Review of warp strike mitigation methods on <28m commercial trawl vessels in New Zealand

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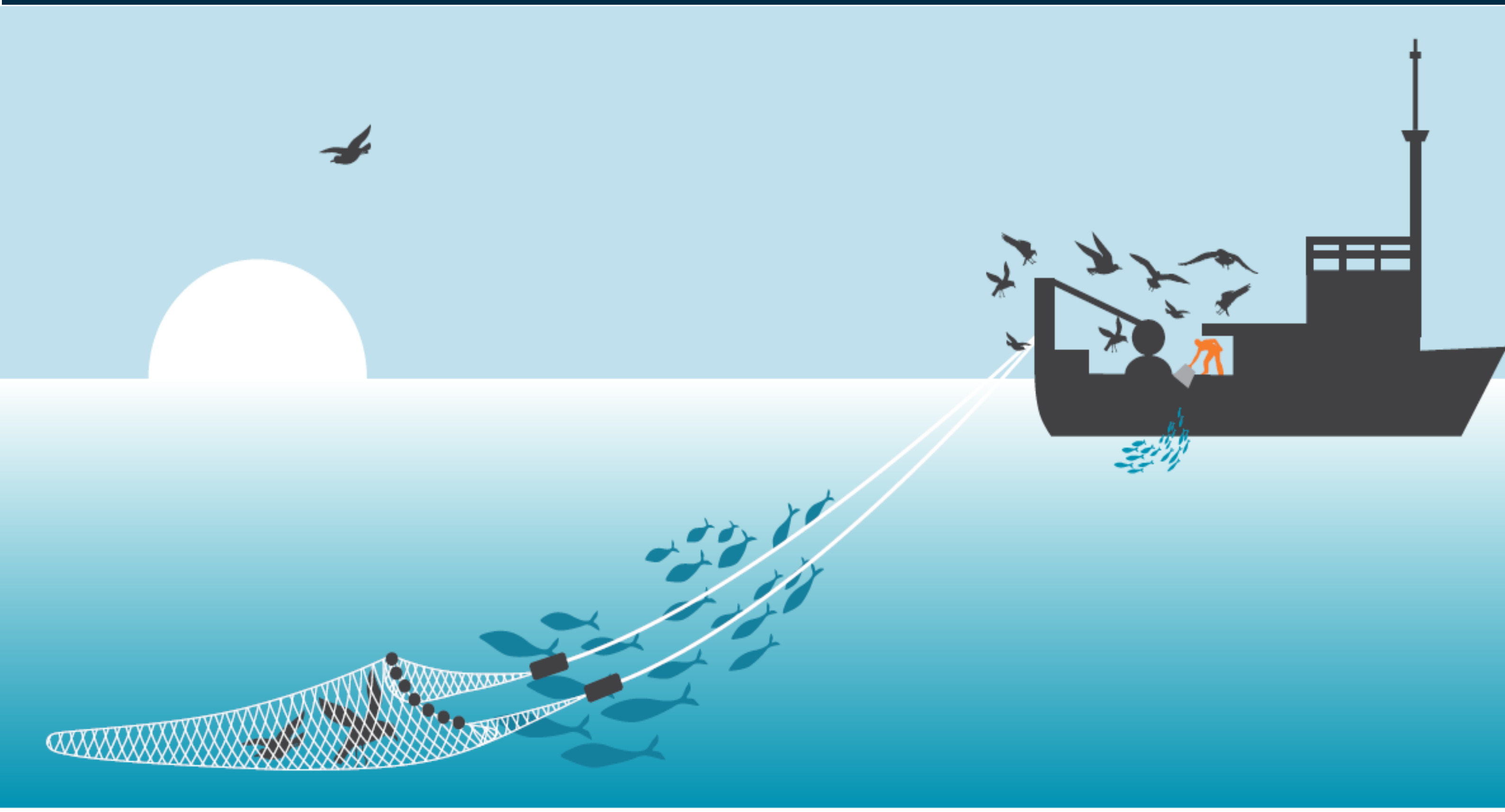
Client Report for the Department of Conservation/Te Papa Atawhai, Conservation Services Programme

Proteus Client Report: MIT2022-07A

31 July 2023



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Citation: Rachel P. Hickcox and Darryl I. MacKenzie. (2023). Review of warp strike mitigation methods on <28m commercial trawl vessels in New Zealand. Report for the Department of Conservation. Proteus Client Report: MIT2022-07A. Proteus, Outram, New Zealand.

Front cover photo: National Plan of Action-Seabirds 2020, Fisheries NZ.

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Executive summary

The incidental catch of seabirds due to warp or cable strike is one of the main risks posed by coastal commercial trawl fisheries. Several different types of seabird bycatch mitigation devices are used that attach to or around warps, cables, and the vessel to form physical and visual barriers to deter seabirds. There is uncertainty, however, about the effectiveness of mitigation devices on small vessels, and there are no mandatory requirements for trawl vessels <28m in length to employ such devices. There is also no clear guidance or best practice due to limited observer data, at-sea trials, and published studies on the effectiveness of warp mitigation devices.

The following literature review provides a brief overview of eight mitigation devices that are used on trawl vessels in New Zealand and around the world, only two of which are currently being used on vessels less than 28 meters in length overall. Data on seabird capture rates from the reviewed studies is presented and supplemented with observer data collected in New Zealand coastal trawl fisheries between 2015 and 2020. Current best practices for data collection regarding seabird abundance and warp strike observations were critiqued in preparation for a workshop that was held with invited experts. Workshop attendees met to discuss research approaches and develop recommendations (Phase 1) for at-sea trials of devices to quantify their relative effectiveness in mitigating warp strike (Phase 2).

Warp strike/capture rate was 0.59 captures/100 tows on observed New Zealand coastal trawl vessels <28m between 2015 and 2020, regardless of mitigation method. Mitigation devices were used during 42% of all observed trawl tows between 2015 and 2020, with the bird baffler being the most frequently used. Based on the review of 14 international studies, it was determined that tori lines, bird bafflers, warp scarers, plastic cones, and water sprayers are the

best candidate devices for trials on trawl vessels <28m to test their effectiveness at reducing seabird warp strike.

During the workshop, tori lines, bird bafflers, pinkie buoy warp deflectors, and plastic cone warp deflectors were recommended for at-sea trials, based on expert opinions of feasibility, cost, practicality, and safety. Due to the large variation in vessel configurations, experts suggested categorising <28m vessels into three additional size classes. Sample size, vessel selection, gear configuration and type (e.g., size, structure, use of Dyneema warps), and the effects of discharge management were also discussed relative to efficient data collection methods and study design. Considerable challenges with testing mitigation devices at sea were raised that may make an at-sea trial difficult and/or impossible, including sample size and the confounding effects of many factors influencing warp strike rates.

Best practices for data collection of abundance and warp strike rates, used by the Agreement on the Conservation of Albatrosses and Petrels, the Department of Conservation, and Fisheries New Zealand, should form the basis of at-sea trial methodology, with some suggested modifications based on international studies and trials. Trial scope, device availability on vessels, cost, and feasibility will determine which of the four recommended mitigation devices are prioritised for testing. If a statistical approach is taken to address project objectives, alternative data collection methods such as electronic monitoring and on-board cameras should be considered to supplement observer data on warp strikes and the effectiveness of mitigation devices.

1. Introduction

Commercial trawl fishing poses a substantial risk to seabirds in New Zealand (Abraham et al., 2017), and warp strike largely contributes to the bycatch risk. As seabirds feed on bycatch or fish waste discarded behind a trawl vessel, they can become tangled in or strike warp cables that connect the trawl net to the vessel or as they interact with catch in the trawl net during net setting or hauling, both above and below the water line (Figure 1). Warp strikes, where some part of the bird hits some part of the warp, may not always result in a warp capture, where the bird becomes tangled in the warp and dies. Rather, a bird may strike a warp but fly away, a type of cryptic mortality if the bird died but was unobserved. All warp captures can be considered a warp strike, but not all warp strikes are detectable. This distinction is important to make when assessing the overall risk of warps to seabirds and how rates are calculated.

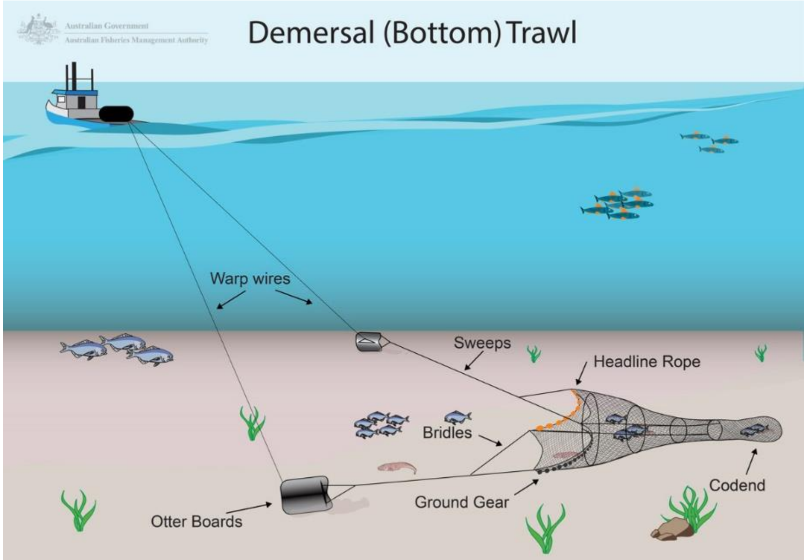

Figure 1. Diagram of bottom trawl gear with warp cables above and below the water line. Source: https://www.afma.gov.au/fisheries-management/methods-and-gear/trawling.

Most coastal commercial trawl fishing occurs up to 12 nautical miles off the coast of New Zealand. During the 2021-2022 fishing year, there were 105 active coastal trawlers, all less than 28 meters in length overall (LOA). Commonly referred to as small, coastal, or inshore vessels (although not all vessels solely operate inshore), they operate in Northland, Bay of Plenty, Hawkes Bay, Cook Strait, Golden Bay, Hokitika Canyon, and the east and south coasts of the South Island. They target a variety of finfish species, including flatfish, snapper, red cod, hoki, ling, gurnard, tarakihi, stargazer, and John Dory (see Appendix Table 1-1 for scientific names). Unlike large/offshore trawlers where it is mandatory for any vessel ≥28 m to protect both warp cables with warp mitigation devices allowed by regulation, there is no legal regulation for warp mitigation on coastal trawlers <28m; however, vessels are obligated by industry, the Ministry of Primary Industries (MPI), and the Department of Conservation (DOC) to report mitigation use according to their protected species risk management plan (PSRMP). Moreover, Fisheries Inshore New Zealand (FINZ) provides Operational Procedures for coastal trawlers specific to the North and South Islands (FINZ, 2018; 2021). The procedures outline the responsibilities of vessel and crew to reduce warp strike. About 36% of <28m vessels voluntarily employed mitigation devices and/or managed organic waste discharge to mitigate bycatch of seabirds and other protected species between 2003 and 2016 (Parker & Rexer-Huber, 2019; Rexer-Huber & Parker, 2019).

Warp mitigation is defined as any modification to equipment and/or fishing practices that reduces the likelihood of seabird interactions with the warp cables (Bull, 2007a). The most common warp mitigation methods are devices that are attached to or deployed around warp cables that visually and physically deter seabirds from the warp danger zone, the area around the warp cables where aerial, surface, and underwater strikes typically occur. However, the most important mitigation technique that limits the number of birds attending the vessel is discharge management. Fish or marine species caught unintentionally as bycatch, as well as offal, or fish waste/by-products generated from catch processing, are often discarded from the vessel deck. The discards are attractants to seabirds; hence discharge management is key to limiting the associated risk (Department of Conservation & Fisheries New Zealand, 2019b).

There is little information on the feasibility and effectiveness of mitigation devices on coastal trawl vessels in the mitigation standards introduced in the National Plan of Action- Seabirds 2020 (NPOA Seabirds 2020), despite ongoing commitments by government agencies to reduce bycatch of seabirds in commercial fisheries operating in the NZ exclusive economic zone. Effectiveness can be influenced by the vessel (i.e., size, configuration, gear), fishing location, economic costs, seabird assemblages around each vessel, and the time and season of the fishing event (Bull, 2007a). Realistically, a combination of measures is required to reduce or eliminate seabird bycatch, and individual vessel refinement of mitigation techniques is often required to maximise their effectiveness within a fishery.

In this project, a literature review was first conducted to summarise existing information to assess the use and effectiveness of warp bycatch mitigation devices currently in use in New Zealand and to discuss other potential mitigation methods that are used internationally (Phase 1 of MIT2022-07A project; Department of Conservation, Conservation Services Programme). Observer data on protected species captures due to warp strike, mitigation device strike, and other capture methods were provided to highlight current mitigation methods on trawl vessels and effectiveness from 2015-2020. Preliminary findings and initial recommendations on potential at-sea data collection protocols for mitigation trials were presented for discussion at a workshop with key experts to finalise recommendations for Phase 2, developing a best practice mitigation and quantifying effectiveness through sea trials. The aims of Phase 1 for this project are as follows:

Literature review

- Collate available information on inshore trawl warp mitigation methods, studies, and other data sources held by DOC, Fisheries NZ, other government or research institutions, and industry.
- Conduct a brief literature review of effectiveness of trawl warp mitigation options used in inshore fisheries nationally and internationally.
- Review and critique methods used to collect information and data on trawl warp mitigation, and suitability of existing data sets that have been made available.

Invited expert workshop

- In collaboration with DOC, organise and lead a 4-hour online expert workshop to discuss initial recommendations and seek feedback on alternative mitigation options.

2. Methods

2.1 Literature review

A literature review was conducted by searching for terms in Google Scholar. Search terms included: inshore AND commercial AND trawl AND fisheries AND seabird AND warp strike AND mitigate. All identified published and grey literature were assessed for relevancy, fishing and mitigation method, vessel size, and country of the study, which resulted in 14 sources which presented data on bycatch mitigation for warp strike on both small and large trawl vessels. Several other studies (e.g., Abraham et al., 2009; Pierre et al., 2012; Rexer-Huber & Parker, 2019) examined the effectiveness of fish waste management strategies but were not reviewed here because they do not address warp strike specifically (Appendix Table 1-3). Additionally, several reviews have previously summarised and evaluated mitigation devices used in New Zealand and internationally to reduce seabird bycatch (Bull, 2007a, 2007b; Løkkeborg, 2011; Parker, 2017a). Although all reviews consider trawl warp strike mitigation devices, they include information on other fishing methods and devices. Therefore, literature is presented specific only to warp strike in trawls, all of which has been previously discussed also in the beforementioned reviews. Due to the limited number of studies for trawl vessels <28m, studies of vessels ≥28m were also considered. Note most of the diagrams of mitigation devices are reproduced from the studies which occurred largely on vessels ≥28m; vessel configuration will thus be different if these devices are deployed on coastal vessels <28m (see Appendix Figure 2-1 for an example schematic of a 26m coastal trawler).

2.2 Data acquisition and summary

The results of the reviewed literature and collated data pertain to the efficacy of mitigation devices, including seabird mortality counts or rates, warp strike interaction or capture rates, and percentage of reduction in captures or mortalities due to the devices. Here, an interaction refers to any contact between a seabird and a trawl warp or mitigation device, even if the bird was not actually captured in the gear. A capture, on the other hand, refers to seabirds that have been caught on or around warp cables or mitigation devices. Most seabirds caught on the warp are captured dead, although some are live-caught and released with their fate unknown (Parker & Rexer-Huber, 2019). Data collected from these sources included the fishery (location and target species), year the data was collected, vessel class/size, number of vessels and tows involved in the study, method of observation and data collection, principal seabird species observed, mitigation methods that were used, and data related to seabird counts/abundance, number or rate of mortalities, warp contact/capture/ mortality rate, and the overall effectiveness of the method at reducing warp strike.

Additionally, warp strike events from 2015-2020 were queried from the Protected Species Captures Database v6 (2021), managed by the MPI. Warp mitigation device has been reported by fishers and observers since 2007, and reporting was made mandatory in 2021. The original extract includes the number of seabird captures and observed fishing effort (i.e., the number of tows observed by a scientific observer) for each fishing year, capture method, and mitigation method. To summarise captures and observed fishing effort, the data was groomed by combining captures into three capture methods: warp strikes (code S), mitigation method including tori line (code TO) and lazy line captures (code L), and other methods including net captures (code N), other (codes O, OT), and unknown (code U) methods. Observed capture rates were calculated across all fishing years as:

$$\text{Observed Capture Rate} = C/(E_O/100) \qquad \textit{(eq. 1)}$$

where C is the sum of warp, mitigation device, and other captures for a specific mitigation method, E_O is the total observed fishing effort, or number of tows, for that method across all fishing years divided by 100 tows. Total effort, E, would include both observed (O) and unobserved (U) tows, such that $E = E_O + E_U$.

Fishing effort was extracted from the Protected Species Captures Database for trawls <28m using an SQL query in R. Effort, or the total number of trawl events, was distinguished for each vessel class and summed per fishing year (2018/2019, 2019/2020, 2020/2021) and fishing area (FMA 1-9).

2.3 At-sea trial data collection method review

When testing mitigation devices or collecting data as part of the observer programme, protocols are recommended for consistent and thorough monitoring. The Department of Conservation (DOC) presented data collection protocols for seabird-fisheries interactions at the 3rd Meeting of the South Pacific Regional Fisheries Management Organisation Scientific Committee in 2015 to determine seabird abundance near vessels and observe warp strike observations (Ramm et al., 2015). In addition, the Agreement on the Conservation of Albatrosses and Petrels (ACAP) has published best practices of data collection for observer programmes specific to ACAP-listed threatened seabird species (Agreement on the Conservation of Albatrosses and Petrels, 2021a, 2021c).

These sources are critiqued as well as protocols for data collection from reviewed literature and existing forms (via paper and electronic monitoring) for vessel and mitigation method information. Study design and sample data forms is discussed, and ways to adapt protocols during at-sea trials of mitigation tools on coastal trawlers in New Zealand are suggested.

2.4 Invited expert workshop

On 22 March 2023, a virtual workshop was chaired by Proteus and DOC (see Appendix 5 for agenda). There were 15 representatives from various organisations, including Fisheries NZ/Ministry of Primary Industries, Fisheries Inshore New Zealand, Deepwater Group, and the Australian Department of Climate Change, Energy, the Environment and Water. Presented throughout this report are some of the discussion points about the practicality, applicability , and perceived effectiveness of several warp strike mitigation devices to inform a prioritised list of devices recommended for future at-sea testing (Phase 2). Experts also discussed data collection methods for the trial to identify the most suitable and cost-effective protocols and the next steps required before testing mitigation methods.

3. Results

3.1 Mitigation methods

There are three legally permitted warp strike mitigation devices in New Zealand specific to seabirds: tori lines, bird bafflers, and warp deflectors (Abraham & Thompson, 2009). Based on 2021-2022 Protected Species Risk Management Plans (Plencner, 2023), approximately a third of vessels used bafflers of different designs and a third used deflectors of different designs, and a third used custom or other mitigation methods (e.g., one vessel used a tori line, two used a combination of bird baffler and deflector). A review of seabird bycatch mitigation methods used in international commercial fisheries (Bull, 2007a), and a more recent stocktake (Parker, 2017a) summarised all types of mitigation device methods used both internationally and in New Zealand fisheries. This review discusses seven devices (Table 1) for warp strike mitigation on trawlers <28m and ≥28m (Table 2, Table 3):

- **Bird-scaring/tori/streamer lines** (Abraham & Thompson, 2009; Cleal et al., 2012; Koopman et al., 2018; Maree et al., 2014; Melvin et al., 2011; Middleton & Abraham, 2007; Parker & Rexer-Huber, 2019; Snell et al., 2012; Sullivan et al., 2006)
- **Bird bafflers** (Abraham & Thompson, 2009; Cleal et al., 2012; Koopman et al., 2018; Melvin et al., 2011; Middleton & Abraham, 2007; Sullivan et al., 2006)
- **Warp scarers** (Abraham & Thompson, 2009; Middleton & Abraham, 2007; Pierre, Gerner, et al., 2014; Sullivan et al., 2006)
- **Pinkie buoy warp deflectors** (Kuepfer, 2017; Parker & Rexer-Huber, 2019; Pierre, Gerner, et al., 2014)
- **Plastic cone warp deflectors** (González-Zevallos et al., 2007).
- **Water sprayer** (Koopman et al., 2018)
- **Lasers** (Melvin et al., 2016)

Recommendations are based on discussions from the expert workshop (see Appendix 5).

Table 1. Description of each mitigation method and primary pros and cons of each device based on the review of relevant literature (see footnote for numbered references). For each device, experts made recommendations for at-sea testing of the device on NZ inshore trawl vessels.

Method	Device description	Pros/Cons	Expert recommendation	Ref*
Tori lines (aka bird-scaring lines BSL, streamer lines)	Backbone of rope with streamers attached, running parallel to outside of both warp cables. Float attached to end at water interface to cause drag. Connected to stern above each trawl block. Can use a boom or lazy line to deploy after shooting and retrieve prior to hauling. Best practice: paired (on both warps)	**Cons:** - Tangles with warp cable. - Harder to deploy, trawl blocks outboard of hull - Streamers break/fade. - Requires proper position, length, weight, spacing. - Safety risk. - Limited by weather conditions. - Tori line strike, with reduced severity and mortality rates. **Pros**: - Inexpensive. - Easier to setup. - Requires less space on vessel.	Significant reduction in warp strike on vessels <28m **Recommended for testing**	1, 3-8, 10, 12, 13
Bird baffler	Two booms behind and to the side of vessel with droppers attached (e.g., ropes with cones, streamers, other material). Multiple designs (e.g., 2- or 4-boom)	**Cons:** - Requires proper boom/dropper length. - Requires proper position, height of warp-block, spacing. - Expensive. - Harder to install. - Requires a structure on the vessel - Takes up deck space **Pros**: - Deployed at beginning of trip (set/forget). - Internationally used. - Easier to maintain.	Mixed results, significant reduction in warp strikes on vessels <28m **Recommended for testing**	1, 3, 4, 5, 7, 14
Warp scarer	Series of rings/clips with rollers connected by netting and rope, with reflective streamers hanging from each ring. Connected to stern via lazy lines and deployed after shooting net and retrieved prior to hauling.	**Cons:** - Tangles with warp cable. - Streamers break/fade. - Requires proper weighting. - Difficult to deploy/retrieve. - Safety risk. - Limited by weather conditions. **Pros**: - Inexpensive	No significant reduction in warp strike **Not recommended for testing**	1, 3, 4, 9
Warp deflector: pinkie buoy	600mm diameter buoy clipped to each warp cable within 400mm of water surface, secured to vessel with a lazy line.	**Cons:** - Tangles with warp cable. - Difficult to position along warp and above water. - Requires proper size, weight, position. - Prone to device loss. - Requires frequent adjustment. - Limited by weather conditions. - Limited effectiveness at reducing flying bird strike high up on warps. **Pros**: - Inexpensive.	Mixed results, limited efficacy and prone to incorrect deployment **Recommended for testing**	9, 12, 14

Warp deflector: plastic cones	Plastic traffic cone attached to each warp cable at water interface. Cut in half and lowered from stern via lazy line after shooting and retrieved prior to hauling.	**Cons:** - Requires adjustment. **Pros**: - Reduced severity and mortality rates if bird strikes cone. - Only one person to deploy/haul. - Inexpensive.	Some evidence of significant reduction in warp strike **Recommended for testing**	2
Water sprayer	Two 4m booms behind vessel and above warps. Each boom has two 4m sprayer arms perpendicular to boom and separated by 2m gap. Sea water pumped through multiple nozzles along the arms.	**Cons:** - Malfunctioning pump or sprayers. - Specific configuration required. - Requires maintenance. - Expensive. - Harder to install. - Crew get wet from the spray. - Safety concern, wet deck. - Requires a structure on the vessel **Pros**: - Deployed at beginning of trip (set-and-forget).	Some evidence of significant reduction in warp strike **Not recommended for testing**	13
Lasers (e.g., SeaBird Saver and the Dazzler)	Lasers of specific power outputs mounted to the stern. Can be static or scanning	**Cons:** - Potential to injure seabirds; negative impacts are unknown - Not effective during the day. - Difficult to manoeuvre or change beam direction. - Requires specific power level, strength/length of beam, field of view. - Electronic device failure - Requires a structure on the vessel - Current devices not supported internationally, specifically by ACAP **Pros**: - Deployed at beginning of trip (set/forget) - Easy to use - Reduced space requirements	Little/no evidence of significant reduction in warp strike **Not recommended for testing/use**	11

***References**

1 Sullivan et al. (2006)
2 González-Zevallos et al. (2007)
3 Middleton and Abraham (2007)
4 Abraham & Thompson (2009)
5 Melvin et al. (2011)
6 Snell et al. (2012)
7 Cleal et al. (2012)
8 Maree et al. (2014)
9 Pierre et al. (2014)
10 Tamini et al. (2015)
11 Melvin et al. (2016)
12 Kuepfer (2017)
13 Parker and Rexer-Huber (2019)
14 Koopman et al. (2018)

Table 2. Reviewed journal articles and grey literature that present results for trawl warp mitigation. Those in grey involve vessels <28m. Some vessels employ offal and/or bycatch discharge management practices (DMP; *) employed on vessels. The *type* of DMP include “retention” of offal/bycatch on-board (i.e., no discharge) or “controlled” discharge with types of DMP including the *method* (e.g., batch, continuous, meal), *position* (e.g., stern, offside), and *timing* of discharge (e.g., shot, tow, haul, processing). If no DMP, discharge is ‘uncontrolled’. For some reviewed studies, the DMP type, method, position, timing, and/or quantity of discharge was explicitly accounted for (i.e., ‘Tested’ or ‘Not tested’).

Reference	Fishery	Year	Vessel class, # of vessels	Observation method	Observed seabird species	Discharge management*	Mitigation method	Seabird counts or mortalities	Warp contact rate	Effectiveness of mitigation method
González-Zevallos et al. (2007)	Golfo San Jorge, Argentina Argentine hake fishery	2004-2006	21.2–30.9 m n = 3 (52 tows)	Observer-recorded frequency of occurrence/species and rates of non-fatal and fatal interactions with nets and both starboard and port warp cables	13 total species, primarily kelp gull, black-browed albatross, white-chinned petrel, southern giant petrel, imperial cormorant (6 species interacted with warp)	*Type:* not stated/controlled *Method:* not stated *Position*: both sides *Time:* not stated **Not tested**	Warp deflector: Plastic cones	- 53 mortalities - 0.14 strike mortalities/tow (11.6% or 5 tows/ 43 total tows) - Estimated 306 warp mortalities/ 2703 in total	- 5.4 ± 7.2 warp strikes/tow	- 89% fewer warp strikes with plastic cones - No warp strike deaths with device and 11 without device over study period
							Control (none)		- 58.5 ± 43.3 warp strikes/tow	
Pierre et al. (2014)	Southern and Eastern Scalefish and Shark Fishery (SESSF)	2012-2013	17.9-26 m n = 9	Observer-recorded frequency of occurrence/species and rates of non-fatal and fatal interactions with warp cables and mitigation devices on offal discharge side of vessel	Shy-type albatross, black-browed albatross, Indian yellow-nosed albatross, wandering albatross, cape petrel, giant petrel, short-tailed shearwater	*Type:* controlled *Method:* continual, batching *Position:* both sides *Time:* during hauling/processing, after processing **Not tested**	Warp deflector: pinkie buoy	1144 interactions/ 507 observation periods	2.32-4.25 warp strikes/tow	- 75% fewer heavy warp strikes of shy-type albatross with deflector - Scarers only effective during aggressive feeding - 2/203 interactions occurred at night
							Warp scarer		3.86-7.56 warp strikes/tow	
							Control (none)		3.22-8.76 warp strikes/tow	
Koopman et al. (2018)	Southeast Australia	2014-2015	29 m and 20m n = 2 (one with baffler + pinkie, one with sprayer + pinkie)	Observer-recorded frequency of interactions with starboard warp cables and mitigation devices (mortalities not measured) Followed Pierre et al. (2014) methods	14 total species, primarily short-tailed shearwaters, giant petrel, silver gull, prions and shearwaters spp., grey-headed albatross, black-browed albatross	*Type:* controlled *Method:* not stated *Position:* not stated *Time:* during processing **Tested**	Bird baffler + pinkie buoy	*Mean observed live birds/tow:* - 186 during offal discharge - 95 during deck release	- 0.1 heavy interactions/tow - 8.7 light interactions/tow	83.7% and 58.9% fewer warp contacts with baffler and sprayer, respectively
							Sprayer + pinkie buoy	- 263 during offal discharge - 146 during deck release	- 2.5 heavy interactions/tow 15.4 light interactions/tow	
							Warp deflector: pinkie buoy (control)	Not reported	- 0.8-6.1 heavy interactions/shot 6.1-35.7 light interactions/shot	

Reference	Fishery	Year	Vessel class, # of vessels	Observation method	Observed seabird species	Discharge management*	Mitigation method	Seabird counts or mortalities	Warp contact rate	Effectiveness of mitigation method
Parker and Rexer-Huber (2019)	New Zealand	2013-2017	13-59.5m n = 33	Data in the Protected Species Captures Database (MPI) and relevant grey literature based on observer-recorded non-fatal and fatal interactions	Black petrel, Buller's shearwater, common diving petrel, flesh-footed shearwater, grey-faced petrel, grey petrel, Cook's petrel, sooty shearwater, white-faced storm petrel, white-capped albatross	*Type:* retention, controlled *Method:* whole fish or offal; batching, mealing, or continuous *Position*: offside, stern *Time:* during shot, tow, or haul **Tested**	Tori lines	*Total captures:* - 15 mortalities/ 4762 tows (0.31/100 tows) - 6 warp captures (17% all interactions) ▪ 5 mortalities ▪ 1 alive	1.42 captures/100 tows (all interaction types)	18-49% reduction in mortality due to warp strike with mitigation devices
							Bird baffler		0.88 captures/100 tows (all interaction types)	
							Other		2.07 captures/100 tows (all interaction types)	
							Control (none)		1.74 captures/100 tows (all interaction types)	
Sullivan et al. (2006)	Falkland Islands Finfish fishery	2003	66m n = 1 (78 tows)	Observer-recorded rates of non-fatal and fatal interactions with starboard warp cables and mitigation devices Methods: Wienecke and Robertson (2002)	Black-browed albatross, cape petrel, southern giant petrel	*Type*: controlled *Method*: whole fish/offal *Position*: stern; both sides (only starboard observed) *Time*: not stated **Not tested**	Bird baffler	3 mortalities in 3/22 trawls	42.95 warp strikes/hour (95% CI 30.95-56.54)	Tori lines, warp scarers significantly reduced mortality due to warp strike
							Warp scarer	1 mortality in 1/17 trawls	6.64 warp strikes/hour (95% CI 2.68-10.73)	
							Tori lines	0 mortalities in 19 trawls	0.91 warp strikes/hour (95% CI 0.34-2.49)	
							Control	14 mortalities in 7/20 trawls	55.78 warp strikes/hour (95% CI 42.62-70.75)	
Maree et al. (2014)	South Africa Deep-water cape hake *and* shallow-water hake	2004-2011	Unspecified length, but likely ≥28m n = 19 (782 tows)	Observer-recorded frequency of occurrence/species and rates of non-fatal and fatal HEAVY interactions with warp cables and mitigation devices	Black-browed albatross Indian yellow-nosed albatross, Atlantic yellow-nosed albatross, white-chinned petrel, cape gannet, shy-type albatross, pintado petrel, great shearwater, sooty shearwater, subantarctic skua, giant petrel	*Type:* controlled *Method:* not stated *Position*: offside *Time:* during shot, tow, or haul **Tested**	Tori lines/bird-scaring lines (2006-2011)	- 41 mortalities/ 996 heavy interactions (obs) - ~990-2264 seabirds/year	Not reported	73–95% reduction in mortality rates due to warp strike with bird-scaring line
							Control (2004-2005)	- 0-0.56 mortalities/hour - 9300 seabirds/ year	Not reported	
Middleton and Abraham (2007)	New Zealand Squid fishery	2006	Unspecified length, but ≥28m n = 18	Observer-recorded non-fatal and fatal interactions with warp cables and mitigation devices on 'active' side of vessel	Not reported	*Type*: controlled *Method*: whole fish, offal, minced, sump *Position*: offside, stern; both sides *Time*: intermittent, continuous **Tested**	Tori lines	Not reported	Number not explicit, graph instead	- 5-20% reduction in seabird mortality with tori lines - 35-90% reduction in lg. seabird mortality and no/slightly significant reduction in sm. seabird mortality with bafflers, scarers
							Bird baffler	Not reported	0.67 warp strikes/obs. period	
							Warp scarer	Not reported	Number not explicit, graph instead	
							Control (none)	Not reported	0.42 warp strikes/ob. period	

Reference	Fishery	Year	Vessel class, # of vessels	Observation method	Observed seabird species	Discharge management*	Mitigation method	Seabird counts or mortalities	Warp contact rate	Effectiveness of mitigation method
Abraham & Thompson (2009)	New Zealand Squid and hoki fisheries	2004-2007	≥28m	Data held by MPI on observer-recorded abundance and rates of non-fatal and fatal interactions with warp cables Methods: Middleton and Abraham (2007)	Not reported	*Type*: controlled *Method*: whole fish, offal, minced, sump *Position*: offside, stern; both sides *Time*: intermittent, continuous **Tested**	Tori lines	- 8469 warp strikes, 2840 mitigation device strikes (58.8% squid fishery, 16.9% hoki fishery) *Inshore only:* - 36 warp strikes, 0 device strikes - 5 (small birds), 129 (large birds) warp captures	- 0.16-0.79 heavy warp interactions/hour - 0.79-2.49 heavy device interactions/hour - 0.2 captures/100 tows	- Significant reduction in strikes with tori lines - No significant reduction in landed captures with warp scarers or bird bafflers - Fewer strikes in the absence of offal discharge
							Bird baffler		- 0.52-3.97 heavy warp interactions/hour - 0.01-0.16 heavy device interactions/hour - 4.4 captures/100 tows	
							Tori lines + baffler		- 0.04-0.47 heavy warp interactions/hour - 2.0 captures/100 tows	
							Warp scarer		- 1.02 heavy warp interactions/hour - 0.03-0.14 heavy device interactions/hour - 2.7 captures/100 tows	
							Control (none)		- 2.24-5.33 heavy warp interactions/hour - 7.4 captures/100 tows	
Melvin et al. (2011)	Bering Sea Walleye pollock fishery	2005	84.1m (vessel M) and 102.4 m (vessel R) n = 2 (170 tows)	Observer-recorded frequency of occurrence/species and rates of non-fatal and fatal interactions with both warps	Various albatross spp.	*Type*: controlled *Method*: minced, mealed, oil *Position*: both sides *Time*: not stated **Tested**	Third-wire snatch block	- 20 mortalities ▪ 17 in net ▪ 2 third-wire strike ▪ 1 warp boom	- 1.6 (M) and 12.2 (R) third-wire strikes/hour	Significantly fewer third-wire and warp strikes occurred with mitigation device
							Warp booms		- 4.5 (M) and 15.1 (R) warp strikes/hour	
							Tori lines		- 0.1 (M) and 0.9 (R) warp strikes/hour	
							Control	- Mean 932 (M) and 268 (M) birds/observation	- 8.4 (M) and 13.2 (R) warp strikes/hour	
Snell et al. (2012)	Falkland Islands Finfish fishery red cod, hoki, kingclip, rock cod	2008	74.5m and 67.8m n = 2 (51 trawls)	Observer-recorded abundance/species and rates of non-fatal and fatal interactions with both starboard and port warp cables	12 total species, primarily cape petrels, giant petrel species (northern/southern), black-browed albatross, southern royal albatross, kelp gulls, white-chinned petrels	*Type*: controlled *Method*: whole fish, offal *Position*: stern; both sides *Time*: not stated **Tested**	Tori lines (original TL-2004 design)	- 1052 strikes - 1 mortality	- 39.7 interactions/hour with warps - 239.1 interactions/ hour with tori lines	- 28% fewer warp strikes with TL-2008 tori lines - 81% of strikes occurred with tori line rather than warp, but with reduced severity/mortality
							Tori lines (modified TL-2008 design)		- 28.6 contacts/hour-warps - 71.7 contacts/hours-tori lines	

Reference	Fishery	Year	Vessel class, # of vessels	Observation method	Observed seabird species	Discharge management*	Mitigation method	Seabird counts or mortalities	Warp contact rate	Effectiveness of mitigation method
Tamini et al. (2015)	Falkland Islands Argentine hake	2008-2010	67.8m n= 2 (389 tows)	Observer-recorded frequency of occurrence/species and rates of non-fatal and fatal interactions with both starboard and port warp cables	17 species, primarily black-browed albatross, southern giant petrel, northern giant petrel, cape petrel	*Type*: not stated/controlled *Method*: not stated *Position*: offside, both sides *Time*: not stated **Not tested**	Tori lines with buoy	- Estimated 19090 killed + injured/year (4 primary species) - 3115 strikes - 36 mortalities (0.15 per hour) 0.33 dead + injured/hour	1.787 warp strikes/hour	- 4.01 warp strikes/hour (all mitigation devices) Significant reduction in warp strikes with mitigation
							Tori lines with *Tamini Tabla* towed device		1.425 warp strikes/hour	
							Control (none)		33.59 warp strikes/hour	
Cleal et al. (2012)	New Zealand Hoki fishery	2012	105m n = 1	Observer-recorded rates of non-fatal and fatal interactions with warp cables and a qualitative assessment	Large species, including albatrosses and giant petrels, and small species, not reported	*Type*: controlled *Method*: whole fish, offal, minced, sump *Position*: offside, stern; both sides *Time*: intermittent, continuous **Tested**	Tori lines (multiple designs)	Not reported	Not reported	Kraton streamers, 3m spacing, 40m backbone, 360mm trawl float performed the best
							2-boom bird baffler			
							4-boom bird baffler			
Kuepfer (2017)	Falkland Islands Finfish fishery	2015	75.4m n = 1 (8 tows)	Observer-recorded rates of non-fatal and fatal interactions with warp cables and mitigation devices	Undefined, but includes black-browed albatross and giant petrel species	*Type*: controlled *Method*: whole fish, offal *Position*: not stated *Time*: during towing; continuous, intermittent **Tested**	Warp deflector: pinkie buoy	Estimated 50-175 live birds within 40m stern (mortalities not reported)	4-16 interactions/hour	In situ trial abandoned due to significant practical and safety issues; not effective
							Tori lines (control)			

Table 3. The type of warp strike mitigation device tested in each of the reviewed sources. Fisheries in red are specific to New Zealand. Small vessel classes are <28m and large vessel classes are ≥28m. See footnote for colour key of the vessels.

Reference	Fishery	Vessel class (# of vessels)	Tori lines	Bird baffler	Warp scarer	Warp deflector: pinkie buoy	Warp deflector: plastic cones	Water sprayer	Lasers
González-Zevallos et al. (2007)	ARG hake	Small (3)					50-100%		
Pierre et al. (2014)	AUS (SESSF)	Small (9)			Inconclusive	50-100% / 0-50%			
Koopman et al. (2018)	AUS	Small (2)		50-100% + pinkie buoy		Inconclusive		50-100% + pinkie buoy	
Parker and Rexer-Huber (2019)	NZ	Small, large (33)	0-50%	0-50%					
Sullivan et al. (2006)	FLK finfish	Large (1)	50-100%	Inconclusive	50-100%				
Middleton and Abraham (2007)	NZ squid	Large (18)	0-50%	Inconclusive / 0-50%	0-50%				
Abraham & Thompson (2009)	NZ squid, hoki	Large	50-100%	Inconclusive	Inconclusive				
Melvin et al. (2011)	USA pollock	Large (2)	50-100%	0-50%					
Cleal et al. (2012)	NZ hoki	Large (1)	Not reported	Not reported					
Snell et al. (2012)	FLK finfish	Large (2)	0-50%						
Maree et al. (2014)	SA hake	Large (19)	50-100%						
Tamini et al. (2015)	FLK hake	Large (2)	50-100%						
Melvin et al. (2016)	USA hake	Large (1)							Inconclusive
Kuepfer (2017)	FLK finfish	Large (1)	Not reported		Inconclusive				

50-100% reduction in observed warp strike/captures
0-50% reduction in observed warp strike/captures
Inconclusive/no significant effect
Not reported/unknown

3.1.1 Tori lines

Tori lines, or bird scaring lines, are often used to deter seabirds from the area behind the vessel where warp strike occurs. Deployed after shooting and retrieved before hauling, the tori lines, which are fixed to the stern of the vessel, run parallel to the outside of the warp cables. They are comprised of rope that has long streamers attached at specific intervals and a buoy or similar weight, that acts as drag on the seaward end (Table 1, Figure 2). Tori lines are best practice mitigation on trawl vessels ≥28 m (DOC & Fisheries NZ, 2019b). For trawl vessels <28m, 10% of observed fishing events (5% of all tows) used tori lines to mitigate warp strike between 2013 and 2017 (Parker & Rexer-Huber, 2019).

Most trials of tori lines have occurred on vessels ≥28 m in New Zealand (Middleton & Abraham, 2007, 2007), the Falkland Islands (Snell et al., 2012; Sullivan et al., 2006; Tamini et al., 2015), and the US (Melvin et al., 2011). All the reviewed studies found tori line use significantly reduced incidental seabird mortality (see Table 2 for capture rates). For instance, warp strike reductions ranged from 5-20% in the New Zealand squid fishery in 2006 and 73–95% in South Africa, although this study is based on 4% observer coverage on a small subset of the entire deepwater trawl fleet (Maree et al., 2014). This low observer coverage is a common problem with warp mitigation studies since most strikes are likely not observed.

Only one study discussed tori lines deployed on vessels <28m in New Zealand, although there have not been any systematic trials of tori lines on inshore fleets (Parker & Rexer-Huber, 2019). Tori lines reduced warp strike mortalities by about 18%, although bafflers were the most effective on small vessels (Parker & Rexer-Huber, 2019). Since there are conflicting results on reductions in warp strike rate when tori lines versus bird bafflers are used (Table 2), both are typically recommended as mitigation methods.

An experimental study by Cleal et al. (2012) qualitatively tested tori line material, backbone configurations, dropper lengths, and terminal objects to determine the best design for vessels ≥28m at reducing seabird bycatch on offshore trawls. Tori line efficacy can be impacted by block height, streamer placement, streamer material, colour, height of line attachment to the vessel, line length, and vessel speed. For instance, semi-flexible streamers are preferable to flexible tubing and have been shown to reduce capture rates by 28% (Snell et al., 2012). Also, streamers cannot be placed too close to the warp for risk of gear entanglement (Parker &

Rexer-Huber, 2019; Snell et al., 2012). Moreover, a properly weighted drag object, such as a 7-8kg trawl float of plastic cone, must be used. The tori line must have a correct backbone length for the vessel size and tow point height to maintain proper tension (Deepwater Group Ltd., 2018). See Appendix Figure 2-2 for the recommended design of paired tori lines on deep-sea trawlers, which could possibly be adapted for small vessels. Tori line recommendations from ACAP suggest that streamers should be placed at a maximum of 5m intervals and that there should be 5m of backbone length per every 1m of block heigh, with a with a 1.2kg weighted terminal object (ACAP, 2021b).

Limitations such as rough seas, strong crosswinds, and vessel maneuvering also make tori lines less effective at reducing seabird captures (Snell et al., 2012). The practicality and safety when deploying and retrieving tori lines are dependent on the design and weather (Snell et al., 2012). Furthermore, the lines themselves can be a source of incidental non-target catch mortalities (Middleton & Abraham, 2007). Tori lines may also be less effective on small trawlers since the warp cables are generally further outboard of the hull compared to large vessels; tori lines will not cover the entire danger zone. It has been suggested that seabirds can strike or become entangled with the tori lines, especially when there is excess tori line in the water, but this issue has not been fully reviewed (Parker, 2017a). Further testing is required on device design/material, particularly on vessels <28m and methods to reduce seabird entanglement in tori lines (ACAP, 2021b).

Recommendation: further testing of tori lines specifically on coastal trawl vessels and the continued use of tori lines as approved mitigation devices.

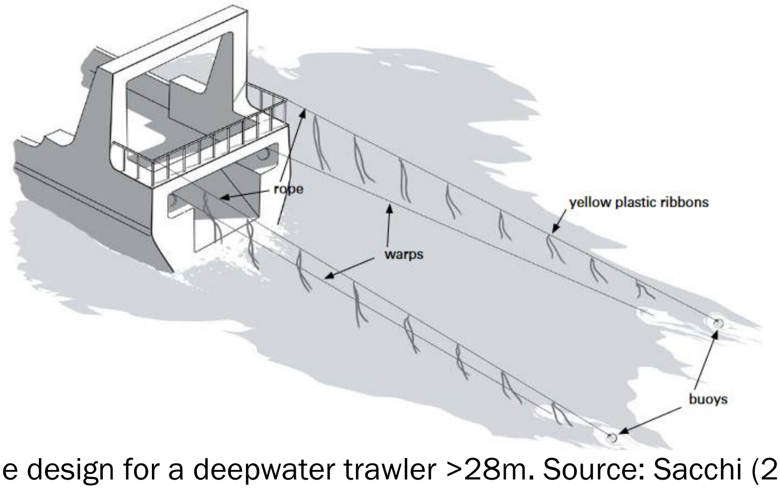

Figure 2. Tori line design for a deepwater trawler >28m. Source: Sacchi (2021). Attachment points may differ for coastal trawlers <28m. For instance, warp blocks could be positioned on the stern of the vessel or on booms extending outside the vessel.

3.1.2 Bird baffler

Bird bafflers (e.g., Brady Baffler first developed in New Zealand) are a series of ropes, cones, and high visibility streamers hanging on booms that extend behind and to the side of both the starboard and port stern quarter (Table 1, Figure 3). There are several designs of the bird baffler that are reported in the inshore trawl fleet Electronic Reporting System (ERS), distinguished by the number of booms and the setup of the device (e.g., a four-boom baffler, two-boom perpendicular baffler, full veil/curtain baffler) (Jones et al., 2021).

Several studies have looked at the effectiveness of bafflers on trawlers ≥28m, particularly in the Falkland Islands and New Zealand with mixed results (Table 2, Table 3). When bafflers were studied in the Falkland Islands in 2003, the difference in strike rate was insignificant (42.95 warp strikes/hour) compared to times when no mitigation was used (55.78 strikes/hour; Sullivan et al., 2006). In New Zealand, there was a higher warp strike rate when a baffler was used in the squid fishery (Middleton & Abraham, 2007) and a slight improvement to capture rates in the hoki and squid fisheries between 2004-2007 (Abraham & Thompson, 2009). There is high variability in strike rate, depending largely on waste management practices, geographic location, and vessel design.

Bafflers are more commonly used on coastal vessels <28m, due to their ease of use and effectiveness in poor weather conditions and are often in conjunction with tori lines. Between 42% and 45% (Parker & Rexer-Huber, 2019) of observed tows in New Zealand from 2013-2017 (5% of all inshore tows) used bafflers to mitigate seabird warp strike. Only one study to date has trialed the effectiveness of bafflers on these coastal trawlers. In Southeast Australia, there were 83.7% fewer warp strikes when a baffler was deployed compared with no mitigation device (Koopman et al., 2018). Parker and Rexer-Huber (2019) reported a capture rate of 0.88 captures/100 tows with a baffler compared to 1.42 captures/100 tows with tori lines and 1.74 captures/100 tows with no mitigation on trawls <28m. Rexer-Huber and Parker (2019) also found bafflers were more effective at reducing interaction rates on small trawlers when reviewing data from NZ inshore fisheries, although bafflers have not been directly tested with the intent of measuring efficacy of the mitigation device.

While bird bafflers do not need to be retrieved prior to net hauling since they can be deployed at the beginning of a fishing trip and retrieved at the end of a fishing trip, they are more expensive than tori lines and can be more difficult to install and maintain. This is particularly important for small vessels where deck space is limited for additional infrastructures. The different designs and deployment methods of bird bafflers means that boom and dropper lengths, positioning, height of the warp block, and spacing of droppers along the boom must be optimal to ensure effectiveness (Bull, 2007a; Parker, 2017a). No baffler will protect the entire warp danger zone, with the warp-water interface typically extending past the droppers. Initial construction of a baffler is costly and highly dependent on vessel design, so it is recommended that testing of bafflers of various designs should occur on vessels with bafflers already installed.

Three prototype bafflers with 2- or 4-booms were trialed in New Zealand on a large trawler 105m LOA (see Cleal et al. (2012) for detailed descriptions of the design and trial results). They found the use of the curtain baffler (Figure 4), which completely encloses the area around the warps, may increase efficacy compared to other baffler designs. However, a modified baffler system using part of the curtain baffler design is more feasible considering the high cost of installing the curtain baffler. Efficacy of these devices at reducing warp strike, however, was not quantified. The Australia government also provides guidelines for baffler design and construction (Appendix Table 2-1).

There is insufficient evidence to draw a firm conclusion on the effectiveness of bafflers, considering the contradictory results between large >28m vessels (5 studies/reviews, limited or no reduction in strike rate) and small <28m vessels (two studies/reviews, some reduction in strike rate). It is unclear what makes bafflers apparently more effective on smaller vessels, and additional studies are required due to the lack of data for small vessels. Bafflers are not recommended by ACAP since there is a lack of experimental testing on the full range of baffler design (ACAP, 2021b). However, considering their high rate of use on coastal trawlers, further testing is recommended where cost and space are both limiting factors.

Recommendation: further testing of bird bafflers specifically on coastal trawl vessels and the continued use of bird bafflers as approved mitigation devices.

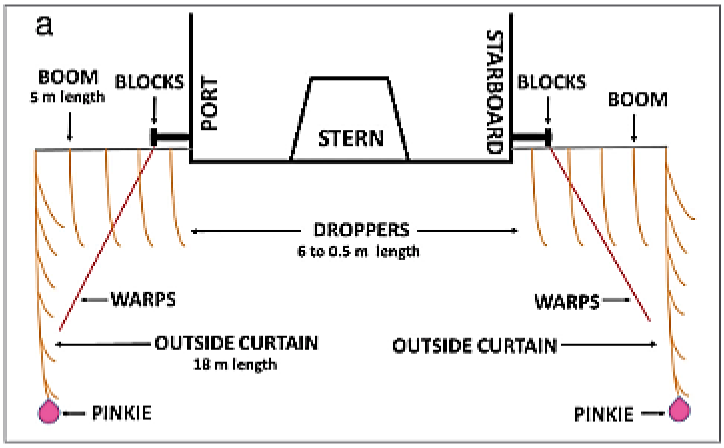

Figure 3. 2-boom bird baffler approved for use on a <28m vessel in the in the Australian Southern and Eastern Scalefish and Shark Fishery. Source: Koopman et al. (2018).

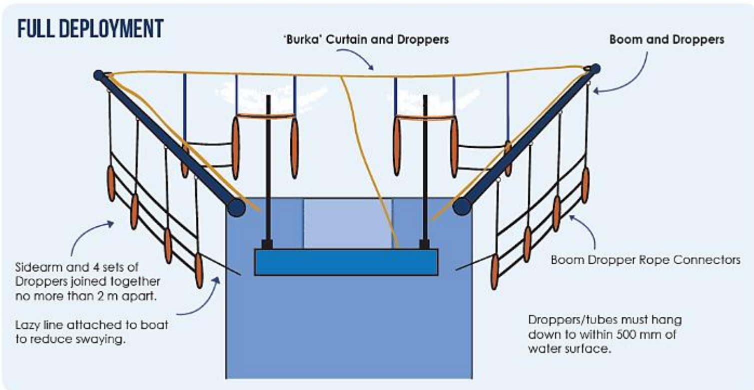

Figure 4. The curtain baffler, a prototype tested by Cleal & Pierre (2016).

3.1.3 Warp scarers

Warp scarers consist of rings and rollers joined by netting that surround the warp cables and have reflective tape hanging from the rings (Sullivan et al., 2006; Weimerskirch et al., 2000). They are connected to the stern via a lazy wire and require setting and retrieving after net shooting and before hauling (Figure 5). Trawl vessels <28m do not use warp scarers, and although legal, are not currently used by any vessel ≥28 either due to safety concerns or limited efficacy at reducing warp strike (Parker, 2017b).

There was no significant difference in warp strike rates when a bird scarer was used in Australia's Southern and Eastern Scalefish and Shark Fishery (SESSF; Pierre, Gerner, et al., 2014) and in New Zealand's squid and hoki fisheries (Table 2; Abraham & Thompson, 2009; Middleton & Abraham, 2007). This method somewhat reduced small seabird strikes in the

Falkland Islands (Sullivan et al., 2006). However, warp scarers are often impractical, because they tangle easily with the warps themselves and proper design, setup, and maintenance of the device is required. They also pose considerable safety risks when being deployed/retrieved, since they are attached to the warp cables by the crew after net setting from a dangerous position aft of the vessel. Warp scarers are not recommended by ACAP due to insufficient evidence and concerns about practicality and safety (ACAP, 2021b).

Recommendation: no further testing of warp scarers on coastal trawl vessels.

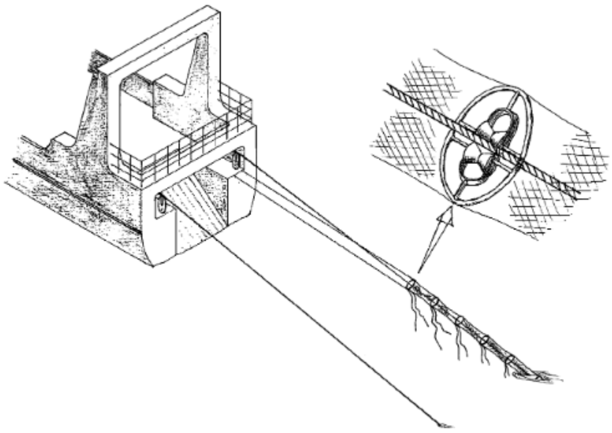

Figure 5. Example warp scarer design on a single cable. Source: Sullivan et al. (2006).

3.1.4 Warp deflectors

Warp deflectors are any item attached to, or hanging from, the trawl warp cable (e.g., Figure 6). Fishers use many kinds of deflectors, both proprietary such as the pinkie buoy (Kuepfer, 2017) or improvised such as plastic cones (González-Zevallos et al., 2007), rollers, or tubs. In New Zealand, warp deflectors are used on about 75% of coastal trawlers due to their feasibility and cost-effectiveness; deflectors are the easier mitigation option to employ. They can also be deployed if a seabird capture occurs or if conditions require a mitigation device (J. Cleal, *MIT2022-07A Inshore Trawl Warp Mitigation Workshop*, 2023).

Findings from an initial trial of pinkie buoys on coastal trawlers 18-26 m LOA in the Australian SESSF suggested that this method was more effective at reducing heavy warp interactions of primarily large seabirds (Table 3; Pierre, Gerner, et al., 2014); however, a follow-up trial in the Falkland Islands in 2015 was abandoned due to significant safety and practicality issues (Table 2; Kuepfer, 2017). Effective positioning of the pinkie is difficult to maintain, and regular re-adjustment is not practical. Entanglement between warp cable, pinkie, and pinkie retrieval lines occurred in almost all deployments, and there were significant safety concerns for crew (Kuepfer, 2017).

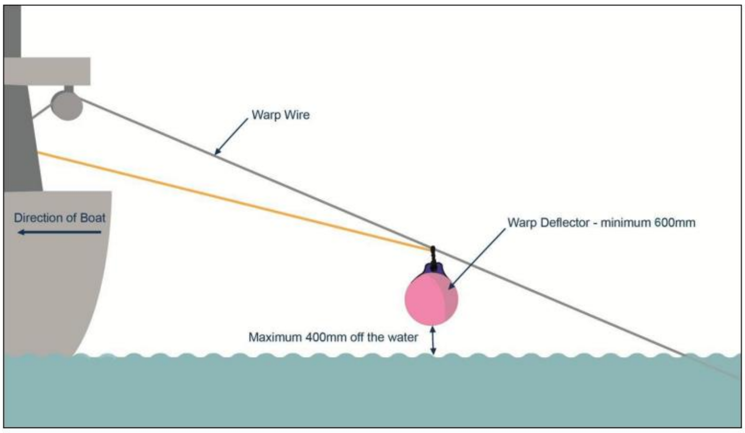

Figure 6. Correct position and design of the warp deflector, or pinkie system. Source: Pierre et al. (2014).

Plastic cones were trialled in on vessels <31m in the Argentine hake fishery in 2004 (Table 2; González-Zevallos et al., 2007). Traffic cones were slid over both warps using a lazy line after shooting the net and prior to hauling and held in place at the water interface (Figure 7). They were successful at reducing warp-seabird interactions by 89%. There were no warp strike mortalities when the device was used compared to 11 mortalities without mitigation (González-Zevallos et al., 2007). To our knowledge, this is the only such trial of cones, although Parker (2017a) reports that cones are used by some coastal trawlers in New Zealand; further information about how many vessels and the design of the deflector is unknown. While ACAP acknowledges cones may be appropriate for small vessels, they do not recommend them or pinkie buoys as mitigation devices (ACAP, 2021b). More research is warranted to determine if deflectors consistently reduce warp strike in New Zealand.

Recommendation: further testing of both pinkie buoy and plastic cone warp deflectors to determine efficacy as a warp strike mitigation device for coastal trawl fisheries.

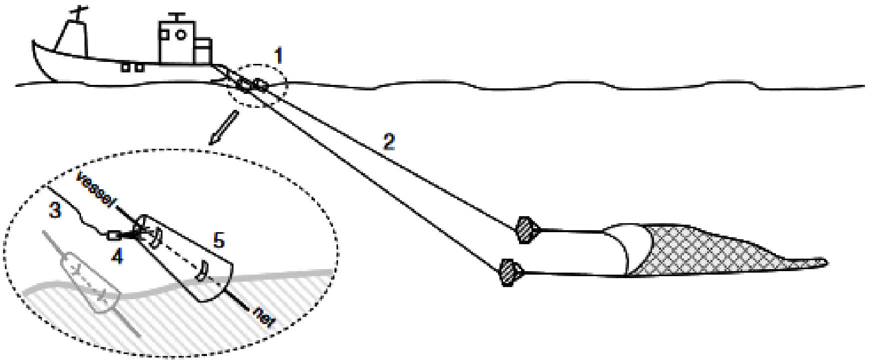

Figure 7. Plastic cone mitigation device. (1) cone, (2) warp cables, (3) lazy line, (4) aluminum hook, and (5) fastener. Source: González-Zevallos et al. (2007).

3.1.5 Water sprayer

A water sprayer was developed by the Australian Fisheries Management Authority and first tested on a 20m trawl vessel in southeast Australia fisheries in 2014-2015 (Koopman et al., 2018). The best design of the sprayer consisted of two 4m booms extending from the stern of the vessel on the outside of the warp cables, with two additional 4m arms positioned perpendicular and 2m apart along the booms (Figure 8, Appendix Table 2-1). As seawater is pumped through nozzles on these arms, the water creates a barrier or exclusion zone around the warp cables. There was a 58.9% reduction in warp contacts when the sprayer was used (Koopman et al., 2018). The National Plan of Action for Minimising Incidental Catch of Seabirds in Australian Capture Fisheries (Department of Agriculture and Water Resources, 2018) reported a 92% reduction in warp-seabird interactions during trials by two Australian fishing associations.

Besides its apparent effectiveness at reducing warp strike, the sprayer does not interfere or depend on trawl gear to operate and can be set at the beginning of a fishing trip and left in position throughout. However, sprayers are expensive to install and may not be economical for small vessels. They also are unlikely to be implemented by fishers, because the displacement of water due to wind and the speed/movement of the vessel results in mist that does not always surround the warps and that makes the crew and deck wet, thus making sprayers an ineffective nuisance and safety concern.

Recommendation: no further testing of water sprayers.

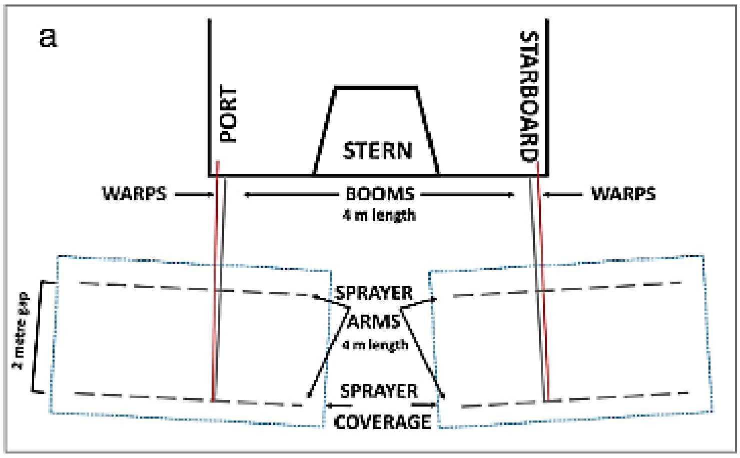

Figure 8. Design of the water sprayer mitigation device on a <28m vessel (see Appendix Table 2-1 for design link. Source: Koopman et al. (2018).

3.1.6 Lasers

Two different stern-mounted lasers, the SeaBird Saver and the Dazzler, were tested on a single large vessel in the Pacific hake fishery in Oregon, USA (Melvin et al., 2016), but information on warp strike rates and mortalities were not reported (hence, not included in Table 2). Rather, they found little response from seabirds to the laser during daylight hours with some aversion response from some species at low and high vessel speeds. The benefits of lasers are the relative ease of use and reduced space requirements; however, little is known about the effects of the lasers on seabirds, especially when interacting directly with the light. Initial studies on the effects of lasers on house sparrows suggest lasers cause eye injuries and altered foraging behaviour (ACAP, 2019). The impacts on seabirds are unknown, particularly if and how lasers cause injury (Parker, 2017a). Lasers are not recommended (ACAP, 2021b) and need more testing to determine effectiveness while not increasing risk of harm and injury to seabirds (ACAP, 2019; Melvin et al., 2016; Sacchi, 2021).

Recommendation: no further testing/use of lasers as mitigation devices due to lack of research, limited effectiveness, and potential negative effects to seabirds.

3.1.7 Discharge management

Seabirds associate fishing vessels with food due to the dumping of offal and bycatch species (Weimerskirch et al., 2000). Seabirds are at a higher risk of warp strike entanglement during discharge from the stern or sides of the vessel (Sullivan et al., 2006). Discharge management practices involve controlling the time of discharge (e.g., discharge during setting, hauling, shooting, towing), the quantity and frequency of discharging (e.g., batch at intervals, continuous, holding), the treatment of offal (e.g., minced, mealed, whole), and the position of discharge (e.g., port, stern, offside; Rexer-Huber & Parker, 2019).

Controlled discharging is frequently conducted on small trawl vessels. Operational procedures and mitigation standards for protected species management in New Zealand does not support discharging before/during shooting and hauling and advocates for batch discarding offal while towing and while warps are in the water (FINZ, 2018; FINZ and Deepwater Group Ltd., 2021). Retention, mealing, batching, and mincing (in order) are recommended offal management measures (ACAP, 2021b) to reduce seabird bycatch in trawl fisheries.

Most of the reviewed studies indicated a higher seabird interaction rate during discharging (e.g., Abraham et al., 2009; Abraham & Thompson, 2009; Maree et al., 2014; Middleton & Abraham, 2007). The discharge location and treatment of offal can significantly impact capture rates. For instance, there were fewer seabird strikes in the New Zealand hoki fishery when mincing offal compared to mealing or discarding whole fish (Table 2; Abraham et al., 2009). Capture rates were also reduced on coastal trawlers in 2013-2016 batch discharging during towing only plus tori line deployment was employed (Rexer-Huber & Parker, 2019).

Recommendation: use effective and suitable discharge management in conjunction with other mitigation methods.

3.1.8 Gear design and fishing practices

The design and material of mitigation devices and trawl gear impacts warp strike and mortality rates. For instance, Parker and Rexer-Huber (2019) suggested that fishing depth could change seabird interaction rates with warps because of the angle of warps relative to the water surface. Furthermore, some vessels use warps made of a composite material called Dyneema®, which are brightly coloured and do not have warp splices; however, no studies on seabird interaction have been conducted using Dyneema warps (Parker & Rexer-Huber, 2019). During the workshop, experts agreed that the effectiveness of Dyneema warps should be systematically trialed, especially the color of the material (e.g., red may be more visible to seabirds).

Cleaning the net between tows to remove any remaining fish and using suitable deck lighting that ‘does not unnecessarily attract or disorient seabirds’ is also best practice currently encouraged in coastal trawl fisheries (DOC & Fisheries NZ, 2019a). Changing fishing practices, such as night fishing, may also reduce warp strike mortalities since there are less seabirds on and in the water (Bull, 2007a); however, birds may also have more difficulty seeing warps which could increase strike rate depending on the number of birds present around the vessel. No systematic trial of night setting has been done in trawl fisheries to assess its economy or effectiveness on bycatch reduction.

3.2 Seabird captures data analysis

Based on captures recorded in the Protected Species Captures Database v6, mitigation devices were used by trawl vessels <28m on 42% (range: 32.3%-56.4%) of all observed tows between 2015 and 2020 (Table 4). The number of seabird captures due to warp strike and other methods during tows without mitigation appears to be comparable or higher than tows with mitigation devices; however, the low observed capture rate for events without mitigation devices is somewhat exaggerated due to the very high fishing effort. Additionally, tows with ‘no mitigation’ may also include events where mitigation was not reported or inadvertent errors in the PSCDB, rather than events where mitigation was not used.

Warp captures represented 25.5% of the total incidental captures of seabirds from 2015-2020 on observed trawlers <28m. Mitigation devices including tori line and lazy line captures caused 8.7% of captures, and 65.7% of captures were due to other causes (including net captures). Bird bafflers were used most frequently as mitigation devices, and vessels using tori lines had the lowest capture rates (0.29 seabirds/100 tows; Table 5), although seven additional captures occurred due to strikes/entanglement with the tori lines themselves.

Table 4. Fishing effort per year (number of observed tows) of trawl vessels <28m according to each type of mitigation device. Some vessels employed multiple mitigation devices. Total observed effort across all years is presented in the last column, and total effort per year across all mitigation devices is presented in the last row in bold. The total effort across all years is shown in red. The percentage of tows during which a mitigation device was used was calculated as the sum of observed effort for all mitigation devices / total observed effort*100.

Mitigation method	**2015/2016**	**2016/2017**	**2017/2018**	**2018/2019**	**2019/2020**	**2015-2020**
No mitigation	1271	2583	1252	994	962	7062
Tori lines	1	401	121	245	283	1051
Bird baffler	650	612	179	135	445	2021
Bird scarer	72	23	168	48	99	410
Other	141	92	81	115	158	587
Tori lines + baffler	0	1	285	134	90	510
Tori lines + other	65	0	0	5	9	79
Tori lines + scarer	0	5	4	0	0	9
Baffler + other	0	97	0	69	134	300
Tori lines + baffler + other	0	0	0	118	24	142
Tori lines + baffler + scarer + other	0	0	0	1	0	1
Total observed effort (tows)	**2200**	**3814**	**2090**	**1864**	**2204**	**12174**
Mitigation device rate (%)	**42.2**	**32.3**	**40.1**	**46.7**	**56.4**	**42.0**

Table 5. The number of observed seabird captures due to warp strike, mitigation device strike/entanglement, and other capture methods including net captures on trawl vessels <28m between 2015 and 2020. The capture rate, or the total number of bird captures/(total number of observed tows/100), was calculated for each mitigation method across all years and capture method as the sum of captures/(number of observed tows/100).

	Warp captures							*Mitigation device captures*							*Other captures*						
	Number of captures					**Total**	**Rate**	**Number of captures**					**Total**	**Rate**	**Number of captures**					**Total**	**Rate**
Mitigation method	2015/ 2016	2016/ 2017	2017/ 2018	2018/ 2019	2019/ 2020	All	All	2015/ 2016	2016/ 2017	2017/ 2018	2018/ 2019	2019/ 2020	All	All	2015/ 2016	2016/ 2017	2017/ 2018	2018/ 2019	2019/ 2020	All	All
No mitigation	3	-	1	1	1	6	0.08	-	-	-	-	-	-	-	19	8	3	8	-	38	0.54
Tori lines	-	-	-	1	2	3	0.29	-	1	5	-	1	7	0.67	-	6	1	3	3	13	1.24
Bird baffler	1	5	-	1	-	7	0.35	-	-	-	-	-	-	-	1	3	1	2	-	7	0.35
Bird scarer	1	-	3	-	6	10	2.44	-	-	-	-	1	1	0.24	1	3	5	-	-	9	1.96
Other	-	-	-	2	-	2	0.34	-	-	-	-	-	-	-	5	1	-	-	-	6	1.02
Tori lines + baffler	-	-	1	1	-	2	0.39	-	-	4	-	-	4	0.78	-	-	7	1	2	10	1.96
Tori lines + other	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tori lines + scarer	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1	11.11
Bird baffler + other	-	-	-	-	5	5	1.66	-	-	-	-	-	-	-	-	4	-	-	-	4	1.33
Tori lines + baffler + other	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	2	1.41
Tori lines + baffler + scarer + other	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total captures	**5**	**5**	**5**	**6**	**14**	**35**	**0.59**	**0**	**1**	**9**	**0**	**2**	**12**	**0.20**	**26**	**26**	**17**	**16**	**5**	**90**	**1.48**

3.3 At-sea trials

The literature review and subsequent discussions at an invited expert workshop identified several warp strike mitigation devices that are recommended for an at-sea trial of warp mitigation devices on trawlers <28m in New Zealand: (1) tori lines, (2) bird bafflers, (3) pinkie buoys, and (4) plastic cones. Approximately $70,000 has been allocated to these trials (I. Debski, *MIT2022-07A Inshore Trawl Warp Mitigation Workshop*, 2023). The following sections discuss recommendations for study design and data collection.

Since certain mitigation devices may be suitable to specific vessel configurations, classes of trawlers <28m LOA need to be distinguished (following those described in Cleal (2023); Table 6). Highest risk, larger *Tier 1* vessels greater than 15m LOA operate in areas with high numbers of albatross, and frequently discharge into warp path. Tier 1 vessels contributed 75.8% of total fishing effort in 2020/2021 fishing year (Table 6). Recommended mitigation includes discard retention or batching and mitigation device use particularly on the discharge side of the warp danger zone (Cleal, 2023). *Tier 2* vessels, 12-15m LOA, also operate in albatross foraging areas but with less regularity and occasionally have higher volumes of discharge. Tier 2 vessels contributed 16.5% of total fishing effort in 2020/2021 fishing year (Table 6). Similar mitigation methods as the tier 1 vessels are recommended, although more options for devices may be available due to vessel size and configuration. Lowest risk *Tier 3* vessels are <12m LOA, operate closer to shore where seabird abundance is lower, and retain discards or discharge away from the warps (Cleal, 2023). Tier 3 vessels contributed 7.6% of total fishing effort in 2020/2021 fishing year (Table 6). Where possible, tier 1 vessels (or alternatively tier 2) should be prioritised for trials.

3.3.1 Study design

It is recommended that the main objective of the at-sea trial be developing and refining best practice to mitigate seabird strikes and warp captures in the coastal trawl fleet on vessels <28m. Best practices should be specific and inclusive of different vessel sizes/structures but not restrictive and be used to improve Mitigation Standards, inform industry or the scientific community, and brief vessel operators and liaison officers on mitigation effectiveness.

Table 6. A matrix of coastal trawler vessel classes based on tiers and strike risks described in Cleal (2023), and the workshop-recommended warp mitigation methods that may be suitable for at-sea trial and/or currently in use on vessels. Fishing effort is provided for the 2020/2021 fishing year, which is the total number of trawls per vessel class. The percentage represents the proportion of fishing effort out of total effort. See Appendix Table 1-2 for fishing effort by year and area FMA per vessel class.

Vessel class	**Tier 1**	**Tier 2**	**Tier 3**
Vessel size	≥ 50ft/15m	40-50ft/12-15m	30-40ft/9-12m
2020/2021 fishing effort (% total)*	31753 (75.8%)	6922 (16.5%)	3198 (7.6%)
Seabird warp strike risk	**High**	**Moderate**	**Low**
Tori lines	✓	✓	✓ (pole)
Bird baffler	✓	✓	X
Warp deflector: pinkie buoy	X	✓	✓
Warp deflector: plastic cone	X	✓	✓
Waste discharge	✓	✓	No discharge

* Fishing effort = number of trawls; % is out of total fishing effort for all vessel classes

The trial could statistically compare capture rates and bird abundance between different mitigation devices rather than testing each device against control events where no mitigation is used. Rigorous statistical analyses of capture rates could be difficult, since there are many confounding variables like weather, currents, vessel speed, and vessel construction (R. Wells, *MIT2022-07A Inshore Trawl Warp Mitigation Workshop*, 2023). Although sample size has not been calculated since trial scope has yet to be defined, a statistically rigorous sample size would likely be prohibitively large, in the order of hundreds or thousands of observed tows. Moreover, observing a warp strike on coastal vessels may be infrequent (compared to observed effort), and the trial would have to be over multiple years. Alternatively, a more subjective study design could be considered if a statistical approach is deemed unsuitable/not possible based on the data collection methods and results. For instance, a safer environment for seabirds could be demonstrated by comparing bird abundance within and outside of the "danger zone" as a proxy. Device longevity, feasibility, cost, and coverage of the warp danger zone could also be analysed. Designing or developing new devices is out of scope, but recommendations may be made for future development.

1. There are general key steps to designing an at-sea trials of seabird warp mitigation devices and general design principles that should be considered (Table 7).
2. Determine a final list of mitigation devices to include in the trial.
3. Decide which data collection approach to implement.
4. Collate an inventory of vessels based in part on fishery, home port, target species,

vessel class, current installed mitigation devices, and vessel construction.

5. Approach vessel owners and operators to determine willingness to participate, which includes allowing an observer onboard and, if needed, modifying fishing gear/practices to fulfil study aims and data collection methods.
6. Determine target sample size of vessels and number of hauls/vessels to observe, dependent on trial scope, available resources, and expected number of captures. A relatively large sample size is likely required due to low observed capture rates.
7. Allocate trial mitigation devices to specific vessels and/or tows, within the practical constraints of deploying each mitigation method. Where possible, mitigation devices already used by vessels should be incorporated into the experimental design. Example: individually and/or simultaneously trial devices on one vessel class, fishing in high-risk areas like FMA 3, 5, or 7, targeting species like ghost fish or ling, and discharging offal.

Table 7. General experimental design considerations that are recommended for at-sea data collection of the effectiveness of warp mitigation devices.

Principle	Description
Confirmation of trial scope	- What is the spatial and temporal extent of the trial? - What fishery and where (all inshore fisheries or restricted to specific inshore fisheries/locations)? - Are there practical limitations due to vessel size such that some vessel types are outside the scope of the trial?
Resource constraints	- What resources are realistically available for the trial? Including: budget, observers, participant vessels/stakeholders.
Vessel matching	- Based on an attributes list (e.g., vessel size, gear type, skipper experience, expected fishing ground, trip timing, current mitigation), 'similar' vessels could be identified and then randomly assigned to different mitigation option groups. - Types of vessels in each group are as similar as possible, with mitigation the primary difference between groups.
Stratification	- Control spatial or vessel-related sources of variation, with suitable data collection protocols applied within each stratum.
Randomisation	- To determine which vessels are assigned to each mitigation option group, which mitigation devices are used, and when (where possible). - Random deployed (or not) on a tow-by-tow or trip-by-trip basis for devices that are more permanent.
Mitigation option groups	- 'Treatment' groups should be clearly identified based on the mitigation devices that are to be trialed, where groups may be defined based on single, or combinations, of devices.
Observation method	- Is the vessel large enough to accommodate an observer? - Is >1 scientific observer required to accurately record warp captures? - Can other methods be used (e.g., electronic monitoring, cameras)?

Warp capture rates vary with a range of spatial, temporal, environmental, and vessel-specific factors; for instance, fishing location, target species, differences in the position/height of the trawl block, the location where the trawl warp enters the water, trawl depth, the size of the warp danger-zone, and the waste discharge point. From a statistical perspective, it is strongly recommended that the study is designed to account for, or otherwise limit, these sources of variation as much as practicalities allow. For instance, a single vessel fishing in a specific location fishing for a specific target species could trial multiple devices and/or designs rather than testing these devices on different vessels. Likewise, the method, frequency, and location of waste discharge should be consistent across vessels and mitigation devices due to the large impact effective discharge management has on reducing warp strike (J. Cleal, *MIT2022-07A Inshore Trawl Warp Mitigation Workshop*, 2023). Considering differences in vessel construction across vessel size classes, recommendations for the inshore fleet should allow some flexibility in device design/structure rather than proving one overall best practice.

The design of the mitigation device(s) should be described in full detail, especially positioning, spacing, material, color, measurements of structures like booms and droppers, condition, and states of repair (Pierre et al., 2015). Designs should be made as consistent as possible across vessels, unless trialling different device configurations. Details on the fishing gear, catch, mitigation method, and bycatch are also needed for accurate data analysis. Data collection and analysis methods should also be specified, particularly temporal, spatial, physical, and operational information (Table 8), for collection during seabird counts and warp strike observations (discussed in more detail in sections 3.3.2.1 and 3.3.2.2, respectively).

Feedback should be sought from fishers at all milestones of the project to refine device design based on utilisation, practicality, and the likely employment of devices by other crew. Fishers may also be a source of potentially new or modified designs based on their experience. The results of all trials, particularly where best practice is concerned, should be communicated with relevant stakeholders, particularly those who participated in the study in some compacity. The successfulness of an at-sea trial depends on the engagement, cooperation, and participation of fisheries and vessel crews.

Table 8. Data to be collected during trials of mitigation devices on trawl vessels <28m for each tow. Bold variables are critical for assessing warp strike. Source: ACAP (2021c).

Category	Variables
Temporal	**Date gear deployed**
	Start time of trawl shoot
	Start and end times of trawl turns
	Start time of haul
	End time of haul
Spatial	**Latitude at trawl shoot**
	Longitude at trawl shoot
	Latitude at end of haul
	Longitude at end of haul
	Latitude at trawl turns
	Longitude at trawl turns
Physical and Environmental	**Sea state (Beaufort Scale)**
	Moon phase
	Wind strength and direction
	Depth fished (average/target depth)
	Cloud cover (important for night setting)
Fishing operation	**Unique vessel identifier**
	Unique observer identifier
	Vessel length
	Tow speed (knots)
	Total number of trawl hours/tows (ideally both)
	Total number of trawl hours/tows (ideally both) observed
	Main discard species
	Target species[1]
Fishing gear	Headline height
	Door type and area
	Headline length/Wingspread
	Lengthener mesh
	Number of codends
	Sweep length
	Codend mesh
Catch	Total catch, actual or estimated (number and/or weight)
	Catch by species (number and/or weight)
Mitigation Measure	**Tori line used (yes/no)**
	Side of tori line deployment (port or starboard or both)
	Number of tori lines used
	Length of tori line (m)
	Aerial coverage (m), are warps and cables covered?
	Attachment height (m above water line)
	Number of streamers
	Distance between streamers
	Dumping of bait/offal (yes/no). Offal management? (e.g., retention, mealing, or batching).
	Deck lighting astern of the vessel (yes/no)
	Other mitigation measures used (provide details)
Bycatch information	**Species identification**
	Number of each species captured
	Type of interaction (entanglement/contact with warp)
	Disposition (dead/alive/injured)
	Description of condition/viability of animal upon release
Other	**Seabird abundance counts**
	Warp strike observations

1 – Target species may be derived in some programmes from the catch composition

3.3.2 Data collection

Commercial fishers must report certain data to Fisheries NZ. These data were originally collected on paper forms (pre-2019 for inshore fisheries). The following forms have been or are being used to collect protected seabird data, vessel, and effort information in coastal trawl fisheries (Pierre et al., 2015). Some of these forms can also be found in the mitigation standards to reduce seabird bycatch in small-vessel trawl fisheries (DOC & Fisheries NZ, 2019a) published by DOC and Fisheries NZ (marked with a * below).

- Trawl Catch Effort Logbook
- Trawl Gear Details Form
- Warp Scarer Details Form*
- Bird Baffler Details Form*
- Tori Line Details Form*
- Mitigation Assessment Warp Strike Form
- Mitigation Assessment Worksheet
- Protected Species Abundance Form
- Non-fish Bycatch Form
- Photographic Log
- Trawl Catch, Effort and Processing Returns (TCEPR) (before 2019, no data on mitigation)
- Trawl Catch Effort Returns (TCER) (before 2019, no data on mitigation)

Since 2019 (and 2017 for offshore vessels ≥28m), these data are reported through the ERS by inshore commercial fishing fleets (Jones et al., 2021). For trawling, the following reports are required via ERS (Fisheries New Zealand, 2021):

- Fish Catch Report
- Mitigation
- Non-Fish or Protected Fish Species Catch Report
- Processing report
- Disposal Report
- Landing Report

A combination of protocols and data collection forms should be used that conform to study objectives and design. Data collected by ERS should be supplemented by data collected by observers, either in paper or digital formats, to reduce the risk of data entry errors and standardise collected data. The paper forms or digital reports will need to be modified to collect additional data like exact device design for at-sea trials (e.g., Trawl, Warp Scarer, Bird Baffler, and Tori Line Details forms, Mitigation Assessment Warp Strike form). For example, data should be completed for every observation period since mitigation devices may move or change between tows. Pictures of the device prior, during, and after deployment should also be taken and later linked digitally to the fishing event.

In addition to the fundamental information that allows for protected species captures to be linked to vessel data (including fishing event information and effort), data specific to seabird abundance, warp strike rates, and mortality should be collected. It is recommended to follow protocols presented by DOC at the 3rd Meeting of the South Pacific Regional Fisheries Management Organisation Scientific Committee in 2015 (Ramm et al., 2015). They describe how, when, and what data should be collected on seabird abundance counts and seabird warp/monitoring cable strike observations with example data collection sheets (Appendix 3 and 4). Similar protocols are considered best practice by ACAP for protected species monitoring and data collection by electronic monitoring (ACAP, 2021a) and observers (ACAP, 2021c).

Protocols for collecting capture and abundance data on seabird-fisheries interactions have also been developed by the Australian Antarctic Division and the Australian Fisheries Management Authority (Wienecke & Robertson, 2002). Several other international studies have followed these protocols, mostly on vessels ≥28m (e.g., Sullivan et al., 2006). These protocols should be incorporated into the DOC/ACAP protocols as appropriate and modified for small vessels, particularly the length of cable observed, observation periods, location of the observer, and observed area size around the stern of the vessel. Contact, contact point, and fate codes should be maintained (Table 9). If possible, both warps should be observed to avoid missing seabird strikes and miscounting birds, although observations are more often made from one side of the vessel due to the single on-board observer (Sullivan et al., 2006).

Table 9. Example data recording codes for seabird contact with trawl fishing gear, reproduced from Wienecke et al. (2002) and Sullivan et al. (2006).

Age	
A	Adult
SA	Sub-adult
J	Juvenile
Contact code	
1	Bird on water, very light contact with vessel/gear
2	Bird on water, heavy contact with vessel/gear, part of bird dragged underwater
3	Bird flying, light contact with vessel/ gear, bird does not deviate from course
4	Bird flying, heavy contact with vessel/ gear, bird deviates from course and/or dragged underwater
5	Bird snagged on loose wire ends (e.g., splice ends)
6	Bird has high speed collision with vessel gear
7	Bird caught in net
8	Bird snagged on net while attempting to feed
9	Bird hauled on trawl door
Contact point	
1	Warp wire
2	Trawl doors
3	Backstops, brides, and sweeper
4	Net
5	Vessel
6	Paravanes (including towing wires)
7	Ropes on bird scaring device
8	Other
Fate	
1	No apparent damage
2	Possible minor injury
3	Possible major injury
4	Death
5	Unknown
6	Suspected death

There is also the potential to use on-board cameras that electronically monitor (EM) fishing activities on the vessel deck and report trip, tow, and catch information. On-board cameras are currently being installed on all trawl vessels <32m in length across New Zealand (see www.mpi.govt.nz/cameras). Considering the low observer coverage on coastal trawlers, on-board cameras could collect proxy data on seabird abundance and possibly seabird warp strikes by (1) using existing footage to verify, for example, warp strikes, mitigation use/design, timing, and general tow information or (2) incorporating the cameras into trial design to ensure that footage is taken of specific locations (e.g., warps). Fishers would need to be unaware of monitored trips, since cameras may change fisher behaviour and introduce another inadvertent type of mitigation option to the study.

Based on the delayed period for on-board camera roll-out for inshore trawl fisheries and the original purpose for the cameras to verify and improve reporting of catch data, GoPros installed on the warps may be a better alternative to monitor mitigation use and warp strike rates. Observations of warp strike could then be compared against camera footage as two sources of information about the same trip, with the potential to compare relative accuracy. Additionally, EM data may be supplemented with additional information about abundance and warp strike to streamline the process, reduce the amount of data collected by observers, and limit potential human errors during collections. The rate of cryptic/undetected mortality (Meyer, in prep.) should also be estimated in some way (e.g., Pierre, Richard, et al., 2014), since recent research into cryptic seabird mortality in demersal trawl fisheries by Parker et al. (2013) found at least 23% of total mortalities and sever injuries were not observed from the vessel.

3.3.2.1 Abundance

Seabird abundance should be recorded following the protocols outlined by Ramm et al. (2015), and subsequently by ACAP (2021c). A minimum of one count per day of birds attending to the vessel in a 100m arc astern of the vessel (Appendix 3). If possible, however, counts should occur (1) before deploying the net, (2) after the net is deployed, (3) during hauling, (4) after catch is released from the net onto the deck, and (5) during discharge (Koopman et al., 2018). Abundance should be determined as the total number of individuals observed and as an abundance class for the overall estimate of the number of individuals (e.g., A = 0-50, B = 50-100, C = 100-150, etc.). This will allow for both categorical and continuous values of abundance for future data analysis. Seabird species should be distinguished if possible. It may be suitable to photograph the bird aggregations to roughly verify counts and species.

3.3.2.2 Warp strike observations

Warp strike observations and counts by on-board observers should be recorded following the protocols outlined by Ramm et al. (2015) and ACAP (2021c; Appendix 4). Similar to counts, warp strike observations should occur (1) during deployment, (2) immediately after net deployment for 15 minutes, (3) immediately prior to net retrieval for 15 minutes, and (4) during net retrieval, if possible (Ramm et al., 2015). Instead of observing one warp on the side of the vessel where dumping is occurring or where there is higher likelihood of strike events, both warps should be observed independently (by different observers) to not only increase the visibility of warp strikes but so that data suitable to determine warp strike and mortality rate can be collected. Some variables, like age, contact type, contact point, and the fate of each seabird observed to contact the warp should be recorded in a standardised manner (Table 9). Moreover, warp strikes need to be clearly defined, and a distinction should be made between aerial collisions of seabirds with warps or water line captures where the bird is dragged under water.

3.3.3 Final recommendations

Based on the expert workshop and literature review, Table 10 presents recommendations for study design options. The matrix can be used to select certain aspects of the trials, and multiple options can be selected or mixed from each category. For instance, observer data could be collected on tori lines and bird bafflers of a single design trialed on a small sample size of Tier 1 and Tier 2 vessels that already have them installed onboard and that retain all discards. Selection of these options depends on trial scope and will need to be refined and added to as the trial is designed and implemented. This matrix is meant to guide initial trial design, and other factors will need to also be considered, such as vessel selection, fishery, home port, tow speed, specific device design, and data collection variables.

Table 10. Recommendation matrix for study design options (columns) discussed during the expert workshop that need to be determined when designing an at-sea trial of warp mitigation devices. Bold options are those that are highly recommended.

Mitigation device	Device design	Vessel class	Infrastructure	Sample size	Timing	Frequency	Fishing areas	Discharge management	Data collection method	Observer	Data collected
Tori line	Single design (e.g., 2-boom baffler OR 4-boom baffler)	**Tier 1 ≥ 50ft/15m (high risk)**	**Already installed on vessel**	Large (>8 vessels)	**Concurrent on multiple vessels**	Single tow/trip	Single, high-risk area (e.g., FMA 3, 5, or 7)	**Retained**	Paper observer forms	**Both warps**	**Warp strikes**
Bird baffler	**Multiple designs (e.g., 2-boom baffler AND 4-boom baffler)**	**Tier 2 40-50ft/12-15m (medium risk)**	Partially installed on vessel (specifically for multiple device trials)	**Medium (4-8 vessels)**	Opportunistic	**Multiple tows/trip**	**Multiple high-risk area**	Bycatch discharge (whole)	**Electronic observer forms**	Single warp, same side as offal discarding	**Warp captures**
Warp deflector-cone		Tier 3 30-40ft/9-12m (low risk)	Newly installed	Small <4 vessels)	**During setting**	One trip/vessel	Medium-risk area	Batching offal	**ERS reports**	Single warp, opposite side as offal discarding	**Abundance in warp danger zone**
Warp deflector-pinkie buoy					**During towing**	**Multiple trip/vessel**	Low-risk area	Mincing offal	On-board cameras		**Abundance outsize warp danger zone**
Warp scarer					**During hauling**	**Random, tow by tow**		Mealing offal	**Go Pros**		**Pictures of mitigation device**
Multiple (at the same time)					**During times of no fishing**	Random, trip by trip		Continuous			**Pictures of captures**
Dyneema					**Morning, midday, evening**			**No discarding when shooting/ hauling**			
								Discarding when shooting/ hauling			
								No management			
								One side of vessel			
								Both sides of vessel			

4. Discussion

Based on the review of 14 New Zealand and international studies and after discussions at the expert workshop, tori lines, bird bafflers, and warp deflectors should be considered for at-sea trials on coastal trawl vessels <28m LOA to test their effectiveness at reducing seabird warp strike. Tori lines and bird bafflers are the most commonly used mitigation devices internationally and should be prioritised for trials, along with different types of warp deflectors since they are used more often on coastal trawlers in New Zealand. The simultaneous use of multiple devices should also be tested. Final trial device selection and design will depend on the scope of the trial, feasibility, cost, availability on vessels, among many other considerations.

Little research currently exists on the effectiveness of mitigation devices on coastal trawlers both for New Zealand and internationally, due primarily to the difficulties in obtaining such data. Consequently, these reviewed sources may not be indicative of conditions in New Zealand inshore trawl fisheries. Considering the extensive variation in vessel configurations in the fleet, the design and application of a mitigation device will be vessel-specific, thus complicating testing devices and determining best practice.

Discussions in the workshop revealed two key obstacles to implementing an at-sea trial of mitigation devices. First, a very large sample size of tows must be observed to obtain sufficient data on abundance or strike rates. Second, the large number of potential confounding variables, such as fishery, target fish species, device material/structure, vessel type/size, vessel speed, tow depth, weather, geographical location, crew behaviour, and discharge management practices, may obscure any underlying patterns of strike rate reduction, despite attempts to reduce/eliminate their effects using randomisation or stratification. There are also inherent difficulties in testing devices at sea, and the high observer effort required to collect the data may not be possible.

Best practices should be followed for abundance and warp strike data collection, used by the ACAP, DOC, and Fisheries NZ, with some suggested modifications based on international studies and expert discussion. While most quantification of mitigation device use and seabird mortalities depend on observers to report data, the use of electronic reporting in New Zealand could be an alternative. The current inshore trawl fleet ERS reports on four seabird bycatch mitigation devices. Further ERS refinement to access bycatch rates, particularly for warp strikes, would significantly improve its usefulness. Additionally, on-board cameras currently being rolled out on inshore trawl vessels could be suitable to estimate a general seabird abundance and monitor mitigation practices (e.g., discharge, device deployment), as suggested by McElderry et al. (2010). However, EM using cameras would be ineffective at determining detailed seabird abundance (e.g., individual counts, by species) or quantifying warp strikes or other seabird mortalities (McElderry et al., 2010). Moreover, cameras could become a mitigation method itself, since they may encourage crew to modify their behaviour or change the type of mitigation device being used.

New and innovative types of devices, particularly those designed for and adapted to the variations of small vessels fishing in New Zealand, should be considered in the future and developed to address seabird warp strike, although this was out of the scope for the proposed at-sea trials during Phase 2 of this project. For instance, there is the vertical warp fairlead newly developed by the Fisheries Research and Development Corporation for the South East Trawl Fishing Industry Association in Australia (J. Barrington, *MIT2022-07A Inshore Trawl Warp Mitigation Workshop*, 2023). The testing of Dyneema warps or other such modifications to the trawl gear itself could also be done simultaneously to not only expand potential warp strike mitigation methods but also combine trial resources, like funding, observer coverage, and data collection effort.

Considering warp strike on small trawl vessels poses a substantial risk to seabirds, effective mitigation practices are necessary to reduce or eliminate incidental catch. Further at-sea trials, like those planned during Phase 2, will establish the best devices that are effective at mitigating warp strike, economical, practical, and safe. Moreover, current information communicated to fishers should be improved by modifying existing ACAP, DOC, and Fisheries NZ guidelines and incorporating international best practices specifically suited to commercial, inshore trawl fisheries and vessels <28m.

Acknowledgements

We thank the Department of Conservation, especially Tiffany Plencner and Igor Debski, for providing data sources, helping to organise the workshop, and giving general feedback over the course of the project. We also thank invited experts for attending the workshop and providing helpful feedback and advice on this review and trial design, and the Technical Working Group for their comments. The data on captures were made available from the Protected Species Captures Database by Fisheries New Zealand and the Ministry for Primary Industries. This project was funded by the Department of Conservation under project code MIT2022-7A.

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Appendices

Appendix 1

Table 1-1. Common and scientific names for referenced seabird, fish, and cephalopods.

Common name	Scientific name
Seabirds	
subantarctic skua	*Catharacta antarctica*
pintado petrel	*Daption capense*
cape petrel	*Dation capense*
southern royal albatross	*Diomedea epomophora*
wandering albatross	*Diomedea exulans*
northern fulmar	*Fulmaris glacialis*
kelp gull	*Larus dominicanus*
silver gull	*Larus novaehollandiae*
black-browed albatross	*Lassarche melanophrys*
southern giant petrel	*Macronectes giganteus*
cape gannet	*Morus capensis*
white-faced storm petrel	*Pelagodroma marina*
common diving petrel	*Pelecanoides urinatrix*
imperial cormorant	*Phalacrocorax atriceps*
short-tailed albatross	*Phoebastria albatrus*
Laysan albatross	*Phoebastria immutabilis*
black-footed albatross	*Phoebastria nigripes*
white-chinned petrel	*Procellaria aequinoctialis*
grey petrel	*Procellaria cinerea*
black petrel	*Procellaria parkinson*
Cook's petrel	*Pterodroma cookii*
grey-faced petrel	*Pterodroma macroptera*
Buller’s shearwater	*Puffinus bulleri*
flesh-footed shearwater	*Puffinus carneipes*
pink-footed shearwater	*Puffinus creatopus*
great shearwater	*Puffinus gravis*
sooty shearwater	*Puffinus griseus*
short-tailed shearwater	*Puffinus tenuirostris*
Indian yellow-nosed albatross	*Thalassarche carteri*
Atlantic yellow-nosed albatross	*Thalassarche chlororhynchos*
grey-headed albatross	*Thalassarche chrysostoma*
white-capped albatross	*Thalassarche cauta steadi*
shy-type albatross	*Thalassarche spp.*

Fish and cephalopods	
mackerel icefish	*Champsocephalus gunnari*
red gurnard	*Chelidonichthys kumu*
Patagonian toothfish	*Dissostichus eleginoides*
kingclip/ling	*Genypterus blacodes*
stargazer	*Kathetostoma giganteum*
hoki	*Macruronus magellanicus*
shallow-water hake	*Merluccius capensis*
Argentine hake	*Merluccius hubbsi*
deep-water cape hake	*Merluccius paradoxus*
tarakihi	*Nemadactylus macropterus*
Gould's squid	*Nototodarus gouldii*
New Zealand arrow squid	*Nototodarus sloanii*
snapper	*Pagrus auratus*
rock cod	*Patagonotothen ramsayi*
red cod	*Salilota australis*
walleye pollock	*Theragra chalcogramma*
John Dory	*Zeus faber*

Table 1-2. The total number of trawls (i.e., fishing effort) per vessel class, summed per fishing year and fishing area (FMA). Data were extracted from the current Protected Species Captures Database (MPI).

Vessel class	FMA1	FMA2	FMA3	FMA4	FMA5	FMA6	FMA7	FMA8	FMA9	Total
Tier 1	16224	14307	20727	5201	6767	3920	23196	3984	4056	**21786**
2018/2019	6021	5555	7050	1468	2132	1552	8650	1118	1371	**7735**
2019/2020	5150	4503	6567	1801	2293	1226	7187	1489	1496	**7129**
2020/2021	5053	4249	7110	1932	2342	1142	7359	1377	1189	**6922**
Tier 2	3	3324	8870	0	2689	0	6122	275	503	**98382**
2018/2019	3	1127	3340	0	907	0	2077	172	109	**34917**
2019/2020	0	1198	2828	0	1011	0	2088	4	0	**31712**
2020/2021	0	999	2702	0	771	0	1957	99	394	**31753**
Tier 3	4	2621	4172	0	0	0	2588	0	0	**9385**
2018/2019	4	1137	1263	0	0	0	858	0	0	**3262**
2019/2020	0	708	1356	0	0	0	861	0	0	**2925**
2020/2021	0	776	1553	0	0	0	869	0	0	**3198**
Total	**16231**	**20252**	**33769**	**5201**	**9456**	**3920**	**31906**	**4259**	**4559**	**129553**

Table 1-3. Assessed references without relevant information to infer the effectiveness of warp mitigation methods for inshore trawl fisheries.

Reference	Notes
Abraham et al. (2009)	Discussed fish waste management strategies to reduce bycatch of seabirds but did not address warp strike specifically
Rexer-Huber & Parker (2019)	Discussed fish waste management strategies to reduce bycatch of seabirds but did not address warp strike specifically
Abraham (2008)	Tested fish waste management strategies to reduce bycatch of seabirds but did not address warp strike specifically
Pierre et al. (2012)	Discussed fish waste management strategies to reduce bycatch of seabirds but did not address warp strike specifically
Richard et al. (2011)	Determined seabird mortality due to warp strikes but did not measure the effectiveness of mitigation devices
Rowe (2007)	Review for marine mammals not seabirds
Rowe (2013)	No abundance, strike rates, or other data comparable to review sources
Weimerskirch et al. (2000)	Presented seabird abundance/mortalities but did not use or address mitigation measures. Focus on netsonde cable mortalities.
Sacchi (2021)	Discussed streamers and lasers for trawl bycatch mitigation but did not measure the effectiveness of the devices
Suazo et al. (2014)	No abundance, strike rates, or other data comparable to review sources
Wilson et al. (2004)	No abundance, strike rates, or other data comparable to review sources
Jannot et al.(2018)	Workshop results for cable strike mitigation in the US. Did not present capture rates, abundance, etc. Discussed all reviewed references.
Pierre et al. (2013)	Reviewed mitigation methods for trawling but trialled device to reduce net captures but not warp strikes
Pierre et al. (2014)	Did not address mitigation measures but provided observer forms for collecting data on mitigation
Pierre et al. (2015)	Reviewed strategic framework for fisheries observers and electronic monitoring in NZ and internationally, but not mitigation methods.
Ramm et al. (2015)	Assessed observer data NZ and recommended data collection protocols for seabird abundance around fishing vessels and warp strikes
Rowe (2008)	CSP Observer report, summarised data in the Protected Species Captures Database. Did not discuss warp strike mitigation specifically
Rowe (2009)	
Ramm (2010)	
Ramm (2012)	

Appendix 2

Table 2-1. Possible designs for mitigation devices recommended for at-sea trials.

Device	Design reference
Tori lines	Cleal (2023a) https://www.afma.gov.au/sites/default/files/2023-02/Fact-Sheet-Tori-Lines.pdf
Bird baffler	https://www.afma.gov.au/sites/default/files/2023-02/bird-baffler-specification-download-for-website-nov16.pdf
Plastic cones	González-Zevallos et al. (2007)
Pinkie buoy	Kuepfer (2017)
Water sprayer	https://www.afma.gov.au/sites/default/files/2023-02/seabird-sprayer-specification-download.pdf

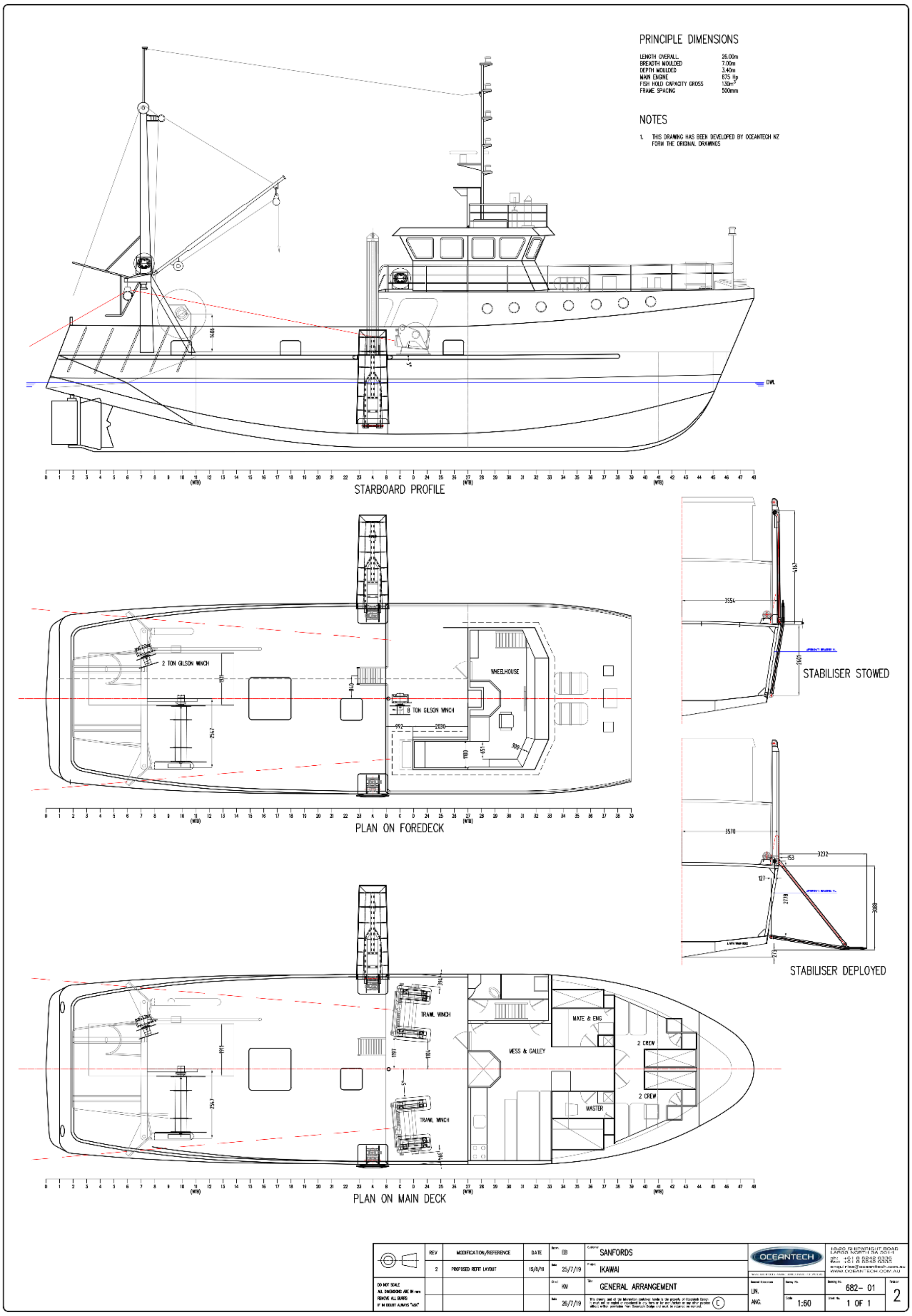


Figure 2-1. Schematic of a 26m trawl vessel, as an example of trawl block and winch positioning, deck dimensions, and warp entry points. Source: Sanford Limited and Fisheries Inshore New Zealand.

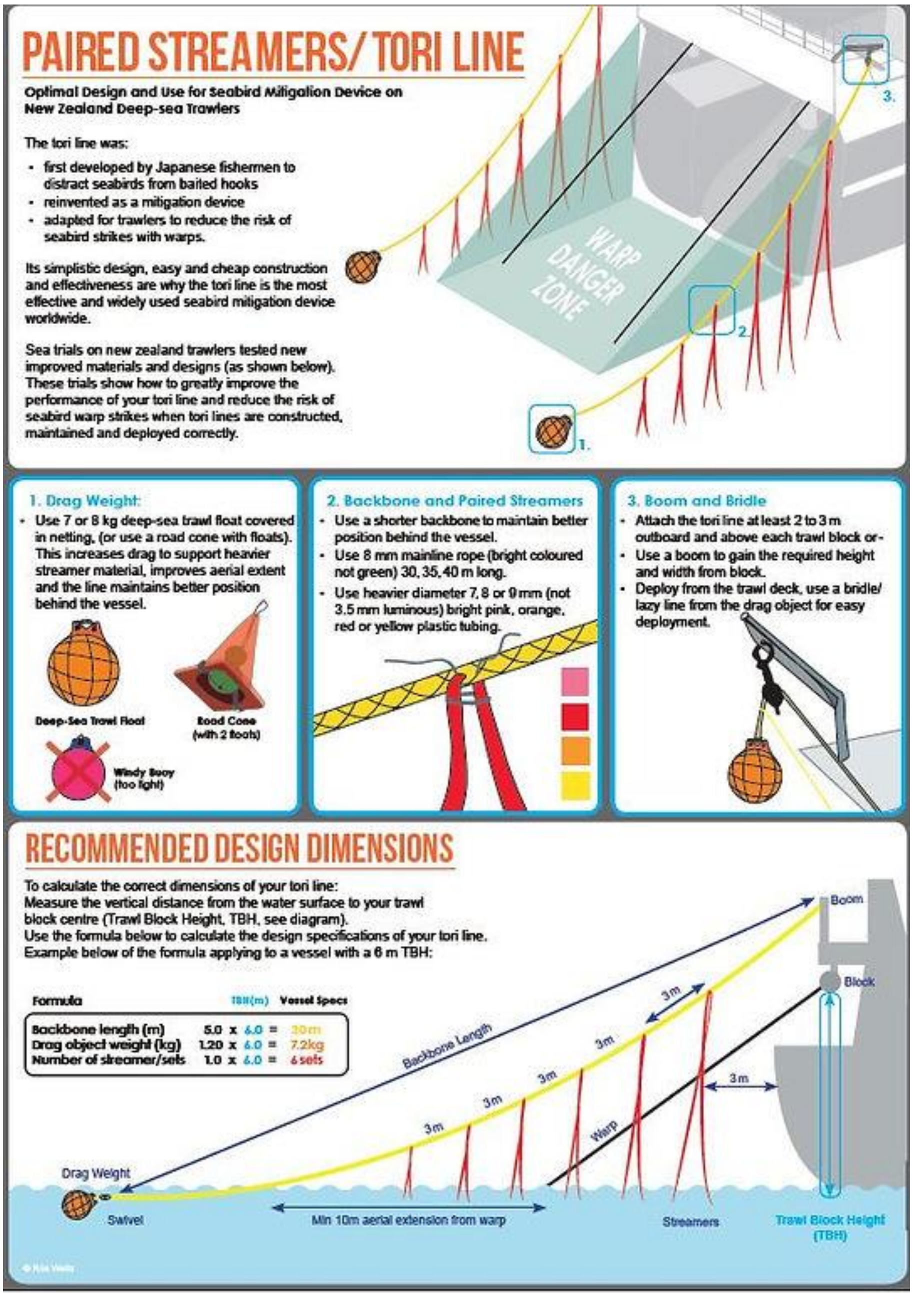


Figure 2-2. Recommended design for paired tori lines on deep-sea, large trawlers, possibly adaptable to inshore trawlers. Source: Deepwater Group Ltd. (2018).

Appendix 3

Protocol for seabird abundance counts for SPRFMO fisheries from Ramm et al. (2015) and ACAP (2021c)

Purpose

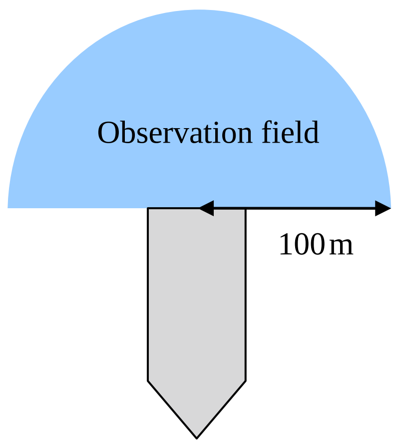
A basic understanding of the variety and abundance of seabird species present around a vessel during fishing activity can inform estimates of the bycatch risk posed by that fishing vessel. This protocol for seabird abundance counts at-sea has been developed following an international review of existing protocols and will enable the collection of directly comparable data across fisheries. A model data collection form is also provided.

Count Frequency

A minimum of one count per day should be undertaken during fishing activity. Where time allows it is recommended that further counts are undertaken during as many fishing events as possible.

Observer Location

A standard observation location should be selected at the beginning of the trip. Where possible this should be at a high point with an unobstructed view of the area 100 m astern of the vessel.



Count Method

The counts are intended to record 'snapshots' of bird abundance around the vessel at a given point, including both birds in flight and on the water. Therefore, it is important that adequate time is taken to assess all birds within the observation field. Depending on sea states this may also mean ensuring seabirds are not obscured by swell.

Note: One form should be completed per count

Observation Steps

1. Fill out Section 1- Summary Data. Provide either a valid ‘linking ID’ (this will vary by jurisdiction) or the vessel effort details. Ensure that positional data is recorded as Latitude / Longitude to at least 0.1 degree resolution in decimal format. All times should be recorded in UTC.

2. A ‘snapshot’ count should be undertaken of all seabirds in the observation field and recorded in Section 2 – Seabird Abundance Data.

   i. Each seabird should be identified to the finest possible taxonomic level and the corresponding FAO species code used. Each taxon should have a separate line.

   ii. If a bird or group of birds cannot be identified to species level, the most appropriate generic code should be used.

   iii. If there is no corresponding FAP code for the species or species group, record this in the Comments field.

   iv. If it is possible to differentiate juveniles from adults, age group should be identified on the form using the following coding:

a	Code
Total	T
Adult	A
Juvenile	J

   v. The Comments field in Section 2 should be used for anything of note about the birds observed. This may include any markings, banding of birds, tracking equipment or presence of fishing gear.

3. Fill out Section 3 - Observation Period.

   i. Record the vessel activity at the time of observation, as categorised below:

Vessel activity
Trawl - set
Trawl - tow
Trawl - haul
Longline/setnet - set
Longline/setnet - soak
Longline/setnet - haul

Purse seine - set
Purse seine - pursing
Purse seine - brailing

ii. For each count ‘eye height’ should be recorded. This is defined as the vertical distance between the observer’s eye and the surface of the water (m).

iii. Presence of other vessels should be marked ‘Yes’ if any vessels are visible by the naked eye.

iv. Wind force should be recorded using the Beaufort scale.

v. The observers position on the vessel should be noted by the following categories:

Position	Code
Port	P
Starboard	S
Stern	R
Other	O

vi. Use of visual aids should be recorded:

Visual aids	Code
Binoculars	B
Other	O
None	N

vii. Any biological discharge from the vessel should be recorded by the observers as Yes **(Y)**, No **(N)** or unobserved **(U)**

viii. The observer should indicate **(Y/N)** whether weather conditions allow them to see up to 100m.

NOTE: every field should be filled with a value

4. Section 4 - Comments should be used to record any unusual events or conditions during the count. These may include gear failures that occurred during the count, noteworthy weather events, or reasons why a count was interrupted.

Seabird Abundance Count Form

1. General information

Linking ID		Observer name(s)		Vessel	
Date		Organization		Position	
Time		Jurisdiction		Event number	

2. Seabird abundance data

FAO species code	Number	Age group	Comments

3. Observer period data

Vessel activity		Eye height (m)		Other vessels		Wind force	
Observer position		Visual aid		Discharge		Visibility ? 100 m	

4. Comments (e.g. decreased viewing angle, changes to observation transect width, noise disturbances)

Seabird abundance form - codes

Vessel activity
Trawl - set
Trawl - tow
Trawl - haul
Longline/setnet - set
Longline/setnet - soak
Longline/setnet - haul
Purse seine - set
Purse seine - pursing
Purse seine - brailing

Age group of birds	
T	= Total birds
A	= Adult birds
J	= Juvenile birds

Observer position	
P	= Port
S	= Starboard
R	= Stern
O	= Other

Visual aid	
B	= Binoculars
O	= Other
N	= None

Other	
Y	= Yes
N	= No
U	= Unknown

Beaufort Scale of Wind Force			
Beaufort Number	Description	Mean wind speed (knots)	Probable wave height* (m)
0	Calm	< 1	
1	Light air	1 - 3	0.1 (0.1)
2	Light breeze	4 - 6	0.2 (0.3)
3	Gentle breeze	7 - 10	0.6 (1.0)
4	Moderate breeze	11 - 16	1.0 (1.5)
5	Fresh breeze	17 - 21	2.0 (2.5)
6	Strong breeze	22 - 27	3.0 (4.0)
7	Near gale	28 - 33	4.0 (5.5)
8	Gale	34 - 40	5.5 (7.5)
9	Strong gale	41 - 47	7.0 (10.5)
10	Storm	48 - 55	9.0 (12.5)
11	Violent storm	56 - 63	11.5 (16.0)
12	Hurricane	> 64	14 (-)

*This table is intended as a rough guide for the open sea. Figures in parentheses indicate the probable maximum wave heights. In coastal areas, greater heights will be experienced.

Figure 3-1. Example data collection form for seabird abundance. Source: Ramm et al. (2015) and ACAP (2021c).

Appendix 4

Protocol for seabird warp/monitoring cable strike observations for SPRFMO fisheries from Ramm et al. (2015) and ACAP (2021c)

Purpose

When seabirds, particularly albatross and larger petrels, are in close attendance to trawl fisheries, there is risk of mortality through warp/ monitoring cable strikes. Detecting such cryptic, or normally unobserved, mortality requires specialised data collection. To investigate this risk further, dedicated observations can be made through implementation of these protocols, which were developed following a review of cryptic mortality of seabirds in trawl fisheries.

Choosing which warp / monitoring cable to observe

Only one warp / monitoring cable will be observed during a recording period. Observers should position themselves at a safe point near the stern of the vessel where:

- the warp / monitoring cable can be clearly seen for its entire length from the point it is outboard of the vessel to the point it ends, or enters the water; and
- any biological discharge occurring can be observed.

The warp / monitoring cable with the highest interaction rate should be selected to sample over the entire tow. This would generally be on the same side of the vessel from which most of the offal/discards are discharged, even if there is no discharge at the time of the sampling observations or if discharge is noted from both sides of the vessel. Availability of a safe observation position must be an overriding factor in determining the side of the vessel observed.

Observation Steps

1) Confirm with the skipper that it is safe, in his/her opinion, to carry out the observations.

2) Fill out Section 1 of the form. Record the start time, date and time zone of the tow using 24 hour format.

3) The observation sequence is as follows:

    a) Sample period 1 begins 15 minutes after the start of the tow

    b) Sample period 2 begins 20 minutes after the end of sample 1

    c) Repeat until end of tow

4) For each sample:

a) Two minutes before the sample period is set to begin, record a bird abundance estimate on the observation form

b) Record start time of observation using 24 hour format

c) Observe the chosen warp for 15 minutes and count bird strikes (defined below) for each category of bird and strike.

d) Record end time of observation using 24 hour format

5) Record bird strikes, noting seabird categorisation below, on the observation work sheet.

6) Complete Section 3 of the form for that sample period (see "instructions for completing sampling form").

7) Observe the haul and record net interactions according to the haul observation protocol described below.

8) Photograph and record details of all birds captured by the fishing gear and mitigation device.

9) Record any pertinent comments in Section 4 of the form.

Sampling periods

Observers should undertake 15-minute sampling periods during each tow where trawling occurs in daylight. As many sampling periods as possible should be carried out per tow. The 20 minute break between sampling periods ensures that one observation is not affected by the period before it.

Sampling periods of 15 minutes each will be used to characterise strikes on the warp / monitoring cable. These are to be carried out during the fishing phase of the tow (i.e. when the net is in the water and cables are no longer being paid out). It is very important to record the correct start and stop time of the observation and the tow.

If conditions change significantly during an observation period; e.g., the wind conditions change considerably, or if the offal discharge rate changes significantly, terminate your observation at that point and note on the form the environmental conditions that prevailed during the observation period. Record the reason for early termination of the sample period under section 4 of the form. Begin a new sampling period later in the tow if possible, or on the next tow.

Start a new form for observations on a new tow.

Instructions for completing the sampling form

The text in bullet points and italics refers to elements to record on the form.

Section 1. Fishing event descriptors

- *At the beginning of the sampling set of observations, record details of the trip, tow, and observer. Note that a new form must be started for each new tow observed.*
- *Record the date, start time, and time zone for the tow. Record times in 24 hour format.*

- *Side observed (P/S) – Record which warp is observed during the tow. P = Port, S = Starboard. Note that the same side should be observed for the whole tow.*
- *Observer initials – Initials of the observer making the observations on this form.*

Section 2. Fifteen-minute warp/mitigation device strike observations and bird abundance

- *Record the time at the start and end of each 15-minute sampling period in 24 h clock times, e.g., 09:30 - 09:45 or 15:00 - 15:15.*

Seabird abundance:

The objective of the abundance estimate is to provide order-of-magnitude level of information about the numbers and species group of birds behind the vessel during the sampling period. This is done by counting the number of birds in the sample area just before the 15 minute observation of warp strikes. Estimate the total number of birds of each species group on the water **and** in the air and record this information separately. Separate the bird groupings in this estimation.

The area in which bird abundance is to be assessed is a 25m radius around the stern of the vessel (Figure 1).

- *Fill in the form by writing the number of birds for each sample period under the bird categories (defined below).*

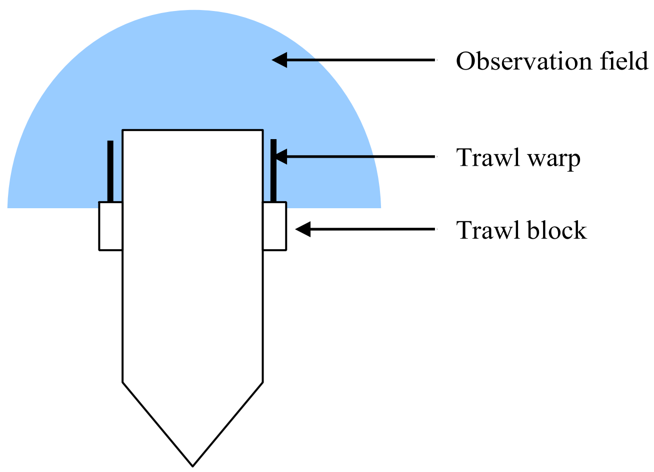


Figure 1. Diagram of a vessel with the warp entry point shown. The 25m radius in which seabird abundance is estimated is highlighted (not to scale).

Number of heavy contacts

- *Record the total number of heavy contacts and the type of contact for each bird category during the 15 minute observation period (see below for definitions of Heavy Contacts, and birds).*

<u>Defining heavy contacts between birds and the trawl warp or mitigation device:</u>

A heavy contact is one in which a bird:

1 has its path of movement deviated when it comes into contact with the trawl warp / monitoring cable; *and*

2 the part of the body contacted is above the 'wrist' joint of the bird (i.e., on the upper part of the wing and or on the head or body).

This can occur on the water or in the air. Birds on the water may be dragged under the water by a heavy contact. Heavy contacts occur either when the bird, through active movement, comes into contact with the warp / monitoring cable or mitigation device, or when the warp/ monitoring cable or mitigation device moves to contact the bird (e.g., whilst the bird is sitting on the water).

Light Contacts are NOT included in this category are when birds may have contacted the warps / monitoring cable or mitigation device but are not moved out of their flight path or position on the water. Light contacts are recorded separately.

Bird size categories:

Birds of different species will be seen in contact with trawl warps/ monitoring cable. Differences in size and behaviour between species result in variation in vulnerability to striking the warp/ monitoring cable or mitigation device. Seabirds have been grouped into 5 categories based on behaviour and size in order to maximise the information coming out of each observation period. These categories were based on bird assemblages around New Zealand domestic trawlers and may need to be adapted to include other groups of species in other fisheries.

L Alb Large albatross: royal and wandering albatross; *Diomedea spp.*

S Alb Small albatross and giant petrels: other albatross; *Thalassarche spp.* and *Phoebetria spp.* plus *Macronectes spp.*

P Shearwaters and other petrels apart from giant petrels and cape pigeons: other Procellariidae.

CP Cape pigeons: *Daption capense*.

O Other species.

Section 3: Environmental factors and offal/fish discharges

- *Swell height (m) - Estimate the average height of the swell during the sampling period in metres.*

- *Swell direction (1-12 h) – Record the direction from which the swell is coming relative to the direction of travel of the vessel. Use a 12 point "clock" scale. The bow of the vessel is defined as the 12h point, therefore a swell coming directly from the stern direction is recorded as 6. Port side is 9, starboard is 3.*

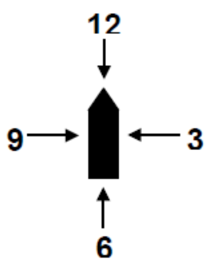


Figure 2. The 12-hour clock scale to be used for swell and wind direction.

- *Wind speed (Beaufort) – Record the wind speed using the Beaufort Scale (below). The information is a rough guide for the open sea. Figures in brackets indicate the probable maximum wave heights. In coastal areas, greater heights will be experienced.*

Beaufort Scale	Description	Mean wind speed (knots)	Wave height (m)
0	Calm	<1	
1	Light air	1 - 3	0.1 (0.1)
2	Light breeze	4 - 6	0.2 (0.3)
3	Gentle breeze	7 - 10	0.6 (1.0)
4	Moderate breeze	11 - 16	1.0 (1.5)
5	Fresh breeze	17 - 21	2.0 (2.5)
6	Strong breeze	22 - 27	3.0 (4.0)
7	Near gale	28 - 33	4.0 (5.5)
8	Gale	34 - 40	5.5 (7.5)
9	Strong gale	41 - 47	7.0 (10.5)
10	Storm	48 - 55	9.0 (12.5)
11	Violent storm	56 - 63	11.5 (16.0)
12	Hurricane	64 and over	14 (-)

- *Wind direction (1-12 h) - Record the direction from which the wind is coming relative to the direction of travel of the vessel. Use a 12 point "clock" scale. See figure 2.*

- *Discharge side - Record whether offal discharge was on the Port (P), Starboard (S), both or Neither (N) sides of the vessel during the observation period.*

- *Discharge rate - Record the rate of offal or discard discharge during each 15-minute sampling period, using four categories (0 = none, 1 = negligible, 2 = intermittent, 3 = continuous). Only one rate should be recorded. If the rate changes significantly, i.e., to the extent that a different discharge rate category would be appropriate, terminate the sample and start a new one later. Note: discharge from all around the vessel should be considered when recording. Diagrams of discharge points should be included in the trip report.*

- *Discharge Type (S/O/D) Multiple types are allowed and should be recorded. Record the type of discharges (S = Sump water, O = offal, meaning heads and guts of processed product, D = whole fish or squid discards). Other material (such as rubbish) on which birds might feed is not included in this category and should not be recorded. If the vessel is discharging any non-fish waste i.e., rubbish, this should be recorded in the comments section of the form.*

- *Mitigation used – record the use of seabird mitigation device deployed in association with the warp being observed (BSL = bird scaring line, BB = bird baffler, O = other – describe in Section 4 Comments).*

Section 4: Haul Observations

In order to better categories net interactions at hauling fill in Section 5 detailing: 1.

Time the net is at the surface

2. For each seabird category:

   a. Abundance around the vessel

   b. Number of seabirds landing on the codend

   c. Number of seabirds swimming around the codend

   d. Number of seabirds actively feeding on the net

   e. Number seabirds diving on the net

Section 5. Comments

Record comments in this section, e.g., if you are required to stop your observations for some reason (wind changes, the vessel does a turn, or an incident happens that means the observation period is cut short). Anecdotal information that might help researchers analyse the data you recorded is also helpful as are general comments on the performance of mitigation devices.

Mitigation Assessment Warp / Monitoring cable Strike Form

1. Fishing event descriptions

Linking ID		Date		Tow start time		Cable angle θ	
Observer trip		Observer tow		Observer initials		Dist. to entry (m)	

See reverse for directions

2. Fifteen-minute warp/ monitoring cable /mitigation device strike observations and bird abundance

Fishing stage	1. At depth / hauling					2. At depth / hauling					3. At depth / hauling					4. At depth / hauling				
15-min observation	Time start		Time end			Time start		Time end			Time start		Time end			Time start		Time end		
Taxa grouping	L Alb	S Alb	P	CP	O	L Alb	S Alb	P	CP	O	L Alb	S Alb	P	CP	O	L Alb	S Alb	P	CP	O
Bird abundance																				
No. light contacts																				
No. heavy contacts:																				
Air																				
Water (deflected)																				
Water (dragged under)																				

3. Environmental factors and mitigation devices

Swell height (m)				
Swell direction (1 - 12 h)				
Wind speed (Beaufort)				
Wind direction (1 - 12 h)				
Discharge location	P / S / R / N	P / S / R / N	P / S / R / N	P / S / R / N
Discharge rate	0 / 1 / 2 / 3	0 / 1 / 2 / 3	0 / 1 / 2 / 3	0 / 1 / 2 / 3
Discharge type	S / O / D	S / O / D	S / O / D	S / O / D
Mitigation used	BSL / BB / O	BSL / BB / O	BSL / BB / O	BSL / BB / O

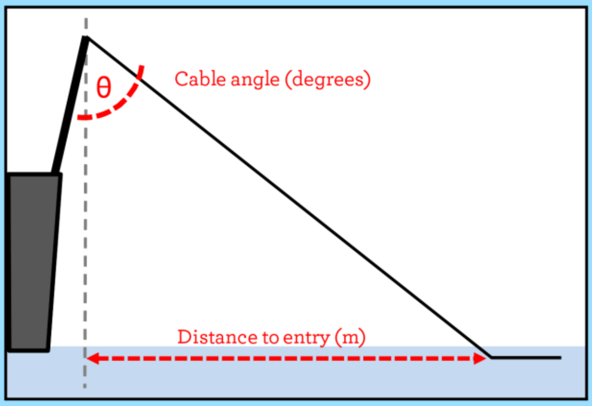
4. Comments: include any usual factors that may have influenced the number of warp strikes, e.g. gear failure or changes in environmental or fishing factors

Reference Tables and Diagrams

Beaufort Scale of Wind Force

Beaufort Number	Description	Mean wind speed (knots)	Probable wave height* (m)
0	Calm	< 1	
1	Light air	1 - 3	0.1 (0.1)
2	Light breeze	4 - 6	0.2 (0.3)
3	Gentle breeze	7 - 10	0.6 (1.0)
4	Moderate breeze	11 - 16	1.0 (1.5)
5	Fresh breeze	17 - 21	2.0 (2.5)
6	Strong breeze	22 - 27	3.0 (4.0)
7	Near gale	28 - 33	4.0 (5.5)
8	Gale	34 - 40	5.5 (7.5)
9	Strong gale	41 - 47	7.0 (10.5)
10	Storm	48 - 55	9.0 (12.5)
11	Violent storm	56 - 63	11.5 (16.0)
12	Hurricane	> 64	14 (-)

*This table is intended as a rough guide for the open sea. Figures in parentheses indicate the probable maximum wave heights. In coastal areas, greater heights will be experienced.



Mitigation codes:

BSL	= bird scaring line
BB	= bird baffler
O	= other

Discharge codes:

Discharge side: (one or more)	
P	= Port
S	= Starboard
R	= Stern
N	= Neither / none

Discharge rate: (record one)	
0	= none
1	= negligible
2	= intermittent
3	= continuous

Discharge type: (one or more)	
S	= sump water (deck wash)
O	= offal, i.e. heads and guts
D	= discards of whole fish

Figure 4-1. Example data collection form for warp cable strike mitigation assessment. Source: Ramm et al. (2015) and ACAP (2021c).

Appendix 5

Workshop agenda

Meeting: **MIT2022-07A Inshore trawl warp mitigation workshop**

Date: Wednesday 22 March 2023

Time: 9:00 am – 1:00 pm

Place: Microsoft Teams Online Meeting

Chair: Darryl MacKenzie (Director, Proteus; darryl@proteus.co.nz)

Tiffany Plencner (Protected Species Liaison Coordinator, DOC; tplencner@doc.govt.nz)

Time:	Event:	
9:00 am	Welcome, Karakia, Introductions, Apologies	Chairs
9:05 am	Project overview and workshop purpose *Objective:* To identify priority inshore trawl mitigation options and testing methods	Chairs
9:10 am	*Presentation*: Review of data on current mitigation use and initial recommendations on potential at-sea data collection protocols for assessing trawl warp mitigation in inshore fisheries	Proteus
9:45 am	Discussion about mitigation devices, their practicality, applicability, and perceived effectiveness to inform a prioritised list of devices for further testing	All
11:00-11:15 am	Break	
11:15 am	Discussion about at-sea trial data collection to identify most the suitable and cost-effective protocols for future use	All
12:30 pm	Next steps	All
1:00 pm	Close of meeting	Chairs

Table 5-1. Workshop attendance list.

Name	Organisation
Darryl MacKenzie	Proteus
Rachel Hickcox	Proteus
Stefan Meyer	Proteus
Tiffany Plencner	Department of Conservation
Igor Debski	Department of Conservation
Rosa Edwards	Fisheries Inshore NZ
Graham Parker	Department of Conservation; Parker Conservation
John Cleal	Department of Conservation; FV Management Services
Ben Leslie	Department of Conservation; Coastal-Equilibrium Ltd.
Richard Wells	Fisheries New Zealand; Resourcewise Ltd.
Robert Win	Fisheries New Zealand
Olivia Hamilton	Fisheries New Zealand
John Richardson	Fisheries New Zealand
Matthew Rolfe	Fisheries New Zealand
Jonathon Barrington	Australian Department of Climate Change, Energy, the Environment and Water