**Agreement on the Conservation of Albatrosses and Petrels**

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# Characterisation of seabird captures in commercial trawl and longline fisheries in New Zealand 1997/98 to 2003/04

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**Executive Summary:**

*Objectives 1 and 2*

Seabird bycatch was estimated using a model-based analysis. This is preferable to the more classical (design-based) methods that have been used to estimate seabird bycatch in the past, as the latter are more prone to bias caused by lack of randomness in the allocation of observers to vessels. A model-based analysis enables similarities in capture rates in different seasons, years, regions or fisheries to be exploited, and can thereby remove some of the bias that may occur as a result of the observer data being unrepresentative with respect to these factors (e.g. disproportionately more observers on large vessels than on small vessels, relative to fishing effort).

There is still the potential for bias in our analysis if the observer data is unrepresentative with respect to factors that have not been included in the models, or if the models fail to capture the true relationship between bycatch and the factors included in those models. The former is a distinct possibility, given the nature of the allocation of observers to vessels in the past. In addition, observers are not dedicated to collecting seabird bycatch information. It would therefore be prudent to exercise caution when interpreting the estimated total level of bycatch, particularly for smaller vessels. We also note that the level of effort devoted by observers to recording seabird bycatch has changed over time, which may produce some spurious patterns in the data. For example, the increase in the estimated number of birds caught in bottom longlining fisheries between 1999-2001 may be a product of increasing effort by observers to record seabird bycatch during this period, rather than a true increase in bycatch.

The number of seabirds caught per tow/set was assumed to have a zero-inflated Poisson distribution that was modelled with a mixture distribution. A biological interpretation of the mixture distribution is that in certain circumstances the number of captures will be a random value from a Poisson distribution, and in all other conditions the number of captures will be zero.

The model was fitted to the data collected from the scientific observer programme, which was then used to predict the number of captures per tow/set on unobserved vessels. Bayesian statistical methods (Markov chain Monte Carlo) were used to analyse the data and predict the total number of captures.

Diagnostics suggest the fitted models are reasonable given the data, although they may be conservative, with possible underestimation of events with large numbers of seabird captures for all fisheries. In addition, the estimated precision may be overly optimistic for bottom long line fisheries.

In trawl fisheries:
- Approximately 450 (95% CI 300-600) albatross were estimated as captured in the 1998 fishing year (i.e., from 1 October – 30 September), and 900-1500 in each of the subsequent years, by vessels greater than 28 metres in length (width of 95% CI's ~500 birds). Smaller vessels were estimated to capture less than 200 albatross per year, but there is greater uncertainty in these estimates due to low observer coverage (width of 95% CI's ~800 birds).
- For all seabirds combined, annual bycatch estimates generally ranged between 2000-3000 birds (width of 95% CI's ~800 birds) for vessels greater than 28 metres, and less than 200 birds (width of 95% CI's ~250 birds) for smaller vessels.
- Most of the bycatch was predicted to occur in FMA's 3-6, primarily in the summer and autumn months (January-June) on tows targeting hoki or squid.

In surface long line fisheries:

- Annual estimates were generally less than 500 seabirds (width of 95% CI's ~500 birds in most years) captured by vessels greater than 28 metres in length, and less than 4000 seabirds (width of 95% CI's ~3500 birds in most years) captured by smaller vessels.
- Capture rates tended to be highest in FMA's 1, 2 and 4 for both classes of vessels, primarily on sets targeting big-eye tuna.

In bottom long line fisheries:

- The number of seabirds captured per year by vessels greater than 28 metres was estimated to have increased by 500 birds per year between 1999-2001 (from 1800 birds), but was estimated to have decreased to 600 birds (95% CI 500-1000) by 2004. For smaller vessels, there is greater uncertainty in the estimated bycatch, due to low observer coverage, with the width of the 95% credible intervals being greater than 10,000 seabirds in 5 of the 6 years. This implies that the level of bycatch is essentially unknown for smaller vessels.
- For larger vessels, capture rates tended be highest in FMA's 5, 6, and 7 on vessels targeting ling. For smaller vessels, they are highest in FMA's 1, 2, 5 and 7 on vessels targeting snapper.

The very wide credible intervals for vessels <28m using long-lining fishing methods implies that the level of bycatch for these types of vessels is essentially unknown, which is not surprising given the lack of observer data. While they may have low strike rates, the sheer volume of the fishing effort represented by these vessel types may result in them having a substantial contribution to the effect of NZ fisheries on seabird populations.

Estimation of seabird bycatch alone does not provide adequate information on the influence of seabird-fishery interactions on seabird populations. At a minimum, bycatch estimates must be coupled with estimates of seabird population sizes to obtain a bycatch mortality rate (fraction of the population bycaught). However due to practical difficulties (e.g., collecting accurate bycatch data from small vessels, determining the originating population of a bycaught seabird etc), a more efficient approach to monitoring the effect of seabird-fishery interactions may be to monitor the seabird populations directly.

It is recommended that an assessment be made of exactly what information is furnished by estimates of seabird bycatch, and how that information is useful to fishers, managers and researchers.

*Objective 3*

Generalised linear models were used to assess which factors may affect the probability of capture of seabirds by fisheries within the New Zealand EEZ. It was assumed that the number of seabirds captured per tow/set followed a negative binomial distribution. Again, the resulting analysis relies on the extent to which the observed fishing activities are representative. Given that observers are not allocated at random to vessels, the results should be extrapolated to all fishing activities with caution.

In surface long line fisheries, capture rates are:

- lower on NZ registered vessels than on Japanese vessels
- lower in autumn than in other seasons
- higher in FMAs 1&10 and 2 compared to other areas

In bottom long line fisheries capture rates are:

- higher in spring than in other seasons
- higher on sets targeting LIN
- higher on sets that started between 0300-0900

In trawl fisheries capture rates are:
- much greater for Korean vessels
- highest in autumn and lowest in winter
- highest on tows targeting SCI and lowest on tows targeting JMA or SBW
- lower for bottom trawls than mid-water trawls
- lower in North Island trawl fisheries
- higher for tows that began between 0900-1500

*Objective 4*

We used the results from Objective 2 to estimate the bycatch (number of birds) and the capture rate (birds per set or per 100 tows) for each combination of vessel size, method, fishing area and season. This provided estimates for all seabirds as well as for albatross caught in trawl fisheries. An advantage of using model-based estimates in this way is that it allows us to estimate bycatch for those vessels, methods, areas and/or seasons for which there was no observer effort. We focussed on the estimates for 2004, but also calculated the average estimate during the period 1998-2004. We also summarised the uncertainty associated with each estimate of bycatch by calculating the width of the corresponding 95% credible interval.

The observer data did not allow estimation of bycatch at an individual species level. It is also prone to observation and recording errors. This means that an assessment of risk based on these data alone a difficult task. The estimates of bycatch, and their levels of uncertainty, should therefore be intepreted as an approximate summary of the relative risk posed by the different fisheries.

In 2004:
- Large trawl vessels in FMA's 5 and 6 account for 25% of seabird bycatch.
- Small longline vessels in FMA's 2 and 4 account for 16% of seabird bycatch.
- Large vessels in FMA's 5 and 6 account for 52% of albatross bycatch in trawl fisheries.
- The greatest uncertainties associated with seabird bycatch are for small longline vessels, especially surface longline vessels in FMA's 2 and 4 and bottom longline vessels in FMA's 1-2 and 8-10.
- The uncertainties associated with albatross bycatch in trawl fisheries are highest for small vessels in FMA's 3 and 7 and for large vessels in FMA's 5 and 6.
- Capture rates of seabirds in trawl fisheries are generally highest for large vessels in FMA's 3, 5 and 6.
- Capture rates of seabirds in longline fisheries are generally highest for surface longline vessels in FMA's 1, 2 and 4.
- Capture rates of albatross in trawl fisheries are generally highest for large vessels in FMA's 3, 5 and 6.
- Seabird and albatross bycatch are generally highest in summer and autumn, as are the corresponding capture rates.

*Objective 5*

We show that a sensible method for determining the relative allocation of observer effort across vessel sizes, fishing methods, fishing areas and seasons is to make it proportional to the corresponding estimate of bycatch. This is an intuitively sensible choice,

and is statistically reliable for skewed data. It means that the results in Objective 4 can be used directly to determine a suitable allocation.

For the purpose of this report, we assume that the objective of the allocation is to provide an estimate of total seabird bycatch across all fisheries. In addition, we consider the relative allocation required to estimate total albatross bycatch across all trawl fisheries. A fuller discussion of the benefits of this estimate in assessing risk to individual species is beyond the scope of this report. We note again, however, that the observer data do not allow estimation of bycatch at an individual species level.

We focus here on the relative allocation of observer effort for two reasons. First, it is beyond the scope of this report to determine a suitable level of precision required to assess risk, even given the caveat regarding individual species mentioned above. Second, it is difficult to predict in advance what the precision of a model-based estimate of total bycatch will be for a given absolute amount of observer effort, as it depends in part on the model that is fitted. It is also possible that other methods of estimation will be used in future projects dealing with this estimation, although we would recommend continuation of the model-based approach.

**Objectives:**

1. To estimate and report the total numbers, and rates of captures, releases and deaths of seabirds, where possible by species, fishery and fishing method, caught in fishing operations up to the end of the fishing year 2002/03.

2. To provide an estimate of rate of seabird incidental capture, where possible by species, fishery and fishing method, for the fishing year 2003/04.

3. To examine factors related to fishing operations influencing the probability of capture of seabirds.

4. To classify fishing areas, seasons and fishing methods into different risk categories in relation to the probability of seabird incidental captures.

5. To recommend the observer coverage levels needed to estimate seabird captures within these risk categories, with highest precision in areas of highest risk. Options for varying levels of accuracy in estimation shall be provided using appropriate metrics for the sampling regime(s) recommended.

**Introduction**

Under the sustainability measures set out in the Fisheries Act (1996, s 15), the fishing-related mortality of marine mammals or other wildlife may be managed to avoid, remedy or mitigate any adverse effects of fishing on the related protected species. It is well known that many seabird species suffer from fishing-related mortalities, however the overall level of mortality and factors that may influence capture rates are less well known. Although the level of seabird incidental catch (i.e., bycatch) has been shown to vary significantly between fisheries and within each fishery by season, and location (Baird 2004*a*, 2004*b*, 2004*c*, 2005).

The aim of this project was to estimate the level of incidental catch in both trawl and longline fisheries for the 1997/98-2003/04 fishing seasons, and to investigate the factors that influence capture probability in these fisheries. Fisheries were then placed in different risk categories according to the probability of seabird incidental catch, and advice on the level of observer coverage required was to be provided.

The main source of information available on seabird incidental catch was the non-fish bycatch records collected by the Scientific Observer Programme, with catch-effort data obtained form the Ministry of Fisheries database *Warehou*. However, scientific observers are placed on vessels in an ad-hoc manner (with respect to monitoring and managing seabird incidental catch) hence the results presented here are not as conclusive about causal factors as if a more statistically valid sampling scheme had been used.

This project provides a detailed analysis of the factors that affect incidental capture rates of seabirds within New Zealand fisheries. Estimates of the level of seabird incidental catch in specific fisheries and also at spatially larger scales are provided.

**Objectives 1 and 2**
1. To estimate and report the total numbers, and rates of captures, releases and deaths of seabirds, where possible by species, fishery and fishing method, caught in fishing operations up to the end of the fishing year 2002/03.
2. To provide an estimate of rate of seabird incidental capture, where possible by species, fishery and fishing method, for the fishing year 2003/04.

**Methods**
*Data*

The Ministry of Fisheries (MFish) was requested to extract data from databases relevant to this research for trawl, surface long line (SLL) and bottom long line (BLL) fisheries for fishing events from 1 October 1997-30 September 2004 (Appendix A). The general nature of the request was to provide datasets where each record corresponded to one observed tow (or set), characteristics of the tow (e.g., start time, location, sea/weather conditions) and the number of captures of each observer-identified seabird species. A second set of datasets were requested comprising of effort data that were required to predict total bycatch. Effort data was also requested at the resolution of per tow/set, however this was unable to be provided due to the manner in which data is collected from fishers and subsequently stored. The rational for requesting data at the per tow/set level was that data in this form would provide maximum flexibility for potential methods of analysis. Once received, data were carefully checked for obvious errors and omissions (e.g., statistical area or FMA not recorded) and corrections made where possible. Careful attention was devoted to ensure that "effort" as recorded in the catch effort data was correctly interpreted for different fishing methods and form types.

For all fisheries, a fishing year was defined as encompassing the period of time from 1 October in the previous year, to 30 September of the current year. For example, the 1998 fishing year was the period 1 October 1997-30 September 1998. Fisheries management areas are shown in Figure 1.

Initial assessments of the data indicated that it would not be practical to estimate bycatch at the level of individual seabird species, hence the data was pooled for all species. For trawl fisheries, however, bycatch of albatross species was separately estimated. No attempt was made to differentiate between live and dead landed birds due to small sample sizes, nor to allow for the possibility that birds released alive may have been traumatised to the extent that compromised their survival.

*Statistical Methods*

Seabird bycatch was estimated using a model-based (as opposed to a design-based) method. The main advantage of using a model-based approach in this setting is the ability to account for some sources of variation in bycatch with auxiliary variables, and exploit similarities in bycatch rates among different seasons, years, regions or fisheries. For example, the model could be used to predict seabird bycatch in fisheries where there is little or no observer coverage, under the assumption that the model is a reasonable representation of the biological reality. However, as with design-based estimation methods, generalising results beyond the observed vessels requires the data to be collected within a statistical valid sampling scheme. This is because there may be factors influencing bycatch that are not allowed for in the modelling. If the observed sets/tows are not representative of the whole fishery with respect to any of these unmodelled factors, the resulting estimates may be biased.

Having as much randomisation in the sampling scheme as possible can help avoid the observed data being unbalanced in this way.

To account for the large number of fishing events with zero bycatch, a Poisson mixture model consisting of two components was used. The first component is a binary (0-1) random variable ($Z$) which is used to model the excess number of zeros. If $Z = 0$ then no seabirds will be bycaught, but if $Z = 1$, then the number of seabirds caught will be a random value from a Poisson distribution (the second model component). We therefore need to estimate two parameters; the probability $Z = 1$ ($p$) and the Poisson rate parameter ($\lambda$; lambda). These parameters can be modelled to allow them to vary for fishing events conducted in different years, regions, seasons and so forth. Here, up to five factors were included in the models for $p$ and $\lambda$; fishing year, season, fishing area, target species and vessel size class. The seasons were defined to be spring (Oct.–Dec.), summer (Jan.–March), autumn (Apr.–June) and winter (July–Sep.). Fishing areas were based upon fishery management areas (FMAs) and vessels were categorised as being greater or less than 28 metres in total length.

The probability that $Z = 1$ for a fishing event in fishing year Y, season S, fishing area F by a vessel of size category V was modelled as

$$\text{logit}\left(p_{\text{YSFV}}\right) = \alpha + \beta_{\text{Y}} + \delta_{\text{S}} + \gamma_{\text{F}} + \upsilon_{\text{V}}$$

where $\beta, \delta, \gamma$ and $\upsilon$ denote the year, season, fishing area and vessel class effects respectively. Note that in order to fit this model one level of each of these effects had to be set equal to zero to establish a control, or baseline, situation where the model would reduce to $\text{logit}\left(p_{\text{YSFV}}\right) = \alpha$. For example, in trawl fisheries the 'standard' situation was defined to be tows conducted in spring of the 1998 fishing year, in fishing area 7, by vessels longer than 28m, and so the constraints $\beta_1 = \delta_1 = \gamma_7 = \upsilon_1 = 0$ were applied. The term 'logit' simply denotes that the logit-link function was used to ensure values of $p$ remained on the 0-1 scale. This is the same link function used in standard logistic regression analyses. Biologically, this component could be regarded as modelling the probability that seabirds are at risk of being bycaught. This will be primarily driven by the seabirds rather than the fishers, and so target species was not included as a factor in this model. Vessel class was included here as a surrogate for effort (e.g., larger vessels may trawl for longer or have more hooks per tow than smaller vessels).

The Poisson rate parameter was modelled using a log-link function (to maintain values of $\lambda$ in the range 0-infinity) with the same factors as above and the addition of target species. Hence, given seabirds were at risk of being bycaught, the bycatch rate for a fishing event in year Y, season S, fishing area F by a vessel of size category V targeting species T was modelled as,

$$\log\left(\lambda_{\text{YSFVT}}\right) = \alpha' + \beta'_{\text{Y}} + \delta'_{\text{S}} + \gamma'_{\text{F}} + \upsilon'_{\text{V}} + \tau'_{\text{T}}.$$

The model was fit to the data using Bayesian statistical methods (Markov chain Monte Carlo; McMC) in the software WinBUGS. The use of McMC methods are becoming more widespread in many areas of applied statistics, including fisheries and wildlife ecology. In a Bayesian analysis a model parameter is considered a random variable. A *prior distribution* is defined for each parameter that represents the state of knowledge about that parameter prior to data collection. Here, vague or uninformative prior distributions were used for all model parameters (normal distributions with mean = 0.0 and variance=100.0). The observed data is then used to update our knowledge of the model parameters, resulting in the *posterior distribution*. Until recently, the Bayesian philosophy to statistical inference has been of limited in its applications due to difficulties in analytically determining the posterior distribution for model parameters. However, McMC methods are an iterative, computer intensive method for approximating posterior distributions of parameters. These methods also

provide a flexible analysis framework that can be simply applied to problems that are difficult to address with a non-Bayesian philosophy.

For the McMC analysis, 3 chains with different initial values were used for each model. Initial values were determined by first using maximum likelihood to get point estimates of the parameters, then selecting a random value from a normal distribution around that point estimate with a standard deviation corresponding to a 30% coefficient of variation. The chains were initially run for 10,000 iterations then visually inspected for convergence and mixing (see Figure 1.1 for an example). If it was determined that convergence had been achieved then the chains were run for a further 25,000 iterations to estimate the posterior distributions of the model parameters (hence 75,000 samples per parameter), otherwise additional iterations were performed until convergence was achieved. To predict the observed and unobserved bycatch, 10,000 post-convergence iterations were used for trawl fisheries and 20,000 iterations for long line fisheries.

As part of the analysis, it is also very easy to predict the outcome of unobserved sampling units. For example in this context, in the summer of fishing year 2004, fishing area 6, trawl vessels longer than 28m targeting squid (i.e., Y = 7, S = 2, F = 6, V = 1 and T = 6) conducted 2623 unobserved tows. Given the current estimates of the model parameters ($\hat{p}_{7,2,6,1}$ and $\hat{\lambda}_{7,2,6,1,6}$), the number of unobserved tows where seabirds are at risk of capture ($x$) could be predicted as a binomial random variable from 2623 trials with probability of 'success' $\hat{p}_{7,2,6,1}$. Likewise, using the properties of Poisson random variables, the number of seabirds bycaught on unobserved tows would be a random value from a Poisson distribution with rate parameter $x\hat{\lambda}_{7,2,6,1,6}$. The total level of bycatch is then the predicted number plus the number actually observed. Predicting bycatch in this manner automatically accounts for two important sources of variation: uncertainty in the level of bycatch for specific values of $\hat{p}_{7,2,6,1}$ and $\hat{\lambda}_{7,2,6,1,6}$ (due to the stochastic nature of bycatch), and uncertainty in the values of $\hat{p}_{7,2,6,1}$ and $\hat{\lambda}_{7,2,6,1,6}$ themselves.

From the model, bycatch is predicted at a relatively fine scale (i.e., year × season × area × vessel class × target species). Here results are reported at both this (see Electronic Appendix) and coarser scales (e.g., year × vessel class) which is achieved by simply aggregating the predicted bycatch across the unreported factor levels. However, as the scientific observer programme has tended to target larger vessels, results are reported separately for each vessel size class, as those for vessels shorter than 28m may be less reliable. Summaries at levels other than those presented here are available upon request.

In this section of the final report, the posterior distribution for the estimated level of bycatch is summarised by the median and the 2.5th and 97.5th percentiles (i.e., the central 95% credible interval).

To verify the reasonableness of the model, the above procedure for predicting bycatch on unobserved tows can also be applied to observed tows. That is, the model can be used to predict the number of seabirds caught for observed tows in each combination of year × season × area × vessel class × target species (see Electronic Appendix). If the model is reasonable, then the observed number of captures should lie within the 'typical' range of predicted values (i.e., it would be expected that 95% of the observed values lie between the 2.5th and 97th percentiles of the distributions for the predicted values). Standardised residuals could also be calculated from the predicted distributions as:

$$R_i = \frac{O_i - P_i^{50}}{\left( P_i^{97.5} - P_i^{2.5} \right)/4}$$

where $O_i$ is the observed number of seabirds caught in the $i$th combination of year, season, area, vessel class and target species and $P_i^k$ is the $k$th percentile from the distribution of the predicted number of seabirds caught (thus $P_i^{50}$ is the median of this distribution). The denominator is simply a between-combination scaling factor that has been used to place the residuals on a common scale, similar to that used in linear regression. Note however that these standardised residuals are not expected to be normally distributed because the data come from an extremely skewed, discrete-valued distribution. Thus residual Q-Q plots may not result in a straight line even if the model is a reasonable representation of the data. These residuals may be plotted against various factors to check for systematic deficiencies within the model, as is typically done for linear regression applications.

## Results

*Trawl Fisheries*

Table 1.1 presents a summary of the number of tows and observed number of albatross and seabird captures for each vessel class from the 1998 to 2004 fishing years. On vessels greater than 28m, approximately 10% of all tows were observed each year, while observer coverage on smaller vessels was minimal over this period. Further data summaries can be extracted from the Electronic Appendix.

Applying the above modelling procedure to the observer data for albatross (see Appendix B for details), albatross bycatch in trawl fisheries was estimated to be approximately 450 birds (95% credible interval 300-600 birds) in the 1998 fishing year, and between 900-1500 in subsequent years by vessels longer than 28m (width of 95% CI's ~500 birds; Figure 1.2). For smaller vessels, albatross bycatch tended to be less than 200 birds, but there is great deal of uncertainty surrounding these estimates (width of 95% CI's ~800 birds; Figure 1.3). The corresponding estimated capture rates (per 100 tows; total estimated bycatch/total tows×100) display a similar pattern (Figures 1.4 and 1.5). The estimated albatross bycatch and capture rates for all trawl fisheries by fishing area are given in Tables 1.2-1.5 (which indicate most the bycatch is predicted to occur in FMAs 3-6), and estimates summarised by target species are given in Tables 1.6-1.9 (which indicate most bycatch is predicted to occur in hoki and squid fisheries).

Total seabird bycatch in trawl fisheries by vessels longer than 28m is estimated to have been relatively stable from 1998-2004, at between 2000-3000 birds (width of 95% CI's ~800 birds; Figure 6; see Appendix C for details of the modelling), with bycatch in 1998 estimated to be slightly lower, and that in 2001 estimated to be higher. For smaller vessels, total seabird bycatch was again estimated to be relatively low (<200), but a high degree of uncertainty (width of 95% CI's ~250 birds; Figure 1.7). Again, a similar trend is apparent from the estimated capture rates (Figures 1.8 and 1.9). Summarised by fishing area, most of the seabird bycatch is predicted to occur in FMAs 3-6 (Tables 1.10-1.13), and in the hoki and squid fisheries when summarised by target species (Tables 1.14-1.17).

Comparison of the observed number of seabird captures to that predicted by the model does not indicate any major systematic problems for either albatross or all seabirds combined. There is a tendency for the residuals to be positive which may indicate bycatch estimates are conservative (i.e., slightly underestimated), or this could be a result of the skewed distribution for the number of captures. Approximately 6% of standardised residuals are >3 which seems reasonable (would be 2.5% if they were normally distributed). The fraction of Year×Area×Season×Target Species×Vessel Class observations that lie below the 2.5[th] percentile of the distribution of the predicted observations is 2.7% and 4.8% lie above the 97.5[th] percentile.

*Surface Long Line Fisheries*

Table 1.18 presents a summary of the number of sets and observed number of seabird captures for each vessel class from the 1998 to 2004 fishing years. Greater than 50% of sets by larger vessels were observed in each year, but observer coverage of smaller vessels was again minimal. Further data summaries can be extracted from the Electronic Appendix.

Total seabird bycatch in surface long line fisheries by vessels longer than 28m was generally estimated to be less than 500 birds (width of 95% CI's ~500 birds in most years), although the upper bound of the credible intervals in the 1998 and 2002 fishing years was relatively high at approximately 1700 birds (Figure 1.10; see Appendix D for details of the modelling). For smaller vessels, the 95% credible intervals for total seabird bycatch generally ranged between 500-4000 birds (Figure 1.11), with notable exceptions being those for the 2000 and 2002 fishing years, which were much larger. For the larger vessels, capture rates exhibit a similar trend as for total bycatch (Figure 1.12), but for smaller vessels the capture rates for the 2000 and 2002 fishing years are not overly different from other years (Figure 1.13). Summarised by fishing area, most of the seabird bycatch is predicted to occur in FMAs 1, 2 and 4 (near the boundary with FMA 2; Tables 1.19-1.22), and primarily in the big-eye tuna fishery when summarised by target species (Tables 1.23-1.27).

Comparison of the observed number of seabird captures to that predicted by the model does not indicate any major systematic problems. There is a tendency for the residuals to be positive which may indicate bycatch estimates are conservative (i.e., slightly underestimated), or this could be a result of the skewed distribution for the number of captures. Approximately 5% of standardised residuals are >3 which seems reasonable. The fraction of Year×Area×Season×Target Species×Vessel Class observations that lie below the 2.5$^{th}$ percentile of the distribution of the predicted observations is 1.6% and 4.9% lie above the 97.5$^{th}$ percentile.

At an Aquatic Environment Working Group meeting in August 2005 some members felt that the aggregated estimates for the larger vessels were too high, considering the very higher observer coverage on joint venture vessels. However, note that no distinction has been made in this modelling between joint venture and domestic vessels and that the apparently high estimates may be due to unobserved domestic vessels. A closer examination of the predicted bycatch in the electronic appendix verifies that this is likely to be the case. For example, for large vessels in the 2004 fishing year most of the predicted bycatch is from vessels fishing in summer in FMAs 2 & 4, targeting BIG. However, there were no observed sets for that combination of factors. This is reflected in the width of the 95% CI being very large for this estimate, corresponding to a high degree of uncertainty. The predicted total bycatch for those fisheries with high level of observer coverage is generally only a few birds greater that that observed.

*Bottom Long Line Fisheries*

Table 1.28 presents a summary of the number of sets and observed number of seabird captures for each vessel class from the 1998 to 2004 fishing years. The observed bycatch was considered too low in the 1998 fishing year to reliably model hence only the data from 1999 onwards was used. Approximately 10% of sets by larger vessels were observed in most years, with much greater levels of observer coverage in the 2002 and 2003 fishing years. Observer coverage of smaller vessels was, again, minimal. Further data summaries may be extracted from the Electronic Appendix.

Total seabird bycatch in bottom long line fisheries by vessels longer than 28m was estimated to be increasing by approximately 500 birds per year from 1999-2001, but was estimated to have steadily decreased in recent years to 600 seabirds (95% CI 500-1000) bycaught in 2004 (Figure 1.14; see Appendix E for details of the modelling). Seabird bycatch

by smaller vessels in bottom long line fisheries was estimated with much less precision, with point estimates generally in the range of (approximately) 2000-4000 birds, but the width of the 95% credible intervals was larger than 10,000 seabirds in 5 of the 6 years (Figure 1.15) indicating a very high degree of uncertainty. Capture rates for both vessel types exhibit similar trends to those for total seabird bycatch (Figures 1.16 and 1.17). Summarised by fishing area, most of the seabird bycatch for larger vessels is predicted to occur in FMAs 3-7 (Tables 1.28 and 1.29), and in FMAs 1, 2, 8-10 for smaller vessels (Tables 1.30 and 1.31). Summarised by target species, for larger vessels the majority of the bycatch was predicted to occur on sets targeting ling, and on sets targeting snapper for smaller vessels.

Comparison of the observed number of seabird captures to that predicted by the model does not indicate any major systematic problems, although there may be insufficient variation in the predicted data compared to the observed (13.7% of observations were below the $2.5^{th}$ percentile of the distribution of the predicted observations, 11.8% were above the $97.5^{th}$ percentile) which may translate to the reported credible intervals being too narrow. However this may also be an artefact of only 51 Year×Area×Season×Target Species×Vessel Class combinations being observed (e.g., a small sample problem). There was a tendency for the residuals to be positive which may indicate bycatch estimates are conservative (i.e., slightly underestimated), or this could be a result of the skewed distribution for the number of captures. Approximately 12% of standardised residuals are >3 which is high and may be due to insufficient variation in the predicted values or small sample size.

**Conclusions**

The general methods used here to estimate seabird bycatch are statistically valid, although there may be some question as to whether the model captures the very rare occasions when a large number of birds are bycaught on a single tow or set. Additionally, no allowance has been made here to accommodate for the hierarchical nature of the sampling (i.e., observers are placed on vessels at the beginning of a trip, and observe all/most fishing events on that trip). Hence using tows/sets as the basic sampling unit may not be completely appropriate. The most serious consequence of not accounting for these aspects of the data in the model is that credible intervals will tend to be too narrow. While such improvements to the model are theoretically simple to implement, especially with the Bayesian methods, these were not feasible to consider due to computing power, particularly for estimating bycatch in multiple years. For example, based on the time taken to run a single analysis (approximately 4 hours of CPU time), an estimate of the time required to conduct a single analysis at the level of individual tows is 60 days.

While it could be argued the modelling of the observed data could possibly be improved, it is questionable as to whether this would provide more reliable estimates of seabird bycatch. Regardless of the exact model structure used on the observed data, in order to generalise the results of the model to unobserved events, the data collected on bycatch from observed vessels must be representative of the bycatch on unobserved vessels. Given the nature in which observers have been allocated to vessels in the past, and the very low levels of observer coverage of small vessels (<28m), caution should be exercised when interpreting the estimated level of bycatch from currently collected scientific observer data regardless of the statistical method employed to provided that estimate. At present it may only be possible to reliably estimate seabird bycatch in a small number of fisheries. Such estimates may be of limited value for managing and mitigating seabird bycatch, as 'problem' fisheries would be difficult to identify without the context provided by having reliable estimates from the majority of fisheries.

Furthermore, to consider the impact of bycatch on seabird populations, estimates of seabird bycatch must be coupled with information on the size of seabird populations. For

example, when considering if bycatch of 1,000 or 10,000 seabirds is too much obviously depends upon population size. This also requires that the population from which bycaught seabirds belong can be reliably identified. Due to these (and other) practical difficulties, a more efficient use of resources to monitoring the impact of seabird-fishery interactions may be to monitor the seabird populations directly rather than focusing on bycatch estimation per se. For example, bycatch is one source of mortality faced by seabirds, hence a reduction in bycatch should correspond to an increase in survival that could be monitored with population banding studies.

Finally, at an Aquatic Environment Technical Group meeting in August 2005 a suggestion was made to draw comparisons between the estimated level of bycatch presented here and previous estimates. However, such a comparison would be meaningless due to the fundamental differences between the methods of analysis and treatment of the raw data.

**Objective 3**

To examine factors related to fishing operations influencing the probability of capture of seabirds.

**Methods**

Data was limited to fishing activities within the New Zealand EEZ. Potential variables were checked for completeness and missing values. Variables with greater than 5% missing values were not considered in the analysis. Where an included variable had a missing value, that tow/set was removed from the dataset. Note that many of the most interesting variables that might be considered for this analysis (e.g., offal discharge) are only recorded in the *obs_lfs* database when bycatch of a protected species occurs. In order to be able to consider the effects of such variables, it is important that they are recorded for all observed tows or sets.

To investigate the factors affecting seabird capture rates, a generalized linear model (GLM) was used, with the number of birds captured on a tow/set being assumed to follow a negative binomial distribution. This is a generalisation of the Poisson distribution, parameterised here as:

$$\Pr\left(X = x\right) = \frac{\Gamma\left(x + \theta\right)}{\Gamma\left(\theta\right)x!}\frac{\mu^{x}\theta^{\theta}}{\left(\mu + \theta\right)^{x+\theta}}$$

where $\mu$ is the capture rate and $\theta$ is an overdispersion parameter, i.e. it allows for greater variation in the counts that would be expected from a Poisson distribution. Within the GLM framework used by the statistical package R, $\mu$ may be a function (on the natural log scale) of predictor variables, while a single value for $\theta$ is estimated for the entire data set. GLM's have been used previously within the New Zealand context for assessing the factors that may affect bycatch of protected species (e.g. Manly et al 2002, Smith and Baird 2004). The negative binomial distribution has been used because of the skewness in the data. Note that we considered using the two-component mixture model from Objectives 1 & 2, but decided upon this simpler approach, as interpreting the net effect of a factor on capture rate via two separate components would be difficult.

To assess the relative importance of the variables included in the models, all possible models were fitted to the data, and ranked according to Akaike's Information Criteria (AIC). AIC model weights were then calculated and summed for each variable (Burnham and Anderson 2004, MacKenzie et al. 2005). Inferences were based upon a model that included only the most important variables (those with summed AIC weights > 50%). Model fit was assessed using randomised quantile residuals (Dunn and Smyth 1996, Smith and Baird 2004).

We also note that the data used here would be classified as an observational study, hence there is the potential that the apparent effects of some factors may actually be the result of an unknown confounded factor which has not been included in the analysis. The data collection is also "unbalanced" (unequal replication for different factor combinations) therefore some caution must be exercised when interpreting results as there may be a risk of confounding occurring among the factors that have been included in the model.

**Results**

*Surface Longlining*

Between the 1998 and 2004 fishing years (as defined in the results for Objectives 1 and 2), records for 3230 observed sets were available. Potential variables and the proportion of missing values for each variable are given in Table 3.1. Taiwanese vessels were only observed in the 2003 fishing year, and as such were removed from the data set. The following

analysis was based upon 2974 observed sets that had complete information for all included variables.

*Season* was defined as for Objective 2, although because of the relatively low number of observed sets in winter, spring and summer, the data from these seasons were pooled. Three categories for *Target Species* were used; BIG, STN and Other, and *Fishing Areas* were based upon recorded FMA's with the following 6 categories

1. FMAs 1 & 10
2. FMA 2
3. FMAs 3 & 6
4. FMA 5
5. FMA 7
6. FMAs 8 & 9

Sets were defined as being either nighttime or daytime sets according to the recorded start and end times. Sets that began between 1500 and 0300 hours and were completed before 0900 hours were defined to be nighttime sets.

Eight variables were considered for inclusion in the analysis, resulting in 256 possible models. The summed AIC model weights given in Table 3.2. The low model weights for *Vessel Class*, *Target Species* and *Hooks Set* suggest they are less important than the other variables. Table 3.3 provides estimates of the model coefficients associated with the "important" variables. Their effects on capture rate are indicated in Figures 3.1-3.5. The main results appear to be that capture rates are lower on NZ registered vessels than Japanese, lower in Autumn than in other seasons, and higher in FMAs 1&10 and 2 compared to other areas. Residual plots (Figures 3.6 and 3.7) do not suggest any evidence of systematic lack of fit.

*Bottom Longlining*

Between the 1999 and 2004 fishing years, records for 6421 observed sets were available. Potential variables and the proportion of missing values for each variable are given in Table 3.4. The following analysis was based upon the 5520 observed sets that had complete information for all included variables.

*Target Species* was defined as LIN (=0) and Other (=1), and *Fishing Areas* were based upon recorded FMA's with 4 categories:

1. FMAs 1-3, 7-10
2. FMA 4
3. FMAs 5
4. FMA 6

Four categories were also used with respect to the *Start* and *End Time* of sets:
1. 2100-0300
2. 0300-0900
3. 0900-1500
4. 1500-2100

Eight variables were considered for inclusion in the analysis, resulting in 256 possible models. The summed AIC model weights given in Table 3.5. The low model weights for *Vessel Class*, *Fishing Area* and *Hooks Set* suggest they are less important than the other variables. Table 3.6 provides estimates of the model coefficients associated with the "important" variables. Their effects on capture rates are indicated in Figures 3.8-3.11. The main results appear to be that capture rates are higher in spring than in other seasons, higher on sets targeting LIN, and higher on sets that started between 0300-0900. Note that the year effects should be interpreted with caution prior to 2001, as recording bycatch was not a

primary responsibility of scientific observers hence a unknown fraction of hooks on any given tow was observed. Residual plots (Figures 3.12 and 3.13) do not suggest any evidence of systematic lack of fit.

*Trawl Fisheries*

Between the 1998 and 2004 fishing years, records for 55,185 observed tows were available. 3,259 records were deleted as they were outside the EEZ (excluding tows in SOI) and a further 541 records were deleted as recorded fishing speeds were outside the range of reasonable levels (i.e., <1 or >10 knots). Potential variables and the proportion of missing values for each variable (from the remaining 51,385 observed tows) are given in Table 3.7. Headline height was not considered as a predictor variable, as it was highly correlated with *Trawl Type* (mid-water (=0) vs bottom (=1) trawl; correlation=-0.81). The analysis was based upon 51,272 observed tows that had complete information for all included variables.

Vessels were categorised in to five nationalities:

1. NZ
2. Korean
3. Japanese
4. Russian/Ukrainian
5. Other (including "NZOTH") or undetermined.

The same 7 target species categories were used here as in Objective 2:

1. HOK
2. JMA
3. ORH
4. SBW
5. SCI
6. SQU
7. Other

*Fishing Areas* were based upon recorded FMA's with 6 categories:

1. FMAs 1, 2, 8-10
2. FMA 3
3. FMA 4
4. FMA 5
5. FMA 6
6. FMA 7.

*Fishing on Marks* was used to indicate whether vessels were actively targeting fish sign (1 if yes, 0 if no), and the *Start* and *End Times* of trawls were categorised as for bottom longlining above, i.e.:

1. 2100-0300
2. 0300-0900
3. 0900-1500
4. 1500-2100.

Eleven variables were included in the modelling of the seabird bycatch data, resulting in 2048 possible models. The summed AIC model weights are given in Table 3.8. The low model weights for *Vessel Class* and *End Time* suggest they are less important than the other

variables. Table 3.9 provides estimates of the model coefficients associated with the "important" variables. Their effects on capture rates are indicated in Figures 3.14-3.22. The main results appear to be that capture rates were much greater for tows by Korean vessels, highest in autumn and lowest in winter, highest on tows targeting SCI and lowest on tows targeting JMA or SBW, lower for bottom trawls than mid-water trawls, lower in North Island trawl fisheries, and higher for tows that began between 0900-1500. Residual plots (Figures 3.23 and 3.24) do not indicate any systematic lack of fit.

**Conclusions**

There does not appear to any overwhelmingly consistent patterns across all fishing types, although for both bottom longline and trawl fisheries, capture rates appear to be higher for sets/tows that are conducted during the day.

It must be noted that the above results pertain to the tows/sets observed by scientific observers. Whether these results are relevant to the entire fishing fleet depend upon how representative the observed fishing activities are of the situation in general. Given that observers are not allocated at random to vessels, then the above results should be extrapolated to all fishing activities with caution.

**Objective 4**

To classify fishing areas, seasons and fishing methods into different risk categories in relation to the probability of seabird incidental captures.

**Introduction**

A full assessment of the risk of fisheries bycatch on seabird populations is beyond the scope of this report, and is currently being dealt with as part of the ENV2004/05 project. The latter project will consider individual species, and issues such as their foraging ranges, that are not covered in this report. In addition, the observer data we were provided did not allow us to estimate bycatch at an individual species level. Observer data are also prone to observation and recording errors, making an assessment of risk based on these data alone a difficult task.

Given these caveats, we provide here a summary of the relative risk posed by the different fisheries (method and vessel-size) classified by fisheries management area and season within the fishing year. In doing so, we present results for all seabirds and for albatross caught in trawl fisheries.

There are a number of ways in which relative risk could be defined in this context. The most obvious and natural is the estimated total number of birds caught in a year. Clearly the ideal would be to have an estimate of this for species of particular concern. Having said that, the information on albatross bycatch in trawl fisheries goes some way to addressing species-level concerns.

An alternative measure of risk is the amount of uncertainty associated with the estimate of the number of birds caught. This highlights where more information is needed, as a high degree of uncertainty means that the estimated bycatch could be much lower or much higher than we estimate. A simple measure of uncertainty is provided by the width of the 95% credible interval associated with the estimate, expressed as a number of birds.

In addition to considering total bycatch, we also include summaries showing the estimated capture rate (birds per set or per 100 tows) for the different combinations of vessel size, method, fishing area and season. This information might be useful if the amount of fishing effort for any particular vessel size/method/area/season were thought likely to change substantially. For example, a particular method-area combination may have a relatively low total bycatch, and yet have a relatively high capture rate. If the fishing effort for this combination increases, the number of birds caught may increase to a level where it is considered a high risk.

**Methods**

We used the results from the modelling in Objective 2 to estimate the *bycatch* (number of birds) and the *capture rate* (birds per set or per 100 tows) for trawl, bottom longline and surface longline fishing. We aggregated the predictions across target species. This allowed us to calculate an estimate of bycatch and capture rate for each combination of vessel size, method, fishing area and season (referred to hereafter as "vessel-method-area-season").

We carried out these calculations using estimates for the most recent fishing year (2004) as well as for the average estimate across all fishing years (1998-2004 for trawl and surface longline; 1999-2004 for bottom longline). In our discussion of the results we focus on the estimates for 2004: we have provided the average over all years in case there is interest in assessing patterns over a longer time period.

For some vessel-method-area-seasons, there was no fishing effort (observed or unobserved) corresponding to that method and vessel-size, and these are shown as blanks in the relevant tables. Note that the modelling we used in Objective 2 allows us to estimate

bycatch and capture rates for those area-season combinations for which there was no observer effort, unlike previous estimates of the kind presented here.

**Results and Conclusions**

Table 4.1 shows the estimates of total bycatch (number of birds) across all vessel-sizes, methods, areas and seasons, for both 2004 and the average over 1998-2004. Each estimate is also shown as a percentage of the sum of the estimates across all vessel-method-area-season combinations. The results are ranked in descending order of the estimated bycatch in 2004. For ease of presentation, we have removed those combinations of vessel-method-area-season for which the estimate in 2004 was less than 0.5% of the total. Figures 4.1-4.4 provide an alternative, visual, summary of the estimates of bycatch in 2004, for both seabirds and albatross (note that the estimates for seabirds have been split according to fishing method and that the 95% credible intervals are also shown). Large trawl vessels in areas 5 and 6 account for an estimated 25% of the total bycatch in 2004, over the summer and autumn seasons. Small longline vessels in areas 2 and 4 are estimated to account for a further 16%, again over the summer and autumn seasons in 2004. Table 4.2 shows the corresponding estimates of total bycatch for albatrosses caught in trawl fisheries. An estimated 52% of the bycatch in 2004 can be attributed to large vessels in areas 5 and 6, over the summer and autumn seasons.

Table 4.3 shows the uncertainty associated with the estimates of total seabird bycatch for 2004 (Table 4.1 and Figures 4.1-4.3). The uncertainty is also shown as a percentage of the total estimated bycatch for 2004. The results have been ranked in descending order and those vessel-method-area-season combinations for which the uncertainty was less than 2% of the estimated total bycatch in 2004 have been omitted from the table. The major uncertainties are associated with small longline vessels, especially surface longline vessels in areas 2 and 4 and bottom longline vessels in areas 1-2 and 8-10. Table 4.4 shows the corresponding uncertainties associated with estimates of albatross bycatch in trawl fisheries in 2004 (Table 4.2 and Figure 4.4). The major uncertainties are associated with small vessels in areas 3 and 7 and large vessels in areas 5 and 6.

Table 4.5 shows the estimates of capture rate (birds per 100 tows) in trawl fisheries across all vessel-sizes, areas and seasons, for both 2004 and the average over 1998-2004. We have ranked the results in descending order of the estimated rate in 2004. Tables 4.6 and 4.7 show the corresponding estimates for seabird capture rate in longline fisheries (birds per set), and albatrosses capture rate in trawl fisheries (birds per 100 tows).

The highest estimated capture rates of seabirds in trawl fisheries in 2004 come from large vessels in areas 3, 5 and 6, in both summer and autumn seasons. In longline fisheries, the highest capture rates are generally associated with surface longline vessels in areas 1, 2 and 4. The highest estimate capture rates of albatross in trawl fisheries come from large vessels in areas 3, 5 and 6, in both the summer and autumn seasons.

**Objective 5**
To recommend the observer coverage levels needed to estimate seabird captures within these risk categories, with highest precision in areas of highest risk.

**Introduction**
    The issues discussed in the introduction to the report on Objective 4 are also relevant here. We might consider one of the main objectives of collecting the observer data is to assess the risk to seabird populations of particular concern. Leaving aside the issues as to how to assess risk and which populations should be of most concern (which we are working on in ENV2004/05), the observer data we were provided does not allow for estimation of bycatch at the species-level.

    Give the above caveats, we can consider the objective here to be one of providing advice as to the level of observer coverage required in order to be able to estimate seabird bycatch (number of birds) to an appropriate level of precision. The difficulty is then one of defining what we mean by an appropriate level of precision. A level corresponding to a 20% CV has been used by DOC, but this is an arbitrary choice.

    There is also the question as to the need for precision at the NZ-wide level of estimation versus obtaining precise estimates of bycatch for particular vessel-sizes, methods, areas or seasons. We choose to consider the relative allocation of observer effort required in order to maximise the precision of the estimate of total seabird bycatch across all vessel-sizes, methods, areas and seasons. In addition, we consider the allocation required to maximise precision of the estimate of total albatross bycatch across all vessel-sizes, areas and seasons. The precision of estimates at a finer scale than covered in this report could be considered if that were thought to be useful.

    The work in Objective 4 uses estimates of bycatch from the model-based analysis in Objective 2. It is difficult to predict in advance what the precision of such model-based estimates will be for a given level of observer effort in future years. It is also possible that other methods of estimation will be used in future projects dealing with this estimation, although we would recommend continuation of the model-based approach. We therefore consider the relative allocation of observer effort by using a standard approach developed in the context of stratified sampling. The resulting allocation can also be argued on heuristic grounds, and should be reliable even though the results will not be analysed as if they were from a stratified random sample.

**Methods**
    We calculated the relative allocation of observer effort to a particular vessel-method-area-season combination by making it proportional to the expected fishing effort multiplied by the expected mean capture rate, i.e.

$$w_i \propto N_i \mu_i$$

where, for vessel-method-area-season $i$

    $w_i$   =   proportion of total observer effort allocated
    $N_i$   =   expected fishing effort
    $\mu_i$   =   expected mean capture rate

The resulting allocation ensures that there will be more observer effort where there is expected to be more fishing effort, an obvious requirement. In addition, it also ensures that

there will be more observer effort where there is expected to be a high mean capture rate. This is because the precision of the resulting estimate of total bycatch is improved by concentrating effort where there is high variation in capture rate, and this is associated with a high mean capture rate (see Appendix F for details).

**Results and Conclusions**

As the expression $N_i\mu_i$ is the expected bycatch for that vessel-method-area-season, this allocation rule has a simple, direct interpretation. The allocation of observer effort to a particular vessel-method-area-season combination should be in direct proportion to the estimate of bycatch for that combination. This means that the estimated percentages of total bycatch shown in Tables 4.1 and 4.2 determine the relative allocation required for estimating seabird bycatch and albatross bycatch (in trawl fisheries) respectively.

Thus small surface longline vessels in areas 2 and 4 in summer account for an estimated 10% of total seabird bycatch in 2004 (Table 4.1). This suggests that 10% of the observer effort should be allocated to these vessels. Likewise, large vessels in area 6 in summer account for an estimated 18% of the total albatross bycatch in trawl fisheries in 2004 (Table 4.2). This suggests that 18% of the observer effort should allocated to those vessels. Note that there is a choice here between determining the allocation according to whether we wish to estimate total seabird bycatch or wish to estimate total albatross bycatch in trawl fisheries.

Table 1.1: Number of observed tows and total tows, and number of albatross and all seabird observed as bycatch by each vessel class for the 1998-2004 fishing years.

| Fishing Year | Vessel Class | Obs. Tows | Total Tows | % Tows Obs. | Alb. Bycatch | Seabird Bycatch |
|---|---|---|---|---|---|---|
| 1998 | >28m | 6712 | 80626 | 8% | 37 | 96 |
|  | <28m | 415 | 115481 | 0% | 4 | 10 |
| 1999 | >28m | 7067 | 80428 | 9% | 128 | 269 |
|  | <28m | 556 | 103047 | 1% | 7 | 17 |
| 2000 | >28m | 7387 | 71519 | 10% | 102 | 173 |
|  | <28m | 844 | 86617 | 1% | 4 | 8 |
| 2001 | >28m | 8900 | 69376 | 13% | 244 | 683 |
|  | <28m | 358 | 83571 | 0% | 10 | 11 |
| 2002 | >28m | 7602 | 75544 | 10% | 189 | 322 |
|  | <28m | 611 | 79952 | 1% | 5 | 5 |
| 2003 | >28m | 6619 | 72986 | 9% | 126 | 298 |
|  | <28m | 367 | 80053 | 0% | 2 | 2 |
| 2004 | >28m | 6378 | 66097 | 10% | 167 | 290 |
|  | <28m | 167 | 76065 | 0% | 4 | 4 |

Table 1.2: Estimated albatross bycatch from 1998-2004 by fisheries management area for trawl fisheries by vessels greater than 28 metres in length.

| Fishing Year | FMA | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 9 | Other |
| 1998 | 0 | 13 | 87 | 55 | 138 | 109 | 32 | 0 | 0 |
| | (0, 3) | (3, 31) | (52, 138) | (36, 84) | (90, 205) | (71, 162) | (16, 55) | (0, 4) | (0, 7) |
| 1999 | 0 | 31 | 252 | 142 | 492 | 210 | 103 | 0 | 2 |
| | (0, 8) | (12, 62) | (185, 339) | (91, 213) | (374, 642) | (157, 277) | (70, 149) | (0, 9) | (0, 29) |
| 2000 | 0 | 22 | 200 | 91 | 192 | 266 | 73 | 0 | 1 |
| | (0, 6) | (8, 46) | (143, 275) | (58, 138) | (143, 254) | (202, 347) | (44, 113) | (0, 6) | (0, 14) |
| 2001 | 0 | 20 | 210 | 113 | 334 | 250 | 99 | 0 | 2 |
| | (0, 4) | (7, 40) | (157, 276) | (77, 161) | (292, 384) | (197, 313) | (66, 143) | (0, 6) | (0, 18) |
| 2002 | 0 | 21 | 162 | 110 | 393 | 470 | 100 | 0 | 5 |
| | (0, 7) | (7, 43) | (115, 222) | (72, 162) | (324, 477) | (376, 586) | (68, 145) | (0, 6) | (2, 27) |
| 2003 | 0 | 21 | 154 | 118 | 339 | 345 | 80 | 0 | 2 |
| | (0, 5) | (9, 43) | (108, 213) | (83, 164) | (272, 421) | (267, 443) | (52, 118) | (0, 5) | (0, 19) |
| 2004 | 0 | 17 | 128 | 112 | 368 | 585 | 82 | 0 | 2 |
| | (0, 5) | (6, 36) | (90, 177) | (74, 163) | (300, 448) | (482, 708) | (57, 115) | (0, 7) | (0, 21) |

Table 1.3: Estimated albatross bycatch rate (per 100 tows) from 1998-2004 by fisheries management area for trawl fisheries by vessels greater than 28 metres in length.

| Fishing Year | FMA | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 9 | Other |
| 1998 | 0.00 | 0.19 | 0.55 | 0.52 | 1.48 | 0.81 | 0.26 | 0.00 | 0.00 |
| | (0.00, 0.16) | (0.04, 0.46) | (0.33, 0.86) | (0.34, 0.80) | (0.96, 2.19) | (0.53, 1.20) | (0.13, 0.45) | (0.00, 0.22) | (0.00, 0.08) |
| 1999 | 0.00 | 0.56 | 1.95 | 1.32 | 4.85 | 1.82 | 0.89 | 0.00 | 0.01 |
| | (0.00, 0.44) | (0.22, 1.11) | (1.43, 2.63) | (0.85, 1.98) | (3.69, 6.33) | (1.36, 2.40) | (0.60, 1.28) | (0.00, 0.59) | (0.00, 0.20) |
| 2000 | 0.00 | 0.42 | 1.52 | 1.09 | 2.71 | 1.84 | 0.69 | 0.00 | 0.01 |
| | (0.00, 0.36) | (0.15, 0.88) | (1.08, 2.08) | (0.70, 1.66) | (2.02, 3.59) | (1.39, 2.40) | (0.42, 1.08) | (0.00, 0.46) | (0.00, 0.14) |
| 2001 | 0.00 | 0.54 | 1.85 | 1.26 | 4.22 | 1.85 | 0.89 | 0.00 | 0.02 |
| | (0.00, 0.52) | (0.19, 1.07) | (1.39, 2.44) | (0.86, 1.80) | (3.69, 4.85) | (1.46, 2.32) | (0.59, 1.28) | (0.00, 0.48) | (0.00, 0.17) |
| 2002 | 0.00 | 0.70 | 1.74 | 1.25 | 5.37 | 2.47 | 0.94 | 0.00 | 0.03 |
| | (0.00, 0.53) | (0.23, 1.44) | (1.24, 2.39) | (0.82, 1.85) | (4.43, 6.52) | (1.98, 3.08) | (0.64, 1.36) | (0.00, 0.49) | (0.01, 0.18) |
| 2003 | 0.00 | 0.57 | 1.49 | 1.23 | 4.57 | 2.12 | 0.78 | 0.00 | 0.02 |
| | (0.00, 0.33) | (0.24, 1.16) | (1.05, 2.07) | (0.87, 1.71) | (3.67, 5.68) | (1.64, 2.72) | (0.51, 1.15) | (0.00, 0.35) | (0.00, 0.15) |
| 2004 | 0.00 | 0.60 | 1.70 | 1.27 | 6.00 | 3.39 | 1.01 | 0.00 | 0.02 |
| | (0.00, 0.43) | (0.21, 1.26) | (1.19, 2.34) | (0.84, 1.84) | (4.89, 7.30) | (2.80, 4.11) | (0.70, 1.41) | (0.00, 0.29) | (0.00, 0.18) |

Table 1.4: Estimated albatross bycatch from 1998-2004 by fisheries management area for trawl fisheries by vessels less than 28 metres in length.

| Fishing Year | FMA | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 9 | Other |
| 1998 | 0 | 9 | 34 | 1 | 9 | 9 | 28 | 0 | 0 |
| | (0, 8) | (0, 50) | (6, 155) | (0, 8) | (1, 43) | (4, 24) | (4, 134) | (0, 3) | (0, 6) |
| 1999 | 0 | 31 | 115 | 3 | 26 | 15 | 75 | 0 | 0 |
| | (0, 18) | (7, 138) | (25, 504) | (0, 16) | (4, 116) | (3, 58) | (14, 370) | (0, 9) | (0, 8) |
| 2000 | 0 | 20 | 67 | 4 | 18 | 14 | 38 | 0 | 0 |
| | (0, 13) | (3, 90) | (14, 294) | (1, 15) | (3, 82) | (3, 53) | (7, 185) | (0, 6) | (0, 5) |
| 2001 | 1 | 25 | 85 | 5 | 22 | 18 | 47 | 0 | 0 |
| | (0, 15) | (8, 84) | (17, 371) | (2, 17) | (4, 97) | (6, 59) | (8, 221) | (0, 7) | (0, 4) |
| 2002 | 1 | 29 | 80 | 3 | 22 | 16 | 48 | 0 | 0 |
| | (0, 16) | (7, 106) | (18, 339) | (0, 15) | (4, 97) | (3, 62) | (9, 231) | (0, 6) | (0, 6) |
| 2003 | 1 | 18 | 73 | 3 | 18 | 8 | 45 | 0 | 0 |
| | (0, 13) | (2, 72) | (15, 317) | (1, 10) | (3, 82) | (1, 33) | (8, 213) | (0, 4) | (0, 5) |
| 2004 | 1 | 19 | 81 | 2 | 18 | 7 | 62 | 0 | 0 |
| | (0, 17) | (2, 77) | (18, 349) | (1, 8) | (3, 81) | (1, 27) | (12, 300) | (0, 6) | (0, 6) |

Table 1.5: Estimated albatross bycatch rate (per 100 tows) from 1998-2004 by fisheries management area for trawl fisheries by vessels less than 28 metres in length.

| Fishing Year | FMA | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 9 | Other |
| 1998 | 0.00 | 0.06 | 0.10 | 0.08 | 0.17 | 0.40 | 0.10 | 0.00 | 0.00 |
| | (0.00, 0.05) | (0.00, 0.32) | (0.02, 0.47) | (0.00, 0.67) | (0.02, 0.79) | (0.18, 1.08) | (0.01, 0.49) | (0.00, 0.07) | (0.00, 0.05) |
| 1999 | 0.00 | 0.19 | 0.34 | 0.39 | 0.51 | 0.68 | 0.32 | 0.00 | 0.00 |
| | (0.00, 0.15) | (0.04, 0.85) | (0.07, 1.49) | (0.00, 2.07) | (0.08, 2.27) | (0.14, 2.62) | (0.06, 1.56) | (0.00, 0.18) | (0.00, 0.19) |
| 2000 | 0.00 | 0.14 | 0.25 | 0.44 | 0.38 | 0.50 | 0.22 | 0.00 | 0.00 |
| | (0.00, 0.11) | (0.02, 0.62) | (0.05, 1.09) | (0.11, 1.66) | (0.06, 1.73) | (0.11, 1.90) | (0.04, 1.10) | (0.00, 0.13) | (0.00, 0.16) |
| 2001 | 0.01 | 0.19 | 0.32 | 0.63 | 0.43 | 0.66 | 0.28 | 0.00 | 0.00 |
| | (0.00, 0.13) | (0.06, 0.63) | (0.06, 1.40) | (0.25, 2.14) | (0.08, 1.88) | (0.22, 2.15) | (0.05, 1.32) | (0.00, 0.16) | (0.00, 0.15) |
| 2002 | 0.01 | 0.21 | 0.34 | 0.38 | 0.48 | 0.62 | 0.31 | 0.00 | 0.00 |
| | (0.00, 0.15) | (0.05, 0.77) | (0.08, 1.45) | (0.00, 1.89) | (0.09, 2.10) | (0.12, 2.40) | (0.06, 1.50) | (0.00, 0.18) | (0.00, 0.11) |
| 2003 | 0.01 | 0.15 | 0.28 | 0.46 | 0.40 | 0.48 | 0.26 | 0.00 | 0.00 |
| | (0.00, 0.13) | (0.02, 0.58) | (0.06, 1.23) | (0.15, 1.53) | (0.07, 1.81) | (0.06, 1.99) | (0.05, 1.25) | (0.00, 0.14) | (0.00, 0.10) |
| 2004 | 0.01 | 0.17 | 0.36 | 0.49 | 0.50 | 0.66 | 0.33 | 0.00 | 0.00 |
| | (0.00, 0.15) | (0.02, 0.70) | (0.08, 1.54) | (0.24, 1.95) | (0.08, 2.25) | (0.09, 2.55) | (0.06, 1.58) | (0.00, 0.19) | (0.00, 0.17) |

Table 1.6: Estimated albatross bycatch from 1998-2004 by target species for trawl fisheries by vessels greater than 28 metres in length.

| Fishing Year | Target Species | | | | | | |
|---|---|---|---|---|---|---|---|
| | HOK | JMA | ORH | SBW | SCI | SQU | Other |
| 1998 | 182 | 9 | 15 | 0 | 1 | 190 | 38 |
| | (125, 261) | (3, 19) | (6, 28) | (0, 4) | (0, 5) | (125, 280) | (19, 65) |
| 1999 | 501 | 22 | 51 | 3 | 10 | 510 | 130 |
| | (394, 634) | (8, 45) | (31, 83) | (1, 10) | (2, 24) | (382, 672) | (87, 193) |
| 2000 | 423 | 16 | 24 | 1 | 0 | 288 | 97 |
| | (326, 543) | (9, 28) | (11, 43) | (0, 4) | (0, 3) | (214, 383) | (64, 144) |
| 2001 | 448 | 9 | 26 | 2 | 1 | 426 | 116 |
| | (359, 555) | (4, 19) | (14, 45) | (1, 5) | (0, 4) | (369, 494) | (81, 164) |
| 2002 | 466 | 16 | 28 | 2 | 21 | 592 | 136 |
| | (366, 594) | (6, 32) | (15, 52) | (0, 9) | (8, 47) | (492, 715) | (96, 190) |
| 2003 | 361 | 7 | 21 | 1 | 28 | 527 | 117 |
| | (279, 465) | (2, 18) | (9, 40) | (0, 4) | (14, 54) | (427, 649) | (78, 172) |
| 2004 | 309 | 2 | 30 | 1 | 45 | 780 | 128 |
| | (238, 398) | (0, 9) | (15, 52) | (0, 5) | (22, 87) | (658, 921) | (87, 183) |

Table 1.7: Estimated albatross bycatch rate (per 100 tows) from 1998-2004 by target species for trawl fisheries by vessels greater than 28 metres in length.

| Fishing Year | Target Species | | | | | | |
|---|---|---|---|---|---|---|---|
| | HOK | JMA | ORH | SBW | SCI | SQU | Other |
| 1998 | 0.50 | 0.22 | 0.10 | 0.00 | 0.67 | 2.05 | 0.28 |
| | (0.34, 0.72) | (0.07, 0.46) | (0.04, 0.19) | (0.00, 0.17) | (0.00, 3.33) | (1.35, 3.02) | (0.14, 0.48) |
| 1999 | 1.55 | 0.59 | 0.28 | 0.12 | 2.39 | 6.54 | 0.86 |
| | (1.22, 1.96) | (0.21, 1.20) | (0.17, 0.45) | (0.04, 0.40) | (0.48, 5.73) | (4.90, 8.62) | (0.57, 1.28) |
| 2000 | 1.24 | 0.71 | 0.18 | 0.07 | 0.00 | 4.48 | 0.71 |
| | (0.96, 1.59) | (0.40, 1.24) | (0.08, 0.32) | (0.00, 0.27) | (0.00, 8.33) | (3.33, 5.96) | (0.47, 1.06) |
| 2001 | 1.35 | 0.47 | 0.20 | 0.15 | 1.04 | 5.64 | 0.94 |
| | (1.08, 1.67) | (0.21, 0.99) | (0.11, 0.35) | (0.07, 0.37) | (0.00, 4.17) | (4.88, 6.54) | (0.65, 1.32) |
| 2002 | 1.53 | 0.53 | 0.16 | 0.09 | 1.45 | 6.92 | 1.07 |
| | (1.20, 1.95) | (0.20, 1.06) | (0.09, 0.31) | (0.00, 0.39) | (0.55, 3.24) | (5.75, 8.36) | (0.76, 1.50) |
| 2003 | 1.24 | 0.23 | 0.15 | 0.08 | 1.55 | 5.55 | 0.80 |
| | (0.96, 1.60) | (0.07, 0.59) | (0.07, 0.29) | (0.00, 0.31) | (0.78, 2.99) | (4.50, 6.84) | (0.54, 1.18) |
| 2004 | 1.39 | 0.08 | 0.23 | 0.07 | 1.98 | 7.11 | 0.94 |
| | (1.07, 1.79) | (0.00, 0.38) | (0.11, 0.40) | (0.00, 0.34) | (0.97, 3.83) | (6.00, 8.39) | (0.64, 1.34) |

Table 1.8: Estimated albatross bycatch from 1998-2004 by target species for trawl fisheries by vessels less than 28 metres in length.

| Fishing Year | Target Species | | | | | | |
|---|---|---|---|---|---|---|---|
| | HOK | JMA | ORH | SBW | SCI | SQU | Other |
| 1998 | 3 | 0 | 0 | 0 | 11 | 1 | 77 |
| | (0, 14) | (0, 0) | (0, 4) | (0, 0) | (5, 33) | (0, 8) | (14, 356) |
| 1999 | 4 | 0 | 7 | - | 31 | 8 | 221 |
| | (0, 23) | (0, 1) | (0, 37) | | (12, 98) | (1, 40) | (44, 1,008) |
| 2000 | 4 | 0 | 2 | - | 23 | 4 | 131 |
| | (0, 19) | (0, 1) | (0, 11) | | (8, 78) | (0, 21) | (26, 593) |
| 2001 | 5 | 0 | 1 | - | 33 | 12 | 156 |
| | (0, 22) | (0, 1) | (0, 7) | | (15, 93) | (1, 56) | (31, 672) |
| 2002 | 3 | 0 | 1 | - | 32 | 7 | 161 |
| | (0, 15) | (0, 0) | (0, 7) | | (10, 103) | (0, 34) | (32, 691) |
| 2003 | 4 | 0 | 1 | - | 17 | 6 | 141 |
| | (0, 18) | (0, 1) | (0, 6) | | (5, 58) | (0, 30) | (28, 615) |
| 2004 | 5 | 0 | 1 | - | 15 | 4 | 170 |
| | (0, 25) | (0, 1) | (0, 7) | | (6, 44) | (0, 19) | (34, 748) |

Table 1.9: Estimated albatross bycatch rate (per 100 tows) from 1998-2004 by target species for trawl fisheries by vessels less than 28 metres in length.

| Fishing Year | Target Species | | | | | | |
|---|---|---|---|---|---|---|---|
| | HOK | JMA | ORH | SBW | SCI | SQU | Other |
| 1998 | 0.06 | 0.00 | 0.00 | 0.00 | 0.24 | 0.34 | 0.07 |
| | (0.00, 0.29) | (0.00, 0.00) | (0.00, 0.29) | (0.00, 0.00) | (0.11, 0.71) | (0.00, 2.74) | (0.01, 0.34) |
| 1999 | 0.17 | 0.00 | 0.18 | - | 0.59 | 1.35 | 0.24 |
| | (0.00, 0.98) | (0.00, 1.56) | (0.00, 0.97) | | (0.23, 1.87) | (0.17, 6.76) | (0.05, 1.11) |
| 2000 | 0.14 | 0.00 | 0.10 | - | 0.37 | 0.90 | 0.17 |
| | (0.00, 0.68) | (0.00, 2.27) | (0.00, 0.54) | | (0.13, 1.27) | (0.00, 4.73) | (0.03, 0.79) |
| 2001 | 0.19 | 0.00 | 0.07 | - | 0.52 | 1.08 | 0.22 |
| | (0.00, 0.85) | (0.00, 3.70) | (0.00, 0.47) | | (0.24, 1.48) | (0.09, 5.03) | (0.04, 0.93) |
| 2002 | 0.19 | 0.00 | 0.03 | - | 0.46 | 1.20 | 0.24 |
| | (0.00, 0.96) | (0.00, 0.00) | (0.00, 0.20) | | (0.14, 1.48) | (0.00, 5.85) | (0.05, 1.02) |
| 2003 | 0.18 | 0.00 | 0.03 | - | 0.36 | 0.97 | 0.20 |
| | (0.00, 0.81) | (0.00, 3.13) | (0.00, 0.17) | | (0.11, 1.23) | (0.00, 4.83) | (0.04, 0.89) |
| 2004 | 0.20 | 0.00 | 0.05 | - | 0.51 | 1.38 | 0.25 |
| | (0.00, 0.98) | (0.00, 7.69) | (0.00, 0.38) | | (0.20, 1.50) | (0.00, 6.57) | (0.05, 1.09) |

Table 1.10: Estimated seabird bycatch from 1998-2004 by fishing area for trawl fisheries by vessels greater than 28 metres in length.

| Fishing Year | FMA | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 9 | Other |
| 1998 | 0 | 18 | 378 | 124 | 328 | 231 | 78 | 3 | 3 |
| | (0, 31) | (2, 54) | (277, 505) | (89, 170) | (246, 427) | (171, 307) | (49, 115) | (0, 15) | (0, 14) |
| 1999 | 0 | 31 | 714 | 218 | 733 | 343 | 151 | 5 | 12 |
| | (0, 51) | (6, 81) | (575, 880) | (158, 291) | (607, 884) | (274, 426) | (110, 203) | (0, 22) | (1, 43) |
| 2000 | 0 | 21 | 545 | 137 | 346 | 413 | 116 | 2 | 8 |
| | (0, 34) | (3, 58) | (430, 685) | (99, 185) | (279, 425) | (335, 506) | (82, 160) | (0, 11) | (2, 24) |
| 2001 | 0 | 38 | 1129 | 325 | 977 | 717 | 269 | 5 | 15 |
| | (0, 50) | (6, 100) | (963, 1,318) | (254, 408) | (863, 1,110) | (591, 865) | (202, 355) | (0, 20) | (2, 53) |
| 2002 | 0 | 24 | 543 | 184 | 682 | 750 | 163 | 3 | 17 |
| | (0, 49) | (3, 67) | (435, 668) | (135, 246) | (581, 798) | (621, 902) | (120, 217) | (0, 13) | (4, 52) |
| 2003 | 0 | 32 | 666 | 239 | 743 | 715 | 180 | 3 | 14 |
| | (0, 44) | (7, 82) | (532, 827) | (180, 311) | (630, 873) | (588, 864) | (133, 242) | (0, 13) | (2, 49) |
| 2004 | 0 | 25 | 480 | 215 | 702 | 970 | 164 | 7 | 14 |
| | (0, 48) | (4, 67) | (379, 601) | (157, 286) | (589, 831) | (821, 1,149) | (125, 214) | (2, 21) | (2, 45) |

Table 1.11: Estimated seabird bycatch rate (per 100 tows) from 1998-2004 by fishing area for trawl fisheries by vessels greater than 28 metres in length.

| Fishing Year | FMA | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 9 | Other |
| 1998 | 0.00 | 0.27 | 2.37 | 1.18 | 3.51 | 1.71 | 0.64 | 0.17 | 0.03 |
| | (0.00, 1.62) | (0.03, 0.81) | (1.74, 3.16) | (0.85, 1.61) | (2.63, 4.57) | (1.27, 2.27) | (0.40, 0.95) | (0.00, 0.83) | (0.00, 0.16) |
| 1999 | 0.00 | 0.56 | 5.53 | 2.03 | 7.22 | 2.97 | 1.30 | 0.33 | 0.08 |
| | (0.00, 2.79) | (0.11, 1.46) | (4.46, 6.82) | (1.47, 2.70) | (5.98, 8.71) | (2.38, 3.69) | (0.95, 1.74) | (0.00, 1.43) | (0.01, 0.30) |
| 2000 | 0.00 | 0.40 | 4.13 | 1.65 | 4.89 | 2.85 | 1.10 | 0.15 | 0.08 |
| | (0.00, 2.04) | (0.06, 1.11) | (3.26, 5.19) | (1.19, 2.22) | (3.94, 6.01) | (2.31, 3.49) | (0.78, 1.52) | (0.00, 0.84) | (0.02, 0.25) |
| 2001 | 0.00 | 1.02 | 9.97 | 3.63 | 12.34 | 5.31 | 2.41 | 0.40 | 0.14 |
| | (0.00, 6.54) | (0.16, 2.68) | (8.50, 11.64) | (2.84, 4.56) | (10.90, 14.02) | (4.38, 6.41) | (1.81, 3.18) | (0.00, 1.60) | (0.02, 0.49) |
| 2002 | 0.00 | 0.80 | 5.85 | 2.10 | 9.32 | 3.95 | 1.53 | 0.25 | 0.11 |
| | (0.00, 3.69) | (0.10, 2.24) | (4.68, 7.19) | (1.54, 2.80) | (7.94, 10.91) | (3.27, 4.75) | (1.13, 2.04) | (0.00, 1.06) | (0.03, 0.35) |
| 2003 | 0.00 | 0.86 | 6.46 | 2.49 | 10.02 | 4.39 | 1.76 | 0.21 | 0.11 |
| | (0.00, 2.91) | (0.19, 2.22) | (5.16, 8.02) | (1.88, 3.24) | (8.50, 11.77) | (3.61, 5.30) | (1.30, 2.37) | (0.00, 0.92) | (0.02, 0.39) |
| 2004 | 0.00 | 0.88 | 6.36 | 2.43 | 11.44 | 5.63 | 2.01 | 0.29 | 0.12 |
| | (0.00, 4.11) | (0.14, 2.35) | (5.02, 7.96) | (1.77, 3.23) | (9.60, 13.54) | (4.76, 6.66) | (1.54, 2.63) | (0.08, 0.88) | (0.02, 0.38) |

Table 1.12: Estimated seabird bycatch from 1998-2004 by fishing area for trawl fisheries by vessels less than 28 metres in length.

| Fishing Year | FMA | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 9 | Other |
| 1998 | 0 | 3 | 18 | 0 | 3 | 9 | 8 | 0 | 0 |
| | (0, 12) | (2, 13) | (6, 71) | (0, 3) | (0, 14) | (7, 15) | (2, 34) | (0, 3) | (0, 2) |
| 1999 | 4 | 12 | 41 | 0 | 6 | 4 | 14 | 0 | 0 |
| | (4, 22) | (9, 31) | (19, 145) | (0, 3) | (1, 24) | (0, 14) | (4, 60) | (0, 5) | (0, 2) |
| 2000 | 0 | 4 | 24 | 5 | 5 | 4 | 8 | 0 | 0 |
| | (0, 15) | (2, 18) | (10, 87) | (4, 7) | (1, 19) | (1, 13) | (2, 32) | (0, 3) | (0, 2) |
| 2001 | 0 | 10 | 53 | 3 | 10 | 11 | 16 | 1 | 0 |
| | (0, 27) | (6, 36) | (23, 196) | (2, 7) | (3, 38) | (5, 28) | (5, 64) | (0, 5) | (0, 2) |
| 2002 | 0 | 6 | 32 | 0 | 6 | 4 | 11 | 0 | 0 |
| | (0, 19) | (3, 28) | (14, 112) | (0, 3) | (1, 23) | (0, 14) | (3, 42) | (0, 3) | (0, 3) |
| 2003 | 0 | 3 | 38 | 1 | 7 | 3 | 12 | 0 | 0 |
| | (0, 19) | (0, 23) | (16, 135) | (1, 4) | (1, 25) | (0, 10) | (3, 48) | (0, 3) | (0, 3) |
| 2004 | 0 | 3 | 39 | 1 | 6 | 2 | 15 | 0 | 0 |
| | (0, 23) | (0, 22) | (17, 134) | (1, 3) | (1, 24) | (0, 8) | (5, 62) | (0, 3) | (0, 2) |

Table 1.13: Estimated seabird bycatch rate (per 100 tows) from 1998-2004 by fishing area for trawl fisheries for vessels less than 28 metres in length.

| Fishing Year | FMA | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 9 | Other |
| 1998 | 0.00 | 0.02 | 0.05 | 0.00 | 0.06 | 0.40 | 0.03 | 0.00 | 0.00 |
| | (0.00, 0.08) | (0.01, 0.08) | (0.02, 0.22) | (0.00, 0.25) | (0.00, 0.26) | (0.31, 0.67) | (0.01, 0.12) | (0.00, 0.07) | (0.00, 0.02) |
| 1999 | 0.03 | 0.07 | 0.12 | 0.00 | 0.12 | 0.18 | 0.06 | 0.00 | 0.00 |
| | (0.03, 0.18) | (0.06, 0.19) | (0.06, 0.43) | (0.00, 0.39) | (0.02, 0.47) | (0.00, 0.63) | (0.02, 0.25) | (0.00, 0.10) | (0.00, 0.05) |
| 2000 | 0.00 | 0.03 | 0.09 | 0.55 | 0.11 | 0.14 | 0.05 | 0.00 | 0.00 |
| | (0.00, 0.13) | (0.01, 0.12) | (0.04, 0.32) | (0.44, 0.78) | (0.02, 0.40) | (0.04, 0.47) | (0.01, 0.19) | (0.00, 0.07) | (0.00, 0.07) |
| 2001 | 0.00 | 0.07 | 0.20 | 0.38 | 0.19 | 0.40 | 0.10 | 0.02 | 0.00 |
| | (0.00, 0.24) | (0.04, 0.27) | (0.09, 0.74) | (0.25, 0.88) | (0.06, 0.74) | (0.18, 1.02) | (0.03, 0.38) | (0.00, 0.11) | (0.00, 0.07) |
| 2002 | 0.00 | 0.04 | 0.14 | 0.00 | 0.13 | 0.15 | 0.07 | 0.00 | 0.00 |
| | (0.00, 0.17) | (0.02, 0.20) | (0.06, 0.48) | (0.00, 0.38) | (0.02, 0.50) | (0.00, 0.54) | (0.02, 0.27) | (0.00, 0.09) | (0.00, 0.06) |
| 2003 | 0.00 | 0.02 | 0.15 | 0.15 | 0.15 | 0.18 | 0.07 | 0.00 | 0.00 |
| | (0.00, 0.19) | (0.00, 0.19) | (0.06, 0.52) | (0.15, 0.61) | (0.02, 0.55) | (0.00, 0.60) | (0.02, 0.28) | (0.00, 0.11) | (0.00, 0.06) |
| 2004 | 0.00 | 0.03 | 0.17 | 0.24 | 0.17 | 0.19 | 0.08 | 0.00 | 0.00 |
| | (0.00, 0.20) | (0.00, 0.20) | (0.07, 0.59) | (0.24, 0.73) | (0.03, 0.67) | (0.00, 0.75) | (0.03, 0.33) | (0.00, 0.09) | (0.00, 0.06) |

Table 1.14: Estimated seabird bycatch from 1998-2004 by target species for trawl fisheries by vessels greater than 28 metres in length.

| Fishing Year | Target Species | | | | | | |
|---|---|---|---|---|---|---|---|
| | HOK | JMA | ORH | SBW | SCI | SQU | Other |
| 1998 | 639 | 23 | 31 | 4 | 4 | 365 | 104 |
| | (489, 818) | (11, 41) | (18, 54) | (1, 10) | (0, 12) | (273, 478) | (67, 157) |
| 1999 | 1144 | 37 | 91 | 8 | 13 | 669 | 217 |
| | (950, 1,374) | (20, 62) | (66, 130) | (2, 18) | (4, 28) | (541, 821) | (161, 298) |
| 2000 | 993 | 22 | 38 | 4 | 0 | 378 | 158 |
| | (821, 1,199) | (13, 35) | (22, 61) | (2, 10) | (0, 5) | (303, 471) | (114, 219) |
| 2001 | 2055 | 24 | 71 | 8 | 3 | 1003 | 316 |
| | (1,803, 2,348) | (14, 39) | (44, 112) | (4, 15) | (0, 8) | (878, 1,144) | (242, 418) |
| 2002 | 1133 | 32 | 50 | 8 | 34 | 889 | 223 |
| | (941, 1,358) | (19, 51) | (29, 86) | (2, 19) | (16, 71) | (770, 1,024) | (168, 297) |
| 2003 | 1182 | 21 | 47 | 4 | 57 | 1007 | 282 |
| | (982, 1,424) | (11, 35) | (27, 81) | (0, 10) | (32, 99) | (859, 1,174) | (214, 372) |
| 2004 | 914 | 6 | 60 | 6 | 86 | 1246 | 264 |
| | (753, 1,108) | (1, 14) | (37, 94) | (2, 14) | (49, 146) | (1,073, 1,444) | (199, 355) |

Table 1.15: Estimated seabird bycatch rate (per 100 tows) from 1998-2004 by target species for trawl fisheries by vessels greater than 28 metres in length.

| Fishing Year | Target Species | | | | | | |
|---|---|---|---|---|---|---|---|
| | HOK | JMA | ORH | SBW | SCI | SQU | Other |
| 1998 | 1.76 | 0.55 | 0.21 | 0.17 | 2.67 | 3.93 | 0.78 |
| | (1.34, 2.25) | (0.26, 0.98) | (0.12, 0.36) | (0.04, 0.43) | (0.00, 8.00) | (2.94, 5.15) | (0.50, 1.17) |
| 1999 | 3.53 | 0.99 | 0.49 | 0.32 | 3.10 | 8.58 | 1.43 |
| | (2.93, 4.24) | (0.53, 1.65) | (0.36, 0.71) | (0.08, 0.71) | (0.95, 6.68) | (6.94, 10.53) | (1.06, 1.97) |
| 2000 | 2.91 | 0.98 | 0.28 | 0.27 | 0.00 | 5.88 | 1.16 |
| | (2.41, 3.52) | (0.58, 1.55) | (0.16, 0.45) | (0.14, 0.68) | (0.00, 13.89) | (4.72, 7.33) | (0.84, 1.61) |
| 2001 | 6.18 | 1.25 | 0.55 | 0.60 | 3.13 | 13.27 | 2.55 |
| | (5.42, 7.06) | (0.73, 2.04) | (0.34, 0.87) | (0.30, 1.12) | (0.00, 8.33) | (11.62, 15.14) | (1.95, 3.38) |
| 2002 | 3.71 | 1.06 | 0.29 | 0.34 | 2.35 | 10.40 | 1.76 |
| | (3.08, 4.45) | (0.63, 1.70) | (0.17, 0.50) | (0.09, 0.82) | (1.10, 4.90) | (9.00, 11.98) | (1.33, 2.35) |
| 2003 | 4.07 | 0.69 | 0.34 | 0.31 | 3.16 | 10.61 | 1.94 |
| | (3.38, 4.91) | (0.36, 1.15) | (0.20, 0.59) | (0.00, 0.78) | (1.77, 5.48) | (9.05, 12.37) | (1.47, 2.56) |
| 2004 | 4.10 | 0.25 | 0.46 | 0.41 | 3.79 | 11.36 | 1.94 |
| | (3.38, 4.97) | (0.04, 0.59) | (0.28, 0.72) | (0.14, 0.95) | (2.16, 6.43) | (9.78, 13.16) | (1.46, 2.60) |

Table 1.16: Estimated seabird bycatch from 1998-2004 by target species for trawl fisheries by vessels less than 28 metres in length.

| Fishing Year | Target Species | | | | | | |
|---|---|---|---|---|---|---|---|
| | HOK | JMA | ORH | SBW | SCI | SQU | Other |
| 1998 | 1 | 0 | 0 | 0 | 11 | 0 | 30 |
| | (0, 6) | (0, 0) | (0, 2) | (0, 0) | (9, 19) | (0, 3) | (11, 130) |
| 1999 | 1 | 0 | 1 | - | 23 | 2 | 57 |
| | (0, 6) | (0, 1) | (0, 8) | | (18, 38) | (0, 10) | (24, 234) |
| 2000 | 1 | 0 | 0 | - | 13 | 1 | 36 |
| | (0, 5) | (0, 0) | (0, 3) | | (9, 26) | (0, 6) | (14, 147) |
| 2001 | 2 | 0 | 0 | - | 22 | 6 | 77 |
| | (0, 9) | (0, 0) | (0, 3) | | (14, 49) | (1, 23) | (33, 308) |
| 2002 | 1 | 0 | 0 | - | 11 | 2 | 48 |
| | (0, 5) | (0, 0) | (0, 2) | | (6, 31) | (0, 9) | (19, 192) |
| 2003 | 1 | 0 | 0 | - | 7 | 2 | 55 |
| | (0, 6) | (0, 0) | (0, 3) | | (3, 21) | (0, 10) | (23, 220) |
| 2004 | 1 | 0 | 0 | - | 7 | 1 | 59 |
| | (0, 8) | (0, 0) | (0, 3) | | (4, 18) | (0, 7) | (24, 238) |

Table 1.17: Estimated seabird bycatch rate (per 100 tows) from 1998-2004 by target species by trawl fisheries for vessels less than 28 metres in length.

| Fishing Year | Target Species | | | | | | |
|---|---|---|---|---|---|---|---|
| | HOK | JMA | ORH | SBW | SCI | SQU | Other |
| 1998 | 0.02 | 0.00 | 0.00 | 0.00 | 0.24 | 0.00 | 0.03 |
| | (0.00, 0.12) | (0.00, 0.00) | (0.00, 0.14) | (0.00, 0.00) | (0.19, 0.41) | (0.00, 1.03) | (0.01, 0.12) |
| 1999 | 0.04 | 0.00 | 0.03 | - | 0.44 | 0.34 | 0.06 |
| | (0.00, 0.26) | (0.00, 1.56) | (0.00, 0.21) | | (0.34, 0.73) | (0.00, 1.69) | (0.03, 0.26) |
| 2000 | 0.04 | 0.00 | 0.00 | - | 0.21 | 0.23 | 0.05 |
| | (0.00, 0.18) | (0.00, 0.00) | (0.00, 0.15) | | (0.15, 0.42) | (0.00, 1.35) | (0.02, 0.20) |
| 2001 | 0.08 | 0.00 | 0.00 | - | 0.35 | 0.54 | 0.11 |
| | (0.00, 0.35) | (0.00, 0.00) | (0.00, 0.20) | | (0.22, 0.78) | (0.09, 2.06) | (0.05, 0.43) |
| 2002 | 0.06 | 0.00 | 0.00 | - | 0.16 | 0.34 | 0.07 |
| | (0.00, 0.32) | (0.00, 0.00) | (0.00, 0.06) | | (0.09, 0.45) | (0.00, 1.55) | (0.03, 0.28) |
| 2003 | 0.04 | 0.00 | 0.00 | - | 0.15 | 0.32 | 0.08 |
| | (0.00, 0.27) | (0.00, 0.00) | (0.00, 0.08) | | (0.06, 0.45) | (0.00, 1.61) | (0.03, 0.32) |
| 2004 | 0.04 | 0.00 | 0.00 | - | 0.24 | 0.35 | 0.09 |
| | (0.00, 0.31) | (0.00, 0.00) | (0.00, 0.16) | | (0.14, 0.61) | (0.00, 2.42) | (0.04, 0.35) |

Table 1.18: Number of observed sets and total sets in surface long line fisheries, and number of seabirds observed as bycatch by each vessel class for the 1998-2004 fishing years.

| Fishing Year | Vessel Class | Obs. Sets | Total Sets | % Sets Obs. | Seabird Bycatch |
|---|---|---|---|---|---|
| 1998 | >28m | 357 | 609 | 59% | 171 |
| | <28m | 81 | 3119 | 3% | 45 |
| 1999 | >28m | 413 | 635 | 65% | 74 |
| | <28m | 37 | 5307 | 1% | 10 |
| 2000 | >28m | 267 | 380 | 70% | 40 |
| | <28m | 36 | 6658 | 1% | 34 |
| 2001 | >28m | 272 | 533 | 51% | 15 |
| | <28m | 190 | 7631 | 2% | 38 |
| 2002 | >28m | 275 | 488 | 56% | 80 |
| | <28m | 123 | 8336 | 1% | 87 |
| 2003 | >28m | 605 | 663 | 91% | 115 |
| | <28m | 0 | 7242 | 0% | - |
| 2004 | >28m | 466 | 571 | 82% | 70 |
| | <28m | 76 | 5007 | 2% | 2 |

Table 1.19: Estimated seabird bycatch from 1998-2004 by fishing area for surface long line fisheries by vessels greater than 28 metres in length.

| Fishing Year | FMA | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 and 4 | 3 and 6 | 5 | 7 | 8 and 9 | Other |
| 1998 | 393 | 212 | 0 | 37 | 4 | 0 | 0 |
| | (110, 1,423) | (171, 325) | (0, 0) | (32, 46) | (2, 10) | (0, 2) | (0, 9) |
| 1999 | 81 | 118 | 2 | 56 | 5 | 0 | 0 |
| | (23, 288) | (45, 400) | (2, 2) | (52, 64) | (4, 10) | (0, 1) | (0, 10) |
| 2000 | 57 | 28 | 13 | 21 | 11 | 0 | 0 |
| | (9, 279) | (11, 152) | (11, 21) | (13, 32) | (9, 16) | (0, 0) | (0, 41) |
| 2001 | 52 | 55 | 2 | 12 | 3 | 0 | 6 |
| | (9, 240) | (15, 216) | (1, 6) | (11, 15) | (3, 6) | (0, 1) | (0, 50) |
| 2002 | 130 | 229 | 4 | 94 | 10 | 0 | 42 |
| | (27, 560) | (67, 829) | (1, 14) | (82, 109) | (8, 16) | (0, 0) | (0, 278) |
| 2003 | 10 | 49 | 0 | 37 | 9 | 0 | 15 |
| | (10, 12) | (49, 87) | (0, 0) | (34, 43) | (9, 13) | (0, 0) | (13, 22) |
| 2004 | 0 | 164 | 3 | 46 | 18 | 0 | 0 |
| | (0, 0) | (46, 590) | (3, 3) | (46, 49) | (16, 29) | (0, 0) | (0, 3) |

Table 1.20: Estimated seabird bycatch rate (per set) from 1998-2004 by fishing area for surface long line fisheries by vessels greater than 28 metres in length.

| Fishing Year | FMA | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 and 4 | 3 and 6 | 5 | 7 | 8 and 9 | Other |
| 1998 | 3.61 | 2.08 | 0.00 | 0.32 | 0.02 | 0.00 | 0.00 |
| | (1.01, 13.06) | (1.68, 3.19) | (0.00, 0.00) | (0.28, 0.40) | (0.01, 0.06) | (0.00, 0.03) | (0.00, 4.50) |
| 1999 | 1.45 | 2.11 | 0.03 | 0.24 | 0.04 | 0.00 | 0.00 |
| | (0.41, 5.14) | (0.80, 7.14) | (0.03, 0.03) | (0.22, 0.28) | (0.03, 0.07) | (0.00, 0.01) | (0.00, 0.91) |
| 2000 | 4.07 | 2.33 | 0.35 | 0.19 | 0.06 | 0.00 | 0.00 |
| | (0.64, 19.93) | (0.92, 12.67) | (0.30, 0.57) | (0.12, 0.29) | (0.05, 0.09) | (0.00, 0.00) | (0.00, 3.42) |
| 2001 | 0.95 | 0.83 | 0.04 | 0.07 | 0.04 | 0.00 | 0.12 |
| | (0.16, 4.37) | (0.23, 3.27) | (0.02, 0.13) | (0.06, 0.09) | (0.04, 0.08) | (0.00, 0.01) | (0.00, 0.96) |
| 2002 | 5.00 | 4.32 | 0.22 | 0.46 | 0.07 | 0.00 | 1.11 |
| | (1.04, 21.54) | (1.26, 15.64) | (0.06, 0.78) | (0.40, 0.53) | (0.06, 0.11) | (0.00, 0.00) | (0.00, 7.32) |
| 2003 | 0.22 | 0.67 | 0.00 | 0.21 | 0.05 | 0.00 | 0.11 |
| | (0.22, 0.26) | (0.67, 1.19) | (0.00, 0.00) | (0.19, 0.24) | (0.05, 0.07) | (0.00, 0.00) | (0.09, 0.16) |
| 2004 | 0.00 | 1.89 | 1.00 | 0.20 | 0.08 | 0.00 | 0.00 |
| | (0.00, 0.00) | (0.53, 6.78) | (1.00, 1.00) | (0.20, 0.21) | (0.07, 0.13) | (0.00, 0.00) | (0.00, 0.60) |

Table 1.21: Estimated seabird bycatch from 1998-2004 by fishing area for surface long line fisheries by vessels less than 28 metres in length.

| Fishing Year | FMA | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 and 4 | 3 and 6 | 5 | 7 | 8 and 9 | Other |
| 1998 | 1154 | 513 | 0 | 0 | 0 | 0 | 8 |
| | (352, 2,050) | (142, 901) | (0, 1) | (0, 0) | (0, 2) | (0, 2) | (0, 28) |
| 1999 | 1127 | 695 | 0 | 1 | 0 | 0 | 7 |
| | (307, 2,199) | (167, 1,248) | (0, 1) | (0, 4) | (0, 2) | (0, 3) | (0, 25) |
| 2000 | 2251 | 1603 | 0 | 3 | 1 | 0 | 17 |
| | (592, 4,611) | (363, 3,170) | (0, 3) | (0, 12) | (0, 4) | (0, 5) | (1, 59) |
| 2001 | 757 | 577 | 0 | 1 | 0 | 0 | 9 |
| | (177, 1,698) | (140, 1,117) | (0, 1) | (0, 5) | (0, 1) | (0, 2) | (0, 31) |
| 2002 | 3277 | 2732 | 0 | 6 | 4 | 0 | 28 |
| | (878, 6,299) | (737, 4,965) | (0, 2) | (0, 26) | (0, 17) | (0, 8) | (3, 90) |
| 2003 | 1041 | 1683 | 0 | 3 | 0 | 0 | 10 |
| | (260, 2,251) | (422, 3,601) | (0, 4) | (0, 13) | (0, 3) | (0, 3) | (0, 37) |
| 2004 | 678 | 999 | 0 | 1 | 2 | 0 | 2 |
| | (139, 1,602) | (193, 2,205) | (0, 2) | (0, 6) | (0, 11) | (0, 1) | (1, 8) |

Table 1.22: Estimated seabird bycatch rate (per set) from 1998-2004 by fishing area for surface long line fisheries by vessels less than 28 metres in length.

| Fishing Year | FMA | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 and 4 | 3 and 6 | 5 | 7 | 8 and 9 | Other |
| 1998 | 0.55 | 0.79 | 0.00 | 0.00 | 0.00 | 0.00 | 0.11 |
| | (0.17, 0.99) | (0.22, 1.38) | (0.00, 1.00) | (0.00, 0.00) | (0.00, 0.12) | (0.00, 0.01) | (0.00, 0.39) |
| 1999 | 0.36 | 0.59 | 0.00 | 0.08 | 0.00 | 0.00 | 0.07 |
| | (0.10, 0.70) | (0.14, 1.05) | (0.00, 1.00) | (0.00, 0.31) | (0.00, 0.09) | (0.00, 0.00) | (0.00, 0.27) |
| 2000 | 0.67 | 0.78 | 0.00 | 0.09 | 0.04 | 0.00 | 0.13 |
| | (0.18, 1.37) | (0.18, 1.55) | (0.00, 0.25) | (0.00, 0.38) | (0.00, 0.14) | (0.00, 0.00) | (0.01, 0.43) |
| 2001 | 0.21 | 0.25 | 0.00 | 0.02 | 0.00 | 0.00 | 0.04 |
| | (0.05, 0.47) | (0.06, 0.49) | (0.00, 0.33) | (0.00, 0.10) | (0.00, 0.10) | (0.00, 0.00) | (0.00, 0.13) |
| 2002 | 0.88 | 0.90 | 0.00 | 0.08 | 0.02 | 0.00 | 0.16 |
| | (0.24, 1.70) | (0.24, 1.64) | (0.00, 0.29) | (0.00, 0.33) | (0.00, 0.10) | (0.00, 0.01) | (0.02, 0.50) |
| 2003 | 0.46 | 0.44 | 0.00 | 0.04 | 0.00 | 0.00 | 0.09 |
| | (0.12, 1.00) | (0.11, 0.93) | (0.00, 0.17) | (0.00, 0.18) | (0.00, 0.07) | (0.00, 0.00) | (0.00, 0.34) |
| 2004 | 0.44 | 0.40 | 0.00 | 0.03 | 0.01 | 0.00 | 0.07 |
| | (0.09, 1.03) | (0.08, 0.88) | (0.00, 0.15) | (0.00, 0.18) | (0.00, 0.03) | (0.00, 0.00) | (0.03, 0.28) |

Table 1.23: Estimated seabird bycatch from 1998-2004 by target species for surface long line fisheries by vessels greater than 28 metres in length.

| Fishing Year | Target Species | | | |
|---|---|---|---|---|
| | BIG | STN | ALB | Other |
| 1998 | 420 | 228 | 1 | 0 |
| | (113, 1,532) | (203, 259) | (0, 7) | (0, 9) |
| 1999 | 141 | 116 | 0 | 4 |
| | (30, 593) | (96, 152) | (0, 0) | (0, 31) |
| 2000 | 84 | 57 | - | - |
| | (14, 400) | (47, 72) | | |
| 2001 | 103 | 31 | - | - |
| | (22, 445) | (20, 53) | | |
| 2002 | 356 | 162 | 0 | - |
| | (77, 1,486) | (123, 225) | (0, 4) | |
| 2003 | 0 | 47 | 75 | 0 |
| | (0, 3) | (43, 53) | (73, 82) | (0, 38) |
| 2004 | 122 | 79 | 20 | 3 |
| | (18, 529) | (70, 97) | (5, 52) | (0, 52) |

Table 1.24: Estimated seabird bycatch rate (per set) from 1998-2004 by target species for surface long line fisheries by vessels greater than 28 metres in length.

| Fishing Year | Target Species | | | |
|---|---|---|---|---|
| | BIG | STN | ALB | Other |
| 1998 | 2.49 | 0.53 | 0.25 | 0.00 |
| | (0.67, 9.07) | (0.47, 0.60) | (0.00, 1.75) | (0.00, 3.00) |
| 1999 | 1.45 | 0.23 | 0.00 | 0.10 |
| | (0.31, 6.11) | (0.19, 0.31) | (0.00, 0.00) | (0.00, 0.76) |
| 2000 | 2.40 | 0.17 | - | - |
| | (0.40, 11.43) | (0.14, 0.21) | | |
| 2001 | 0.52 | 0.09 | - | - |
| | (0.11, 2.25) | (0.06, 0.16) | | |
| 2002 | 4.19 | 0.40 | 0.00 | - |
| | (0.91, 17.48) | (0.31, 0.56) | (0.00, 2.00) | |
| 2003 | 0.00 | 0.13 | 0.29 | 0.00 |
| | (0.00, 0.11) | (0.11, 0.14) | (0.28, 0.32) | (0.00, 19.00) |
| 2004 | 3.05 | 0.16 | 0.59 | 0.30 |
| | (0.45, 13.23) | (0.14, 0.20) | (0.15, 1.53) | (0.00, 5.20) |

Table 1.25 Estimated seabird bycatch from 1998-2004 by target species for surface long line fisheries by vessels less than 28 metres in length.

| Fishing Year | Target Species | | | |
|---|---|---|---|---|
| | BIG | STN | ALB | Other |
| 1998 | 1553 | 27 | 54 | 29 |
| | (455, 2,622) | (5, 120) | (9, 278) | (6, 91) |
| 1999 | 1724 | 40 | 34 | 23 |
| | (443, 3,193) | (7, 173) | (6, 168) | (3, 74) |
| 2000 | 3607 | 114 | 77 | 42 |
| | (875, 7,137) | (24, 491) | (13, 385) | (7, 140) |
| 2001 | 1239 | 43 | 18 | 30 |
| | (289, 2,591) | (8, 194) | (2, 89) | (6, 96) |
| 2002 | 5433 | 334 | 114 | 114 |
| | (1,416, 9,678) | (77, 1,433) | (22, 559) | (21, 363) |
| 2003 | 2305 | 258 | 73 | 50 |
| | (551, 4,709) | (53, 1,143) | (14, 340) | (8, 177) |
| 2004 | 1434 | 130 | 24 | 58 |
| | (270, 3,164) | (26, 582) | (3, 130) | (8, 216) |

Table 1.26: Estimated seabird bycatch rate (per set) from 1998-2004 by target species for surface long line fisheries by vessels less than 28 metres in length.

| Fishing Year | Target Species | | | |
|---|---|---|---|---|
| | BIG | STN | ALB | Other |
| 1998 | 0.67 | 0.17 | 0.10 | 0.32 |
| | (0.19, 1.12) | (0.03, 0.76) | (0.02, 0.52) | (0.07, 1.01) |
| 1999 | 0.41 | 0.09 | 0.06 | 0.16 |
| | (0.11, 0.76) | (0.02, 0.40) | (0.01, 0.31) | (0.02, 0.53) |
| 2000 | 0.68 | 0.18 | 0.12 | 0.34 |
| | (0.17, 1.35) | (0.04, 0.76) | (0.02, 0.62) | (0.06, 1.12) |
| 2001 | 0.21 | 0.05 | 0.03 | 0.11 |
| | (0.05, 0.44) | (0.01, 0.23) | (0.00, 0.16) | (0.02, 0.34) |
| 2002 | 0.94 | 0.22 | 0.14 | 0.53 |
| | (0.25, 1.67) | (0.05, 0.96) | (0.03, 0.66) | (0.10, 1.68) |
| 2003 | 0.53 | 0.13 | 0.09 | 0.36 |
| | (0.13, 1.09) | (0.03, 0.58) | (0.02, 0.42) | (0.06, 1.28) |
| 2004 | 0.47 | 0.09 | 0.07 | 0.35 |
| | (0.09, 1.05) | (0.02, 0.40) | (0.01, 0.35) | (0.05, 1.31) |

Table 1.27: Number of observed sets and total sets in bottom long line fisheries, and number of seabirds observed as bycatch by each vessel class for the 1999-2004 fishing years.

| Fishing Year | Vessel Class | Obs. Sets | Total Sets | % Sets Obs. | Seabird Bycatch |
|---|---|---|---|---|---|
| 1999 | >28m | 769 | 10456 | 7% | 93 |
| | <28m | 51 | 22796 | 0% | 0 |
| 2000 | >28m | 993 | 9034 | 11% | 203 |
| | <28m | 0 | 23214 | 0% | - |
| 2001 | >28m | 847 | 7978 | 11% | 509 |
| | <28m | 63 | 22709 | 0% | 26 |
| 2002 | >28m | 1093 | 5387 | 20% | 431 |
| | <28m | 0 | 20376 | 0% | - |
| 2003 | >28m | 1598 | 4278 | 37% | 426 |
| | <28m | 10 | 18979 | 0% | 1 |
| 2004 | >28m | 760 | 6164 | 12% | 122 |
| | <28m | 236 | 17342 | 1% | 10 |

Table 1.28: Estimated seabird bycatch from 1999-2004 by fishing area for bottom long line fisheries for vessels greater than 28 metres in length.

| Fishing Year | FMA | | | | |
|---|---|---|---|---|---|
| | 1, 2, 8, 9 and 10 | 3 and 4 | 5 and 7 | 6 | Other |
| 1999 | 1 | 462 | 171 | 1158 | 0 |
| | (0, 8) | (301, 694) | (108, 262) | (857, 1,566) | (0, 2) |
| 2000 | 6 | 892 | 206 | 1251 | 0 |
| | (0, 25) | (638, 1,223) | (168, 252) | (993, 1,562) | (0, 3) |
| 2001 | 13 | 680 | 298 | 1804 | 0 |
| | (6, 35) | (504, 899) | (261, 342) | (1,537, 2,110) | (0, 5) |
| 2002 | 4 | 798 | 194 | 796 | 0 |
| | (0, 28) | (698, 918) | (146, 252) | (594, 1,057) | (0, 0) |
| 2003 | 39 | 330 | 213 | 601 | 0 |
| | (0, 359) | (218, 656) | (186, 246) | (507, 712) | (0, 0) |
| 2004 | 1 | 186 | 104 | 341 | 0 |
| | (0, 6) | (104, 393) | (89, 126) | (251, 465) | (0, 1) |

Table 1.29: Estimated seabird bycatch rate (per set) from 1999-2004 by fishing area for bottom long line fisheries for vessels greater than 28 metres in length.

| Fishing Year | FMA | | | | |
|---|---|---|---|---|---|
| | 1, 2, 8, 9 and 10 | 3 and 4 | 5 and 7 | 6 | Other |
| 1999 | 0.00 | 0.10 | 0.21 | 0.17 | 0.00 |
| | (0.01, 0.07) | (0.15, 0.23) | (0.34, 0.52) | (0.23, 0.31) | (0.00, 0.00) |
| 2000 | 0.00 | 0.20 | 0.52 | 0.29 | 0.00 |
| | (0.07, 0.30) | (0.28, 0.38) | (0.64, 0.78) | (0.37, 0.46) | (0.00, 0.00) |
| 2001 | 0.01 | 0.26 | 0.55 | 0.53 | 0.00 |
| | (0.03, 0.09) | (0.35, 0.46) | (0.63, 0.72) | (0.62, 0.72) | (0.00, 0.00) |
| 2002 | 0.00 | 0.26 | 0.34 | 0.28 | 0.00 |
| | (0.02, 0.16) | (0.30, 0.34) | (0.45, 0.59) | (0.38, 0.51) | (0.00, 0.00) |
| 2003 | 0.00 | 0.11 | 0.51 | 0.27 | 0.00 |
| | (0.34, 3.12) | (0.17, 0.34) | (0.58, 0.67) | (0.33, 0.39) | (0.00, 0.00) |
| 2004 | 0.00 | 0.05 | 0.23 | 0.11 | 0.00 |
| | (0.01, 0.04) | (0.09, 0.19) | (0.27, 0.32) | (0.15, 0.21) | (0.00, 0.00) |

Table 1.30: Estimated seabird bycatch from 1999-2004 by fishing area for bottom long line fisheries for vessels less than 28 metres in length.

| Fishing Year | FMA | | | | |
|---|---|---|---|---|---|
| | 1, 2, 8, 9 and 10 | 3 and 4 | 5 and 7 | 6 | Other |
| 1999 | 1262 | 45 | 307 | 0 | 0 |
| | (214, 8,213) | (4, 383) | (45, 2,332) | (0, 1) | (0, 0) |
| 2000 | 2219 | 46 | 532 | 1 | 0 |
| | (415, 11,496) | (5, 341) | (77, 3,906) | (0, 80) | (0, 0) |
| 2001 | 3209 | 31 | 504 | 2 | 0 |
| | (623, 16,610) | (2, 290) | (74, 3,679) | (0, 59) | (0, 0) |
| 2002 | 1692 | 28 | 312 | 0 | 0 |
| | (302, 10,295) | (2, 213) | (44, 2,353) | (0, 46) | (0, 0) |
| 2003 | 1482 | 32 | 223 | 0 | 0 |
| | (265, 9,385) | (3, 236) | (33, 1,646) | (0, 38) | (0, 0) |
| 2004 | 247 | 14 | 64 | 0 | 0 |
| | (49, 1,671) | (1, 140) | (8, 530) | (0, 3) | (0, 0) |

Table 1.31: Estimated seabird bycatch rate (per set) from 1999-2004 by fishing area for bottom long line fisheries for vessels less than 28 metres in length.

| Fishing Year | FMA | | | | |
|---|---|---|---|---|---|
| | 1, 2, 8, 9 and 10 | 3 and 4 | 5 and 7 | 6 | Other |
| 1999 | 0.01 | 0.00 | 0.02 | 0.00 | 0.00 |
| | (0.06, 0.42) | (0.05, 0.42) | (0.16, 1.19) | (0.00, 0.50) | (0.00, 0.00) |
| 2000 | 0.02 | 0.01 | 0.04 | 0.00 | 0.00 |
| | (0.11, 0.56) | (0.07, 0.49) | (0.28, 2.09) | (0.50, 40.00) | (0.00, 0.00) |
| 2001 | 0.03 | 0.01 | 0.04 | 0.00 | 0.00 |
| | (0.16, 0.81) | (0.08, 0.77) | (0.28, 2.03) | (1.00, 29.50) | (0.00, 0.00) |
| 2002 | 0.02 | 0.00 | 0.03 | 0.00 | 0.00 |
| | (0.09, 0.56) | (0.06, 0.43) | (0.21, 1.60) | (0.00, 23.00) | (0.00, 0.00) |
| 2003 | 0.02 | 0.00 | 0.02 | 0.00 | 0.00 |
| | (0.09, 0.56) | (0.05, 0.34) | (0.15, 1.10) | (0.00, 19.00) | (0.00, 0.00) |
| 2004 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 |
| | (0.02, 0.11) | (0.02, 0.21) | (0.05, 0.38) | (0.00, 0.75) | (0.00, 0.00) |

Table 1.32: Estimated seabird bycatch from 1999-2004 by target species for bottom long line fisheries for vessels greater than 28 metres in length.

| Fishing Year | Target Species | | |
|---|---|---|---|
| | LIN | SNA | Other |
| 1999 | 1779 | - | 13 |
| | (1,302, 2,433) | | (3, 47) |
| 2000 | 2355 | - | 4 |
| | (1,877, 2,941) | | (0, 19) |
| 2001 | 2795 | - | 4 |
| | (2,403, 3,247) | | (4, 13) |
| 2002 | 1776 | 0 | 14 |
| | (1,503, 2,112) | (0, 21) | (1, 67) |
| 2003 | 1026 | 38 | 117 |
| | (906, 1,163) | (0, 358) | (23, 444) |
| 2004 | 543 | - | 84 |
| | (425, 694) | | (16, 326) |

Table 1.33: Estimated seabird bycatch rate (per set) from 1999-2004 by target species for bottom long line fisheries for vessels greater than 28 metres in length.

| Fishing Year | Target Species | | |
|---|---|---|---|
| | LIN | SNA | Other |
| 1999 | 0.19 | - | 0.01 |
| | (0.14, 0.26) | | (0.00, 0.04) |
| 2000 | 0.33 | - | 0.00 |
| | (0.26, 0.41) | | (0.00, 0.01) |
| 2001 | 0.49 | - | 0.00 |
| | (0.42, 0.57) | | (0.00, 0.01) |
| 2002 | 0.33 | 0.00 | 0.27 |
| | (0.28, 0.40) | (0.00, 10.50) | (0.02, 1.29) |
| 2003 | 0.27 | 0.79 | 0.25 |
| | (0.24, 0.31) | (0.00, 7.46) | (0.05, 0.95) |
| 2004 | 0.13 | - | 0.05 |
| | (0.10, 0.16) | | (0.01, 0.18) |

Table 1.34: Estimated seabird bycatch from 1999-2004 by target species for bottom long line fisheries for vessels less than 28 metres in length.

| Fishing Year | Target Species | | |
|---|---|---|---|
| | LIN | SNA | Other |
| 1999 | 42 | 1464 | 113 |
| | (4, 283) | (271, 9,392) | (8, 1,214) |
| 2000 | 66 | 2578 | 157 |
| | (7, 439) | (513, 13,549) | (11, 1,646) |
| 2001 | 81 | 3436 | 217 |
| | (9, 533) | (697, 17,907) | (16, 2,264) |
| 2002 | 50 | 1856 | 121 |
| | (5, 330) | (353, 11,260) | (9, 1,294) |
| 2003 | 52 | 1583 | 93 |
| | (6, 341) | (299, 9,980) | (6, 975) |
| 2004 | 19 | 247 | 54 |
| | (2, 121) | (51, 1,685) | (3, 585) |

Table 1.35: Estimated seabird bycatch rate (per set) from 1999-2004 by target species for bottom long line fisheries for vessels less than 28 metres in length.

| Fishing Year | Target Species | | |
|---|---|---|---|
| | LIN | SNA | Other |
| 1999 | 0.02 | 0.10 | 0.02 |
| | (0.00, 0.15) | (0.02, 0.64) | (0.00, 0.19) |
| 2000 | 0.04 | 0.17 | 0.03 |
| | (0.00, 0.25) | (0.03, 0.89) | (0.00, 0.26) |
| 2001 | 0.06 | 0.23 | 0.03 |
| | (0.01, 0.37) | (0.05, 1.20) | (0.00, 0.36) |
| 2002 | 0.03 | 0.14 | 0.02 |
| | (0.00, 0.21) | (0.03, 0.86) | (0.00, 0.22) |
| 2003 | 0.02 | 0.15 | 0.02 |
| | (0.00, 0.15) | (0.03, 0.93) | (0.00, 0.16) |
| 2004 | 0.01 | 0.03 | 0.01 |
| | (0.00, 0.07) | (0.01, 0.19) | (0.00, 0.09) |

Table 3.1  Percentage of missing values for the predictor variables for modelling the surface longlining data.

|  | % missing |
|---|---|
| Vessel Class | 0.00% |
| Vessel Nationality | 0.00% |
| Season | 0.00% |
| Target Species | 0.09% |
| FMA | 0.59% |
| Start Time | 0.00% |
| End Time | 0.03% |
| Cloud | 7.93% |
| Barometric Pressure | 17.77% |
| Wind Direction | 8.76% |
| Wind Force | 5.39% |
| Weather Code | 100.00% |
| Birds | 87.09% |
| Hooks Set | 0.00% |

Table 3.2 Variables included in the modelling of the surface longlining data, together with their summed AIC weights (*w*)

|  | *w* |
|---|---|
| Vessel Class | 0.36 |
| Vessel Nationality | 1.00 |
| Season | 0.94 |
| Fishing Year | 1.00 |
| Target Species | 0.19 |
| Fishing Area | 1.00 |
| Nighttime Set | 0.63 |
| Hooks Set | 0.28 |

Table 3.3  Estimates and standard errors for the coefficients in the modelling of surface longlining data. The "intercept" refers to Japanese Vessels, Area 1, 1998, Daytime, Not in Autumn.

|  | Est | SE |
|---|---|---|
| Intercept | -0.76 | 0.60 |
| Nationality = NZ | -0.85 | 0.17 |
| Season = Autumn | -0.63 | 0.20 |
| Year 2 | -0.54 | 0.21 |
| Year 3 | -0.02 | 0.22 |
| Year 4 | -1.15 | 0.23 |
| Year 5 | 0.27 | 0.20 |
| Year 6 | -0.35 | 0.25 |
| Year 7 | -0.43 | 0.21 |
| Area 2 | 0.34 | 0.21 |
| Area 3 | -1.30 | 0.36 |
| Area 4 | -0.66 | 0.29 |
| Area 5 | -2.26 | 0.31 |
| Area 6 | -31.52 | 4.75E+05 |
| Night | 0.98 | 0.56 |
| $\theta$ | 0.32 | 0.04 |

Table 3.4  Percentage of missing values for the predictor variables for modelling the bottom longlining data.

|  | % missing |
|---|---|
| Vessel Class | 0.00% |
| Vessel Nation | 47.29% |
| Date | 0.00% |
| Target Species | 0.00% |
| Start Time | 0.08% |
| End Time | 0.25% |
| Hooks Set | 0.00% |

Table 3.5  Variables included in the modelling of the bottom longlining data, together with their summed AIC weights (*w*)

|  | *w* |
|---|---|
| Vessel Class | 0.44 |
| Season | 1.00 |
| Fishing Year | 1.00 |
| Target Species | 0.81 |
| Fishing Area | 0.00 |
| Start Time | 1.00 |
| End Time | 0.17 |
| Hooks Set | 0.27 |

Table 3.6  Estimates and standard errors for the coefficients in the modelling of bottom longlining data. The "intercept" relates to vessels targeting LIN in spring of 1999, beginning sets between 2100-0300 hours.

|  | Est | SE |
|---|---|---|
| Intercept | -1.35 | 0.22 |
| Season 2 | -0.67 | 0.15 |
| Season 3 | -0.80 | 0.18 |
| Season 4 | -1.26 | 0.12 |
| Year 2 | 0.84 | 0.25 |
| Year 3 | 1.22 | 0.21 |
| Year 4 | 0.59 | 0.23 |
| Year 5 | 0.41 | 0.22 |
| Year 6 | -0.34 | 0.24 |
| TSp | -1.09 | 0.25 |
| SC2 | 0.63 | 0.13 |
| SC3 | 0.21 | 0.15 |
| SC4 | 0.02 | 0.15 |
| $\theta$ | 0.13 | 0.01 |

Table 3.7: Percentage of missing values for the predictor variables for modelling the trawl fisheries data.

|  | % missing |
|---|---|
| Vessel Class | 0.00% |
| Vessel Nationality | 1.31% |
| Company | 39.65% |
| Date | 0.00% |
| Target Species | 0.00% |
| Trawl Type | 0.01% |
| Fishing on Marks | 0.08% |
| Area | 0.00% |
| Start Time | 0.00% |
| End Time | 0.00% |
| Fishing Speed | 0.00% |

Table 3.8: Variables included in the modelling of the trawl fisheries data, together with their summed AIC weights ($w$)

|  | $w$ |
|---|---|
| Vessel Class | 0.27 |
| Vessel Nationality | 1.00 |
| Season | 1.00 |
| Fishing Year | 1.00 |
| Target Species | 1.00 |
| Trawl Type | 1.00 |
| Fishing on Marks | 0.80 |
| Fishing Area | 1.00 |
| Start Time | 1.00 |
| End Time | 0.34 |
| Fishing Speed | 0.95 |

Table 3.9: Estimates and standard errors for the coefficients in the modelling of trawl fisheries data. The "intercept" relates to NZ vessels targeting HOK in spring of 1998, using mid-water trawls in North Island FMAs, beginning sets between 2100-0300 hours and fishing at 4 knots.

|  | Est. | SE |
|---|---|---|
| Intercept | -5.64 | 0.29 |
| Nat2 | 1.50 | 0.13 |
| Nat3 | 0.61 | 0.18 |
| Nat4 | 0.24 | 0.19 |
| Nat5 | 0.80 | 0.10 |
| Seas2 | -0.29 | 0.11 |
| Seas3 | 0.38 | 0.10 |
| Seas4 | -0.96 | 0.17 |
| FY2 | 1.14 | 0.14 |
| FY3 | 0.56 | 0.15 |
| FY4 | 1.22 | 0.14 |
| FY5 | 1.03 | 0.15 |
| FY6 | 1.05 | 0.15 |
| FY7 | 1.16 | 0.15 |
| TSp2 | -1.93 | 0.24 |
| TSp3 | -0.34 | 0.19 |
| TSp4 | -2.22 | 0.38 |
| TSp5 | 0.55 | 0.20 |
| TSp6 | 0.10 | 0.12 |
| TSp7 | -0.42 | 0.13 |
| BT | -0.83 | 0.09 |
| FOM | -0.15 | 0.07 |
| Area2 | 1.57 | 0.22 |
| Area3 | 0.95 | 0.22 |
| Area4 | 1.60 | 0.22 |
| Area5 | 1.27 | 0.22 |
| Area6 | 0.36 | 0.25 |
| SC2 | 0.29 | 0.11 |
| SC3 | 0.69 | 0.10 |
| SC4 | 0.16 | 0.11 |
| FSpd | 0.20 | 0.07 |
| $\theta$ | 0.08 | 0.004 |

Table 4.1 Estimated bycatch of seabirds (number of birds) in all fisheries, according to vessel size, method, area and season, for both 2004 and the average over the period 1998-2004 (1999-2004 for bottom longline). The estimates have been ranked in descending order according to the bycatch in 2004. The corresponding percentage of total bycatch is also shown. Those vessel-method-area-season combinations with less than 0.5% of the estimated bycatch in 2004 have been omitted from the table. Vessel sizes and seasons are defined as follows: Small = <28m; Large = >28m; Spring = Oct-Dec; Summer = Jan-Mar;  Autumn = Apr-Jun; Winter = Jul-Sep.

| Vessel | Method | Area | Season | 2004 Birds | 2004 % Birds | 98-04 Birds | 98-04 % Birds |
|--------|--------|------|--------|-------|---------|-------|---------|
| Small | SLL | 2 & 4 | Summer | 519 | 10% | 659 | 7% |
| Large | Trawl | 6 | Autumn | 377 | 7% | 230 | 2% |
| Large | Trawl | 6 | Summer | 372 | 7% | 223 | 2% |
| Large | Trawl | 5 | Autumn | 338 | 6% | 241 | 3% |
| Small | SLL | 2 & 4 | Autumn | 320 | 6% | 446 | 5% |
| Large | Trawl | 5 | Summer | 298 | 5% | 309 | 3% |
| Small | SLL | 1 | Winter | 248 | 5% | 518 | 6% |
| Large | Trawl | 3 | Autumn | 225 | 4% | 332 | 4% |
| Large | Trawl | 6 | Spring | 202 | 4% | 120 | 1% |
| Small | SLL | 1 | Spring | 171 | 3% | 396 | 4% |
| Small | SLL | 1 | Summer | 154 | 3% | 297 | 3% |
| Large | BLL | 6 | Spring | 151 | 3% | 333 | 4% |
| Large | SLL | 2 & 4 | Summer | 141 | 3% | 45 | 0% |
| Large | Trawl | 3 | Summer | 133 | 2% | 169 | 2% |
| Large | Trawl | 7 | Winter | 108 | 2% | 92 | 1% |
| Large | Trawl | 3 | Spring | 93 | 2% | 109 | 1% |
| Large | BLL | 5 & 7 | Spring | 89 | 2% | 191 | 2% |
| Large | BLL | 6 | Autumn | 88 | 2% | 278 | 3% |
| Large | Trawl | 4 | Autumn | 87 | 2% | 77 | 1% |
| Small | BLL | 1-2 & 8-10 | Autumn | 87 | 2% | 342 | 4% |
| Small | SLL | 1 | Autumn | 82 | 2% | 207 | 2% |
| Small | BLL | 1-2 & 8-10 | Summer | 81 | 1% | 293 | 3% |
| Small | SLL | 2 & 4 | Spring | 77 | 1% | 95 | 1% |
| Large | BLL | 6 | Summer | 66 | 1% | 245 | 3% |
| Small | BLL | 1-2 & 8-10 | Winter | 64 | 1% | 294 | 3% |
| Large | Trawl | 4 | Summer | 63 | 1% | 65 | 1% |
| Large | Trawl | 5 | Spring | 57 | 1% | 76 | 1% |
| Small | SLL | 2 & 4 | Winter | 56 | 1% | 38 | 0% |
| Large | Trawl | 4 | Spring | 54 | 1% | 56 | 1% |
| Large | BLL | 3 & 4 | Spring | 54 | 1% | 260 | 3% |
| Large | BLL | 3 & 4 | Winter | 54 | 1% | 191 | 2% |
| Large | SLL | 5 | Autumn | 46 | 1% | 43 | 0% |
| Large | BLL | 3 & 4 | Autumn | 44 | 1% | 65 | 1% |
| Large | Trawl | 7 | Autumn | 42 | 1% | 52 | 1% |
| Large | BLL | 6 | Winter | 33 | 1% | 132 | 1% |
| Large | BLL | 3 & 4 | Summer | 31 | 1% | 39 | 0% |
| Small | BLL | 5 & 7 | Spring | 29 | 1% | 208 | 2% |
| Large | Trawl | 3 | Winter | 28 | 1% | 22 | 0% |

Table 4.2 Estimated bycatch of albatross (number of birds) in trawl fisheries, according to vessel size, area and season, for both 2004 and the average over the period 1998-2004. The estimates have been ranked in descending order according to the bycatch in 2004. The corresponding percentage of total bycatch is also shown. Those vessel-area-season combinations with less than 0.5% of the estimated bycatch in 2004 have been omitted from the table. Vessel sizes and seasons are defined as follows: Small = <28m; Large = >28m; Spring = Oct-Dec; Summer = Jan-Mar; Autumn = Apr-Jun; Winter = Jul-Sep.

| Vessel | Area | Season | 2004 Birds | % Birds | 98-04 Birds | % Birds |
|---|---|---|---|---|---|---|
| Large | 6 | Summer | 270 | 18% | 154 | 13% |
| Large | 5 | Summer | 186 | 12% | 198 | 16% |
| Large | 6 | Autumn | 183 | 12% | 91 | 7% |
| Large | 5 | Autumn | 153 | 10% | 84 | 7% |
| Large | 6 | Spring | 122 | 8% | 65 | 5% |
| Large | 7 | Winter | 55 | 4% | 49 | 4% |
| Large | 3 | Summer | 48 | 3% | 54 | 4% |
| Large | 3 | Autumn | 44 | 3% | 73 | 6% |
| Large | 4 | Spring | 36 | 2% | 36 | 3% |
| Large | 4 | Summer | 35 | 2% | 35 | 3% |
| Large | 4 | Autumn | 33 | 2% | 29 | 2% |
| Large | 3 | Spring | 28 | 2% | 33 | 3% |
| Small | 3 | Autumn | 28 | 2% | 25 | 2% |
| Small | 7 | Autumn | 26 | 2% | 20 | 2% |
| Small | 3 | Summer | 24 | 2% | 26 | 2% |
| Large | 5 | Spring | 23 | 2% | 34 | 3% |
| Small | 3 | Spring | 23 | 2% | 20 | 2% |
| Large | 7 | Autumn | 17 | 1% | 20 | 2% |
| Small | 7 | Spring | 15 | 1% | 11 | 1% |
| Small | 7 | Winter | 12 | 1% | 8 | 1% |
| Small | 7 | Summer | 9 | 1% | 9 | 1% |
| Large | 3 | Winter | 8 | 1% | 7 | 1% |
| Large | 6 | Winter | 8 | 1% | 8 | 1% |

Table 4.3 Uncertainty (width of 95% credible interval) associated with estimates of bycatch of seabirds (number of birds) in all fisheries in 2004, according to vessel size, method, area and season. The uncertainty is also shown as a percentage of the total estimated bycatch for 2004. The uncertainties have been ranked in descending order and those vessel-method-area-season combinations for which the uncertainty was less than 2% of the estimated total bycatch in 2004 have been omitted from the table. Vessel sizes and seasons are defined as follows: Small = <28m; Large = >28m; Spring = Oct-Dec; Summer = Jan-Mar;  Autumn = Apr-Jun; Winter = Jul-Sep.

| Vessel | Method | Area | Season | Birds | % Total |
|--------|--------|------|--------|-------|---------|
| Small | SLL | 2 & 4 | Summer | 991 | 18% |
| Small | SLL | 2 & 4 | Autumn | 803 | 15% |
| Small | SLL | 1 | Winter | 764 | 14% |
| Small | BLL | 1-2 & 8-10 | Summer | 564 | 10% |
| Small | BLL | 1-2 & 8-10 | Autumn | 559 | 10% |
| Large | SLL | 2 & 4 | Summer | 521 | 10% |
| Small | BLL | 1-2 & 8-10 | Winter | 475 | 9% |
| Small | SLL | 1 | Spring | 378 | 7% |
| Small | SLL | 1 | Summer | 268 | 5% |
| Small | BLL | 5 & 7 | Spring | 260 | 5% |
| Small | SLL | 2 & 4 | Spring | 210 | 4% |
| Small | SLL | 1 | Autumn | 205 | 4% |
| Small | SLL | 2 & 4 | Winter | 197 | 4% |
| Large | Trawl | 6 | Autumn | 176 | 3% |
| Small | BLL | 5 & 7 | Summer | 169 | 3% |
| Large | Trawl | 5 | Autumn | 155 | 3% |
| Large | BLL | 6 | Spring | 133 | 2% |
| Large | Trawl | 3 | Autumn | 125 | 2% |
| Large | Trawl | 6 | Spring | 123 | 2% |
| Large | Trawl | 6 | Summer | 119 | 2% |
| Large | BLL | 3 & 4 | Autumn | 115 | 2% |
| Large | Trawl | 5 | Summer | 111 | 2% |

Table 4.4 Uncertainty (width of 95% credible interval) associated with estimates of bycatch of albatross (number of birds) in trawl fisheries in 2004, according to vessel size, area and season. The uncertainty is also shown as a percentage of the total estimated bycatch for 2004. The uncertainties have been ranked in descending order and those vessel-area-season combinations for which the uncertainty was less than 2% of the estimated total bycatch in 2004 have been omitted from the table. Vessel sizes and seasons are defined as follows: Small = <28m; Large = >28m; Spring = Oct-Dec; Summer = Jan-Mar;  Autumn = Apr-Jun; Winter = Jul-Sep.

| Vessel | Area | Season | Birds | % Total |
|--------|------|--------|-------|---------|
| Small | 7 | Autumn | 124 | 8% |
| Small | 3 | Autumn | 121 | 8% |
| Large | 6 | Autumn | 104 | 7% |
| Small | 3 | Summer | 104 | 7% |
| Large | 6 | Summer | 101 | 7% |
| Large | 6 | Spring | 90 | 6% |
| Large | 5 | Summer | 86 | 6% |
| Small | 3 | Spring | 86 | 6% |
| Large | 5 | Autumn | 81 | 6% |
| Small | 7 | Spring | 77 | 5% |
| Small | 7 | Winter | 53 | 4% |
| Small | 7 | Summer | 45 | 3% |
| Large | 3 | Summer | 43 | 3% |
| Large | 4 | Spring | 40 | 3% |
| Large | 3 | Autumn | 39 | 3% |
| Large | 7 | Winter | 39 | 3% |
| Large | 4 | Summer | 37 | 3% |
| Large | 4 | Autumn | 36 | 2% |
| Large | 3 | Spring | 30 | 2% |

Table 4.5 Estimated capture rate of seabirds (birds per 100 tows) in trawl fisheries, according to vessel-size, area and season, for both 2004 and the average over the period 1998-2004. The estimates have been ranked in descending order according to the capture rate in 2004. Vessel sizes and seasons are defined as follows: Small = <28m; Large = >28m; Spring = Oct-Dec; Summer = Jan-Mar; Autumn = Apr-Jun; Winter = Jul-Sep. Blank cells correspond to vessel-area-season combinations for which there were no data.

| Vessel | Area | Season | 2004 | 98-04 | Vessel | Area | Season | 2004 | 98-04 |
|---|---|---|---|---|---|---|---|---|---|
| Large | 5 | Autumn | 18.4 | 12.7 | Small | 5 | Summer | 0.1 | 0.2 |
| Large | 3 | Autumn | 11.4 | 9.6 | Small | 3 | Summer | 0.1 | 0.1 |
| Large | 5 | Summer | 10.3 | 8.2 | Small | 7 | Autumn | 0.1 | 0.1 |
| Large | 6 | Autumn | 9.9 | 6.9 | Small | 5 | Spring | 0.1 | 0.1 |
| Large | 6 | Summer | 7.0 | 4.3 | Small | 5 | Winter | 0.1 | 0.1 |
| Large | 3 | Summer | 6.3 | 5.0 | Small | 7 | Summer | 0.1 | 0.1 |
| Large | 5 | Spring | 5.1 | 4.9 | Small | 7 | Spring | 0.1 | 0.0 |
| Large | 7 | Autumn | 4.8 | 3.4 | Small | 3 | Winter | 0.1 | 0.0 |
| Large | 3 | Spring | 4.5 | 3.7 | Large | Other | Winter | 0.0 | 0.0 |
| Large | 4 | Autumn | 3.9 | 3.9 | Large | 1 | Spring | 0.0 | 0.0 |
| Large | 6 | Spring | 3.5 | 2.7 | Large | 1 | Summer | 0.0 | 0.0 |
| Large | 7 | Summer | 2.6 | 2.3 | Large | 1 | Autumn | 0.0 | 0.0 |
| Large | 4 | Summer | 2.1 | 2.0 | Large | 1 | Winter | 0.0 | 0.0 |
| Large | 3 | Winter | 2.0 | 1.9 | Large | 9 | Winter | 0.0 | 0.0 |
| Large | 4 | Spring | 1.8 | 1.7 | Small | 2 | Autumn | 0.0 | 0.0 |
| Large | 5 | Winter | 1.7 | 2.4 | Small | 2 | Summer | 0.0 | 0.0 |
| Large | 7 | Winter | 1.6 | 1.2 | Small | 7 | Winter | 0.0 | 0.0 |
| Large | 7 | Spring | 1.6 | 1.2 | Small | 1 | Spring | 0.0 | 0.0 |
| Large | 2 | Autumn | 1.5 | 1.1 | Small | 1 | Summer | 0.0 | 0.0 |
| Large | 4 | Winter | 1.3 | 0.9 | Small | 1 | Autumn | 0.0 | 0.0 |
| Large | 2 | Summer | 1.0 | 0.7 | Small | 1 | Winter | 0.0 | 0.0 |
| Large | 6 | Winter | 0.8 | 0.7 | Small | 2 | Spring | 0.0 | 0.1 |
| Large | 2 | Spring | 0.6 | 0.5 | Small | 2 | Winter | 0.0 | 0.0 |
| Large | 9 | Autumn | 0.6 | 0.5 | Small | 4 | Summer | 0.0 | 0.0 |
| Large | 2 | Winter | 0.4 | 0.3 | Small | 4 | Autumn | 0.0 | 0.0 |
| Small | 6 | Autumn | 0.4 | 0.2 | Small | 6 | Summer | 0.0 | 0.2 |
| Small | 5 | Autumn | 0.4 | 0.3 | Small | 6 | Winter | 0.0 | 0.0 |
| Small | 4 | Spring | 0.3 | 0.3 | Small | 9 | Spring | 0.0 | 0.0 |
| Small | 3 | Autumn | 0.3 | 0.2 | Small | 9 | Summer | 0.0 | 0.0 |
| Large | 9 | Summer | 0.2 | 0.2 | Small | 9 | Autumn | 0.0 | 0.0 |
| Large | 9 | Spring | 0.2 | 0.3 | Small | 9 | Winter | 0.0 | 0.0 |
| Large | Other | Autumn | 0.2 | 0.1 | Small | Other | Spring | 0.0 | 0.0 |
| Small | 6 | Spring | 0.2 | 0.1 | Small | Other | Summer | 0.0 | 0.0 |
| Small | 3 | Spring | 0.2 | 0.1 | Small | Other | Autumn | 0.0 | 0.0 |
| Large | Other | Summer | 0.1 | 0.1 | Small | Other | Winter | 0.0 | 0.0 |
| Large | Other | Spring | 0.1 | 0.0 | Small | 4 | Winter | | 0.0 |

Table 4.6 Estimated capture rate of seabirds (birds per set) in longline fisheries, according to vessel-size, method, area and season, for both 2004 and the average over the period 1998-2004. The estimates have been ranked in descending order according to the capture rate in 2004. Vessel sizes and seasons are defined as follows: Small = <28m; Large = >28m; Spring = Oct-Dec; Summer = Jan-Mar;  Autumn = Apr-Jun; Winter = Jul-Sep. Blank cells correspond to vessel-method-area-season combinations for which there were no data.

| Vessel | Method | Area | Season | 2004 | 98-04 | Vessel | Method | Area | Season | 2004 | 98-04 |
|--------|--------|------|--------|------|-------|--------|--------|------|--------|------|-------|
| Large | SLL | 2 & 4 | Summer | 3.1 | 5.2 | Large | BLL | Other | Summer | 0.0 | 0.0 |
| Large | SLL | 3 & 6 | Autumn | 1.0 | 0.2 | Large | BLL | Other | Autumn | 0.0 | 0.0 |
| Small | SLL | 2 & 4 | Summer | 0.8 | 0.9 | Large | BLL | Other | Winter | 0.0 | 0.0 |
| Small | SLL | 2 & 4 | Spring | 0.7 | 0.8 | Small | BLL | 3 & 4 | Spring | 0.0 | 0.1 |
| Small | SLL | 1 | Summer | 0.5 | 0.6 | Small | BLL | 5 & 7 | Autumn | 0.0 | 0.1 |
| Large | SLL | 2 & 4 | Autumn | 0.4 | 0.7 | Small | BLL | 1-2 & 8-10 | Autumn | 0.0 | 0.1 |
| Small | SLL | 1 | Winter | 0.4 | 0.5 | Small | BLL | 5 & 7 | Winter | 0.0 | 0.1 |
| Small | SLL | 1 | Spring | 0.4 | 0.5 | Small | BLL | 1-2 & 8-10 | Winter | 0.0 | 0.1 |
| Large | BLL | 5 & 7 | Spring | 0.4 | 0.5 | Small | BLL | 1-2 & 8-10 | Summer | 0.0 | 0.1 |
| Small | SLL | 1 | Autumn | 0.3 | 0.4 | Small | BLL | 3 & 4 | Winter | 0.0 | 0.0 |
| Large | SLL | 5 | Autumn | 0.2 | 0.2 | Small | BLL | 3 & 4 | Summer | 0.0 | 0.0 |
| Small | SLL | 2 & 4 | Winter | 0.2 | 0.6 | Small | BLL | 3 & 4 | Autumn | 0.0 | 0.0 |
| Small | SLL | 2 & 4 | Autumn | 0.2 | 0.4 | Small | BLL | 1-2 & 8-10 | Spring | 0.0 | 0.1 |
| Large | BLL | 6 | Spring | 0.2 | 0.5 | Small | BLL | 6 | Spring | 0.0 | 0.3 |
| Large | BLL | 3 & 4 | Spring | 0.2 | 0.4 | Small | BLL | 6 | Winter | 0.0 | 0.0 |
| Large | SLL | 7 | Autumn | 0.1 | 0.1 | Small | BLL | Other | Spring | 0.0 | 0.0 |
| Small | SLL | Other | Autumn | 0.1 | 0.0 | Small | BLL | Other | Summer | 0.0 | 0.0 |
| Large | BLL | 6 | Autumn | 0.1 | 0.3 | Small | BLL | Other | Autumn | 0.0 | 0.0 |
| Large | BLL | 6 | Summer | 0.1 | 0.3 | Small | BLL | Other | Winter | 0.0 | 0.0 |
| Large | BLL | 6 | Winter | 0.1 | 0.4 | Large | SLL | 1 | Spring | | 3.1 |
| Large | BLL | 3 & 4 | Autumn | 0.1 | 0.2 | Large | SLL | 1 | Summer | | 2.9 |
| Large | BLL | 5 & 7 | Winter | 0.1 | 0.1 | Large | SLL | 1 | Autumn | | 1.3 |
| Large | BLL | 3 & 4 | Summer | 0.1 | 0.2 | Large | SLL | 1 | Winter | | 2.0 |
| Large | BLL | 5 & 7 | Summer | 0.1 | 0.2 | Large | SLL | 2 & 4 | Winter | | 3.0 |
| Large | BLL | 3 & 4 | Winter | 0.1 | 0.2 | Large | SLL | 3 & 6 | Spring | | |
| Small | BLL | 5 & 7 | Spring | 0.1 | 0.4 | Large | SLL | 3 & 6 | Summer | | 0.1 |
| Small | BLL | 5 & 7 | Summer | 0.1 | 0.1 | Large | SLL | 3 & 6 | Winter | | |
| Large | SLL | 7 | Winter | 0.0 | 0.0 | Large | SLL | 5 | Spring | | |
| Large | SLL | 2 & 4 | Spring | 0.0 | 4.1 | Large | SLL | 5 | Winter | | |
| Large | SLL | 5 | Summer | 0.0 | 0.2 | Large | SLL | 7 | Spring | | |
| Large | SLL | 8 & 9 | Winter | 0.0 | 0.0 | Large | SLL | 7 | Summer | | 0.0 |
| Large | SLL | Other | Spring | 0.0 | 0.2 | Large | SLL | 8 & 9 | Spring | | 0.0 |
| Small | SLL | 5 | Autumn | 0.0 | 0.0 | Large | SLL | 8 & 9 | Summer | | 0.0 |
| Small | SLL | 7 | Autumn | 0.0 | 0.0 | Large | SLL | 8 & 9 | Autumn | | 0.0 |
| Small | SLL | 3 & 6 | Autumn | 0.0 | 0.0 | Large | SLL | Other | Summer | | 0.4 |
| Small | SLL | 7 | Spring | 0.0 | 0.0 | Large | SLL | Other | Autumn | | 0.0 |
| Small | SLL | 7 | Winter | 0.0 | 0.0 | Large | SLL | Other | Winter | | 0.1 |
| Small | SLL | 8 & 9 | Spring | 0.0 | 0.0 | Small | SLL | 3 & 6 | Spring | | 0.0 |
| Small | SLL | 8 & 9 | Summer | 0.0 | 0.0 | Small | SLL | 3 & 6 | Summer | | 0.0 |
| Small | SLL | 8 & 9 | Autumn | 0.0 | 0.0 | Small | SLL | 3 & 6 | Winter | | |
| Small | SLL | 8 & 9 | Winter | 0.0 | 0.0 | Small | SLL | 5 | Spring | | |
| Small | SLL | Other | Spring | 0.0 | 0.1 | Small | SLL | 5 | Summer | | 0.0 |
| Small | SLL | Other | Summer | 0.0 | 0.1 | Small | SLL | 5 | Winter | | 0.0 |
| Small | SLL | Other | Winter | 0.0 | 0.1 | Small | SLL | 7 | Summer | | 0.0 |
| Large | BLL | 1-2 & 8-10 | Autumn | 0.0 | 0.0 | Large | BLL | 1-2 & 8-10 | Summer | | 0.0 |
| Large | BLL | 1-2 & 8-10 | Spring | 0.0 | 0.2 | Large | BLL | 1-2 & 8-10 | Winter | | 0.0 |
| Large | BLL | 5 & 7 | Autumn | 0.0 | 0.0 | Small | BLL | 6 | Summer | | |
| Large | BLL | Other | Spring | 0.0 | 0.0 | Small | BLL | 6 | Autumn | | 0.3 |

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Table 4.7 Estimated capture rate of albatross (birds per 100 tows) in trawl fisheries, according to vessel-size, area and season, for both 2004 and the average over the period 1998-2004. The estimates have been ranked in descending order according to the capture rate in 2004. Vessel sizes and seasons are defined as follows: Small = <28m; Large = >28m; Spring = Oct-Dec; Summer = Jan-Mar; Autumn = Apr-Jun; Winter = Jul-Sep. Blank cells correspond to vessel-area-season combinations for which there were no data.

| Vessel | Area | Season | 2004 | 98-04 | Vessel | Area | Season | 2004 | 98-04 |
|--------|------|--------|------|-------|--------|------|--------|------|-------|
| Large | 5 | Autumn | 8.4 | 4.5 | Small | 7 | Spring | 0.3 | 0.3 |
| Large | 5 | Summer | 6.4 | 5.1 | Small | 5 | Winter | 0.3 | 0.2 |
| Large | 6 | Summer | 5.1 | 2.9 | Small | 2 | Autumn | 0.2 | 0.2 |
| Large | 6 | Autumn | 4.8 | 2.7 | Small | 2 | Summer | 0.2 | 0.2 |
| Large | 3 | Summer | 2.3 | 1.6 | Small | 7 | Winter | 0.2 | 0.1 |
| Large | 3 | Autumn | 2.2 | 2.1 | Small | 2 | Spring | 0.2 | 0.2 |
| Large | 6 | Spring | 2.1 | 1.5 | Small | 3 | Winter | 0.1 | 0.1 |
| Large | 5 | Spring | 2.1 | 2.1 | Small | 2 | Winter | 0.1 | 0.1 |
| Large | 7 | Autumn | 1.9 | 1.3 | Large | Other | Autumn | 0.0 | 0.0 |
| Large | 4 | Autumn | 1.5 | 1.5 | Large | 1 | Spring | 0.0 | 0.0 |
| Large | 7 | Summer | 1.5 | 1.5 | Large | 1 | Summer | 0.0 | 0.0 |
| Large | 3 | Spring | 1.4 | 1.1 | Large | 1 | Autumn | 0.0 | 0.0 |
| Large | 4 | Spring | 1.2 | 1.1 | Large | 1 | Winter | 0.0 | 0.0 |
| Large | 4 | Summer | 1.2 | 1.1 | Large | 9 | Spring | 0.0 | 0.0 |
| Large | 7 | Spring | 1.2 | 0.8 | Large | 9 | Summer | 0.0 | 0.0 |
| Large | 5 | Winter | 1.0 | 0.9 | Large | 9 | Autumn | 0.0 | 0.0 |
| Large | 4 | Winter | 0.9 | 0.5 | Large | 9 | Winter | 0.0 | 0.0 |
| Large | 7 | Winter | 0.8 | 0.6 | Large | Other | Spring | 0.0 | 0.0 |
| Large | 2 | Autumn | 0.8 | 0.6 | Large | Other | Summer | 0.0 | 0.0 |
| Large | 2 | Summer | 0.7 | 0.5 | Large | Other | Winter | 0.0 | 0.0 |
| Small | 6 | Autumn | 0.7 | 0.7 | Small | 1 | Spring | 0.0 | 0.0 |
| Small | 5 | Autumn | 0.7 | 0.6 | Small | 1 | Summer | 0.0 | 0.0 |
| Small | 6 | Summer | 0.7 | 0.6 | Small | 1 | Autumn | 0.0 | 0.0 |
| Large | 2 | Spring | 0.6 | 0.5 | Small | 1 | Winter | 0.0 | 0.0 |
| Large | 3 | Winter | 0.6 | 0.6 | Small | 4 | Summer | 0.0 | 0.0 |
| Small | 4 | Spring | 0.6 | 0.4 | Small | 4 | Autumn | 0.0 | 0.1 |
| Small | 5 | Summer | 0.6 | 0.5 | Small | 6 | Winter | 0.0 | 0.1 |
| Small | 6 | Spring | 0.6 | 0.2 | Small | 9 | Spring | 0.0 | 0.0 |
| Small | 5 | Spring | 0.5 | 0.4 | Small | 9 | Summer | 0.0 | 0.0 |
| Small | 7 | Autumn | 0.5 | 0.4 | Small | 9 | Autumn | 0.0 | 0.0 |
| Small | 3 | Autumn | 0.4 | 0.4 | Small | 9 | Winter | 0.0 | 0.0 |
| Small | 3 | Spring | 0.4 | 0.3 | Small | Other | Spring | 0.0 | 0.0 |
| Small | 7 | Summer | 0.4 | 0.3 | Small | Other | Summer | 0.0 | 0.0 |
| Large | 6 | Winter | 0.3 | 0.3 | Small | Other | Autumn | 0.0 | 0.0 |
| Large | 2 | Winter | 0.3 | 0.3 | Small | Other | Winter | 0.0 | 0.0 |
| Small | 3 | Summer | 0.3 | 0.3 | Small | 4 | Winter |  | 0.0 |

Figure 1. Fisheries management areas (FMAs) in New Zealand, with number and letter codes.
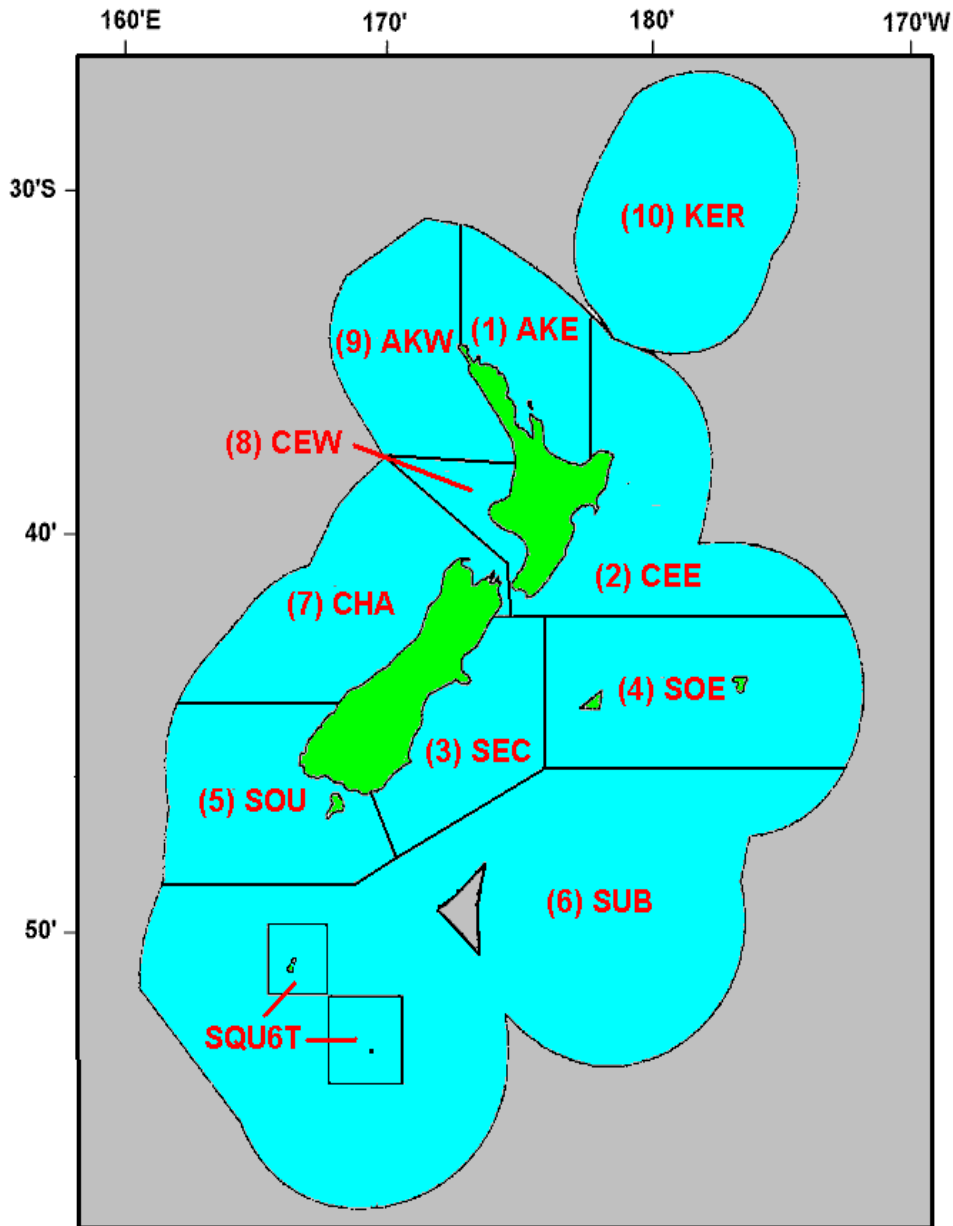
Figure 1.1: Example of determining convergence of chains in analysis using Markov chain Monte Carlo techniques.



alpha chains 1:3

Initial starting values for each chain. Note chains tend to be parallel indicating lack of mixing.

Chains are crossing over and fluctuating across a similar range of values. This was interpreted as evidence of mixing and convergence.
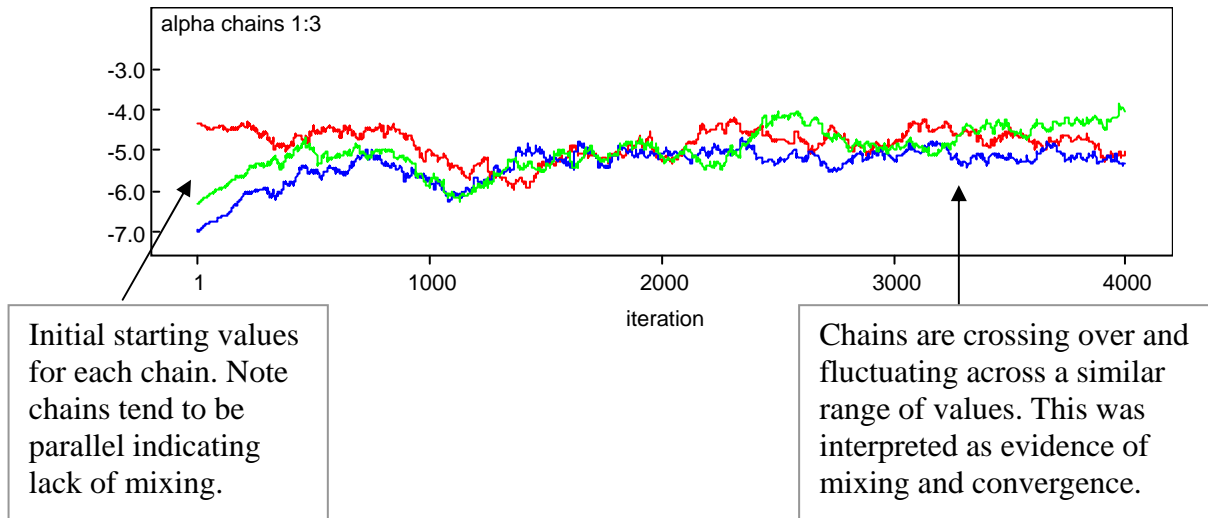
Figure 1.2: Estimated total albatross bycatch in trawl fisheries by vessels longer than 28 metres.
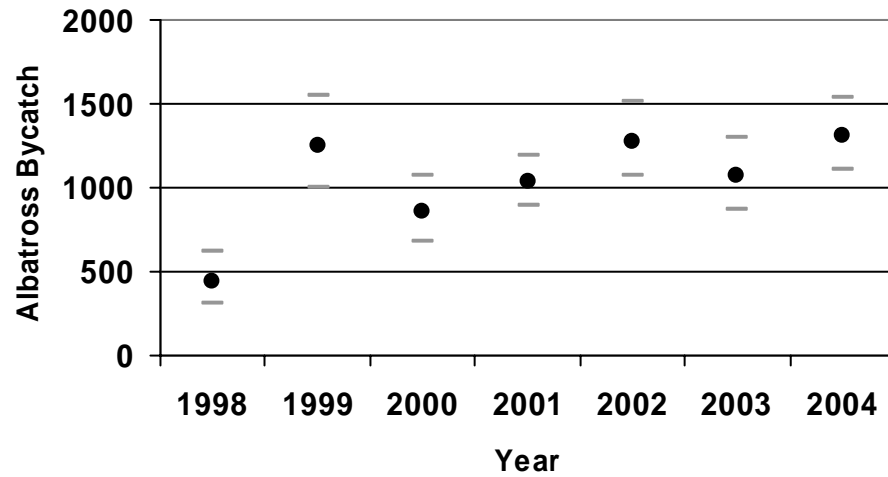


Figure 1.3: Estimated total albatross in trawl fisheries by vessels less than 28 metres in length.
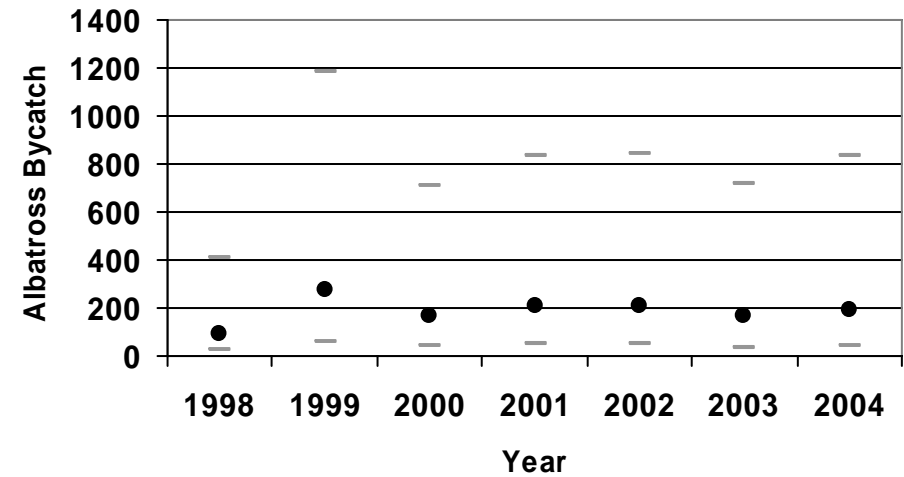


Figure 1.4: Estimated total albatross capture rate (per 100 tows) in trawl fisheries by vessels longer than 28 metres.
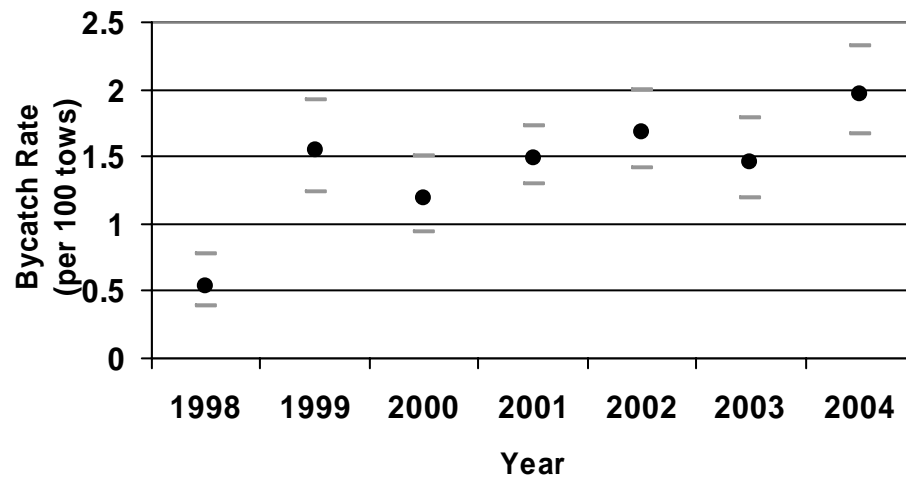


Figure 1.5: Estimated total albatross capture rate (per 100 tows) in trawl fisheries by vessels longer than 28 metres.
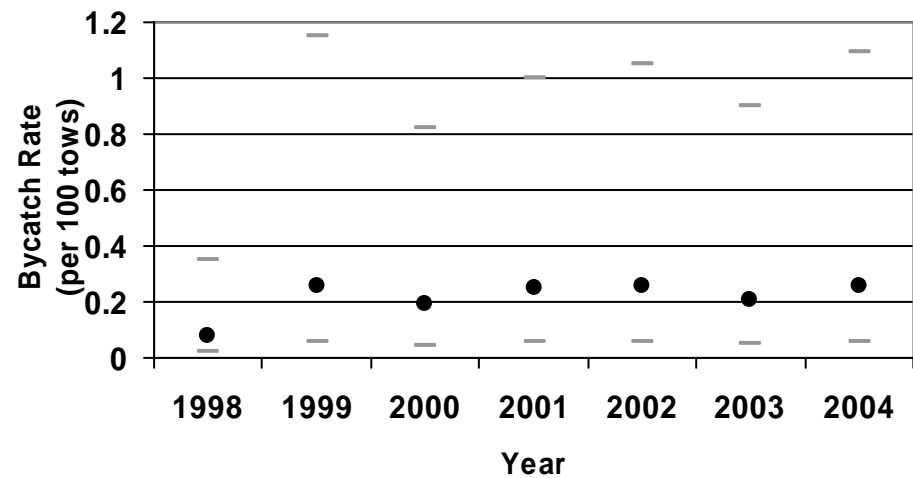
Figure 1.6: Estimated total seabird bycatch in trawl fisheries by vessels greater than 28 metres in length.
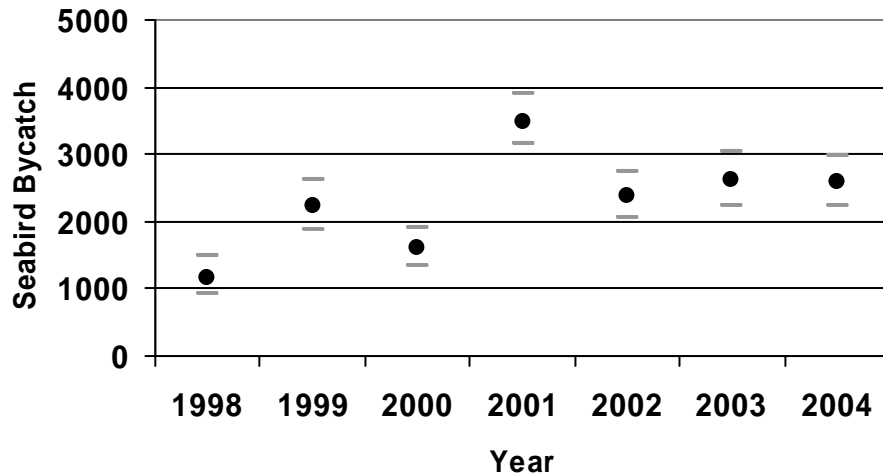


Figure 1.7: Estimated total seabird bycatch in trawl fisheries by vessels less than 28 metres in length.
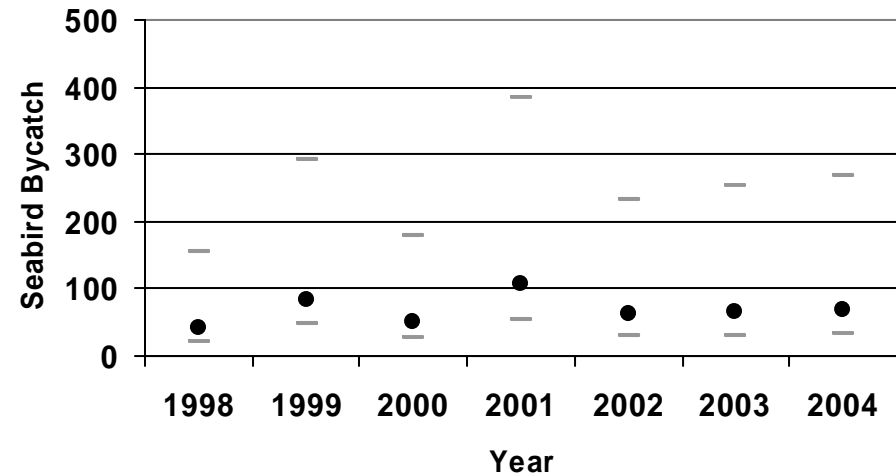


Figure 1.8 Estimated seabird capture rate (per 100 tows) in trawl fisheries by vessels greater than 28 metres in length.
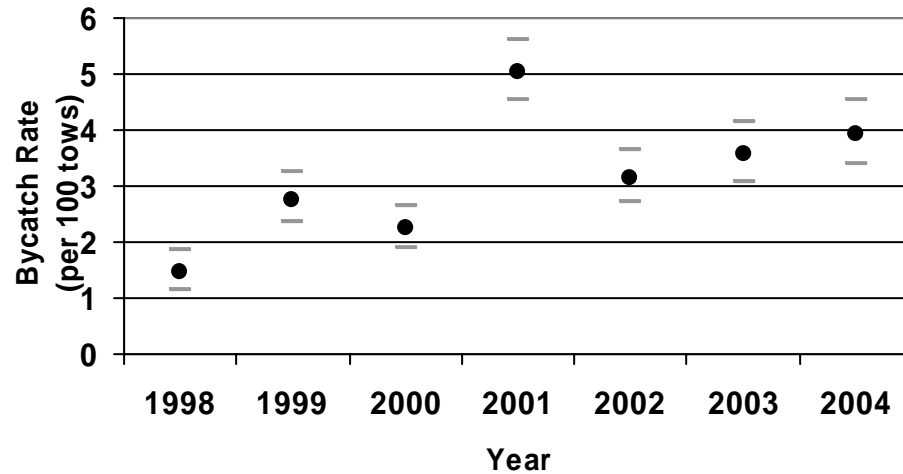


Figure 1.9: Estimated seabird capture rate (per 100 tows) in trawl fisheries by vessels less than 28 metres in length.
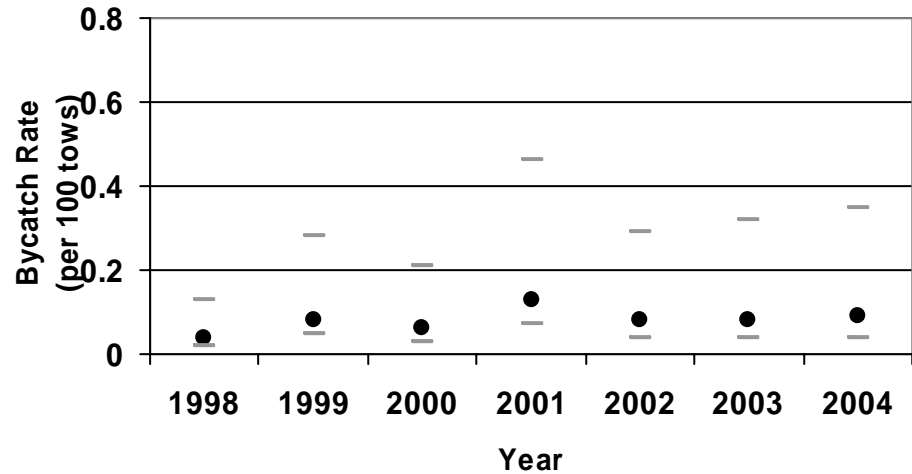
Figure 1.10: Estimated total seabird bycatch in surface long line fisheries by vessels greater than 28 metres in length.
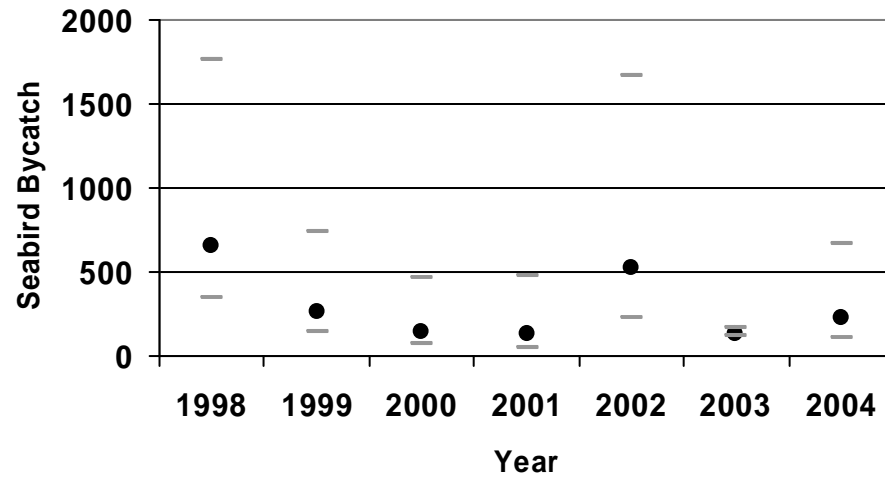


Figure 1.11: Estimated total seabird bycatch in surface long line fisheries by vessels less than 28 metres in length.
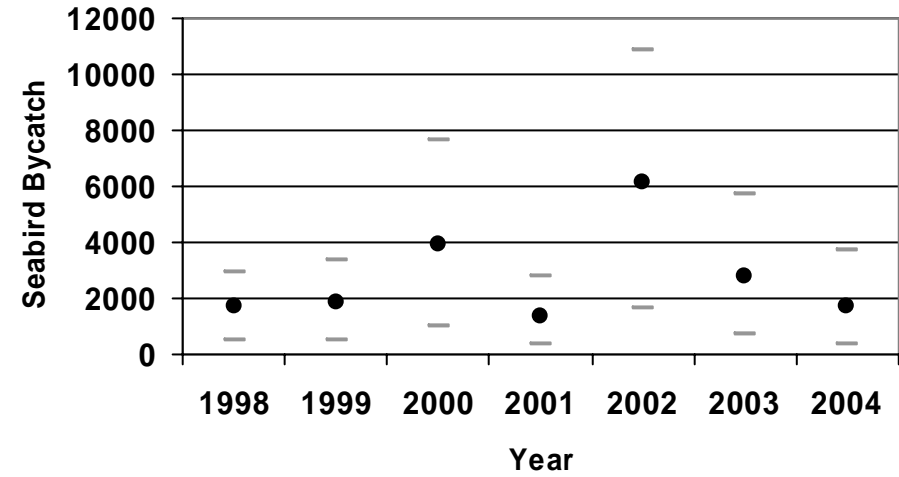


Figure 1.12: Estimated total seabird capture rate (per set) in surface long line fisheries by vessels greater than 28 metres in length.
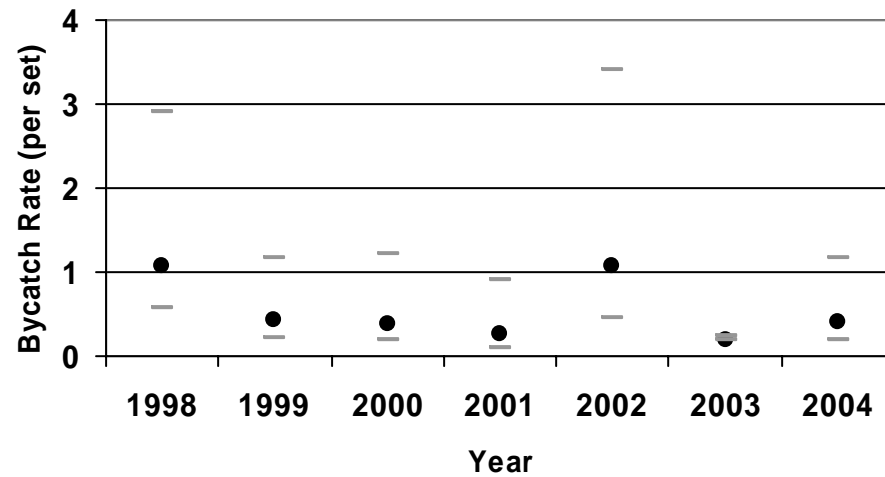


Figure 1.13: Estimated total seabird capture rate (per set) in surface long line fisheries by vessels less than 28 metres in length.
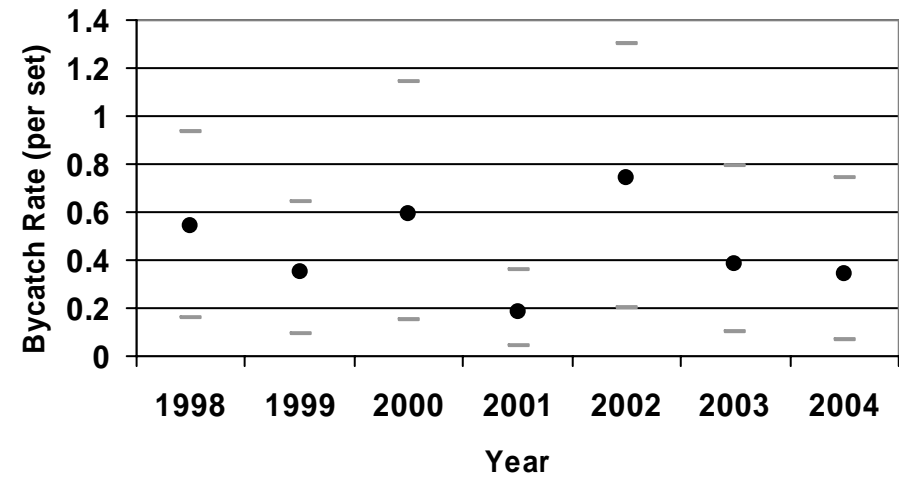
Figure 1.14: Estimated total seabird bycatch in bottom long line fisheries by vessels greater than 28 metres in length.
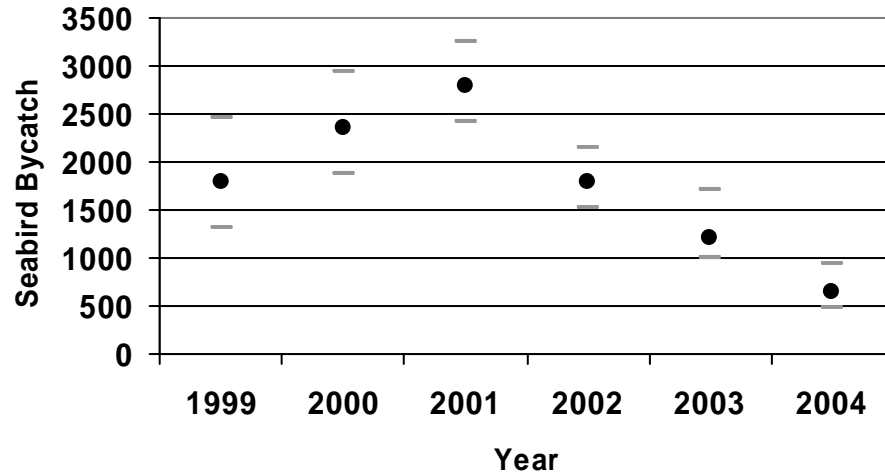


Figure 1.15: Estimated total seabird bycatch in bottom long line fisheries by vessels less than 28 metres in length.
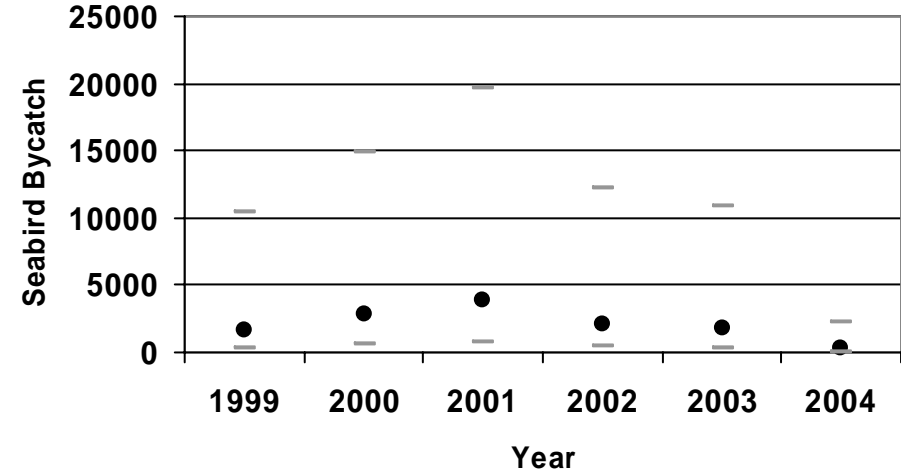


Figure 1.16: Estimated total seabird capture rate (per set) in bottom long line fisheries by vessels greater than 28 metres in length.
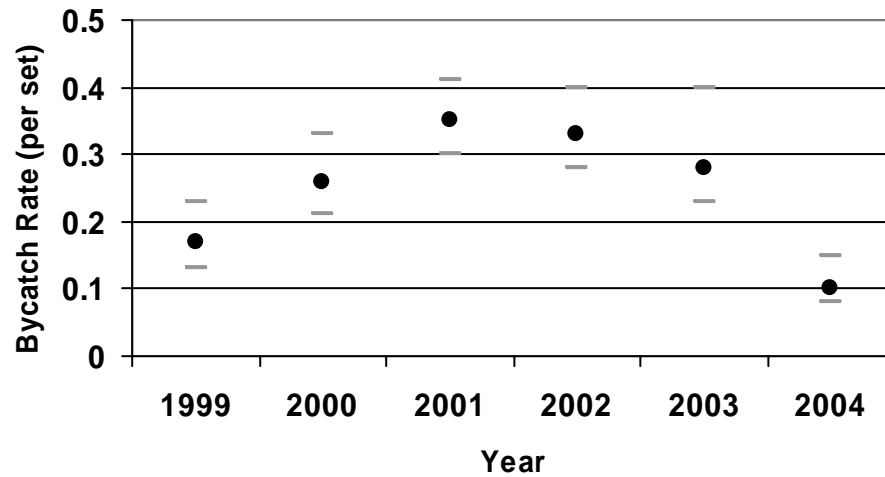


Figure 1.17: Estimated total seabird capture rate (per set) in bottom long line fisheries by vessels less than 28 metres in length.
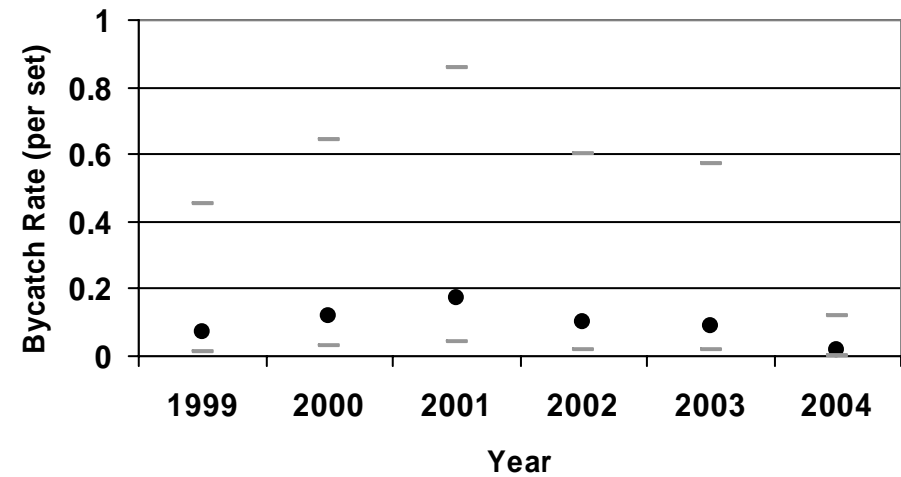
Figure 3.1  Relative effect of vessel nationality for surface longlining data. The solid dot represents the estimate and dashes represent the 95% credible interval. The first class is the reference class and will therefore have a relative effect of 1.0. The number of observed sets for each category are indicated in parentheses.
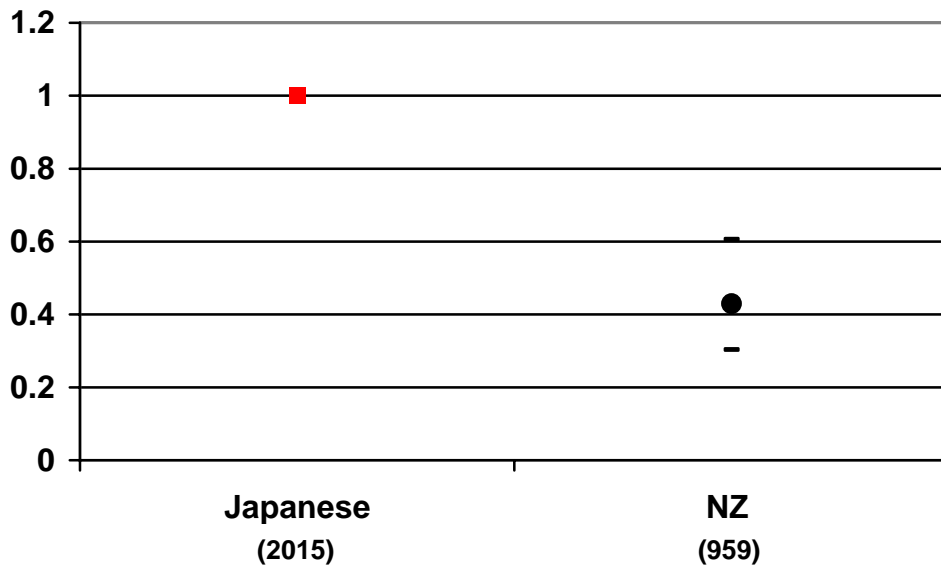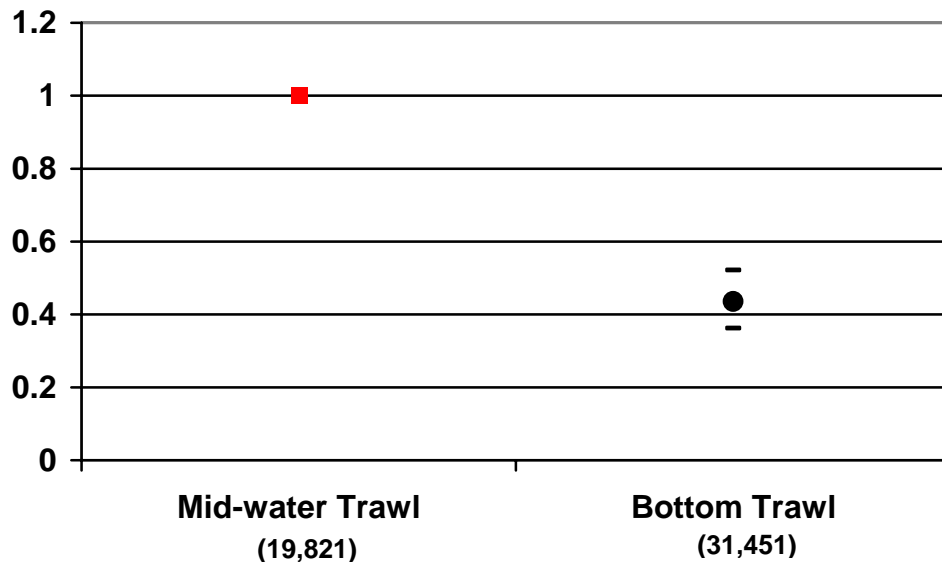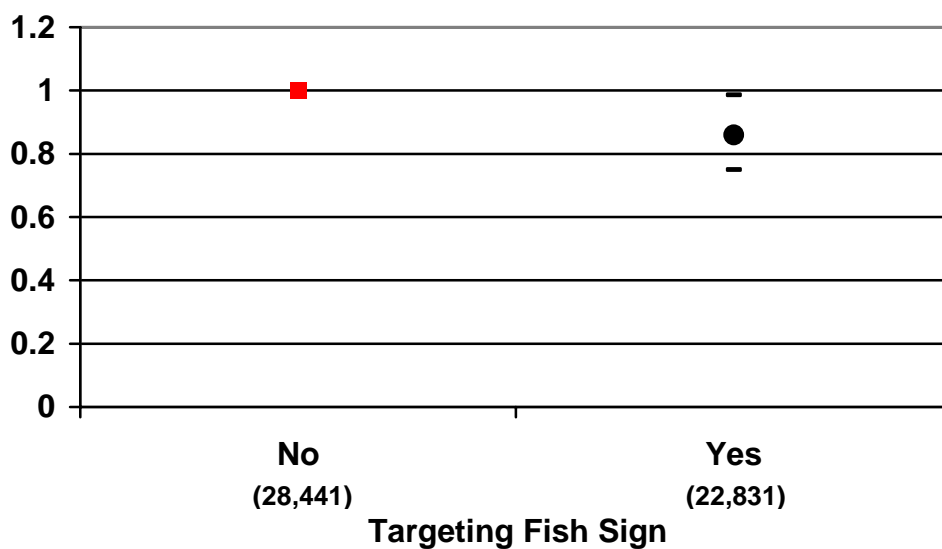


Figure 3.2  Relative effect of season for surface longlining data. The solid dot represents the estimate and dashes represent the 95% credible interval. The first class is the reference class and will therefore have a relative effect of 1.0. The number of observed sets for each category are indicated in parentheses.
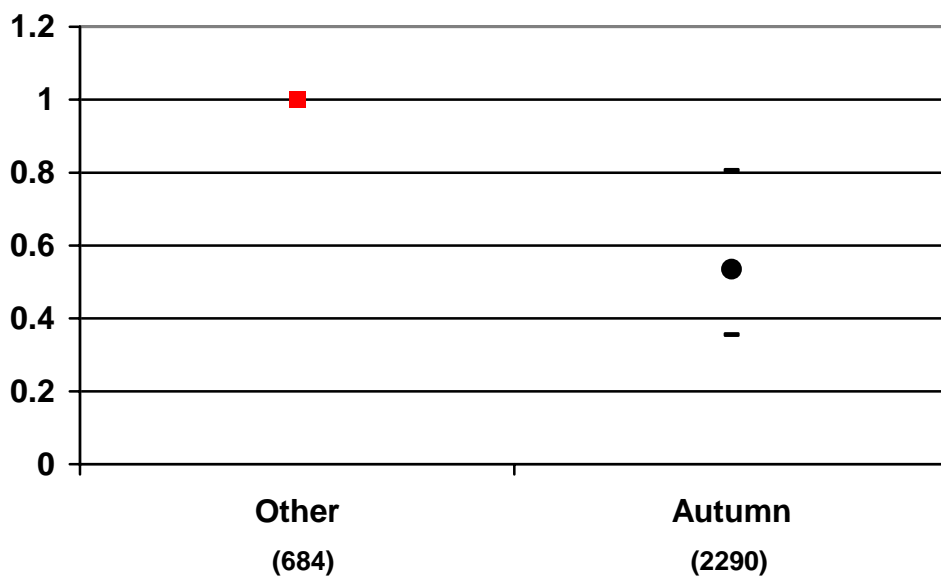
Figure 3.3 Relative effect of fishing year for surface longlining data. The solid dot represents the estimate and dashes represent the 95% credible interval. The first class is the reference class and will therefore have a relative effect of 1.0. The number of observed sets for each category are indicated in parentheses.
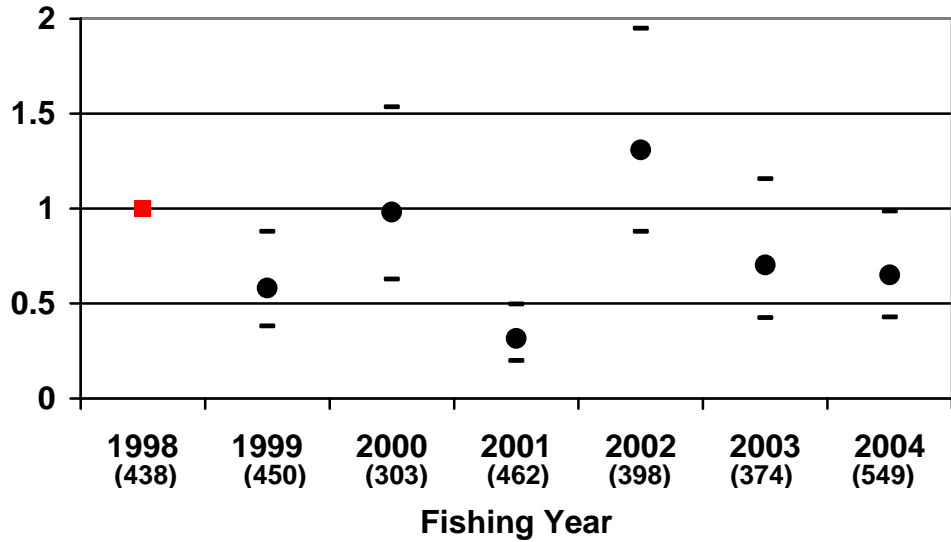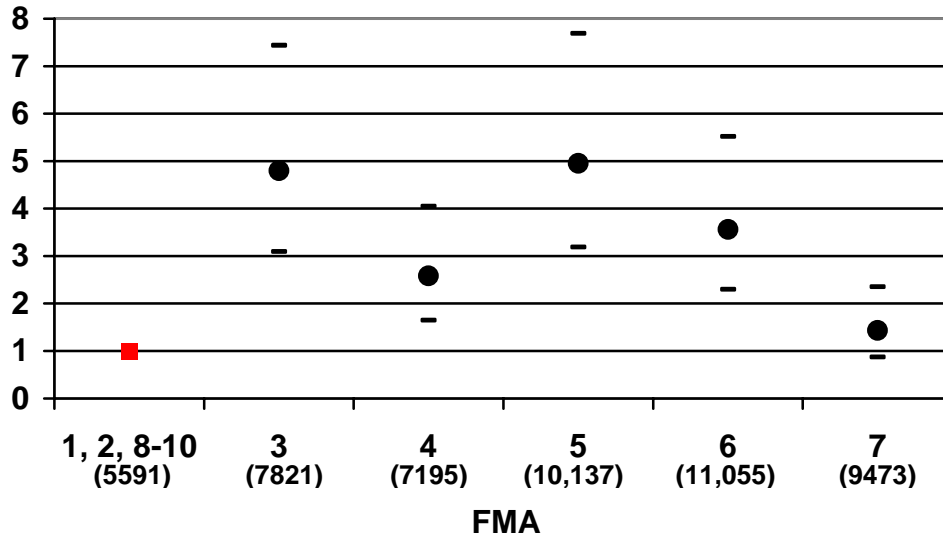


Figure 3.4 Relative effect of fishing area for surface longlining data. The solid dot represents the estimate and dashes represent the 95% credible interval. The first class is the reference class and will therefore have a relative effect of 1.0. The number of observed sets for each category are indicated in parentheses.
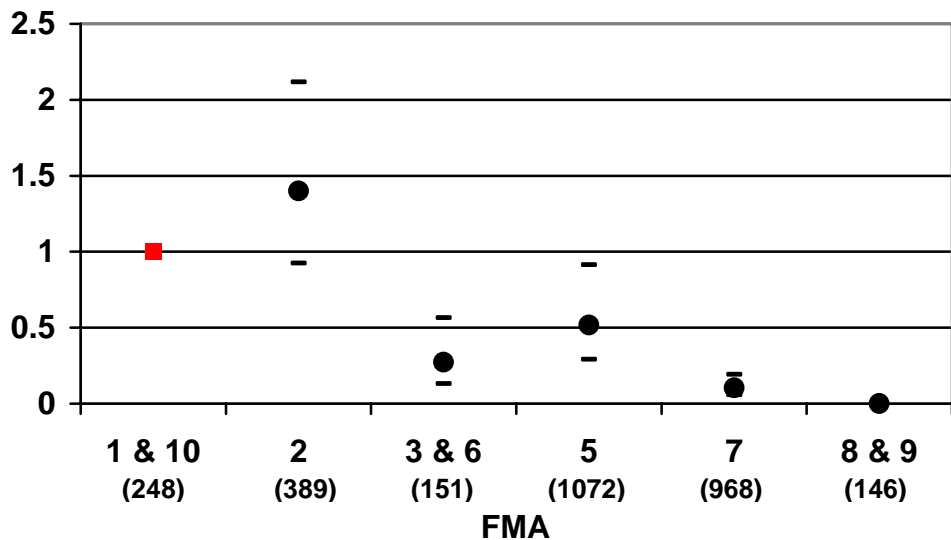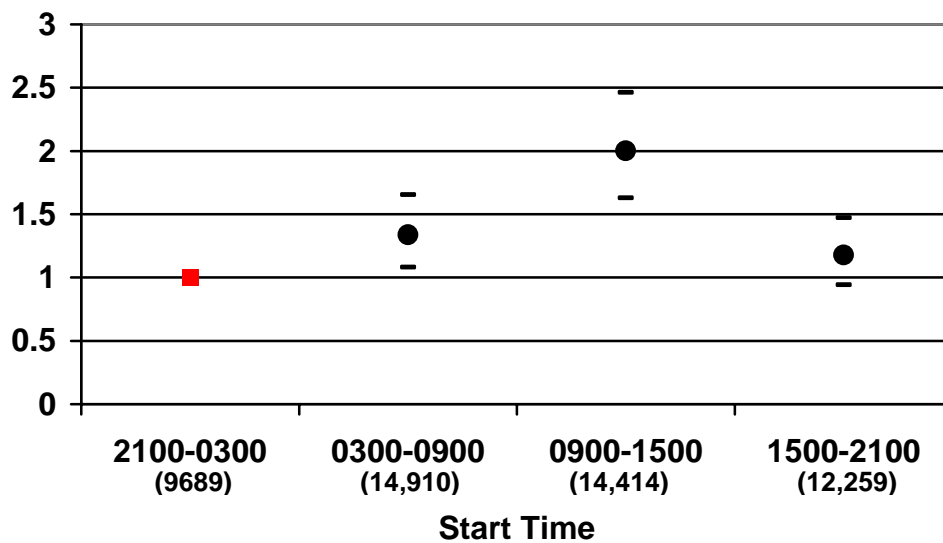
Figure 3.5  Relative effect of fishing time for surface longlining data. The solid dot represents the estimate and dashes represent the 95% credible interval. The first class is the reference class and will therefore have a relative effect of 1.0. The number of observed sets for each category are indicated in parentheses.
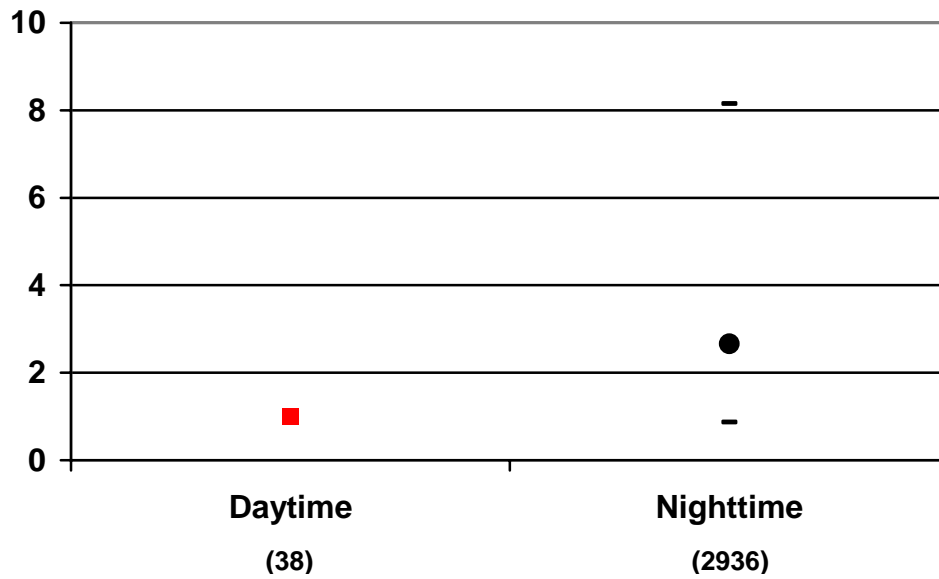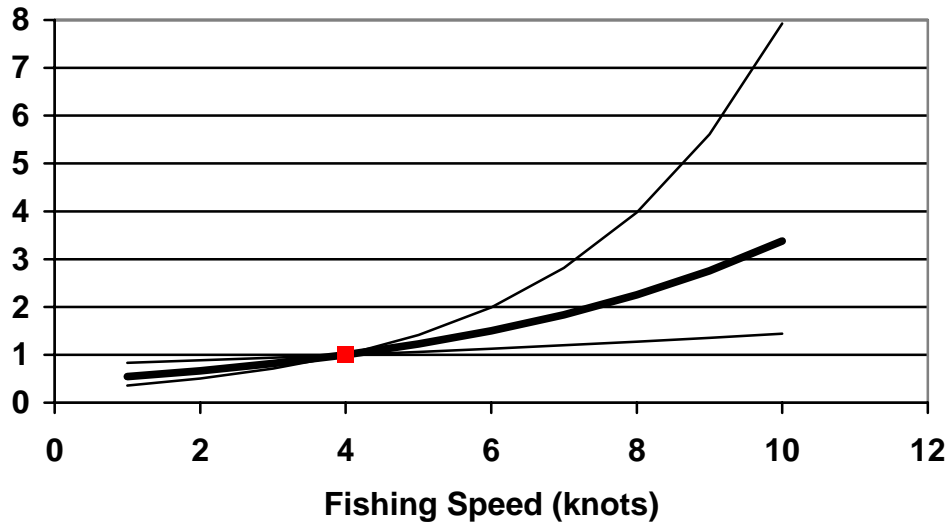
Figure 3.6  Randomised-quantile-residuals versus fitted values, for the modelling of surface longlining data.
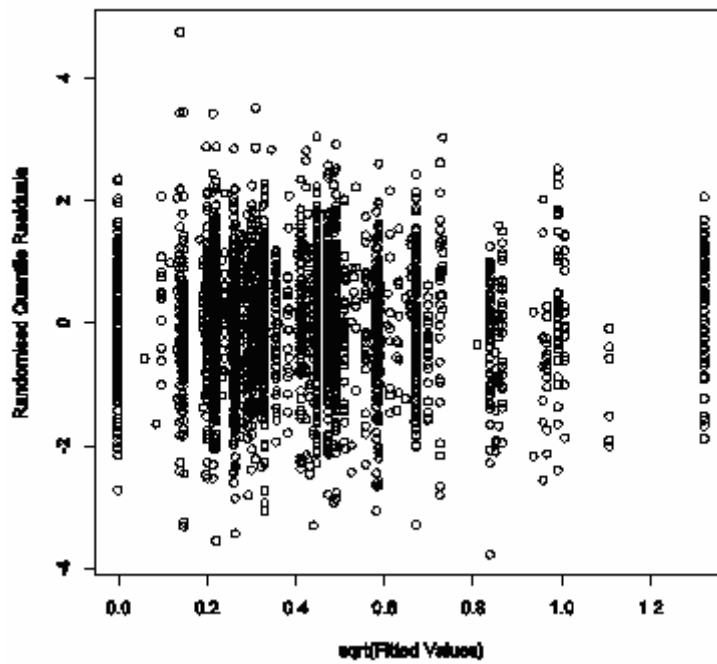


Figure 3.7  Randomised-quantile-residuals Q-Q plot for the modelling of surface longlining data.
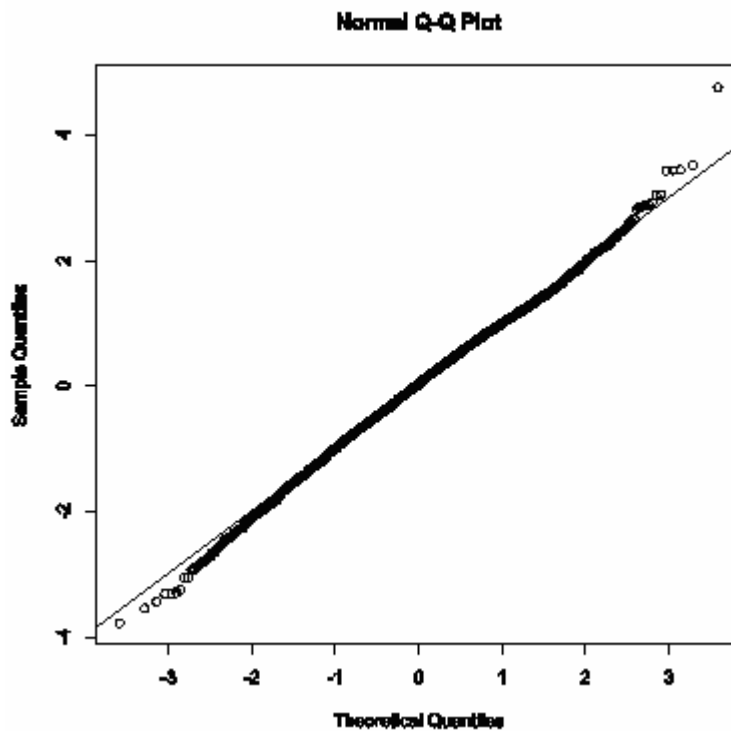
Figure 3.8  Relative effect of season for bottom longlining data. The solid dot represents the estimate and dashes represent the 95% credible interval. The first class is the reference class and will therefore have a relative effect of 1.0. The number of observed sets for each category are indicated in parentheses.
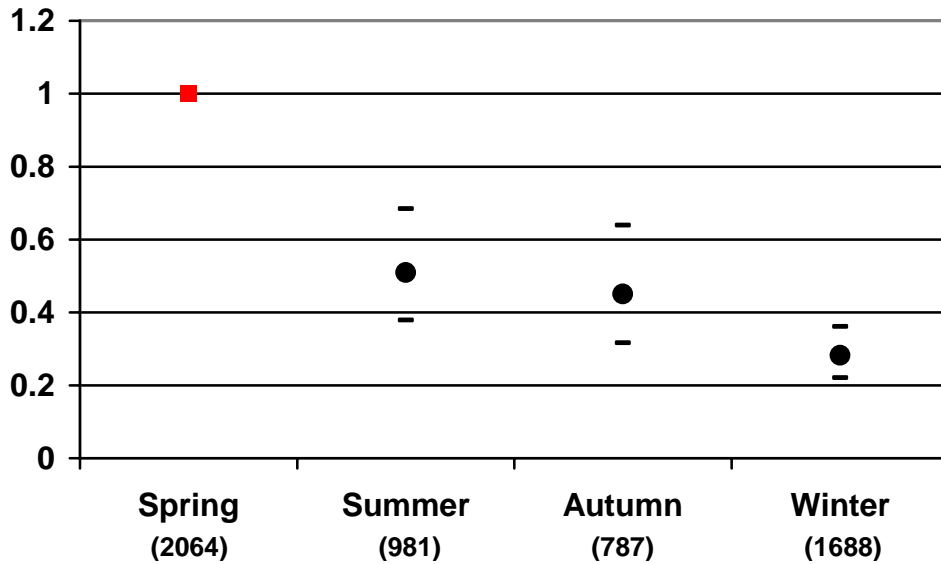


Figure 3.9  Relative effect of fishing year for bottom longlining data. The solid dot represents the estimate and dashes represent the 95% credible interval. The first class is the reference class and will therefore have a relative effect of 1.0. The number of observed sets for each category are indicated in parentheses.
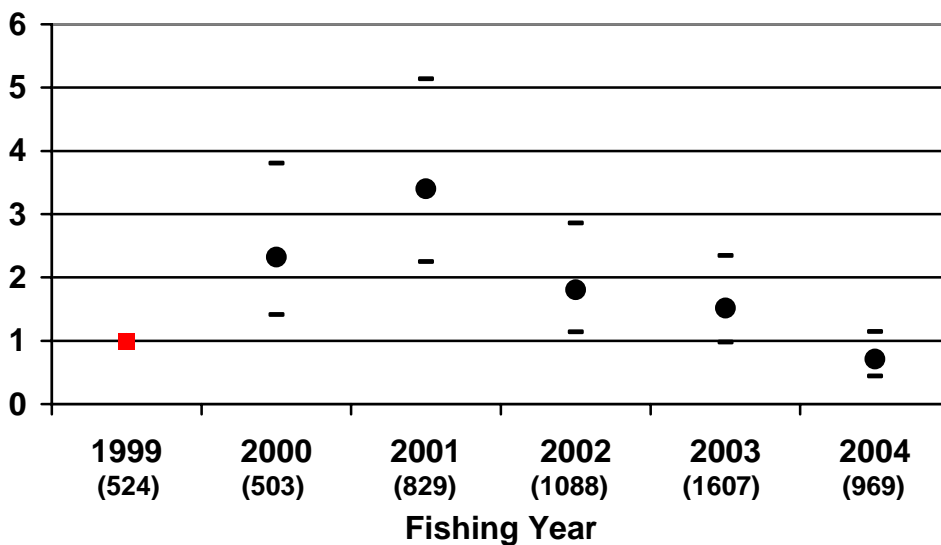
Figure 3.10  Relative effect of target species for bottom longlining data. The solid dot represents the estimate and dashes represent the 95% credible interval. The first class is the reference class and will therefore have a relative effect of 1.0. The number of observed sets for each category are indicated in parentheses.
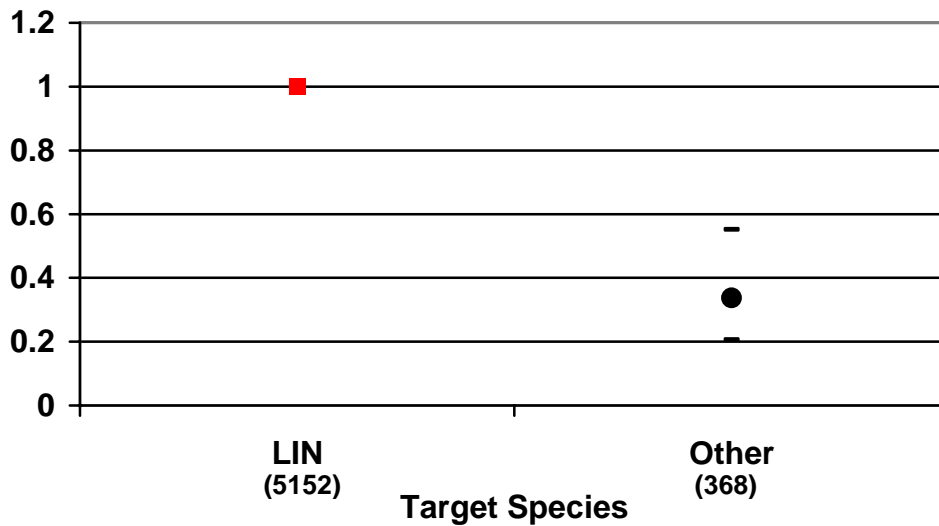


Figure 3.11  Relative effect of start time for bottom longlining data. The solid dot represents the estimate and dashes represent the 95% credible interval. The first class is the reference class and will therefore have a relative effect of 1.0. The number of observed sets for each category are indicated in parentheses.
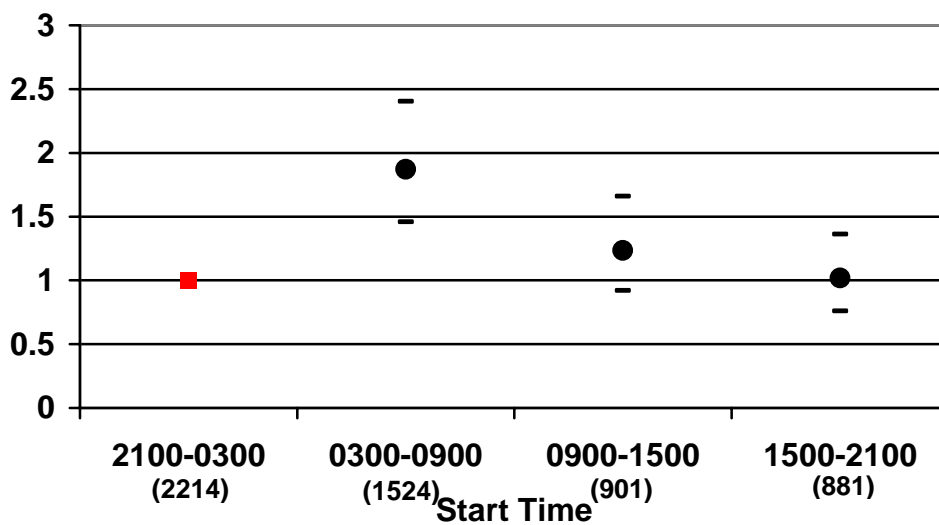
Figure 3.12  Randomised-quantile-residuals versus fitted values, for the modelling of bottom longlining data.
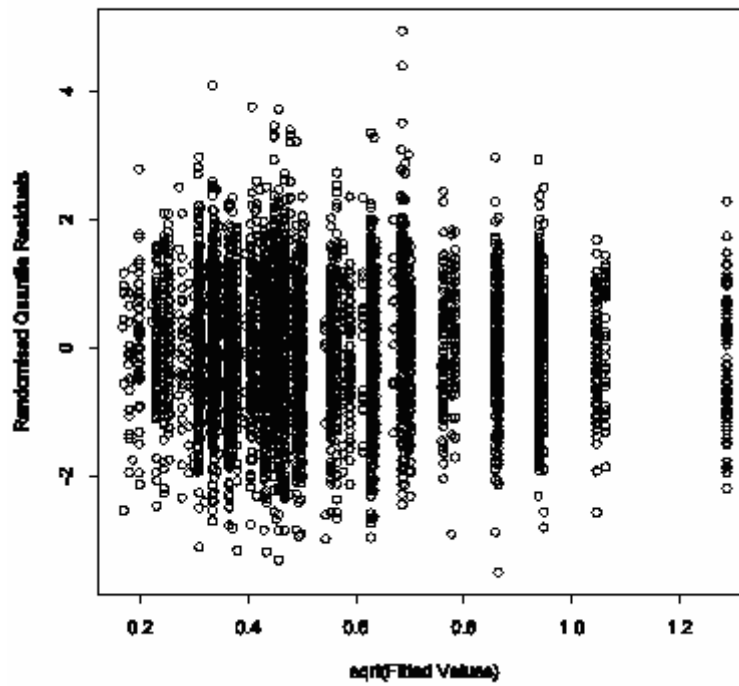


Figure 3.13  Randomised-quantile-residuals Q-Q plot for the modelling of bottom longlining data.
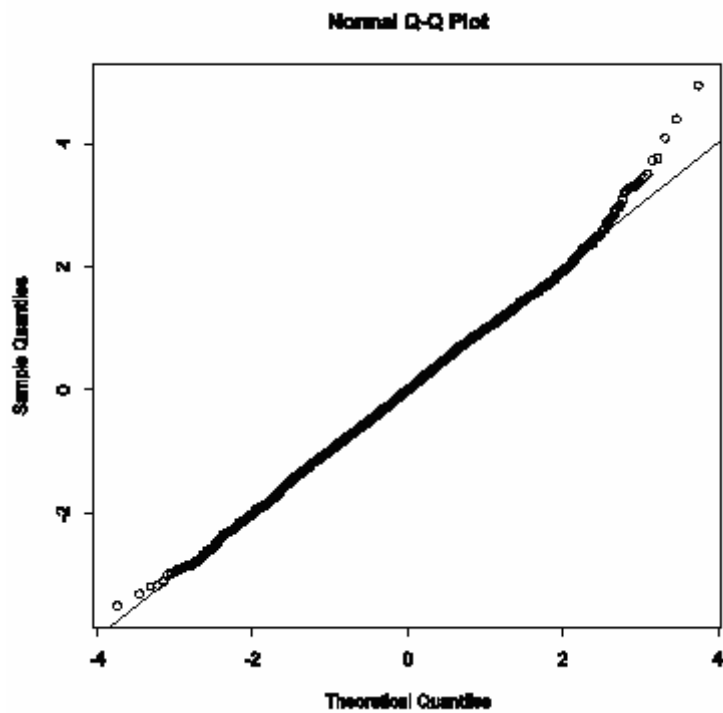
Figure 3.14: Relative effect of season for trawl fisheries data. The solid dot represents the estimate and dashes represent the 95% credible interval. The first class is the reference class and will therefore have a relative effect of 1.0. The number of observed tows for each category are indicated in parentheses.
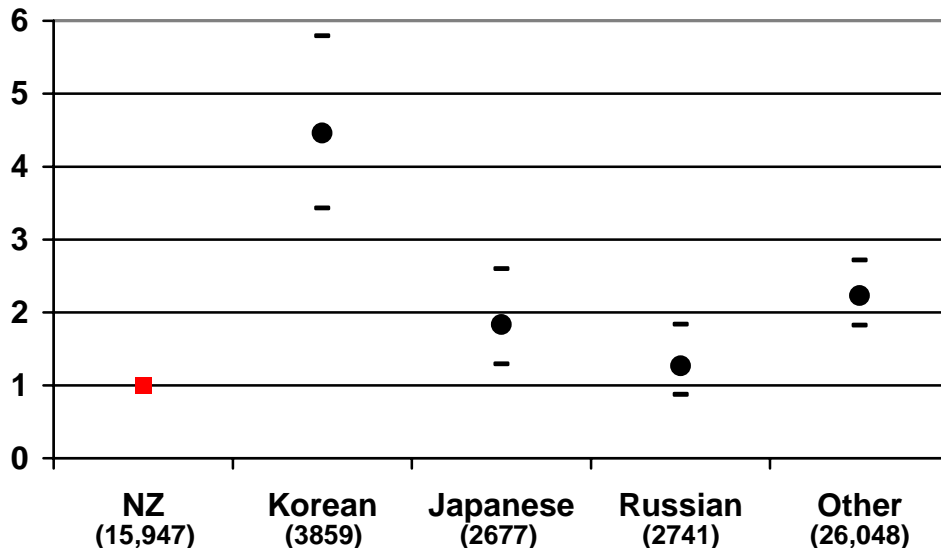


Figure 3.15: Relative effect of season for trawl fisheries data. The solid dot represents the estimate and dashes represent the 95% credible interval. The first class is the reference class and will therefore have a relative effect of 1.0. The number of observed tows for each category are indicated in parentheses.
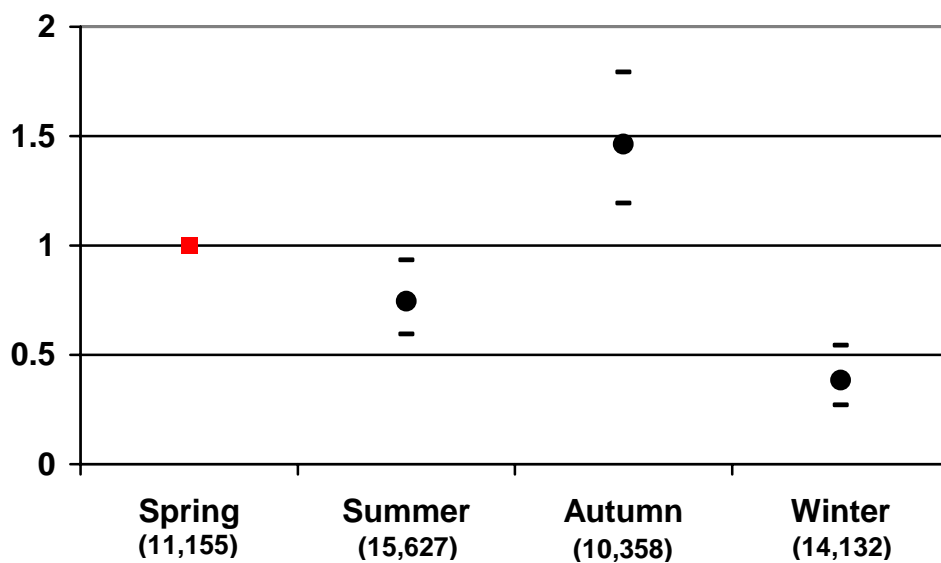
Figure 3.16: Relative effect of fishing year for trawl fisheries data. The solid dot represents the estimate and dashes represent the 95% credible interval. The first class is the reference class and will therefore have a relative effect of 1.0. The number of observed tows for each category are indicated in parentheses.
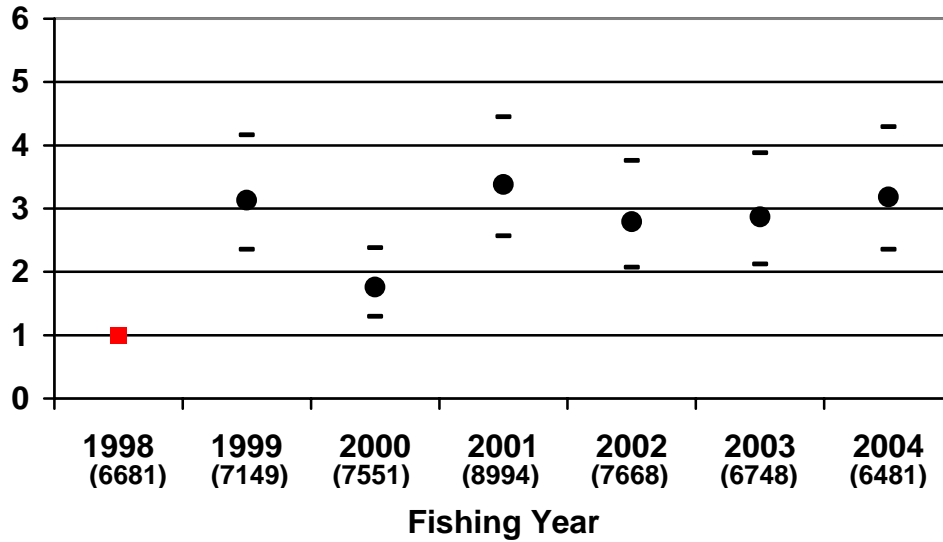


Figure 3.17: Relative effect of target species for trawl fisheries data. The solid dot represents the estimate and dashes represent the 95% credible interval. The first class is the reference class and will therefore have a relative effect of 1.0. The number of observed tows for each category are indicated in parentheses.



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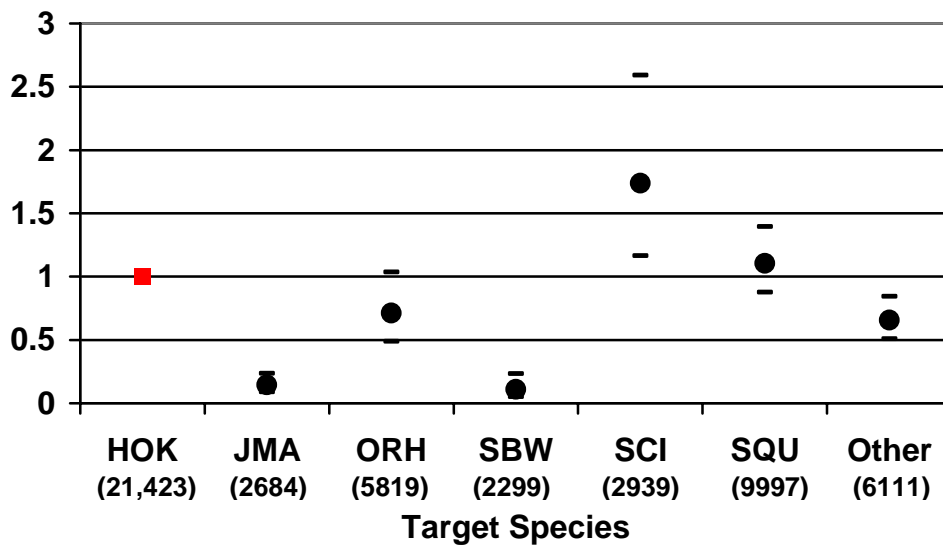
Figure 3.18: Relative effect of trawl type for trawl fisheries data. The solid dot represents the estimate and dashes represent the 95% credible interval. The first class is the reference class and will therefore have a relative effect of 1.0. The number of observed tows for each category are indicated in parentheses.



Figure 3.19: Relative effect of fishing on marks for trawl fisheries data. The solid dot represents the estimate and dashes represent the 95% credible interval. The first class is the reference class and will therefore have a relative effect of 1.0. The number of observed tows for each category are indicated in parentheses.

Figure 3.20: Relative effect of fishing area for trawl fisheries data. The solid dot represents the estimate and dashes represent the 95% credible interval. The first class is the reference class and will therefore have a relative effect of 1.0. The number of observed tows for each category are indicated in parentheses.



Figure 3.21: Relative effect of start time for trawl fisheries data. The solid dot represents the estimate and dashes represent the 95% credible interval. The first class is the reference class and will therefore have a relative effect of 1.0. The number of observed tows for each category are indicated in parentheses.

Figure 3.22: Relative effect of fishing speed for trawl fisheries data. The thick line represents the estimate and the thin lines the 95% credible interval. Fishing speed was standardised about the speed of 4 knots, hence the relative effect of a vessel fishing at 4 knots is 1.0. 95% of the 51,272 observed tows had recorded fishing speeds between 2.5 and 5.3 knots.

Figure 3.23  Randomised-quantile-residuals versus fitted values, for the modelling of trawl fisheries data
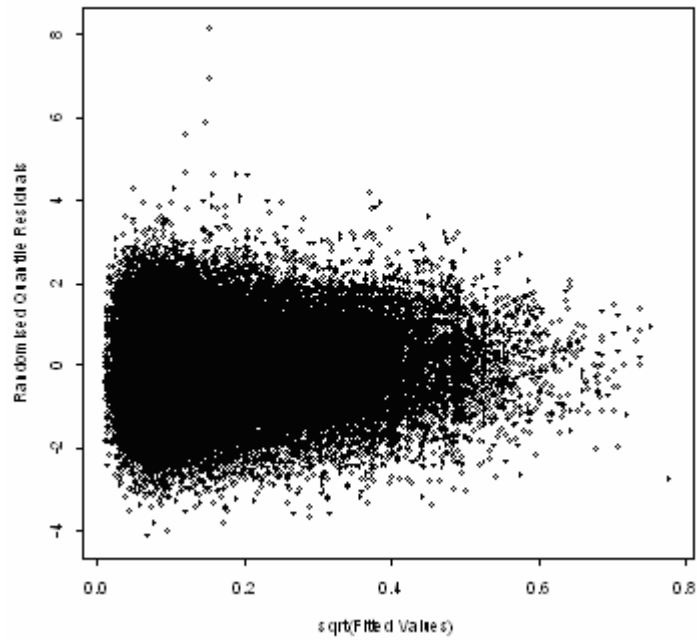


Figure 3.24 Randomised-quantile-residuals Q-Q plot for the modelling of trawl fisheries data.
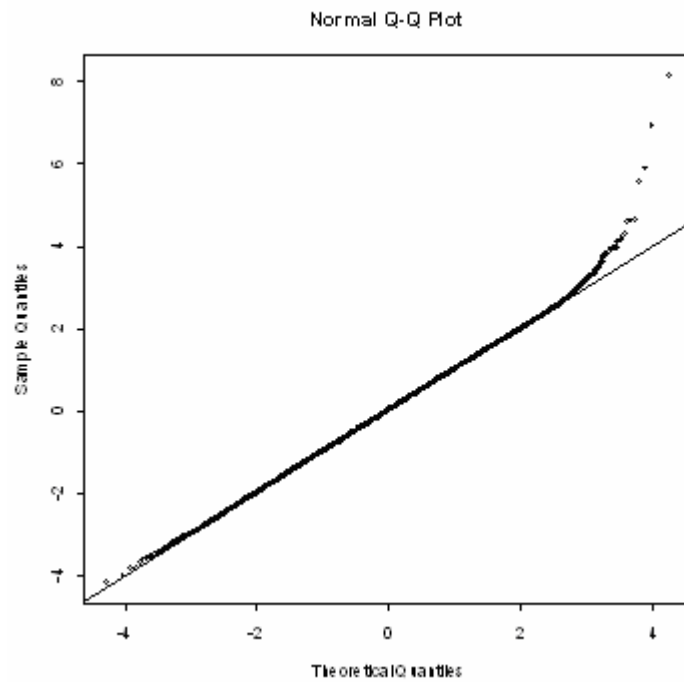
Figure 4.1 Graphical summary of results from Table 4.1, showing the estimated seabird bycatch (number of birds) in trawl fisheries during 2004, together with 95% credible intervals.
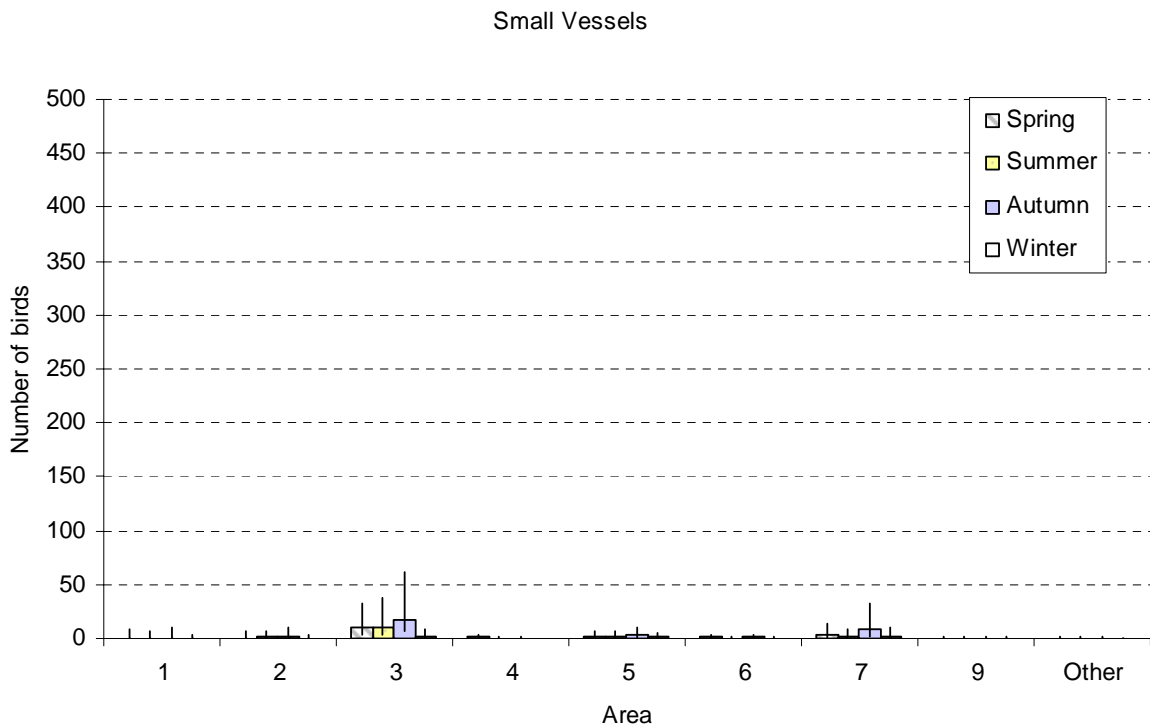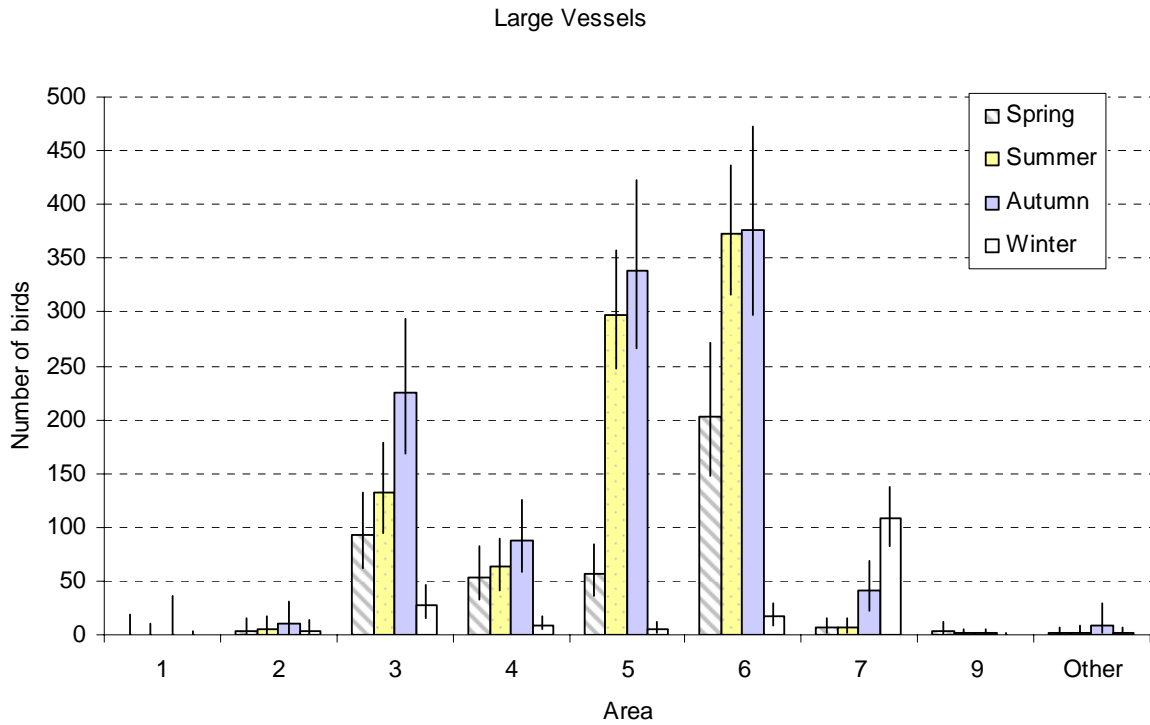
Figure 4.2 Graphical summary of results from Table 4.1, showing the estimated seabird bycatch (number of birds) in surface longline fisheries during 2004, together with 95% credible intervals.
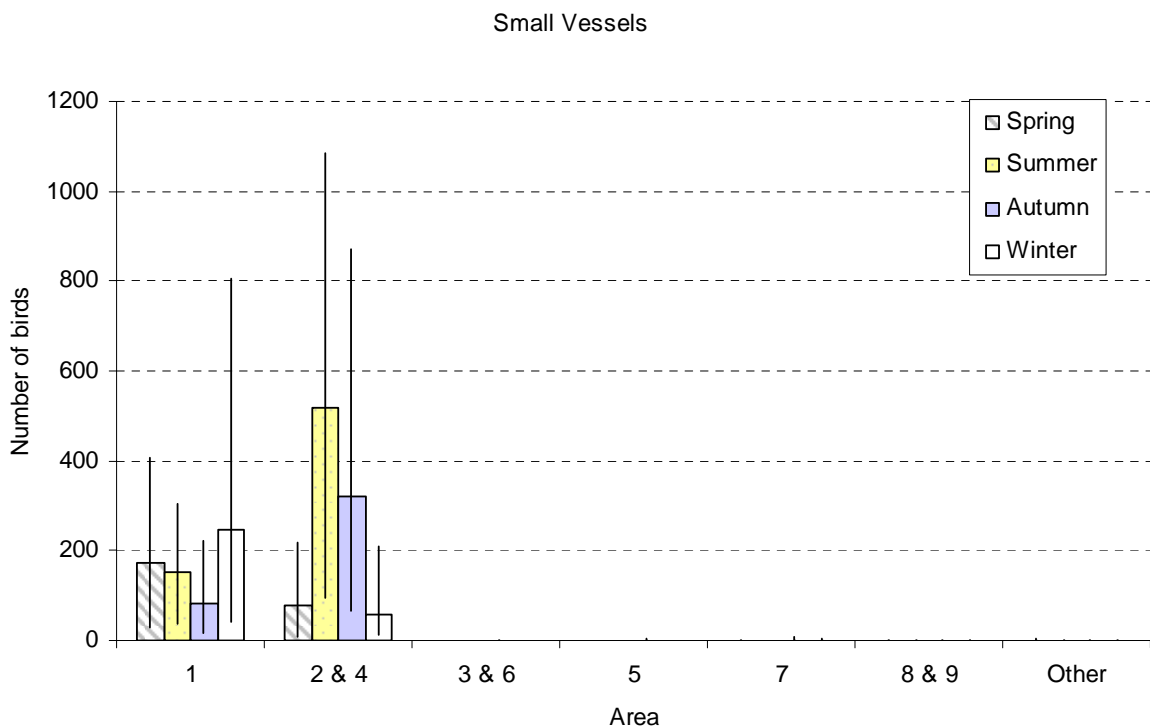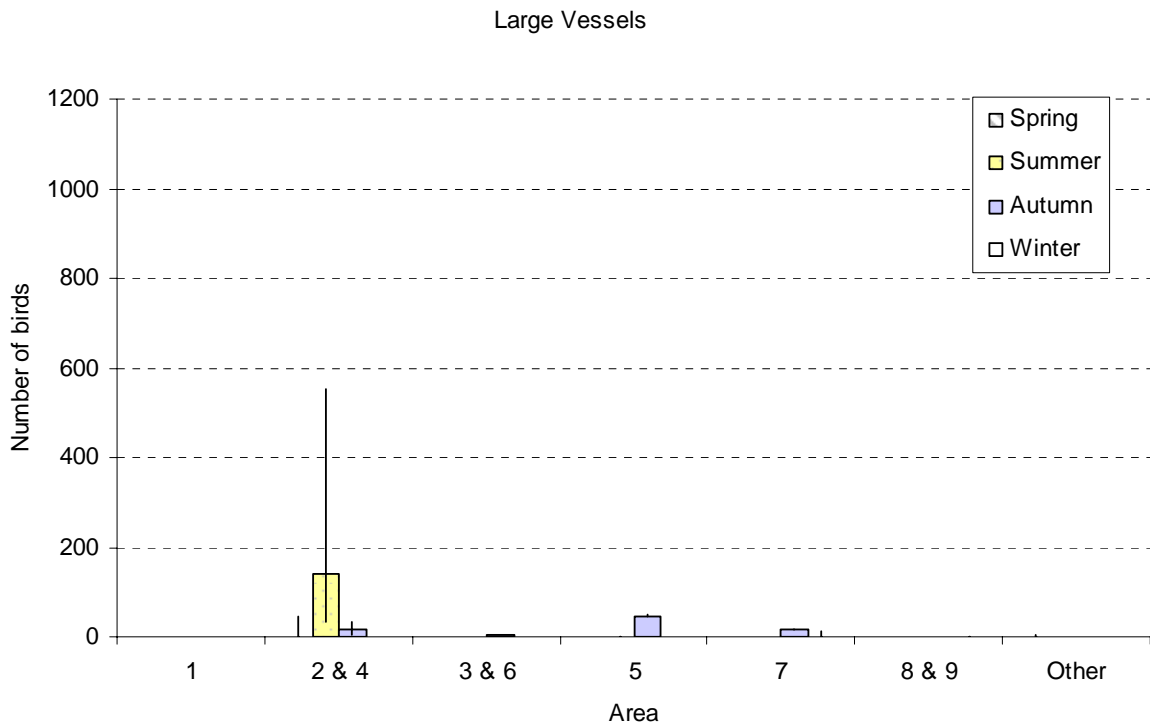
Figure 4.3 Graphical summary of results from Table 4.1, showing the estimated seabird bycatch (number of birds) in bottom longline fisheries during 2004, together with 95% credible intervals.
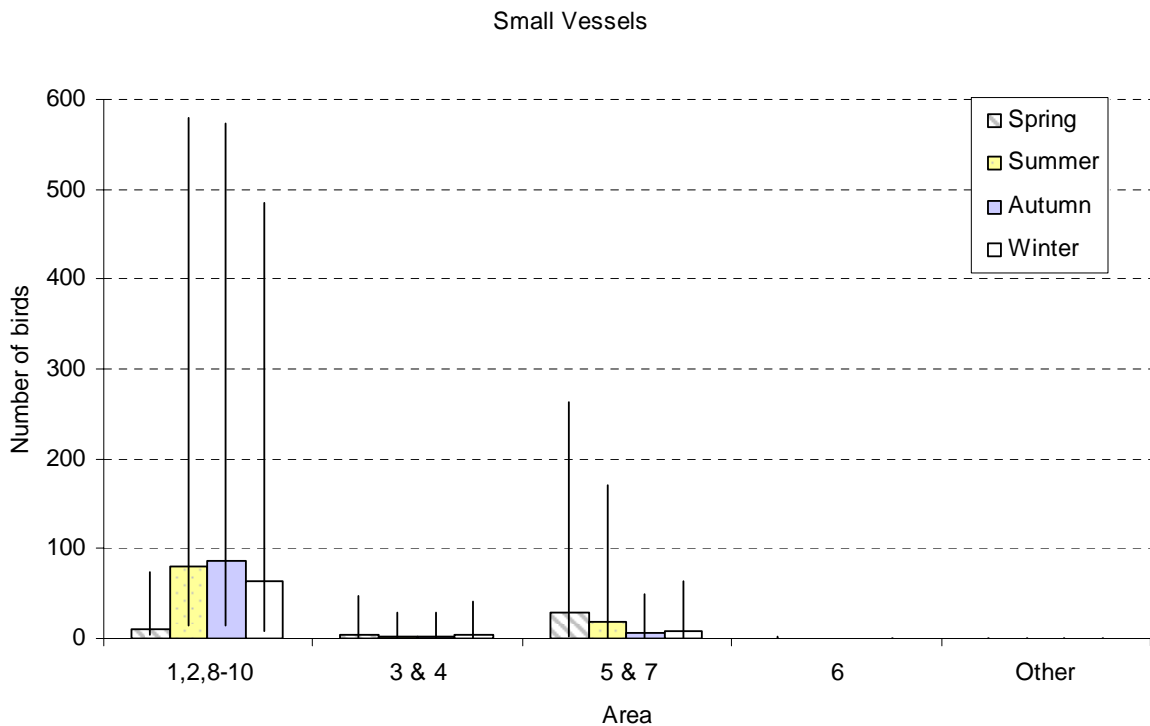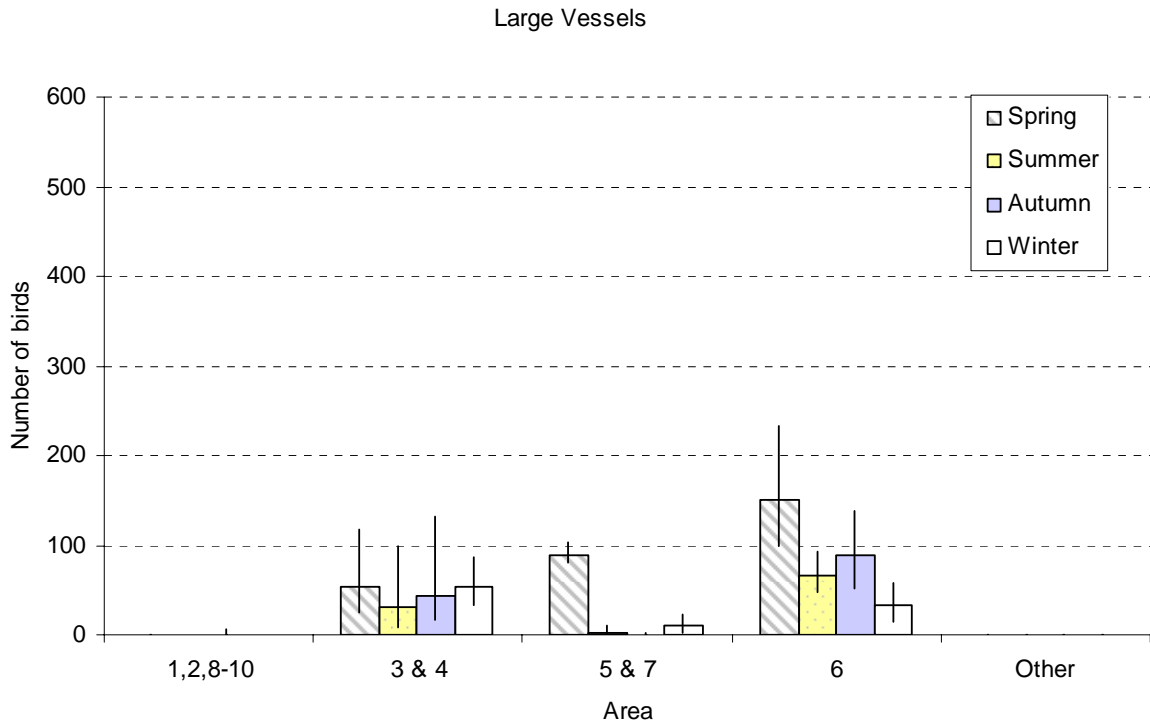
Figure 4.4 Graphical summary of results from Table 4.2, showing the estimated albatross bycatch (number of birds) in trawl fisheries during 2004, together with 95% credible intervals.
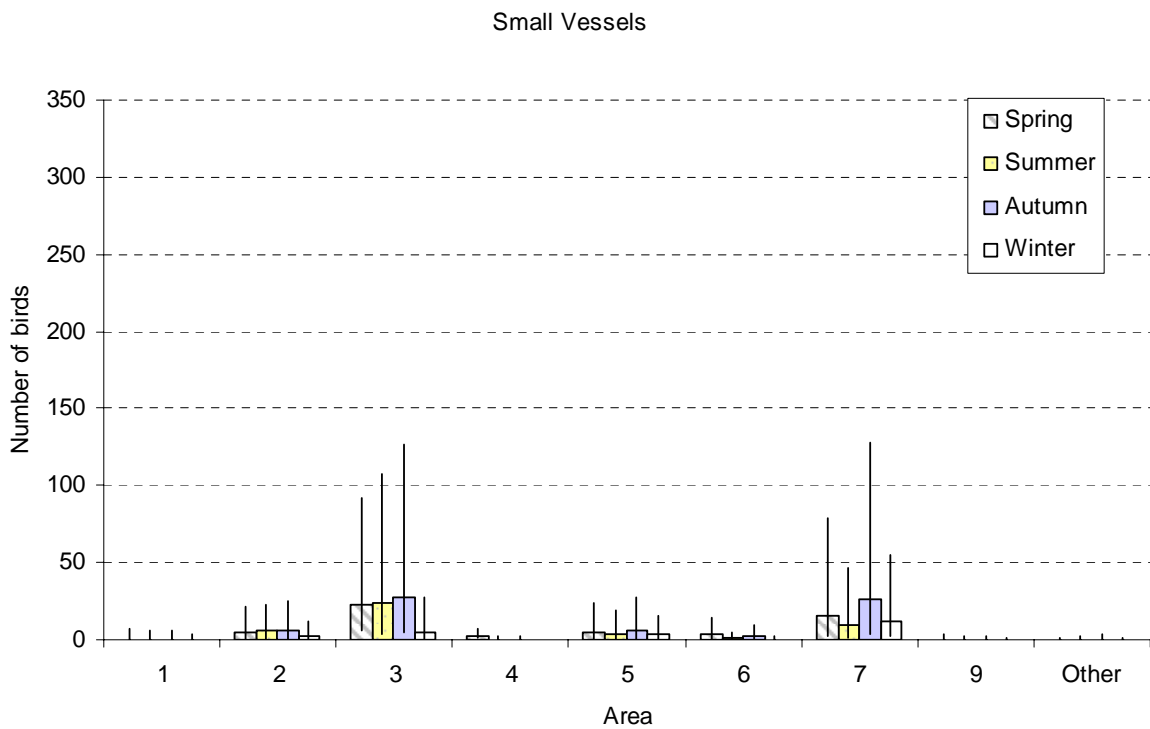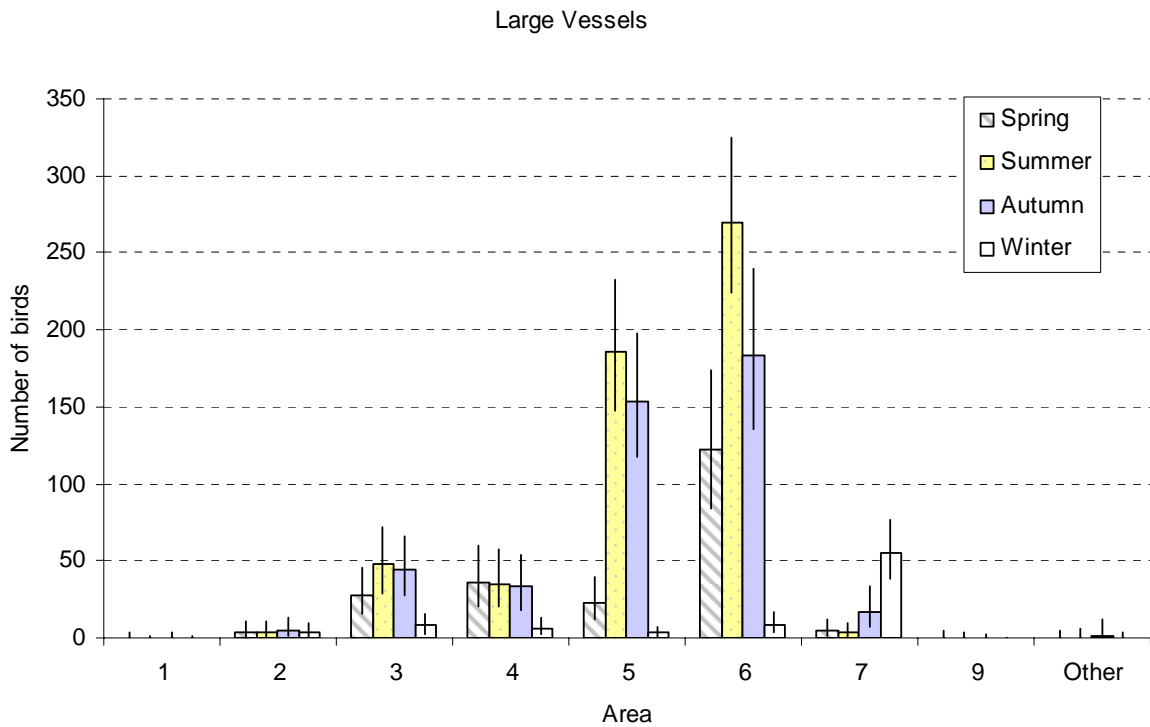
**Appendix A: Data request (Objectives 1&2)**

Below is a copy of the original data request to the Ministry of Fisheries. Full documentation of the data used with the analysis will be supplied in the final report as per the data management requirements of this project.

**Data request for ENV 2004/04 by Proteus Wildlife Research Consultants**
**Contact Person at PWRC: Darryl MacKenzie, darryl@proteus.co.nz, 03 486 1168.**

*Purpose of data required*: Data is required to estimate capture rates and total number of seabirds bycaught in New Zealand fisheries. Information is therefore required on the number of seabirds bycaught per observed tow/set and total number of tows/sets in each fishery. Information that could be used to characterise each tow/set is also required, where available, (e.g., time, location, tow configuration, sea conditions, target species, etc.), as is vessel information (e.g., vessel type, size, nationality, type, skipper nationality).

*Timeframe of data required*: All data is required for the period 1 October 1997 – 30 September 2004.

*Seabird bycatch data for trawl and bottom long-line fisheries*: We have been advised that the relevant data is held in the *obs* and *obs_lfs* databases. Please inform us if there is any additional data held in other databases, particularly if there are additional sources of information that could be used to investigate factors that may impact upon bycatch rates. We require a dataset with one entry for each observed tow/set that includes information on trip, vessel, target species, gear configuration, environmental conditions and number of seabirds caught on that tow/set (in total and also by bird species). From our reading of the available database documentations, it would appear the information we require should be obtainable by linking the tables *obs>new_observer_trip* and *obs>new_observer_station*. To this new table, the necessary vessel information needs to be added (vessel type, length, tonnage, engine power, breadth, draught, nationality, chartered/domestic, onboard meal plant and skipper nationality). Finally, the number of seabirds caught per tow/set needs to be added using the information from *obs_lfs>t_nonfish_catch*. The information from *obs_lfs>t_nonfish_catch* needs to summarised at a per tow/set level to provide the number of birds caught categorized by *alive* status and *species_obs* (i.e., separate columns for each species [as identified by observers] further separated into the number of alive, dead, killed and decomposing birds). Note this final table will include tow/sets with no seabird bycatch.

*Seabird bycatch data for surface long-line fisheries*: A similar table to above is required for surface long-lining fisheries. As we understand it, all of the relevant information (except for vessel information) can be obtained from the *l_line* database. We request a table that has one entry for each set including all fields in the table *t_line_set*. This table needs to be linked with relevant vessel (see fields specified above for trawl and bottom long-lining), trip (*t_trip*) and baiting strategies used (*t_bait*) for each set. The number of seabirds caught on each set categorized by species and life condition (as above) is required (from *t_ctch_spec*). This final table should also have records with no seabird bycatch.

*Catch/effort data for all fisheries*: From the information above it will be possible to calculate capture rates of seabirds per observed tow/set. In order to estimate the total number of seabirds caught, information is required about all tows/sets conducted within each fishery. To avoid double counting of seabird bycatch it is necessary to be able to match, as closely as

possible, which tows/sets were observed (hence have supplied data above) and which were unobserved. From the database documentation it appears the much of the relevant information can be obtained from the table *t_fishing_events* in the *fish_ce* database. To this table, we request that information on skipper nationality and whether the tow/set was observed be added.

*Other comments*: We have been advised that time fields may be recorded as either NZST or NZDT in different databases. Please ensure all time fields are given in NZST. Also please ensure that all latitude and longitude positions are given in decimal format, to 1-tenth of a degree accuracy.

**Appendix B: Details of Modelling for Albatross Bycatch in Trawl Fisheries (Objectives 1&2)**

The levels associated with the factors fishing area and target species used here were:

| Factor | Level | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Fishing Area | FMA 1 | FMA 2 | FMA 3 | FMA 4 | FMA 5 | FMA 6 | FMA 7 | FMA 9 | Other |
| Target Species | HOK | JMA | ORH | SBW | SCI | SQU | Other | | |

Below, the posterior distributions for the estimated parameters are summarised, where a 'l' prefacing the parameter name indicates that parameters that are associated with the estimation of $\lambda$ rather than $p$. 'Lower' and 'Upper' and the lower an upper limits of the central 95% credible interval. The prior distribution for all parameters was normal with mean=0.0 and variance =100.0 (standard deviation = 10.0).

| Parameter | Mean | SD | Lower | Median | Upper |
|---|---|---|---|---|---|
| alpha | -4.52 | 0.75 | -5.82 | -4.56 | -2.81 |
| Yr[2] | 0.31 | 0.38 | -0.46 | 0.32 | 1.02 |
| Yr[3] | 0.36 | 0.39 | -0.39 | 0.37 | 1.10 |
| Yr[4] | 1.15 | 0.37 | 0.43 | 1.16 | 1.85 |
| Yr[5] | 0.85 | 0.38 | 0.11 | 0.86 | 1.58 |
| Yr[6] | 1.26 | 0.46 | 0.42 | 1.23 | 2.21 |
| Yr[7] | 1.56 | 0.41 | 0.79 | 1.57 | 2.34 |
| FA[1] | -4.97 | 1.74 | -8.37 | -4.94 | -1.62 |
| FA[2] | 0.86 | 1.82 | -1.68 | 0.72 | 3.97 |
| FA[3] | 0.37 | 0.65 | -1.08 | 0.40 | 1.48 |
| FA[4] | -0.31 | 0.64 | -1.72 | -0.26 | 0.79 |
| FA[5] | 0.85 | 0.65 | -0.61 | 0.89 | 1.94 |
| FA[6] | 1.17 | 0.68 | -0.37 | 1.19 | 2.37 |
| FA[8] | -4.97 | 1.74 | -8.37 | -4.94 | -1.62 |
| FA[9] | -4.97 | 1.74 | -8.37 | -4.94 | -1.62 |
| S[2] | 0.43 | 0.35 | -0.31 | 0.45 | 1.07 |
| S[3] | 0.46 | 0.33 | -0.26 | 0.48 | 1.05 |
| S[4] | 0.14 | 0.67 | -1.22 | 0.15 | 1.40 |
| Class | 1.57 | 0.85 | 0.13 | 1.48 | 3.43 |
| lalpha | -0.88 | 0.68 | -2.40 | -0.83 | 0.22 |
| lYr[2] | 0.86 | 0.38 | 0.16 | 0.86 | 1.62 |
| lYr[3] | 0.51 | 0.38 | -0.20 | 0.50 | 1.29 |
| lYr[4] | -0.05 | 0.37 | -0.76 | -0.05 | 0.66 |
| lYr[5] | 0.33 | 0.38 | -0.39 | 0.33 | 1.08 |
| lYr[6] | -0.24 | 0.45 | -1.20 | -0.22 | 0.57 |
| lYr[7] | -0.29 | 0.40 | -1.06 | -0.29 | 0.47 |

| lFA[1] | 1.28 | 1.45 | -2.09 | 1.46 | 3.63 |
| lFA[2] | -1.32 | 1.17 | -3.76 | -1.30 | 0.91 |
| lFA[3] | -0.41 | 0.58 | -1.39 | -0.46 | 0.94 |
| lFA[4] | 0.37 | 0.57 | -0.63 | 0.33 | 1.68 |
| lFA[5] | -0.31 | 0.58 | -1.30 | -0.36 | 1.10 |
| lFA[6] | -0.83 | 0.61 | -1.88 | -0.88 | 0.64 |
| lFA[8] | 1.28 | 1.45 | -2.09 | 1.46 | 3.63 |
| lFA[9] | 1.28 | 1.45 | -2.09 | 1.46 | 3.63 |
| lS[2] | -0.33 | 0.33 | -0.96 | -0.33 | 0.35 |
| lS[3] | -0.13 | 0.30 | -0.70 | -0.14 | 0.52 |
| lS[4] | -0.78 | 0.61 | -1.92 | -0.79 | 0.48 |
| lTS[2] | -0.97 | 0.33 | -1.64 | -0.96 | -0.35 |
| lTS[3] | -0.88 | 0.26 | -1.40 | -0.88 | -0.38 |
| lTS[4] | -2.53 | 0.81 | -4.36 | -2.44 | -1.16 |
| lTS[5] | 0.17 | 0.33 | -0.45 | 0.17 | 0.81 |
| lTS[6] | 1.08 | 0.13 | 0.82 | 1.08 | 1.34 |
| lTS[7] | -0.22 | 0.17 | -0.56 | -0.22 | 0.10 |
| lClass | -1.24 | 0.77 | -2.77 | -1.21 | 0.24 |

Following is a series of residual plots where the standardised residuals for the number of observed seabirds bycaught in each combination of fishing year $\times$ fishing area $\times$ season $\times$ target species $\times$ vessel class have been calculated as stated above.

Figure B.1: Residual plot of residuals vs fishing year for albatross bycatch in trawl fisheries. Factor levels have been "jittered" to ease interpretation.
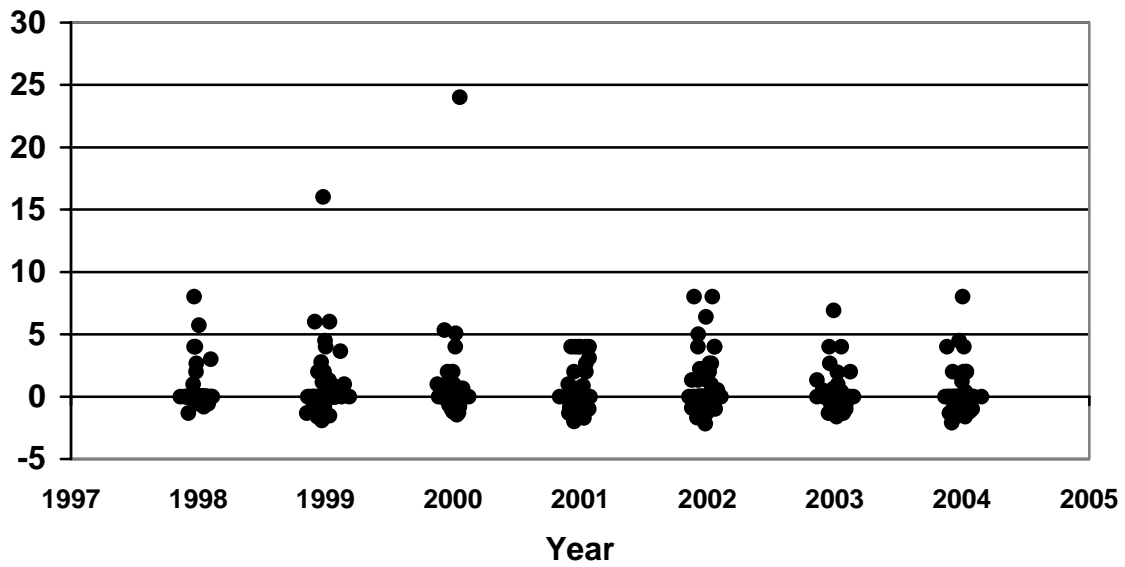


Figure B.2: Residual plot of residuals vs fishing area for albatross bycatch in trawl fisheries. Factor levels have been "jittered" to ease interpretation.
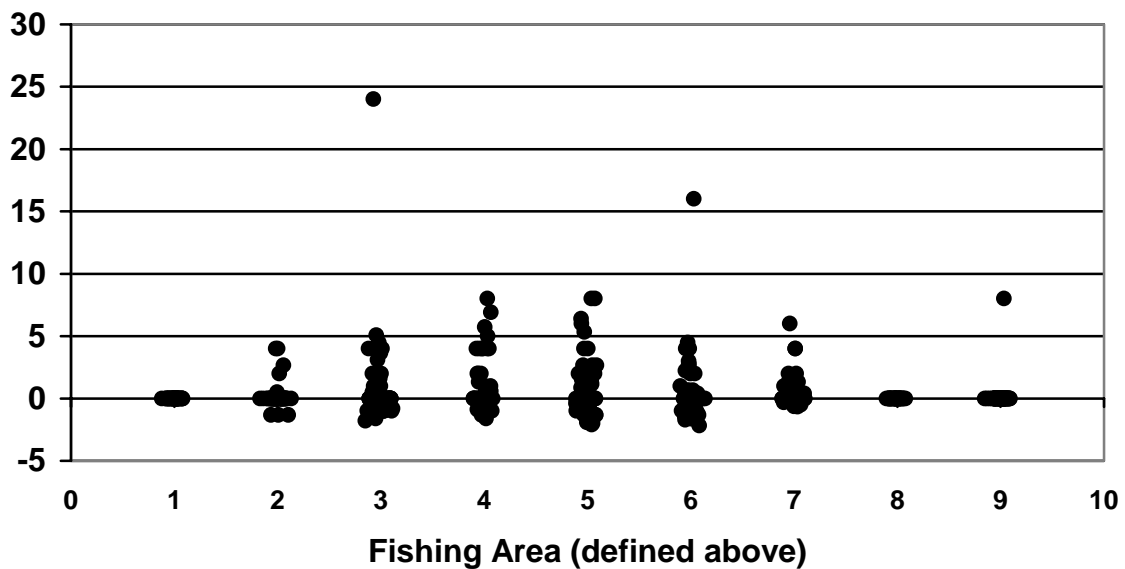
Figure B.3: Residual plot of residuals vs season for albatross bycatch in trawl fisheries. Factor levels have been "jittered" to ease interpretation.



**Season**
**(1 = Spring)**
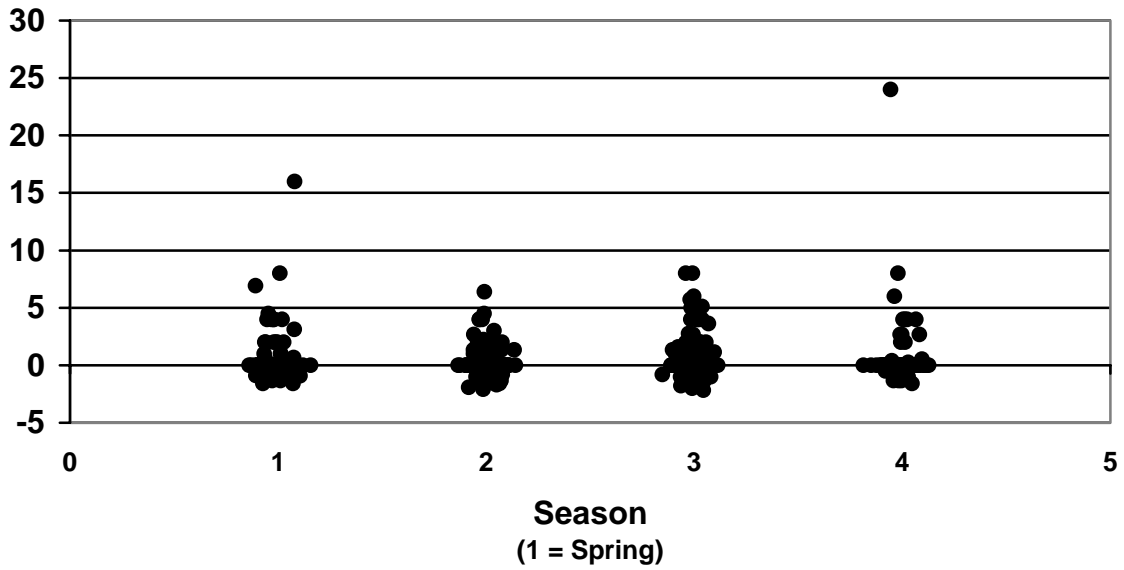
Figure B.4: Residual plot of residuals vs target species for albatross bycatch in trawl fisheries. Factor levels have been "jittered" to ease interpretation.



**Target Species (defined above)**
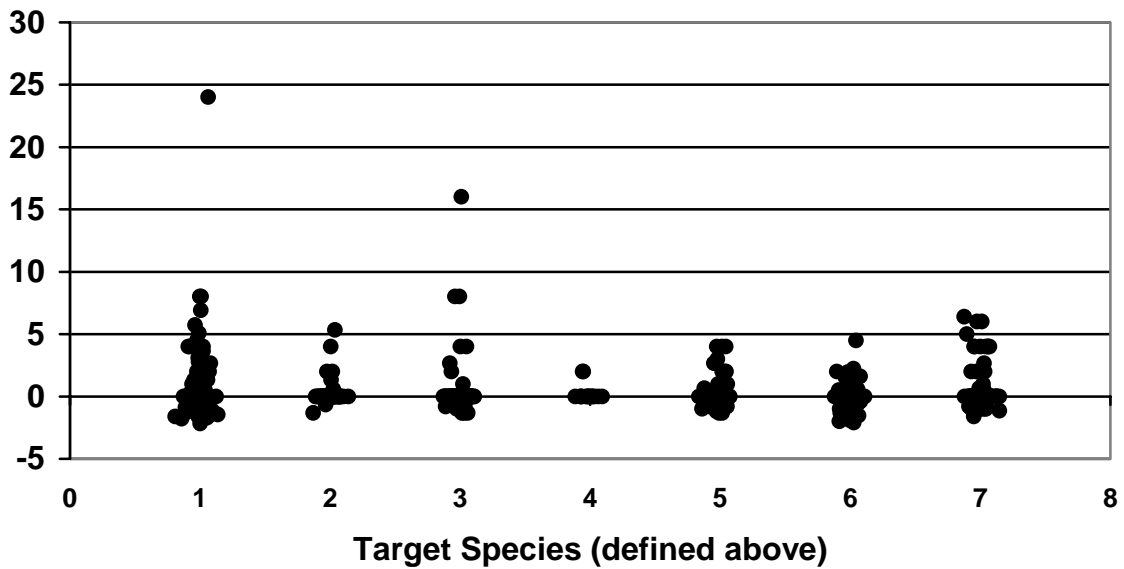
Figure B.5: Residual plot of residuals vs vessel class for albatross bycatch in trawl fisheries. Factor levels have been "jittered" to ease interpretation.



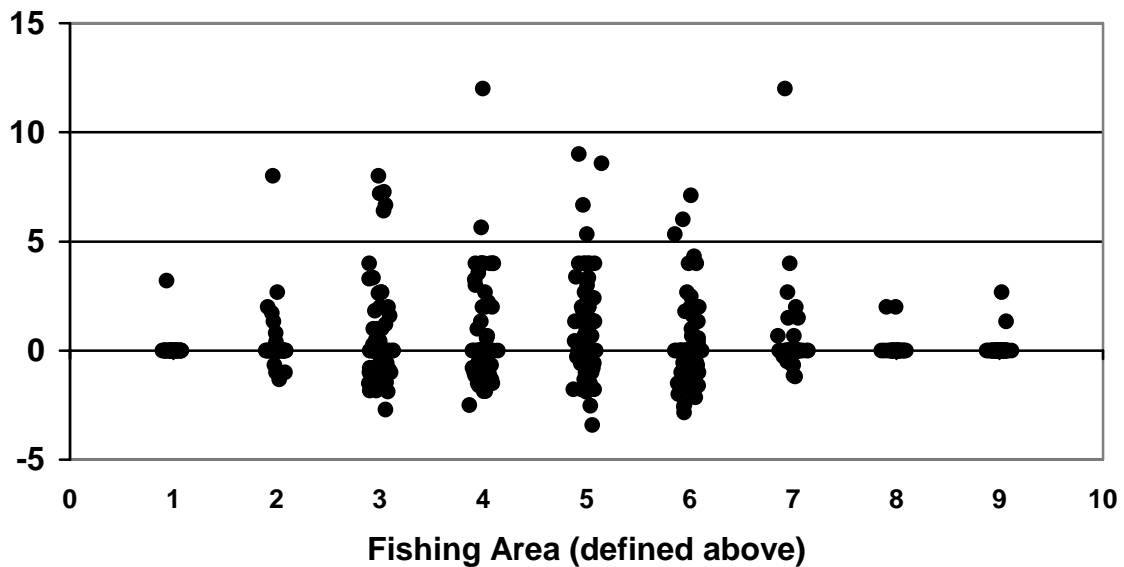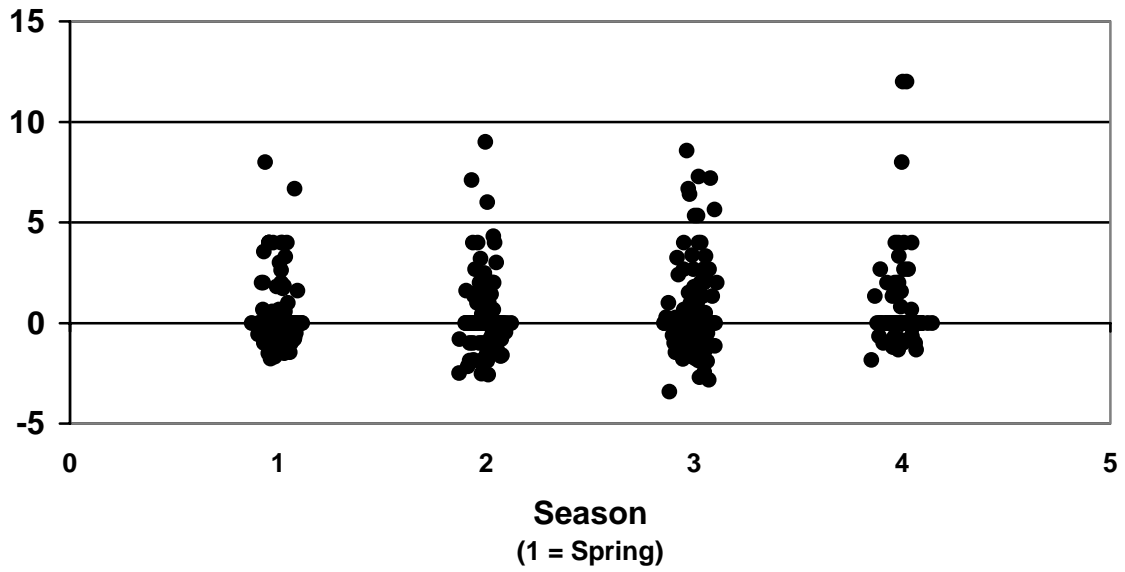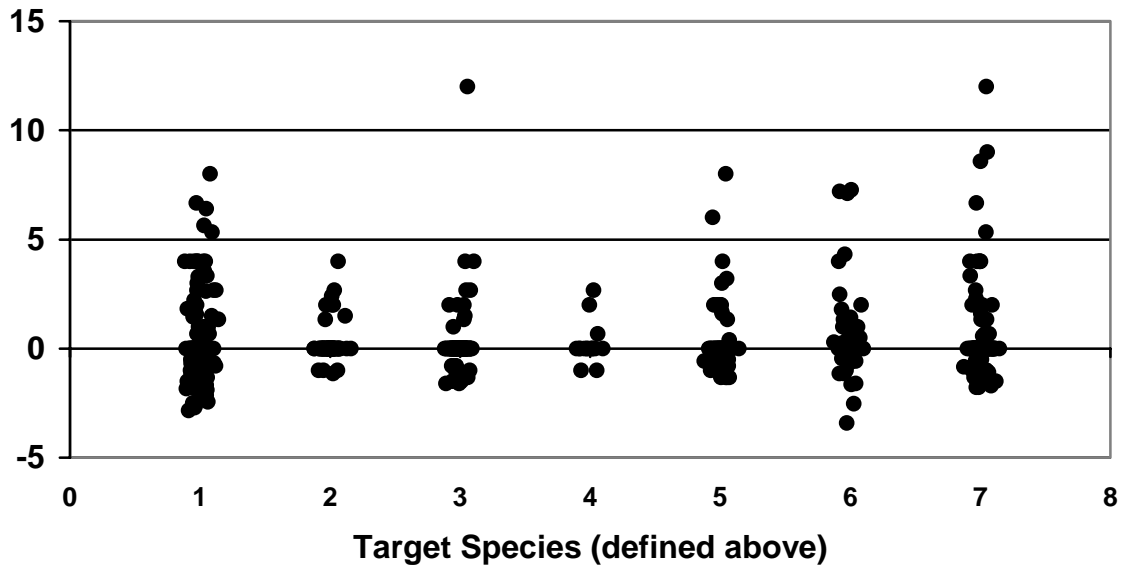**Vessel Class**
**(1 = >28m)**
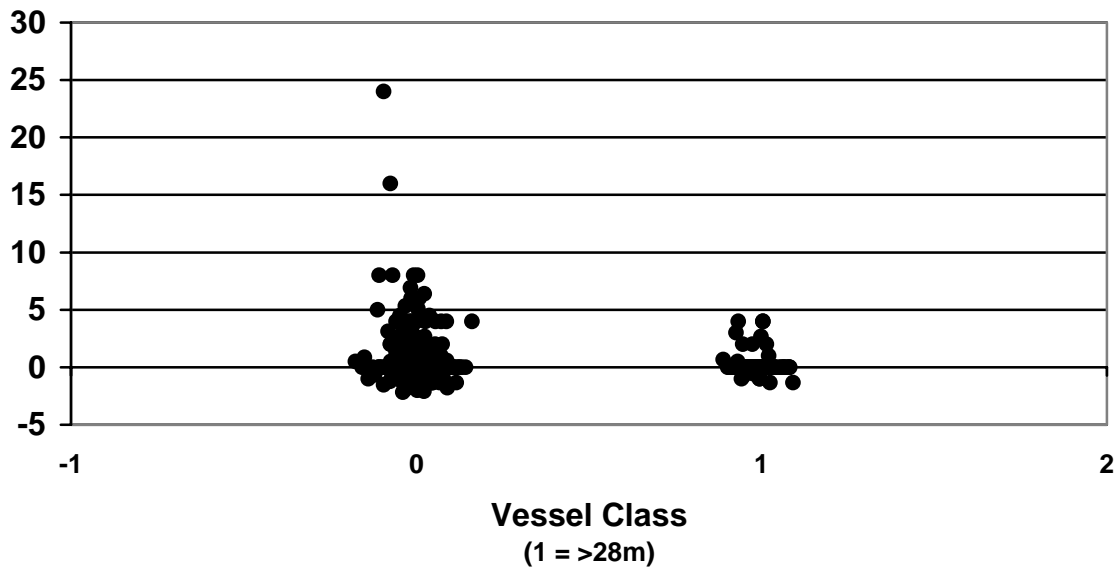
Figure B.6: Residual plot of residuals vs observed bycatch for albatross in trawl fisheries.



**Observed Bycatch**
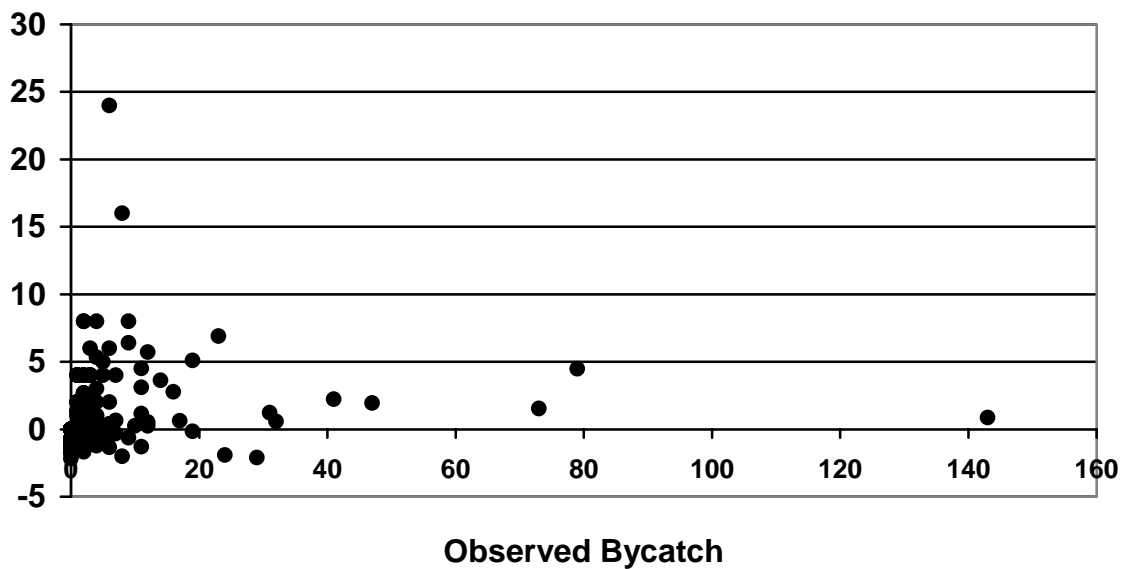
Figure B.7: Residual Q-Q plot for albatross bycatch in trawl fisheries.



**Normal Quantile**
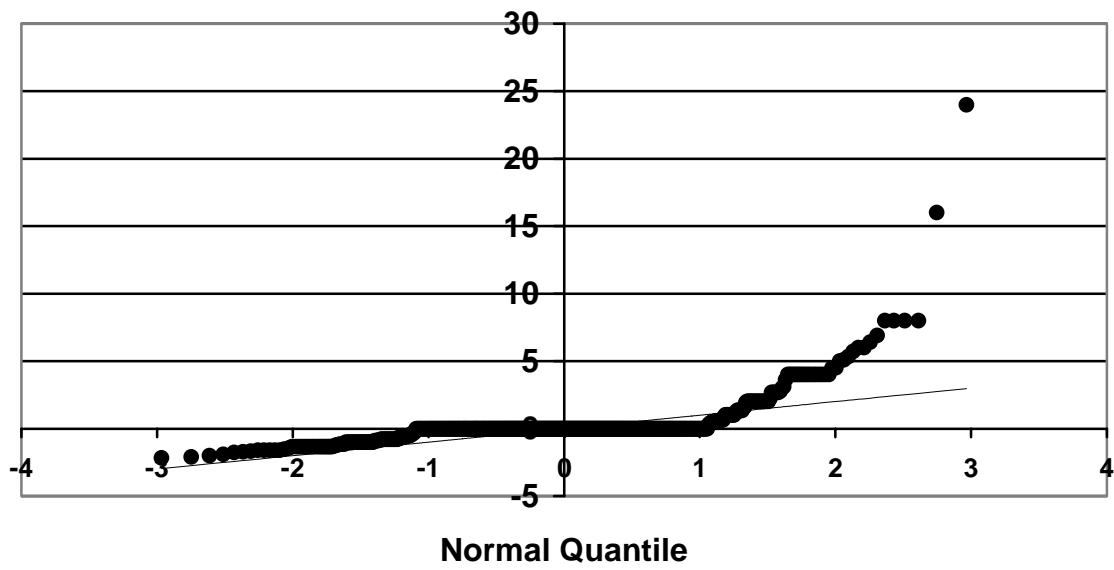
**Appendix C: Details of Modelling for Seabird Bycatch in Trawl Fisheries (Objectives 1&2)**

The levels associated with the factors fishing area and target species used here were:

| Factor | Level | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Fishing Area | FMA 1 | FMA 2 | FMA 3 | FMA 4 | FMA 5 | FMA 6 | FMA 7 | FMA 9 | Other |
| Target Species | HOK | JMA | ORH | SBW | SCI | SQU | Other | | |

Below, the posterior distributions for the estimated parameters are summarised, where a 'l' prefacing the parameter name indicates that parameters that are associated with the estimation of $\lambda$ rather than $p$. 'Lower' and 'Upper' and the lower an upper limits of the central 95% credible interval. The prior distribution for all parameters was normal with mean=0.0 and variance =100.0 (standard deviation = 10.0).

| Parameter | Mean | SD | Lower | Median | Upper |
|---|---|---|---|---|---|
| alpha | -4.01 | 0.39 | -4.82 | -3.98 | -3.32 |
| Yr[2] | 0.29 | 0.21 | -0.13 | 0.29 | 0.70 |
| Yr[3] | 0.61 | 0.23 | 0.17 | 0.61 | 1.06 |
| Yr[4] | 0.80 | 0.19 | 0.42 | 0.80 | 1.17 |
| Yr[5] | 0.67 | 0.21 | 0.26 | 0.67 | 1.08 |
| Yr[6] | 0.89 | 0.21 | 0.47 | 0.90 | 1.31 |
| Yr[7] | 1.06 | 0.22 | 0.64 | 1.07 | 1.48 |
| FA[1] | -7.06 | 3.08 | -15.47 | -6.27 | -3.49 |
| FA[2] | -1.63 | 0.76 | -3.10 | -1.63 | -0.15 |
| FA[3] | 0.12 | 0.34 | -0.51 | 0.10 | 0.79 |
| FA[4] | -0.13 | 0.36 | -0.78 | -0.14 | 0.59 |
| FA[5] | 0.58 | 0.33 | -0.04 | 0.56 | 1.25 |
| FA[6] | 0.55 | 0.35 | -0.09 | 0.54 | 1.28 |
| FA[8] | 5.78 | 6.39 | -2.56 | 4.15 | 21.16 |
| FA[9] | -2.45 | 2.31 | -4.99 | -2.88 | 2.67 |
| S[2] | 0.82 | 0.14 | 0.52 | 0.82 | 1.09 |
| S[3] | 0.50 | 0.13 | 0.23 | 0.51 | 0.75 |
| S[4] | 0.06 | 0.35 | -0.54 | 0.03 | 0.77 |
| Class | 5.53 | 3.09 | 2.01 | 4.68 | 14.06 |
| lalpha | -0.56 | 0.38 | -1.23 | -0.59 | 0.27 |
| lYr[2] | 0.43 | 0.19 | 0.06 | 0.43 | 0.81 |
| lYr[3] | -0.12 | 0.22 | -0.53 | -0.12 | 0.31 |
| lYr[4] | 0.47 | 0.18 | 0.13 | 0.46 | 0.82 |
| lYr[5] | 0.20 | 0.20 | -0.17 | 0.20 | 0.59 |
| lYr[6] | 0.07 | 0.20 | -0.32 | 0.06 | 0.47 |
| lYr[7] | 0.03 | 0.21 | -0.37 | 0.02 | 0.44 |

| | | | | | |
|---|---|---|---|---|---|
| lFA[1] | 4.05 | 0.93 | 1.99 | 4.13 | 5.62 |
| lFA[2] | 0.43 | 0.60 | -0.67 | 0.42 | 1.60 |
| lFA[3] | 0.50 | 0.33 | -0.18 | 0.52 | 1.12 |
| lFA[4] | 0.12 | 0.34 | -0.57 | 0.13 | 0.76 |
| lFA[5] | 0.34 | 0.33 | -0.34 | 0.35 | 0.95 |
| lFA[6] | -0.18 | 0.34 | -0.89 | -0.17 | 0.47 |
| lFA[8] | -3.55 | 1.67 | -6.20 | -3.89 | 0.38 |
| lFA[9] | 0.04 | 1.60 | -4.22 | 0.34 | 2.29 |
| lS[2] | -0.57 | 0.15 | -0.84 | -0.57 | -0.28 |
| lS[3] | 0.30 | 0.12 | 0.07 | 0.30 | 0.54 |
| lS[4] | -0.70 | 0.34 | -1.43 | -0.68 | -0.10 |
| lTS[2] | -1.40 | 0.23 | -1.85 | -1.39 | -0.96 |
| lTS[3] | -1.18 | 0.20 | -1.57 | -1.18 | -0.80 |
| lTS[4] | -1.70 | 0.41 | -2.55 | -1.68 | -0.93 |
| lTS[5] | 0.02 | 0.26 | -0.47 | 0.02 | 0.53 |
| lTS[6] | 0.35 | 0.09 | 0.17 | 0.35 | 0.53 |
| lTS[7] | -0.58 | 0.12 | -0.82 | -0.58 | -0.35 |
| lClass | -3.18 | 0.50 | -3.98 | -3.25 | -1.96 |

Following is a series of residual plots where the standardised residuals for the number of observed seabirds bycaught in each combination of fishing year × fishing area × season × target species × vessel class have been calculated as stated above. One point has not been plotted here (1999, FMA 6, spring, ORH, large vessels) that had a residual value of 62.0.

Figure C.1: Residual plot of residuals vs fishing year for seabird bycatch in trawl fisheries. Factor levels have been "jittered" to ease interpretation.
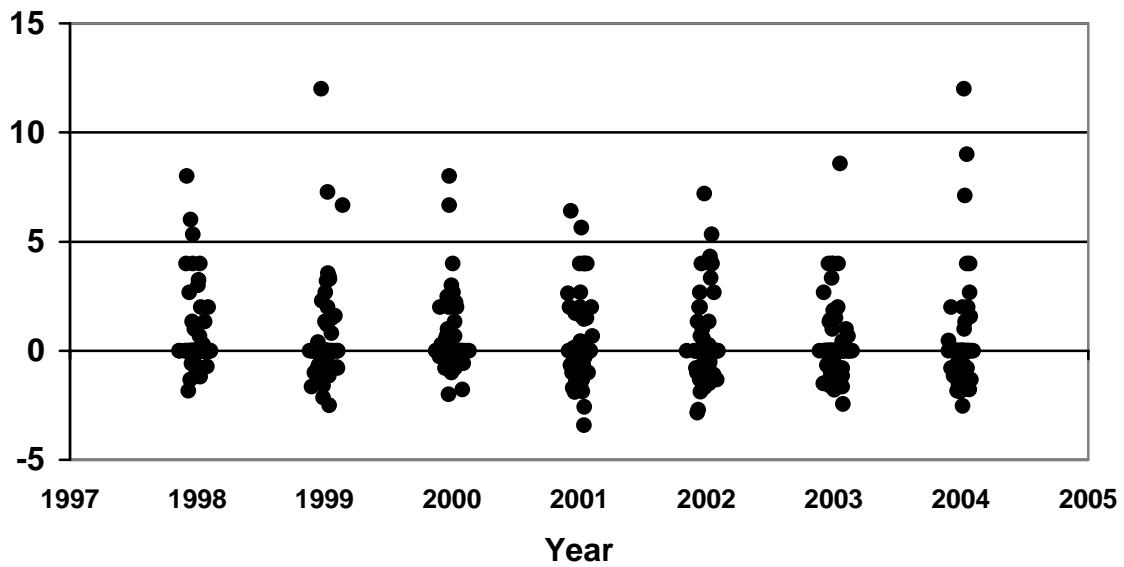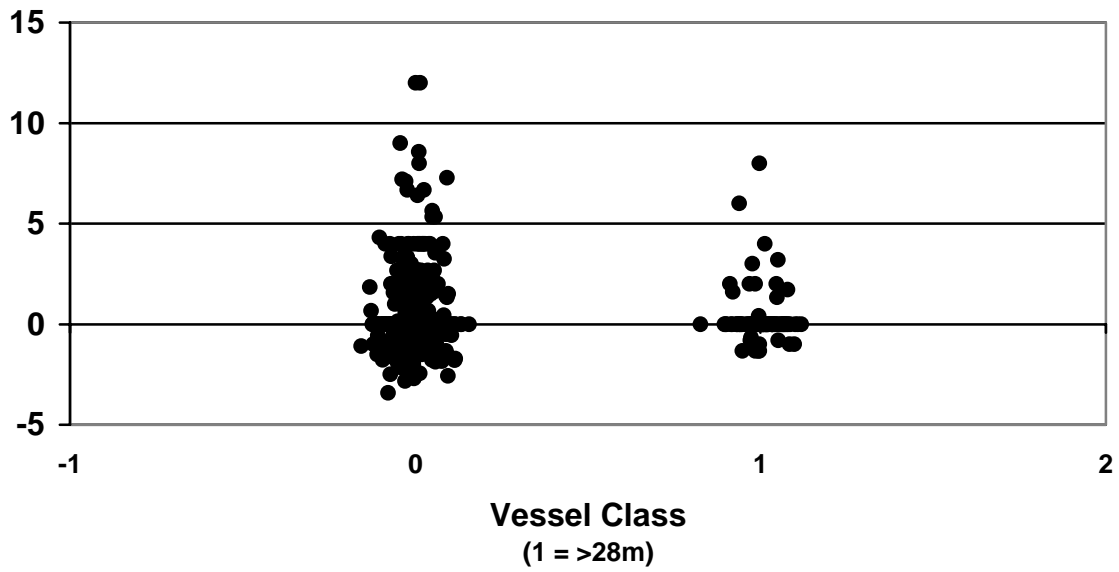


Figure C.2: Residual plot of residuals vs fishing area for seabird bycatch in trawl fisheries. Factor levels have been "jittered" to ease interpretation.

Figure C.3: Residual plot of residuals vs season for seabird bycatch in trawl fisheries. Factor levels have been "jittered" to ease interpretation.



**Season**
**(1 = Spring)**

Figure C.4: Residual plot of residuals vs target species for seabird bycatch in trawl fisheries. Factor levels have been "jittered" to ease interpretation.



**Target Species (defined above)**

Figure C.5: Residual plot of residuals vs vessel class for seabird bycatch in trawl fisheries. Factor levels have been "jittered" to ease interpretation.



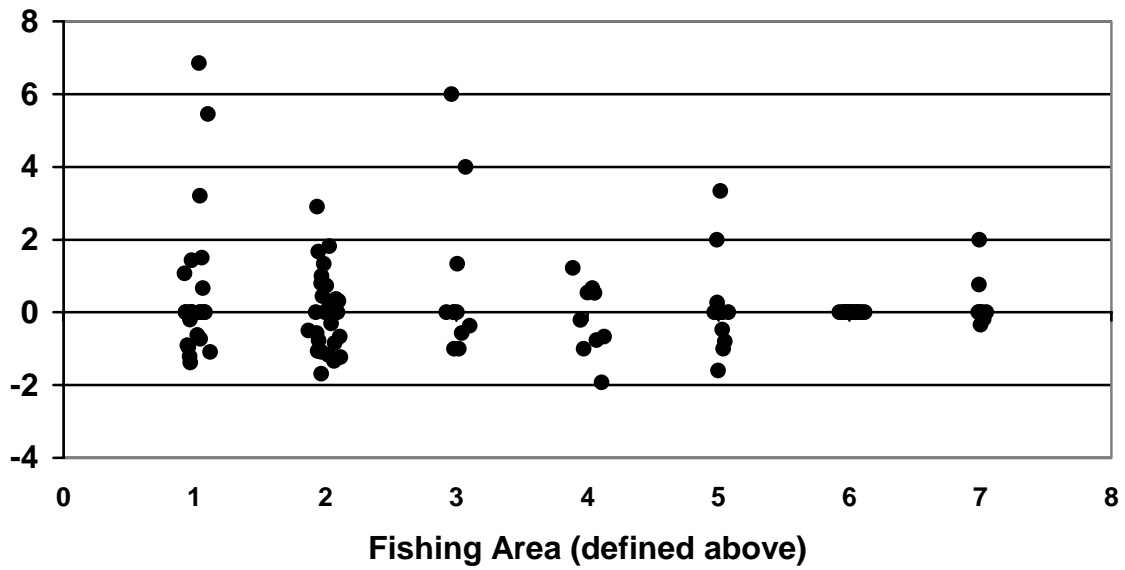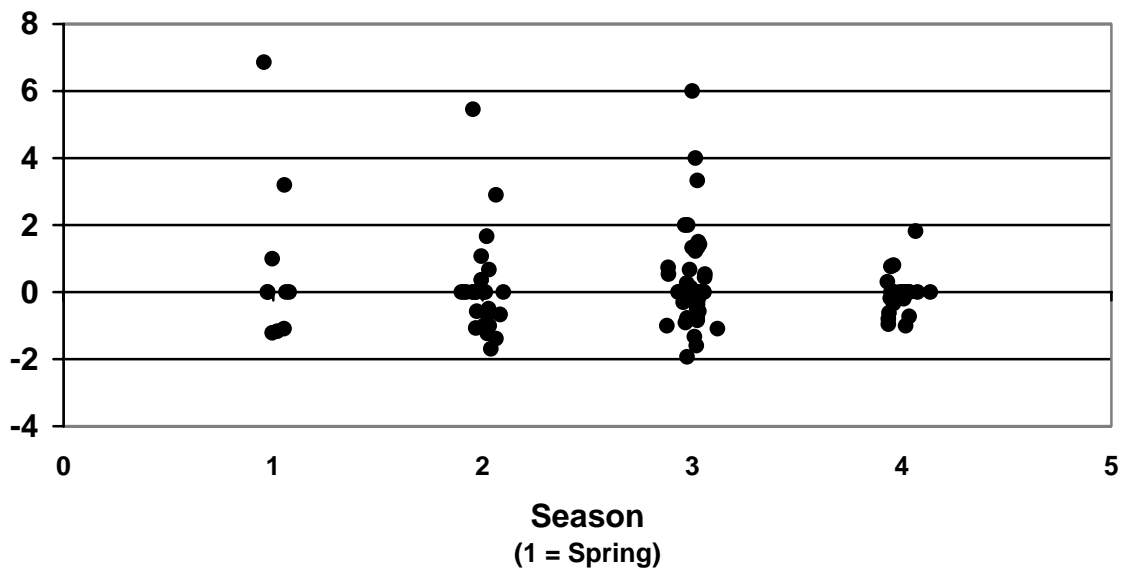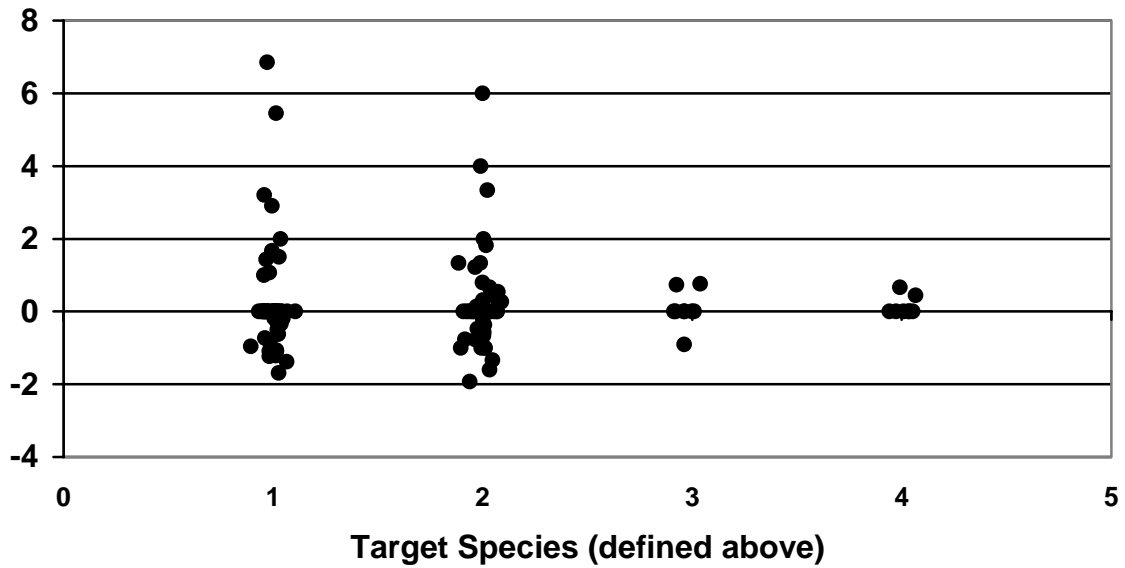**Vessel Class**
**(1 = >28m)**

Figure C.6: Residual plot of residuals vs observed bycatch for seabird bycatch in trawl fisheries.



**Observed Bycatch**
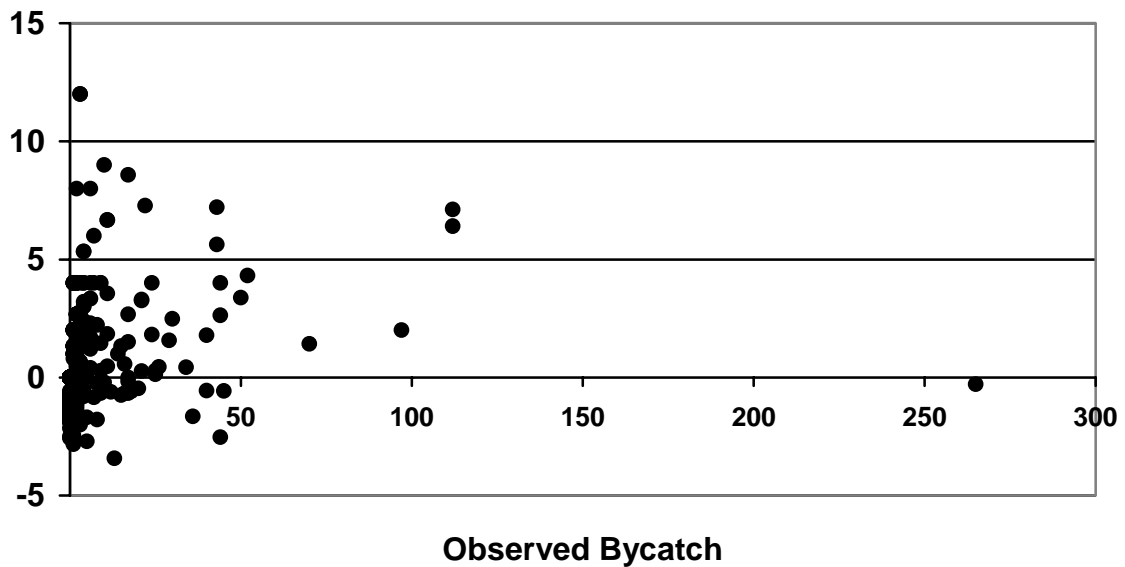
Figure C.7: Residual Q-Q plot for seabird bycatch in trawl fisheries.



**Normal Quantile**
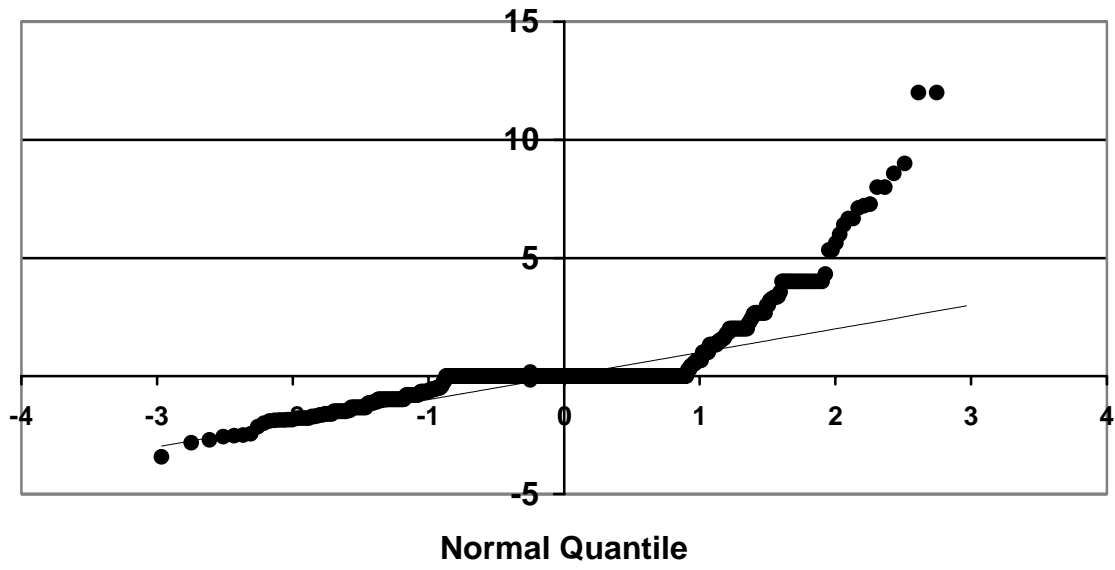
**Appendix D: Details of Modelling for Seabird Bycatch in SLL Fisheries (Objectives 1&2)**

The levels associated with the factors fishing area and target species used here were:

| Factor | Level | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Fishing Area | FMA 1 | FMAs 2 & 4 | FMAs 3 & 6 | FMA 5 | FMA 7 | FMAs 8 & 9 | Other |
| Target Species | BIG | STN | ALB | Other | | | |

Below, the posterior distributions for the estimated parameters are summarised, where a 'l' prefacing the parameter name indicates that parameters that are associated with the estimation of $\lambda$ rather than $p$. 'Lower' and 'Upper' and the lower an upper limits of the central 95% credible interval. The prior distribution for all parameters was normal with mean=0.0 and variance =100.0 (standard deviation = 10.0).

| Parameter | Mean | SD | Lower | Median | Upper |
|---|---|---|---|---|---|
| alpha | -1.64 | 0.48 | -2.53 | -1.66 | -0.73 |
| FA[1] | 1.39 | 0.56 | 0.27 | 1.40 | 2.50 |
| FA[2] | 0.90 | 0.45 | -0.01 | 0.91 | 1.74 |
| FA[3] | -0.26 | 1.69 | -1.79 | -0.49 | 2.31 |
| FA[4] | 1.13 | 0.42 | 0.26 | 1.15 | 1.89 |
| FA[6] | -0.92 | 1.03 | -2.50 | -0.96 | 0.58 |
| FA[7] | -0.92 | 1.03 | -2.50 | -0.96 | 0.58 |
| Yr[2] | 0.12 | 0.34 | -0.52 | 0.11 | 0.83 |
| Yr[3] | -0.15 | 0.39 | -0.93 | -0.16 | 0.63 |
| Yr[4] | -0.47 | 0.52 | -1.34 | -0.52 | 0.71 |
| Yr[5] | 0.04 | 0.31 | -0.57 | 0.04 | 0.66 |
| Yr[6] | -0.09 | 0.38 | -0.82 | -0.10 | 0.69 |
| Yr[7] | -0.81 | 0.38 | -1.50 | -0.83 | 0.00 |
| S[1] | 0.45 | 0.98 | -1.56 | 0.52 | 1.95 |
| S[2] | 1.02 | 0.70 | -0.56 | 1.10 | 2.19 |
| S[4] | 0.61 | 0.45 | -0.15 | 0.57 | 1.66 |
| Class | -0.56 | 0.76 | -1.77 | -0.67 | 1.37 |
| lalpha | 0.51 | 0.77 | -1.02 | 0.59 | 1.85 |
| lFA[1] | 1.41 | 0.46 | 0.56 | 1.39 | 2.37 |
| lFA[2] | 2.21 | 0.41 | 1.46 | 2.19 | 3.06 |
| lFA[3] | 0.90 | 0.62 | -0.50 | 0.94 | 2.00 |
| lFA[4] | 0.74 | 0.36 | 0.08 | 0.73 | 1.47 |
| lFA[6] | -9.73 | 5.76 | -23.55 | -8.59 | -1.84 |
| lFA[7] | 1.35 | 0.83 | -0.27 | 1.35 | 2.99 |
| lYr[2] | -0.51 | 0.23 | -1.00 | -0.50 | -0.09 |
| lYr[3] | 0.13 | 0.29 | -0.43 | 0.13 | 0.68 |

| | | | | | |
|------|------|------|------|------|------|
| lYr[4] | -0.86 | 0.38 | -1.69 | -0.83 | -0.20 |
| lYr[5] | 0.32 | 0.21 | -0.11 | 0.32 | 0.72 |
| lYr[6] | -0.25 | 0.34 | -0.93 | -0.24 | 0.39 |
| lYr[7] | 0.02 | 0.33 | -0.70 | 0.05 | 0.60 |
| lS[1] | 0.06 | 0.64 | -1.01 | -0.02 | 1.52 |
| lS[2] | -0.05 | 0.56 | -0.87 | -0.16 | 1.30 |
| lS[4] | 0.01 | 0.38 | -0.78 | 0.03 | 0.72 |
| lTS[2] | -1.45 | 0.81 | -2.80 | -1.52 | 0.07 |
| lTS[3] | -1.87 | 0.82 | -3.31 | -1.89 | -0.35 |
| lTS[4] | -0.59 | 0.63 | -1.92 | -0.55 | 0.56 |
| lClass | -1.81 | 0.77 | -3.33 | -1.82 | -0.34 |

Following is a series of residual plots where the standardised residuals for the number of observed seabirds bycaught in each combination of fishing year × fishing area × season × target species × vessel class have been calculated as stated above.

Figure D.1: Residual plot of residuals vs fishing year for seabird bycatch in surface longline fisheries. Factor levels have been "jittered" to ease interpretation.
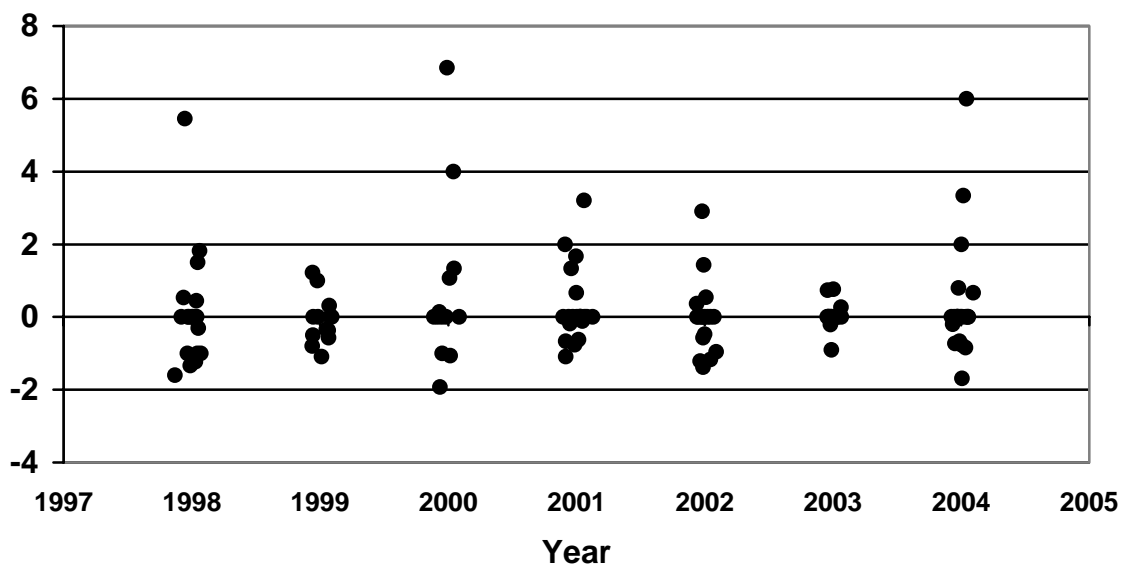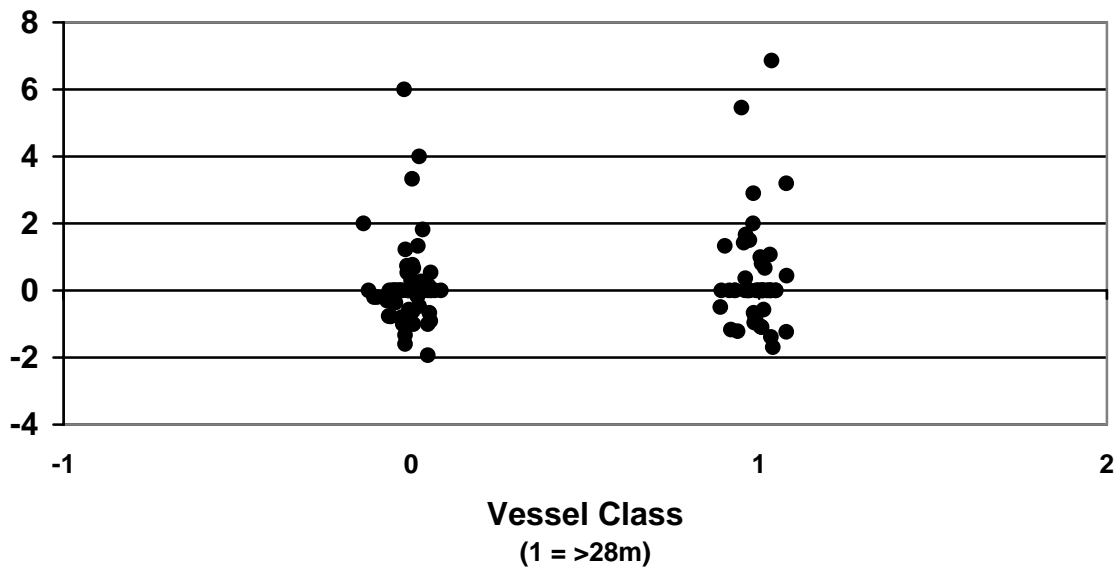
Figure D.2: Residual plot of residuals vs fishing area for seabird bycatch in surface longline fisheries. Factor levels have been "jittered" to ease interpretation.



Figure D.3: Residual plot of residuals vs season for seabird bycatch in surface longline fisheries. Factor levels have been "jittered" to ease interpretation.

Figure D.4: Residual plot of residuals vs target species for seabird bycatch in surface longline fisheries. Factor levels have been "jittered" to ease interpretation.



Figure D.5: Residual plot of residuals vs vessel class for seabird bycatch in surface longline fisheries. Factor levels have been "jittered" to ease interpretation.
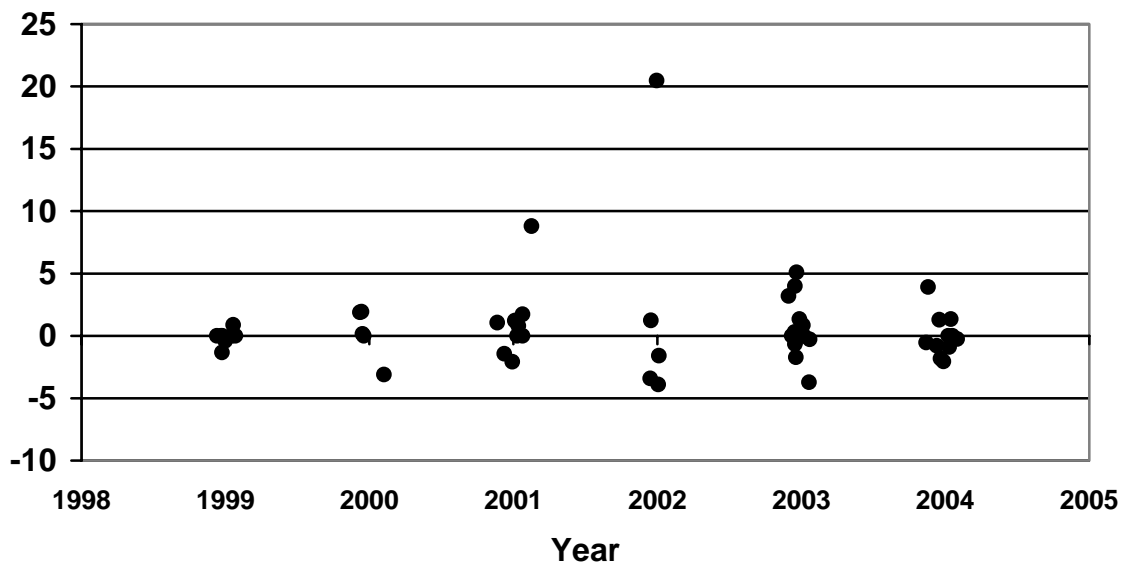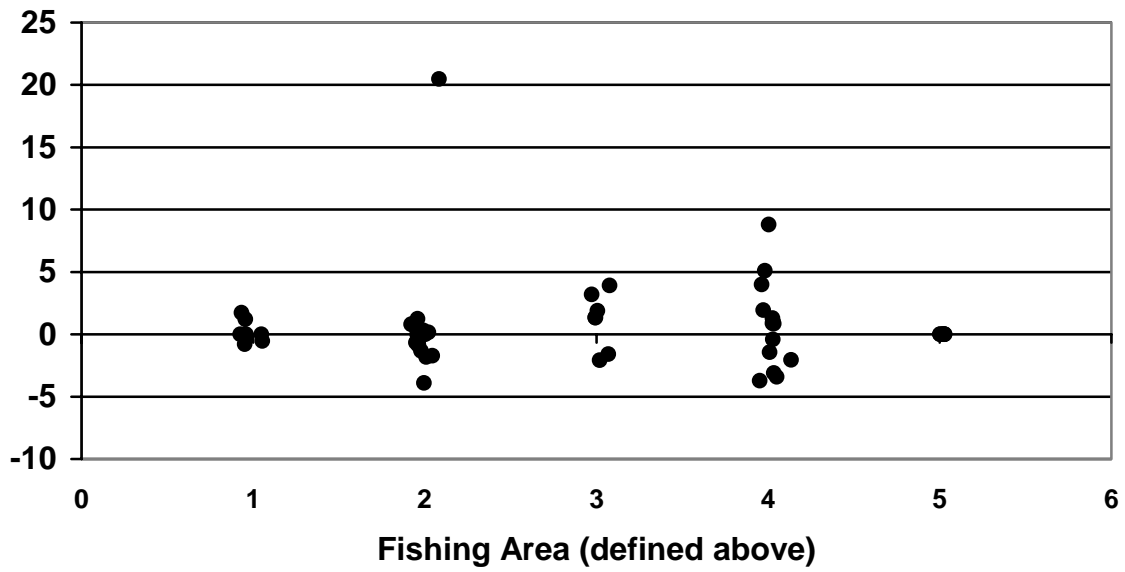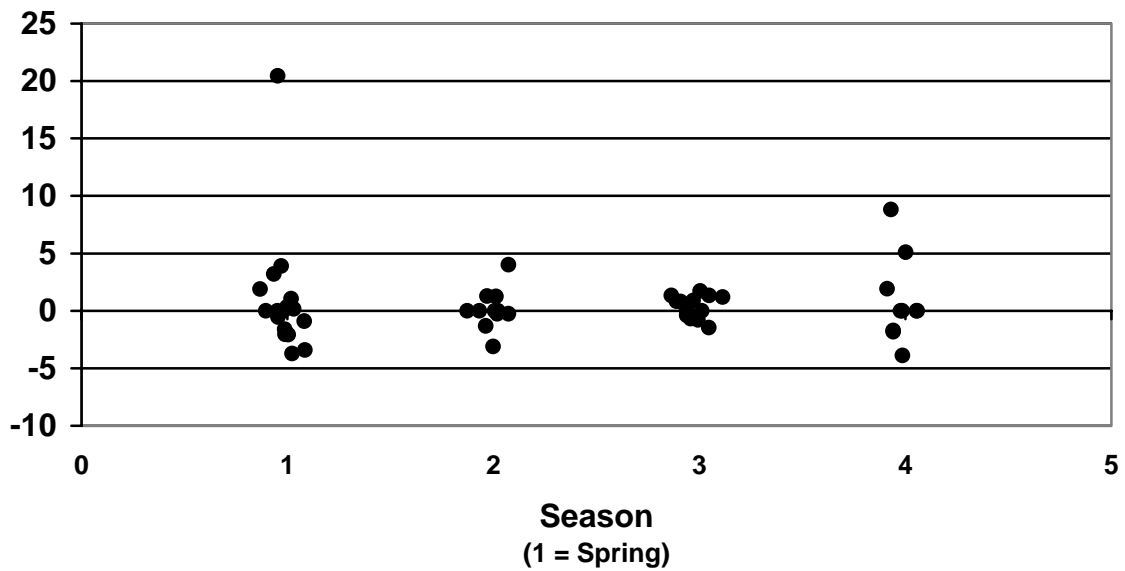
Figure D.6: Residual plot of residuals vs observed bycatch for seabird bycatch in surface longline fisheries.



**Observed Bycatch**
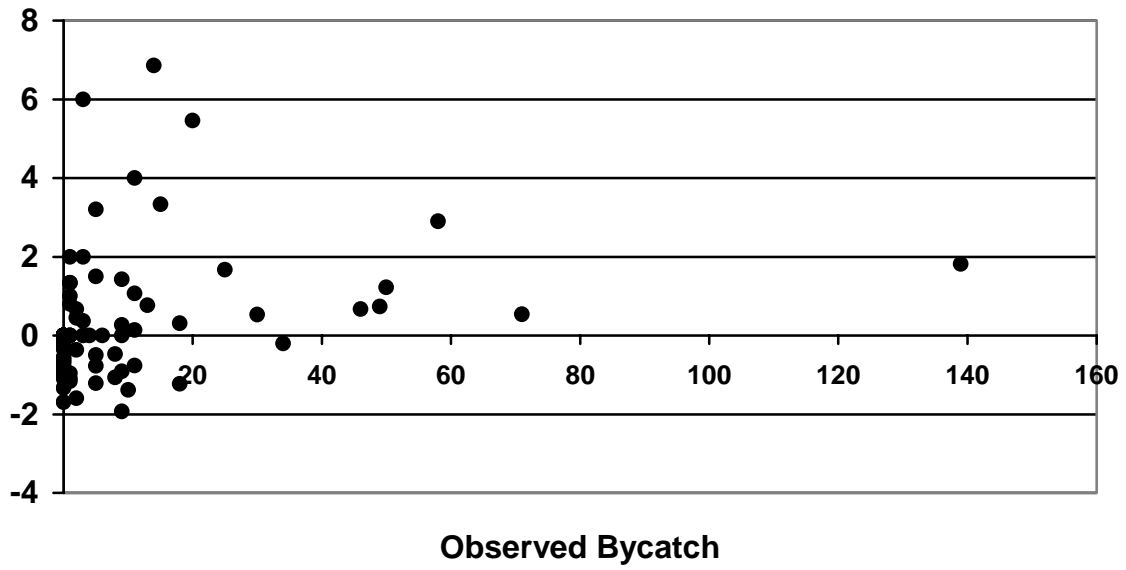
Figure D.7: Residual Q-Q plot for seabird bycatch in surface longline fisheries.



**Normal Quantile**
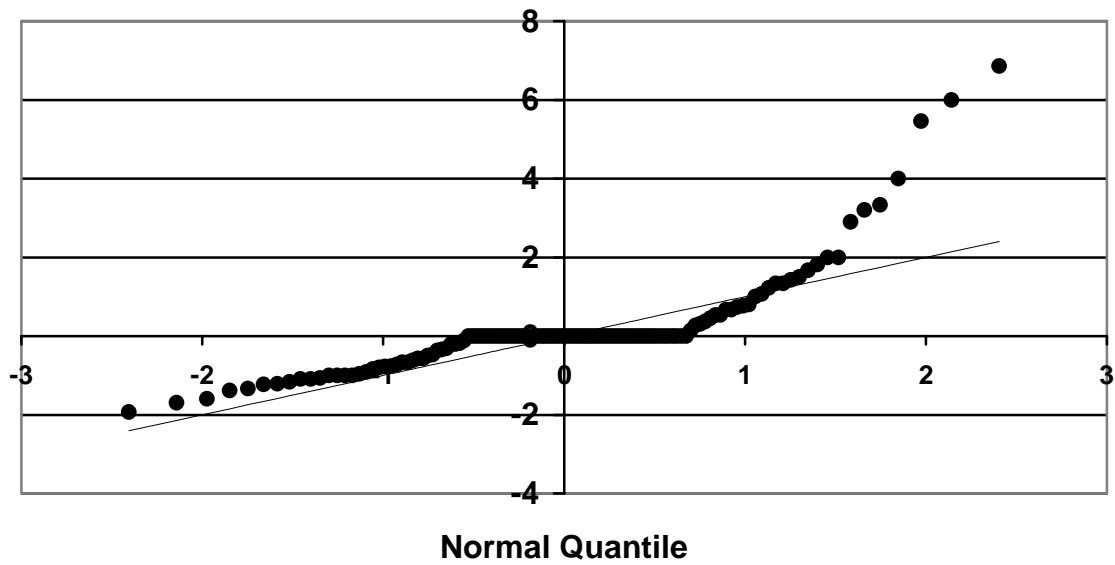
**Appendix E: Details of Modelling for Seabird Bycatch in BLL Fisheries (Objectives 1&2)**

The levels associated with the factors fishing area and target species used here were:

| | Level | | | | |
|---|---|---|---|---|---|
| Factor | 1 | 2 | 3 | 4 | 5 |
| Fishing Area | FMAs 1, 2, 8-10 | FMAs 3 & 4 | FMAs 5 & 7 | FMA 6 | Other |
| Target Species | LIN | SNA | Other | | |

Below, the posterior distributions for the estimated parameters are summarised, where a 'l' prefacing the parameter name indicates that parameters that are associated with the estimation of $\lambda$ rather than $p$. 'Lower' and 'Upper' and the lower an upper limits of the central 95% credible interval. The prior distribution for all parameters was normal with mean=0.0 and variance =100.0 (standard deviation = 10.0).

| Parameter | Mean | SD | Lower | Median | Upper |
|---|---|---|---|---|---|
| alpha | -1.33 | 0.28 | -1.88 | -1.32 | -0.80 |
| Yr[2] | 0.59 | 0.30 | 0.01 | 0.59 | 1.18 |
| Yr[3] | 0.55 | 0.27 | 0.03 | 0.55 | 1.08 |
| Yr[4] | 0.08 | 0.29 | -0.49 | 0.07 | 0.64 |
| Yr[5] | -0.12 | 0.27 | -0.66 | -0.12 | 0.41 |
| Yr[6] | -0.49 | 0.31 | -1.10 | -0.50 | 0.12 |
| S[2] | -0.38 | 0.17 | -0.70 | -0.38 | -0.04 |
| S[3] | 0.23 | 0.21 | -0.17 | 0.23 | 0.66 |
| S[4] | -0.51 | 0.15 | -0.80 | -0.51 | -0.22 |
| FA[1] | -1.28 | 0.99 | -3.05 | -1.35 | 0.81 |
| FA[2] | -0.25 | 0.18 | -0.60 | -0.25 | 0.11 |
| FA[4] | -0.07 | 0.13 | -0.32 | -0.07 | 0.19 |
| FA[5] | -0.07 | 0.13 | -0.32 | -0.07 | 0.19 |
| Class | 0.42 | 1.00 | -1.67 | 0.48 | 2.23 |
| lalpha | 0.54 | 0.23 | 0.07 | 0.54 | 1.01 |
| lYr[2] | 0.00 | 0.24 | -0.48 | 0.00 | 0.48 |
| lYr[3] | 0.40 | 0.22 | -0.04 | 0.40 | 0.84 |
| lYr[4] | 0.33 | 0.25 | -0.16 | 0.33 | 0.82 |
| lYr[5] | 0.24 | 0.23 | -0.21 | 0.24 | 0.71 |
| lYr[6] | -0.14 | 0.26 | -0.66 | -0.14 | 0.38 |
| lS[2] | -0.45 | 0.13 | -0.71 | -0.45 | -0.21 |
| lS[3] | -0.81 | 0.16 | -1.13 | -0.80 | -0.50 |
| lS[4] | -0.23 | 0.09 | -0.42 | -0.23 | -0.05 |
| lFA[1] | -1.52 | 1.04 | -3.52 | -1.52 | 0.51 |
| lFA[2] | -0.19 | 0.11 | -0.41 | -0.19 | 0.04 |
| lFA[4] | 0.18 | 0.09 | 0.01 | 0.18 | 0.35 |
| lFA[5] | -12.23 | 5.11 | -24.67 | -11.13 | -5.42 |

| lTS[2] | 3.47 | 1.08 | 1.44 | 3.42 | 5.78 |
| lTS[3] | 0.42 | 0.72 | -1.06 | 0.45 | 1.75 |
| lClass | -1.78 | 1.01 | -3.87 | -1.77 | 0.13 |

Following is a series of residual plots where the standardised residuals for the number of observed seabirds bycaught in each combination of fishing year $\times$ fishing area $\times$ season $\times$ target species $\times$ vessel class have been calculated as stated above.
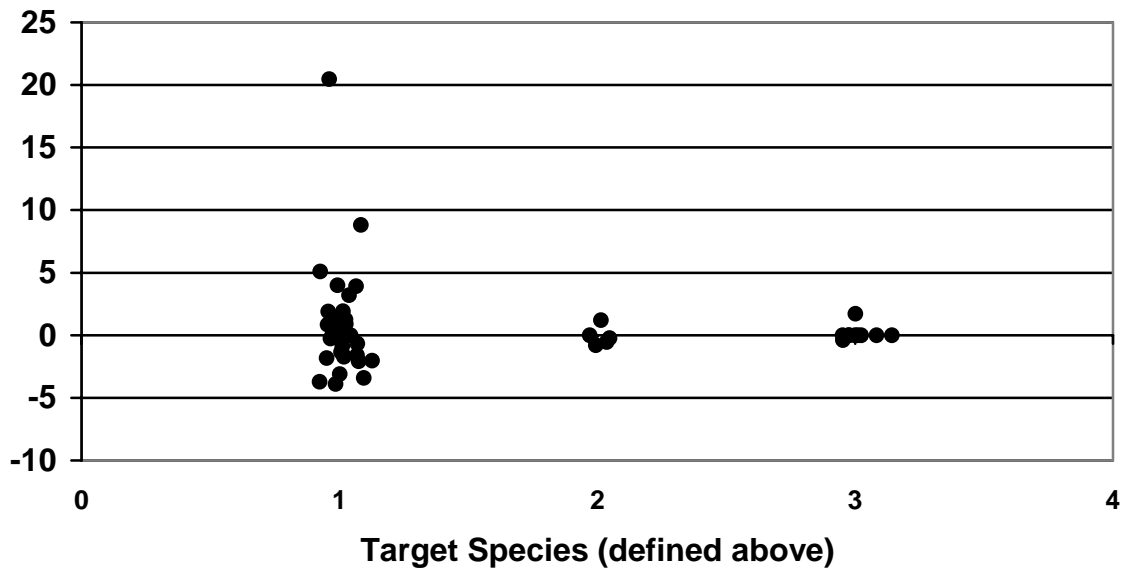
Figure E.1: Residual plot of residuals vs fishing year for seabird bycatch in bottom longline fisheries. Factor levels have been "jittered" to ease interpretation.

Figure E.2: Residual plot of residuals vs fishing area for seabird bycatch in bottom longline fisheries. Factor levels have been "jittered" to ease interpretation.



Figure E.3: Residual plot of residuals vs season for seabird bycatch in bottom longline fisheries. Factor levels have been "jittered" to ease interpretation.

Figure E.4: Residual plot of residuals vs target species for seabird bycatch in bottom longline fisheries. Factor levels have been "jittered" to ease interpretation.



Figure E.5: Residual plot of residuals vs vessel class for seabird bycatch in bottom longline fisheries. Factor levels have been "jittered" to ease interpretation.
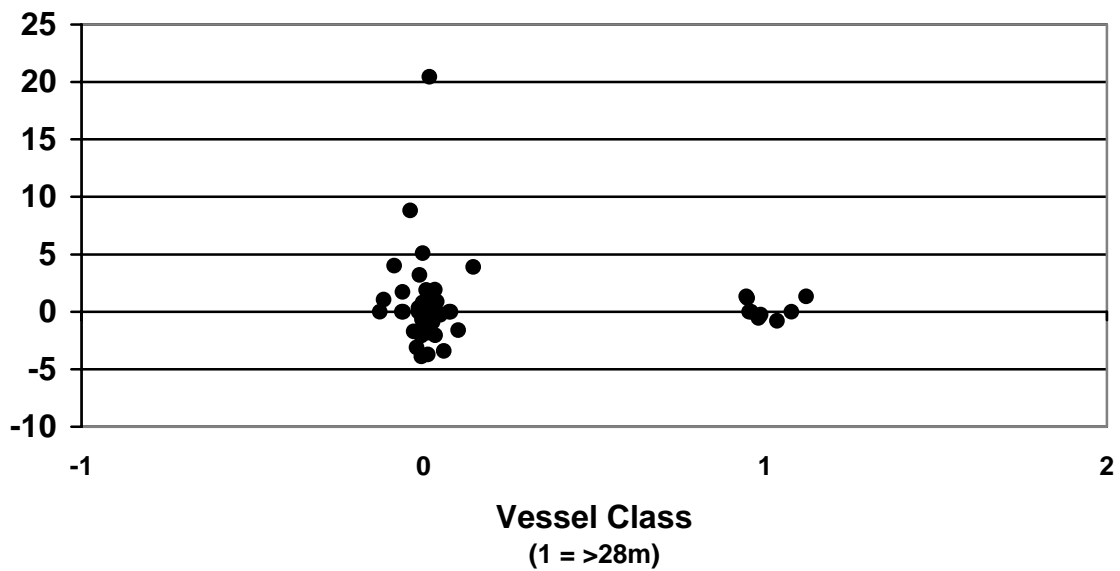
Figure E.6: Residual plot of residuals vs observed bycatch for seabird bycatch in bottom longline fisheries.
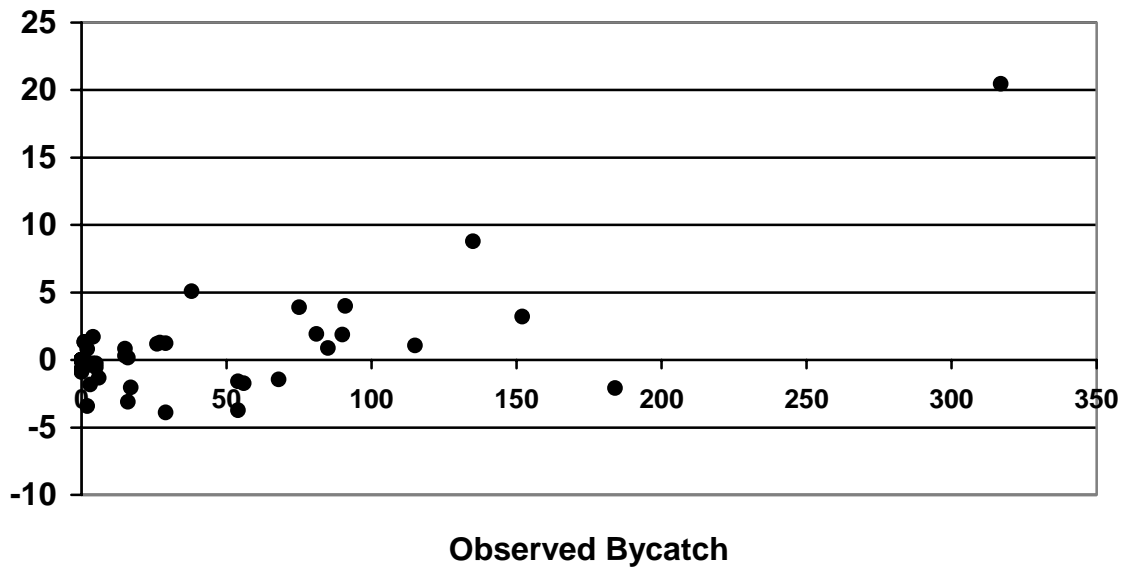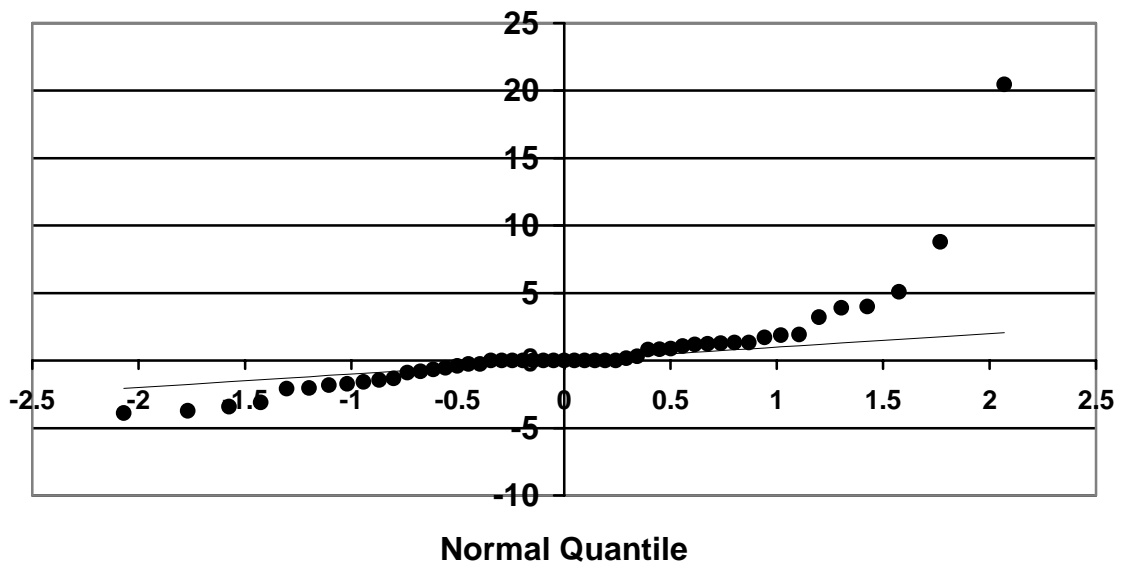


**Observed Bycatch**

Figure E.7: Residual Q-Q plot for seabird bycatch in bottom longline fisheries.



**Normal Quantile**

**Appendix F: Observer Effort Allocation Rule (Objective 5)**

In order to maximise the precision of an estimate of a population mean or total, we make use of the well-developed theory underlying so-called "optimal allocation" of sampling effort in stratified sampling (Cochran, 1977). This theory implies that we should allocate effort using the following rule:

$$w_i \propto N_i \sigma_i$$

where, for vessel-method-area-season $i$

$w_i$ = proportion of total observer effort allocated

$N_i$ = expected fishing effort

$\sigma_i$ = estimated standard deviation in capture rate

For bycatch data, the standard deviation in capture rate ($\sigma_h$) will be roughly proportional to the mean capture rate, i.e.

$$\sigma_i \propto \mu_i$$

This result follows from the fact that a lognormal model should provide a reasonable approximation to the data, for the purposes of developing an allocation rule.

**References**

Baird, S.J. 2004*a*. Incidental capture of seabird species in commercial fisheries in New Zealand waters, 1999-2000. *New Zealand Fisheries Assessment Report 2004/41*.

Baird, S.J. 2004*b*. Incidental capture of seabird species in commercial fisheries in New Zealand waters, 2000-01. *New Zealand Fisheries Assessment Report 2004/58*.

Baird, S.J. 2004*c*. Incidental capture of seabird species in commercial fisheries in New Zealand waters, 2001-02. *New Zealand Fisheries Assessment Report 2004/60*.

Baird, S.J. 2005. Incidental capture of seabird species in commercial fisheries in New Zealand waters, 2001-02. *New Zealand Fisheries Assessment Report 2005/02*.

Burnham, K.P., and D.R. Anderson. 2004. Multimodel inference: understanding AIC and BIC in model selection. *Sociological Methods and Research* 33: 261-304

Cochran, W.G. 1977. *Sampling Techniques*. Wiley, New York (3rd Edition).

Dunn, P.K., and G.K. Smyth. 1996. Randomized quantile residuals. *Journal of Computational and Graphical Statistics* 5: 1-10

MacKenzie, D.I., J.D. Nichols, J.A. Royle, K.H. Pollock, L.L. Bailey and J.E. Hines. 2005. *Occupancy estimation and modelling: inferring patterns and dynamics of species occurrence*. Elsevier, San Diego, USA

Manly, B.F.J., C. Cameron and D.J. Fletcher. 2002. *Longline bycatch of birds and mammals in New Zealand fisheries, 1990/91 to 1995/96, and observer coverage*. DOC Science Internal Series Number 43.

Smith, M.H., and S.J. Baird. 2004. *Factors that may influence the level of incidental mortality of Hooker's sea lions in the squid trawl fishery in SQU 6T*. Unpublished Ministry of Fisheries report