed for this experiment (Figure 8), which recorded the net (port, starboard, centre) in which captures occurred, and whether birds were caught on the restrictor rope itself. Observers were also to complete three fields that linked the experimental form to their other forms which recorded data including gear specifications, and details of target catch and bycatch. Finally, as this was a new experimental protocol, observers were encouraged to document any additional observations relating to the protocol, the restrictors, interactions with seabirds, or the experiment in general.

Data collected were expected to be analysed using generalised linear models executed in a Bayesian statistical framework, to determine whether restrictors were effective in reducing the risk of seabird captures.



Data Collection Form: At-sea testing of net restrictors

Trip number:

*Please complete one line for each bird caught. (Follow the style of example entries.)

	As on Observer Non-fish Bycatch Form		**Birds caught in net (list species code)**					
Date capture landed	**Sample #**	**Tow #**	**Port net**	**Centre net**	**Startboard net**	**Net unknown**	**Caught on restrictor**	**Comments**
15-Dec-12	*3*	*7*		*XFS*				
15-Dec-12	*4*	*9*			*XBP*			

Figure 8: At-sea data collection form for assessment of the efficacy of net restrictors in reducing seabird bycatch in the centre net of triple-rig scampi trawls.

Due to limited capacity within the government observer programme throughout this project, only one observed trip occurred on a scampi vessel testing the net restrictor. However, this trip was successful in implementing the experimental approach, and so confirmed the feasibility of conducting the experiment in the course of a normal fishing trip. The skipper reported that inserting and removing restrictors repeatedly was cumbersome as crew were not able to spread out the centre net on the deck of the vessel to measure the distance between restrictors. Marking the points along the headline and groundrope of the trawl net at which the restrictors were to be attached would address this limitation.

3.1.2 Camera deployment

To understand the effects of the net restrictor on gear configuration (thereby confirming whether or not the restrictor reduced the size of the net mouth underwater astern the vessel) we worked with the research

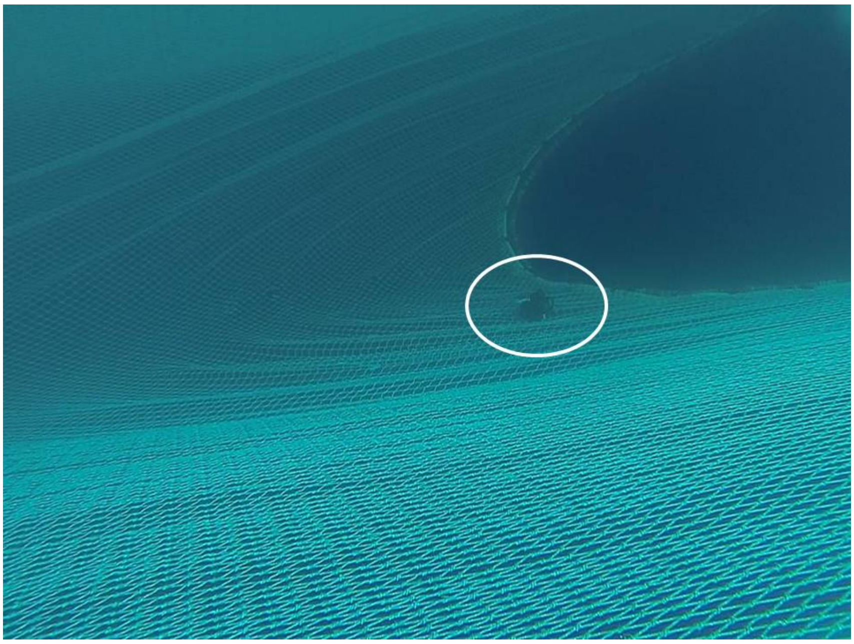


Figure 9: Camera (circled) deployed in the centre net of a triple-rig scampi trawl.

crew conducting stock survey work in QMA SCI6A on the F.V. San Tongariro, to deploy net-mounted underwater cameras (Figure 9). Two test tows using a Hampidjan 50-m scampi trawl were conducted on 24 March 2013, in waters north of the Auckland Islands. Restrictors were not deployed during the first tow, and eight restrictor ropes were deployed across the centre net during the second tow (Figure 10). The gear was monitored with two GoPro cameras in place. These cameras were underwater-capable to 50 m depth. One camera was attached approximately 1 m behind the headline and 1 m to the starboard side of centre of the top centre panel of the centre trawl net. The second camera was attached approximately 1 m behind the groundrope on the bottom centre panel of the centre net, and 1 m off-centre to the port side. No light, other than natural light, was used during recording. The net was shot astern with 90 m of sweep out, to a depth of 48 m. The gear was in the water for 10–15 minutes per shot. The headline height and water depth during both tows were determined using the vessel's Furuno CN22 net monitor.

Cameras were successful in capturing a video record showing the configuration of the centre trawl net underwater during the two test tows. Due to the depth limitation of the cameras, trawl doors and skids were not deployed on the filmed tows. However, the skipper confirmed that the configuration of the net underwater was analogous to the shape it would take in a typical commercial shot, i.e., when at fishing depth. The camera deployed close to the headline delivered the best view of the restrictors. This camera was more stable than the groundrope camera, due to a more secure fitting, and because the meshes behind the groundrope were less stable than behind the headline. Movement of the groundrope during towing resulted in the camera affixed there capturing a highly dynamic view such that it was often not clear which part of the net featured in the video recording.

During recording, the centre net spread to approximately 15 m (estimated wing end spread). Without restrictors in place (Figure 11, Figure 12), the height of the centre net mouth was measured as 4.0–4.5 m. With restrictors in place (Figure 13, Figure 14), this diameter decreased to a maximum of 1.0–1.2 m at 48 m depth, with lower headline heights detected during shooting and hauling. In addition to the altered net dimensions achieved by the restrictors, video also showed that the headline and some of the body of mesh around the headline sat lower in the water column when restrictors were in place. When restrictors were not in place, the trawl headline was clearly visible at the water surface and associated meshes floated as well. The weight of the groundrope (350–400 kg in air) was observed to pull the

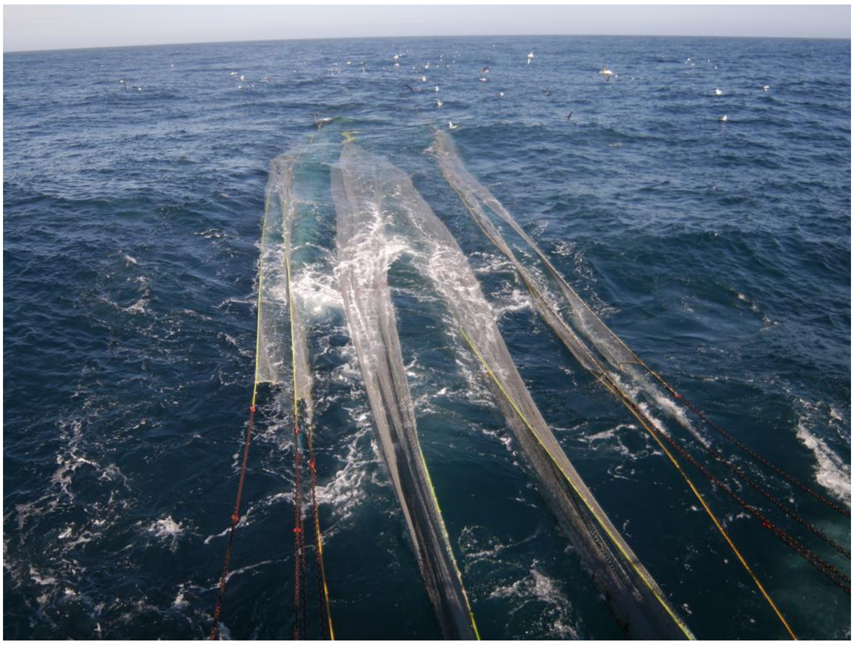


Figure 10: Net hauling on the vessel from which tows were recorded during trials of net restrictors.

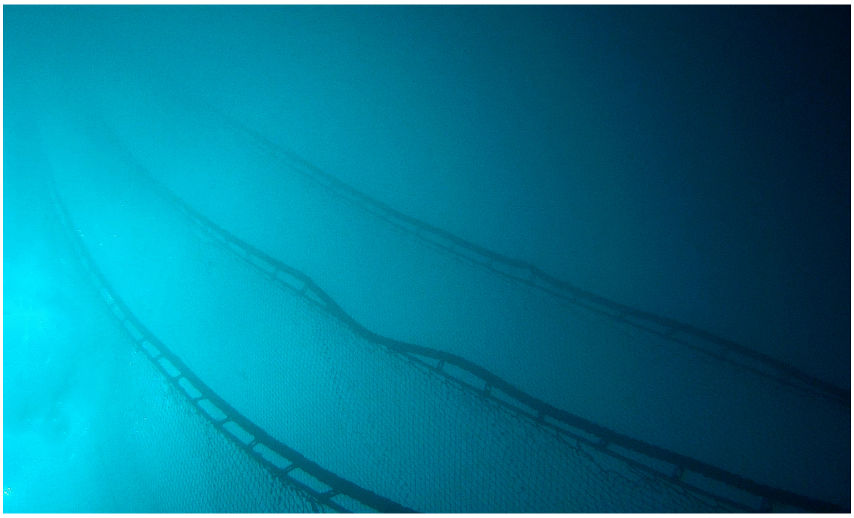


Figure 11: Deployed scampi trawl without net restrictors in place.

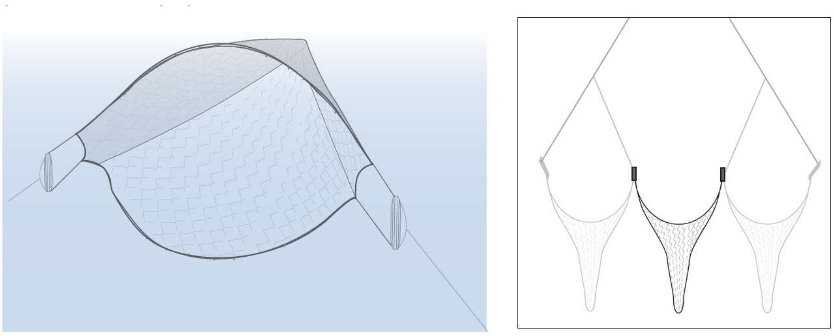


Figure 12: Diagrammatic representation of the centre net of a triple-rig scampi trawl during hauling without restrictors in place. Diagram: Ros Wells

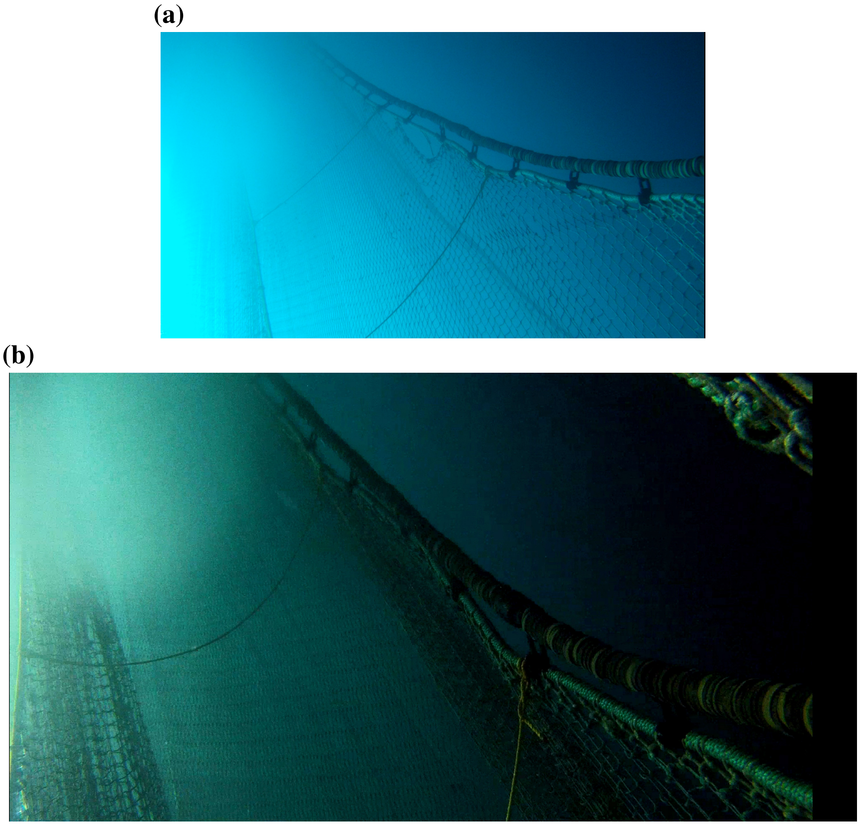


Figure 13: Net restrictors across the centre net of a triple-rig scampi trawl during hauling.

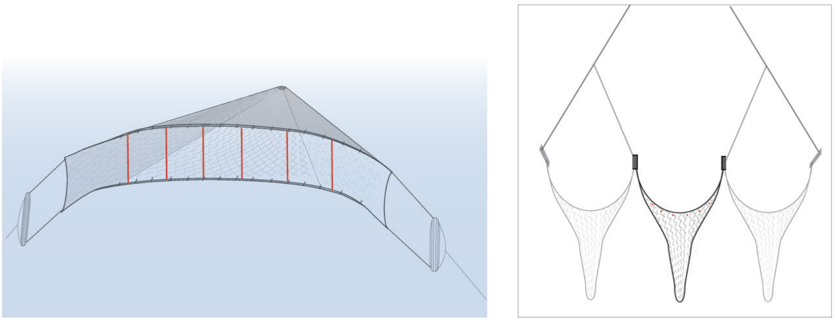


Figure 14: Diagrammatic representation of net restrictors across the mouth of the centre net of a triple-rig scampi trawl during hauling. Diagram: Ros Wells.

headline down below the water surface more rapidly when restrictors are in place.

4. DISCUSSION

Three main areas were identified for further work aimed at reducing seabird captures in the scampi fishery. These were the implementation of robust batch discharge regimes, improvement of streamer line designs, and the experimental deployment of the net restrictor. Ongoing crew education, combined with feedback from government fisheries observers monitoring vessels at sea will facilitate ongoing implementation of robust batch discharge regimes on scampi vessels. Recommendations have been developed for the design and construction of paired streamer lines on vessels $\geq$ 28 m. These recommendations have been promulgated amongst the deepwater trawl fleet in the form of a fact sheet (Cleal et al. 2013). While streamer lines described by these recommendations will require some tailoring to smaller scampi vessels, the principles of good design and materials will be similar to those in other trawl fisheries (e.g., ensuring aerial extent and warp coverage).

Constraints on the delivery of government observer services prevented the empirical testing of the net restrictor at sea. However, an experimental design and protocol were developed and trialled, with which this potential mitigation measure could be tested in future. Video footage collected from the centre net of a triple-rig confirmed that the restrictor was effective in reducing the size of the net opening at hauling. The underwater footage also showed that meshes around the headline sat lower in the water during shooting and hauling operations when restrictors were in place. Based on these characteristics, the restrictor is expected to be effective in reducing seabird bycatch risk created by the mouth of the trawl net and possibly also by reducing the lofting of meshes around the headline at the sea surface. In addition, because the net still deploys at fishing depth in accordance with its design specifications, no negative impacts on scampi catch are expected or likely.

The deployment of net restrictors is not currently required in the scampi fishery. However, in lieu of a designed experiment, deploying the restrictor over time will facilitate determination of its efficacy, in terms of both the rate of seabird bycatch and the volume of fish and invertebrate bycatch landed. To this end, we recommend that for the next five years, the data collection form included here (Figure 8) is distributed to observers on scampi vessels that are using restrictors in the centre net of triple-rig gear, and that this form is completed together with regular forms describing seabird, fish and invertebrate bycatch. Although not a controlled experiment, this level of data collection would allow a quantitative comparison of seabird (and fish and invertebrate) bycatch rates before and after the restrictors were deployed.

Currently, the scampi fishery has the second highest rate of observed seabird bycatch of any New Zealand trawl fishery (excluding inshore trawl fisheries, for which observer coverage in most areas is insufficient to support the robust estimation of bycatch rates) (Abraham et al. 2013). Reported seabird captures in the scampi fishery include species of particular conservation concern, based on their threat status (IUCN 2012) and that estimated potential captures in commercial fisheries are likely exceeding the species' sustainability limits (e.g., black petrel, Salvin's albatross, and flesh-footed shearwater Richard & Abraham (2013)). Although not a substitute for a designed experiment, preliminary results from underwater footage show that the net restrictor may be effective in reducing the risk of seabird bycatch in centre nets. If so, this method would reduce the seabird bycatch risk in the scampi fishery. We recommend the empirical testing of the efficacy of net restrictors in scampi trawl operations, and potentially in other demersal fisheries where seabirds are caught in trawl nets. Following the findings of this project, the Deepwater Group is set to support implementation of restrictors in the scampi fleet as appropriate, commencing with triple-rig systems (R. Wells, pers. comm.).

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