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Minimum standards for mitigation measures with curtain systems in demersal trawl fisheries

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SUMMARY

In the southern summers and winters of 2023, ATF-Chile conducted new experiments to generate evidence on minimum standards and the effectiveness of tailored mitigation measures for net sonar and warp cables in demersal trawl fisheries. This initiative, supported by ACAP grants and fisheries associations in south-central Chile, aimed to develop a step-by-step process to reduce seabird collisions with cables using a combined system of net sonar curtains and engine-powered Bird Bafflers. The goal was to prevent collisions across the entire aerial coverage of cables and their risk area of contact with the water surface. The Bird Baffler aims to prevent seabird collisions at the water level with the warp cables and also to prevent aerial collisions in the upper section of the net sonar cable. Meanwhile, the net sonar curtain aims to prevent seabird aerial collisions in the following two-thirds of the net sonar and also collisions and entanglements with the net sonar at the water surface. We monitored 48 complete trawl tows (each approximately 3 hours long, totaling 144 hours of observation) onboard demersal trawl vessels targeting South Pacific hake in south-central Chile, during the winter period when there is increased overlap with albatross species distribution in the Humboldt Current System. The Combined Curtain System (CCS) demonstrated a reduction in collisions of over 90% for nine seabird species, including five ACAP-listed species. This represents one of the first instances of evidence on the minimum standards required for the effectiveness of complementary mitigation systems for demersal trawl vessels in the southeastern Pacific. It holds significant potential for application to other fleets operating in higher latitudes under wind regimes that affect the performance of tori lines in southern Chile and beyond.

1. INTRODUCTION

Seabird bycatch in trawl fisheries is primarily concentrated at the stern of vessels, as previously described, due to collisions and entanglements with cables and the net (e.g., Bartle, 1991). Since then, various bycatch mitigation measures have been proposed to reduce interactions with warp and net sonde (monitoring) cables, primarily represented by tori lines acting as physical barriers in trawl fisheries development (Bull, 2009; Jiménez et al. 2023).

Trawl fisheries vary widely, from small-scale operations to large industrial factory vessels with diverse onboard facilities (Tamini et al. 2015). These differences necessitate the development of effective mitigation measures tailored to their specific requirements and operational performance, directly impacting compliance in reducing seabird bycatch (e.g., Suazo et al. 2023).

One of the major challenges lies in developing mitigation measures for undetectable and extensive net sonde cables, which pose significant threats of aerial and underwater collisions and entanglements for albatrosses and petrels (Melvin et al. 2023).

To address this challenge—with support from the ACAP small grants scheme, Chilean fisheries associations, and trawl fleets—we aim to develop and trial minimum standards for implementing a combined curtain mitigation system for trawl vessels at sea.

This initiative encompass materials, dimensions, and safe operational practices aimed at reducing seabird collisions with warp and net sonde cables in the demersal trawl fishery for South Pacific hake in south-central Chile.

2. THE DEVELOPMENT OF A COMBINED CURTAIN SYSTEM FOR MITIGATION IN TRAWL VESSELS

To mitigate collisions or entanglements with warp and netsonde cables, *ad hoc* measures have been developed in accordance with domestic regulations for trawl fisheries in Chilean waters (e.g., SUBPESCA, Res. Nº2941/2019; https://www.subpesca.cl/portal/615/w3-article-105375.html).

The combined curtain system for mitigation is designed to deploy physical barriers that deter seabirds from high-risk collision areas with cables. This system was originally designed during the study period in 2021, and it has been onboard for assessing new device functionality since February 2023. Ongoing assessments include evaluating their combined performance and the frequency of seabird collisions during the southern winter (June 2023), a period of high overlap with albatrosses and petrels during trawl operations in south-central Chile as recorded a decade ago (ATF-Chile, 2013).

These mitigation measures involve deploying physical barriers to deter seabirds from risk areas, offering alternatives to using tori lines, which are often disregarded due to windy conditions by southern fleets. The combined system consists of engine-powered Bird Bafflers (port and starboard) and a netting curtain attached along the netsonde.

2.1. Engine-powered Bird Baffler

The ***Bird Baffler*** aim to prevent collisions with birds at water level with warp cables and the upper section of the netsonde, while the netsonde curtain aims to prevent aerial collisions with warp cables and the netsonde cable.

In order to automate the use of mitigation measures and ensure safe handling by the crew, this new version of the Bird Baffler included new elements such as:

i) A rod for mounting droppers, with a minimum length that allows coverage including the area where the trawl cables enter the water. Its arrangement includes the option to adjust the rod's exit angle from the stern relative to the ship's centerline, in response to fishing operation and/or weather conditions.

ii) Yellow diving hoses to ensure long-term durability of droppers, with a minimum length of 50 cm above the water surface, based on calm harbor conditions.

iii) Spacing between Bird Baffler droppers: these can range from every 50 cm to every 1 m.

iv) Guide rope to tie down the Bird Baffler and keep it connected to the stern of the vessel.

v) Rotating base and electric winch for deployment and retrieval (Fig. 1).

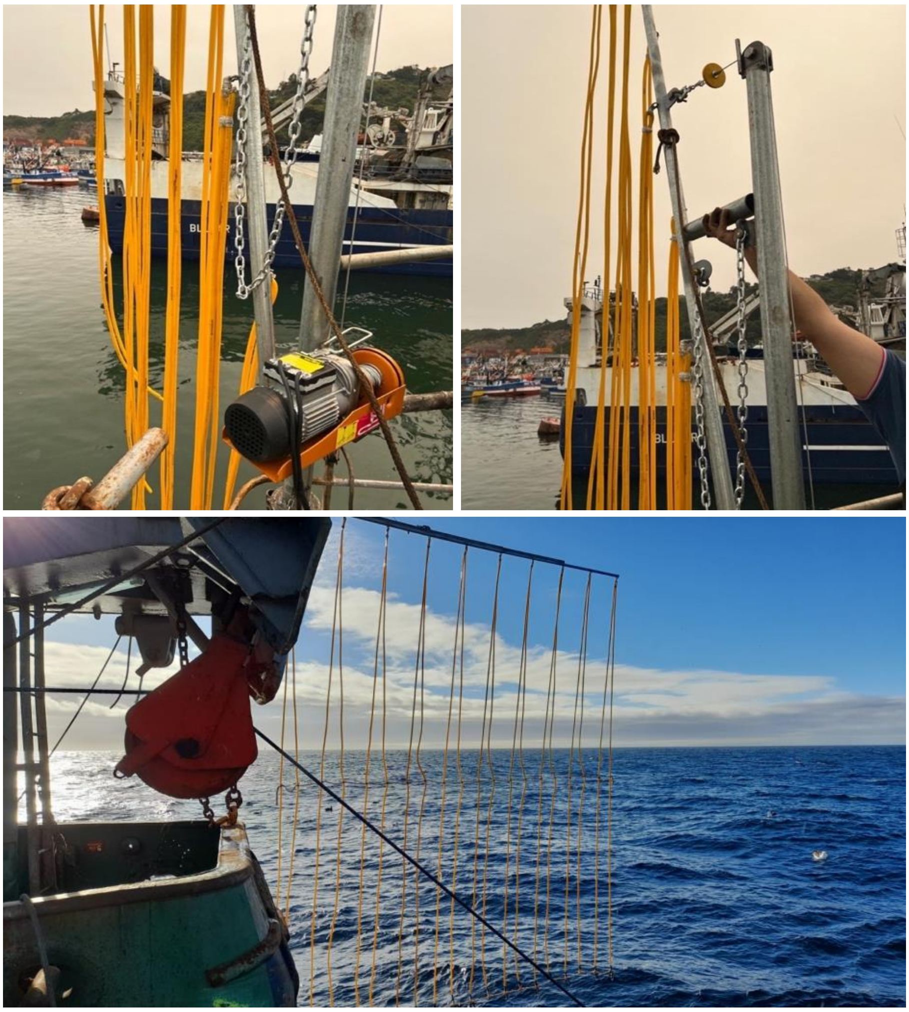

Figure 1. The Bird Baffler used in the combined curtain system in the demersal trawl fishery for South Pacific hake, south-central Chile (© ATF-Chile).

2.2. Netsonde Curtain

The deployment of the ***Netsonde Curtain*** is an experimental device aimed at enhancing the detectability of net sonar cables by deploying a physical barrier attached to them. This barrier can be constructed from net material, but to enhance its detection, the use of warm colors (red, orange, yellow) is recommended, as outlined in Resolution SUBPESCA, Res. Nº2569/2021; https://www.subpesca.cl/portal/615/w3-article-112252.html.

It should be noted that, regarding the deployment of the sonar curtain system, it does not require additional devices and equipment for deployment from the stern ramp. This process is manual and can be safely carried out at low speed by only one crew member responsible for the maneuver (Deployment details in video: https://bit.ly/3FcHhek; ATF-Chile).

However, the deployment of the sonar curtain should consider reducing the amount of mesh used (mesh height) and ensuring its visibility, as well as reducing the amount of material in its upper extension as indicated in the theoretical scheme of Resolution No. 2569/2021 (see Fig. 2). This is necessary to ensure its quick extension when the net is hauled.

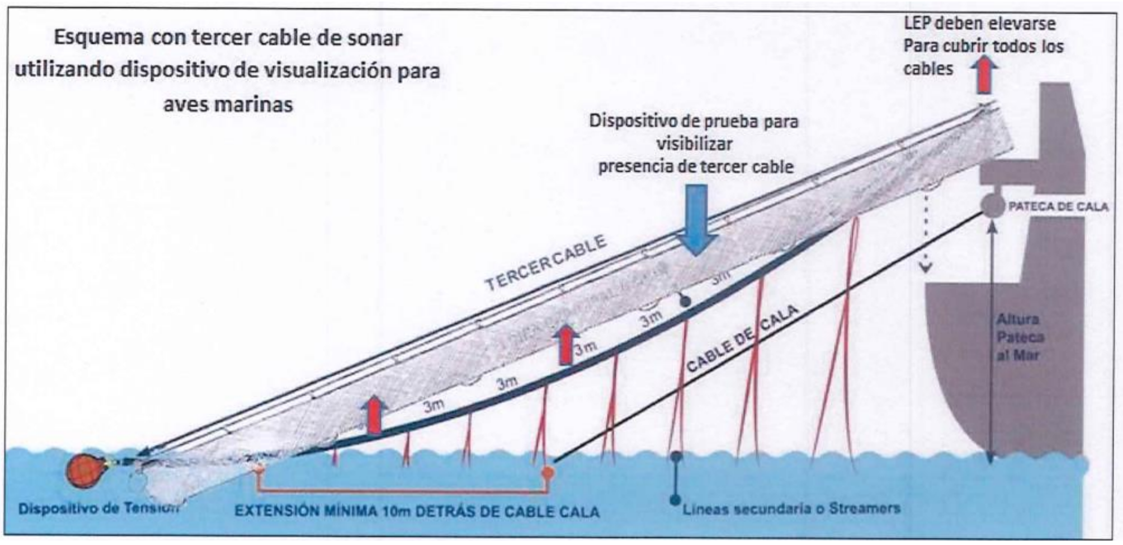

Figure 2. Conceptual diagram of the netsonde curtain deployed. Sourced from SUBPESCA, Resolution No. 2569/2021.

The interaction of the sonar curtain with other extensive deployment devices such as tori lines simultaneously is not recommended due to the potential entanglement with the curtain and handling times by crew members. Therefore, it is advisable to deploy the netsonde curtain alongside a system that emphasizes the upper (aerial) part of the latter, as well as providing coverage to the bird risk area with haul cables, including the use of weights or chains in its lower section (Fig. 3).

Figure 3. Netsonde curtain for the middle and lower section of the netsonde cable (upper plate showing deployment and final weighted blocks for netsonde curtain) (© ATF-Chile).

Other technical aspects and minimum standards to consider regarding the netsonde curtain, are:

i) Consideration of parts with greater durability.

The blocks that support and facilitate the movement of the netsonde curtain should be composed of materials that reduce abrasion and heat generation, aiming to ensure longer material lifespan and prevent damage to the netsonde.

For this purpose, the construction of the net curtain in this study has considered evaluating different original designs of blocks for the proper deployment of the curtain. These designs include the use of parts resistant to increased frictional heat and the incorporation of weighted blocks if necessary to ensure the correct deployment of the curtain, thereby reaching the level above the contact zone of the curtain with the water.

Therefore, instead of metallic blocks like stainless steel, this study identifies high-performance materials such as blocks made of Technyl® Polyamide (https://www.technyl.com/), which have shown durability in marine environments and ensured the integrity of the net sonar cable (Fig. 4).

Figure 4. Evolution in block designs for netsonde curtain deployment. For use along the curtain, it is recommended to have double blocks with Teflon wheels, where one of them can have a lock to facilitate removal and replacement (left-bottom). If it is necessary to support the proper deployment of the curtain, the use of systems with added weights in the lower section of the curtain is recommended, such as attached chains, or alternatively, installing blocks with added weight on the block rail that deploys the curtain above the water level, thus facilitating its deployment along the middle and lower 2/3 of the netsonde cable (see right image, 10 kg for reference).

ii) Reduce possibilities of snagging/entanglement in the curtain.

Similar to purse seine nets (pages 7 and 8; https://bit.ly/3F414fG), spaces between the block train that supports the curtain along the cable, as well as gaps in the connection of the curtain to its main line, can facilitate seabird entanglements. Additionally, all thread remnants from this structure should be removed, and regular maintenance of knots and connectors, all sources of seabird entanglement, should be conducted.

The overall design of such a net should include a mesh opening not exceeding 3 ¼ inches, a critical point for entanglement of smaller seabirds, such as shearwaters, which are prone to collisions with the netsonda.

In this study, a minimum height of 40 cm for the curtain panel was identified to ensure detectability by birds in flight (change in flight trajectory) and on the water. However, beyond this minimum value, the curtain height can vary according to the vessel's visibility requirements from the bridge and also depending on the handling capacity of the curtain and crew safety on deck (Fig. 5).

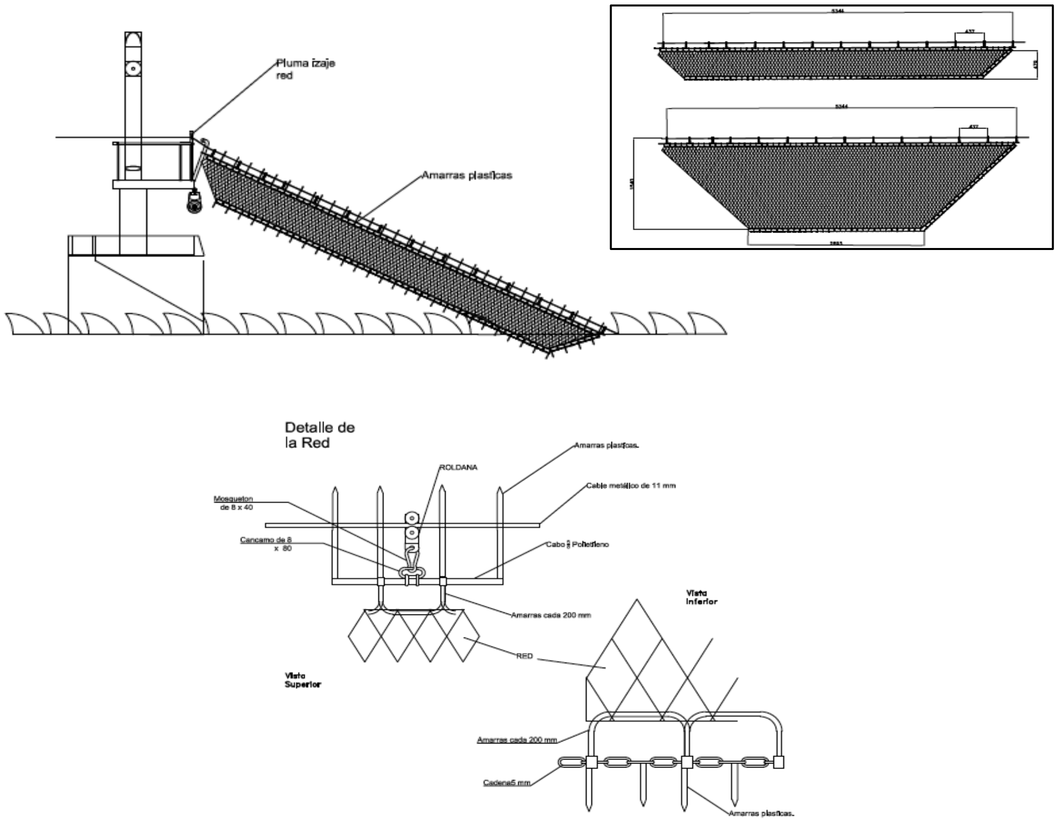

Figure 5. Features of the connectors of the netsonde curtain and minimum standards for assembly to deter the reduce the risk of seabird entanglement. It is recommended to use shoe systems with smaller mesh sizes (top left) and lower height (top right). Additionally, the overlap system of the curtain can include elements that prevent marine birds from passing through these risk areas, such as adding extensions like semi-rigid-colored ties (bottom).

2.3. Combined Curtain System (CCS) / Sistema Combinado de Cortinas (SCC)

A Combined Curtain System (CCS) for trawl vessels considers exclusion zones for seabird collisions and entanglements in aerial sections covered by the Bird Baffler (warp cables and the upper 1/3 of netsonde cables), as well as the following 2/3 of the middle and lower aerial portion of the netsonde covered by the netsonde curtain.

The specifications previously described for the Bird Baffler are crucial for its performance in conjunction with the netsonde curtain. Therefore, it is necessary to ensure a minimum extension for the mounting rod of the Bird Baffler droppers to ensure coverage of warp cables, including their entry section into the water.

Additionally, it must be ensured that the ends of the Bird Baffler droppers are no more than 50 cm from the water surface, with smooth sea conditions in port as a reference. Finally, the droppers of the Bird Baffler should be connected in the middle part using a guide rope to prevent birds from passing between the device and the vessels' stern. This same rope should be the connector of the Bird Baffler with the vessels' stern.

Regarding the extension of the netsonde curtain (which includes the deployed netting panel and a pair of hoses acting as streamers attached to the terminal end of the curtain; see Fig. 6), it will effectively cover the middle and lower 2/3 of the net sonar cable section. Additionally, to prevent tangling of the curtain's final section with the netsonde the curtain should replace the last 1-2 m (the contact zone of the netsonde with the water). Thus, it is necessary to deploy warm-colored hoses attached to the bottom of the curtain to act as deterrent double streamers in the lower area for these last 1-2 m without curtain coverage (Fig. 6).

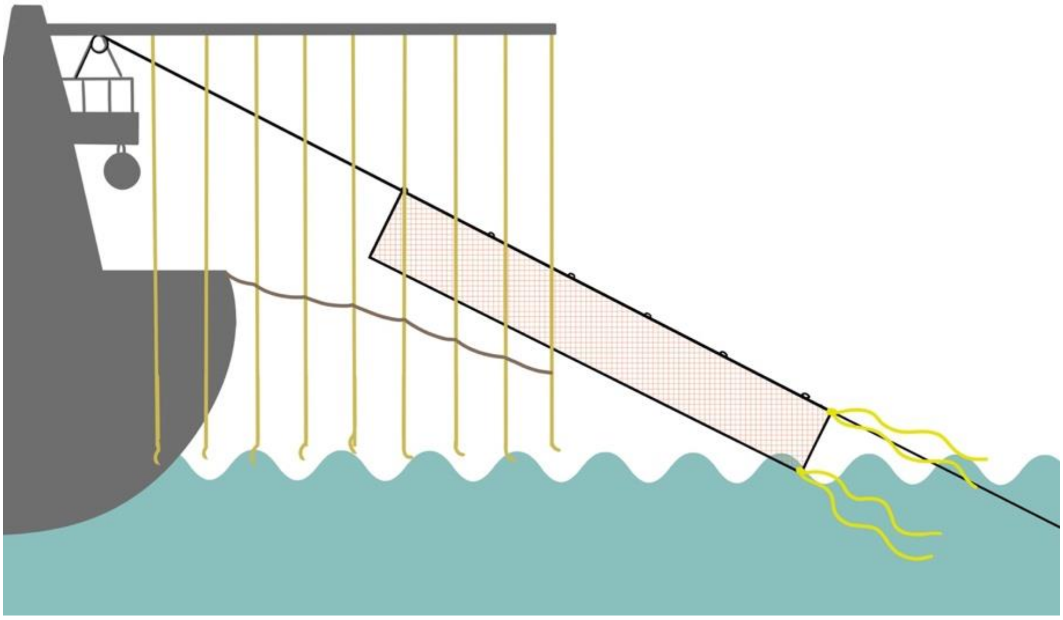

Figure 6. Representative scheme of the combined curtain system (CCS) for demersal trawl vessels. Note the extension of droppers from the Bird Baffler rod, as well as their overlap with the aerial coverage of the netsonde curtain encompassing more than 2/3 of the aerial extent of the net sonar cable (© ATF-Chile).

3. CCS AND SEABIRD COLLISIONS IN TRAWL VESSELS

Regarding the evaluation of the CCS aimed at reducing seabird collisions in cables their operational performance and mitigation effectiveness were assessed both individually and in combination. During these assessments in the summer-to-autumn transition of 2023, when there was increased overlap with albatrosses, 48 complete trawl hauls (~3 hours each, totalling 144 hours of observation) were conducted with the presence of mitigation devices (among these n=18 tows with CCS deployment; ~54 h observation), compared to hauls conducted without these devices (n=12; ~36 h observation). These operations departed from the port of San Vicente, Biobío Region (Fig. 7).

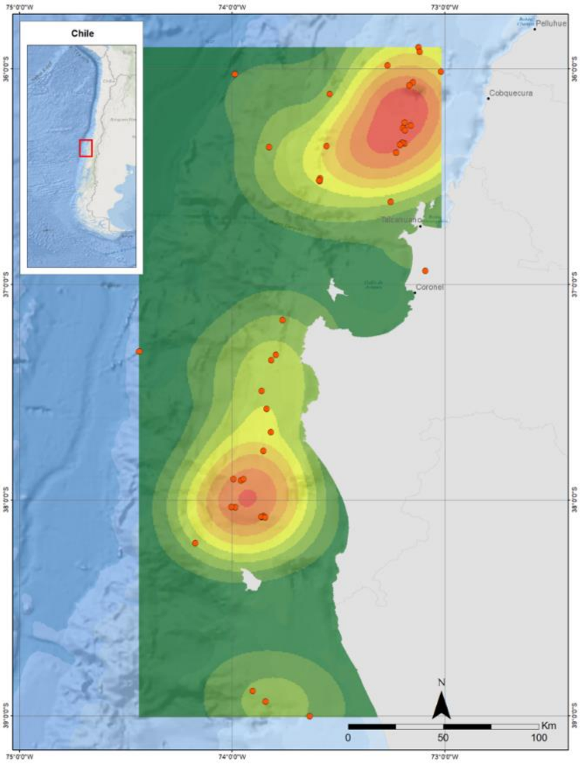

Figure 7. Trial distribution area of the net sonar curtain and Bird Baffler onboard the demersal South Pacific hake fishery, south-central Chile (© ATF-Chile).

3.1. Seabird collisions on warp cables

Seabird collisions on warp cables were observed under different conditions: tows with netsonde curtain only (n= 7; 14.6% of observed effort), Bird Baffler only (n= 11; 22.9%), the CCS (n= 18; 37.5%), and tows without any measures (n= 12; 25.0%). In the control setting (no measures), we observed a collision rate of 6.83 birds per tow (2.28 birds/h) with warp cables.

Collision rates with netsonde curtain only were 3.28 birds/tow (1.09 birds per hour), and 1.00 bird/tow (0.33 birds/h) with Bird Baffler only. When measures were combined under CCS, we recorded a collision rate on warp cables of 0.05 birds/tow (0.01 birds/h), which is nearly 80 times lower than the control and represents a reduction of 98.7% between these rates (G_{adj}= 58.31, df= 3, P<0.01; Fig. 8).

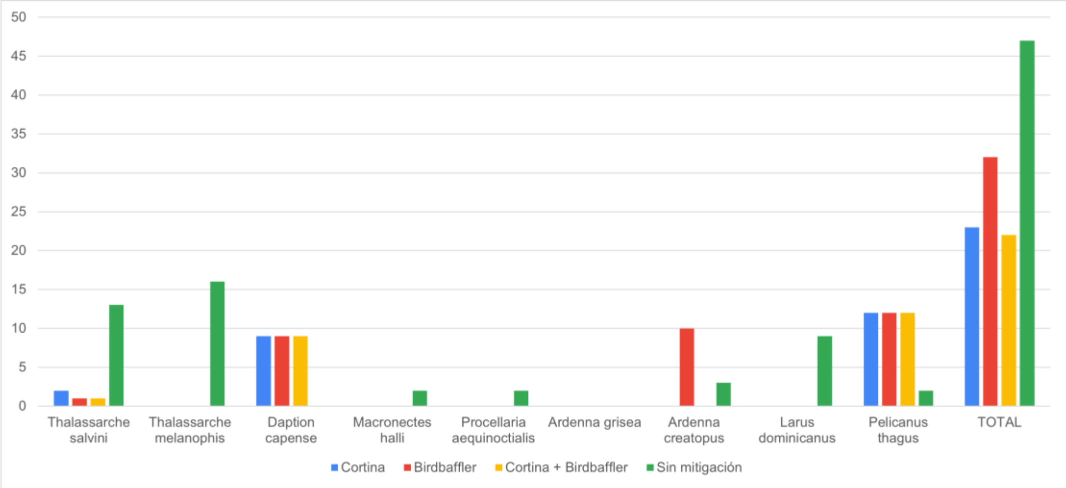

Figure 8. Collision frequency (number of individuals) for seabird species on warp cables under different mitigation scenarios in the demersal trawl fishery for South Pacific hake (south-central Chile). Blue= curtain only, Red= Bird Baffler only; Yellow= CCS; Green= no mitigation.

3.1. Seabird collisions on netsonde

Collision rates with the netsonde cable were higher in the presence of only the Bird Baffler or in the absence of any mitigation measures, at 24.00 birds/tow (8.00 birds/hour) and 13.91 birds/tow (13.16 birds/hour), respectively (Fig. 9).

The higher collision rate with the netsonde and Bird Baffler only occurred due to aerial and water-level collisions in the last 2/3 of the netsonde, particularly involving the Black-browed albatross, White-chinned petrel *P. aequinoctialis*, and Pink-footed shearwater.

In contrast, the CCS showed a 95.6% and 92.4% reduction in nominal collision rates compared to Bird Baffler only or under control scenario with no mitigation measures, respectively (G_{adj}= 1,631.43, df= 3, P<0.01; Fig. 9).

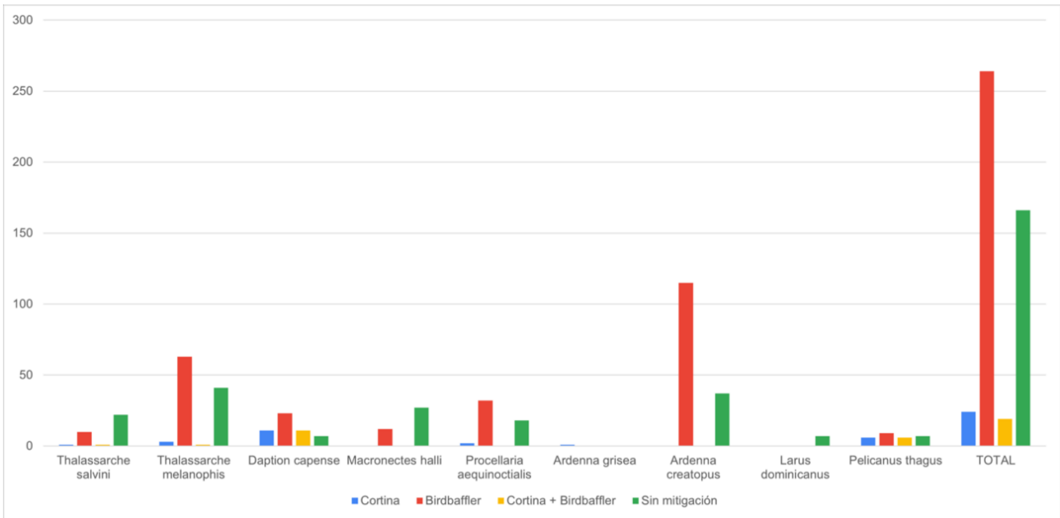

Figure 9. Collision frequency (number of individuals) for seabird species on netsonde under different mitigation scenarios in the demersal trawl fishery for South Pacific hake (south-central Chile). Blue= curtain only, Red= Bird Baffler only; Yellow= CCS; Green= no mitigation.

More than half of all observed collisions involved ACAP-listed species, specifically the Pink-footed shearwater (*Ardenna creatopus*) and the Black-browed albatross (*Thalassarche melanophris*), and these collisions predominantly occurred around the netsonde (Table 3). Overall, collisions with netsonde outnumbered those with warp cables by sixfold, accounting for 85.2% of total collisions $X^2_{(Y)}$= 76,440.5; P<0.01) (Table 1).

Table 1. Collision of seabird species with warp and netsonde cables, within the industrial demersal trawl fishery for South Pacific hake, in south-central Chile. Nominal collisions/hour with presence of CCS= 18 tows; ~54 h observation) and with no mitigation devices deployed n=12 tows; ~36 h observation).

Seabird species	Netsonde collisions with no mitigation (collisions/h)	Warp collisions with no mitigation (collisions/h)	Total collisions with no mitigation (collisions/h)	Netsonde collisions and mitigation: Bird baffler + netsonde curtain (collisions/h)	Warp cable collisions and mitigation: Bird baffler + netsonde curtain (collisions/h)
Salvin's albatross (*Thalassarche salvini*)	0.94	0.47	1.41	0.02	0
Black-browed albatross (*T. melanophris*)	3.00	0.44	3.44	0.02	0
Cape petrel (*Daption capense)*	1.44	0.25	1.69	0.20	0
Northern giant petrel (*Macronectes halli*)	1.08	0.06	1.13	0	0
White-chinned petrel (*Procellaria aequinoctialis*)	1.44	0.06	1.50	0	0
Sooty sheawater (*Ardenna grisea*)	0.02	0.00	0.02	0	0
Pink-footed shearwater (*A. creatopus*)	4.25	0.36	4.61	0	0
Kelp gull (*Larus dominicanus*)	0.19	0.25	0.44	0	0
Peruvian pelican (*Pelecanus thagus*)	0.77	0.39	1.16	0.11	0.01
Total	13.16	2.28	15.44	0.35	0.01

6. CURRENT STATUS OF THE COMBINED CURTAIN SYSTEM

Monitoring of the CCS is ongoing to enhance guidelines for its maintenance and deployment in future training packages for crew members onboard trawl vessels, as explored in the same fishing grounds using tori lines in Chile (Suazo et al. 2014, 2019). Based on these experiences, we have identified the CCS as a safe mitigation measure for crew members and as effective in reducing the frequency of collisions with cables for both small and large seabird species, including shearwaters and albatrosses, respectively.

In March 2024, we submitted a technical report for advisory to SUBPESCA's management committee for the hake fishery, presenting evidence for updating current regulations on mitigation measures for trawl vessels in Chile and the updating processes of the NPOA-Seabirds by SUBPESCA. Consequently, these materials (minimum standards package of materials, dimensions, performance, and training modules) are also being prepared for pilot sessions to train crew members of trawl fleets associated with the Industrial Fisheries Association of the Biobío Region.

An important aspect is the strong link between the presence of netsonde and seabird bycatch, as well as their impact on the fishing performance of demersal trawl fisheries in Chilean waters (e.g., Adasme et al., 2019; Richard, Y. & L. Adasme, 2019). In this regard, evidence and tailored mitigation guidelines for netsonde remain a priority.

This study represents the first contribution from the Humboldt Current to understand the role of curtain systems like Bird Bafflers across various fleets (e.g., Cleal & Pierre, 2016; Cleal et al., 2016; AFMA, 2017) and their complement with the netsonde curtain.

Therefore, this experience contributes to diversifying measures and will inform the update of regulations on mitigation measures applicable to the entire national fleet of trawl vessels currently in place for Chile. It also enhances our understanding of mitigation measures that require further evidence to recommend them as efficient solutions (e.g., ACAP, 2023).

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