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EXECUTIVE SUMMARY

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This report contains an analysis of data on seabird warp strike collected by fisheries observers. The survey was carried out in the Auckland Islands squid fishery (SQU6T/1T) over the summer of 2004–05. The key results are listed below.

- There were 904 good observations made from 526 separate tows, on 19 different vessels.
- A total of 789 large bird heavy contacts were observed, an average rate of 3.5 heavy contacts per hour (c.v. 9%).
- The number of small bird heavy contacts was lower, with 306 contacts over the entire survey. This corresponds to an average rate of 1.4 per hour (c.v. 12%).
- Offal discharge was the most significant factor associated with large bird strikes.
- Discharging offal increased the large-bird strike rate by an estimated factor of 6, compared with no offal discharge.
- The strike-rate for large birds decreased by an estimated factor of 2 when bird bafflers were used.
- Higher small-bird strikes were observed at higher discharge rates, and the small-bird strike rates were not strongly dependent on discharge type.
- Less than half of the vessels observed used bird bafflers. More than half of the vessels discharged offal on more than 20% of the tows.
- A total of 106 dead or injured birds were recovered from the tows, a rate of 0.2 birds per tow (c.v. 13%).
- The discharge of offal was the factor most significantly associated with the recovery of dead and injured birds from the warps.
- Recovery of dead or injured birds from the warp was significantly associated with the warp strike rate.

CONTENTS

1. INTRODUCTION

Seabirds may be killed by collisions with warps during trawl fishing, either while the birds are in the air or on the water (Wienecke & Robertson 2002; Sullivan et al. 2006a, 2006b). Fisheries observers routinely record the numbers of seabirds that are killed and brought on board vessels (e.g. Baird 2005), however the occurrence of warp strike in New Zealand trawl fisheries is unknown. To begin gathering information on rates of warp strike, observers conducted a survey in the Auckland Islands squid trawl fishery (targeting the arrow squid, *Notodarus spp.*, in areas SQU6T/1T), during the 2004–05 season. The primary aims of the survey were to test whether warp strike could be successfully monitored by observers, and to determine the factors that influence warp strike in this fishery.

The use of observers allowed a good coverage of the fishery to be achieved, with strike observations being made on 19 vessels. Each observer was asked to monitor heavy contacts of seabirds with the trawl warps for 15 minute periods, with observations being made while the vessel was fishing. A complete copy of the instructions, and of the survey form, is given in Appendix A. Only heavy contacts, where a bird was deflected from its flight path or moved through the water, were counted. The contacts were classified as either large birds (albatrosses, mollymawks, and giant petrels) or small birds (petrels, prions, storm petrels, gannets, gulls, and shags). No attempt was made to record the likely fate of the birds after the contact (i.e. whether or not the strike was likely to be fatal), however any recovery of dead or injured birds onto the vessel was also recorded.

The information collected is to be used in developing actions to reduce the incidental mortality of seabirds within the fishery. In this report, the survey data are analysed. As part of the strike observations, other data (such as the type and quantity of discharge, wind and sea state) were recorded. Brady bird bafflers (Crysel 2002) were used in this fishery to help reduce the impact of fishing activity on the seabird populations. Whether or not bafflers were used during an observation was also noted., and this allows their efficacy to be determined. Some discussion on how the protocol could be improved is included in Appendix B.

2. DATA SUMMARY

2.1 Number of observations

A total of 1094 observations were made, of which 190 (17%) were excluded from the analysis. Reasons for excluding observations are given in Table 1. Some of these rejections are inevitable, but the rejection rate could be reduced by observer training. In particular, missing data accounted for the rejection of 86 observations. It is expected that this number could be reduced, and a rejection rate of less than 10% should be achievable. All observations from one observer were excluded, as it became clear during the post-voyage debrief that they had not adequately followed the instructions given with the protocol.

In addition to the rejected observations, other observations also contain missing data. In general, the rate of missing data is less than 2% for each field.

Table 1: Rejected observations, giving the number rejected for each reason

Reason	Number
Observer unreliable	45
Bird abundance data missing	37
Bird strike data missing	27
Sample interval not 15 minutes	17
Net haul started during observation	13
Discharge rate data missing	11
Baffler use not recorded	11
Other reasons	5
Poor visibility	5
Incinerator running on deck	4
Practice observation	4
Discharge changed during observation	4
Observation abandoned before completion	4
Significant change in wind	2
Vessel turned	1
Total	190

2.2 Vessels, observers, and tows

Observations were retained from 18 different observers and 19 different vessels. The vessels ranged in length from 43 to 98 m, with a median length of 86 m. Engine power ranged from 193 to 6000 kilowatt, with a median of 3700 kilowatt. The vessel data were obtained from the Fisheries Information System (FIS). More information on the tows (such as catch size and tow length) could have been obtained from observer data, but this was not available at time of writing. Only vessel characteristics (length, engine power and nationality) were included. The nationality should be crew nationality, but may sometimes be recorded as the flag state. The data were accepted as provided by the Ministry of Fisheries.

The observations were taken from 526 separate tows. On 330 tows, 2 observations were made, on 172 tows only 1 observation was made, and on 24 tows 3 observations were made. The number of tows recorded per trip varied widely (between 8 and 66), and this was reflected in a wide range of observations per trip (15 to 127), with the median being 42.

2.3 Environmental conditions

Observers recorded swell height (m) and direction relative to the ship heading. A direction from 1 to 12 was used, following a clock face, with the 12 aligned with the ship heading. The Beaufort scale was used to estimate the wind speed, and a similar 1 to 12 ship-relative scale was used for the ship direction.

A wide range of swell and wind conditions was encountered, with the swell ranging in height between 0 and 7 m (median of 2 m) (Figure 1), and the wind speed ranging between Force 0 and Force 9 (median of 4) (Figure 2).

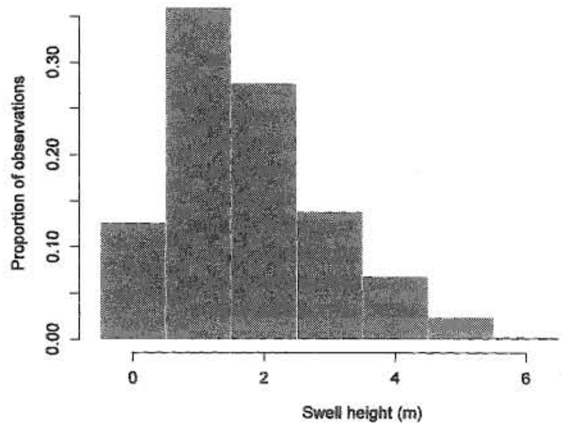

Figure 1: Summary of recorded swell heights.

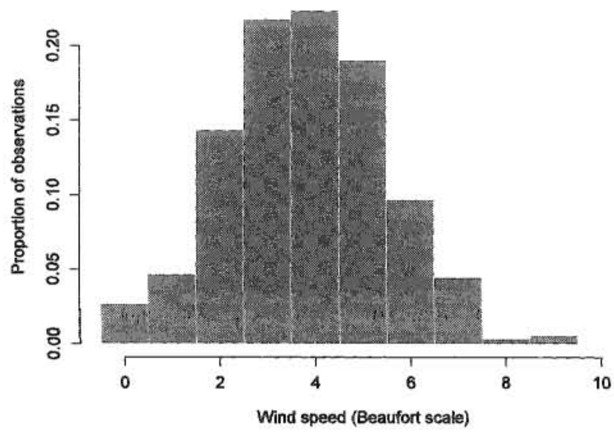

Figure 2 Summary of recorded wind speeds.

2.4 Time of day

Observers were asked to make observations throughout the day, with at least one warp strike observation during each hour of daylight. Good coverage was achieved between 5:40 a.m. and 8:30 p.m., with a few observations outside those hours (Figure 3).

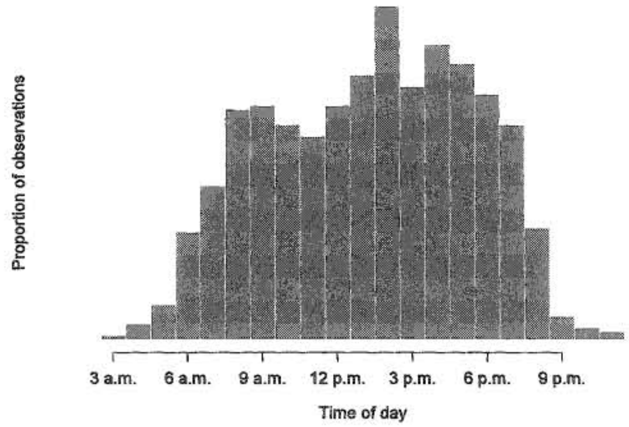

Figure 3: Frequency of observations taken during each hour of the day.

2.5 Discharge

Discharge rate was categorized as either 0 (no discharge), 1 (negligible), 2 (intermittent) or 3 (continuous). No attempt was made to quantify the volume of the discharge. Only one rate was recorded during each observation, and if the rate changed significantly then the observation was abandoned.

Observers successfully watched for warp strikes under a range of discharge conditions (Figure 4), with close to a third of observations being made when there was no discharge, and a quarter of observations being made with continuous discharge.

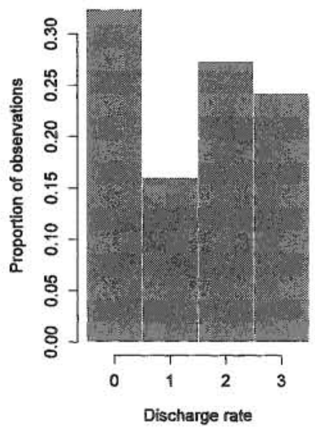

Figure 4: Summary of discharge rate.

The type of discharge was recorded. Discharge could be either sump water; minced material that had been put through a macerator; material that had been through a cutter pump and was coarser than the minced material; offal, head and guts, and other leftovers of the processed product; or discards of whole fish or squid. Other waste, such as kitchen scraps, was not recorded.

The most frequent type of discharge was sump water, followed by offal (Figure 5). The other discharge types are all observed, but occurred less frequently. More than one type of discharge was recorded on 25% of all observations.

Observations were typically made on the side of the primary discharge. This was not always possible due to the vessel set up. Where recorded, the discharge side differed from the warp observed on only 2.7% of observations.

Of the 19 vessels, 10 had meal plants. Meal plants were running during 20% of the sampled tows.

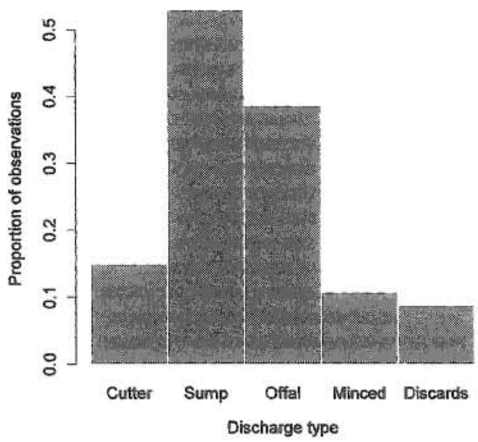

Figure 5: Summary of the discharge type.

2.6 Mitigation

A key variable recorded by the observers was the use of mitigation. Observers recorded the use of bird bafflers, tori lines, gas cannon, sonic scarers, or any other mitigation. The only mitigation measures used during the observation periods were bird bafflers. Of the 19 vessels, 8 had bird bafflers and used them on every tow; 1 vessel had bird bafflers and used them on all but 2 tows; and 10 did not have bird bafflers. While there was a relatively even split between the vessels using and not using bafflers, only 31% of the tows were recorded with bafflers.

The baffler was recorded as complete 86% of the time that it was used, and was deployed on both sides of the vessel 92% of the time. A complete baffler was deployed on both sides of the vessel 75% of the time that it was used.

2.7 Bird counts

Immediately before each observation, the bird abundance was estimated in an area surrounding the entry point of the warp (Figure 6). The bird count was characterised as 0 (no birds), 1 (fewer than 10 birds), 2 (10–100 birds) or 3 (more than 100 birds). Most observations were made with a bird abundance in category 2 (10–100 birds), for both small and large birds (Figure 7).

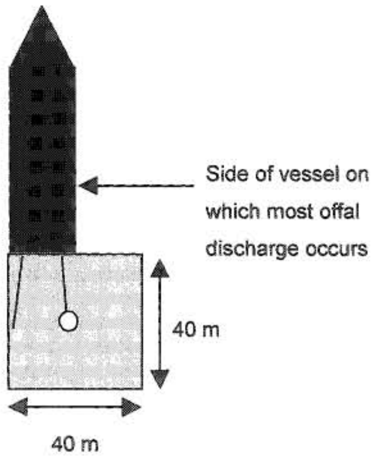

Figure 6: Area for estimating bird abundance. The warp entry point is shown as a circle, about 20 m from the stern of the vessel. The area in which seabird abundance was estimated is a square that extends 20 m on each side of the warp, and 20 m beyond the warp entry point, on the side of the vessel that the primary offal discharge is occurring during the sampling period.

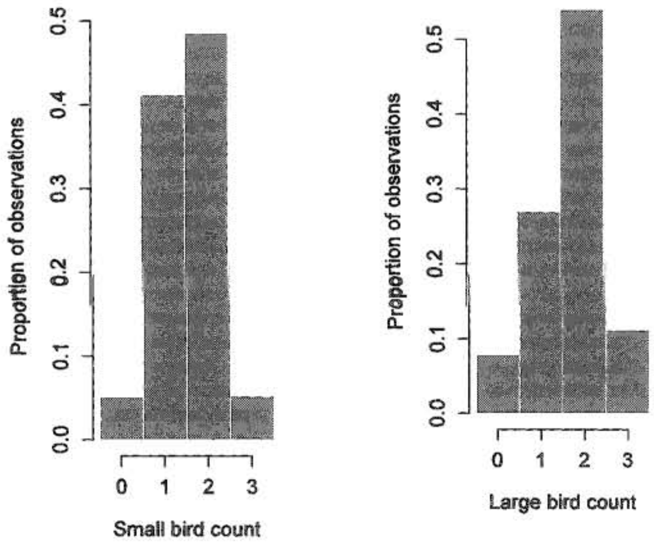

Figure 7: Distribution of bird count observations.

2.8 Bird strikes

Small bird strikes were seen during 140 observation periods, with a total of 306 small bird strikes recorded during the survey. This is equivalent to an average rate of 1.4 small bird contacts per hour per warp (c.v. 12%). The coefficient of variation is calculated using non-parametric bootstrap re-sampling of the data, with 5000 samples. The distribution of contacts has a long tail, with a maximum of 14 contacts being seen during any single observation period (Figure 8).

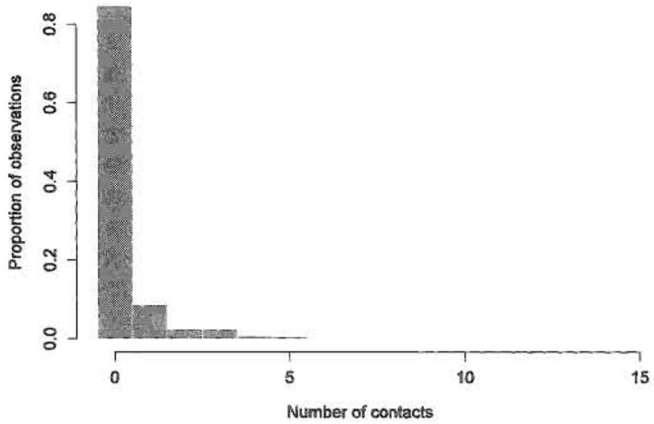

Figure 8: Frequency distribution of numbers of small bird contacts.

Warp strikes by large birds were more frequent, with heavy contacts being observed on 226 of the tows. The total number of contacts over the whole survey was 789, equivalent to an average strike rate of 3.5 contacts per hour per warp (c.v. 9%). As with small birds, the distribution of contacts has a long tail, with 86 observations having a single contact and one observation recording 35 contacts (Figure 9).

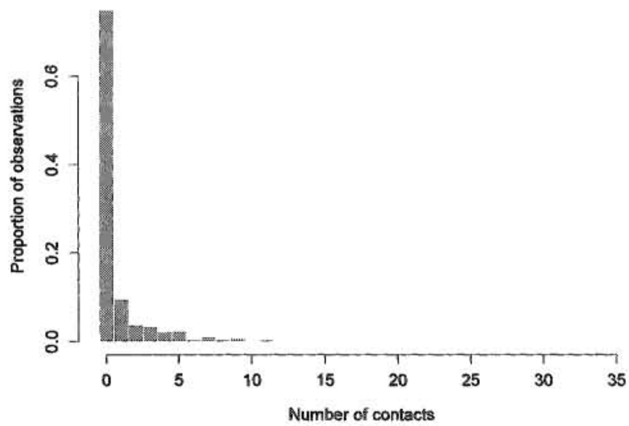

Figure 9: Frequency distribution of numbers of large bird contacts.

Observers watched a single warp: the average strike rates per hour would have been higher if strikes on both warps had been included. Because observers were asked to count strikes on the side of the primary discharge, the total strike rate may not be as high as twice the strike rate for observed warps.

2.9 Dead and injured birds

The birds recovered from each tow were recorded by observers. The birds were not classified into large and small, but were categorised by whether they had been recovered from the warp or the net, and whether they were dead or injured. The definition of an injured bird followed the guidelines given in the draft code of practice (HFMC & SFMC 2004). A bird is said to be injured if it has one or more of the following characteristics

- Broken or drooping wing
- Broken beak or leg
- Open wound
- Hook in bird (whether removed or not)

From the entire survey, 106 dead or injured birds were recovered on board the vessel, with the numbers of dead birds being evenly split between the warp and the net (Table 2). The total rate of retrieval of dead or injured birds was 0.20 birds per tow (c.v. 13%). Further information on the recovered birds is available from the observer non-fish bycatch forms, but was not ready at time of writing. A maximum of 4 birds were recovered dead or injured from the net on any single tow, with multiple dead or injured birds being recovered from the net on 7 tows. A maximum of 3 birds were recovered dead or injured from the warps on any single tow, with multiple dead or injured birds being recovered from the warps on 12 tows.

Table 2: Summary of location and state of recovered birds.

	Dead	Injured	Non-injured	Total
Warp	45	6	2	53
Net	51	0	11	62
Unknown	4	0	2	6
Total	100	6	15	121

2.10 Sprags and grease

The presence of thick grease or sprags (broken and exposed individual wires) on the warps may lead to more birds being recovered from the warps. Data on sprags and grease were recorded at the warp level. However in most cases (99% for grease and 93% for sprags) they occurred either on neither warp or on both warps. The data were converted to a presence-absence measure.

Sprags were reported on five vessels, with three always having sprags and two vessels sometimes having sprags. Warp grease was reported on eight vessels, with five always having grease, one mostly having grease, and two occasionally having grease on the warps. In total, sprags were reported in 25% of observations and grease was reported in 15% of observations.

3. MODELLING

A primary goal of the analysis is to establish the factors that are related to warp strike. Because of the many relationships between the explanatory variables it is not sufficient to simply look at the correlations between warp strike and the measured factors. Instead, a model of the warp strike rate is constructed. The model allows an estimate to be made of the average warp strike rate as a function of the measured factors.

The observations are of count data. Even given the same average contact rate, the observed count would be expected to vary between observation periods. If the average rate is unchanging, and if the rate is low, then the counts are expected to follow a Poisson distribution. However, if the mean rate varies, then it is common for count observations to be over-dispersed relative to a Poisson distribution. Indeed, the warp strike data have a long tail, with rare observations of large numbers of contacts (Figure 8, Figure 9). In this case, it is appropriate to model the count data as a negative binomial distribution (Appendix C). The dispersion is controlled through a parameter, θ. If it is assumed that θ is a constant, not depending on any of the explanatory variables, then a generalised linear model (GLM) may be used to fit the data. This is the procedure that is followed here, using methods from Venables & Ripley (1996), implemented in the open-source analysis software R (R Development Core Team, 2004).

Separate analyses were made of small bird strikes and large bird strikes, because different factors seemed to affect the two bird groups. These differences may be related to different flight and feeding behaviours. Counts of bird abundance were initially left out of the model, as bird abundance is itself affected by practices such as discharge. By comparing models built with and without abundance, an understanding can be gained of what factors control warp strike, beyond their influence on abundance. For example, the use of mitigation is expected to influence the number of warp strikes, but not to influence bird count. In contrast, discharge will cause birds to aggregate around the vessel, without independently causing warp strike.

3.1 Large bird warp strikes

3.1.1 Primary model

The model was built by initially including a full suite of potential explanatory factors (meal plant on vessel, meal plant running during tow, warp observed, sample period (1, 2, or 3), start time, baffler used, swell height, swell direction, wind speed, wind direction, discharge side, discharge rate, discharge type, vessel nationality, vessel length, vessel kilowatts, baffler complete, sprags, grease on warps). Discharge rate was included as a factor with four levels. Vessel length, vessel kilowatts, wind speed and swell height were included as numeric and factor variables. An automated step-wise approach was then used to drop terms with little power, reducing the explanatory variables to a small subset. This was achieved by minimising the Bayes information criterion (BIC), which allows a trade-off to be made between maximising the fit of the model to the data and minimising the number of degrees of freedom. Factors which occur in a group, such as discharge rate or type, were added or removed from the model together rather than singly.

After following this process, the model given in Table 3 was obtained. The predicted value of the negative binomial dispersion is $\theta = 0.52$. This model explains 49% of the deviance in the data. The significance is given by the stars, with two stars indicating a significance of $p < 0.01$, and three stars indicating that $p < 0.001$. In this table, and the other tables of model results, the explanatory variables are listed in order of decreasing significance. The most significant single factor is a discharge type of offal, with a coefficient of 1.9 (1.5–2.3, 90% c.i.). The multiplicative effect of a factor on the strike rate is obtained by taking the exponential of the product of the model coefficient and the value of the factor. This implies an increase in the strike rate by 6.7 (4.4–10.1, 90% c.i.) when offal is discharged. The deviance figures are obtained by sequentially adding the factors to the model in order of decreasing significance. The offal discharge factor on its own captures 41% of the deviance. The next most significant term is the discharge rate, with an increase in the discharge implying an increase in the warp strike rate. The use of a bird baffler reduces the warp strike rate by a factor of 1.9 (1.3–2.8, 90% c.i.). The remaining factor is the vessel engine power, with larger vessels having a lower warp strike rate.

Table 3: Factors influencing the warp strike rate, in order of decreasing significance.

Factor	Coefficient	Standard error	Significance	Deviance
Intercept	-4.01	0.73	***	Initial: 892
Discharge type offal	1.90	0.21	***	370
Discharge rate 3	3.68	0.75	***	51
Discharge rate 2	3.44	0.75	***	
Discharge rate 1	2.50	0.76	**	
Baffler used	-0.63	0.21	**	7
Vessel kilowatts	-2×10^{-4}	6×10^{-5}	**	9
				Residual: 455

By assuming that the vessel has a mid range engine power of 4000 kw, the model can be used to estimate the dependence of the average number of large bird warp strikes on the discharge type, the discharge rate, and the use of a bird baffler. The highest contact rates (over 8 contacts per hour) occur with the highest discharge rate, the discharge of offal, and without a baffler. They are halved by using a bird baffler, but at all discharge rates offal discharge has the greatest effect.

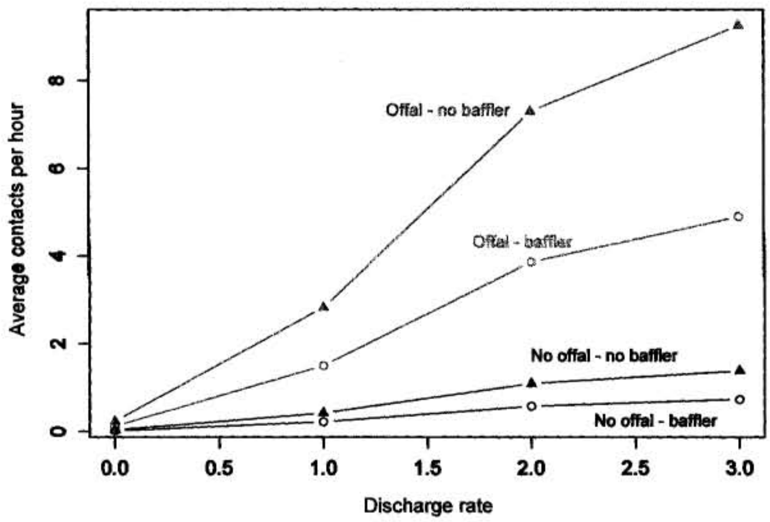

Figure 10: Modelled large bird contacts as a function of the discharge rate, for different combinations of offal discharge and baffler use.

3.1.2 Comparison with the data

Having identified offal discharge, discharge rates and the use of a baffler as significant factors, the data can be checked to see whether the model predictions are sensible. Observations with discharge rates of 2 and 3 were selected and grouped by offal discharge and baffler use. The average large-bird contact count was calculated. A 90% confidence interval was calculated for each average by a non-parametric bootstrap procedure. The original data were re-sampled and divided into the same groups, and the means were recalculated. This was repeated 1000 times, and the 5th and 95th percentiles calculated.

The results, shown in Figure 11, broadly agree with the model. In all groups, the model estimate of the contacts per hour for a discharge rate of 3 is within the 90% confidence interval. The highest contact rates are for offal discharge, and without a baffler. Using a baffler decreases the contact rate by a factor of 2 and not discharging offal decreases the contact rate by a factor of 5.

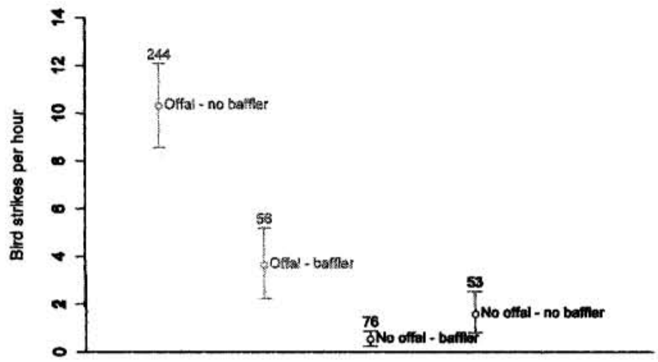

Figure 11: Average number of bird strikes, for discharge rates of 2 and 3, for the groups shown. The bars give a 90% c.i. calculated using a bootstrap procedure. The numbers of observations in each group are given above the bars.

A comparison between the negative binomial distribution (with model mean and dispersion) and the contact count frequencies (from observations where the dispersal rate was 3, offal was discharged and no baffler was used) is shown in Figure 12. Because of the low counts, a χ^2 test of the goodness of fit may not be accurate. However, if the observation of 35 contacts is excluded, then these two distributions cannot be shown to be different using the Pearson χ^2 test ($\chi^2 = 17.8$, d.f. = 14, $p = 0.2$).

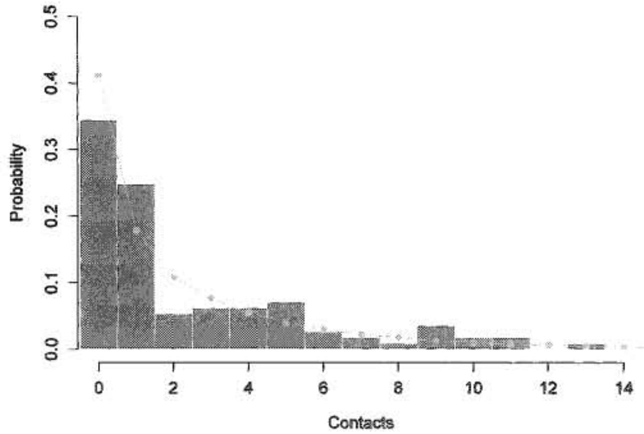

Figure 12: Distribution of large bird contacts per observation, for a discharge rate of 3, discharge of offal, and no baffler. The data (bars) are compared with the predictions from the negative binomial distribution (line), with mean and dispersion given by the model. Four observations with counts larger than 15 are not shown.

3.1.3 How robust are the results?

There are several possible limitations with the model. Firstly, no account has been made for possible observer effects. Each observer may have a different skill at counting the bird contacts, particularly in deciding whether a contact is heavy or not, and they may also make different estimates of the discharge rate. Because there is only one observer on each vessel, there is no opportunity to directly compare observations by different observers. A second issue is with the outlying observations; it is possible that the results are being skewed by the four observations of more than 15 bird contacts in the sample period. Thirdly, it is likely that observations within each tow are correlated, and so cannot be taken as independent.

In order to check whether the model is robust, it is fitted to the data again, but with three differences. Firstly, a factor is included for each observer, so the model has the freedom to separately scale the observations from each observer. Secondly, observations of more than 15 bird contacts are excluded. Thirdly, observations are weighted according to how many observations were made during each tow. For example, if three observations were made during a tow they are each given a weight of 1/3; if two observations were made they are given a weight of 1/2; and if only one observation was made it is given a weight of 1. This acts to decrease the importance of multiple observations made under the same conditions. Other approaches could have been used, such as using only one observation per tow, or including a tow effect in the model. It was felt that the approach followed here was conservative (consistent with assuming high correlation between repeated observations on the same tow), while not discarding any information.

With these changes, offal discharge and the discharge rate are still significant (Table 4). The significance of offal has decreased, and the coefficient is smaller, so that the expected number of contacts increases by only a factor of 3.8 (1.7–8.6, 90% c.i.) if offal is discharged. In contrast, the discharge rate now has a larger effect, but the difference between a discharge rate of 1, 2, or 3 is not significant at a 95% confidence interval.

The use of a bird baffler is no longer significant. This is because baffler use is largely associated with particular vessels, and so any signal of baffler use is soaked up by the observer factor. Similarly, the vessel engine power was not included in the model as it is not independent of the observer factor. None of the individual observer factors were significant, and the BIC criterion would reject the inclusion of this term.

This analysis supports the importance of offal discharge as a primary factor affecting the large bird contact rate.

Table 4: The terms in the model of large bird contacts, after including an observer factor, removing outliers, and down-weighting repeated observations from the same tow.

Factor	Coefficient	Standard error	Significance
Discharge type offal	1.33	0.41	**
Discharge rate 3	4.76	1.09	***
Discharge rate 2	4.19	1.08	***
Discharge rate 1	3.05	1.07	**
Baffler used	28.11	9×10^6	

Intercept and observer factors not shown

3.1.4 Including bird count

The model building is now repeated with the large bird count included as a categorical factor (Table 5). All the factors in the initial model are included again, with the addition of bird count, and the same model selection procedure is followed. As is expected, bird count is strongly associated with the warp strike rate, with high counts leading to high numbers of strikes. The other model terms indicate which factors are significant at changing the warp strike rate, for a given bird count. Discharge rate is no longer important, and the use of a baffler is now the most significant factor. While baffler use appears to have more effect when bird count is controlled for, its coefficient is not significantly different from its coefficient in the model without bird count. Similarly the discharge of offal has a coefficient which is not significantly different from its coefficient in the model without bird count. However, the discharge type of sump is now significant.

Table 5: Terms in the model of large bird contacts, when bird count is included.

Factor	Coefficient	Standard error	Significance	Deviance
Intercept	-5.76	0.51	***	Initial: 1103
Large bird count	1.56	0.14	***	362
Baffler used	-1.15	0.20	***	195
Discharge type sump	0.79	0.15	***	27
Discharge type offal	1.59	0.21	***	25
Vessel length	0.04	0.01	***	9
Vessel kilowatts	6×10^{-4}	1.2×10^{-4}	***	22
				Residual: 464

3.2 Small bird warp strikes

3.2.1 Primary model

A generalised linear model was fitted to the data on small bird strikes (Table 6), following the same procedure outlined for the large bird data. In this case, discharge type is not important, and the most significant factors are the discharge rates, which account for 25% of the deviance. Other factors that have explanatory power include the vessel length, kilowatts, and the presence of grease on the warps. These indicate a vessel effect, and taken together they explain only a further 4.6% of the deviance.

Table 6: Model of small bird contacts. The table shows the value of the coefficient and the significance of the factors.

Factor	Coefficient	Standard error	Significance	Deviance
Intercept	-5.59	0.85	***	Initial: 498
Discharge rate 1	3.07	0.76	***	126
Discharge rate 2	3.76	0.73	***	
Discharge rate 3	4.29	0.74	***	
Vessel length	0.029	0.0093	**	2
Vessel kilowatts	-4×10^{-4}	1×10^{-4}	**	12
Grease	-0.83	0.29	**	7
				Residual: 349

3.2.2 Comparison with the data

The key factor for the small bird contacts is the discharge rate. By grouping the data by discharge rate, the dependence of the mean contact rate on discharge can be determined. As with the large birds, a non-parametric bootstrap procedure is used to estimate the 90% c.i. of these means. The model predictions agree well with the data mean (Figure 13), being within the confidence interval for all the points.

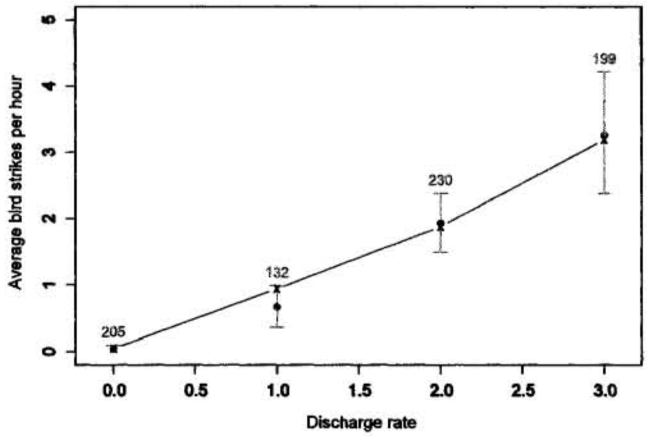

Figure 13: Small bird contacts. Comparison between the modelled data and the observations, for a range of discharge rates. The error bars show the 90% c.i. of the mean, and the number of observations in each category is given above the point.

3.2.3 How robust are the results?

As with the large bird contacts, it is necessary to check that the results are robust. The model is modified by including a separate factor for each observer, removing large observations (4 observations with a strike count of over 10), and down-weighting repeated observations on the same tow. These modifications have little effect on the model (Table 7), suggesting that the relationship between the discharge rate and the small bird contacts is not an artefact. The vessel factors don't appear, as they are not independent of the observers, and the grease factor is no longer significant as it is very closely related to vessel.

Table 7: The terms in the model of small bird contacts, after including an observer factor, removing outliers, and down-weighting repeated observations from the same tow.

Factor	Coefficient	Standard error	Significance
Discharge rate 1	3.09	1.08	**
Discharge rate 2	4.24	1.06	***
Discharge rate 3	4.69	1.09	***
Grease	-1.56	1.66	

Intercept and observer factors not shown

3.2.4 Including bird count

If bird count is included as an explanatory variable, it becomes the most significant factor at explaining the small bird strikes (Table 8). Unlike the large birds, discharge rate is still significant. Interestingly, the bird baffler now appears as a significant variable, with an efficacy of 2.6 (1.5–4.3, 90% c.i.). Using a bird baffler appears to cause a similar decrease in the observed number of small bird strikes as it did for large birds.

Table 8: Terms in the model of small bird contacts, when bird count is included.

Factor	Coefficient	Standard error	Significance	Deviance
Intercept	-7.71	0.94	***	Initial: 590
Small bird count	1.46	0.18	***	135
Discharge rate 1	2.62	0.78	***	66
Discharge rate 2	3.07	0.75	***	
Discharge rate 3	3.06	0.76	***	
Vessel length	0.04	0.01	***	7
Vessel kilowatts	-5×10^{-4}	1×10^{-4}	***	19
Baffler used	-0.96	0.26	***	14
				Residual: 349

4. DEAD AND INJURED BIRDS

4.1 Associations between bird recoveries and other factors

As a first step toward understanding the relationship between the bird recovery rates and the recorded factors, the association between each of the factors and the number of birds recovered dead or injured from the warps is discussed. The recovered bird information was for the whole tow, rather than for the observation periods. Because the tow level data are duplicated for each observation within a tow, the first good observation was selected from each tow. Tows with no good observations were excluded. This left data from 526 separate tows. Of these tows 89 (17%) had missing or incomplete data on the recovered birds. A further 18 tows had missing information on sprags or grease on the warps. Only the complete data were used to determine the factors associated with high rates of dead or injured birds.

An exact Fisher test was used to determine the significance of the association for all factors with less than six categories (these include baffler complete, baffler side, baffler used, discharge rate, discharge side, discharge type cutter, discharge type discards, discharge type minced, discharge type offal, discharge type sump, grease, large bird count, categorised large contacts, meal plant on vessel, meal plant running during tow, net dead, net non-injured, small bird count, categorised small contacts, sprags, categorised swell height, unknown dead, unknown non-injured, categorised vessel kilowatts, categorised vessel length, warp dead, warp hurt, warp injured, warp non-injured, warp observed, categorised wind speed).

The factors which have a significant association with the warp recovery rate are shown in Table 9. The most significant associations are with a discharge type of offal, large bird contacts, vessel length, and the discharge rate. The direction of the association was determined by fitting a single factor model to the warp dead and injured data. When taken on their own, the only factors which have a negative association with the recovery rate are warp-grease and baffler use.

Table 9: Significance of the association between the recorded factors and the warp recovery rate. The direction of the association is shown as positive, negative, or indeterminate. The factors are ordered by significance. Only the significant factors are given.

Factor	Significance	Direction
Discharge type offal	***	+
Large bird contacts	***	+
Vessel length	***	
Discharge rate	***	+
Large bird count	**	+
Vessel kilowatts	**	
Meal plant on vessel	**	+
Sprags on warps	**	+
Grease on warps	*	-
Meal plant running during tow	*	+
Baffler used	*	-
Net dead	*	+

The association between the recovery of dead or injured birds from the warp and offal discharge is shown in Table 10. There were only 2 injured or dead birds recovered from tows in which offal was not being discharged.

Table 10. Categorisation of tows by offal discharge, and by the number of dead or injured birds recovered from the warps. The bold numbers show where the counts are higher than would be expected if there was no association between offal discharge and the recovery of dead or injured birds from the warps.

Dead or injured	No offal	Offal
0	**276**	160
1	2	**24**
2	0	**11**
3	0	1

The results of a similar analysis for recoveries of dead and injured birds from the net are shown in Table 11. The only factor which is significant at $p < 0.01$ is the vessel engine power. There is a weaker relationship with the discharge rate and with the numbers of birds recovered from the warp. It is likely that factors that are outside the scope of this study, such as the length of time the net is on the surface or the way the net is recovered, are affecting the bycatch of seabirds in the net. The net recoveries are not considered further.

Table 11: Significance of the association between the recorded factors and the net recovery rate. The direction of the association is shown as positive, negative, or indeterminate. The factors are ordered by significance. Only the significant factors are given.

Factor	Significance	Direction
Vessel kilowatts	***	+
Vessel length	*	+
Discharge type - cutter	*	+
Warp dead and injured	*	+
Discharge rate	*	+

4.2 Modelling of dead and injured birds

4.2.1 Logistic regression model

Because the count numbers were low, the warp recovery data were reduced to a presence-absence measure. If one or more birds were recovered, the value is set to 1. These data were modelled using a generalised linear model, assuming a binomial distribution and a logistic link function (Venables & Ripley, 1996). Initially the factors with significant associations were included (except for bird counts and net recoveries). A subset was then selected by minimising the Akaike information criterion (AIC). The coefficients may be used to calculate the linear predictor, η, which is a related to the mean of the binomial distribution, μ, by $\eta = \log(\mu/(1-\mu))$. The mean can be interpreted as the probability that at least one bird will be recovered dead or injured from the warps. The most significant factor is a discharge type of offal (Table 12), followed by a factor related to mid-range vessel engine power. The probability is also increased by having either sprags or grease on the warps.

Table 12: Significant factors in the logistic model of the probability at least one dead or injured bird will be recovered from the warps.

Factor	Coefficient	Standard error	Significance	Deviance
Intercept	-7.08	0.99	***	Initial: 261
Discharge type offal	3.58	0.90	***	53
Vessel kilowatts 2k – 4k	1.93	0.58	***	7
Sprags	1.39	0.45	**	12
Grease	3.57	1.31	**	11
				Residual: 178

4.2.2 Comparison with the data

A comparison between the model and the data is shown in Figure 14. The observations are sorted by the predicted probability, and a non-parametric smoothed curve is generated (using the R function 'supsmu'). On the left of the figure, where all the observations are 0, this curve is 0; it increases towards 1 as the relative proportion of observations of dead and injured birds increases. For comparison, a line giving the predicted probability is shown. The close correspondence between these curves indicates that the model is fitting the data.

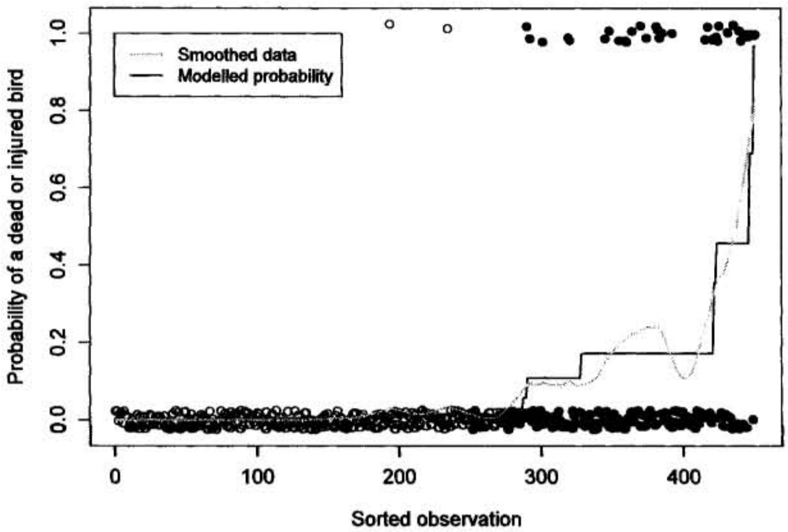

Figure 14: Comparison between the data (circles) and the logistic regression model, with the data ordered by the predicted probability of a dead or injured bird. The stepped line gives the predicted model probabilities, and the curve is obtained from a moving average of the data. The data points are shaded by whether or not offal is discharged, with a filled circle indicating offal discharge.

5. DISCUSSION

5.1 The voluntary code of practice

A voluntary code of practice has been introduced to help minimise the impact of the squid fishery on seabirds (HFMC & SFMC 2004). The code is operative for five years from 2004–05, and has a goal of reducing the incidental seabird captures by a minimum of 20% over the five-year period. There are four key practices which are intended to minimise the interaction between the fishery and the seabirds. Each vessel is required to

1) use some mitigation (bird baffler, tori line, or an acoustic device)
2) not discharge offal or other wastes during shooting or hauling of trawl gear
3) minimise the time the net is on the surface of the water
4) adopt net maintenance practices that minimise risks to birds

The data in this survey are relevant to the first and second requirements. The only mitigation being used was bird bafflers and only 9 of the 19 vessels used a bird baffler. As far as offal discharge was concerned, 3 of the 19 vessels were never observed discharging offal during the tow (Figure 15), and 9 vessels (47%) discharged offal during less than 20% of observations. At the other extreme, were 3 vessels that discharged offal during more than 80% of observation periods. Note, however, that the voluntary code of practice requires only that the there is no discharge of offal during shooting and hauling of gear, and does not require vessels to refrain from discharging waste while towing. All the observations in the survey were made while vessels were towing. While it is the factor most strongly associated with large-bird strikes, the observed discharge of offal is not inconsistent with the code of practice.

There was no relationship between offal discharge practices and use of a bird baffler, so there were only three vessels (16%) that used a bird baffler on most tows and they discharged offal on less than 20% of tows.

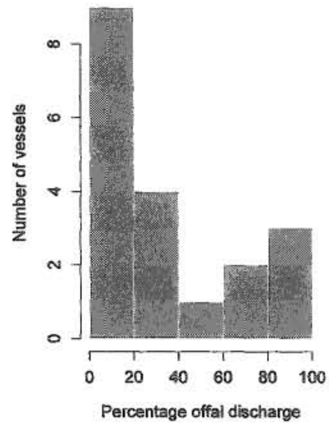

Figure 15: Discharge of offal by vessels, showing the percentage of observations during which offal was discharged.

5.2 Offal discharge and mitigation

It is clear, from the analysis of both the warp contact data and the number of dead and injured birds recovered from the warp, that offal discharge is the single most important factor affecting interaction between seabirds and fishing gear. This has already been recognised at a management level, as is reflected in the code of practice. Use of a bird baffler acted to reduce the warp contact rates, by a factor of about 2. For small birds the baffler effect was only evident when bird count was included. However, because baffler use was largely associated with particular vessels it is possible that this is purely a vessel effect. There is considerable variability between vessels in the position of the discharge, the volume of discharge, in the positioning of the warps, and in the warps' entry point into the water. In addition bafflers will differ between the vessels. All these effects will lead to differences in the warp strike between vessels, even if all the recorded factors are the same. While multiple discharge rates and types were seen on each vessel, the close relationship between baffler-use and vessel means the observed baffler effect may be an artefact. This would, however, require that baffler use was correlated with these vessel effects. The design of the survey does not allow this correlation to be assessed.

In an experimental investigation of the efficacy of mitigation in a Falkland Islands finfish trawl fishery, the use of bird bafflers reduced the mean warp strike-rate from 16.8 contacts per hour (12.7–22.2 95% c.i.) to 9.72 contacts per hour (6.85–14.72 95% c.i.) (Sullivan et al. 2006a). While these means are not different at the 99% confidence interval, the proportional decrease in the contact rate is similar to the result obtained here. In the same paper, a decrease of the contact rate to a low 0.29 (0.03–0.97) contacts per hour was achieved through the use of tori lines. A similar comparison of the mitigating effects of tori lines and bird bafflers within the squid fishery would be interesting.

The use of a meal plant should reduce offal discharge, but there was a positive association between a discharge type of offal and the whether the meal plant was running (Fisher exact test, odds ratio = 3.5, 2.5–3.5 95% c.i.). This is likely to be because both offal discharge and the running of a meal plant occur when catch is being processed. The survey was unable to identify a mitigating effect of the meal plant.

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Appendix A: Sampling design and instructions

This is a copy of instructions given to observers, detailing the sampling design and protocol for the warp strike research program.

Introduction

Seabirds occasionally come into contact with fishing gear on trawlers, and some of these interactions lead to mortalities. To better understand what it is about certain fishing operations that lead to higher rates of warp strikes than others, a trial sampling programme will be implemented in the 2005 SQU fishery. This document defines how data will be collected and analysed for this pilot research programme. This work is not designed to enable the estimation of mortalities of seabirds through warp strikes.

Objective

1. To examine which factors are associated with the occurrence of warp strikes in trawl fishing.
2. To validate the methodology defined here for collecting data on warp strike occurrence.

Rationale

This sampling programme is intended to provide an index of relative intensity of seabird strikes on trawl vessel warps (cables). This measure needs to be able to be compared between tows, trips, vessels, fleets, areas and time of year. Therefore a standardised way of estimating warp strike intensity needs to be used. Information from tows when no warp strikes occur is also necessary.

Sampling is aimed at determining which factors have most effect on the probability of warp strikes occurring. The factors being examined include vessel, fishery, and environmental factors. These include such things as the type of vessel [fresher, filleter, etc], the use of mitigation techniques, fishing gear used, and discharge of offal. Fishing area or time of year can also play a role in the likelihood of warp strike, along with the sea state and time of day. Similarly, the number of birds behind the boat can influence the probability of warp strike occurring.

Research Overview

This research is possible through the establishment of a sampling instrument and observational research design, and will be trialled during the Southern Squid Fishery during early 2005, which commences on 1 February and runs until approximately May. Data collection will be undertaken by Ministry of Fisheries Observers working on commercial fishing vessels. At this stage the final number of vessels involved in the study has yet to be determined but it is expected to be between 8 and 10.

Each vessel undertakes trips of up to 6 weeks.

Sampling Design

Observers will be tasked with undertaking two 15-minute observations per tow in a day resulting in approximately 80 observations per observer per trip. Only one tow per day needs to be sampled, but where other duties allow, sampling more than one tow in a day is desirable.

To investigate "time of day" effects, observers will be required to undertake their observations across all daylight hours (see "Sampling Schedule"). Of the anticipated 80 observations undertaken during each trip, at least one observation will be made for each daylight hour. Further details about the sampling schedule are provided with the instructions for the form. Spreading sampling times through the day in a systematic way will also mean that samples are taken across a range of fishing and environmental conditions. It is particularly important to record observations when there is no offal discharge, and also when there are no warp strikes occurring to provide contrast in the dataset.

As offal discharge is believed to be a likely factor in the incidence of bird strikes, at least 25% of the observations must occur while there is no offal discharge.

Sampling Instrument

The observation form is given in Figure 16 and Figure 17.

Sampling Procedure

Setup

The design is naturalistic observation. Observers will be stationed at a point near the stern of the vessel where:

- they can clearly see the warp lines from the stanchions through to where they enter the water
- they can note whether offal discharge is occurring
- only 1 warp will be observed during an observation period

Choosing which warp to observe

The warp observed must be the one on the side of the vessel that most offal is discharged from, even if no offal is being discharged at the time of the sampling observations. Observers will need to determine this when coming on board the vessel, and if two observers are on the vessel, they will have to agree which warp is to be observed. When offal is discharged from both sides of the vessel, observers should stick with observing only one warp.

Observation steps

1. Record bird abundance estimate on the observation form
2. Record start time of observation using 24 hour format
3. Observe warp for 15 minutes and count only heavy bird strikes for both small bird and large birds on separate clickers or on a notebook
4. Record end time of observation using 24 hour format
5. Record clicker (or notebook) sums of large and small bird strikes on the observation form
6. Complete the remainder of the sampling form (see "instructions for completing sampling form")
7. Observe the haul and note the number of birds captured by the fishing gear
8. Fill in section 4 of the form.
9. Observe the pound emptying as fully as possible.

SEABIRD WARP-STRIKE OBSERVATIONS (TRAWL)

1. Fishing event descriptors.

Observer trip number		Tow number		TCEPR form number		Observer initials	
Meal plant on vessel	Y / N	Meal plant running during tow	Y / N			Warp observed	P / S

2. Fifteen-minute warp-strike observations and bird abundance

	Sampling period 1								Sampling period 2								Sampling period 3							
	Large birds				Small birds				Large birds				Small birds				Large birds				Small birds			
	0	<10	10-100	>100	0	<10	10-100	>100	0	<10	10-100	>100	0	<10	10-100	>100	0	<10	10-100	>100	0	<10	10-100	>100
Bird abundance																								
15-Minute Observation	Time Start				Time End				Time Start				Time End				Time Start				Time End			
No. heavy contacts																								

3. Mitigation& Environment Factors			
Tori line	Y / N	Y / N	Y / N
Tori line length (m)			
Tori line height (m)			
Number streamers			
Bird Baffler	Y / N	Y / N	Y / N
Baffler complete	Y / N	Y / N	Y / N
No. sides deployed	P / S / B	P / S / B	P / S / B
Sonic scarer (number)			
Gas canon (number)			
Other (describe)			
Sprags on Portside warp	Y / N / U	Y / N / U	Y / N / U
Sprags on Starboard warp	Y / N / U	Y / N / U	Y / N / U
Grease on warps	P / S / B / N	P / S / B / N	P / S / B / N
Swell height (m)			
Swell direction (1-12 h)			
Wind speed (Beaufort)			
Wind direction (1-12 h)			
Discharge side	P / S / B / N	P / S / B / N	P / S / B / N
Discharge rate	0 / 1 / 2 / 3	0 / 1 / 2 / 3	0 / 1 / 2 / 3
Discharge type *	S / M / C / O / D	S / M / C / O / D	S / M / C / O / D

*several types permissible

Codes for completing the form:

Discharge rate	0 = none, 1 = negligible, 2 = intermittent, 3 =continuous. Record one only.
Discharge type	S = Sump water, M = minced, C = cutter pump, O = offal, ie heads and guts, D = discards of whole fish. Record one or more.
Elsewhere	P = Port, S = Starboard, N = Neither / None, B = Both, Y = Yes, U = Unknown

Figure 16: Warp strike observation form (front side).

4. Birds recovered from the net or warps during the haul – totals for the whole tow

Recovered from warps

No. dead [ ] No. injured [ ] No. non-injured [ ]

Recovered from net

No. dead [ ] No. injured [ ] No. non-injured [ ]

Recovered from unknown sources

No. dead [ ] No. injured [ ] No. non-injured [ ] % pound emptying observed [ ]

5. Comments : Record anything that may result in a sample being removed from the analysis, e.g. gear failure or the environmental or fishing factors changed, or the vessel does a turn meaning that the conditions , such as wind direction changes during the sampling period

Sample 1	
Sample 2	
Sample 3	

Instruction for use of Section 4 (Birds dead or injured on trawl)

Record the number of birds recovered from the net or warps, using the definitions below. The sum of the six groups of birds (dead, injured, non-injured from net and warps) should equal the total number of birds observed caught on the vessel during the whole tow. This includes birds caught on the warps or net but dislodged during hauling. Record 0 birds when none was observed, and U (Unknown) when no observation was made.

Record the proportion of the pound that was observed being emptied (%), estimate by time or volume as appropriate.

Definition of injury / death

Dead – Birds show no signs of life, e.g. no corneal reflex, no muscle reflex

Injured – Birds with any of the following injuries:

-Broken or drooping wing (ie the bird cannot fold the wing up)

-Broken beak or leg

-Open wound

-Hook in bird (whether removed or not)

***Non Injured* – Birds without the above injuries, and not dead.**

Beaufort Scale of Wind Force

Beaufort Number	Descriptive term	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 and over	14 (-)

Figure 17: Warp strike observation form (reverse side).

Sampling periods

Sampling periods of 15 minutes will be used to assess warp strike intensity. These are to be carried out twice during a tow per day during the fishing phase of the tow (i.e., when the net is in the water and cables are no longer being paid out). Start the sampling periods on the hour (or half hour). Leave at least one hour between sampling periods. An example schedule is shown in Table 13. It is very important to record the correct start and stop time of the observation. If conditions change significantly during an observation period; e.g., the vessel turns or wind conditions change considerably, or offal discharge rate changes significantly, terminate your observation at that point and note on the form the environmental conditions. Record the reason for early termination of the sample period under section 5 of the form. Begin a new sampling period later in the tow if duties permit.

A minimum of one complete 15-minute observation period per day needs to be completed as safety considerations allow. The whole procedure should take around 30 minutes to complete. The observer must report to the bridge before undertaking observations at the stern of the vessel.

There is room on the sampling form to carry out a 3rd observation if the Observer has the opportunity to do this. Additional sampling of other tows is also useful, but note that observations on a new tow require a new form.

Instructions for completing the sampling form

Text with a bullet point and in italics refers to elements to record on the form.

Section 1. Fishing event descriptors

Most of the information to categorise the fishery is recorded on other forms you will fill out as part of your general observer requirements, so Observers only need to fill out minimal information on this form.

- *At the beginning of the sampling set of observations, you must record the trip number for the observer, tow number, the TCEPR number for the tow, and the initials of the observer. A new form must be started for each new tow observed.*

- *Meal plant on vessel (y/n) - Record whether the vessel has a meal plant on board.*

- *Meal plant running during tow (y/n) -Record whether the meal plant was in operation during the tow that was sampled.*

- *Warp observed (p/s) – Record which warp is observed during the tow. P = Port, S = Starboard.*

Table 13: Example sampling programme for an observer, setting out the sequence of information recording sampling periods within one tow.

Time	Description	Activity
08:58	Pre-sample period 1.	Record bird abundance estimate and tow level information (e.g. time of start, tow number, TCEPR number, initials of observer)
09:00–09:15	Sample period 1	Record warp strike numbers by observing warp in period 1
09:16–09:20	Post-sample period	Record environment and fishery information about sample period 1
9:58	Pre-sample period 2	Record bird abundance estimate for sample period 2
10:00–10:15	Sample period 2	Record warp-strike numbers by observing warp in period 2
10:16–10:20	Post-Sample period 2	Record environment and fishery information about sample period 2
11:28*	Pre-sample period 3	Record bird abundance estimate, for sample period 3
11:30–11:45*	Sample period 3	Record warp-strike numbers by observing warp in period 3
11:46–11:50*	Post-Sample period 3	Record environment and fishery information about sample period 3
12:30 onwards	During haul and processing	Record the number of birds captured by the vessel from the warps and net dead, injured or non-injured categories during the haul and through observing the emptying of the pound. Separate the warp-recovered and net-recovered birds when recording

* Optional observation

Section 2. Bird abundance and fifteen-minute warp strike observations

Seabird abundance

The objective of the abundance estimate is to provide order-of-magnitude level of information about the numbers of birds behind the vessel during the sampling period. Numbers of birds are grouped into 0 birds, <10 birds, 10–100 birds, > 100 birds. This should be done just before the 15 minute observation of warp strikes. Estimate the total number of birds on the water and in the air. Separate the large and small bird groupings in this estimation.

The area in which bird abundance is to be assessed is roughly 40 x 40 metres, centred around the position of the warp entry point into the water, for the warp that is being observed. The warps enter the water at roughly 20 m from the stern of the vessel. Using this entry distance as a guide, imagine a square of water that extends an equal distance from the warp entry point, towards and beyond the vessel, and to each side and count the birds within it. (Figure 18).

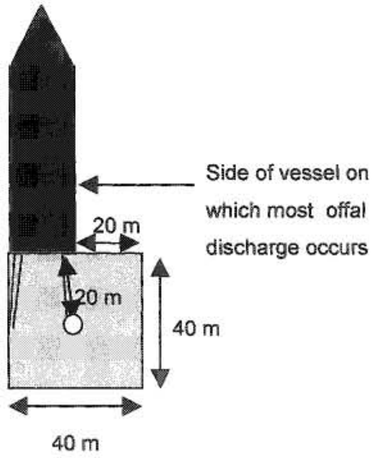

Figure 18 : Diagram of a vessel with the warp entry point shown as a circle, at approximately 20 m from the stern of the vessel. The area in which seabird abundance is estimated is a square that extends 20m on each side of the warp, and 20 m beyond the warp entry point, on the side of the vessel that the primary offal discharge is occuring during the sampling period.

- *Fill in the form by ticking one box for each sample period under 'Large Bird' and one under 'Small Bird'.*
- *E.g. Tick the 10–100 category for Large bird if around 50 albatrosses were present in the 40x40 box around the warp entry point, AND tick the >100 category for Small Bird if 200 petrels and prions were present in the 40x40 box during the observation period.*
- See below for the definitions of small and large birds.

Fifteen Minute Warp Strike Observations

Record the number of birds coming into heavy contact with trawl-warps during each sampling period of fifteen minutes. Sample only during the fishing (tow) phase of the trawling. Complete a minimum of two observation periods in a day if safety considerations allow. Two periods are required by the sampling design, but the occasional single event can be accommodated in the analysis. Collecting more than two samples in a day is useful, as duties allow. When more than two sample periods are done, sample more than one tow.

Note 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. As part of the research protocol we would like to sample every daylight hour of the day at least once during the trip. To that end we have included a table to help you keep track of when you undertake your observations (Table 14). Add a tally mark against the appropriate hour for each observation you make. Undertake the observations as the occasion arises, and try to move to a new start time (hour) with each subsequent tow observed. If it's not possible to sample at a particular time (e.g. 6 am), during a series of tows, then skip this one and move on to later times. However, if the occasion arises to do a sample at 6 am later in the trip, then complete a sample at this time.

Ensure that between 25% and 50% of observations take place during a period when offal is not being discharged.

Table 14: Tally of the start time of each strike observation.

Sampling period starts in this hour	Count of observations (tally marks)
04:01–05:00	
05:01–06:00	
06:01–07:00	
07:01–08:00	
08:01–09:00	
09:01–10:00	
10:01–11:00	
11:01–12:00	
12:01–13:00	
13:01–14:00	
14:01–15:00	
15:01–16:00	
16:01–17:00	
17:01–18:00	
18:01–19:00	
19:01–20:00	
20:01–21:00	
21:01–22:00	
22:01–23:00	

Number of heavy contacts

- *Record the total number of heavy contacts between small birds and large birds with the observed trawl warp during the 15 minute observation period (see below for definitions of heavy contacts, and small and large birds).*

Defining heavy contacts between birds and the trawl cables:

A heavy contact is one in which a bird has its path of movement deviated when it comes into contact with the trawl warp, and the part of the body contacted is above the 'wrist' joint of the bird (ie 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 though active movement comes into contact with the warp, or when the warp moves to contact the bird (e.g. whilst the bird is sitting on the water).

Contacts NOT included in this category are when birds may have touched the warps but are not moved out of their flight path or on the water position.

Note: A training video will illustrate to you what is defined as a heavy contact. These are usually rare events.

It is suggested to observe the number of contacts between large and small birds, and use clicker-counters tally these during the observation, or record these in a notebook. The form can be filled in after the observation period with the total numbers of heavy contacts observed.

Defining bird size categories:

Birds of different species will be seen in contact with trawl warps. Because we are trying to analyse whether petrels and smaller birds, which have different flight patterns to albatrosses, are vulnerable to warp strikes in different conditions than larger birds, we need to separate out these two categories of birds in the observations. The two categories of birds that will be noted during the sampling periods:

Small Birds – this includes petrels, prions, and storm petrels gannets and gulls and shags.

Large Birds – this includes all albatrosses and also includes giant petrels.

Section 3. Mitigation & Environmental Factors

For each sampling period of 15 minutes, record the factors about the fishing and environmental factors that occurred during the sampling period. This includes what mitigation techniques were employed if any, and what the environmental states were (e.g. swell height, wind direction), and information about the fishing event (e.g. warp angles) and offal discharge. Some of these require subjective assessment, but try to be consistent between the different sampling periods observed. If conditions change significantly during a sampling period, terminate that sample and record the time. Restart sampling later in the tow if duties permit.

- *Tori-line – Record Y if a tori line was used during the sampling period, N if one was not. For the other elements to do with tori-lines (below) leave them blank if no tori line was used.*
- *Tori line length – Record the length of the tori line in metres from the stern of the vessel to the entry point in the sea*
- *Tori line height - Record the height of the tori line in metres above the sea at the stern of the vessel,*
- *Number of streamers – Record the number of streamers when the tori line was deployed. Streamers are the cords or tapes that hang vertically down from the tori line.*
- *Bird Baffler – Record Y if a bird baffler was deployed. Complete the other elements to do with bafflers if you answered Y to this question.*
- *Baffler complete - Record if the baffler is 'entire'; i.e. has all of its deterrent devices attached or whether these have been displaced or disabled during deployment (e.g. cones/streamers are hung up on the structure, or one 'wing' is not deployed).*
- *No. sides deployed - Record whether the baffler is being deployed on both sides of the vessel (P = port, S = Starboard, B = Both).*
- *Sonic scarer (number) - Record if a high-frequency sonic device was used during the sampling period, by recording the number of times it was activitated. Record 0 if it was not used or not present.*

- *Gas cannon (number) – Record if a gas cannon was used during the sampling period to scare birds by recording the number times it was activated. Record 0 if it was not used or not present.*

- *Other (describe) - Record what other mitigation devices or techniques were used during the sampling period not covered by the above. Record 'N' if there was none.*

- *Sprags on portside warps - Record whether there are jutting sharp parts of the cables that are not bound or covered, onto which birds can become attached or injured on the portside warp. Y = Yes, N = No, U = Unknown.*

- *Sprags on starboard warps - Record whether there are jutting sharp parts of the cables that are not bound or covered, onto which birds can become attached or injured on the starboard warp. Y = Yes, N = No, U = Unknown.*

- *Grease on warps – Record whether there are substantial quantities of heavy grease on cables. Heavy grease is thick and sticky enough for birds to become attached to the cables with it. Choose one option among the following: P = Port, S = Starboard, B = Both, N = None.*

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

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

- *Wind speed (Beaufort) – Record the wind speed using the Beaufort Scale (Table 15), 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.*

- *Wind direction (1–12 h) - Use a 12 h clock system to define the bearing of the wind relative to the direction of travel of the vessel. To do this, imagine a clock face, with the bow of the vessel is defined as the 12 h point. Therefore a wind coming directly from the stern direction is recorded as 6 h. Port side is 9 h, starboard is 3 h.*

- *Discharge side - Record whether offal discharge was on the Port (P), Starboard (S), or Both (B) 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.*

- *Discharge Type (S/M/C/O/D) Multiple types are allowed and should be recorded. Record the type of discharges (S = Sump water, M = minced material that has been through a macerator, cloudy consistency in the water, C = cutter pump is lumpier than minced material, 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.*

Table 15: The Beaufort scale.

Beaufort Number	Descriptive term	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 and over	14 (-)

Birds dead or injured on the trawl

The information in these fields relates to the whole tow, not just the sampling periods. This is recorded on the rear of the form, and needs to be done after the whole haul has been observed. It is important that the total number of birds is consistent between information recorded on this form and the Non-Fish Bycatch form. In some cases, the observer's shift will have ended and a second observer will be recording this information.

Divide the numbers of birds, dead, injured and non-injured into those recovered from the warps and those recovered from the net. Some birds may be recovered and if it unknown whether they come from the warps or net, these are recorded in the 'Unknown' category. The birds recorded in these sections should include birds observed to have been caught, but which don't get landed on the vessel, because they fall off the warps or net during the hauling process.

When zero birds are observed in a category, record a '0', but when no observation was made, record 'U' for unknown.

Use the definition of dead and injured birds provided on the back of the form (and below) to categorise the birds into a) dead, b) injured, c) non-injured. Birds that have collided with the structure of the vessel or become oiled on the deck are not included in this tally. The sum of the birds in these nine categories is equal to the total number of birds captured during the fishing event.

- *Number dead* - Definition: a dead bird is one with no sign of life, measured by the lack of muscle reflex or corneal (eyelid) reflex. *Record the number of birds retrieved from the tow that fall under this definition.*

- *Number injured* - Definition: an injured bird has any of the following conditions, and is not 'dead':
    - Broken or drooping wing (ie the bird cannot fold the wing up)
    - Broken beak or leg
    - Open wound
    - Hook in bird (whether removed or not)

  Record the number of birds retrieved from the tow that fall under this definition.

- *Number non-injured* - Definition: Birds unharmed (without the above injuries, and not dead). *Record the number of birds retrieved from the tow that fall under this definition. These birds should be safely released.*

- *% pound observed - Record the proportion of the pound that was observed being emptied. This gives an indication of the ability to estimate the total number of seabirds captured during the fishing operation. The optimum situation is to observe the entire pound being emptied for a tow that observations of warp strike are made on. In this case, record 100% in this field. If this is not possible because of other duties, estimate the total time that the pound emptied over, and note the time that it was observed. If time can't be estimated, then indicate the proportion of the pound observed during emptying by the volume.*

- *Comments - Record if anything happened during the 15-minute sampling period that would be likely to lead to its exclusion from any analyses. For example, a gear-failure could have resulted in unusual fishing conditions occurring, or if environmental conditions changed significantly during a sampling period.*

Appendix B: Revising the protocol

The following are notes from the Ministry of Fisheries Technical Working Group Meeting on Warp Strike Protocol, 27 July 2005.

Present

Alan Martin, Susan Waugh, Edward Abraham, Antony Kennedy, Dave Banks, David Middleton, Kim George, Tamara Fitzgerald

Apologies

Wendy Norden

Purpose

To review the warp strike protocol and form, from the perspective of observers using the form, and to recommend any change to the form or protocol to increase the ease of usage or data quality.

Comments from the group

Suggestions were tabled by Datamine as to amendments that could be considered to the protocol and form. In general the protocol seemed to be effective and gave clear information. No immediate amendment to the form or protocol was suggested, as observer catch effort forms were due to be changed in a few months, and at the point where these changes were implemented, a revision of the warp strike protocol could be undertaken.

Title

Suggested changing the title to "Warp Observations (Trawl)"

Section 1. Tow level details

- Include both TCEPR form number and TCEPR tow number
- Record Observer tow number and date
- Specify whether it was the observer or TCEPR tow number (tick box to be added).
- Add Sprags (y/n) and Grease (y/n) to this top section, but note that in the future these could be deleted if they aren't shown to be an important factor or prove difficult to capture accurate data on.

Section 2. Fifteen minute observations

- Agreement on the usefulness of small / large bird split, and the simple nature of this section to increase data accuracy.
- There was discussion on having bird abundance taken as an average, or at sometime during the 15 min observation period, but the group decided to retain the current format (abundance taken before the observation period)

Section 3. Mitigation and environmental factors

- Tori-line – change to "Tori line deployed"
- Could be deleted in future if this information is captured on observer catch-effort forms
- Baffler Y/N – this line was redundant
- Sprags and Grease rows – delete and up into section 1.
- Swell height – was considered unnecessary as it was difficult to assess and didn't appear to play an important role in the warp strike probability, so delete

- Windspeed (Beaufort) – the description should be in the Observer Manual, so doesn't need to be repeated here, and if it is set out should relate to sea state variables, rather than the description used on the current forms
- Offal going under warps – add a line to describe this.
- Improve the description of discharge type and locations
- Reduce discharge types to include M=minced / cutter pump. Stick water = residue from mealing, discharged at different locations than discards.
- Add the requirement for observers to take note of processing of waste prior to the observation period.

Additional notes:

- Consider analysing the offal descriptions recorded to see what the common categories used were, and how these differ between vessels and observers.
- Processing of previous tow can affect the offal type, and could be considered as part of the analysis for in the future
- Could look at waste volume from previous tow.

Appendix C: The negative binomial model

The negative-binomial generalised linear model estimates the logarithm of the mean of the negative binomial distribution, μ, as a linear function of the explanatory variables, x,

$$\log(\mu) = b_0 + b_1 x_1 + b_2 x_2 + b_3 x_3 + \ldots,$$

where b are the fitted coefficients. The negative binomial distribution is given by the formula

$$f(y;\theta,\mu) = \frac{\Gamma(\theta + y)}{\Gamma(\theta) y!} \frac{\mu^y \theta^\theta}{(\mu + \theta)^{\theta + y}},$$

where Γ is a gamma function, and the variance of the distribution is $\mu + \mu^2 / \theta$. The additional parameter, θ, is also estimated during the fitting procedure.

Fitting of the model was carried out using the function 'glm.nb' from the 'MASS' library of the analysis software R (Venables & Ripley 2004). A log link function was used.