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Discard management as a seabird bycatch mitigation tool: Results from further batch-discard trials in the Falkland Islands trawl fishery

Amanda Kuepfer, Joost Pompert

SUMMARY

In trawl fisheries, incidental seabird mortality is driven by the foraging opportunities provided through fish waste discard. Limiting these foraging opportunities by managing this discard such as through strategic discharging has been shown to reduce the risk of seabird bycatch. In line with key objectives of the Falkland Islands National Plan of Action for Reducing Incidental Catch of Seabirds in Trawl Fisheries (FI-NPOA-S-T), the Falkland Islands Fisheries Department is conducting experimental studies in relation to discard management. With the arrival of a second vessel equipped with a discard storage system in the Falkland Islands trawl fleet, further batch-discard trials were carried out to evaluate effectiveness and limitations. Using three distinct discarding treatments (zero discarding, batch discarding and continuous discarding) during trawling activities, we assessed the effect of discard management on the level of seabird bycatch risk. Effects of experimental treatments were assessed using the abundance of high-risk species (black-browed albatross *Thalassarche melanophris* and giant petrel species *Macronectes spp.*), as well as the rate of contacts these birds incurred with the fishing gear. The results from preliminary analyses show significantly reduced abundance and contact rates in the presence of waste management and highlight the importance of adequate storage periods and a swift discharge mechanism. The work adds support to the current ACAP recommendations relating to waste management.

1. INTRODUCTION

1.1. Background

In the Falkland Islands trawl fishery, the presence of fisheries waste has been identified as the most important factor to determine seabird interaction and incidental mortality (Sullivan & Reid 2003; Sullivan et al. 2006; Kuepfer 2016). Fisheries waste includes unwanted whole fish and processing waste (offal), and is collectively also referred to in this report as ‘discard’. The most recent estimates from 2015-2016 suggest a seabird mortality rate of minimum 1046 in the commercial trawl fleet of the Falkland Islands, of which 60% were the result of heavy warp strikes and a further 4% the result of tori-line entanglements (Kuepfer 2016). The remainder of mortalities were net-related (Kuepfer 2016). The species most prone to incidental catch in the Falkland Islands trawl fleet are the black-browed albatross (*Thalassarche melanophris*) and, to a lesser extent, giant petrels (*Macronectes spp.*).

Whilst mitigation devices such as bird scaring lines (also known as tori-lines) have shown to reduce contact rates with the fishing gear, numerous issues relating to their practical, safe and effective use have been identified (e.g. Snell et al. 2011; Løkkeborg 2011; ACAP 2016; Kuepfer 2016). Reducing the attractiveness of trawlers to seabirds should reduce the need to rely on such mitigation devices (e.g. Pierre et al. 2010).

Managing fish waste through discard retention and strategic batch discarding has been shown to successfully prevent cable strikes and reduce the risk of incidental seabird mortalities (e.g. Abraham et al. 2009; Pierre et al. 2010; Pierre et al. 2012; Kuepfer et al. 2016). The Falkland Islands Fisheries Department (FIFD) acknowledges the potential of discard management as an effective long-term solution to the issue of seabird bycatch under the Falkland Islands National Plan of Action for Reducing Incidental Catch of Seabirds in Trawl Fisheries (FI-NPOA-S-T, Quintin & Pompert 2014), and is investing in targeted research and development to assess options for the Falkland Islands trawl fleet.

With the arrival of a second trawl vessel with a retro-fitted discard storage tank, and the first system to store all waste, this study is the second of its kind in the Falkland Islands to evaluate the effectiveness of temporary discard storage and batch discarding on reducing seabird interactions in the demersal finfish trawl fishery. Using three distinct discarding treatments, the effect of discard management on bycatch risk was measured based on seabird abundance and warp-related contact rates of high-risk species.

2. METHOD

2.1. Vessel and waste management system

The study was conducted aboard a 48 m Falkland Islands-flagged stern trawler targeting demersal finfish in Falkland Island waters. The vessel’s factory had been retro-fitted with a discard storage system consisting of two tanks totalling 3 m^3.The system was designed to collect and temporarily store all of the factory’s fish waste.

The main tank (tank 1) was built to receive and store all whole fish and solid processing waste (heads, tails and ray skins). When full, this tank emptied directly out to sea at portside through the manual operation of a hydraulic door. The maximum possible storage time of tank 1 was intended to be two hours, depending on catch species and processing rate.

The second tank (tank 2) collected all remaining processing waste (guts and soft tissue from squid) via a suction system. Depending on catch species, tank 2 was intended to store waste for up to five hours. When the tank reached capacity, the tank was emptied through a pipe at starboard via a manually operated hydraulic system.

2.2. Experimental set-up and data collection

The study was carried out by the FIFD Seabird Observer over a period of 19 days, from 10 – 28 April 2017. Three experimental discard treatments were implemented: zero discarding, batch discarding and continuous discarding (Table 1). Prior to commencing the study, treatments were assigned to trawls according to a randomised block design, with a total of 40 observed trawls estimated to take place during the study period. Normal fishing practices occurred during the study period, and obligatory bird scaring lines (tori-lines) were deployed during all trawling activities. For practical and safety reasons, factory water discharge continued whenever factory work was in progress.

Table 1 Discard treatments used in the study.

Treatment	Definition
Zero	No discard of any kind was discharged (no factory work in progress).
Batch	All processing waste and unwanted whole fish was temporarily stored before being batch discharged. Batch discharges occurred as and when the tanks reached capacity or when factory work had been completed. Between the batch discharges, filtered factory water continued to be discharged at a continuous rate.
Continuous	All waste was discharged on a continuous/ ad-hoc basis as and when it became available.

The effect of the three discard treatments on seabird interactions were measured using two proxy variables for bycatch risk: abundance of commonly present high-risk species groups (black-browed albatross and giant petrel species), and the number of contacts these species groups incurred with the fishing gear during observation periods.

Abundance was assessed separately for each species group in three defined areas at the stern of the vessel (summarised in Table 2) through a series of sweep counts, after Abraham et al. (2009). The sweep counts were conducted at the start of every 5 min sub-sample period for the 40 m area counts, and at 2 min intervals for the danger area counts. Contacts data were collected during 10 min sample periods as per the FIFD Seabird Monitoring Protocol (FIFD 2017).

In addition, data collection involved a suite of environmental and operational variables at the start of every 10 min sample period, or whenever a variable changed (in which case a new sample period was started). These variables included discard level (the volume of discard discharged), discard rate (the frequency at which it was discharged), discard type (whole fish, guts, head/tail, all offal, factory water), discard size, wind speed and direction, sea state, weather conditions and the number of vessels in the vicinity.

Observation periods for the purpose of this study were confined to trawling activities, although additional observations of shoots and hauls were conducted for standard FIFD seabird monitoring work. For the zero discarding treatment, observation periods per trawl were typically 60 min. Observation periods for treatments with discard (batch or continuous) were typically longer to also allow collection of standard FIFD seabird interactions data.

Table 2 Areas at the back of the stern used for abundance counts.

Category	Definition
40 m semi-circle from the stern (water)	Birds on water counted at the start of every 5 min sub-sample period.
40 m semi-circle from the stern (air)	Birds in air counted at the start of every 5 min sub-sample period.
Danger area (water)[1]	Area between tori-lines (ca. 30 m x 10 m) where birds were most likely to come into contact with the warp cables. Birds on the water counted every 2 min.

[1]These data were only collected as of day 6 of data collection.

2.3. Data analysis

To assess the effect of discard treatments on seabird abundance, a separate one-way ANOVA with post-hoc Tukey HSD test was carried out for each species group and each count area. For the 40 m counts, analyses were conducted on the raw data. For the danger area counts, analyses were conducted on the averages obtained for every 10 min sample period. Preliminary one-way ANOVAs with Tukey HSD post-hoc tests were also run to compare average contact rates in relation to each of the three discard treatments, with data pooled by trawl for each discard treatment. Other environmental and operational variables were not considered in this preliminary analysis due to the relatively small sample number. All analyses were performed in the R statistical package (R core team 2015).

3. RESULTS

3.1. Data overview

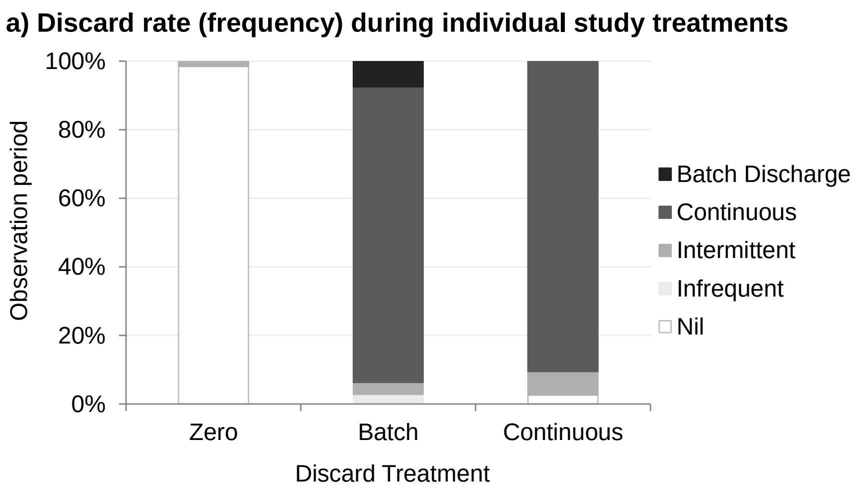
Table 3 summarises the data collected for each discard treatment during the 16 days of fishing conducted and observed. Two to three trawls were conducted per day (total of 34 trawls). Due to adverse weather conditions, total fishing days and trawl numbers were lower than predicted. For technical and operational reasons, it was not always possible to follow the randomly allocated treatment schedule. Due to hauling times and early hours of darkness, the zero discarding treatment could only be applied during the morning trawl (between ca. 0800 and 1300 local time) when no factory work was in progress. The batch and continuous discarding treatments were generally randomly applied to the afternoon trawls (between ca. 1300 and 1800); however, in order to resolve tank issues during the first week, the batch discarding treatment was initially applied more often than was randomly allocated.

Table 3 Summary of data collected over 16 days of fishing between 10 and 28 April 2017.

Discard treatment	Number of observations conducted					
	Days	Trawls[1]	Hours	40 m counts	Averaged danger area counts	Contact periods
Zero	16	16	16.07	204	107	107
Batch	12	13	26.35	324	126	241
Continuous	9	9	18.97	206	97	207

[1] Note that during some trawls, more than one discard treatment was applied.

Figure 1a and b summarise the relative amount of discard discharged during individual treatments. The 20 min of (intermittent) low levels of discard that was recorded during the zero discarding period was the result of organic kitchen waste being thrown out which influenced bird interactions. For the batch discarding treatment, discard levels were initially of low levels until the issue of the ray skins and fish tails was resolved, and subsequently were generally always of negligible levels. Negligible discard levels consisted exclusively of factory water with generally no visible particles but some discolouring of the water.



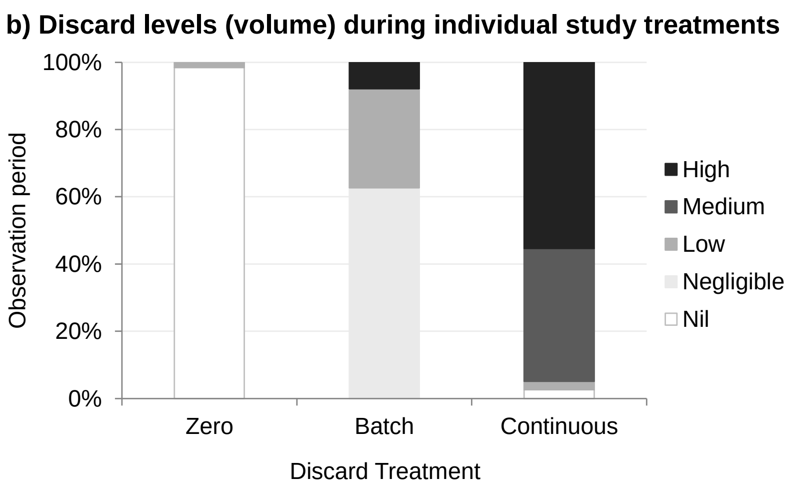


Figure 1 Frequency and level of discard made available during the study treatments (total observation time = 61.39 hrs).

For batch discard treatments, storage periods were measured from the time batch discharging stopped until the next batch discharge (of either tank) started. Tank 2 was rarely discharged during observation periods due to its long storage capacity. However, a technical issue with tank 1 meant that large volumes of water needed to be added to the tank to avoid blockages, and this reduced its storage periods considerably. Overall, discard storage times averaged 18 min, and ranged from 3 to 42 min (Figure 2). Storage periods shorter than 7 min were the result of the two tanks being emptied within a short timeframe of one another. Batch discharge events were always recorded as full minutes and averaged 1.5 min (spread of 1 to 5 min). Batch discharges that exceeded 3 min in duration were generally the result of the second tank being emptied shortly after the first tank had finished emptying. Overall, observations of the batch discarding treatment involved 24.28 hours of discard storage, 1.97 hrs of batch discharge events and 6 min during which a problem with the door of tank 1 resulted in continuous discarding of high levels of discard.

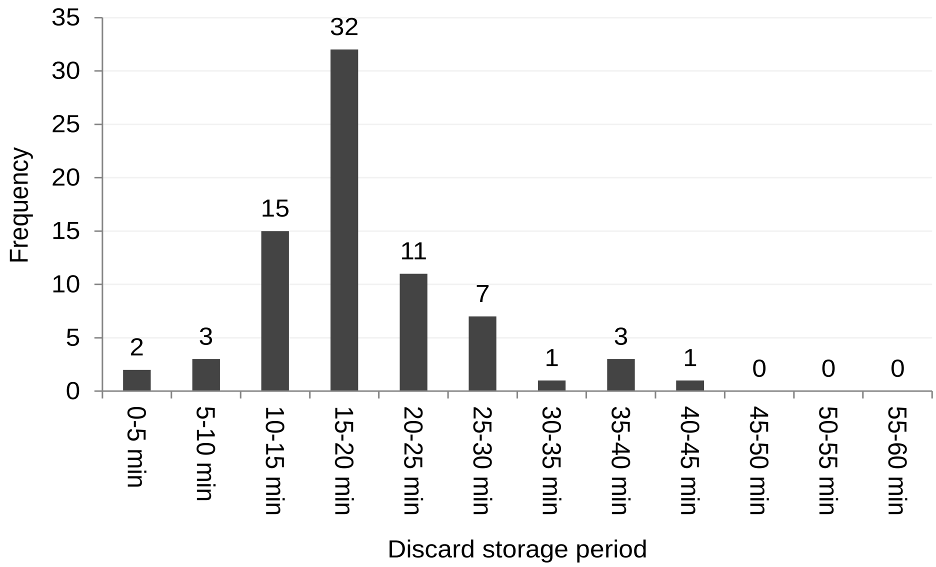


Figure 2 Histogram showing the frequency of various storage periods achieved during the study.

3.2. Discard treatment effect on seabird abundance

The number of black-browed albatrosses and giant petrel species differed significantly between discard treatments (Table 4; Figure 4). Continuous discarding held the highest average bird numbers in all count areas. Temporarily storing discard reduced bird presence significantly, with the greatest level of reduction observed within the danger area, which experienced an overall 83.5% decrease in mean bird abundance compared to when discard was released continuously (see an example of the difference in Figure 3). This observation held true even when data for 40 m counts were restricted to the reduced period during which the danger area counts were collected (results not presented here). Compared to continuous discarding, batch discarding reduced mean bird abundance in the 40 m area by 27.7% and 20.7% for birds on the water and in the air, respectively. The batch discarding treatment did attract significantly higher average bird numbers compared to when there was no discharge of any kind. Although a low number of birds generally remained present within 40 m from the vessel during zero discarding (overall 2.8% of the average number of birds present during continuous discarding), no birds entered the danger area during this treatment at any time.

It should be noted that, during batch discharge events, seabird abundance on the water increased instantly and substantially, but decreased again within two minutes to below the average number of birds present during storage periods as the vessel moved away at trawl speed from the discard patch. Bird numbers resumed their average levels roughly 2 to 5 min after a batch discharge event had occurred. This rapid change in bird numbers was not captured in the count data.

Table 4 The mean abundance of black-browed albatrosses and giant petrels present in each count area during the various discard treatments. The asterisks highlight the level of significance from the control treatment (continuous discarding), as derived from the one-way ANOVA test: ** = significant at p<0.01, *** = significant at p<0.001 **** = significant at p<0.000.

Discard treatment	**Black-browed albatross**			**Giant petrel spp.**		
	40 m (water)	**40 m (air)**	**Danger area**	**40 m (water)**	**40 m (air)**	**Danger area**
Zero	2.58****	1.62****	0.00****	0.94****	0.65****	0.00****
Batch	72.20****	36.11****	3.56****	39.35****	6.33**	3.01****
Continuous	96.14	45.23	24.60	58.24	8.32	15.27

a) b)

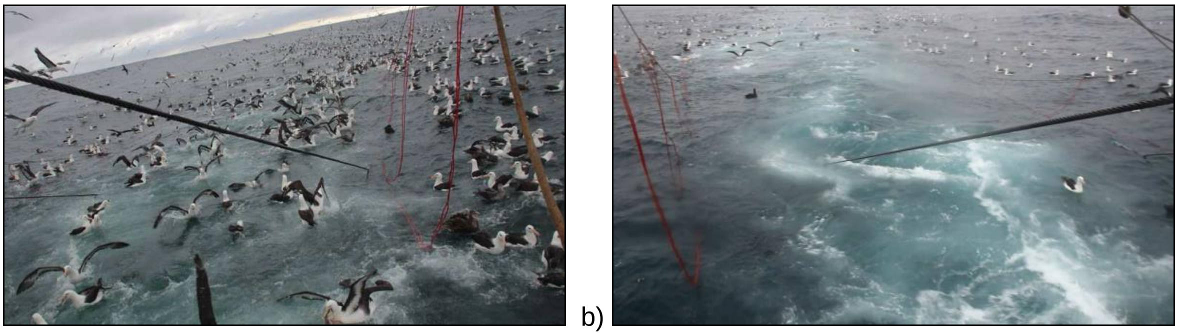


Figure 3 Example of bird presence inside the danger areas during periods of (a) continuous discarding; (b) discard storage (factory water present only).

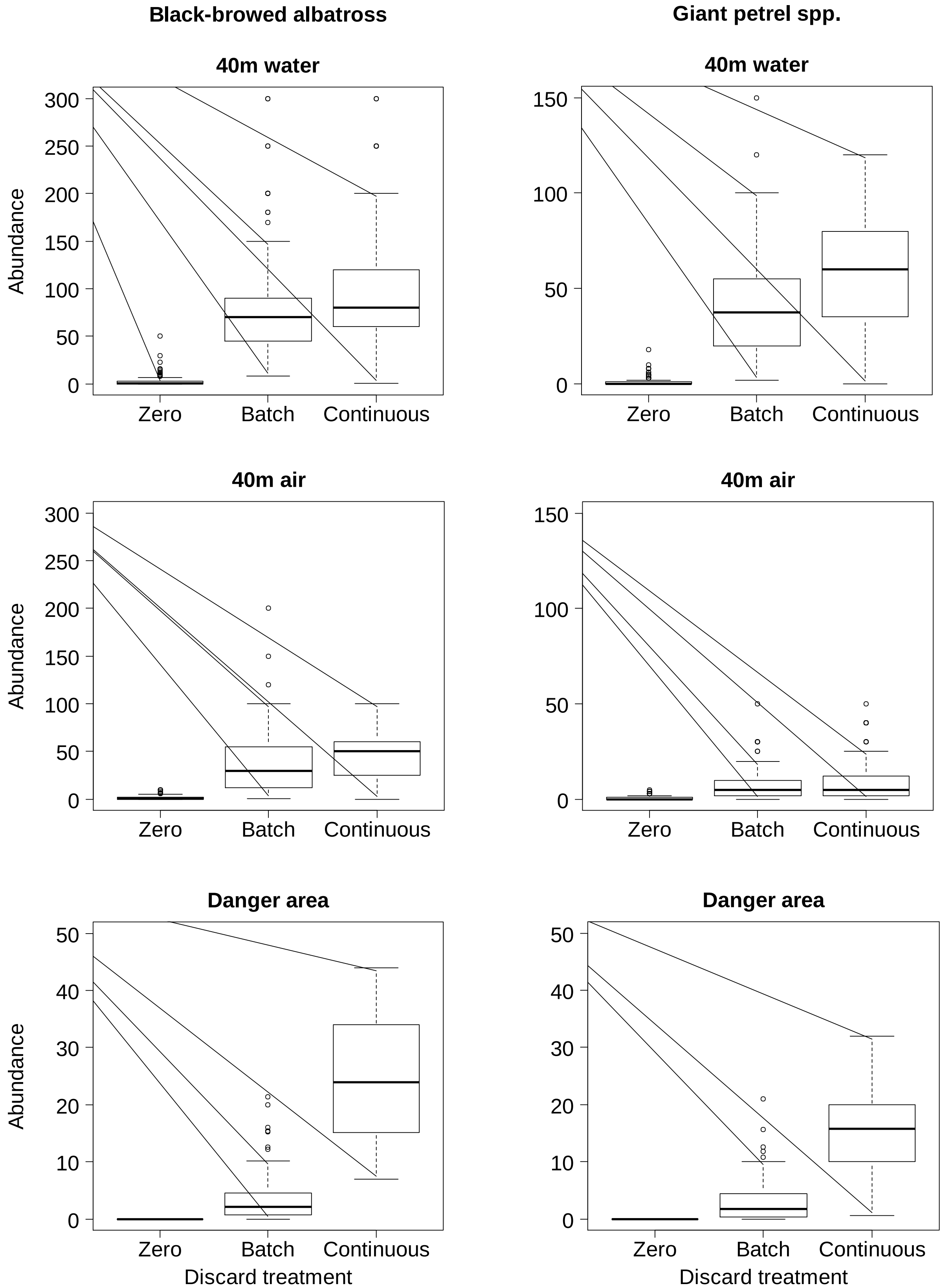


Figure 4 Boxplots showing the relative abundance of black-browed albatross and giant petrel species present during the three discard treatments. Note the difference in scale.

3.3. Discard treatment effect on contact rates

A total of 5192 contacts were recorded between high-risk species and the warp cable during 61.39 hrs of contacts observations. Thirteen percent (n=668) of contacts were heavy interactions, and resulted in mortality (n=5), possible serious injury (n=4), possible minor injury (n=2), unknown fate (n=109), and no apparent damage (n=548).

For both species groups, the continuous discarding treatment experienced the highest average contact rates, including total contacts, heavy contacts and harmful or potentially harmful contacts. In comparison, the batch discarding treatment saw a significant reduction in average contact rates (Table 5; Figure 5), with overall heavy contacts and contacts of potentially harmful fates reduced by 80.5% and 88.2%, respectively. Contact rates during the batch discarding treatment were substantially higher than during zero discarding, although this difference was not statistically significant. No contacts occurred during the zero discarding treatment. During the batch discarding treatment, 72.1% of all contacts occurred during batch discharge events (Figure 6).

Incidental Mortalities

Ten incidental mortalities were recorded, all black-browed albatrosses. Five of the mortalities were recorded during trawling observations, and the remaining during hauling observations. At least 80% of mortalities occurred during continuous discarding. At least one mortality occurred during the batch discarding treatment during a batch discharge event.

Table 5 Average contact rates for the three discard treatments. H = Heavy contacts; HF/ U = Contacts that resulted in harmful or unknown fates. The asterisks highlight the level of significance from the control treatment (continuous discarding), as derived from the one-way ANOVA test: * = significant at $p<0.05$, ** = significant at $p<0.01$; *** = significant at $p<0.001$, **** = significant at $p<0.000$.

Treatment	Black-browed albatross			Giant petrel spp.		
	All	**H**	**HF/ U**	**All**	**H**	**HF/ U**
Zero	0*	0**	0**	0****	0****	0**
Batch	17.42*	2.39*	0.46*	18.41***	3.00****	0.19*
Continuous	121.56	11.39	4.00	102.37	16.29	1.48

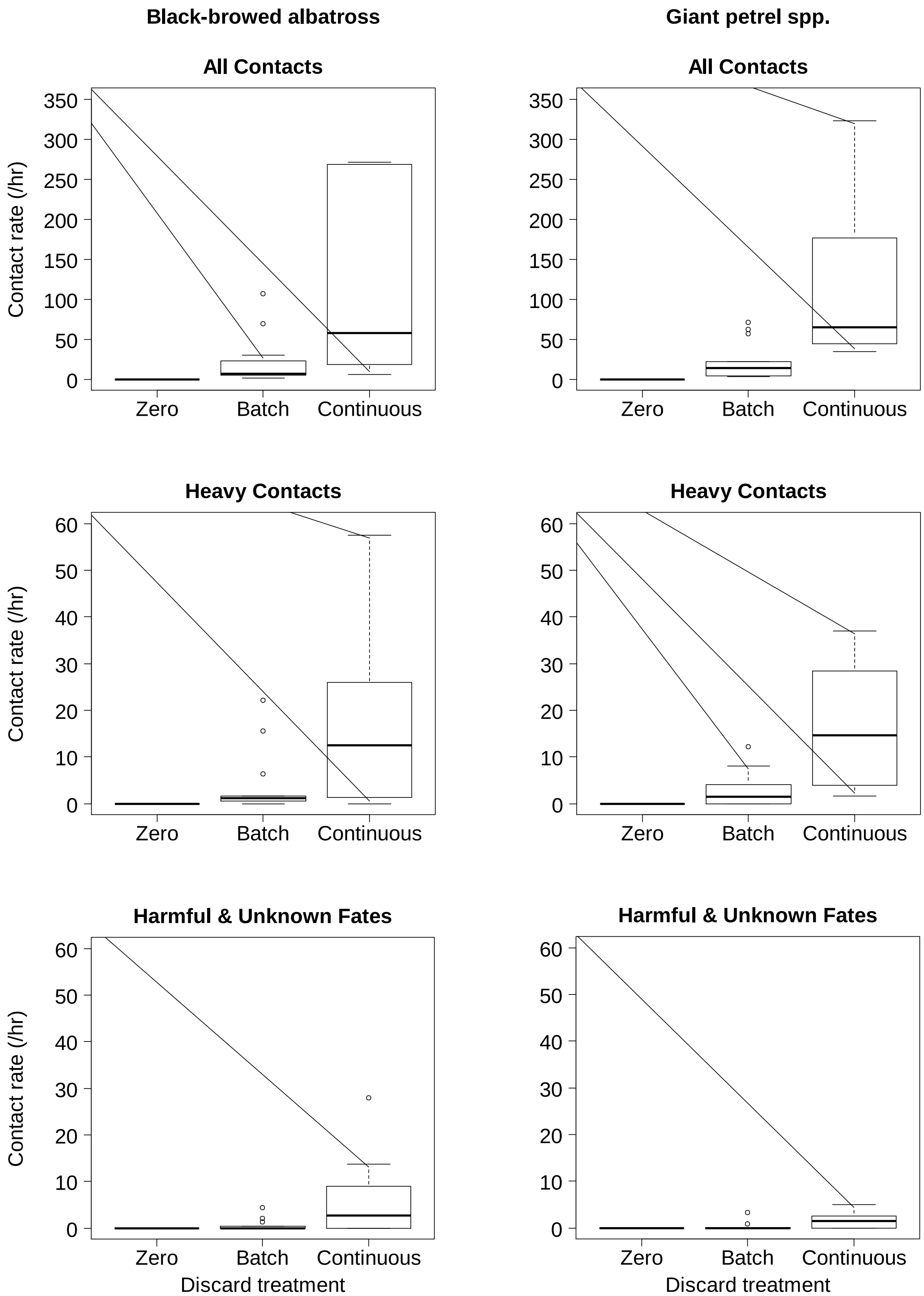


Figure 5 Boxplots showing the average contact rates by black-browed albatross and giant petrel species with the warp cable during the three discard treatments. Note the difference in scale.

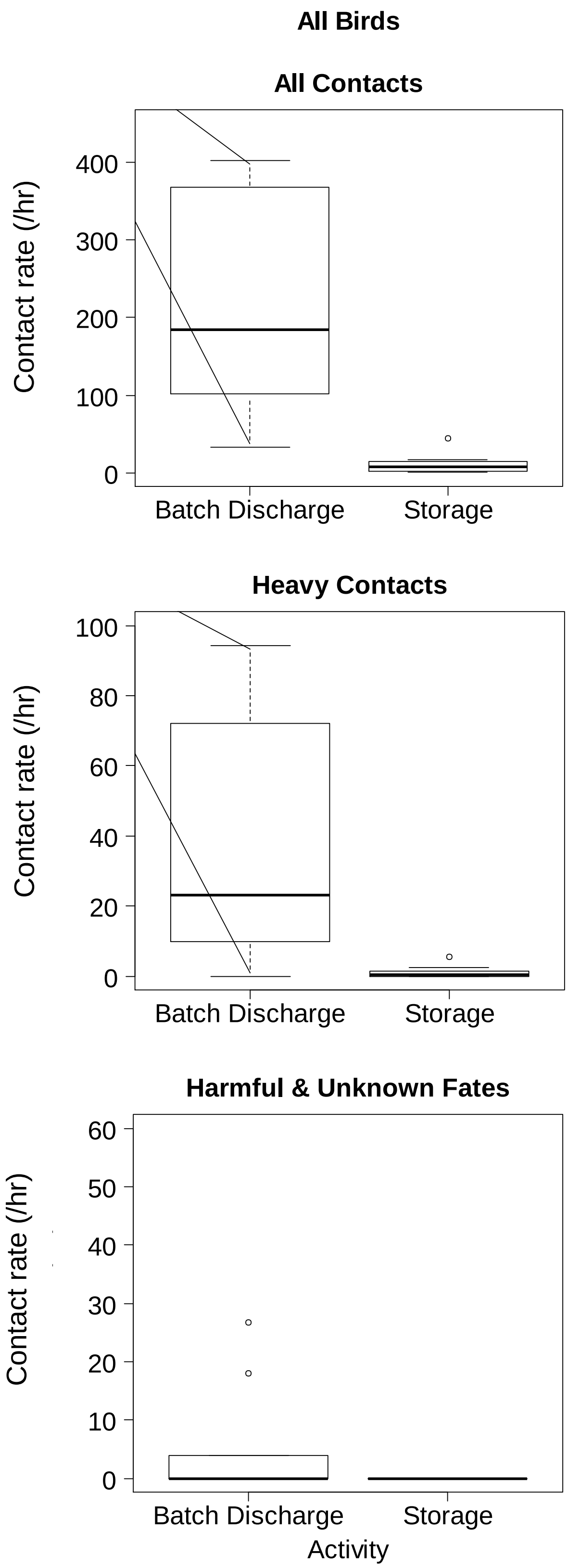


Figure 6 Boxplots showing the average contact rates incurred by high-risk species (here black-browed albatross and giant petrel species) during batch discharges and storage periods. Note the difference in scale.

4. DISCUSSION

4.1. Discard management effect on seabird interactions

Despite some of the practical issues encountered during the short study period, it was possible to collect appropriate data to assess the effect of discard management on seabird-vessel interactions. Consistent with previous findings (e.g. Sullivan et al. 2006; Abraham et al. 2009; Løkkeborg 2011; Melvin et al. 2011; Pierre et al. 2010; Pierre et al. 2012; Pierre et al. 2014; Kuepfer et al. 2016), our results demonstrate that discharging unwanted whole catch and processed fish from fishing vessels attracts seabirds, and that eliminating all discards can successfully discourage high-risk species such as black-browed albatrosses and giant petrels from the area where they are most at risk from being struck by warp cables. In our current study, zero discard attracted zero birds into the danger area and resulted in zero contacts. Over 80 hours of FIFD data collected during zero discarding have shown the same result (FIFD unpubl. data; also see e.g. Sullivan et al. 2006; Pierre et al. 2014).

Concurrent with previous findings (including Kuepfer et al. 2016), we further show that discharging discard continuously on an ad-hoc basis is the least favourable form of discard management as this treatment attracted the highest numbers of seabirds and incurred the highest numbers of warp contacts and mortalities. Temporarily storing discard and batch discharging it significantly reduced the average number of large high-risk seabirds in the 40 m count areas, and particularly, in the danger area. When discard was present, it generally drifted through the danger area, encouraging birds into that region. In contrast, black-browed albatross and giant petrel species were rarely seen to feed when only factory water was being discharged (unlike the much smaller Cape petrels (*Daption capense*)), and thus their bycatch risk was minimised. This was reflected by a significant reduction in contact rates and mortality incidents during batch discarding treatments. Various studies have used seabird abundance as a proxy for contact rates and mortality risk (e.g. Middleton and Abraham 2007; Abraham et al. 2009; Pierre et al. 2010; Pierre et al. 2012; Kuepfer et al. 2016; but see e.g. Melvin et al. 2011). The current study supports this method, having shown consistent patterns of the three variables used in conjunction.

In our initial study (Kuepfer et al. 2016), the decrease in giant petrel species inside the danger area was not significant when discard was batch discharged compared to when discard was being continuously discarded. Kuepfer et al. (2016) speculated that this may have been due to the bird-scaring effect of the tori-line, which encouraged giant petrel species to feed mostly outwith the danger area. In the current study, giant petrel species were visibly more inclined to feed inside the danger area when discard was present. This difference in behaviour may be the result of various factors, including environmental, seasonal, intra-specific or vessel-specific.

In comparison to zero discarding, the batch discarding treatment did see significantly higher seabird abundance and substantially higher contact rates. Given the relatively short storage periods, it is not clear whether it was the presence of factory water, the fairly frequent batch discharges or a combination of these that kept birds in the vicinity. Pierre et al. (2010) did find significant increases in seabird abundance between zero discharge and factory water discharge, but also found that proportionately more birds attended the vessel in the air during shorter holding periods in order to forage when discard became available. Furthermore, Pierre at al. (2010, 2012) found that the number of large seabirds attending the vessel decreased significantly after holding periods of 2-4 hrs, with 8 hrs being still preferable.

During the batch discarding treatment, almost three quarters of all contacts occurred during batch discharging periods, which represented 8% of the entire batch discarding treatment time. At least one observed mortality occurred during these batch discharges. This highlights the importance of prolonged storage periods and a discharge system that disposes of discard as swiftly as possible to minimise compromising the prolonged storage periods.

4.2. Further work

Our preliminary analysis conducted does not currently account for the time-dependent nature of the data, nor does it consider the effect of other environmental and operational variables. Whilst our current results nevertheless compare with previous findings, further analyses using mixed effects models or Bayesian methods for more robust results are envisaged. In addition, whilst previous work to date consistently shows that longer holding periods are preferred (e.g. Pierre et al. 2010; Pierre et al. 2012), further research is recommended to determine the minimum holding period required to reduce interactions and mortalities of high-risk species to negligible levels.

4.3. Waste storage systems: design implications

The waste management system used in the current study highlighted various design aspects that are useful to consider in future installations of similar systems.

i) For reasons of practicality and compliance, waste storage tanks should be automated, either through automatic discharging or through alarm sounding when capacity is reached.

ii) Tanks that empty via gravity should ideally have a steeply inclined floor to reduce the risk of blockage and accelerate batch discharges.

iii) Steeply inclined conveyor belts intending to transport soft tissue such as ray skins or guts need to be adequately designed to avoid these tissues tumbling off.

4.4. Summary

The volume of fish waste discharged from Falkland Islands finfish trawlers is substantial, and is the prime cause for seabird-fisheries interactions. Reducing the attraction of seabirds to the vessels by managing this discard is key to reducing bycatch. If full waste retention is not an option for reasons of vessel configuration, batch discarding can still result in a significantly reduced bycatch risk. The minimum storage period required to significantly reduce interactions has varied between work and as such the longest storage periods possible are recommended. Based on peer-reviewed publications, ACAP best practice guidelines currently recommend a minimum storage period of 2 hours, preferably 4 hours (ACAP 2016).

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