New Zealand Aquatic
Environment and Biodiversity
Report No. 40
2009
ISSN 1176-9440

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New Zealand Aquatic Environment and Biodiversity Report No. 40
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Published by Ministry of Fisheries
Wellington
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ISSN 1176-9440

Smith, M.H.; Baird, S.J. (2009).
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New Zealand Aquatic Environment and Biodiversity Report No. 40. 90 p.

This series continues the
Marine Biodiversity Biosecurity Report series
which ceased with No. 7 in February 2005.

EXECUTIVE SUMMARY

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New Zealand fur seals (*Arctocephalus forsteri*) are distributed around the New Zealand coastline, on offshore islands, and on subantarctic islands. Inside the New Zealand Exclusive Economic Zone (EEZ), most fur seal captures were observed during trawl operations south of 40º S. New Zealand fur seals have also been reported caught on surface longlines that target southern bluefin tuna and on bottom longlines in southern waters. This work exclusively reports on observed fur seal captures for fishing using trawl nets and uses model-based prediction methods to predict total fur seal captures and strike rates from trawl fishing south of 40º S for the 12 fishing years 1994–95 to 2005–06.

For modelling purposes the trawl fishing region south of 40º S was divided into six areas based on the start positions of the tows. These are: east coast Wairarapa/Cook Strait (ECCO), Chatham Rise (CHAT), Sub-Antarctic (SANT), Stewart-Snares shelf/Puysegur (STSP), west coast South Island (WCSI), and the southern blue whiting fishery in FMA 6 (SBW6). All target species are included in each area except for SANT (where all tows except those targeting southern blue whiting are included) and SBW6. Not all tows south of 40º S are included in one of the six areas; however, these were in waters where no fur seal captures were observed in the 12 years (Macquarie Ridge waters inside the EEZ and the Golden Bay/Tasman Bay/Taranaki Bight region).

Models are fitted to each area using the observer data, which includes fur seal captures. After fitting, the model for each area is applied to the unobserved tows in the area to obtain the predictive distribution of the fur seal captures for unobserved tows. The observed captures are then added to get the predictive distribution of the total fur seal captures. Predicted strike rate distributions are obtained by dividing total captures by total tows. The model-based method adjusts the capture rates for differences between observed and unobserved tows in suitable covariates that are related to capture rates and, thus, helps correct for any lack of the representativeness of observer coverage.

Predicted annual fur seal captures in the ECCO area varied between 30 and 292 over the fishing years (ignoring the very large predicted number of captures for the 1996–97 fishing year when only 9 tows were observed). The predicted total fur seal captures in the ECCO area over the 12 fishing years is over 2100, but this includes inflated predicted captures for 1996–97 (and for 1994–95) and a more realistic total would be 1600. Predicted fur seal strike rates vary between 0.3% and 5.9% (in 2005–06) and the strike rate is 1.8% over all years. Except for the 1994–95 and 1996–97 years, when there were few observed tows and no observed captures, the c.v.s for the total captures and strike rates were between 40% and 98%. In the observer data, 15% of fur seals captured in the ECCO area were released alive.

Predicted fur seal captures in the CHAT area over the 12 fishing years varied between 721 in 1996–97 and 208 in 2005–06 with 4700 predicted captures in total. Predicted strike rates varied between 0.7% and 1.6% and the predicted strike rate is 1.4% over all years. All c.v.s were 55% or less. In the observer data, 28% of the fur seals captured in the CHAT area were released alive.

Predicted total fur seal captures in the SANT area ranged between 21 in 1999–2000 and 65 in 2001–02. The total predicted fur seal captures numbered 490 for all years. Predicted strike rates showed less variation, at between 0.4% and 1.0%, with a strike rate of 0.7% over the 12 years. However, c.v.s are large, between 52% and 124%, as a consequence of the relatively few captures observed in each year. In the observer data, 19% of fur seals captured in the SANT area were released alive.

Predicted fur seal captures in the STSP area varied from 316 in 2002–03 to over 1100 in both 1997–98 and 1998–99. The total number of predicted captures for the 12 years is 7080. Predicted strike rates varied between 1.7% (in 2002–03) and 5.4% (in 1998–99) and show an apparent downward trend with the four lowest strike rates occurring in the last four years. The c.v.s are moderate and vary between 33% and 47%. In the observer data, 19% of fur seals captured in the STSP area were released alive.

In the WCSI area, the predicted numbers of fur seal captures varied between 1840 in 1995–96 and 573 in 2005–06 and totalled 18 908 over all 12 years. Predicted strike rates varied between 10.2% in 1995–96 and 4.2% in 1994–95 and 2005–06 and have an apparent downward trend. The c.v.s are moderate to small with a range of 32–44% and a c.v. of 20% for the total captures. In the observer data, 6% of fur seals captured in the WCSI area were released alive.

Predicted total fur seal captures in the SBW6 fishery area averaged more than 100 per year and varied between 49 in 2003–04 and 200 in 1998–99. Total predicted captures for the 12 years numbered 1237. Predicted strike rates varied considerably between 28% in 1994–95 and 6.7% in 2003–04, and there is some evidence of a downward trend in the predicted strike rates. The c.v.s vary between 17% and 54% with the lower c.v.s (and higher strike rates) corresponding to years with a higher proportion of tows in the Bounty Plateau subarea where the capture rate is higher than in the rest of SBW6. In the observer data, 2% of fur seals captured in the SBW6 fishery area were released alive.

The mean annual total predicted fur seal captures in New Zealand waters south of 40º S varied between 1375 in 2003–04 and 3710 in 1996–97. Most c.v.s are in the range 20–24%, but the c.v.s for 1994–95 and 1996–97 are inflated because of the very large c.v.s for the predicted captures in the ECCO area in those years. The mean total predicted captures for those years will also be inflated because of the highly skewed predictive distributions in the ECCO area. The predicted total number of captures over the 12 years is 28 450 with a c.v. of 15%. The predicted total captures series shows a trend downwards over the years, but the total commercial tows have also trended down. However, a small downward trend in the predicted strike rates is still apparent. In the observer data, an estimated 14% of fur seals captured inside the EEZ south of 40º S were released alive, using an average weighted over the areas by the predicted total captures.

There is an issue which may lead to inflated predicted totals for fur seal captures. In the 12 years, only 13 tows (all in the CHAT area) of the 80 706 observed tows targeted flatfish species. No fur seals were captured on these tows and very little is known about the capture rate of fur seals during flatfish tows. For modelling and prediction purposes, tows targeting flatfish were included in the shallow group target species, a group that includes barracouta, tarakihi, and red cod. In the four coastal areas, ECCO, CHAT, STSP, and WCSI between 16% and 38% of unobserved tows targeted flatfish. If, as seems likely because of the size of the nets used and the very shallow depths of the tows, the capture rates for flatfish are lower than those for other shallow species, then the predicted total captures will have been correspondingly inflated for those areas. A sensitivity analysis was used to determine what effect setting the capture rate for unobserved tows targeting flatfish to zero would have on the total predicted captures in the four coastal areas. This resulted in lower bounds for total captures, and the reductions in the total predicted captures were 0.3% for the ECCO area, 20% for the CHAT area, 44% in the STSP area, and 32% in the WCSI area.

Inside the EEZ and north of 40º S, 11 fur seals were captured on the 6862 observed tows in the 12 years. All were caught off the west coast of the North Island in either 2004–05 or 2005–06.

1. INTRODUCTION

New Zealand fur seals (*Arctocephalus forsteri*) are distributed around the New Zealand coastline, on offshore islands, and on subantarctic islands. The species was heavily exploited during the 18th and 19th centuries and protection was given to it in 1894, but restricted licences were still issued for seal harvest in certain locations. In 1978, New Zealand fur seals were given total protection under the New Zealand Marine Mammals Protection Act (Mattlin 1987).

Statutory obligations require that the Ministry of Fisheries (MFish) monitors the bycatch of associated or dependent species during commercial fishing operations in New Zealand waters. The MFish Observer Programme collects data on the incidental catch of marine mammals as part of its monitoring programme. Observers record these captures as landed dead or released alive. Data on the interaction between trawl fishing operations and fur seals have been collected since the beginning of the observer programme in 1986, with data in the late 1980s mainly being collected from the west coast South Island hoki (*Macruronus novaezelandiae*) fishery where large numbers of fur seals were observed caught in 1989 (Mattlin 1994). This incidental capture data collection is secondary to the collection of fisheries data and thus data available for the estimation of marine mammal captures are generally based on programmes that are not specifically designed to collect incidental capture data.

Fur seals have been observed caught during bottom and midwater trawl operations (particularly for hoki, squid (*Nototodarus* spp.), and southern blue whiting (*Micromesistius australis*) around the coastline of the South Island and the offshore islands in the southern waters of the 200 n. mile Exclusive Economic Zone (EEZ) (Baird & Smith 2007). Although most observed captures occur in trawl fishing, New Zealand fur seals have also been reported caught on surface longlines that target southern bluefin tuna (*Thunnus maccoyii*), and on bottom longlines (for example, bluenose (*Hyperoglyphe antarctica*)) in waters south of 40º S (Baird 2008). Animals caught on tuna longlines are more likely to be landed and released alive, whereas most fur seals caught in trawl nets are dead on landing. This work reports on fur seal captures for fishing using trawl nets exclusively.

This report is concerned with Objective 1 of the project PRO2006/05: *to estimate and report the total numbers, releases and deaths of marine mammals where possible by species, fishery and fishing method, caught in commercial fisheries for the years 1990 to the end of the fishing year 2005/06.* It was agreed with MFish that the work would cover model-based estimation of fur seal bycatch for trawl fishing south of latitude 40º S in the 12 fishing years (1 October–30 September), 1994–05 to 2005–06. This is the region where almost all fur seal captures in trawl nets have been observed in those fishing years.

2. METHODS

This section describes the sources and treatment of data and the model-based prediction method used to predict the strike rates and total numbers of fur seal captures during trawl fishing in New Zealand waters.

2.1 Data sources and treatment

Data sources included Trawl Catch Effort Processing Returns (TCEPR), Catch Effort Landing Returns (CELR), and MFish *obs* and *obs_lf* databases. Extensive data grooming and preparation was carried out on both the observer and the commercial data sets (see Figures A1 and A2 for the effects of the grooming on the observed and commercial tow start positions). High resolution position coordinates were included in the observer records, in the TCEPR records, and in the relatively few CELR records that included positional data. This was necessary to calculate some of the covariates used in the modelling and proved useful for assigning tows to area groupings and for grooming positional data.

Firstly, the observer data set was obtained from the *obs* database including all observed tows for the fishing years 1994–95 to 2005–06, both north and south of 40º S and both inside and outside the EEZ. Tows that were continuations of observed trips commenced in 2005–06 and which continued into the 2006–07 fishing year were also included for completeness. It was found that one tow appeared twice and, after the duplicate was deleted, there were 86 224 tows in the complete observer dataset. The dataset was augmented with fur seal capture data from *obs_lf*. There were 749 tows that were in the 2006–07 fishing year (21 of which were outside the EEZ) and 4769 tows outside the EEZ, leaving a dataset of 80 706 observed tows inside the EEZ for the 12 fishing years of the study (Table A1).

Grooming of the observer data was important because the observer data were used to fit the fur seal capture models that were used to predict fur seal captures for the unobserved tows. Grooming of position, date, time, target species, and fishing gear variables was carried out by first using adjacencies of tows within trips, start and finish times and positions, and cross-checking with commercial data, to identify possible anomalies. Necessary changes were then made manually. The effect of the grooming on the start positions of many observed tows is obvious in the plots in Figure A1.

Secondly, we describe the preparation and grooming of the commercial trawl data (data recorded on TCEPR or CELR forms) supplied by MFish in two datasets. The first dataset of 654 577 TCEPR records (one tow for each record) and 4997 CELR records (each record comprising one or more tows in a single day targeting the same species, using the same fishing gear and method, and fishing in the same statistical area) comprised all records with start latitudes that were south of 40º S. The second dataset consisted of a further 203 426 records, all recorded on CELR forms with missing start latitude coordinates, but with effort recorded as being in statistical areas 015–017, 036–039, 703, and all statistical areas south thereof. Therefore, the initial dataset of all commercial data consisted of 654 577 tows recorded on TCEPR forms and 208 423 records (each record usually included multiple tows) recorded on CELR forms.

As for the observer data, possible anomalies in the position, statistical area, date and time, and gear variables were identified using values for adjacent tows by the same vessel and start position plots. The effect of the grooming on the start positions of tows is shown in the plots in Figure A2. Common values or sequences of fishing event database codes were also used in the commercial data to identify wrong times, days, months, and years. Target species were groomed in a similar manner, using adjacent tows by the same vessel for identifying possible anomalies. Sometimes, likely “typo” errors were identified and in other cases (especially where the target was missing) some targets were assigned to broad target groups on the basis of other information such as targets of tows by the same vessel, net depth, and fishing targets by statistical area for the vessel.

In the CELR data, there were large numbers of missing or impossible (the largest was 4500) effort numbers (numbers of tows per record). For these records, new values for effort number were assigned using the median effort number by the vessel grouped by statistical area and by target, and also within duration groups when practicable. If groupings were empty, broader groupings were used to calculate the median. Duration of effort was treated in a similar way with groupings of CELR tows that included effort number (instead of duration) if available. Following grooming, the CELR records were converted to individual tow-by-tow data by repeating each record by the reported number of tows (effort number) for that record. The duration of each tow was set to the total duration for the record divided by the number of tows for the record.

A total of 1 116 330 commercial tows were used in the predictive method for estimating bycatch over the 12 fishing years (the total for all areas in Table A1), 45% of which were recorded on CELRs.

No automatic changes using generic scripts were made in the grooming, as in our experience these often create further errors by changing the wrong variable. (This was especially evident in some data from the 1990s where some automatic “corrections”, based on a wrong assumption about which date or time variable required correcting, led to further changes to what were correct dates and times in order to preserve the order of tows.)

2.2 Model-based predictive method for estimating fur seal bycatch

In the predictive method for estimating fur seal bycatch the trawl fishing region inside the EEZ and south of 40º S was partitioned into a number of areas. The definitions of the areas are based on experience gained with earlier model-based estimation of fur seal captures applied to separate fishery areas (Baird & Smith 2007). The method was applied separately to six of these areas (described in Section 2.3) where fur seal captures were observed in sufficient numbers for models to be fitted successfully. The remaining areas in the trawl fishing region were not modelled because no fur seal captures were recorded on any of the observed tows in these areas in the 12 fishing years covered by this study. The areas not modelled are: the statistical areas 037, 038, and 039 off the west coast of the North Island, statistical areas 205, 206 and the parts of statistical areas 014 and 204 south of 40º S off the east coast of the North Island, and the Macquarie Ridge area, which approximates statistical areas 503, 601, and 616. The areas are plotted in Figures A1 and A2 and the unlabelled areas inside the EEZ and south of 40º S are the areas not modelled.

A fully Bayesian predictive approach using hierarchical models was used to obtain all the estimates of total captures and strike rates for each area. The method was described by Smith & Baird (2007), where it was used to predict New Zealand sea lion captures in the SQU 6T fishery, and in other references therein. Each model uses season random effects, vessel-season random effects, and selected fixed covariates. In the predictive approach the model for a particular area is fitted, using Bayesian methods, to a set of observer data for the area that covers all years in the study. The fitted model is in the form of a sequence of realisations (usually 5000) of a Markov chain Monte Carlo (MCMC) sample from the joint posterior distribution of the model parameters. The chain encapsulates the uncertainty in the parameter estimates and is used to provide realisations from the predictive distributions of total fur seal captures and fur seal strike rates for each fishing year.

Each realisation from the predictive distribution of the total fur seal captures is obtained in five steps. There are usually 5000 realisations in total, related to the MCMC sample from posterior distribution of the parameters in the fitted model. Firstly, the unobserved tows are identified. Secondly, the mean capture rate for each unobserved tow is calculated using the current realisation from the posterior distribution of the parameters. If the vessel was not observed in the particular year, a value for the vessel-season effect is generated from the gamma distribution using the current realisation of the vessel-season effects shape parameter θ^{vs}. Thirdly, a realisation of the actual number of fur seal captures for each tow is drawn from the negative binomial distribution with the mean capture rate for the tow and the current realisation of the extra-dispersion shape parameter θ. Fourthly, the realisations for all the unobserved tows are added to get a realisation from the predictive distribution of the unobserved captures. Finally, the total observed captures are added to get a realisation from the predictive distribution of the total captures. This procedure yields 5000 realisations from the predictive distribution of the total captures from which mean, c.v., and predictive intervals can be obtained. The predictive distribution incorporates uncertainty in the model parameter estimates, uncertainty in the unobserved vessel-season effects (which correlate captures among tows by the same vessel within each season), and variability in the actual number of fur seals captured on every unobserved tow (through the negative binomial error model).

The realisations from the predictive distribution of the fur seal strike rates are obtained in a slightly different way. The same first two steps are used to generate tow by tow realisations of the mean capture rate for each unobserved tow. These are then added to get a realisation of the mean total unobserved fur seal captures, which in turn is added to the total observed captures. The sum is then divided by the total number of commercial tows to get a realisation from the predictive distribution of the strike rate. Note that these realisations only include the uncertainty in the parameter estimates and do not include the added variation from the negative binomial error of the actual unobserved captures.

The realisations are then used to obtain estimates of the characteristics of the predictive distributions such as means, medians, standard deviations, c.v.s, and 95% predictive intervals.
The predictive distributions for total captures and for strike rates each incorporate the finite population correction directly because all the uncertainty comes from the unobserved tows.

2.3 Trawl areas

The region within the New Zealand EEZ, south of 40º S, excluding statistical areas 014, 037–040, 204–206, and 502, and excluding the Macquarie Ridge, was first divided into five trawl fishery areas. The boundaries were defined, to a greater or lesser extent, by fishing fleet activities, boundaries used in previous work, and statistical area boundaries. Four areas are bounded by the coastlines of the North and South Islands. The remaining region was partitioned into two areas: one fishery area comprising tows targeting southern blue whiting and another area in the south comprising tows targeting any other species. The areas are shown in Figures A1 and A2 and described below:

East coast Wairarapa and Cook Strait area (ECCO)

> The area defined by statistical areas 015, 016, and 017.

Chatham Rise area (CHAT)

> The area in the EEZ, east of the South Island, south of 42° 10´ S, and north of latitude 46° S, and statistical areas 018, 019, and 024.

Stewart-Snares shelf and Puysegur area (STSP)

> The area Fisheries Management Area 5 (FMA 5), excluding the Macquarie Ridge, south of 45° 30´ S and east of 165° E; and the area in FMA 3 and the area in FMA 6, excluding the Macquarie Ridge, south of 46° 03´ S, north of 49° 30´ S and west of the line joining 46° 03´ S and 173° E with 49° 30´ S and 170° 32´ E.

Sub-Antarctic area (SANT)

> The area in the EEZ, south of 46° S, excluding the areas CHAT and STSP and excluding the Macquarie Ridge. Tows targeting southern blue whiting are not included.

West coast South Island area (WCSI)

> The area in the EEZ bounded in the south by 45° 30´ S, in the east by the coast of the South Island and 172° 41´ E, and in the north by 40° S.

Southern blue whiting fishery area in FMA 6 (SBW6)

> The FMA 6 area, excluding the Macquarie Ridge, and only including tows targeting southern blue whiting.

Tows south of 40° S in statistical areas 014, 037–039, 204–206, and 502 were not included in any of the areas because no fur seal captures were observed in these statistical areas in 1994–95 to 2005–06. All tows in SANT and SBW6 were recorded on TCEPR forms.

Most CELR records have missing position coordinates with the only positional information recorded being the statistical area. This presented a problem for assigning such records to the WCSI area where the boundary does not coincide with the boundary between statistical areas. In the south of the WCSI area the boundary between it and the STSP area is 45º 30′ S, which passes through the centre of statistical area 031. The second situation is the northern boundary of WCSI, 40º S, which passes through the middle of the statistical areas 036, 702, and 703. The resolution of these problems is described in Section 2.6.
The use of larger groupings of all target species and all commercial tows (recorded on either TCEPR or CELR forms) is an attempt to obtain comprehensive estimates of fur seal captures covering all of the fishing effort south of 40° S.

This approach is more flexible than that used by Baird & Smith (2007) because it includes all target species, which makes for more comprehensive models that can be used to predict fur seal captures for all the unobserved tows in the area and for sub-groupings of unobserved tows such as those targeting individual species.

2.4 Model description

The model-based hierarchical approach used for the prediction of total fur seal captures combines season and vessel-season random effects with covariates to model variation in capture rates among tows. The model is fitted to the observer data for the area and the fur seal captures are predicted for the unobserved commercial data. The predicted captures reflect the differences between the observed and the unobserved data by the adjustment, tow by tow, of the mean capture rate through the covariates and the season and vessel factors. Along with the covariate values for each unobserved tow, season and vessel-season random effects (for any unobserved tows by vessels observed during the season) are used to adjust the mean capture rate for the tow. For the tows by vessels not observed in the season the variation among vessel-season effects is incorporated as additional sampling variation to account for the uncertainty. Finally, the total uncertainty in the actual number of fur seal captures in the unobserved tows is incorporated using the negative binomial error distribution of the model (in relation to the mean total number of captures), together with the uncertainty in the parameter estimates, to give the mean total unobserved captures through the Bayesian predictive approach.

The model used for fitting the observer data and for the prediction of total fur seal captures is described in terms of the mean rates of fur seal captures for the tows (as by Baird & Smith 2007). The error distribution assumption of the model is that the number of fur seal captures in the i^{th} season for the k^{th} tow by the j^{th} vessel has a negative binomial distribution with mean rate (per tow) parameter $\mathrm{E}\left(y_{ijk}\right)=\mu_{ijk}$ and shape parameter θ. The model allows the mean rate parameters, μ_{ijk}, to vary among tows through a log-linear relationship involving fixed and random parameters and it is also assumed that θ does not vary among the tows. We report the value of θ, indirectly, through its reciprocal, which is the *extra-dispersion variance* of the negative binomial error model.

Each mean rate parameter is built from the parameters and covariates in a multiplicative way (log-linear). All models are hierarchical and have the following components.

1. A set of base season mean capture rate parameters, λ_i (random effects).
2. A set of multiplicative vessel-season random effects, v_{ij} (random effects).
3. A log-linear component involving covariates and parameter coefficients. This component acts as a scaling of the mean capture rate by an exponential function of the standard form linear model. The sets of covariates used in the models vary among areas.

The mean capture rate parameter for the *ijk*th tow is then given by

$$\mu_{ijk} = \lambda_i v_{ij} \exp\left(\mathbf{x}_{ijk}\boldsymbol{\beta}\right) \qquad (1)$$

where $\mathbf{x}_{ijk}$ is a row matrix of covariate values for tow *ijk* and $\boldsymbol{\beta}$ is a column matrix of coefficient parameters.

The distributional assumptions for the season random effects are that the base season capture rates (λ_i) are an independent sample from a single lognormal distribution, with a log-mean and log-variance parameters. The vessel-season effects (v_{ij}) are assumed to be an independent sample from a single gamma distribution with mean 1 and a shape parameter θ^{vs}, which is the same for all seasons and all vessels. Again we report a value of θ^{vs} indirectly, through its reciprocal, which is the *vessel-season effects variance*.

Models, special to each area, are fitted using the observer data for the area. Random effects and vessel-season effects appear in the model for each area. The set of covariates that appears in a model is specific to the area. The covariates used in at least one of the area models are described below.

day.no: day of fishing year. A variable with sine and cosine transformations to give a two-component periodic covariate. This is the first harmonic of the Fourier series approximation to a periodic function with period 1 year.

DN: time of day of tow. Factor variable with levels:
- day (base level) – tow entirely in daylight or twilight
- dusk – tow includes end of evening twilight (sun 12º below horizon)
- night – tow entirely in darkness
- dawn – tow includes start of morning twilight (sun 12º below horizon)

For long duration tows that include more than one twilight event, the level is determined by the first twilight.

duration: duration of tow plus a quarter of an hour to allow inclusion of zero duration tows and to add an arbitrary time for setting and hauling. Continuous variable transformed by the logarithm.

d.shore: distance of start of the tow from the nearest shore. Continuous variable transformed by the logarithm.

gear: type of gear used in trawl. Factor with levels:
- BT – bottom trawl gear
- MW – midwater trawl gear.

For each fishery, the most commonly used gear type in the observer data was used as the base level in the fitted model.

subarea: the fishery area is divided into sub-areas producing a factor covariate. The sub-areas are specific to the individual areas.

targ.g: target species group, a factor variable. Three or more levels are used in each area, with any added levels for an area being specific species groups that are commonly targeted in the area. The three commonly used target groups are (see Table A2 for the species included in each group):

shallow – species generally targeted in the shallower depths.
mid depth – species generally targeted in the middle depths.
deep – species generally targeted in deep water.

The use of a periodic transformation of the *day.no* variable ensures that the values of the transformed covariate coincide at the beginning and the end of the fishing year. It is important to ensure that any *day.no* effects are less likely to get incorporated into the base season effects because of different distributions of effort in different fishing years.

For each area, the grouping of target species for the *targ.g* factor is dictated primarily by the target species composition of the observer data, but the target groups are designed to group together the targets that would be fished commercially using similar fishing practices. In some areas, a single commonly targeted species is used as an additional group on its own. This is justified when there are sufficient observed tows targeting the single species and targeting the remaining species in the group to which it usually belongs.

As in previous applications of the model-based predictive approach, we did not consider covariates relating directly to individual vessels, such as nationality, power, and length, as any effects will be included in the vessel-season effects.

2.5 Model fitting

Models for each of the six areas were fitted to the observer data using WinBUGS (Spiegelhalter et al. 2003), run from within the statistics package R (R Development Core Team 2008). Limited model selection was carried out in some of the areas and this involved the selection of which covariates were included in the covariate component of the model. Selection decisions were based on the deviance information criterion (DIC) (Spiegelhalter et al. 2002) and the size of the extra-dispersion variance. Covariate components of models used for STSP and WCSI reflect the results that Mormede et al. (2008) obtained in their study of associations of capture rates with covariates.

MCMC samples from the joint posterior distribution of the parameters for the fitted model in each area were obtained by running the chains for 100 000 iterations keeping every 20^{th} iteration following a burn in of 100 000 iterations. This resulted in samples of 5000 iterations for use in the predictions of total fur seal captures and strike rates. Convergence of the chains was checked using Geweke (Geweke 1992) and Heidelberger and Welch (Heidelberger & Welch 1983) criteria.

The following subsections describe the models fitted for each area, including the specific covariates used in the fixed effects component for each model. The posterior distributions of the parameters of the fitted model, the goodness of the model fit, and the distributions of observed and commercial effort are discussed. The tables and figures relevant to each of the fishery areas are given in the appendices as follows: all areas in Appendix A, ECCO in Appendix B, CHAT in Appendix C, SANT in Appendix D, STSP in Appendix E, WCSI in Appendix F, and SBW6 in Appendix G.

2.5.1 East coast Wairarapa and Cook Strait area (ECCO)

This area was changed from the HCOOK hoki fishery area used by Baird & Smith (2007) to include all target species, which resulted in the inclusion of a large number of additional tows recorded on CELR forms (more than 50% of all commercial tows, Table B1). The spatial area was changed to the area containing all tows with starting positions in the statistical areas 015–017. This was necessary to resolve the problem of assigning CELR tows without positional data to areas (see Figure B1 for maps showing the boundaries).

The area was difficult to model because observer coverage concentrated mainly on tows targeting hoki and scampi (Table A3) and on tows in June to September (density plot of *day.no* in Figure B2). Observer coverage was very low at less than 2% over the 12 years, with fewer than 100 tows observed in the 1994–95 to 1996–97 and the 2005–06 fishing years (Table B1). Relatively few fur seal captures were observed, none of which occurred in tows targeting shallow species. This led to large uncertainties for the parameters in the fitted model and, consequently, large uncertainties in the total capture estimates, which are, in turn, reflected in the inflated c.v.s.

The model used for ECCO had the covariate component:

DN + *targ.g* + periodic(*day.no*).

The target groups used for *targ.g* factor in the ECCO area are:

shallow	species targeted in the shallower depths,
mid depth	(base level) species targeted in the middle depths (except for SCI),
scampi	scampi (SCI),
deep	species targeted in the deep.

The limited process of model selection started with consideration of the covariate component of the model used by Baird & Smith (2007) for the HCOOK hoki fishery (*DN* + *gear* + log(duration) + log(*d.shore*)). The target group variable *targ.g* was added to the covariate component of the model for the ECCO area. While *d.shore* proved useful in pinpointing the Cook Strait canyon in the model used by Baird & Smith (2007) specifically for hoki tows, it was not considered as a candidate covariate for the model for the ECCO area because most tows targeted species other than hoki. A *subarea* covariate was also not considered for the model for the ECCO area because *targ.g* effectively divided the observed effort into subareas. About 95% of observed tows targeted hoki or scampi (Table A3) with scampi tows predominating in statistical area 014 (off the Wairarapa coast) and hoki tows predominating in the Cook Strait canyon.

In the model selection phase of the fitting process, the covariate component of *targ.g* + *DN* + *gear* + log(*duration*) + periodic(*day.no*) was the initial model fitted. Dropping the log(*duration*) term from the model decreased both the DIC and the mean extra-dispersion variance, so the log(*duration*) term was dropped from the model. Next, dropping the periodic *day.no* term resulted in a large increase in DIC, but a small increase in the mean extra-dispersion variance, so the periodic(*day.no*) term was retained. Finally, dropping the *gear* factor resulted in a very small increase in the DIC but produced a 5% decrease in extra-dispersion variance so the *gear* factor was dropped from the model. This suggests that including the *gear* factor increases the predictive power of the model slightly, but at the expense of an increase in extra dispersion.

The final model was fitted using a burn in of 100 000 iterations and a further 100 000 iterations of which every 20th iteration was retained. This gave a sample of 5000 iterations from the joint posterior distribution of the model parameters. The model fit appeared to be satisfactory because the predicted frequencies of fur seal captures per tow coincided well with the observed frequencies (Table B2).

The posterior distributions of some of the model parameters exhibit the large standard errors that were expected from limitation of the observer data (Table B3). In particular, the posterior distributions of the 1995 and 1997 base capture rate parameters and the target shallow and deep parameters have very large standard deviations and c.v.s of more than 250%. This is because no fur seal captures were observed for tows in the 1994–95 and 1996–97 years nor for any tows targeting either shallow or deep species. There were also very few observed tows in these categories (Table B1 and Figure B2). The effects of fishing at dusk, night, and dawn on capture rates are all more than 6 times the rate for tows entirely in the day time. The periodic *day.no* covariate has a peak multiplicative effect occurring late in July and the lowest multiplicative effect occurring late in January.

2.5.2 Chatham Rise area (CHAT)

This area has minor boundary changes from the HCHAT hoki fishery area used by Baird & Smith (2007). The CHAT area includes all tows that started in statistical areas 018, 019, and 024 and excludes those that started in statistical areas 205 and 206 (the northern boundary, excluding statistical areas 018 and 019, was changed from 42º S to 42º 10′ S and now coincides with the boundary between FMA 2 and FMA 4). The changes were forced by the inclusion of all tows targeting all species and all tows in CELR records.

The details of the covariates peculiar to the CHAT area, and the selection procedure, are described below. The base level for the *gear* factor was MW, because this was the predominant gear type in the observer data. The *d.shore* covariate measures distance from the shore of the South Island. The target groups used for the *targ.g* factor in the CHAT area are:

shallow	species targeted in the shallower depths,
mid depth	(base level) species targeted in the middle depths (except for SCI, JMA),
jack mac	jack mackerels (JMA),
scampi	scampi (SCI),
deep	species targeted in the deep.

The model used for predicting captures in CHAT has the covariate component:

DN + *gear* + *targ.g* + log(*d.shore*) + periodic(*day.no*).

The model selection phase of the fitting process was quite limited. A *subarea* covariate was not considered for the CHAT area because past work had shown that the *d.shore* variable was quite strongly associated with spatial changes in capture rates (Baird & Smith 2007). The covariate component *targ.g* + *DN* + *gear* + log(*d.shore*) was fitted in our initial model. This was the covariate component of the model used by Baird & Smith (2007) for their HCHAT hoki fishery area with the log(*duration*) term removed and the *targ.g* factor added. The log(*duration*) term was not included in our initial model because the posterior distribution of the log(*duration*) coefficient of Baird & Smith (2007) was centred very close to zero. Inclusion of the term was likely to add randomness to any predictions, with little adjustment to the mean capture rates from any differences between observed and unobserved tow durations. The second model tried was the initial model with the periodic(*day.no*) term added. This resulted in a reduction in both the DIC and the mean extra-dispersion variance and, consequently the periodic(*day.no*) term was retained. As a check, the model was run with the log(*duration*) term added. The DIC decreased by 1.5%, but the mean extra-dispersion variance increased by more than 9%. Again, the posterior distribution of the coefficient of log(*duration*) was centred near zero and therefore it was decided not to include the log(*duration*) term in the final model for CHAT area.

The model was fitted using a burn in of 100 000 iterations and a further 100 000 iterations of which every 20th iteration was retained. This gave a sample of 5000 iterations from the joint posterior distribution of the model parameters. The model fit appeared to be satisfactory because the predicted frequencies of fur seal captures per tow coincided well with the observed frequencies (Table C2).

The posterior distributions of the parameters of the fitted model had relatively small dispersion characteristics (Table C3), reflecting the relatively large amount of observed tows and captures. For the effects associated with factor covariates (base capture rates, *DN*, *gear*, and *targ.g*) most had c.v.s less than 100%. The only exceptions were the *targ.g*, shallow, and deep effects (relative to mid depth) which had very small posterior means.

All the 95% credibility intervals for the parameters associated with the two continuous covariates (*d.shore* and *day.no*) excluded zero. This suggests that the capture rate is strongly associated with distance from the South Island and day of the fishing year. The periodic *day.no* covariate has a peak multiplicative effect of about 4.4 occurring in early September and a trough multiplicative effect of 0.23 in early March.

2.5.3 Sub-Antarctic area (SANT)

For the SANT area, there are major changes from the spatial boundaries of the HSUBA hoki fishery area boundaries used by Baird & Smith (2007). The spatial extent of the SANT area is that of the old HSUBA hoki fishery area with the STSP area (see Section 2.5.4) removed (see Figures A1 and D1). The SQU6T squid fishery area of Baird & Smith (2007) is wholly included in SANT. Tows targeting all species, except southern blue whiting, are included. However, the SANT area essentially contains effort targeted at mid depth and deep species because very few observed tows and unobserved tows targeted shallow species (see Table A3). All tows in the SANT area were recorded on TCEPR forms.

The base level for the *gear* factor is BT. Target species groups for the *targ.g* factor are:

shallow	species targeted in the shallower depths,
mid depth	species targeted in the middle depths (except for SCI and SQU),
scampi	scampi (SCI),
squid	(base level) squid species (SQU),
deep	species targeted in the deep.

The model used for predicting captures in SANT has the covariate component:

$$DN + gear + targ.g + \log(duration).$$

It can be seen from Table D1 and Figure D1 that there were relatively few observed fur seal capture incidents and a low observed strike rate, and therefore it was desirable to have a relatively parsimonious model. The use of a sub-area factor was not considered because the target groups in the observer data define possible sub-areas to a large extent. Although *d.shore* appeared in the HSUBA hoki fishery model used by Baird & Smith (2007), the mean of the posterior distribution was very close to 0 and, therefore, unlikely to have much effect on the predicted captures. Thus, *d.shore* was not included in the initial SANT model. The factors *DN* and *gear* and the logarithm of *duration* were retained from the HSUBA model of Baird & Smith (2007) and the *targ.g* factor was added. As a check, a second model was run with log(*d.shore*) included. This model had a slightly reduced DIC (by 4%), but the extra-dispersion variance increased by 17%. Again, zero was near the centre of the 95% credibility interval for the *d.shore* parameter and thus, *d.shore* was not included in the final model.

The model was fitted using a burn in of 100 000 iterations and a further 100 000 iterations of which every 20^{th} iteration was retained. This gave a sample of 5000 iterations from the joint posterior distribution of the model parameters. The model fit appeared to be satisfactory because the predicted frequencies of fur seal captures per tow coincided well with the observed frequencies (Table D2).

The posterior distributions of the model parameters have quite large standard deviations, mainly because relatively few captures were observed (compared with the other areas) (Tables D1 and D3). The effect of the shallow target species (relative to the squid target) has a very large standard deviation because there were so few observed tows in this group, none of which caught fur seals. The extra-dispersion variance was much larger for this area than for any of the other areas, possibly due to the relatively few captures and low strike rate.

2.5.4 Stewart-Snares shelf and Puysegur area (STSP)

The spatial extent of the STSP area combines the spatial extents of the Stewart-Snares shelf squid fishery area (SSTEW) and the Puysegur hoki fishery area (HPUYS) of Baird & Smith (2007) (see Figures A1 and E1). The area boundaries were adjusted in the west to coincide with the boundaries of statistical areas 029 and 030 and in the east to coincide with the boundary of statistical area 024. Decision rules, based on target species, for assigning CELR tows in statistical area 031 which is split by the boundary (at 45º 30´ S) between the STSP and WCSI are described in section 2.6.

Most observed tows in STSP targeted squid. The jack mackerel tows were also of sufficient number to justify a separate group while leaving sufficient tows in the mid depth group. The target groups in the *targ.g* factor for the STSP model are:

shallow	species targeted in the shallower depths,
mid depth	species targeted in the middle depths (except JMA and SQU),
jack mack	jack mackerels (code JMA),
squid	(base level) squid species (code SQU),
deep	species that are targeted in the deep.

The covariate component model used for predicting captures in STSP has the covariate component:

$$DN + subarea + targ.g + \text{periodic}(day.no).$$

The choice of covariates for the final model was based on work by Baird & Smith (2007) and Mormede et al. (2008) who studied the STEW (Stewart-Snares shelf) area for all observed target species to determine covariates associated with variation in fur seal capture rates. Mormede et al. (2008) found an association between capture rate and a region factor. In particular, there was a strong increase in capture rate off the south Otago coast north of 46º 30´ S (region A in their analysis). They also found associations between the fur seal capture rate and the time of year, through a third order polynomial transformation of the *day.no* covariate, and between fur seal capture rates and a target group factor. On the basis of these results we decided to include a *subarea* factor, a *targ.g* factor, and a periodic *day.no* covariate (because of the periodic nature of the covariate) in our model.

The STSP spatial area was divided into three subareas: the Puysegur subarea (coincides with the overlap of the STSP area with the separate hoki fishery area HPUYS of Baird & Smith (2007)), the Otago coast subarea (identified by Mormede et al. 2008), and the remainder of the STSP area (named the Stewart-Snares shelf subarea and corresponding to the squid fishery area SSTEW in Baird & Smith 2007, excluding the Otago coast subarea) (see Figure E1). Because of the problem of assigning CELR tows to subareas, the Otago coast subarea was set to the statistical area 026, which includes all positions with longitudes between 169º E and 171º E and latitudes between 46º 03´ S and 47º 01´ S. The Puysegur subarea includes all positions in STSP west of a line joining the point 47º 30´ S and 166º E with the point 45º 24´ S and 167º 30´ E and north of 47º 06´ S. The unshaded Stewart-Snares shelf subarea in Figure E1 is the base level of the *subarea* factor.

The model was fitted using a burn in of 100 000 iterations and a further 100 000 iterations of which every 20th iteration was retained. This gave a sample of 5000 iterations from the joint posterior distribution of the model parameters. The model fit appeared to be satisfactory because the predicted frequencies of fur seal captures per tow coincided well with the observed frequencies (Table E2).

The posterior distributions of the parameters of the fitted model had relatively small dispersion characteristics (Table E3), reflecting the relatively large numbers of observed tows and captures. For the effects associated with factor covariates (base capture rates, *DN*, *subarea*, and *targ.g*), the c.v.s were of moderate size (all less than 40%, but most less than 30%). Both of the 95% credibility intervals for the sine and cosine parameter coefficients associated with *day.no* excluded zero, with zero more than 3 standard deviations away from the nearest limit in both cases, which suggests that capture rate is strongly associated with day of the fishing year. The periodic *day.no* covariate has a peak multiplicative effect of about 4 occurring in mid August and the trough multiplicative effect of 0.25 in mid February.

2.5.5 West coast South Island area (WCSI)

There are some changes to the spatial extent of the WCSI area compared with the HWCSI hoki fishery area of Baird & Smith (2007). These changes are in the north and were the consequence of including tows recorded on CELR forms. The spatial extent of the WCSI area includes all points inside the EEZ, west of the South Island, with latitudes north of 45º 30´ S and south of 40º S, and with longitudes west of 172º 41´ E (the western boundary of statistical area 036) (Figures A1 and F1). It was necessary to use non-spatial rules to assign the unobserved tows reported from statistical areas 031, 036, and 703 (but with no start position coordinates) to the WCSI area or not (see Section 2.6).

Tows targeting all species were included in the WCSI area. The jack mackerels were separated from the other mid depth species because they are the second largest mid depth fishery (see Table A3) in the WCSI area over the 12 years. The groups in the *targ.g* factor are:

shallow	species targeted in the shallower depths,
mid depth	(base level) species, other than JMA, targeted in the middle depths,
jack mack	jack mackerels (JMA),
deep	species targeted in the deep.

In the observer coverage for the WCSI area, the hoki fishery is over represented with 83% of the observed tows, while the hoki fishery is less than 40% of the unobserved tows (Table A3 and Figure F2, where the mid depth target group is mostly hoki). This fishery will contribute most to the parameter estimates in any model, because models are fitted to the observer data. Mormede et al. (2008) analysed the west coast South Island hoki observer data and found that, for the core fleet, the variables *DN*, region (their subarea factor), and log(*duration*) were important in explaining the greatest reduction in deviance. They also found that fishing year and vessel were important and these variables were incorporated in our season and vessel-season random effects. We added the *targ.g*. factor and defined a *subarea* factor in a similar way to their region factor. The covariate component of the model we used for predicting fur seal captures in the WCSI area was:

$$DN + subarea + targ.g + \log(duration).$$

We defined the *subarea* factor as follows, taking note of the region factor used by Mormede et al. (2008) for the hoki fishery. Firstly, because the deep species group also defines a subarea with limited spatial overlap with other target species in the WCSI area, we defined a deep subarea to be all tows in the deep group of *targ.g*. Thus, deep is a common level to both the *targ.g* and subarea factors but cannot be treated as a level for both factors in the fitting of the model. The remaining (non-deep) tows, which target shallow, mid depth, or jack mackerel species groups, were then assigned to 3 subarea groups with boundaries defined by the latitudes separating statistical areas 034, and 035, and 036, which are 41º 45´ S and 40º 47´ S, respectively. The three subarea groups are named Hokitika Canyon, Cape Foulwind, and northern, going from south to north (see Figure F1). The base level group for model fitting is Hokitika Canyon. Initially we bounded Hokitika Canyon in the south by 44º 01´ S, which defined a fourth, more southern group. However, there were so few non-deep tows (observed or unobserved) in the fourth group that the two southern groups were amalgamated. The effect for tows in the separate deep group is relative to tows in both the Hokitika Canyon subarea and the mid depth target group.

The model was fitted using a burn in of 100 000 iterations and a further 100 000 iterations of which every 20^{th} iteration was retained. This gave a sample of 5000 iterations from the joint posterior distribution of the model parameters. The model fit appeared to be satisfactory because the predicted frequencies of fur seal captures per tow coincided well with the observed frequencies (Table F2).

The posterior distributions of the parameters of the fitted model had relatively small dispersion characteristics (Table F3), again reflecting the relatively large amount of observed tows and captures. For the effects associated with factor covariates (base capture rates, *DN*, *subarea*, and *targ.g*), the c.v.s were generally of moderate size (with all less than 40% except for the northern subarea effect). The 95% credibility interval for the log(*duration*) parameter coefficient excludes zero, with zero nearly 3 standard deviations away from the nearest limit, which suggests that capture rate is strongly associated with *duration*. The capture rate increases approximately with the square root of the *duration* (posterior mean of the coefficient is close to 0.5).

2.5.6 Southern blue whiting fishery area (SBW6)

This fishery is exactly the same fishery area that was used in Baird & Smith (2007). This fishery area represents the confined nature of the southern blue whiting fishery in both space and time of year (August to October include over 97% of the effort) and the good observer coverage. All tows were recorded on TCEPR forms.

The SBW6 fishery fishing year was defined as between 1 April and 31 March after the southern stocks of this species were included in the Quota Management System in late 1999 (Ministry of Fisheries 2008). In this report, we defined a season variable that was different from both the generic fishing year (1 October–30 September) and the SBW6 fishing year. Thus, for this analysis, each season starts on 1 July and overlaps two (generic) fishing years, because the main fishery finishes around the end of October. Consequently, there are 13 levels for the season random factor giving rise to 13 base capture rate coefficients (Table G3). For predicting total captures for the 1994–95 fishing year for example, the 1994 or 1995 base capture effects were both used, depending on whether the unobserved tows were before or after 1 July 1995.

The spatial extent of SBW6 was defined by the positions of all tows targeting southern blue whiting in the 12 years of this study (Figure G1). We used the same distinct fishing subareas as Baird & Smith (2007), namely: Auckland Islands (6A), Campbell Rise (6I), Pukaki Rise (6R), and Bounty Plateau (6B). Baird & Smith (2007) found that the capture rate in the Bounty Plateau subarea (6B) was much greater than for the other subareas. A high proportion of the observed fishing effort (80%) and commercial tows effort (83%) was concentrated in the Campbell Rise subarea and this was used as the base level of the *subarea* factor. The covariate component used to predict fur seal captures in the SBW6 fishery area was:

DN + *gear* + *subarea* + log(*duration*) + log(*d.shore*).

This was the same as that used by Baird & Smith (2007), except that it used four *subarea* groups compared with the two groups (Bounty Plateau (6B) and the rest) used in the previous modelling. A comparison of the 4-level and 2-level *subarea* factors showed that the fit with the 2-level factor was not as good because the DIC increased and the extra-dispersion variance increased very slightly. The *d.shore* variable in the SBW6 area measures the distance from the nearest land. The gear effect was for bottom trawl nets relative to the use of midwater nets.

The model was fitted using a burn in of 100 000 iterations and a further 100 000 iterations of which every 20th iteration was retained. This gave a sample of 5000 iterations from the joint posterior distribution of the model parameters. The model fit appeared to be satisfactory as the predicted frequencies of fur seal captures per tow coincided well with the observed frequencies (Table G2).

The posterior distributions of the parameters of the fitted model had relatively small dispersion characteristics (Table G3), again reflecting the relatively large amount of observed tows and captures. Note that a season base capture rate for 1994 is included because of the overlap with fishing years. For the effects associated with the fixed factor covariates (base capture rates, *DN*, *gear*, and *subarea*), the c.v.s were generally of moderate size (with all less than 50% except for the Auckland Islands and subarea effects). There is a greatly increased capture rate (a multiplicative factor of nearly 40 times) for fishing in the Bounty Plateau subarea relative to fishing on the Campbell Rise subarea. However, the size of this effect will be a little inflated to compensate for the *d.shore* coefficient, which is positive and therefore reduces the capture rates for tows in the Bounty Plateau subarea because they are generally closer to land than they are in the other subareas. Because of the differences between the proportions of observed and unobserved tows in the Bounty Plateau subarea, the size of its effect will be very important for adjusting predicted capture rates. Both of the 95% credibility intervals for parameter coefficients associated with continuous covariates *duration* and *d.shore* excluded zero, which suggests that capture rate is associated with both.

2.6 Treatment of missing values in the unobserved data

2.6.1 Missing position values

There were two problems associated with missing position data: assigning tows to the six fishery areas to be modelled and assigning tows to subareas within a fishery area. First, we describe the manner in which tows with problematic position data were assigned to an area. The unobserved tows in the commercial data are used in the model-based prediction method and before a commercial tow can be classified as unobserved it has to be assigned to one of the six areas or determined to be outside of those areas. For most of the commercial data this presents no difficulty. All tows have either start position coordinates or statistical areas and it is only tows which have missing start coordinates or belong to a statistical area overlapping an area boundary that have to be assigned to areas using some other rule. This occurs at the boundary between the STSP and WCSI areas and at the northern boundary (latitude 40º S) of the WCSI area.

Because the northern boundary of STSP area with the WCSI area (latitude 45º 30´ S) passes through the middle of statistical area 031, tows appearing in CELR records without latitude coordinates had to be assigned to either STSP or WCSI by another rule. For commercial tows in statistical area 031 with latitudes recorded, 183 of the 186 tows north of 45º 30´ S targeted deep species, whereas only 5 of the 423 tows south of 45º 30´ S targeted deep species. Therefore, of the 414 tows in statistical area 031 with missing coordinates, the 9 tows targeting deep species were assigned to WCSI and the remaining 405 tows were assigned to STSP. The effect of any wrongly assigned tows will be negligible on the fur seal capture predictions for either area because of the small number of reassigned tows.

The northern boundary of WCSI (latitude 40º S) passes through the centre of statistical areas 036 and 703, the two statistical areas affected that included CELR tows with missing start latitudes. We were unable to formulate a decision rule for separating tows in 036 and 703 into those north or south of 40º S because the TCEPR commercial tow dataset was limited to tows south of 40° S. Consequently, all 4339 unobserved tows without latitude coordinates in 036 and all 32 tows without latitude coordinates in 703 were assigned to the WCSI area. All but 11 of those tows in 036 and 9 of those in 703 targeted shallow species.

Second, we describe the way in which unobserved tows with missing start coordinates were assigned to subareas. This presented a problem only for the *subarea* covariate factor in the STSP area, because it is the only area where a statistical area overlaps two subareas. For unobserved tows in the STSP area with missing coordinates, the statistical areas 025, 027, 028, and 029 are all part of the Stewart-Snares shelf subarea and the unobserved tows in statistical area 031 belong in the Puysegur subarea. However, the statistical area 030 is divided by the boundary between the Puysegur and Stewart-Snares shelf subareas and further criteria were needed to assign unobserved tows in 030 to a subarea. Tows in statistical area 030 without coordinates were assigned between the two subareas by target species, on the basis of the subarea that commercial tows with starting coordinates belonged to. The 30 139 tows in statistical area 030 with one or both coordinates missing were recorded on CELR forms, 49.7% targeted flatfish, and 43.6% targeted stargazers. Tows targeting scampi (424 tows), ling (323), spiny dogfish (119), red cod (92), orange roughy (4), or blue cod (3) were assigned to Puysegur and all other tows (all targeting shallow species) were assigned to Stewart-Snares shelf.

Among the commercial tows in statistical area 030 that had start coordinates recorded (13 429 tows), this rule would have wrongly assigned to the Puysegur subarea: 217 of 535 scampi tows, 8 of 520 ling tows, 7 of 533 orange roughy tows, and 1 of 590 red cod tows; and wrongly assigned to the Stewart-Snares shelf subarea: 15 of 121 barracouta tows and 135 of 507 stargazer tows. Most of the tows (93%) with start coordinates were recorded on TCEPR forms and therefore may not be very representative of the tows with missing coordinates, all of which were recorded on CELR forms, and probably from smaller vessels. The largest effect on predicted captures from incorrect assignment of subarea is likely to be from wrongly assigning tows targeting stargazer to the Stewart-Snares shelf (instead of to the Puysegur subarea). The effect is likely to be reduced because smaller vessels are less likely to fish in the Puysegur subarea because of the distance from the nearest fishing port (Bluff). The Puysegur subarea effect, relative to Stewart-Snares shelf, is greater than one (Table E3); consequently, wrongly assigning tows with missing coordinates in this manner is likely to lead to reduced predicted fur seal capture numbers.

2.6.2 Other missing covariate values

It was also necessary, for each area, to assign or impute covariate values that could not be calculated directly because the values of certain variables were still missing from some unobserved tows after the grooming process. However, the *day.no* covariate was unaffected in this way because all start dates were present in the records for all unobserved tows.

It was not possible to calculate the values of the *DN* factor for any CELR recorded tows because start time and end time data were not collected on these forms. Therefore all CELR tows were assigned the day level for *DN*. The effect of wrongly assigning the day level in the four coastal areas would be to reduce the predicted captures because all the *DN* effects, relative to day, are greater than 1 (see Tables B3, C3, E3, and F3). For the few unobserved TCEPR tows with missing end times or missing end coordinates, it was generally possible to impute the level of *DN* from adjacent tows or, otherwise, an assumption was made about the likely end time.

Missing values for the *duration* covariate in CELR tows were replaced by the average tow duration for the record (the total duration divided by the number of tows in the record) with a quarter hour added. For the few unobserved TCEPR recorded tows with missing end times, in most cases, it was possible, as for the *DN* covariate, to impute the *duration* from adjacent tow start and end times or, otherwise, an assumption was made about the likely end time and a quarter hour was added.

The *d.shore* covariate was used only in the models for the CHAT and SBW6 areas and, of these, only the CHAT area had tows recorded on CELR forms. For the unobserved CELR tows, missing values for *d.shore* were replaced by the median of *d.shore* for tows with the same target group in the same statistical area.

The few missing values for the *gear* covariate were replaced by the net type used by the same vessel for tows on adjacent dates. Most missing values for target species in the unobserved data were substituted for during the grooming process. Missing values for *targ.g* were assigned the majority target group for tows by the vessel on adjacent dates in the same statistical area.

3. RESULTS

3.1 Predicted fur seal captures

In this section we report the predicted fur seal captures and the predicted strike rates for the six modelled fishery areas and for the areas combined (trawl effort south of 40º S).

3.1.1 East coast Wairarapa and Cook Strait area (ECCO)

Fur seal captures for the ECCO area were difficult to predict from the available observer data because the observer data were unrepresentative of the total unobserved fishing effort. The relative proportions of observed and unobserved tows by target group and day of fishing year differ markedly (Figure B2). Most of the unobserved effort was divided between mid depth and shallow groups, whereas the observed effort was concentrated primarily at the mid depth target group, with little coverage of shallow tows; and observed tows were concentrated in July–September, whereas the unobserved effort was more evenly dispersed throughout the year. The model-based prediction method adjusts the capture estimates for differences between observed and unobserved tows, but there are some limitations when there are groupings. The area also has a large proportion of tows recorded on CELR forms (53%, Table B4), but very few were observed (only 5% of observed tows, Table B4).

Differences between the proportions of observed and unobserved tows among the more commonly targeted shallow group species are very apparent in the ECCO area (Table A3). For tows targeting shallow species, 52 tows were observed (2.5% of all observed tows and no captures were observed). Of the unobserved tows, 44% targeted shallow species so the lack of any real capture information for shallow target species meant that there were large uncertainties associated with the predictions for this area.

Predicted fur seal captures in the ECCO area varied between 30 and 292 over the fishing years (ignoring the very large predicted number of captures for the 1996–97 fishing year) (Table B4). The 1996–97 fishing year had the greatest number of tows (14 490) and yet only 9 were observed. As a consequence, a very large standard deviation was associated with the 1997 base capture rate (Table B3) and this resulted in a highly skewed predictive distribution (see Figure B3) for the 1997 total captures. When a distribution is highly skewed to the right the mean is very inflated compared with the median, in this case 606 compared with 179. The same was true, to a lesser extent, for the 1994–95 fishing year where the mean of the predictive distribution of the number of captures was 163 and the median 66. The predictive c.v.s are greater than 80% in the years when there was either 0 or 1 observed fur seal capture, confirming that it is primarily the observed number of captures rather than the observed number of tows that determines the accuracy of predicted captures. The predicted total fur seal captures in the ECCO area over the 12 fishing years was 2105, but this is inflated by the two fishing years with virtually no observer coverage. If the data for these two years are ignored, the total number of predicted captures is 1336.

Annual predicted strike rates reveal trends and are not affected by any annual variations in the amounts of effort. They are not standardised indices though, because they may reflect different fishing practices (which may have different capture rates) or different vessels fishing in the different years. The predicted strike rates are plotted, together with their 95% prediction intervals, to show any trends (Figure B4). Other than the strike rate in 1996–97, the trend was relatively flat until the last two years when there seems to have been a real increase in the strike rate. The 2004–05 and 2005–06 predicted strike rates are each significantly different from the all strike rates other than the 1994–95, 1995–96, 1996–97, and the 2001–02 predicted strike rates. The 2001–02 predicted strike rate is significantly different from each of the 1997–98, 1999–2000, and the 2003–04 predicted strike rates. No other pairs of predicted strike rates are significantly different. Here, we say two predicted strike rates are significantly different if the 95% prediction interval for the difference between the two strike rates excludes zero.

The predicted total captures for the 2004–05 and 2005–06 years are larger than those for any of the predicted captures in the preceding years other than 1996–97 (Table B4). Nevertheless, the predictive method has made large adjustments to the predicted total compared with the ratio estimates. This has occurred because a high proportion of the total observed captures was made by a single vessel in each of the two years. The inclusion of vessel-season random effects in the model meant that the high capture rates for the two vessels were not applied to unobserved tows by other vessels in the ECCO area.

Because of the influence of the hoki fishery in the ECCO area, predictions were made of captures and strike rates for the ECCO hoki fishery (all tows targeting hoki) (see Table B5). The same problems with lack of observer coverage applied equally to the hoki fishery. It was clear that a very large proportion of the predicted fur seal captures in the ECCO area came from the hoki fishery. The trends in the hoki fishery strike rates (Figure B5) mimic those for all targets in the area, only scaled by a factor of about 2 because about half the effort targets hoki.

In the observer data, 15% of fur seals captured in the ECCO area were released alive. Most fur seal capture incidents caught one fur seal, though up to four animals were observed caught per tow (Table B2).

3.1.2 Chatham Rise area (CHAT)

Over the 12-year period, effort has reduced from a high of 51 310 tows in 1997–98 to a low of 29 990 tows in 2005–06 (Table C1). Similar numbers of tows were reported from both form types each fishing year, with 49% of the total dataset effort reported on CELR forms. The annual observer coverage varied from between 2.3% and 6.2%, and reasonable numbers of observed captures in each fishing year, ensured that the c.v.s for the predicted captures and strike rates were not as large for CHAT as for some other areas, ECCO in particular.

The observer coverage was reasonably representative for the *gear* and *day.no* covariates, less representative for the *DN* factor covariate, and non-representative for the *targ.g* and *d.shore* covariates (Figure C2). There were particularly large discrepancies between the proportions of observed and unobserved target groups: a few percent of observed tows targeted shallow species compared with more than 50% of unobserved tows, whereas most observer coverage targeted mid depth species (over 50%) and deep species (about 40%). A finer breakdown of target species between observed and unobserved tows is given in Table A3. It is the discrepancy in the observed and unobserved proportions of tows targeting shallow species that is the main contribution to the peak, at small distances, in the unobserved *d.shore* density plot (Figure C2). The model-based approach will correct for the discrepancies in observer coverage, but there is concern that the shallow target species effect was not estimated with any accuracy because few tows targeting shallow species were observed. This concern occurs in the four areas where CELRs were used because they all share the problem of the large discrepancy between observed and unobserved proportions of tows targeting shallow species.

Predicted fur seal captures over the 12 fishing years varied between 721 in 1996–97 and 208 in 2005–06 with 4700 captures in total. All c.v.s were 55% or less (Table C4). Total fishing effort dropped over the 12 year period so there is more variation in the total captures than in the predicted strike rates. Plots of the predictive distributions of the total captures are unremarkable, though the greater accuracy since the 1999–2000 fishing year is obvious (Figure C3). The predicted strike rates varied between 0.7% and 1.6% and the series appears to show lower strike rates in the second half of the time series, though the c.v.s are large enough for any trend to be not significant (Figure C4). However, the 1996–97 predicted strike rate is significantly different from the predicted 1999–2000, 2001–02, and 2005–06 strike rates. No other pairs of predicted strike rates are significantly different.

Total captures and strike rates were also predicted for the hoki fishery in CHAT (Table C5 and Figure C5). This fishery accounted for less than 40% of the predicted captures in the CHAT area. The predicted strike rates for the hoki fishery were greater than for all targets and also show larger values in the earlier years and the most recent years (Figure C5). There also appears to be an increasing trend in recent years but any apparent trends are not significant because of the size of the c.v.s.

In the observer data, 28% of fur seals captured in the CHAT area were released alive. Most fur seal incidents caught 1 fur seal (table C2).

3.1.3 Sub-Antarctic area (SANT)

Fishing in the SANT area targets mid depth and deep species (only 1% of tows targeted shallow species, Table A3) and no trawl effort was recorded by vessels using CELR forms in the 12 years studied. Total effort remained reasonably constant over the years, varying between about 4000 and almost 7000 tows, with no obvious trend (Table D1). However, a smaller number of vessels was responsible for the effort in recent years. Vessel numbers dropped from 76 in 1994–95 to 47 in 2005–06.

Observer coverage averaged 16% over the 12 years and was reasonably representative for the four covariates used in the model, *DN*, *gear*, *targ.g*, and *duration* (Figure D2). Only the proportions of observed and unobserved tows for the squid and scampi target groups differ greatly. However, the spatial distribution of observer coverage does vary between years (Figure D1).

Predicted captures varied between 21 in the 1999–2000 fishing year and 65 in the 2001–02 fishing year (Table D4). A total of 490 fur seal captures was predicted for the 12 years of the study. The c.v.s are quite large because of the relatively few captures observed in each year. The relatively high uncertainties in some years are also obvious in the spread of the plots of the predictive densities of the total captures (Figure D3). Predicted strike rates show a little less variation (between 0.4% and 1.0%, Table D4), but any apparent trends are not significant because of the large uncertainty, as shown by the 95% prediction intervals (Figure D4). No pairs of predicted strike rates are significantly different.

In the SANT area, 39% of all tows targeted squid and predicted captures and strike rates were calculated for the 12 fishing years for this fishery. Predicted fur seal captures from the squid fishery varied between 1 and 36, and the predicted strike rates appear lower in the later years but not significantly so (Table D5). The c.v.s are generally smaller than for all target species (except for years when no captures were observed) because of the higher observer coverage. This is especially so in 2000–01 when there was 97.5% observer coverage in the squid fishery.

Fur seals are captured in the subantarctic hoki fishery and predicted total captures and strike rates have been obtained for theses fisheries (Table D6).

In the observer data, 19% of fur seals captured in the SANT area were released alive. Most observed incidents caught one fur seal (Table D2).

3.1.4 Stewart-Snares shelf and Puysegur area (STSP)

In the 12 year period, 45% of tows were recorded on CELR forms (Table E1) and most of these targeted shallow species (99% of all CELR recorded tows, Table A3)). Flatfish, in particular, were the target of 77% of CELR tows and the target of 35% of all commercial tows. Commercial effort has dropped over the years from a high of 21 331 tows in 1996–97 to 16 312 tows in 2005–06, but most of the reduction has occurred in tows recorded on TCEPR forms. The numbers of vessels fishing in the STSP area has also dropped over the years, particularly of vessels using TCEPR forms.

Observer coverage in STSP over the 12 years varied between 2.8% in 1995–96 and more than 16% in 2000–01, though coverage in 8 years from 1998–99 was 8% or more, low compared with some of the other areas. Most observed tows targeted either squid or other mid depth species, as reflected in the distribution of observed tows (Table A3 and Figures E1 & E2). No CELR tows were observed (Table E4). It is apparent that the observer coverage is not very representative (Figure E2) for the factor *subarea* (few observed tows in the Otago coast subarea), the target group factor *targ.g*, and the time of year variable *day.no* (observed tows more concentrated in the first half of calendar year). The model-based approach corrects the predicted captures and strike rates, to some extent, for the non-representativeness of observer coverage in the model covariates.

Predicted fur seal captures in the STSP area varied from under 400 for each of the years 2002–03 to 2005–06 to over 1100 in each of 1997–98 and 1998–99 (Table E4). The c.v.s are reasonably constant over the years at about 40%. Plots of the densities of the predictive distributions are unremarkable (Figure E3). Predicted strike rates vary between 1.7% and 5.4% and show an apparent downward trend since the 1998–99 year with the four lowest strike rates occurring in the last four years (Figure E4). The trend is unlikely to be significant because of the relatively large c.v.s (Table E4). The 1997–98 and 1998–99 predicted strike rates are each significantly different from the strike rates other than the 1994–95, 1995–96, 1996–97, and the 2002–03 predicted strike rates. Other pairs of predicted strike rates that are significantly different are: the 1997–98 and 1996–97 predicted strike rates, the 1998–99 and 2002–03 predicted strike rates, and the 2001–02 and 2002–03 predicted strike rates. No other pairs of predicted strike rates are significantly different.

The squid fishery is an important fishery in the STSP area and total captures and strike rates were also predicted for all tows targeting squid (Table E5). This fishery accounted for 40% of the effort and 22% of the predicted captures. The predicted strike rates for the squid fishery were similar to those for all targets, but showed more variation between years (Figure E5). The strike rates show a trend downwards from the 1997–98 year.

Fur seals are captured in the Puysegur and Stewart/Snares hoki fisheries and predicted total captures and strike rates have been obtained for theses fisheries (Tables E6 and E7).

In the observer data, 19% of fur seals captured in the STSP area were released alive. Most fur seal incidents caught one fur seal, with the maximum number of four fur seals per observed tow (Table E2).

3.1.5 West coast South Island area (WCSI)

In the period of this study 50% of all tows in the WCSI were recorded on CELR forms (Table F1) and most of these tows (91%) targeted shallow species (Table A3). Effort in the WCSI area dropped over the years from a high of 22 362 tows in 1996–97 to the low of 13 609 tows in 2005–06. There was also a corresponding drop in the numbers of vessels fishing in the area, from 81 in 1994–95 to 40 in 2005–06.
Observer coverage in the WCSI area varied between 4.7% in 1994–95 and 9.2% in 2001–02 (Table F1). Relatively large numbers of captures were observed each year. No tows recorded on CELR forms were observed (Table F4). Coverage was reasonably representative for the *subarea* factor and for the tow duration covariate (Figure F2). However, there were differences between the proportions of observed and unobserved tows for the levels of the *DN* factor and large differences for the shallow and mid depth target species, primarily due to the influence of the CELR data in the unobserved tows.

With the large amount of annual fishing effort, relatively high strike rates, and proximity of the fishing activity to numerous fur seal haulouts and rookeries, this area has historically been regarded as the region where the largest numbers of fur seals are captured in trawl fishing gear. This status for the region is confirmed by the model-based predicted fur seal captures for the WCSI area. For the 12 years, the predicted fur seal captures, for all target species combined, varied annually between 1840 in 1995–96 and 573 in 2005–06 and totalled 18 908 (Table F4). The c.v.s for the annual totals are relatively small (smaller than the other four multi-target areas), with most in the range of 30–40%, and a c.v. of 20% for the total captures for all years. The density plots of the predictive distributions exhibit similar right skewed shapes with differences, over the years, among the mean predicted captures and their standard deviation (Figure F3). Predicted strike rates varied between 10.2% in 1995–96 and 4.2% in 1994–95 and 2005–06. After the peak in 1995–96, the strike rate series shows a downward trend (Figure F4). With c.v.s around 40% and positive correlation between years, this is unlikely to be significant. However, the 1995–96 strike rate is significantly different from each of the strike rates for 1994–95, 1998–99, 2001–02, 2002–03, 2003–04, and 2005–06. No other pairs of strike rates are significantly different in the WCSI area.

The hoki fishery accounted for 42% of the WCSI tows, 83% of the observed tows, and 85% of observed fur seal captures over the 12 years. Predicted captures for tows targeting hoki varied between 710 in 1995–96 and 96 in 2005–06 and totalled 4485 (Table F5). The c.v.s are smaller than for the captures from all tows, which is to be expected because a high proportion of the observed tows targeted hoki (Table A3). Predicted strike rates for the hoki fishery are smaller than those for all targets because the shallow species group was the target for over 50% of the unobserved tows (Table A3) and the model effect for the group is more than 2.6 relative to the mid depth group (Table F3). The strike rates for the hoki fishery varied between 9.4% in 1995–96 and 2.7% in 2005–06 (Table F5). The apparent downward trend in the hoki strike rate series reflects the influence of the hoki fishery on the strike rate (Figure F5).

In the observer data, 6% of fur seals captured in the WCSI area were released alive. Although most fur seal incidents were of 1 animal, this area had a higher proportion of multiple captures per tow compared with all other areas except SBW6, with a maximum of 12 animals in one tow (Table F2). Since 2002–03, no more than 4 fur seals were observed per tow.

3.1.6 Southern blue whiting fishery area (SBW6)

The effort in the SBW6 fishery area is confined mainly to July to October and all tows were recorded on TCEPR forms (Table G1). Between 9 and 14 vessels reported effort during 1997–98 to 2001–02, and in other years 4–7 vessels were in the fishery. The fishing effort remained reasonably steady (around 500–800 tows) over the 12 year period except for 3 years of relatively high effort of over 1100 tows (1997–98, 1998–99, and 2001–02).

Observer coverage in SBW6 was higher on average (37%) than for any of the other areas, and varied between 28% in 1998–99 and 58% in 2000–01 (Table G1). Over the 12 fishing years the observer coverage was reasonably representative (Figure G2). However, the spatial coverage differed among the 12 years (Figure G1). In particular, the observer coverage in the Bounty Plateau subarea was much higher than it was in the whole of SBW6 in the 1994–95, 1997–98, 2000–01, and 2005–06 fishing years and much lower than in the whole of SBW6 in the 2001–02, 2002–03, and 2003–04 fishing years. As a result of these discrepancies, major adjustments would have been made to the predicted captures and strike rates from the observed captures and strike rates for the different fishing years (Table G4).

Predicted total fur seal captures in the SBW6 fishery area averaged more than 100 per year and varied between 49 in 2003–04 and 200 in 1998–99. Density plots of the predicted captures illustrate the variation between years (Figure G3). Total predicted captures for the 12 years numbered 1237. Predicted strike rates varied considerably between 28% in 1994–95 and 6.7% in 2003–04. Much of this was due to variation among the fishing years in the proportions of tows in the high capture rate Bounty Rise subarea. The c.v.s of both the predicted captures and the strike rates are the smallest for any of the areas, reflecting the relatively high observer coverage. There is some evidence of a downward trend in the predicted strike rates (Figure G4), but little can be inferred because the sizes of the strike rates mainly reflect the proportions of tows in the Bounty Plateau subarea. The years with the six highest proportions of tows in the Bounty Plateau subarea are exactly the years with the six highest strike rates. Predicted strike rates are not standardised in the sense of standardised catch per unit effort indices. The base capture rate parameters (Table G3) on the other hand, are open to interpretation as standardised relative strike rates. These show much smaller variation.

In the observer data, 2% of fur seals captured in the SBW6 fishery area were released alive. Up to 22 fur seals were reported per tow in SBW6 and in most years this area had the highest proportion of multiple capture tows relative to single capture tows than any of the other areas.

3.1.7 Total fur seal captures south of 40º S

The main purpose of this work was to produce a 12 year series of predicted total fur seal captures and of predicted strike rates from trawl fishing in the EEZ south of latitude 40º S. To achieve this for each fishing year, the mean annual predicted captures from each of the five multi-target species areas and from the southern blue whiting fishery (SBW6) were added together to give the predicted mean captures. The mean predicted strike rate for tows in the six modelled areas was the mean total captures divided by the total tows. The five multi-target areas (and SBW6) do not cover the whole of the EEZ south of 40º S (Figure A2, lower panel). In the 12 years, nearly 2500 tows were observed in the region south of 40º S but outside the study area and no fur seal captures were observed (Table A4). The observer coverage in the outside region was less than 2% in the 12 year period because there were more than 118 000 commercial tows (Table A1). It was assumed therefore, that no fur seals were caught in the outside region and consequently the mean predicted total captures for the modelled areas are assumed to be the totals for all fishing in the EEZ south of 40º S. However, the strike rates apply to all tows within the six modelled areas only.

Total predicted fur seal captures in New Zealand waters south of 40º S varied between 1375 in 2003–04 and 3710 in 1996–97 (Table A5). Most c.v.s are in the range of 20–24%, but the c.v.s for 1994–95 and 1996–97 are inflated because of the very large c.v.s for the predicted captures in the ECCO area in those years. The mean total predicted captures for those years will also be inflated in those years because of the highly skewed predictive distributions in the ECCO area (Figure B3). The predicted total captures series appears to trend downwards over the years, but the total commercial tows also have a strong downward trend (see Table A1) and much of the trend in total captures is due to this. The predicted total captures for the 12 years in total was 28 450 with a c.v. of 15%.

The overall strike rate for the six areas varied between 3.4% in 1996–97 and 1.6% in 2002–03, with c.v.s less than 25%, except for 1994–95 and 1996–97 (Table A5). There is some evidence of a downward trend in the overall predicted strike rates, because the strike rates are lower in the second half of the series. The overall predicted strike rate covering all six areas and all twelve years is 2.5% with a c.v. of 15%.
In the observer data, an estimated 14% of fur seals captured inside the EEZ south of 40º S were released alive, based on an average weighted over the areas by the predicted total capture numbers given in Table A5.

3.2 Fur seal captures observed in trawl fishing north of 40º S

A total of 6862 tows was observed in the 12 years, north of 40º S and within the EEZ (Table A6). Eleven fur seal captures were observed (six captures from six tows in 2004–05 and five captures from four tows in 2005–06). All were off the west coast of the North Island (Figure A1). Nine of the captures occurred on tows targeting jack mackerels and two occurred on tows targeting barracouta.

Outside the New Zealand EEZ, one fur seal capture was observed in 2005–06 on a tow targeting orange roughy on a seamount in the Louisville chain (Figure A1).

4. DISCUSSION

The use of the model-based prediction method takes care of two shortcomings of the ratio estimate method used in earlier work. The method results in more realistic estimates of the dispersion in the capture estimates because they include the contribution from correlation in capture rate among tows by the same vessel. More important though is that the method adjusts for differences between the observer data and unobserved data in covariates that have been included in the models and therefore compensates, in some part, for the non-representativeness of the observer coverage. Because the observer coverage was very unrepresentative in relation to the target species, it would not have been feasible to use ratio estimators of total captures in the five multi-target species areas. For reference, the ratio estimates were included in the tables giving the predicted total captures, and the twelve year totals differ considerably for the ECCO area (Table B4), the STSP area (Table E4), and the WCSI area (Table F4). There is also a more than 50% difference between the ratio estimated and the predicted 12 year totals for the squid fishery in the STSP area (Table E5).

Application of the model-based prediction method has enabled us to extend the prediction of fur seal captures to all fishing in New Zealand waters south of 40º S. In earlier work (Baird & Smith 2007), predictions were made only for specific fisheries restricted by target species and area, which covered a small proportion of the fishing effort (mainly the middle depth fisheries that were primarily targeted for observer coverage). In our approach, we have divided the sub 40º S region into five areas covering all target species (except SBW) and one area covering all tows targeting SBW for fitting models and predicting captures. The extension of the models to include all target species has meant that more data were available for fitting, which generally means better fitted models. However, the very large differences between the observed and unobserved proportions of different sized vessels (as indicated by whether tows were recorded in the commercial data on TCEPR or CELR forms, Tables A3, B4, C4, E4, and F4) and also the corresponding differences among the proportions of target species groups (also apparent from Table A3) is likely to be problematic when predicting captures for unobserved tows, particularly in the four areas with coastal waters adjacent to the South Island. The use of the target group covariate in the models helps correct for these differences by scaling by the target group effects. Of necessity the shallow target group includes a number of species (Table A2), some of which are the target of very few or no observed tows in the area (Table A3). Little is known about the fur seal capture rates for tows targeting these species, and for the prediction procedure all unobserved tows targeting shallow species were scaled by the same effect irrespective of the particular shallow species. This extrapolation needs to be acknowledged as a very real source of possible bias in the prediction of total fur seal captures.

The tows targeting the species of all flatfish are particularly susceptible to this problem. In the four areas with waters adjacent to the South Island, not only are there large numbers of unobserved tows targeting flatfish (16% of all unobserved tows in ECCO, 24% in CHAT, 38% in STSP, and 28% in WCSI, Table A3), but no observed tows targeted flatfish (apart from the 13 flatfish observed tows in the CHAT area). Almost all flatfish tows are recorded on CELR forms, which are returned by the smaller vessels using the smallest nets in commercial fishing operations and occur in the shallowest depths, usually less than 30 m deep. It is not known whether any unobserved flatfish tows have caught a fur seal. It seems therefore that the capture rate effect for flatfish tows is likely to be much smaller than for tows targeting barracouta, which comprises the greatest proportion of the observed tows in the shallow group and therefore contributes the most to the shallow group effects in the models.

As a sensitivity analysis, it was decided (on advice from the Aquatic Environment Working Group) to determine the effect of setting the capture rate for unobserved tows targeting flatfish to zero on the total predicted captures in the four areas with coastal waters. To do this it was not necessary to refit the models for the four areas to the observer data as, in three of the areas no observed tows targeted flatfish and in the fourth, CHAT, less than 0.06% of the observed tows targeted flatfish. Predicted total captures in the four areas were recalculated by setting the capture rate effect of the target group covariate to zero for unobserved tows targeting flatfish.

In the ECCO area, there was virtually no change to the mean total captures of the predictive distribution (comparing Table A7 with Table A5). This was to be expected because, in the ECCO area, no observed tow with a target species in the shallow group caught a fur seal and therefore the shallow group effect for the *targ.g* covariate is close to zero (Table B2). However, for the other three areas, the changes were much more dramatic. In the CHAT area, the mean of the predicted total captures over the 12 years dropped by 20% from 4688 to 3733, with the totals for each fishing year dropping by between 38 captures (in 2004–05) and 155 captures (in 1998–99). In the WCSI area, the mean of the predicted total captures over the twelve years dropped by 32% from 12 851 to 8758, with the totals for each fishing year dropping by between 193 captures (in 2003–04) and 648 captures (in 1996–97). Proportionally the reductions in the mean predicted captures were greatest in the STSP area (to be expected because the area had the largest proportion of tows targeting flatfish). The mean predicted total captures over the 12 years dropped by 44% from 7080 to 3965, with the totals for each fishing year dropping by between 146 captures (in 2005–06) and 506 captures (in 1997–98). The mean predicted total captures for all fishing south of 40º S over the 12 years dropped by 29% from 28 450 to 20 283, with the totals for each fishing year dropping by between 412 captures (in 2002–03) and 1063 captures (in 1997–98).

No modelling of live and dead captures was carried out. The overall estimate of proportion of fur seal captures that were released alive (14%) is an average weighted by the total predicted captures for each area. If, as might well be the case, target species is related to whether a captured fur seal is alive or not, then this estimate may not be the most accurate. As has been emphasised in the earlier paragraphs, the proportions of observed tows by target species group are very different from the proportions in the unobserved tows (Table A3) in the four areas adjacent to the South Island where most captures occurred. Other variables that might affect whether a captured fur seal is alive include depth of trawl, location, net type, and time of day.

Great care should be taken in interpreting the effects of the covariates because the covariates themselves are likely to be standing in for other important predictor variables for which no observer data have been collected throughout the time series (possible examples: fur seal abundance by time and location, climate variables, offal discharge, and fishing strategy). There are also some variables, which have observer data available, that have not been considered as covariates because there are no data available for the unobserved tows. The inclusion of a covariate in the model does not imply any cause and effect relationship between the covariate and fur seal captures, but only a statistical association between the covariate and capture rates.

5. ACKNOWLEDGMENT

This work was funded by the Ministry of Fisheries under project PRO2006/05, Objective 1.

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APPENDIX A: TABLES AND FIGURES RELATING TO NEW ZEALAND FUR SEAL CAPTURES FOR ALL AREAS

Table A1: Observed and commercial effort by fishing year for the six areas.

Observed tows

Year	ECCO	CHAT	SANT	STSP	WCSI	SBW6	All areas	Other*	Total
1994–95	53	1 857	417	703	932	240	4 202	824	5 026
1995–96	60	1 153	678	540	1 204	144	3 779	593	4 372
1996–97	9	1 028	1 019	882	998	249	4 185	593	4 778
1997–98	227	2 456	726	1 252	1 101	418	6 180	654	6 834
1998–99	376	1 862	477	1 724	1 585	342	6 366	892	7 258
1999–00	214	1 751	1 163	1 734	1 233	316	6 411	1 240	7 651
2000–01	279	2 597	994	3 181	1 298	388	8 737	378	9 115
2001–02	318	1 945	1 127	1 847	1 425	333	6 995	724	7 719
2002–03	149	2 138	882	1 525	1 014	279	5 987	853	6 840
2003–04	131	1 536	1 355	1 299	1 402	251	5 974	575	6 549
2004–05	157	1 927	1 243	2 015	1 245	337	6 924	788	7 712
2005–06	78	1 681	1 054	1 402	1 180	217	5 612	1 240	6 852
All	2 051	21 931	11 135	18 104	14 617	3 514	71 352	9 354	80 706

Commercial tows

Year	ECCO	CHAT	SANT	STSP	WCSI	SBW6	All areas	Other†	Total
1994–95	11 799	44 395	6 182	17 664	19 636	460	100 136	11 337	111 473
1995–96	14 393	42 975	6 972	19 014	18 080	583	102 017	11 083	113 100
1996–97	14 490	45 421	6 321	21 331	22 362	618	110 543	11 524	122 067
1997–98	11 207	51 310	4 595	20 691	17 750	1 181	106 734	11 499	118 233
1998–99	10 123	47 554	3 933	20 861	21 248	1 243	104 962	9 423	114 385
1999–00	9 477	43 562	5 706	17 345	16 930	694	93 714	8 744	102 458
2000–01	8 283	41 581	4 914	19 355	18 731	664	93 528	8 200	101 728
2001–02	7 046	36 011	6 635	19 326	15 511	1 159	85 688	9 444	95 132
2002–03	7 953	39 715	6 500	18 985	16 019	638	89 810	9 948	99 758
2003–04	7 783	32 867	6 840	16 898	15 406	740	80 534	9 708	90 242
2004–05	6 482	33 028	6 108	17 736	13 726	870	77 950	9 482	87 432
2005–06	4 991	29 990	5 189	16 312	13 609	623	70 714	7 736	78 450
All	114 027	488 409	69 895	225 518	209 008	9 473	1 116 330	118 128	1 234 458

* All observed tows inside the New Zealand EEZ and outside of the 6 areas.

† All TCEPR and CELR tows inside the EEZ, outside the 6 areas, and south of 40º S, except that none of the CELR tows in statistical area 014 are included in Other.

APPENDIX A – *continued*

Table A2: Target species groups by common name, scientific name, and code.

Group	Common name	Scientific name	Code
shallow	Albacore tuna	*Thunnus alalunga*	ALB
	Barracouta	*Thyrsites atun*	BAR
	Blue cod	*Parapercis colias*	BCO
	Blue shark	*Prionace glauca*	BWS
	Blue warehou	*Seriollela brama*	WAR
	Brill	*Colistium guntheri*	BRI
	Elephantfish	*Callorhinchus milii*	ELE
	Flatfish		FLA
	Frostfish	*Lepidopus caudatus*	FRO
	Hapuku	*Polyprion* spp.	HAP
	Gemfish	*Rexea solandri*	SKI
	Ghost shark	*Hydrolagus novaezealandiae , H. bemisi*	GSH
	John dory	*Zeus faber*	JDO
	Kahawai	*Arripis trutta*	KAH
	Leatherjacket	*Parika scaber*	LEA
	Lookdown dory	*Cyttus traversi*	LDO
	Moki	*Latridopsis ciliaris*	MOK
	Orange perch	*Lepidoperca aurantia*	OPE
	Queen scallop	*Chlamys delicatula*	QSC
	Ray's bream	*Brama brama*	RBM
	Red cod	*Pseudophycis bachus*	RCO
	Ribaldo	*Mora moro*	RIB
	Rig	*Mustelus lenticulatus*	SPO
	Rubyfish	*Plagiogeneion rubiginosum*	RBY
	School shark	*Galeorhinus galeus*	SCH
	Sea perch	*Helicolenus* spp.	SPE
	Silver dory	*Cyttus novaezealandiae*	SDO
	Silver warehou	*Seriolella punctata*	SWA
	Skate	Rajidae Arhynchobatidae	SKA
	Snapper	*Pagrus auratus*	SNA
	Spiny dogfish	*Squalus acanthias*	SPD
	Stargazer	*Kathetostoma giganteum*	STA
	Red gurnard	*Chelidonichthys kumu*	GUR
	Tarakihi	*Nemadactylus macropterus*	TAR
	Trevally	*Pseudocaranx dentex*	TRE
mid water	Hake	*Merluccius australis*	HAK
	Hoki	*Macruronus novaezelandiae*	HOK
	Ling	*Genypterus blacodes*	LIN
	Javelinfish	*Lepidorhynchus dentculatus*	JAV
	Mackerels	*Trachurus declivis, T. murphyi, T. novaezelandiae, Scomber australasicus*	JMA
	Scampi	*Metanephrops challengeri*	SCI
	Squid	*Nototodarus sloanii, N. gouldi*	SQU
	White warehou	*Seriolella caerulea*	WWA
deep	Alfonsino	*Beryx splendens, B. decadactylus*	BYX
	Bluenose	*Hyperoglyphe antarctica*	BNS
	Cardinalfish	*Epigonus telescopus*	CDL
	Orange roughy	*Hoplostethus atlanticus*	ORH
	Oreos	*Allocytus niger, Neocyttus rhomboidalis, Pseudocyttus maculatus*	OEO
	Patagonian toothfish	*Dissostichus eleginoides*	PTO

APPENDIX A – *continued*

Table A3: Comparison of numbers of observed and unobserved tows targeting various species in the four coastal areas and the SANT area for the fishing years 1994–95 to 2005–06. Tows in each area are categorised as observed tows, unobserved tows recorded on TCEPR forms, or unobserved tows recorded on CELR forms. All tows (observed or unobserved) in the commercial data for the SANT area were recorded on TCEPR forms. Quantities in parentheses are numbers of tows expressed as percentages of all tows in the column.

	ECCO area			CHAT area		
Target species	Observed	Uob TCEPR	Uob CELR	Observed	Uob TCEPR	Uob CELR
Barracouta	0	558 (1.1)	5 229 (8.7)	375 (1.7)	11 683 (5.1)	10 288 (4.3)
Flatfish	0	35 (0.1)	18 085 (30)	13 (0.1)	21 (0.0)	111 956 (47)
Redcod	0	48 (0.1)	5 162 (8.6)	32 (0.1)	10 277 (4.5)	81 935 (34)
Stargazer	0	2 (0.0)	44 (0.1)	0	574 (0.3)	1 835 (0.8)
Tarakihi	19 (0.9)	606 (1.2)	8 831 (15)	7 (0.0)	1 648 (0.7)	10 991 (4.6)
other shallow*	33 (1.6)	1 253 (2.4)	9 889 (16)	90 (0.4)	3 054 (1.3)	12 905 (5.4)
Hoki	1 605 (78)	42 742 (82)	12 254 (20)	10 777 (49)	113 986 (50)	1 637 (0.7)
Mackerel	0	14 (0.0)	25 (0.0)	369 (1.7)	3 913 (1.7)	78 (0.0)
Scampi	339 (17)	2 007 (3.9)	36 (0.1)	1 398 (6.4)	10 856 (4.8)	147 (0.1)
Squid	0	5 (0.0)	25 (0.0)	358 (1.6)	17 844 (7.8)	2 807 (1.2)
other mid depth*	0	32 (0.1)	75 (0.1)	141 (0.6)	5 488 (2.4)	319 (0.1)
deep*	55 (2.7)	4 643 (8.9)	377 (0.6)	8 371 (38)	48 768 (21)	3 945 (1.7)
All	2 051 (100)	51 945 (100)	60 032 (100)	21 931 (100)	228 112 (100)	238 843 (100)

	STSP area			WCSI area		
Target species	Observed	Uob TCEPR	Uob CELR	Observed	Uob TCEPR	Uob CELR
Barracouta	667 (3.7)	4 382 (4.1)	168 (0.2)	258 (1.8)	2 745 (3.0)	19 498 (19)
Flatfish	0	21 (0.0)	78 201 (77)	0	111 (0.1)	55 281 (53)
Redcod	2 (0.0)	1 005 (0.9)	1 507 (1.5)	0	141 (0.2)	7 327 (7.0)
Stargazer	0	58 (0.1)	18 037 (18)	0	285 (0.3)	1 551 (1.5)
Tarakihi	0	3 (0.0)	248 (0.2)	13 (0.1)	721 (0.8)	7 768 (7.5)
other shallow*	306 (1.7)	4 379 (4.1)	2 365 (2.3)	54 (0.4)	1 101 (1.2)	2 709 (2.6)
Hoki	4 288 (24)	36 434 (34)	0	12 165 (83)	70 496 (78)	5 699 (5.5)
Mackerel	1 343 (7.4)	4 950 (4.7)	0	668 (4.6)	6 249 (6.9)	23 (0.0)
Scampi	3 (0.0)	353 (0.3)	611 (0.6)	2 (0.0)	70 (0.1)	2 (0.0)
Squid	10 064 (56)	44 405 (42)	35 (0.0)	0	145 (0.2)	70 (0.1)
other mid depth*	562 (3.1)	5 325 (5.0)	498 (0.5)	680 (4.7)	4 446 (4.9)	449 (0.4)
deep*	869 (4.8)	4 478 (4.2)	125 (0.1)	777 (5.3)	3 868 (4.3)	3 753 (3.6)
All	18 104 (100)	105 793 (100)	101 795 (100)	14 617 (100)	90 378 (100)	104 130 (100)

	SANT area	
Target species	Observed	Uob TCEPR
Barracouta	4 (0.0)	6 (0.0)
Flatfish	0	0
Redcod	0	41 (0.1)
Stargazer	0	0
Tarakihi	0	1 (0.0)
other shallow*	4 (0.0)	33 (0.1)
Hoki	1 555 (14)	10 613 (18)
Mackerel	18 (0.2)	15 (0.0)
Scampi	1 277 (11)	15 081 (26)
Squid	6 400 (57)	21 081 (36)
other mid depth*	26 (0.2)	1 259 (2.1)
deep*	1 851 (17)	10 717 (18)
All	11 135 (100)	58 847 (100)

* other shallow species:
ALB, BCO, BRI, BWS, ELE, FRO, GSH, GSP, GUR, HAP, HPB, JDO, LDO, KAH, LEA, MOK, OPE, QSC, RBM, RBY, RIB, SCH, SDO, SKA, SKI, SNA, SPD, SPE, SPO, TRE, SWA, WAR.
other mid depth species:
HAK, JAV, LIN, WWA.
deep species:
BNS, BYX, CDL, OEO, ORH, PTO.

APPENDIX A – *continued*

Table A4: Observed tows by fishing year and FMA outside the six areas, within the EEZ, and south of 40º S. No fur seal captures were observed.

Year	FMA2	FMA5	FMA6	FMA7	FMA8	Total
1994–95	111	1	14	30	51	207
1995–96	39		30	44	16	129
1996–97	13	29	48	49	28	167
1997–98	89	89	41	12	17	248
1998–99	221	45	48	44	14	372
1999–00	164	62	157	40	7	430
2000–01	59	12		46	26	143
2001–02	52	110	38	7	44	251
2002–03	46	64	27	34	53	224
2003–04		25	16	3	2	46
2004–05	16	7	7	49	44	123
2005–06	5		8	67	72	152
All	815	444	434	425	374	2 492

Table A5: Predicted fur seal captures and strike rates by fishing year for the six areas. All c.v.s are percentages.

Area	**ECCO**		**CHAT**		**SANT**		**STSP**		**WCSI**		**SBW6**		**All areas**	
Predicted fur seal captures														
Fish. year	Caps	c.v.	Caps	c.v.	Caps	c.v.	Caps	c.v.	Caps	c.v.	Caps	c.v.	Caps	c.v.
1994–95	163	290	357	55	45	72	561	47	829	41	130	20	2 085	32
1995–96	164	97	449	50	55	66	605	44	1 840	34	89	41	3 202	23
1996–97	606	347	721	52	36	61	547	46	1 733	36	67	34	3 710	60
1997–98	30	86	443	50	43	116	1 118	40	1 475	34	111	17	3 219	22
1998–99	130	42	716	50	30	73	1 134	35	1 051	35	200	33	3 260	20
1999–00	34	91	292	53	21	79	526	40	1 200	33	181	33	2 253	21
2000–01	96	40	372	52	27	98	453	33	1 098	32	79	16	2 124	20
2001–02	202	55	246	54	65	124	740	39	865	35	118	40	2 236	21
2002–03	63	74	305	45	34	102	316	41	665	40	53	54	1 436	23
2003–04	36	98	258	47	59	59	379	44	593	41	49	37	1 375	24
2004–05	289	44	322	53	52	84	343	38	929	38	88	34	2 022	21
2005–06	292	60	208	48	24	52	358	39	573	44	73	18	1 528	23
All	2 105	105	4 688	38	490	37	7 080	29	12 851	20	1 237	13	28 450	15
Predicted strike rate (%)														
Fish. year	Rate	c.v.	Rate	c.v.	Rate	c.v.	Rate	c.v.	Rate	c.v.	Rate	c.v.	Rate	c.v.
1994–95	1.4	289	0.8	54	0.7	68	3.2	47	4.2	40	28.4	15	2.1	32
1995–96	1.1	96	1.0	50	0.8	63	3.2	44	10.2	34	15.2	34	3.1	23
1996–97	4.2	344	1.6	52	0.6	58	2.6	46	7.7	35	10.8	26	3.4	60
1997–98	0.3	84	0.9	49	0.9	115	5.4	39	8.3	33	9.4	13	3.0	22
1998–99	1.3	41	1.5	49	0.8	61	5.4	35	4.9	35	16.1	30	3.1	20
1999–00	0.4	89	0.7	53	0.4	76	3.0	40	7.1	33	26.0	29	2.4	21
2000–01	1.2	39	0.9	52	0.5	96	2.3	33	5.9	32	11.9	11	2.3	20
2001–02	2.9	54	0.7	54	1.0	109	3.8	38	5.6	34	10.2	34	2.6	20
2002–03	0.8	72	0.8	45	0.5	98	1.7	40	4.2	40	8.3	40	1.6	23
2003–04	0.5	96	0.8	46	0.9	56	2.2	43	3.8	41	6.7	30	1.7	23
2004–05	4.5	43	1.0	53	0.8	83	1.9	38	6.8	37	10.1	30	2.6	21
2005–06	5.9	60	0.7	48	0.5	46	2.2	39	4.2	43	11.8	12	2.2	23
All	1.8	104	1.0	38	0.7	35	3.1	29	6.1	20	13.1	11	2.5	15

APPENDIX A – *continued*

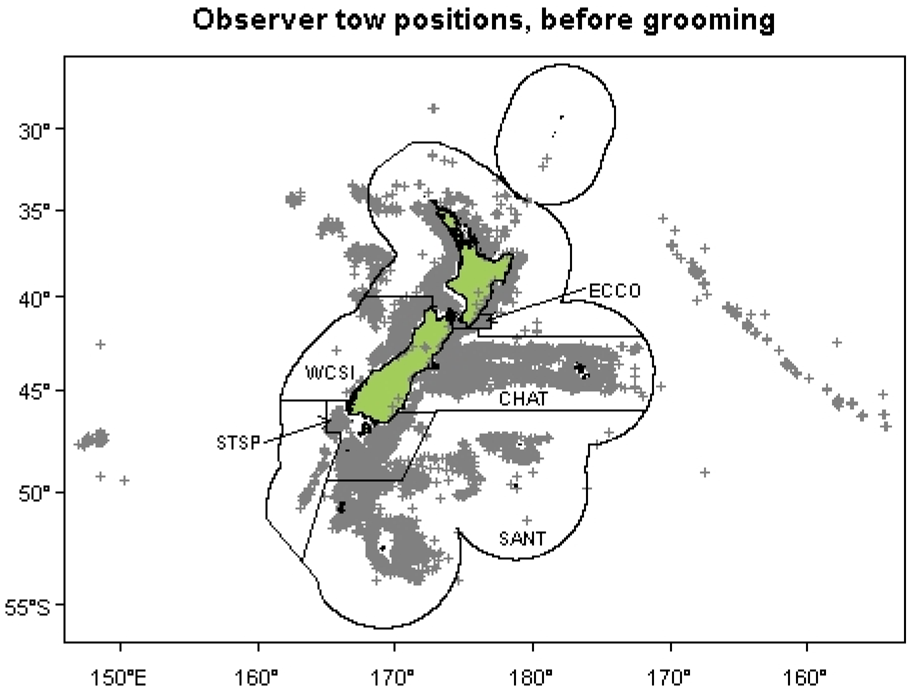
Table A6: Observed tows and observed fur seal captures by fishing year and FMA within the EEZ and north of 40º S. Numbers of fur seal captures are in parentheses.

Year	FMA 1	FMA 2	FMA 7	FMA 8	FMA 9	FMA 10	Total
1994−95	49	239	29	300			617
1995−96	344	55	15	47	3		464
1996−97	214	107	18	62	25		426
1997−98	153	42	12	87	96	16	406
1998−99	211	213	38	35	23		520
1999−00	486	177	7	22	118		810
2000−01		181	11	43			235
2001−02	171	69	29	34	170		473
2002−03	242	48	29	102	208		629
2003−04	180		2	51	296		529
2004−05	100	14	83 (1)	158 (1)	310 (4)		665 (6)
2005−06	365	5	37	388 (4)	293 (1)		1 088 (5)
All	2 515	1 150	310 (1)	1 329 (5)	1 542 (5)	16	6 862 (11)

Table A7: Predicted fur seal captures by fishing year for the six areas and in total, assuming all tows targeting flatfish (FLA) have a zero capture rate. All c.v.s are percentages.

	ECCO		CHAT		SANT		STSP		WCSI		SBW6		All areas	
Fish. year	Caps	c.v.	Caps	c.v.	Caps	c.v.	Caps	c.v.	Caps	c.v.	Caps	c.v.	Caps	c.v.
1994−95	162	270	286	49	45	72	319	38	542	39	130	20	1 485	35
1995−96	163	96	354	41	55	66	323	34	1 264	30	89	41	2 248	20
1996−97	605	337	597	48	36	61	287	36	1 085	32	67	34	2 676	78
1997−98	30	84	364	42	43	116	612	28	997	31	111	17	2 156	18
1998−99	130	42	561	44	30	73	661	23	683	31	200	33	2 264	16
1999−00	33	90	226	47	21	79	305	30	928	31	181	33	1 695	19
2000−01	96	40	304	46	27	98	270	23	797	30	79	16	1 572	18
2001−02	202	53	195	49	65	124	430	27	646	31	118	40	1 656	17
2002−03	62	70	238	37	34	102	168	29	470	37	53	54	1 024	21
2003−04	35	93	201	40	59	59	192	33	400	38	49	37	937	20
2004−05	288	43	239	43	52	84	187	26	606	35	88	34	1 460	19
2005−06	292	64	170	42	24	52	212	31	339	39	73	18	1 110	23
All	2 099	104	3 733	29	490	37	3 965	14	8 758	15	1 237	13	20 283	14

APPENDIX A – *continued*



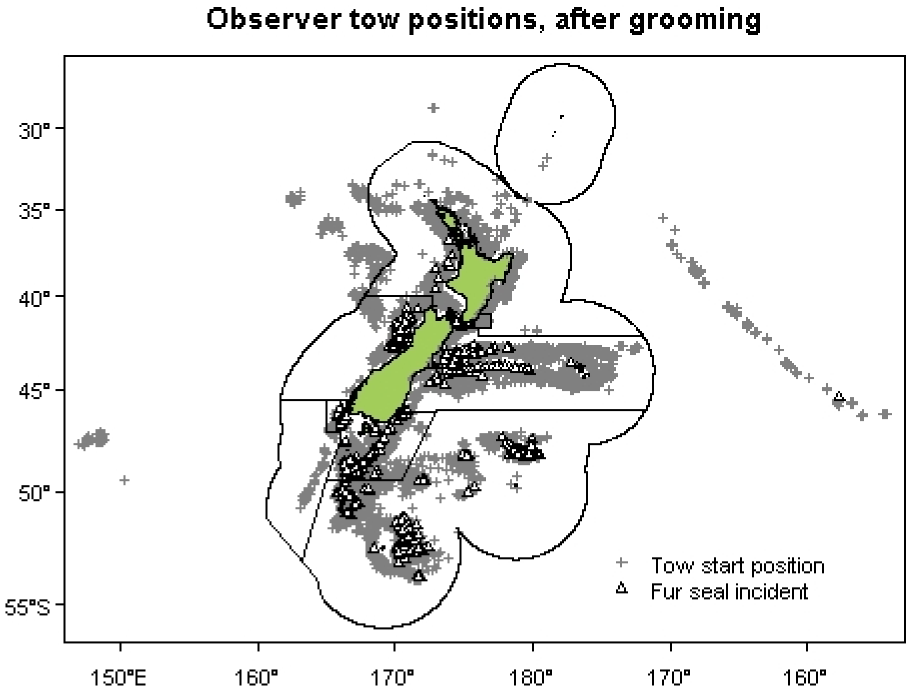
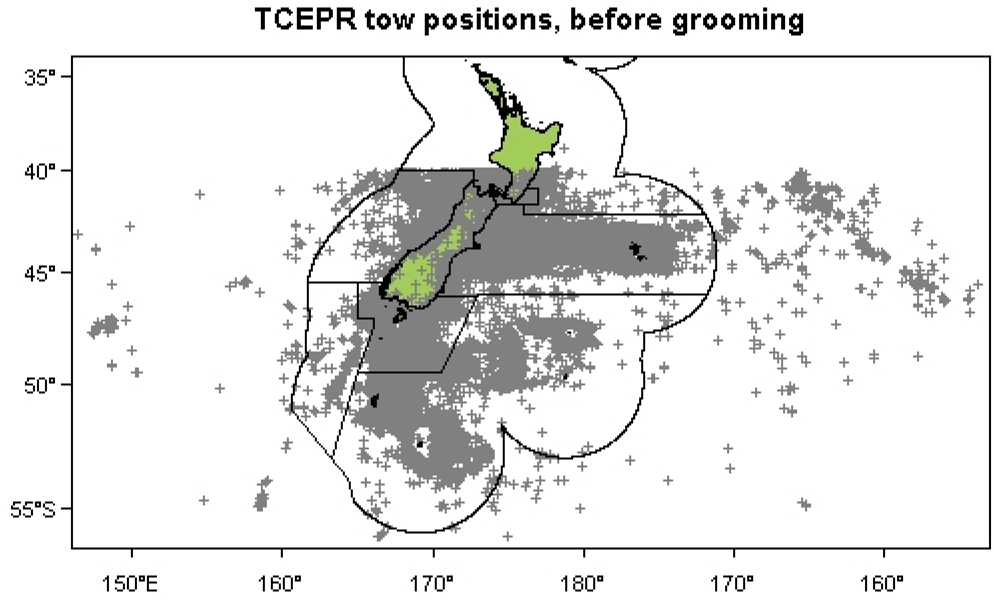


Figure A1: Start positions of observed tows in the fishing years 1994–95 to 2005–06, before and after data grooming. Also shown are the boundaries of the 5 multi-species areas, with their names given in the upper panel. The start positions of tows with observed fur seal incidents (at least one capture) are shown in the lower panel.

APPENDIX A – *continued*



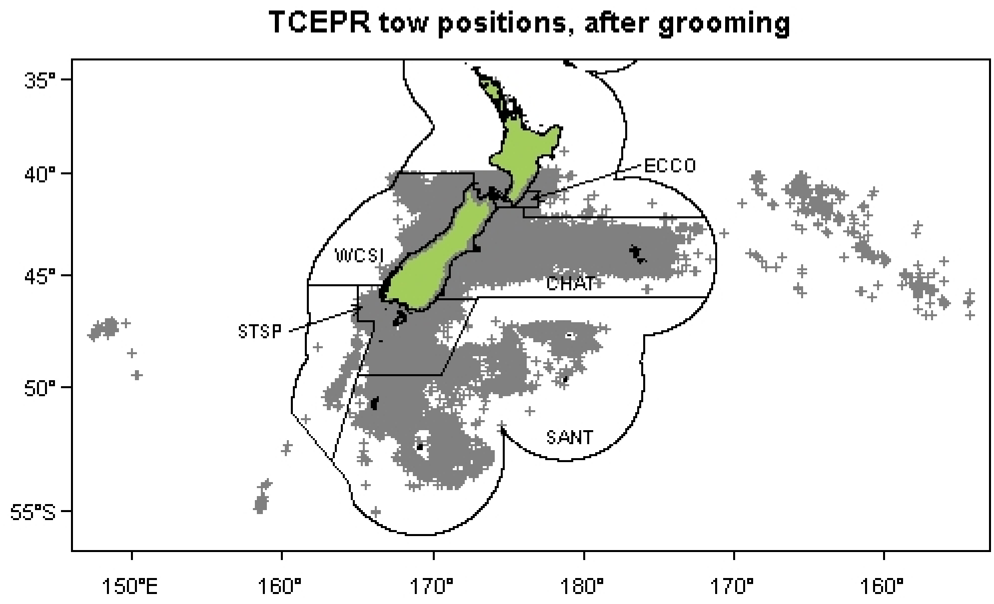


Figure A2: Start positions of Trawl Catch Effort Processing Return (TCEPR) tows for the fishing years 1994–95 to 2005–06, before and after data grooming.

APPENDIX B: EAST COAST WAIRARAPA AND COOK STRAIT AREA (ECCO)

Table B1: Observed and commercial effort and observed fur seal captures, by fishing year, for the ECCO area.

Observed

Fishing year	Vessels	Trips	Tows	Coverage (%)	Fur seal captures	Obs. strike rate(%)
1994−95	4	5	53	0.4	0	0.0
1995−96	8	8	60	0.4	1	1.7
1996−97	2	3	9	0.1	0	0.0
1997−98	12	13	227	2.0	1	0.4
1998−99	17	20	376	3.7	12	3.2
1999−00	11	11	214	2.3	1	0.5
2000−01	11	13	279	3.4	11	3.9
2001−02	13	14	318	4.5	23	7.2
2002−03	8	9	149	1.9	4	2.7
2003−04	7	7	131	1.7	1	0.8
2004−05	12	15	157	2.4	33	21.0
2005−06	8	8	78	1.6	19	24.4
All	49	126	2 051	1.8	106	5.2

Commercial

	TCEPR forms		CELR forms		All forms	
Fishing year	Vessels	Tows	Vessels	Tows	Vessels	Tows
1994−95	45	4 637	67	7 162	110	11 799
1995−96	57	7 709	62	6 684	118	14 393
1996−97	52	7 778	57	6 712	107	14 490
1997−98	46	5 240	51	5 967	94	11 207
1998−99	36	4 748	48	5 375	84	10 123
1999−00	36	4 381	54	5 096	89	9 477
2000−01	38	4 005	46	4 278	84	8 283
2001−02	32	3 041	43	4 005	75	7 046
2002−03	35	3 797	44	4 156	79	7 953
2003−04	30	3 253	48	4 530	78	7 783
2004−05	26	3 150	45	3 332	71	6 482
2005−06	25	2 141	33	2 850	58	4 991
All	88	53 880	151	60 147	219	114 027

APPENDIX B – *continued*

Table B2: Comparison of observed and expected fur seal capture frequencies for the observer data in the ECCO area.

Observed numbers of tows

	Number of fur seal captures per tow				
Year	0	1	2	3	4
1994–95	53				
1995–96	59	1			
1996–97	9				
1997–98	225	1			
1998–99	366	9		1	
1999–00	213	1			
2000–01	269	9	1		
2001–02	297	19	2		
2002–03	146	2	1		
2003–04	130	1			
2004–05	137	11	5	4	
2005–06	66	7	4		1

Expected numbers of tows

	Number of fur seal captures per tow				
	0	1	2	3	4+
1994–95	53	0.2	0.0	0.0	0.0
1995–96	59	1.1	0.1	0.0	0.0
1996–97	9	0.0	0.0	0.0	0.0
1997–98	224	1.9	0.1	0.0	0.0
1998–99	366	9.3	0.9	0.2	0.1
1999–00	212	1.7	0.1	0.0	0.0
2000–01	269	9.0	0.9	0.1	0.0
2001–02	301	13.4	2.5	0.8	0.5
2002–03	145	3.6	0.3	0.0	0.0
2003–04	129	1.5	0.1	0.0	0.0
2004–05	136	14.2	3.9	1.4	1.1
2005–06	67	7.2	2.0	0.7	0.8

APPENDIX B – *continued*

Table B3: Characteristics of the posterior distribution of the parameters in the fitted model for the ECCO area.

Parameter	Mean	sd	Median	95% credibility interval	
1995 base capture rate (%)	1.26	3.34	0.48	0.02	7.05
1996 base capture rate (%)	0.64	0.71	0.44	0.05	2.41
1997 base capture rate (%)	2.54	10.45	0.70	0.02	15.08
1998 base capture rate (%)	0.20	0.20	0.15	0.02	0.70
1999 base capture rate (%)	1.01	0.61	0.87	0.30	2.58
2000 base capture rate (%)	0.29	0.31	0.20	0.03	1.11
2001 base capture rate (%)	0.85	0.50	0.73	0.24	2.12
2002 base capture rate (%)	3.46	2.00	3.00	1.09	8.37
2003 base capture rate (%)	0.59	0.47	0.46	0.10	1.87
2004 base capture rate (%)	0.33	0.36	0.23	0.03	1.17
2005 base capture rate (%)	3.68	1.90	3.28	1.23	8.44
2006 base capture rate (%)	5.16	3.27	4.41	1.36	13.52
DN dusk	7.24	5.51	5.93	1.36	20.62
DN night	7.75	2.61	7.28	4.03	14.28
DN dawn	6.08	4.26	5.10	1.30	17.32
target shallow	0.06	0.42	0.00	0.00	0.49
target deep	0.06	0.59	0.00	0.00	0.49
target scampi	0.15	0.17	0.10	0.01	0.62
sin(day.no) coefficient	-1.52	1.10	-1.47	-3.83	0.48
cos(day.no) coefficient	2.10	1.01	2.04	0.29	4.29
Vessel-season effects variance	0.67	0.37	0.60	0.13	1.57
Extra-dispersion variance	1.46	0.65	1.37	0.44	2.94

APPENDIX B – *continued*

Table B4: Observer data capture details and characteristics of the predictive distribution of the total number of fur seals captured, by fishing year, for all tows in the ECCO area

Observed

Fishing year	Tows	CELR tows	Coverage (%)	Captures	Obs. strike rate(%)	Ratio est. captures
1994–95	53	0	0.4	0	0.0	0
1995–96	60	6	0.4	1	1.7	240
1996–97	9	0	0.1	0	0.0	0
1997–98	227	0	2.0	1	0.4	49
1998–99	376	11	3.7	12	3.2	323
1999–00	214	8	2.3	1	0.5	44
2000–01	279	0	3.4	11	3.9	327
2001–02	318	55	4.5	23	7.2	510
2002–03	149	0	1.9	4	2.7	214
2003–04	131	4	1.7	1	0.8	59
2004–05	157	31	2.4	33	21.0	1 362
2005–06	78	0	1.6	19	24.4	1 216
All	2 051	115	1.8	106	5.2	4 344

Predicted

		CELR	Predicted fur seal captures				Predicted strike rate	
Fishing year	Tows	tows (%)	Captures	c.v. (%)	95% pred. interval		Rate (%)	c.v. (%)
1994–95	11 799	60.7	163	290	2	865	1.4	289
1995–96	14 393	46.4	164	97	15	573	1.1	96
1996–97	14 490	46.3	606	347	5	3593	4.2	344
1997–98	11 207	53.2	30	86	4	97	0.3	84
1998–99	10 123	53.1	130	42	59	264	1.3	41
1999–00	9 477	53.8	34	91	4	114	0.4	89
2000–01	8 283	51.6	96	40	44	188	1.2	39
2001–02	7 046	56.8	202	55	90	453	2.9	54
2002–03	7 953	52.3	63	74	15	183	0.8	72
2003–04	7 783	58.2	36	98	4	118	0.5	96
2004–05	6 482	51.4	289	44	126	606	4.5	43
2005–06	4 991	57.1	292	60	106	711	5.9	60
All	114 027	52.7	2 105	105	987	5 939	1.8	104

APPENDIX B – *continued*

Table B5: Observer data capture details and characteristics of the predictive distribution of the total number of fur seals captured, by fishing year, for tows targeting hoki (HOK) in the ECCO area

Observed

Fishing year	Tows	Coverage (%)	Captures	Obs. strike rate(%)	Ratio est. captures
1994–95	0	0.0			
1995–96	41	0.5	1	2.4	218
1996–97	0	0.0			
1997–98	226	3.9	1	0.4	26
1998–99	295	6.1	12	4.1	197
1999–00	165	3.5	1	0.6	28
2000–01	263	6.4	11	4.2	172
2001–02	145	5.8	20	13.8	344
2002–03	135	3.5	4	3.0	115
2003–04	131	3.3	1	0.8	30
2004–05	139	4.9	33	23.7	676
2005–06	65	3.6	19	29.2	535
All	1 605	2.8	103	6.4	2 341

Predicted

			Predicted fur seal captures				Predicted strike rate	
Fishing year	Tows	CELR tows (%)	Captures	c.v. (%)	95% pred. interval		Rate (%)	c.v. (%)
1994–95	4 923	34.2	163	279	2	909	3.3	281
1995–96	8 935	21.5	162	97	15	565	1.8	96
1996–97	8 271	15.6	615	399	6	3447	7.4	404
1997–98	5 870	22.3	30	86	3	97	0.5	84
1998–99	4 852	17.4	128	41	60	254	2.6	40
1999–00	4 694	23.4	33	89	4	108	0.7	87
2000–01	4 103	23.4	94	40	42	185	2.3	39
2001–02	2 494	19.5	191	58	83	438	7.7	57
2002–03	3 873	23.8	62	71	15	168	1.6	70
2003–04	3 926	27.7	35	95	4	119	0.9	94
2004–05	2 846	15.4	280	46	119	577	9.8	45
2005–06	1 830	16.9	287	62	103	708	15.7	62
All	56 617	21.8	2 079	122	967	5 703	3.7	124

APPENDIX B – *continued*

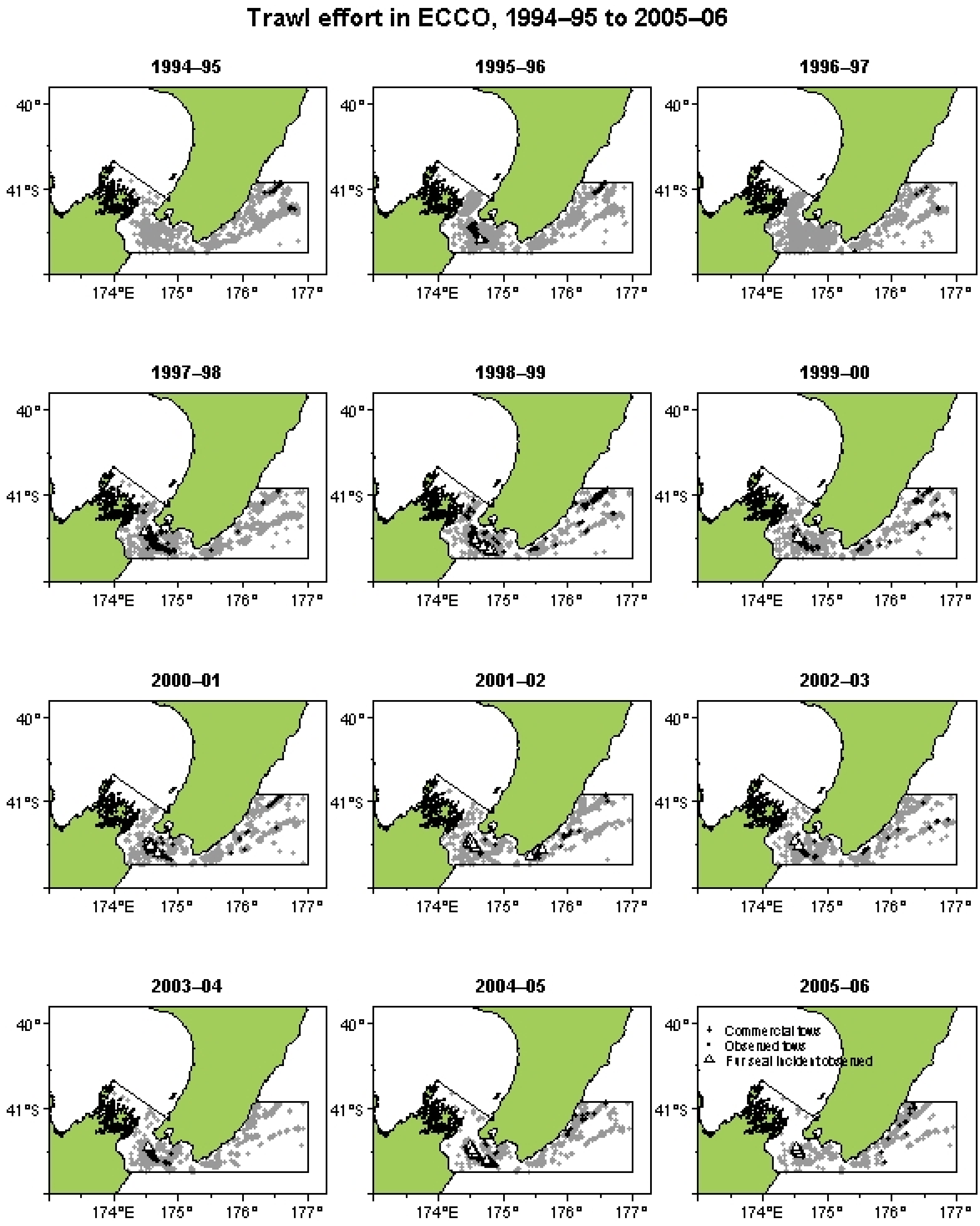


Figure B1: Plot of start positions of commercial tows, observed tows, and observed fur seal incidents by fishing year for the ECCO area.

APPENDIX B – *continued*

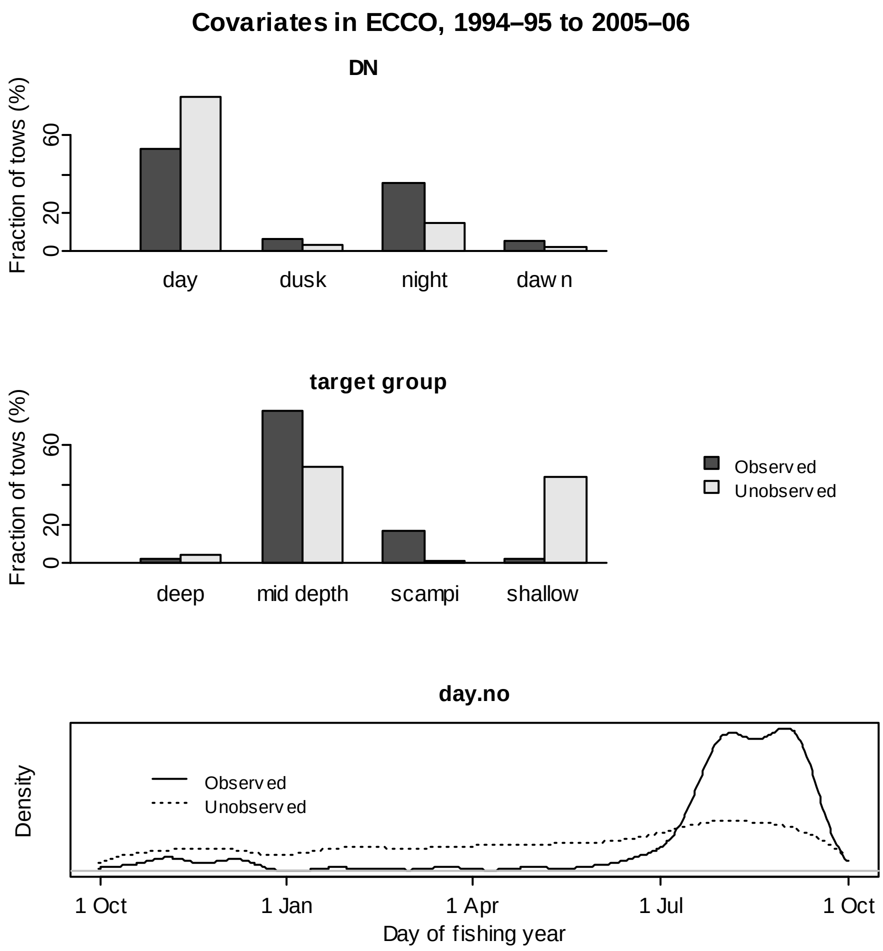


Figure B2: Bar and density plots for the fixed covariates used in the model for fur seal captures in the ECCO area.

APPENDIX B – *continued*

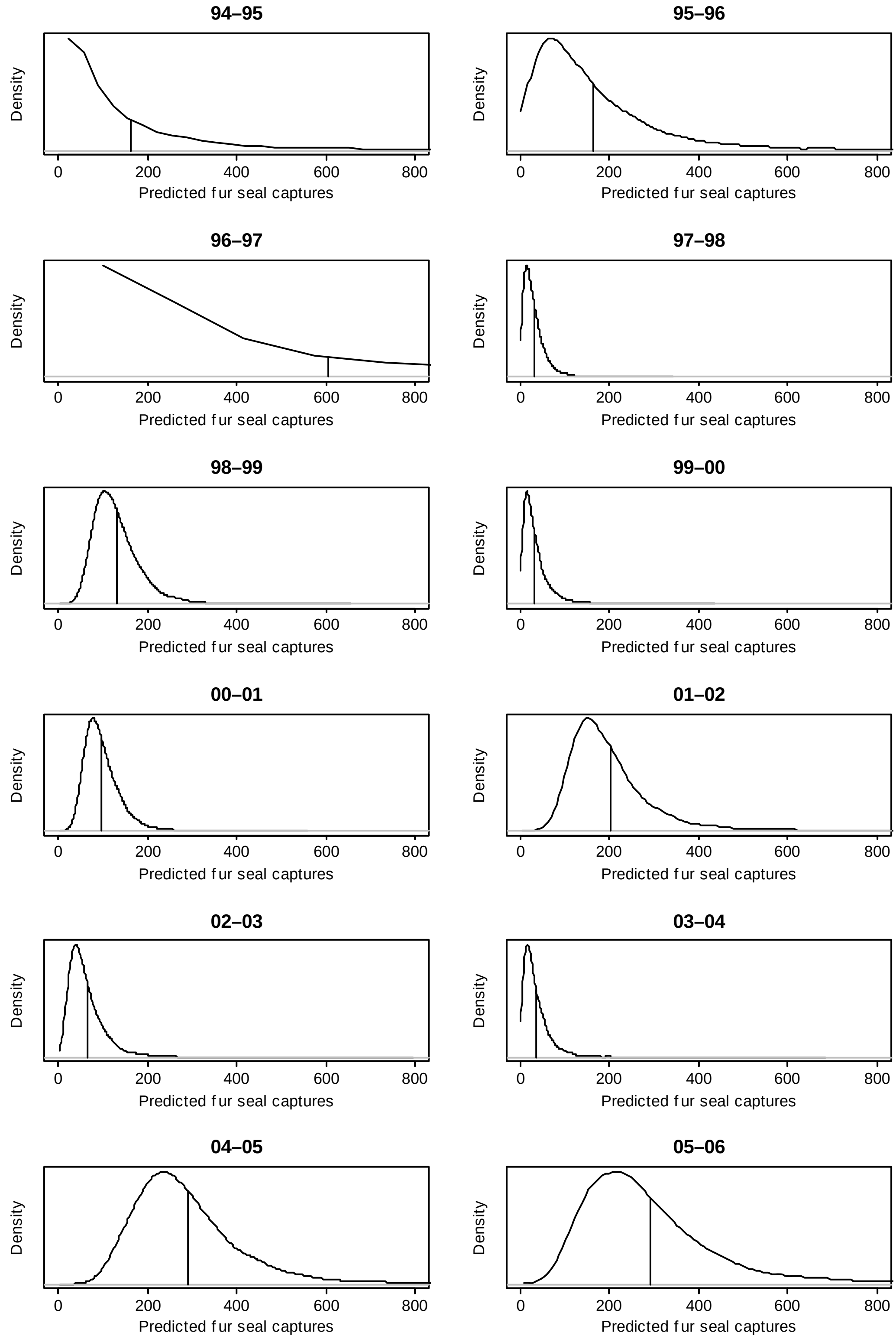


Figure B3: Plots of the predictive densities, by fishing year, for fur seal captures for all tows in the ECCO area.

APPENDIX B – *continued*

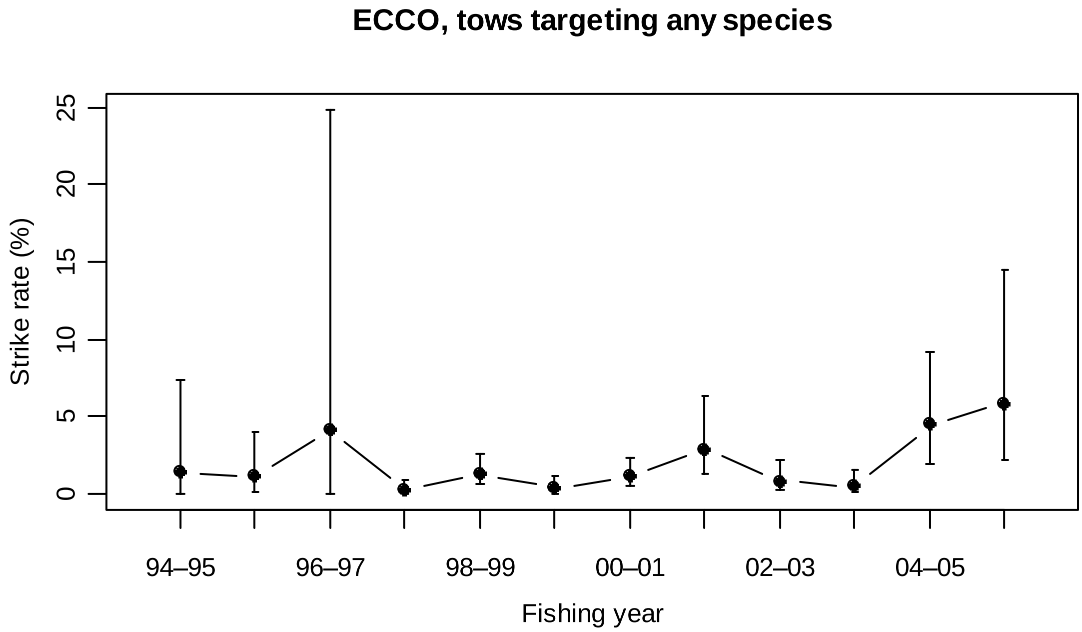


Figure B4: Predicted strike rates, with 95% prediction intervals, by fishing year, for all tows in the ECCO area.

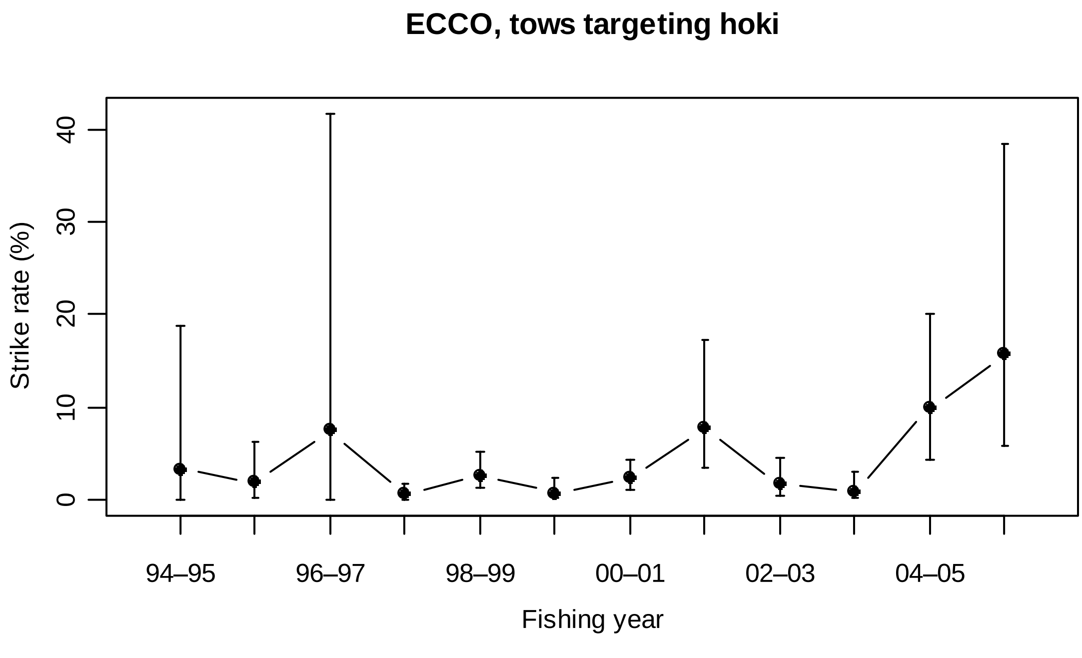


Figure B5: Predicted strike rates, with 95% prediction intervals, by fishing year, for tows targeting hoki (HOK) in the ECCO area.

APPENDIX C: CHATHAM RISE AREA (CHAT)

Table C1: Observed and commercial effort and observed fur seal captures, by fishing year, for the CHAT area.

Observed

Fishing year	Vessels	Trips	Tows	Coverage (%)	Fur seal captures	Obs. strike rate(%)
1994−95	21	34	1 857	4.2	10	0.5
1995−96	17	23	1 153	2.7	16	1.4
1996−97	20	24	1 028	2.3	18	1.8
1997−98	29	36	2 456	4.8	8	0.3
1998−99	33	35	1 862	3.9	22	1.2
1999−00	28	32	1 751	4.0	6	0.3
2000−01	33	49	2 597	6.2	15	0.6
2001−02	31	36	1 945	5.4	8	0.4
2002−03	34	44	2 138	5.4	16	0.7
2003−04	24	33	1 536	4.7	17	1.1
2004−05	22	32	1 927	5.8	17	0.9
2005−06	24	34	1 681	5.6	16	1.0
All	102	404	21 931	4.5	169	0.8

Commercial

	TCEPR forms		CELR forms		All forms	
Fishing year	Vessels	Tows	Vessels	Tows	Vessels	Tows
1994−95	101	21 574	118	22 821	219	44 395
1995−96	115	23 004	113	19 971	227	42 975
1996−97	110	23 532	113	21 889	222	45 421
1997−98	109	28 043	101	23 267	208	51 310
1998−99	99	24 554	108	23 000	206	47 554
1999−00	81	22 671	104	20 891	185	43 562
2000−01	75	20 829	96	20 752	171	41 581
2001−02	70	18 402	92	17 609	162	36 011
2002−03	76	20 269	86	19 446	162	39 715
2003−04	67	16 404	95	16 463	162	32 867
2004−05	64	15 062	89	17 966	153	33 028
2005−06	63	14 917	74	15 073	137	29 990
All	189	249 261	233	239 148	410	488 409

APPENDIX C – *continued*

Table C2: Comparison of observed and expected fur seal capture frequencies for the observer data in the CHAT area.

Observed numbers of tows

	Number of fur seal captures per tow				
Year	0	1	2	3	4
1994−95	1 849	6	2		
1995−96	1 139	12	2		
1996−97	1 012	14	2		
1997−98	2 447	8			
1998−99	1 840	22			
1999−00	1 746	4	1		
2000−01	2 583	13	1		
2001−02	1 937	8			
2002−03	2 121	11	1	1	
2003−04	1 520	15	1		
2004−05	1 913	11	3		
2005−06	1 669	10	1		1

Expected numbers of tows

	Number of fur seal captures per tow				
	0	1	2	3	4+
1994−95	1 848	8.3	0.9	0.2	0.1
1995−96	1 140	11.6	1.2	0.2	0.1
1996−97	1 014	12.0	1.3	0.3	0.1
1997−98	2 446	8.7	0.4	0.1	0.0
1998−99	1 845	15.1	1.6	0.4	0.2
1999−00	1 744	7.0	0.4	0.1	0.0
2000−01	2 583	12.5	0.9	0.1	0.1
2001−02	1 936	8.5	0.7	0.1	0.1
2002−03	2 120	12.3	1.3	0.3	0.2
2003−04	1 521	12.6	1.7	0.4	0.3
2004−05	1 914	10.7	1.3	0.3	0.2
2005−06	1 667	11.8	1.4	0.4	0.3

APPENDIX C – *continued*

Table C3: Characteristics of the posterior distribution of the parameters in the fitted model for the CHAT area.

Parameter	Mean	sd	Median	95% credibility interval	
1995 base capture rate (%)	0.30	0.12	0.28	0.12	0.59
1996 base capture rate (%)	0.36	0.13	0.34	0.17	0.67
1997 base capture rate (%)	0.46	0.20	0.41	0.21	0.97
1998 base capture rate (%)	0.28	0.10	0.26	0.12	0.51
1999 base capture rate (%)	0.46	0.17	0.43	0.23	0.89
2000 base capture rate (%)	0.26	0.10	0.25	0.11	0.51
2001 base capture rate (%)	0.35	0.13	0.33	0.17	0.67
2002 base capture rate (%)	0.26	0.10	0.25	0.11	0.48
2003 base capture rate (%)	0.30	0.11	0.29	0.14	0.56
2004 base capture rate (%)	0.31	0.11	0.29	0.13	0.57
2005 base capture rate (%)	0.38	0.15	0.36	0.18	0.75
2006 base capture rate (%)	0.30	0.11	0.28	0.13	0.55
DN dusk	1.96	0.51	1.90	1.13	3.13
DN night	1.72	0.38	1.68	1.10	2.59
DN dawn	1.79	0.46	1.74	1.04	2.85
gear MW	2.49	0.66	2.41	1.44	4.05
target shallow	0.35	0.26	0.29	0.06	1.05
target deep	0.08	0.05	0.07	0.01	0.19
target jack mack	3.06	1.63	2.70	1.02	7.20
target scampi	0.45	0.27	0.39	0.12	1.13
log(distance to land) coefficient	-0.69	0.16	-0.69	-1.03	-0.37
sin(day.no) coefficient	-1.28	0.21	-1.28	-1.69	-0.87
cos(day.no) coefficient	0.74	0.16	0.74	0.44	1.06
Vessel-season effects variance	1.23	0.37	1.18	0.61	2.05
Extra-dispersion variance	3.64	1.10	3.59	1.55	6.29

APPENDIX C – *continued*

Table C4: Observer data capture details and characteristics of the predictive distribution of the total number of fur seals captured, by fishing year, for all tows in the CHAT area.

Observed

Fishing year	Tows	CELR tows	Coverage (%)	Captures	Obs. strike rate(%)	Ratio est. captures
1994−95	1 857	0	4.2	10	0.5	239
1995−96	1 153	0	2.7	16	1.4	596
1996−97	1 028	0	2.3	18	1.8	795
1997−98	2 456	0	4.8	8	0.3	167
1998−99	1 862	0	3.9	22	1.2	562
1999−00	1 751	252	4.0	6	0.3	149
2000−01	2 597	7	6.2	15	0.6	240
2001−02	1 945	29	5.4	8	0.4	148
2002−03	2 138	0	5.4	16	0.7	297
2003−04	1 536	17	4.7	17	1.1	364
2004−05	1 927	0	5.8	17	0.9	291
2005−06	1 681	0	5.6	16	1.0	285
All	21 931	305	4.5	169	0.8	4 135

Predicted

			Predicted fur seal captures				Predicted strike rate	
Fishing year	Tows	CELR tows (%)	Captures	c.v. (%)	95% pred. interval		Rate (%)	c.v. (%)
1994−95	44 395	51.4	357	55	133	856	0.8	54
1995−96	42 975	46.5	449	50	190	1024	1.0	50
1996−97	45 421	48.2	721	52	302	1703	1.6	52
1997−98	51 310	45.3	443	50	182	1015	0.9	49
1998−99	47 554	48.4	716	50	298	1641	1.5	49
1999−00	43 562	48.0	292	53	103	670	0.7	53
2000−01	41 581	49.9	372	52	149	866	0.9	52
2001−02	36 011	48.9	246	54	90	599	0.7	54
2002−03	39 715	49.0	305	45	132	649	0.8	45
2003−04	32 867	50.1	258	47	109	550	0.8	46
2004−05	33 028	54.4	322	53	133	778	1.0	53
2005−06	29 990	50.3	208	48	89	459	0.7	48
All	488 409	49.0	4 688	38	2 550	9 313	1.0	38

APPENDIX C – *continued*

Table C5: Observer data capture details and characteristics of the predictive distribution of the total number of fur seals captured, by fishing year, for tows targeting hoki (HOK) in the CHAT area.

Observed

Fishing year	Tows	Coverage (%)	Captures	Obs. strike rate(%)	Ratio est. captures
1994−95	497	5.7	9	1.8	157
1995−96	753	7.0	15	2.0	215
1996−97	413	3.2	16	3.9	498
1997−98	1 644	10.3	6	0.4	58
1998−99	1 330	9.1	18	1.4	198
1999−00	780	6.0	4	0.5	66
2000−01	1 377	12.0	10	0.7	84
2001−02	972	10.6	4	0.4	38
2002−03	877	8.2	13	1.5	159
2003−04	589	7.2	17	2.9	235
2004−05	804	13.9	14	1.7	101
2005−06	741	14.3	13	1.8	91
All	10 777	8.5	139	1.3	1 901

Predicted

		CELR	Predicted fur seal captures				Predicted strike rate	
Fishing year	Tows	tows (%)	Captures	c.v. (%)	95% pred. interval		Rate (%)	c.v. (%)
1994−95	8 688	1.69	89	37	40	167	1.0	35
1995−96	10 809	1.02	177	33	94	319	1.6	31
1996−97	12 862	1.54	309	42	150	634	2.4	41
1997−98	15 926	0.54	187	37	86	350	1.2	35
1998−99	14 625	1.57	249	36	128	465	1.7	35
1999−00	12 928	1.91	113	44	44	231	0.9	42
2000−01	11 498	2.10	138	38	66	268	1.2	36
2001−02	9 163	0.64	83	42	35	169	0.9	40
2002−03	10 734	1.35	142	34	69	258	1.3	33
2003−04	8 158	2.11	132	36	67	251	1.6	34
2004−05	5 785	0.07	117	35	59	218	2.0	33
2005−06	5 198	0.21	64	37	32	120	1.2	35
All	126 374	1.31	1 800	17	1 316	2 476	1.4	17

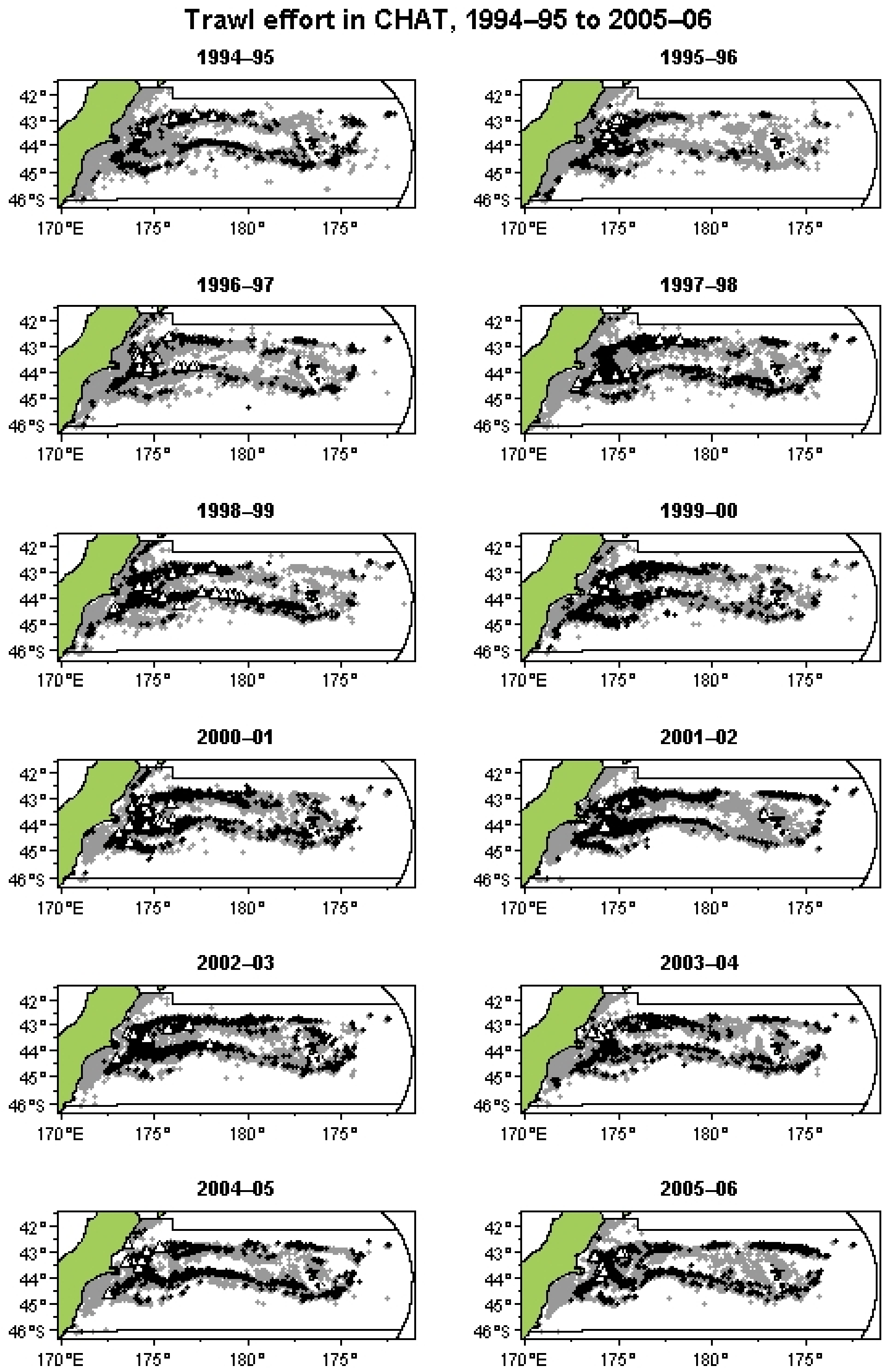


Figure C1: Plot of start positions of commercial tows, observed tows, and observed fur seal incidents by fishing year for the CHAT area. See Figure B1 for legend.

APPENDIX C – *continued*

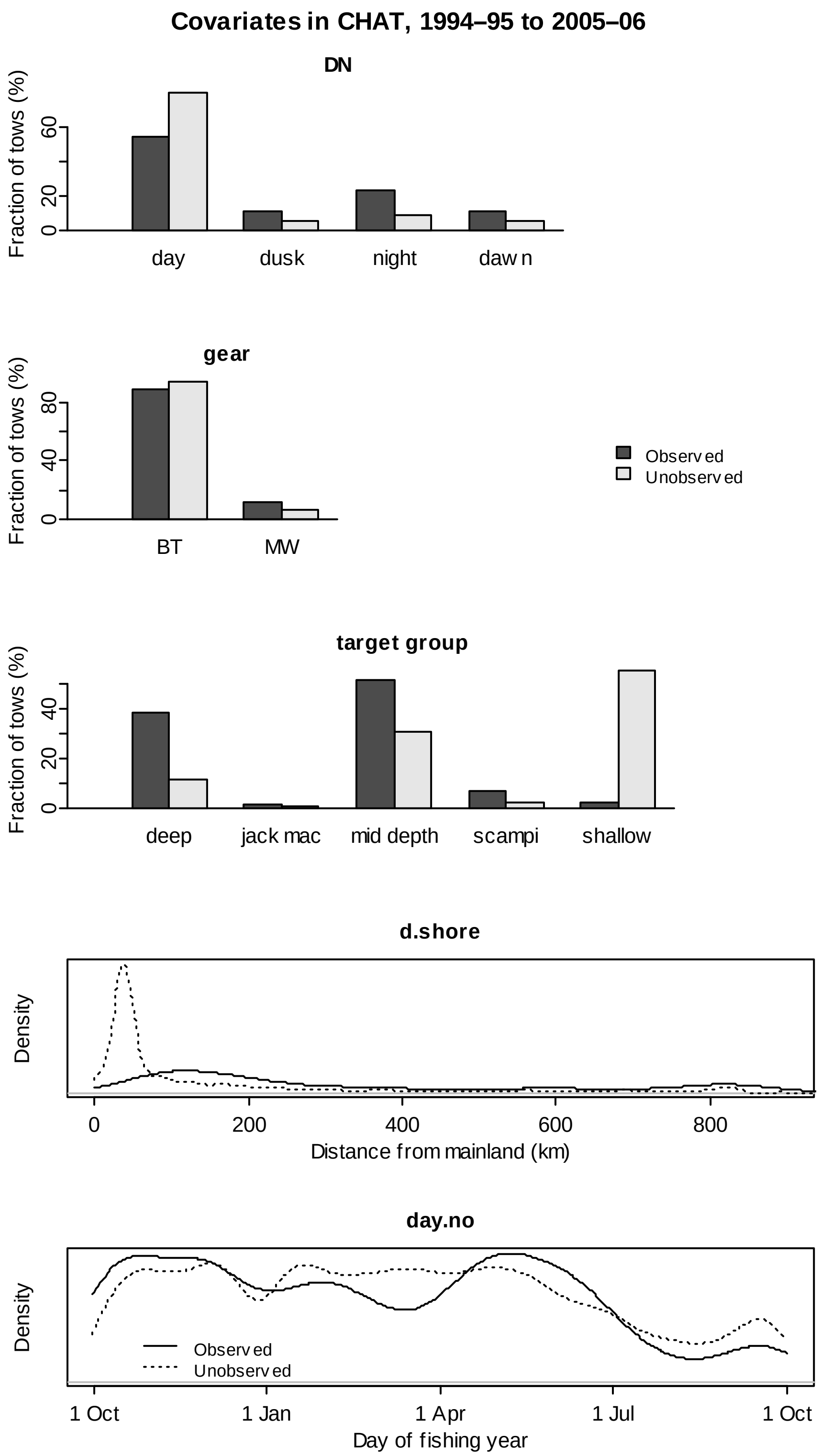


Figure C2: Bar and density plots for the fixed covariates used in the model for fur seal captures in the CHAT area.

APPENDIX C – *continued*

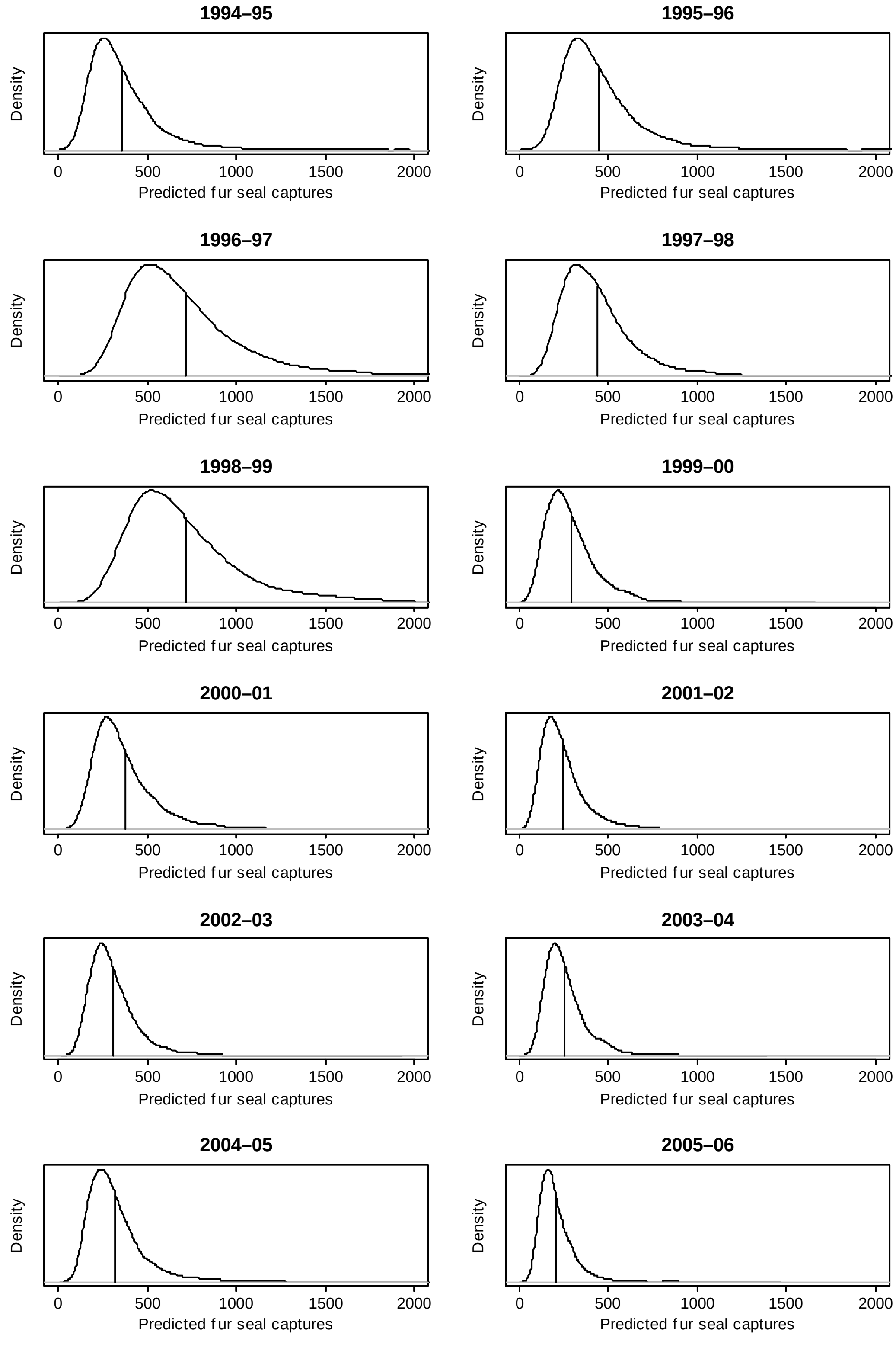


Figure C3: Plots of the predictive densities, by fishing year, for fur seal captures for all tows in the CHAT area.

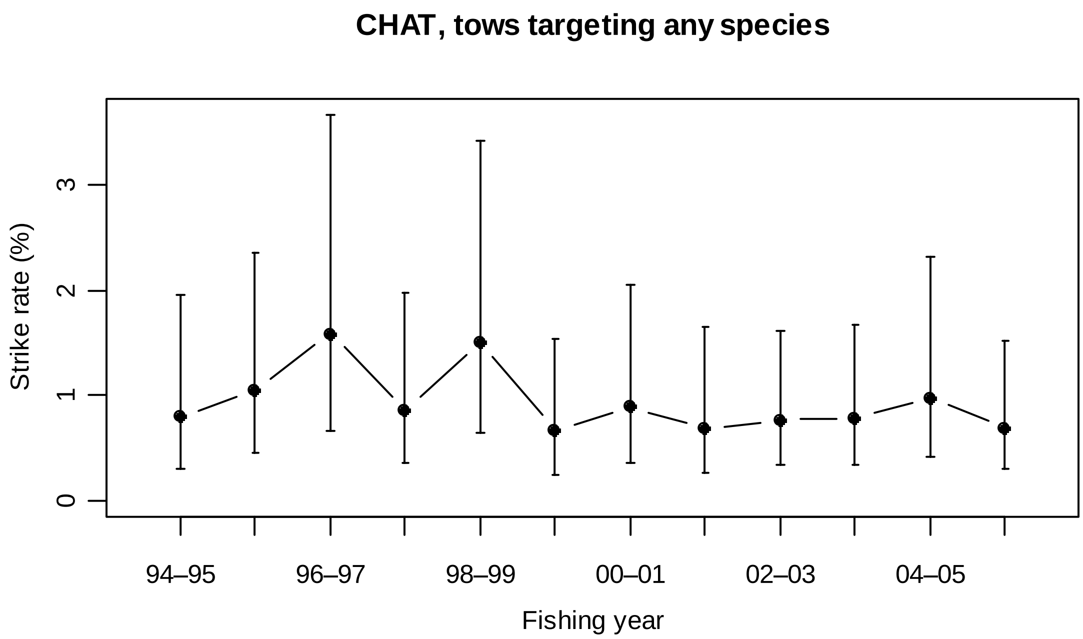


Figure C4: Predicted strike rates, with 95% prediction intervals, by fishing year, for all tows in the CHAT area.

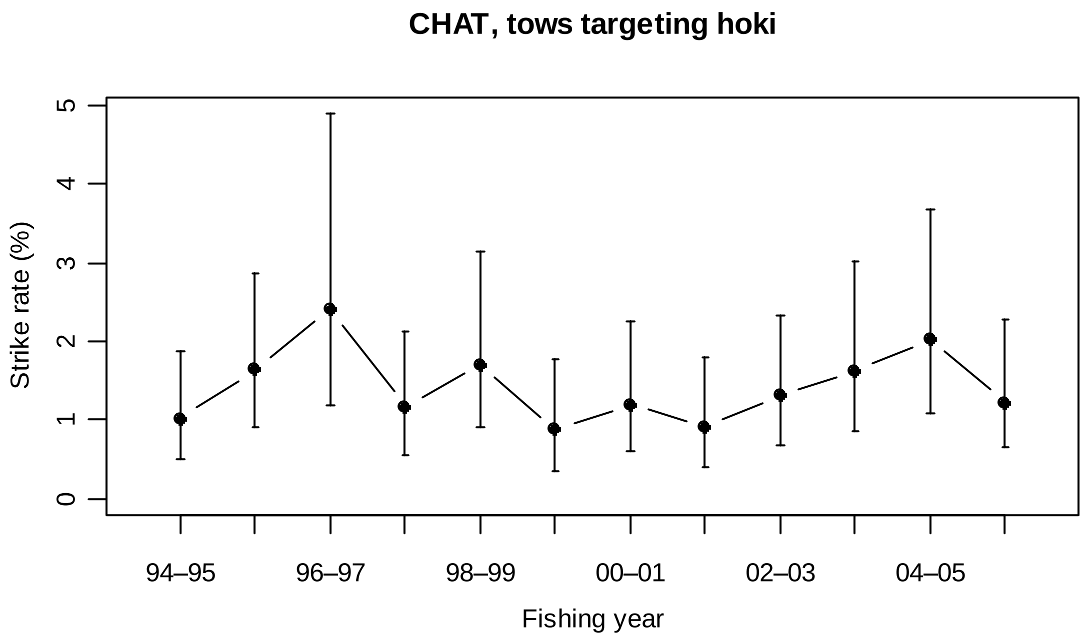


Figure C5: Predicted strike rates, with 95% prediction intervals, by fishing year, for tows targeting hoki (HOK) in the CHAT area.

APPENDIX D: SUB-ANTARCTIC AREA (SANT)

Table D1: Observed and commercial effort and observed fur seal captures, by fishing year, for the SANT area.

Observed

Fishing year	Vessels	Trips	Tows	Coverage (%)	Fur seal captures	Obs. strike rate(%)
1994−95	11	11	417	6.7	3	0.7
1995−96	12	12	678	9.7	8	1.2
1996−97	20	21	1 019	16.1	4	0.4
1997−98	21	24	726	15.8	6	0.8
1998−99	16	17	477	12.1	3	0.6
1999−00	21	24	1 163	20.4	2	0.2
2000−01	31	40	994	20.2	2	0.2
2001−02	23	31	1 127	17.0	13	1.2
2002−03	24	30	882	13.6	0	0.0
2003−04	26	34	1 355	19.8	10	0.7
2004−05	29	36	1 243	20.4	8	0.6
2005−06	25	25	1 054	20.3	5	0.5
All	88	298	11 135	15.9	64	0.6

Commercial

	TCEPR forms		CELR forms		All forms	
Fishing year	Vessels	Tows	Vessels	Tows	Vessels	Tows
1994−95	76	6 182	0	0	76	6 182
1995−96	75	6 972	0	0	75	6 972
1996−97	68	6 321	0	0	68	6 321
1997−98	64	4 595	0	0	64	4 595
1998−99	62	3 933	0	0	62	3 933
1999−00	54	5 706	0	0	54	5 706
2000−01	53	4 914	0	0	53	4 914
2001−02	55	6 635	0	0	55	6 635
2002−03	54	6 500	0	0	54	6 500
2003−04	49	6 840	0	0	49	6 840
2004−05	50	6 108	0	0	50	6 108
2005−06	47	5 189	0	0	47	5 189
All	147	69 895	0	0	147	69 895

Table D2: Comparison of observed and expected fur seal capture frequencies for the observer data in the SANT area.

Observed numbers of tows

	Number of fur seal captures per tow			
Year	0	1	2	3
1994−95	414	3		
1995−96	671	6	1	
1996−97	1 016	4		
1997−98	721	4	1	
1998−99	474	1	1	
1999−00	1 161	2		
2000−01	992	2		
2001−02	1 115	11	1	
2002−03	882			
2003−04	1 345	10		
2004−05	1 237	5		1
2005−06	1 049	5		

Expected numbers of tows

	Number of fur seal captures per tow			
	0	1	2	3
1994−95	415	2.0	0.2	0.1
1995−96	672	5.0	0.6	0.2
1996−97	1 017	3.1	0.2	0.1
1997−98	722	3.6	0.3	0.1
1998−99	473	2.3	0.3	0.1
1999−00	1 160	2.5	0.2	0.0
2000−01	991	2.9	0.2	0.0
2001−02	1 116	9.0	1.2	0.4
2002−03	880	1.8	0.1	0.0
2003−04	1 346	7.6	0.8	0.3
2004−05	1 237	5.4	0.5	0.2
2005−06	1 049	4.7	0.4	0.1

APPENDIX D – *continued*

Table D3: Characteristics of the posterior distribution of the parameters in the fitted model for the SANT area.

Parameter	Mean	sd	Median	95% credibility interval	
1995 base capture rate (%)	0.58	0.45	0.46	0.12	1.70
1996 base capture rate (%)	0.66	0.51	0.52	0.14	1.98
1997 base capture rate (%)	0.49	0.34	0.41	0.12	1.31
1998 base capture rate (%)	0.62	0.47	0.50	0.14	1.85
1999 base capture rate (%)	0.50	0.37	0.41	0.11	1.42
2000 base capture rate (%)	0.36	0.25	0.30	0.07	0.98
2001 base capture rate (%)	0.34	0.23	0.28	0.06	0.91
2002 base capture rate (%)	0.53	0.35	0.45	0.14	1.42
2003 base capture rate (%)	0.29	0.21	0.24	0.04	0.82
2004 base capture rate (%)	0.53	0.33	0.45	0.15	1.39
2005 base capture rate (%)	0.47	0.30	0.40	0.12	1.20
2006 base capture rate (%)	0.40	0.26	0.34	0.10	1.03
DN dusk	0.99	0.61	0.87	0.27	2.43
DN night	0.85	0.42	0.77	0.28	1.87
DN dawn	2.48	1.17	2.24	0.94	5.44
gear MW	1.18	0.73	0.99	0.37	3.08
target deep	4.81	5.12	3.27	0.69	18.53
target mid depth	3.80	3.62	2.84	0.76	13.15
target scampi	0.11	0.15	0.06	0.00	0.52
target shallow	0.25	2.84	0.00	0.00	0.62
log(duration) coefficient	0.46	0.29	0.46	-0.08	1.05
Vessel-season effects variance	3.43	1.68	3.13	1.29	8.62
Extra-dispersion variance	10.69	4.37	10.13	3.37	20.02

APPENDIX D – *continued*

Table D4: Observer data capture details and characteristics of the predictive distribution of the total number of fur seals captured, by fishing year, for all tows in the SANT area. All commercial tows were recorded on TCEPR forms.

Observed

Fishing year	Tows	Coverage (%)	Captures	Obs. strike rate(%)	Ratio est. captures
1994–95	417	6.7	3	0.7	44
1995–96	678	9.7	8	1.2	82
1996–97	1 019	16.1	4	0.4	25
1997–98	726	15.8	6	0.8	38
1998–99	477	12.1	3	0.6	25
1999–00	1 163	20.4	2	0.2	10
2000–01	994	20.2	2	0.2	10
2001–02	1 127	17.0	13	1.2	77
2002–03	882	13.6	0	0.0	0
2003–04	1 355	19.8	10	0.7	50
2004–05	1 243	20.4	8	0.6	39
2005–06	1 054	20.3	5	0.5	25
All	11 135	15.9	64	0.6	425

Predicted

		Predicted fur seal captures				Predicted strike rate	
Fishing year	Tows	Captures	c.v. (%)	95% pred. interval		Rate (%)	c.v. (%)
1994–95	6 182	45	72	13	122	0.7	68
1995–96	6 972	55	66	21	144	0.8	63
1996–97	6 321	36	61	12	89	0.6	58
1997–98	4 595	43	116	12	142	0.9	115
1998–99	3 933	30	73	9	77	0.8	61
1999–00	5 706	21	79	5	63	0.4	76
2000–01	4 914	27	98	5	93	0.5	96
2001–02	6 635	65	124	23	173	1.0	109
2002–03	6 500	34	102	3	120	0.5	98
2003–04	6 840	59	59	24	138	0.9	56
2004–05	6 108	52	84	20	121	0.8	83
2005–06	5 189	24	52	9	56	0.5	46
All	69 895	490	37	296	908	0.7	35

APPENDIX D – *continued*

Table D5: Observer data capture details and characteristics of the predictive distribution of the total number of fur seals captured, by fishing year, for tows targeting squid (SQU) in the SANT area. All commercial tows were recorded on TCEPR forms.

Observed

Fishing year	Tows	Coverage (%)	Captures	Obs. strike rate(%)	Ratio est. captures
1994–95	286	7.1	2	0.7	28
1995–96	556	12.4	8	1.4	64
1996–97	735	19.7	4	0.5	20
1997–98	338	23.3	3	0.9	13
1998–99	156	39.0	0	0.0	0
1999–00	438	36.0	2	0.5	6
2000–01	577	97.5	1	0.2	1
2001–02	568	34.3	4	0.7	12
2002–03	440	25.8	0	0.0	0
2003–04	811	27.7	6	0.7	22
2004–05	807	29.3	1	0.1	3
2005–06	688	27.5	3	0.4	11
All	6 400	23.3	34	0.5	180

Predicted

		Predicted fur seal captures				Predicted strike rate	
Fishing year	Tows	Captures	c.v. (%)	95% pred. interval		Rate (%)	c.v. (%)
1994–95	4 024	31	79	8	91	0.8	75
1995–96	4 478	36	54	14	89	0.8	51
1996–97	3 737	22	55	8	51	0.6	51
1997–98	1 448	10	66	3	27	0.7	60
1998–99	400	1	131	0	6	0.4	86
1999–00	1 217	5	65	2	13	0.4	52
2000–01	592	1	27	1	2	0.2	6
2001–02	1 654	10	56	4	25	0.6	49
2002–03	1 704	4	104	0	15	0.3	81
2003–04	2 926	24	51	10	55	0.8	45
2004–05	2 758	15	64	3	40	0.5	55
2005–06	2 501	13	63	4	33	0.5	56
All	27 439	175	29	105	297	0.6	28

APPENDIX D – *continued*

Table D6: Observer data capture details and characteristics of the predictive distribution of the total number of fur seals captured, by fishing year, for tows targeting hoki (HOK) in the SANT area. All commercial tows were recorded on TCEPR forms.

Observed

Fishing year	Tows	Coverage (%)	Captures	Obs. strike rate(%)	Ratio est. captures
1994–95	24	12.6	0	0.0	0
1995–96	12	6.6	0	0.0	0
1996–97	0	0			
1997–98	14	1.7	2	14.3	120
1998–99	214	22.3	0	0.0	0
1999–00	411	21.9	0	0.0	0
2000–01	247	14.1	1	0.4	7
2001–02	312	13.3	9	2.9	68
2002–03	154	7.4	0	0.0	0
2003–04	152	13.2	1	0.7	8
2004–05	11	2.1	0	0.0	0
2005–06	4	13.8	0	0.0	0
All	1 555	12.8	13	0.8	202

Predicted

		Predicted fur seal captures				Predicted strike rate	
Fishing year	Tows	Captures	c.v. (%)	95% pred. interval		Rate (%)	c.v. (%)
1994–95	191	4	261	0	18	1.9	148
1995–96	183	4	192	0	21	2.4	165
1996–97	226	5	228	0	24	2.3	222
1997–98	840	21	181	2	106	2.5	171
1998–99	959	4	184	0	21	0.4	167
1999–00	1 880	9	127	0	42	0.5	119
2000–01	1 755	18	139	2	74	1.0	134
2001–02	2 341	41	93	12	142	1.7	92
2002–03	2 074	21	140	1	93	1.0	134
2003–04	1 154	17	137	1	74	1.5	127
2004–05	534	14	162	0	59	2.6	154
2005–06	29	0	371	0	4	1.5	189
All	12 166	158	70	50	435	1.3	68

APPENDIX D – *continued*

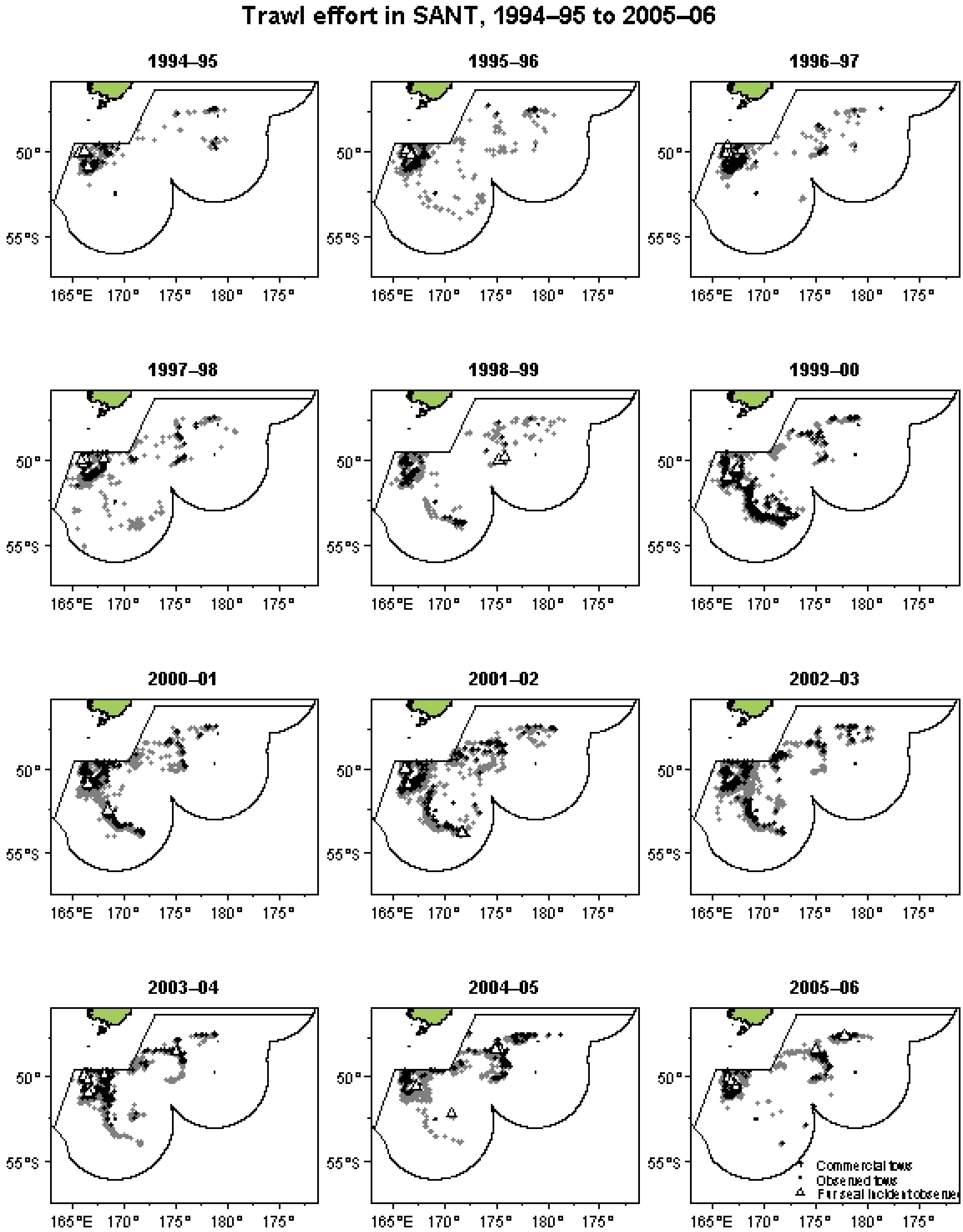


Figure D1: Plot of start positions of commercial tows, observed tows, and observed fur seal incidents by fishing year for the SANT area.

APPENDIX D – *continued*

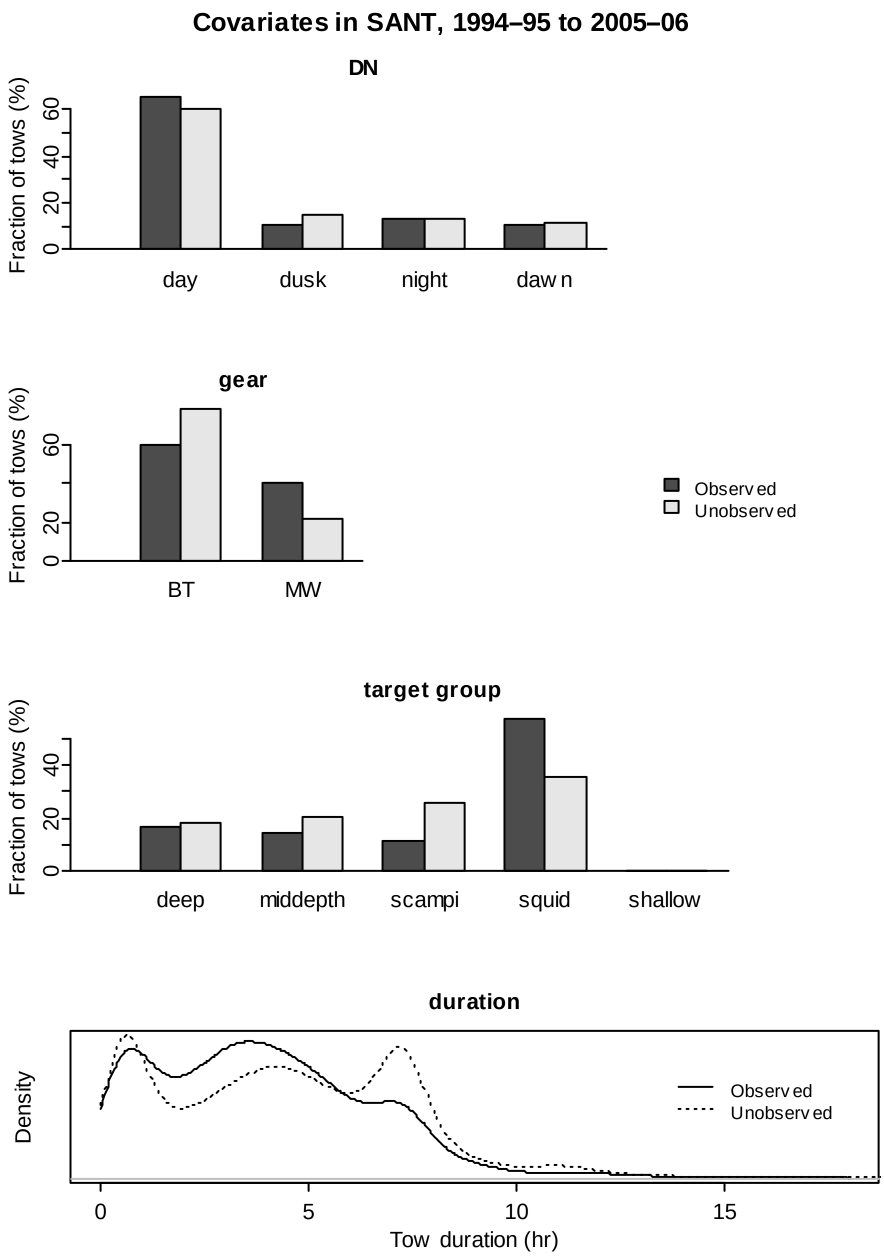


Figure D2: Bar and density plots for the fixed covariates used in the model for fur seal captures in the SANT area.

APPENDIX D – *continued*

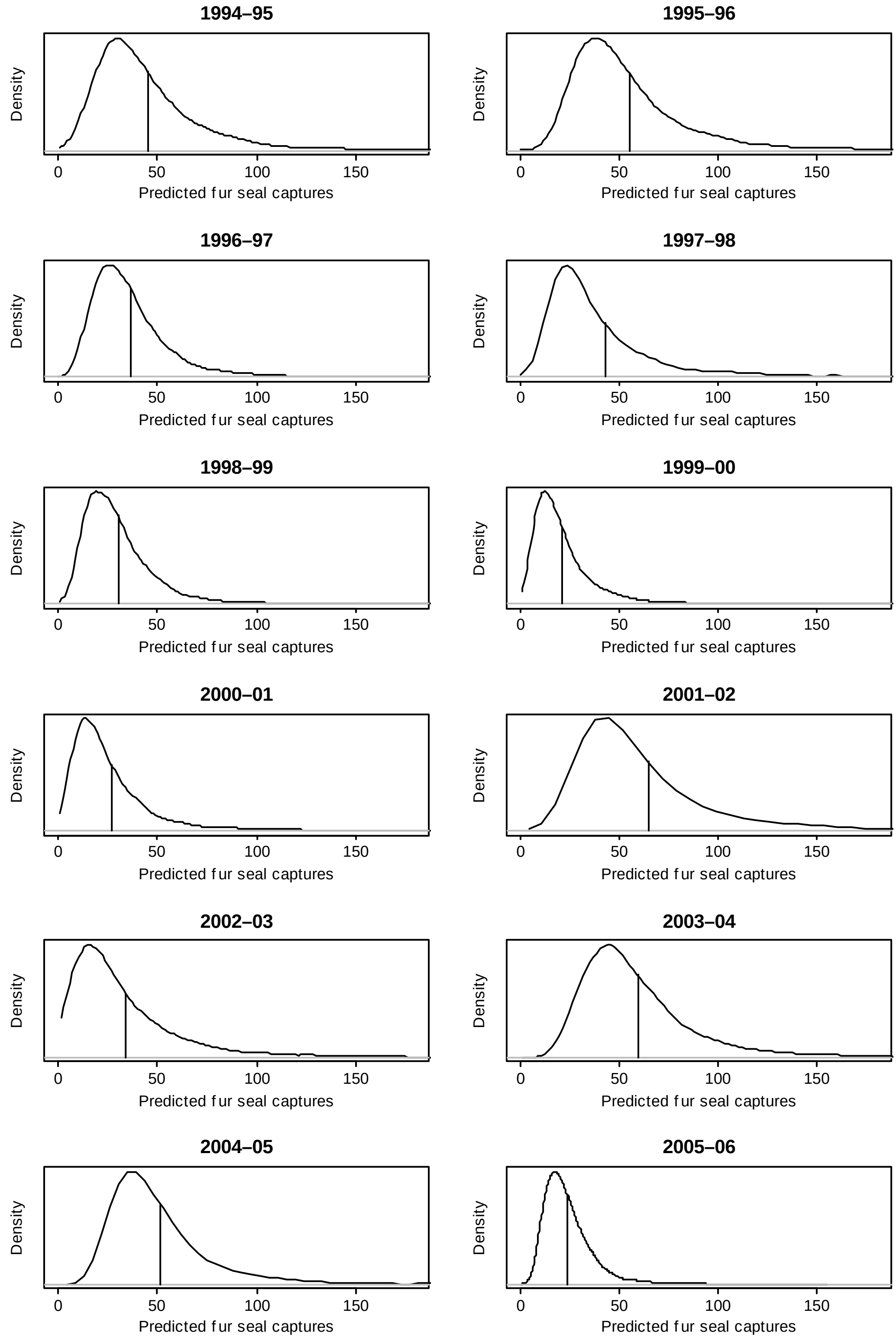


Figure D3: Plots of the predictive densities, by fishing year, for fur seal captures for all tows in the SANT area.

APPENDIX D – *continued*

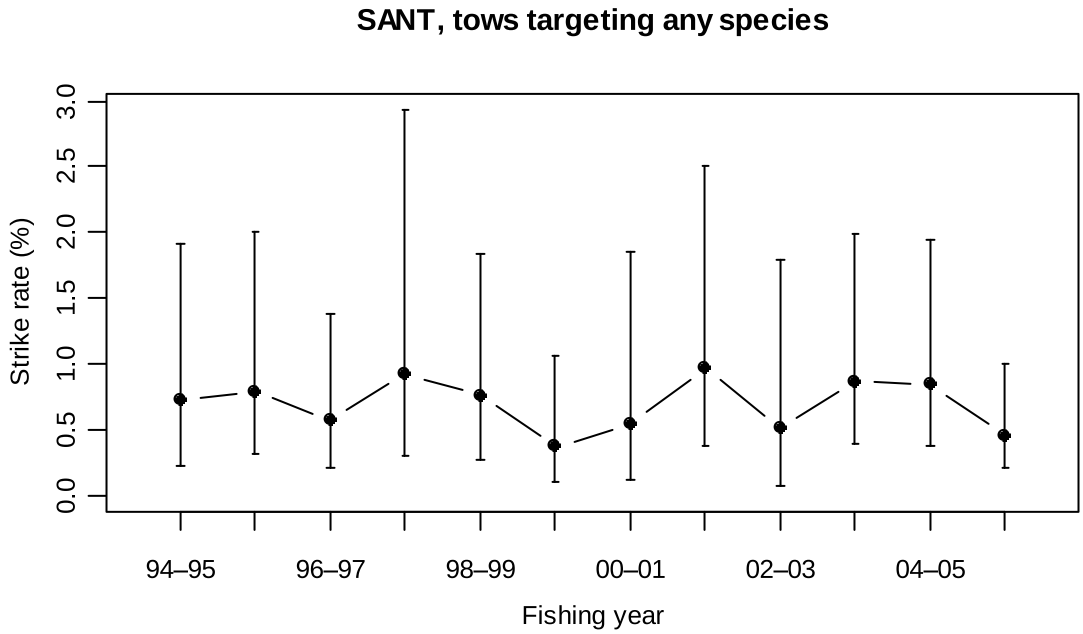


Figure D4: Predicted strike rates, with 95% prediction intervals, by fishing year, for all tows in the SANT area.

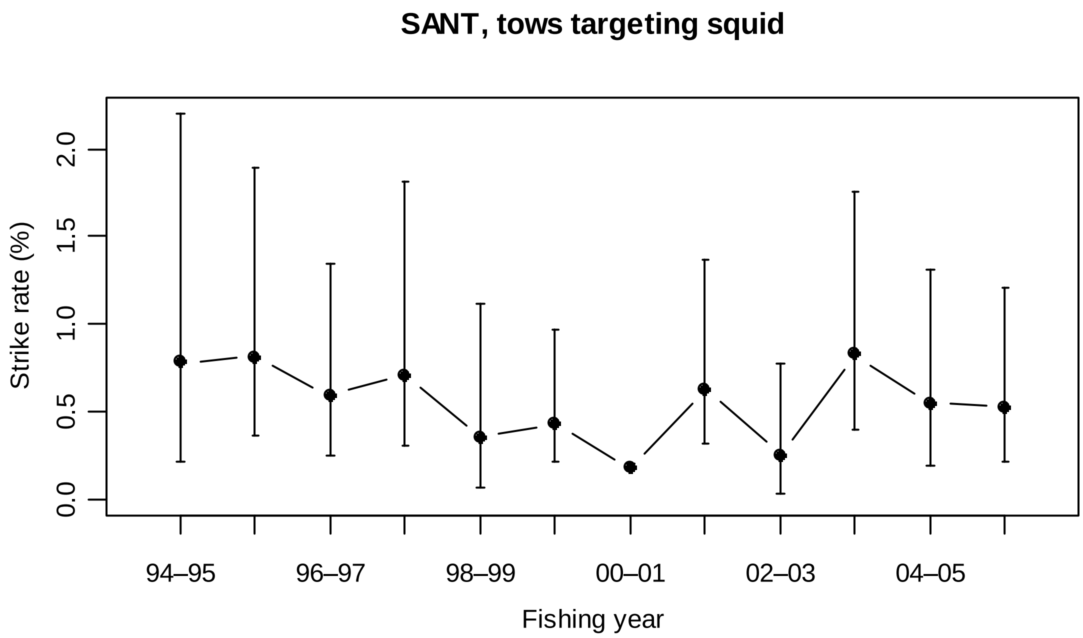


Figure D5: Predicted strike rates, with 95% prediction intervals, by fishing year, for tows targeting squid (SQU) in the SANT area.

APPENDIX E: STEWART-SNARES SHELF PUYSEGUR AREA (STSP)

Table E1: Observed and commercial effort and observed fur seal captures, by fishing year, for the STSP area.

Observed

Fishing year	Vessels	Trips	Tows	Coverage (%)	Fur seal captures	Obs. strike rate(%)
1994−95	14	14	703	4.0	17	2.4
1995−96	13	17	540	2.8	16	3.0
1996−97	21	22	882	4.1	11	1.2
1997−98	20	23	1 252	6.1	36	2.9
1998−99	26	29	1 724	8.3	57	3.3
1999−00	30	32	1 734	10.0	25	1.4
2000−01	32	56	3 181	16.4	37	1.2
2001−02	19	28	1 847	9.6	41	2.2
2002−03	28	38	1 525	8.0	16	1.0
2003−04	27	39	1 299	7.7	12	0.9
2004−05	29	40	2 015	11.4	26	1.3
2005−06	26	30	1 402	8.6	18	1.3
All	88	360	18 104	8.0	312	1.7

Commercial

	TCEPR forms		CELR forms		All forms	
Fishing year	Vessels	Tows	Vessels	Tows	Vessels	Tows
1994−95	78	10 223	58	7 441	136	17 664
1995−96	74	10 140	63	8 874	137	19 014
1996−97	82	11 615	57	9 716	139	21 331
1997−98	70	12 381	55	8 310	125	20 691
1998−99	79	12 703	49	8 158	128	20 861
1999−00	53	9 740	45	7 605	98	17 345
2000−01	51	10 379	45	8 976	96	19 355
2001−02	48	11 047	52	8 279	100	19 326
2002−03	51	9 751	48	9 234	99	18 985
2003−04	46	8 351	45	8 547	91	16 898
2004−05	44	9 307	42	8 429	86	17 736
2005−06	43	8 086	48	8 226	91	16 312
All	169	123 723	135	101 795	300	225 518

APPENDIX E – *continued*

Table E2: Comparison of observed and expected fur seal capture frequencies for the observer data in the STSP area.

Observed numbers of tows

	Number of fur seal captures per tow				
Year	0	1	2	3	4
1994–95	692	9			2
1995–96	524	16			
1996–97	873	7	2		
1997–98	1 220	29	2	1	
1998–99	1 676	42	4	1	1
1999–00	1 711	21	2		
2000–01	3 146	33	2		
2001–02	1 813	28	5	1	
2002–03	1 509	16			
2003–04	1 287	12			
2004–05	1 987	26			
2005–06	1 385	16	1		

Expected numbers of tows

	Number of fur seal captures per tow				
	0	1	2	3	4+
1994–95	692	9.6	1.1	0.3	0.2
1995–96	526	12.8	1.2	0.2	0.1
1996–97	871	10.4	0.7	0.1	0.0
1997–98	1 221	28.3	2.2	0.3	0.1
1998–99	1 677	41.2	4.1	0.8	0.4
1999–00	1 711	22.0	1.3	0.2	0.1
2000–01	3 145	34.4	1.7	0.2	0.0
2001–02	1 815	28.8	2.7	0.6	0.4
2002–03	1 508	15.9	0.9	0.1	0.1
2003–04	1 286	11.9	0.7	0.1	0.0
2004–05	1 988	22.2	1.9	0.4	0.2
2005–06	1 384	16.4	1.1	0.2	0.1

APPENDIX E – *continued*

Table E3: Characteristics of the posterior distribution of the parameters in the fitted model for the STSP area.

Parameter	Mean	sd	Median	95% credibility interval	
1995 base capture rate (%)	2.44	0.90	2.29	1.18	4.66
1996 base capture rate (%)	1.97	0.64	1.89	0.98	3.44
1997 base capture rate (%)	1.42	0.49	1.35	0.64	2.55
1998 base capture rate (%)	3.72	1.10	3.56	2.06	6.32
1999 base capture rate (%)	3.86	1.01	3.74	2.26	6.15
2000 base capture rate (%)	2.30	0.67	2.21	1.25	3.89
2001 base capture rate (%)	1.52	0.38	1.48	0.91	2.37
2002 base capture rate (%)	2.59	0.75	2.47	1.44	4.34
2003 base capture rate (%)	1.12	0.35	1.07	0.56	1.92
2004 base capture rate (%)	1.28	0.40	1.23	0.65	2.21
2005 base capture rate (%)	1.12	0.30	1.09	0.63	1.79
2006 base capture rate (%)	1.35	0.42	1.29	0.70	2.37
subarea Otago coast	3.29	0.87	3.20	1.86	5.23
subarea Puysegur	2.05	0.48	2.01	1.25	3.15
DN dusk	1.65	0.31	1.63	1.11	2.35
DN night	1.25	0.25	1.23	0.83	1.82
DN dawn	1.61	0.30	1.59	1.08	2.29
target deep	0.00	0.00	0.00	0.00	0.00
target mid depth	0.33	0.10	0.31	0.17	0.57
target shallow	0.31	0.13	0.29	0.12	0.60
target jack mack	0.43	0.15	0.41	0.20	0.78
sin(day.no) coefficient	-0.91	0.18	-0.90	-1.26	-0.56
cos(day.no) coefficient	1.05	0.18	1.05	0.70	1.40
Vessel-season effects variance	0.66	0.19	0.64	0.36	1.09
Extra-dispersion variance	2.70	0.74	2.61	1.49	4.37

APPENDIX E – *continued*

Table E4: Observer data capture details and characteristics of the predictive distribution of the total number of fur seals captured, by fishing year, for all tows in the STSP area.

Observed

Fishing year	Tows	CELR tows	Coverage (%)	Captures	Obs. strike rate(%)	Ratio est. captures
1994–95	703	0	4.0	17	2.4	427
1995–96	540	0	2.8	16	3.0	563
1996–97	882	0	4.1	11	1.2	266
1997–98	1 252	0	6.1	36	2.9	595
1998–99	1 724	0	8.3	57	3.3	690
1999–00	1 734	0	10.0	25	1.4	250
2000–01	3 181	0	16.4	37	1.2	225
2001–02	1 847	0	9.6	41	2.2	429
2002–03	1 525	0	8.0	16	1.0	199
2003–04	1 299	0	7.7	12	0.9	156
2004–05	2 015	0	11.4	26	1.3	229
2005–06	1 402	0	8.6	18	1.3	209
All	18 104	0	8.0	312	1.7	4 239

Predicted

		CELR	Predicted fur seal captures				Predicted strike rate	
Fishing year	Tows	tows (%)	Captures	c.v. (%)	95% pred. interval		Rate (%)	c.v. (%)
1994–95	17 664	42.1	561	47	234	1227	3.2	47
1995–96	19 014	46.7	605	44	256	1245	3.2	44
1996–97	21 331	45.5	547	46	218	1165	2.6	46
1997–98	20 691	40.2	1118	40	529	2211	5.4	39
1998–99	20 861	39.1	1134	35	594	2130	5.4	35
1999–00	17 345	43.8	526	40	248	1067	3.0	40
2000–01	19 355	46.4	453	33	245	823	2.3	33
2001–02	19 326	42.8	740	39	371	1495	3.8	38
2002–03	18 985	48.6	316	41	142	633	1.7	40
2003–04	16 898	50.6	379	44	163	791	2.2	43
2004–05	17 736	47.5	343	38	164	675	1.9	38
2005–06	16 312	50.4	358	39	167	702	2.2	39
All	225 518	45.1	7 080	29	4 230	12 224	3.1	29

APPENDIX E – *continued*

Table E5: Observer data capture details and characteristics of the predictive distribution of the total number of fur seals captured, by fishing year, for tows targeting squid (SQU) in the STSP area.

Observed

Fishing year	Tows	Coverage (%)	Captures	Obs. strike rate(%)	Ratio est. captures
1994–95	439	9.1	3	0.7	33
1995–96	186	5.0	5	2.7	100
1996–97	494	10.1	5	1.0	50
1997–98	538	10.5	21	3.9	200
1998–99	824	13.9	37	4.5	267
1999–00	352	17.0	10	2.8	59
2000–01	2 330	63.6	22	0.9	35
2001–02	860	22.0	17	2.0	77
2002–03	809	17.2	8	1.0	46
2003–04	956	20.0	9	0.9	45
2004–05	1 638	26.6	12	0.7	45
2005–06	638	13.6	3	0.5	22
All	10 064	18.5	152	1.5	978

Predicted

			Predicted fur seal captures				Predicted strike rate	
Fishing year	Tows	CELR tows (%)	Captures	c.v. (%)	95% pred. interval		Rate (%)	c.v. (%)
1994–95	4 816	0.0	106	40	47	210	2.2	38
1995–96	3 708	0.0	121	38	54	233	3.3	36
1996–97	4 892	0.0	116	40	49	229	2.4	38
1997–98	5 122	0.1	254	30	140	435	5.0	29
1998–99	5 938	0.2	265	21	174	389	4.5	20
1999–00	2 065	0.5	63	36	31	119	3.0	32
2000–01	3 663	0.0	82	25	51	130	2.2	22
2001–02	3 910	0.0	153	31	83	264	3.9	30
2002–03	4 700	0.2	74	33	37	130	1.6	31
2003–04	4 782	0.0	107	35	52	195	2.2	33
2004–05	6 158	0.0	82	29	45	138	1.3	27
2005–06	4 682	0.0	103	37	48	196	2.2	35
All	54 436	0.1	1 528	14	1 161	2 013	2.8	14

APPENDIX E – *continued*

Table E6: Observer data capture details and characteristics of the predictive distribution of the total number of fur seals captured, by fishing year, for tows targeting hoki (HOK) in the Puysegur subarea of STSP.

Observed

Fishing year	Tows	Coverage (%)	Captures	Obs. strike rate(%)	Ratio est. captures
1994–95	21	6.6	11	52.4	167
1995–96	64	11.8	7	10.9	59
1996–97	32	3.9	3	9.4	77
1997–98	0	0			
1998–99	29	6.0	1	3.4	17
1999–00	32	5.3	0	0.0	0
2000–01	108	11.8	3	2.8	25
2001–02	50	9.0	19	38.0	210
2002–03	54	11.0	5	9.3	46
2003–04	32	22.2	3	9.4	14
2004–05	56	19.2	9	16.1	47
2005–06	34	31.5	7	20.6	22
All	512	8.8	68	13.3	683

Predicted

		Predicted fur seal captures				Predicted strike rate	
Fishing year	Tows	Captures	c.v. (%)	95% pred. interval		Rate (%)	c.v. (%)
1994–95	318	38	34	20	69	11.8	29
1995–96	542	46	39	20	90	8.4	35
1996–97	817	56	41	22	110	6.8	38
1997–98	565	79	38	35	149	14.0	35
1998–99	485	86	34	41	156	17.8	30
1999–00	604	46	42	18	93	7.6	37
2000–01	914	52	33	27	93	5.7	28
2001–02	553	93	31	51	161	16.8	28
2002–03	492	29	38	13	56	5.8	33
2003–04	144	8	43	3	16	5.3	27
2004–05	292	25	31	14	45	8.7	25
2005–06	108	12	38	7	24	11.5	30
All	5 834	570	19	390	814	9.8	18

APPENDIX E – *continued*

Table E7: Observer data capture details and characteristics of the predictive distribution of the total number of fur seals captured, by fishing year, for tows targeting hoki (HOK) in Stewart/Snares area (including the Otago coast subarea) of STSP.

Observed

Fishing year	Tows	Coverage (%)	Captures	Obs. strike rate(%)	Ratio est. captures
1994–95	195	7.6	2	1.0	26
1995–96	213	7.8	4	1.9	51
1996–97	100	2.8	3	3.0	106
1997–98	313	8.5	6	1.9	71
1998–99	564	18.0	17	3.0	94
1999–00	722	15.8	13	1.8	82
2000–01	457	10.5	7	1.5	67
2001–02	449	10.6	1	0.2	9
2002–03	426	17.5	2	0.5	11
2003–04	101	5.2	0	0.0	0
2004–05	90	9.4	1	1.1	11
2005–06	146	19.1	2	1.4	10
All	3 776	10.8	58	1.5	539

Predicted

		Predicted fur seal captures				Predicted strike rate	
Fishing year	Tows	Captures	c.v. (%)	95% pred. interval		Rate (%)	c.v. (%)
1994–95	2 555	60	45	23	127	2.3	43
1995–96	2 732	61	41	26	122	2.2	38
1996–97	3 521	66	45	25	138	1.9	43
1997–98	3 682	104	34	51	190	2.8	33
1998–99	3 128	131	25	79	208	4.2	23
1999–00	4 574	86	28	49	142	1.9	26
2000–01	4 360	69	32	37	124	1.6	30
2001–02	4 242	90	40	39	174	2.1	38
2002–03	2 436	23	47	9	50	1.0	41
2003–04	1 946	26	50	8	59	1.4	45
2004–05	962	16	39	6	30	1.6	29
2005–06	766	12	46	4	26	1.6	37
All	34 904	744	16	539	1 013	2.1	16

APPENDIX E – *continued*

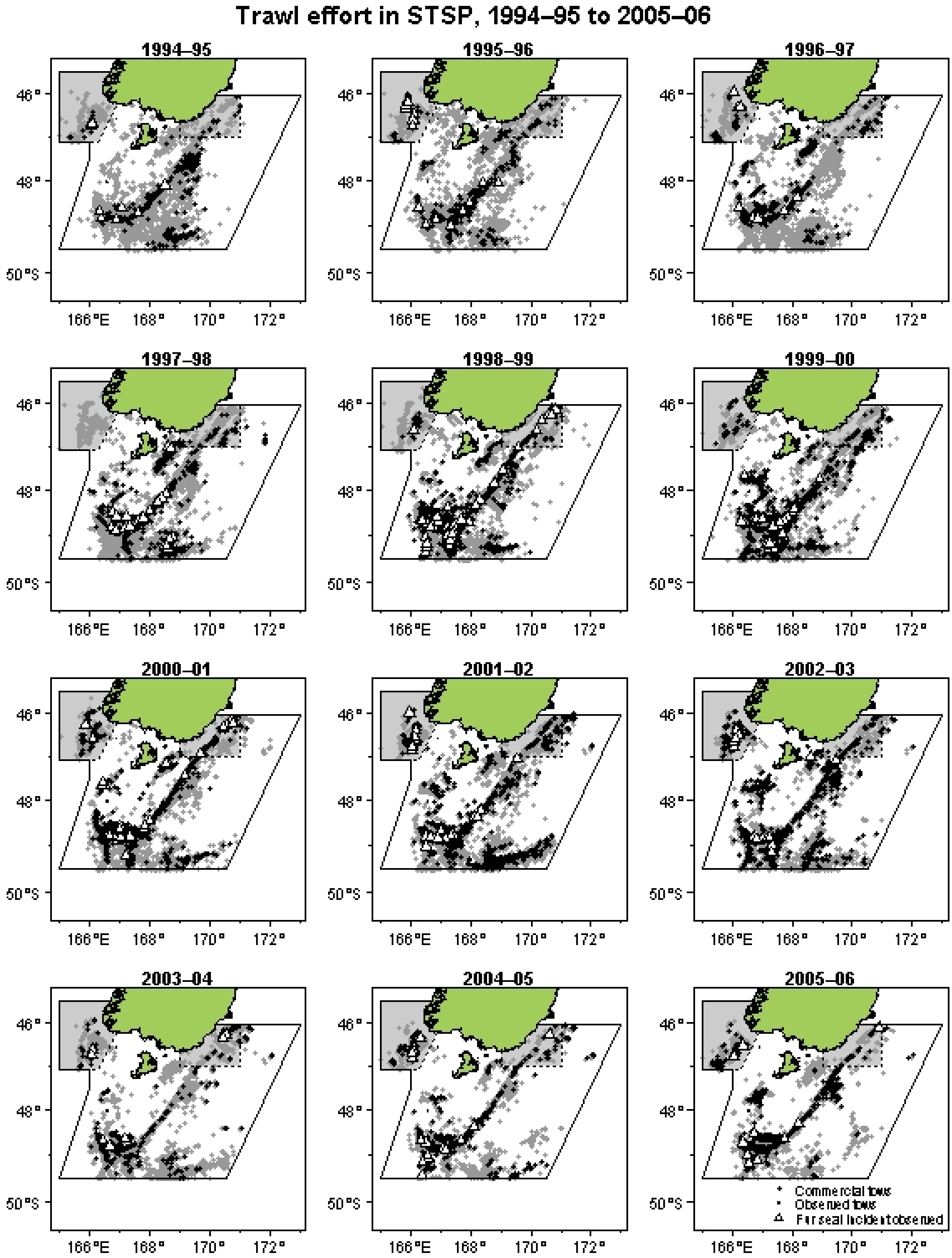


Figure E1: Plot of start positions of commercial tows, observed tows, and observed fur seal incidents by fishing year for the STSP area. Grey shaded regions are the Puysegur and Otago coast subareas.

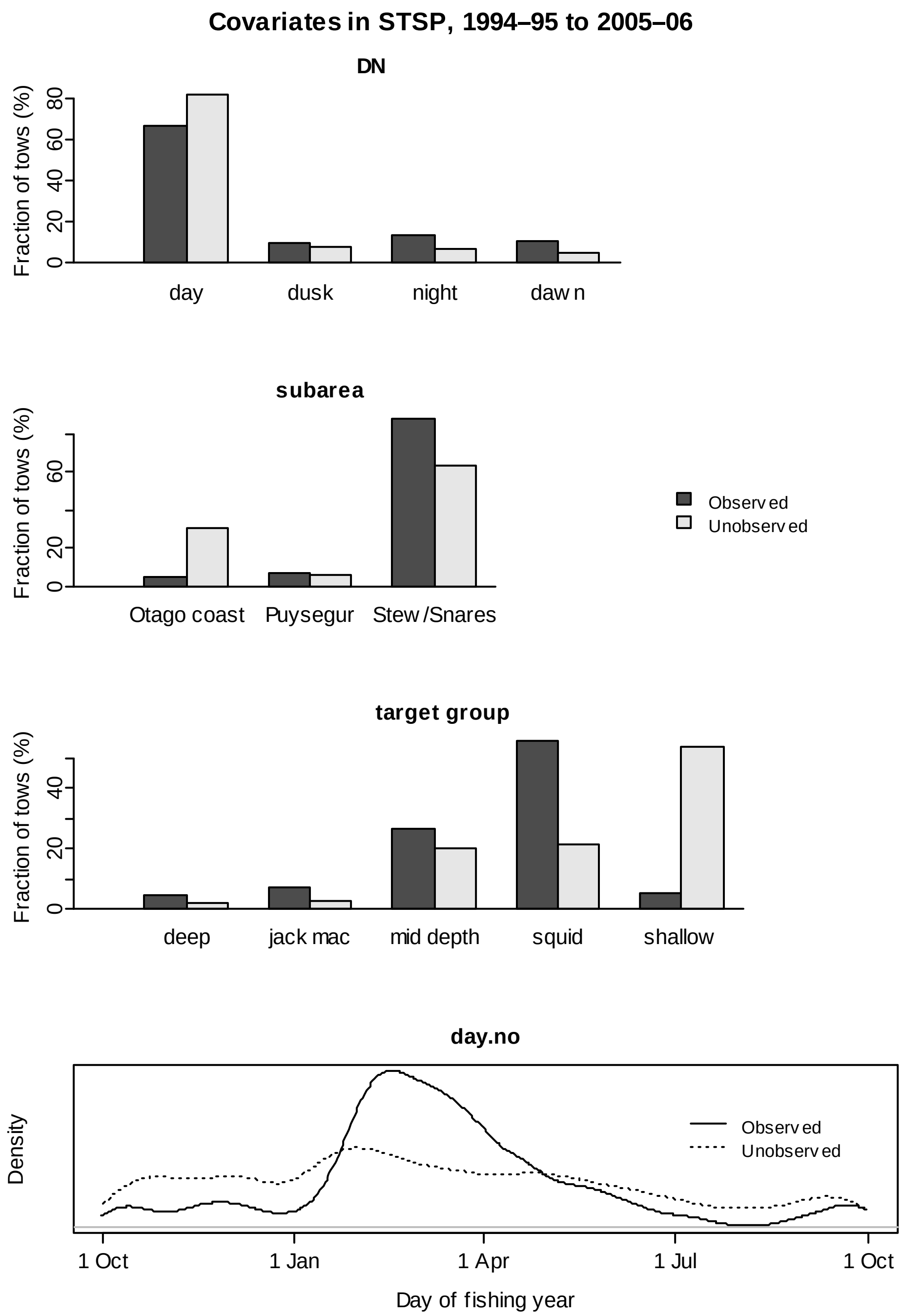


Figure E2: Bar and density plots for the fixed covariates used in the model for fur seal captures in the STSP area.

APPENDIX E – *continued*

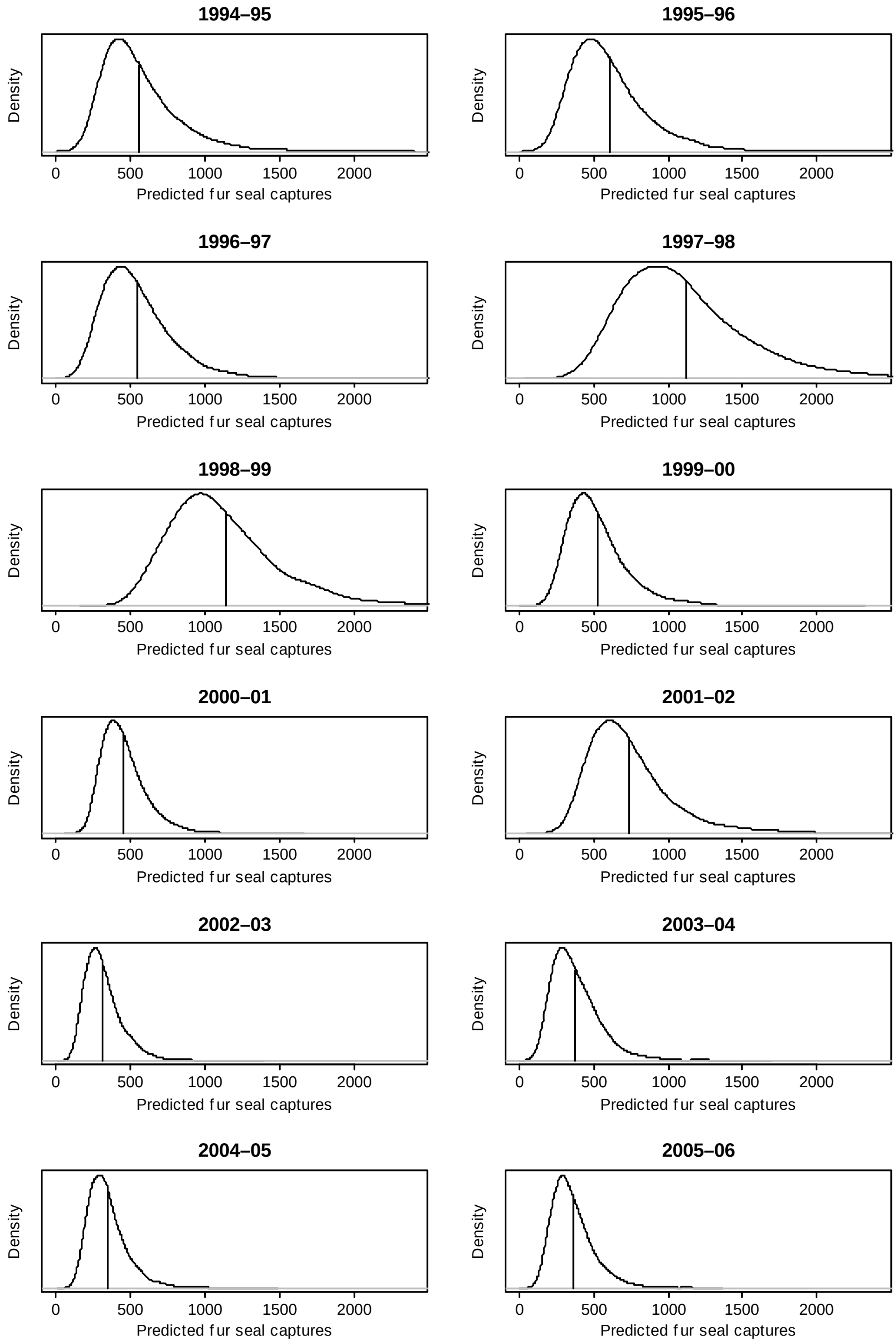


Figure E3: Plots of the predictive densities, by fishing year, for fur seal captures for all tows in the STSP area.

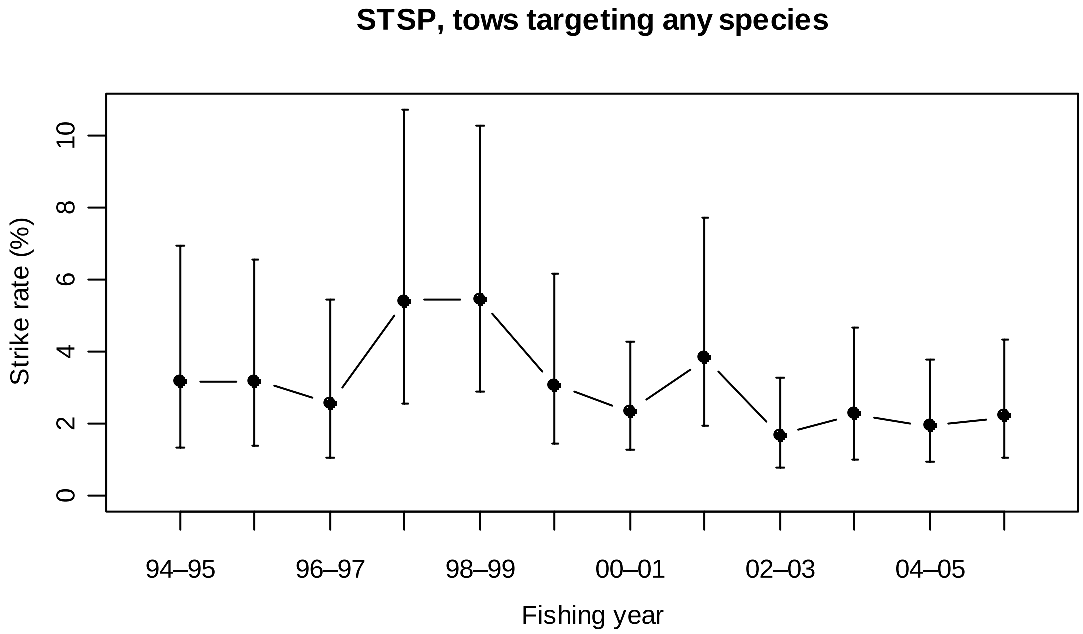


Figure E4: Predicted strike rates, with 95% prediction intervals, by fishing year, for all tows in the STSP area.

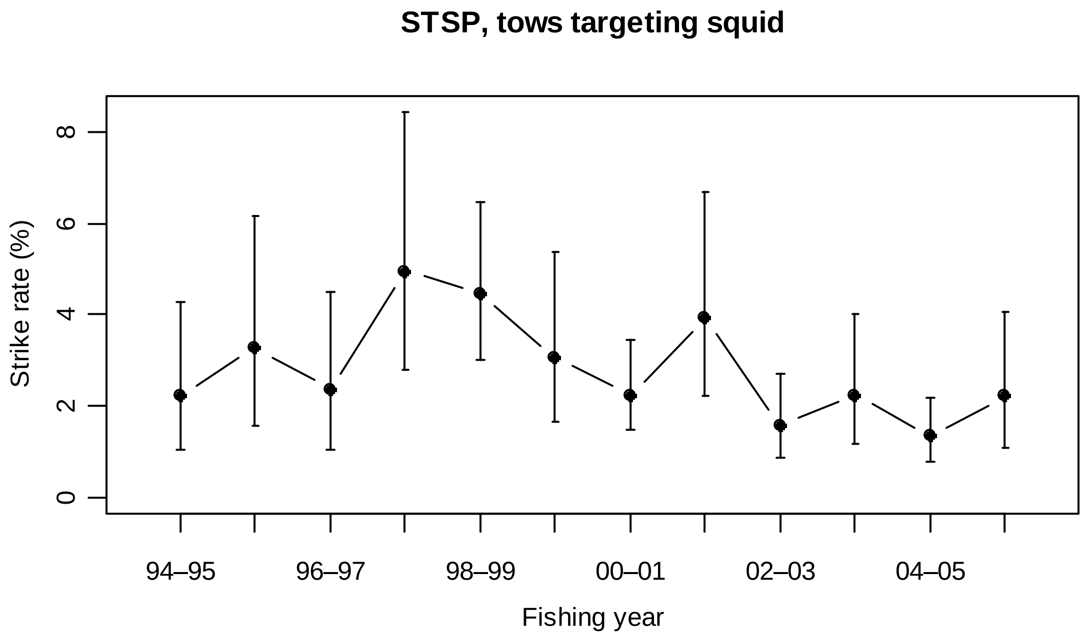


Figure E5: Predicted strike rates, with 95% prediction intervals, by fishing year, for tows targeting squid (SQU) in the STSP area.

APPENDIX F: WEST COAST SOUTH ISLAND AREA (WCSI)

Table F1: Observed and commercial effort and observed fur seal captures, by fishing year, for the WCSI area.

Observed

Fishing year	Vessels	Trips	Tows	Coverage (%)	Fur seal captures	Obs. strike rate(%)
1994−95	14	15	932	4.7	28	3.0
1995−96	18	18	1 204	6.7	160	13.3
1996−97	16	17	998	4.5	77	7.7
1997−98	17	18	1 101	6.2	126	11.4
1998−99	17	17	1 585	7.5	53	3.3
1999−00	18	20	1 233	7.3	83	6.7
2000−01	21	30	1 298	6.9	48	3.7
2001−02	19	21	1 425	9.2	58	4.1
2002−03	15	17	1 014	6.3	21	2.1
2003−04	16	17	1 402	9.1	29	2.1
2004−05	15	18	1 245	9.1	74	5.9
2005−06	16	21	1 180	8.7	30	2.5
All	77	224	14 617	7.0	787	5.4

Commercial

	TCEPR forms		CELR forms		All forms	
Fishing year	Vessels	Tows	Vessels	Tows	Vessels	Tows
1994−95	81	11 305	67	8 331	148	19 636
1995−96	72	8 835	65	9 245	137	18 080
1996−97	88	10 918	70	11 444	158	22 362
1997−98	82	10 248	67	7 502	149	17 750
1998−99	69	9 766	75	11 482	144	21 248
1999−00	59	8 894	67	8 036	126	16 930
2000−01	65	9 999	66	8 732	131	18 731
2001−02	59	8 997	61	6 514	120	15 511
2002−03	53	8 421	53	7 598	106	16 019
2003−04	52	7 120	64	8 286	116	15 406
2004−05	42	5 266	51	8 460	93	13 726
2005−06	40	5 109	47	8 500	87	13 609
All	155	104 878	163	104 130	315	209 008

APPENDIX F – *continued*

Table F2: Comparison of observed and expected fur seal capture frequencies for the observer data in the WCSI area.

Observed numbers of tows

	Number of fur seal captures per tow											
Year	0	1	2	3	4	5	6	7	8	10	11	12
1994–95	912	16	3				1					
1995–96	1 104	71	21	2	1	2	1			1	1	
1996–97	955	27	11	2	1				1	1		
1997–98	1 039	40	10	3	1	2	4	1				1
1998–99	1 543	36	4	1			1					
1999–00	1 170	48	10	5								
2000–01	1 267	23	2	4	1	1						
2001–02	1 386	27	9	2				1				
2002–03	997	15		2								
2003–04	1 374	27	1									
2004–05	1 178	62	4		1							
2005–06	1 158	16	4	2								

Expected numbers of tows

	Number of fur seal captures per tow						
	0	1	2	3	4	5	6+
1994–95	907	20.0	3.3	0.9	0.3	0.1	0.1
1995–96	1 115	58.5	15.9	6.4	3.1	1.7	3.3
1996–97	953	31.2	7.5	2.8	1.3	0.7	1.3
1997–98	1 035	42.3	11.6	4.8	2.5	1.4	2.9
1998–99	1 542	34.5	5.6	1.6	0.6	0.2	0.2
1999–00	1 176	43.1	9.1	2.9	1.1	0.5	0.5
2000–01	1 261	29.7	4.9	1.4	0.5	0.2	0.3
2001–02	1 384	32.6	5.8	1.7	0.6	0.3	0.3
2002–03	995	16.2	2.2	0.5	0.2	0.1	0.0
2003–04	1 376	22.0	3.1	0.8	0.2	0.1	0.1
2004–05	1 190	42.3	8.2	2.5	1.0	0.4	0.5
2005–06	1 152	24.1	3.1	0.7	0.2	0.1	0.1

APPENDIX F – *continued*

Table F3: Characteristics of the posterior distribution of the parameters in the fitted model for the WCSI area.

Parameter	Mean	sd	Median	95% credibility interval	
1995 base capture rate (%)	2.60	0.95	2.49	1.13	4.72
1996 base capture rate (%)	5.23	1.69	4.91	2.94	9.25
1997 base capture rate (%)	4.20	1.34	3.95	2.33	7.43
1998 base capture rate (%)	4.92	1.57	4.62	2.77	8.76
1999 base capture rate (%)	3.04	0.92	2.92	1.64	5.21
2000 base capture rate (%)	4.23	1.28	3.99	2.41	7.32
2001 base capture rate (%)	3.29	0.93	3.17	1.85	5.54
2002 base capture rate (%)	3.40	1.01	3.26	1.89	5.85
2003 base capture rate (%)	2.42	0.83	2.33	1.13	4.27
2004 base capture rate (%)	2.22	0.80	2.12	0.99	4.02
2005 base capture rate (%)	3.51	1.08	3.34	1.92	6.05
2006 base capture rate (%)	2.25	0.79	2.17	0.99	3.99
DN dusk	1.75	0.29	1.74	1.24	2.40
DN night	2.92	0.36	2.90	2.29	3.67
DN dawn	2.38	0.39	2.35	1.70	3.24
subarea Cape Foulwind	0.22	0.04	0.21	0.15	0.31
subarea northern	0.07	0.05	0.06	0.01	0.21
deep	0.00	0.00	0.00	0.00	0.00
target shallow	2.69	0.76	2.58	1.53	4.48
target jack mack	1.23	0.35	1.19	0.70	2.04
log(duration) coefficient	0.48	0.10	0.48	0.28	0.68
Vessel-season effects variance	1.38	0.26	1.35	0.95	1.97
Extra-dispersion variance	5.50	0.54	5.45	4.54	6.65

APPENDIX F – *continued*

Table F4: Observer data capture details and characteristics of the predictive distribution of the total number of fur seals captured, by fishing year, for all tows in the WCSI area.

Observed

Fishing year	Tows	CELR tows	Coverage (%)	Captures	Obs. strike rate(%)	Ratio est. captures
1994–95	932	0	4.7	28	3.0	590
1995–96	1 204	0	6.7	160	13.3	2 403
1996–97	998	0	4.5	77	7.7	1 725
1997–98	1 101	0	6.2	126	11.4	2 031
1998–99	1 585	0	7.5	53	3.3	711
1999–00	1 233	0	7.3	83	6.7	1 140
2000–01	1 298	0	6.9	48	3.7	693
2001–02	1 425	0	9.2	58	4.1	631
2002–03	1 014	0	6.3	21	2.1	332
2003–04	1 402	0	9.1	29	2.1	319
2004–05	1 245	0	9.1	74	5.9	816
2005–06	1 180	0	8.7	30	2.5	346
All	14 617	0	7.0	787	5.4	11 736

Predicted

		CELR	Predicted fur seal captures				Predicted strike rate	
Fishing year	Tows	tows (%)	Captures	c.v. (%)	95% pred. interval		Rate (%)	c.v. (%)
1994–95	19 636	42.4	829	41	346	1623	4.2	40
1995–96	18 080	51.1	1840	34	1020	3324	10.2	34
1996–97	22 362	51.2	1733	36	900	3260	7.7	35
1997–98	17 750	42.3	1475	34	800	2693	8.3	33
1998–99	21 248	54.0	1051	35	537	1946	4.9	35
1999–00	16 930	47.5	1200	33	661	2215	7.1	33
2000–01	18 731	46.6	1098	32	588	1958	5.9	32
2001–02	15 511	42.0	865	35	453	1592	5.6	34
2002–03	16 019	47.4	665	40	295	1322	4.2	40
2003–04	15 406	53.8	593	41	259	1178	3.8	41
2004–05	13 726	61.6	929	38	459	1820	6.8	37
2005–06	13 609	62.5	573	44	241	1163	4.2	43
All	209 008	49.8	12 851	20	8 904	18 908	6.1	20

APPENDIX F – *continued*

Table F5: Observer data capture details and characteristics of the predictive distribution of the total number of fur seals captured, by fishing year, for tows targeting hoki (HOK) in the WCSI area.

Observed

Fishing year	Tows	Coverage (%)	Captures	Obs. strike rate(%)	Ratio est. captures
1994–95	814	9.4	28	3.4	297
1995–96	1 061	14.0	137	12.9	976
1996–97	689	7.7	53	7.7	691
1997–98	914	10.7	119	13.0	1 114
1998–99	1 103	14.5	33	3.0	227
1999–00	1 163	14.8	83	7.1	561
2000–01	1 079	12.1	38	3.5	315
2001–02	1 337	16.4	58	4.3	353
2002–03	928	11.9	19	2.0	160
2003–04	1 317	19.3	27	2.1	140
2004–05	978	24.8	54	5.5	217
2005–06	782	22.1	20	2.6	90
All	12 165	13.8	669	5.5	5 142

Predicted

			Predicted fur seal captures				Predicted strike rate	
Fishing year	Tows	CELR tows (%)	Captures	c.v. (%)	95% pred. interval		Rate (%)	c.v. (%)
1994–95	8 639	1.8	307	36	143	577	3.6	36
1995–96	7 556	4.6	710	26	464	1157	9.4	25
1996–97	8 989	4.9	542	29	318	923	6.0	28
1997–98	8 554	4.4	660	27	410	1089	7.7	26
1998–99	7 584	5.9	321	28	186	525	4.2	27
1999–00	7 862	7.9	477	25	306	754	6.1	24
2000–01	8 953	7.5	433	27	256	700	4.8	26
2001–02	8 131	6.6	346	27	207	574	4.3	27
2002–03	7 831	8.7	227	33	112	406	2.9	32
2003–04	6 838	10.7	193	32	102	341	2.8	31
2004–05	3 937	8.7	173	25	109	278	4.4	24
2005–06	3 531	9.9	96	35	49	177	2.7	32
All	88 405	6.4	4 485	10	3 702	5 530	5.1	10

APPENDIX F – *continued*

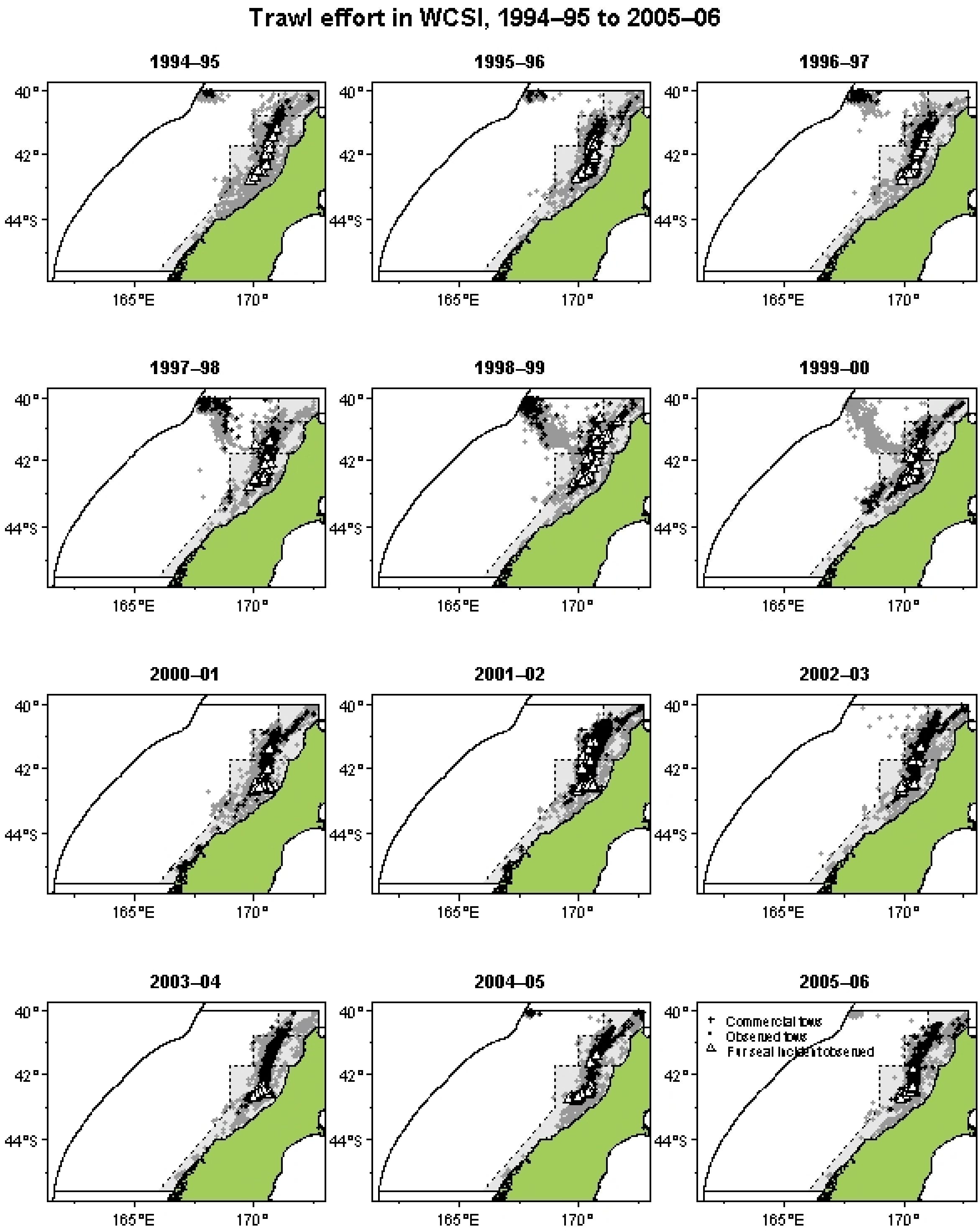


Figure F1: Plot of start positions of commercial tows, observed tows, and observed fur seal incidents by fishing year for the WCSI area. The light-grey shaded regions are the subareas for tows targeting non-deep species: Hokitika Canyon, Cape Foulwind, and northern (going south to north)

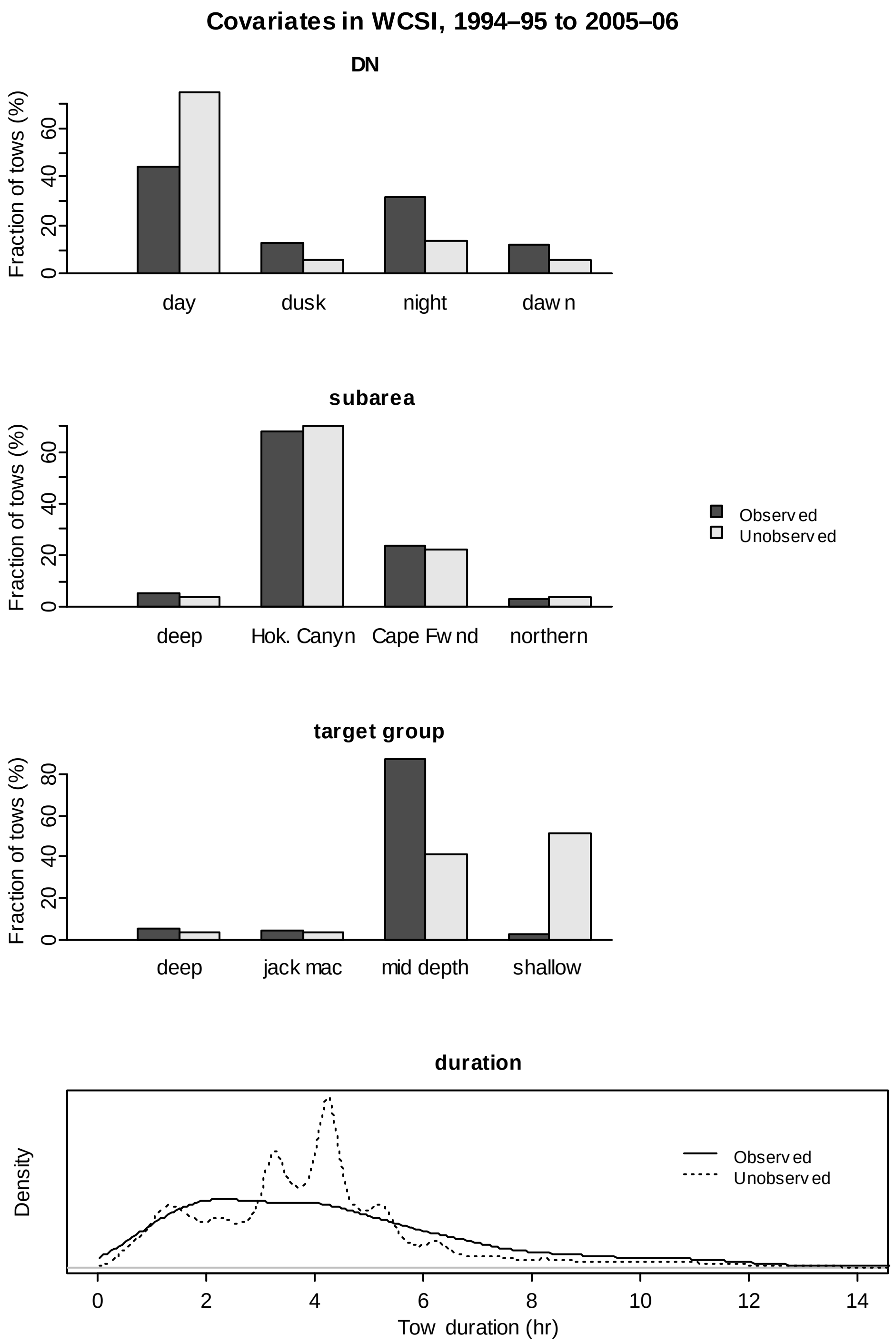


Figure F2: Bar and density plots for the fixed covariates used in the model for fur seal captures in the WCSI area.

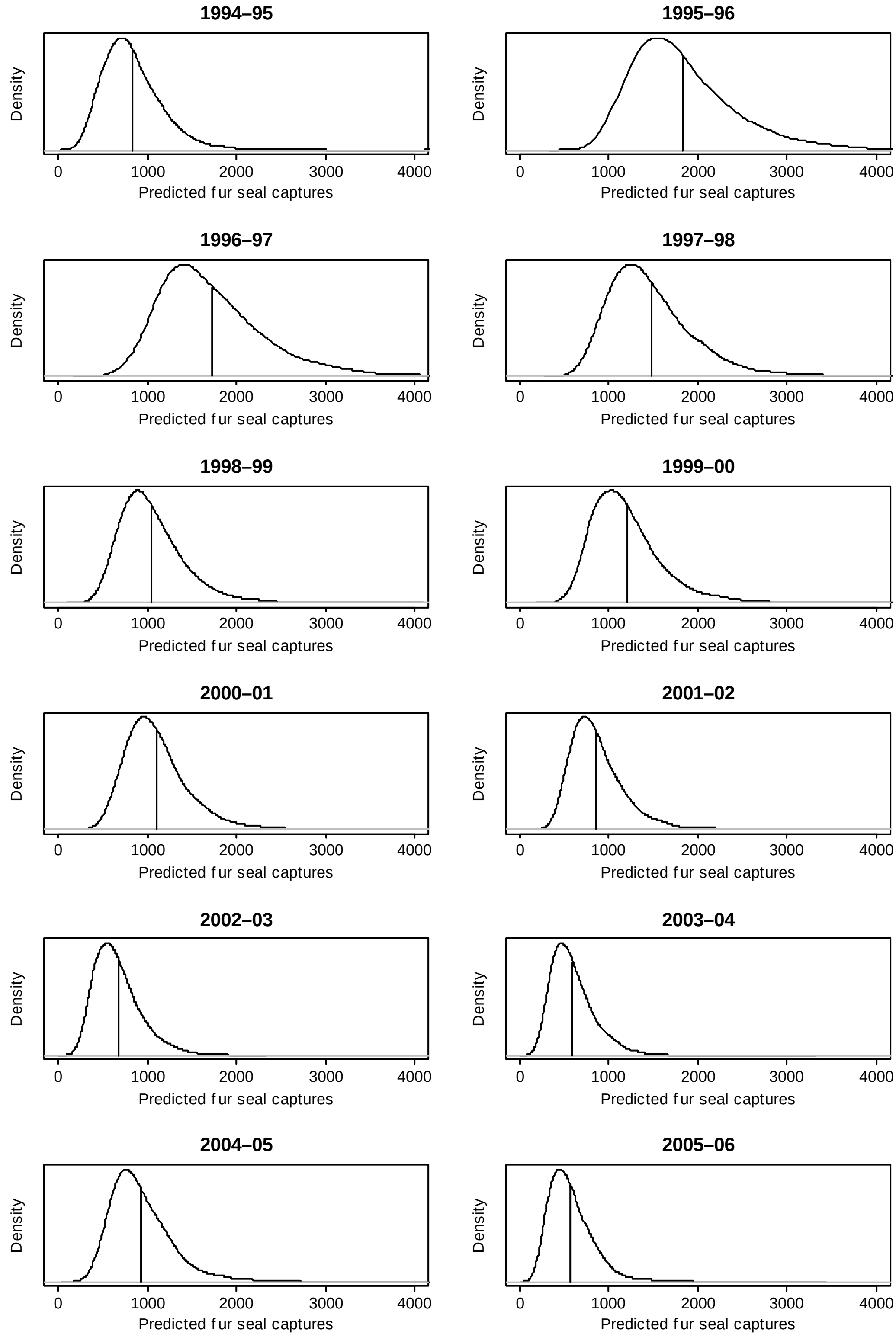


Figure F3: Plots of the predictive densities, by fishing year, for fur seal captures for all tows in the WCSI area.

WCSI, tows targeting any species

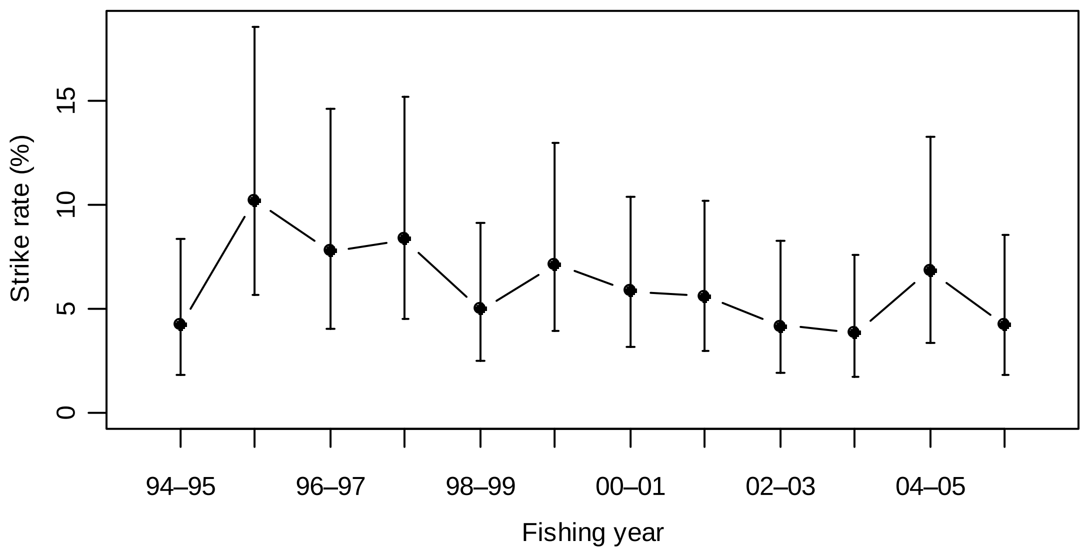


Figure F4: Predicted strike rates, with 95% prediction intervals, by fishing year, for all tows in the WCSI area.

WCSI, tows targeting hoki

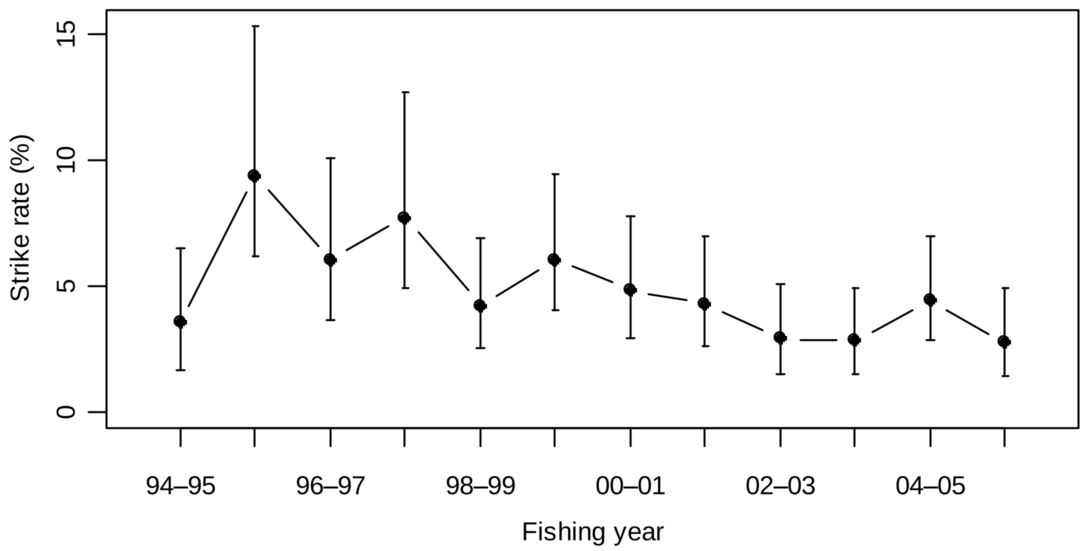


Figure F5: Predicted strike rates, with 95% prediction intervals, by fishing year, for tows targeting hoki (HOK) in the WCSI area.

APPENDIX G: SOUTHERN BLUE WHITING FISHERY AREA IN FMA 6 (SBW6)

Table G1: Observed and commercial effort and observed fur seal captures, by fishing year, for the SBW6 fishery area.

Observed

Fishing year	Vessels	Trips	Tows	Coverage (%)	Fur seal captures	Obs. strike rate(%)
1994−95	5	7	240	52.2	92	38.3
1995−96	4	4	144	24.7	17	11.8
1996−97	6	9	249	40.3	30	12.0
1997−98	9	13	418	35.4	66	15.8
1998−99	10	13	342	27.5	42	12.3
1999−00	14	16	316	45.5	85	26.9
2000−01	12	15	388	58.4	58	14.9
2001−02	10	10	333	28.7	13	3.9
2002−03	6	6	279	43.7	9	3.2
2003−04	7	8	251	33.9	13	5.2
2004−05	7	9	337	38.7	37	11.0
2005−06	6	6	217	34.8	52	24.0
All	29	87	3 514	37.1	514	14.6

Commercial

	TCEPR forms		CELR forms		All forms	
Fishing year	Vessels	Tows	Vessels	Tows	Vessels	Tows
1994−95	16	460	0	0	16	460
1995−96	11	583	0	0	11	583
1996−97	15	618	0	0	15	618
1997−98	30	1 181	0	0	30	1 181
1998−99	26	1 243	0	0	26	1 243
1999−00	21	694	0	0	21	694
2000−01	15	664	0	0	15	664
2001−02	18	1 159	0	0	18	1 159
2002−03	14	638	0	0	14	638
2003−04	18	740	0	0	18	740
2004−05	19	870	0	0	19	870
2005−06	13	623	0	0	13	623
All	54	9 473	0	0	54	9 473

APPENDIX G – *continued*

Table G2: Comparison of observed and expected fur seal capture frequencies for the observer data in the SBW6 fishery area.

Observed numbers of tows

	Number of fur seal captures per tow													
Year	0	1	2	3	4	5	6	7	8	9	10	19	21	22
1994−95	207	15	9	4	1	1			1	1			1	
1995−96	135	3	4	2										
1996−97	234	7	4	1	3									
1997−98	384	22	5	4		1		1			1			
1998−99	316	17	5	1	3									
1999−00	281	18	9	5	1				1					1
2000−01	363	20		2			1	1				1		
2001−02	321	11	1											
2002−03	270	9												
2003−04	246	4								1				
2004−05	314	16	3	2	1	1								
2005−06	197	12	1	3	1		1			1	1			

Expected numbers of tows

	Number of fur seal captures per tow						
	0	1	2	3	4	5	6+
1994−95	206	18.3	6.3	3.1	1.8	1.2	3.2
1995−96	133	7.3	1.7	0.7	0.4	0.2	0.5
1996−97	235	10.0	2.0	0.8	0.4	0.3	0.8
1997−98	384	20.2	5.8	2.9	1.7	1.1	2.7
1998−99	315	16.5	4.9	2.2	1.2	0.7	1.3
1999−00	291	14.0	3.6	1.8	1.1	0.8	3.2
2000−01	363	18.3	3.5	1.3	0.7	0.4	1.2
2001−02	322	9.6	1.2	0.3	0.1	0.1	0.1
2002−03	271	7.5	0.7	0.1	0.0	0.0	0.0
2003−04	240	8.5	1.3	0.4	0.2	0.1	0.3
2004−05	316	13.9	3.2	1.4	0.7	0.4	1.0
2005−06	192	13.8	4.7	2.3	1.3	0.8	1.9

Table G3: Characteristics of the posterior distribution of the parameters in the fitted model for the SBW6 area. The subarea effects are relative to the SBW 6I, Campbell Rise subarea. All observed tows were in the main fishing season (July–October).

Parameter	Mean	sd	Median	95% credibility interval	
1994 base capture rate (%)	2.79	1.21	2.61	1.16	5.48
1995 base capture rate (%)	3.02	0.89	2.89	1.66	5.06
1996 base capture rate (%)	3.08	0.98	2.92	1.68	5.42
1997 base capture rate (%)	3.16	0.95	3.00	1.78	5.48
1998 base capture rate (%)	2.49	0.67	2.43	1.39	4.01
1999 base capture rate (%)	2.18	0.68	2.13	1.02	3.69
2000 base capture rate (%)	3.50	1.05	3.31	1.98	6.04
2001 base capture rate (%)	3.54	0.96	3.39	2.12	5.82
2002 base capture rate (%)	2.36	0.71	2.30	1.13	3.90
2003 base capture rate (%)	2.45	0.73	2.40	1.23	4.08
2004 base capture rate (%)	2.62	0.77	2.52	1.36	4.39
2005 base capture rate (%)	2.43	0.71	2.36	1.29	3.99
2006 base capture rate (%)	2.31	0.70	2.26	1.14	3.88
DN dusk	1.03	0.26	1.00	0.61	1.61
DN night	1.89	0.39	1.86	1.24	2.73
DN dawn	1.62	0.35	1.59	1.03	2.41
gear BT	2.43	1.16	2.20	0.92	5.30
subarea 6A	0.01	0.09	0.00	0.00	0.04
subarea 6B	37.36	12.05	35.32	19.76	65.70
subarea 6R	0.95	0.56	0.82	0.27	2.35
log(duration) coefficient	0.32	0.12	0.32	0.09	0.56
log(distance to land) coefficient	0.63	0.31	0.63	0.03	1.22
Vessel-season effects variance	0.44	0.17	0.42	0.16	0.82
Extra-dispersion variance	3.33	0.47	3.30	2.47	4.34

APPENDIX G – *continued*

Table G4: Observer data capture details and characteristics of the predictive distribution of the total number of fur seals captured, by fishing year, for tows in the SBW6 fishery area. All commercial tows were recorded on TCEPR forms.

Observed

Fishing year	Tows	Coverage (%)	Captures	Obs. strike rate(%)	Ratio est. captures
1994−95	240	52.2	92	38.3	176
1995−96	144	24.7	17	11.8	69
1996−97	249	40.3	30	12.0	74
1997−98	418	35.4	66	15.8	186
1998−99	342	27.5	42	12.3	153
1999−00	316	45.5	85	26.9	187
2000−01	388	58.4	58	14.9	99
2001−02	333	28.7	13	3.9	45
2002−03	279	43.7	9	3.2	21
2003−04	251	33.9	13	5.2	38
2004−05	337	38.7	37	11.0	96
2005−06	217	34.8	52	24.0	149
All	3 514	37.1	514	14.6	1 294

Predicted

		Predicted fur seal captures				Predicted strike rate	
Fishing year	Tows	Captures	c.v. (%)	95% pred. interval		Rate (%)	c.v. (%)
1994−95	460	130	20	102	194	28.4	15
1995−96	583	89	41	43	180	15.2	34
1996−97	618	67	34	40	125	10.8	26
1997−98	1 181	111	17	85	155	9.4	13
1998−99	1 243	200	33	109	367	16.1	30
1999−00	694	181	33	111	334	26.0	29
2000−01	664	79	16	63	110	11.9	11
2001−02	1 159	118	40	55	233	10.2	34
2002−03	638	53	54	21	126	8.3	40
2003−04	740	49	37	25	95	6.7	30
2004−05	870	88	34	52	164	10.1	30
2005−06	623	73	18	58	106	11.8	12
All	9 473	1 237	13	1 004	1 611	13.1	11

APPENDIX G – *continued*

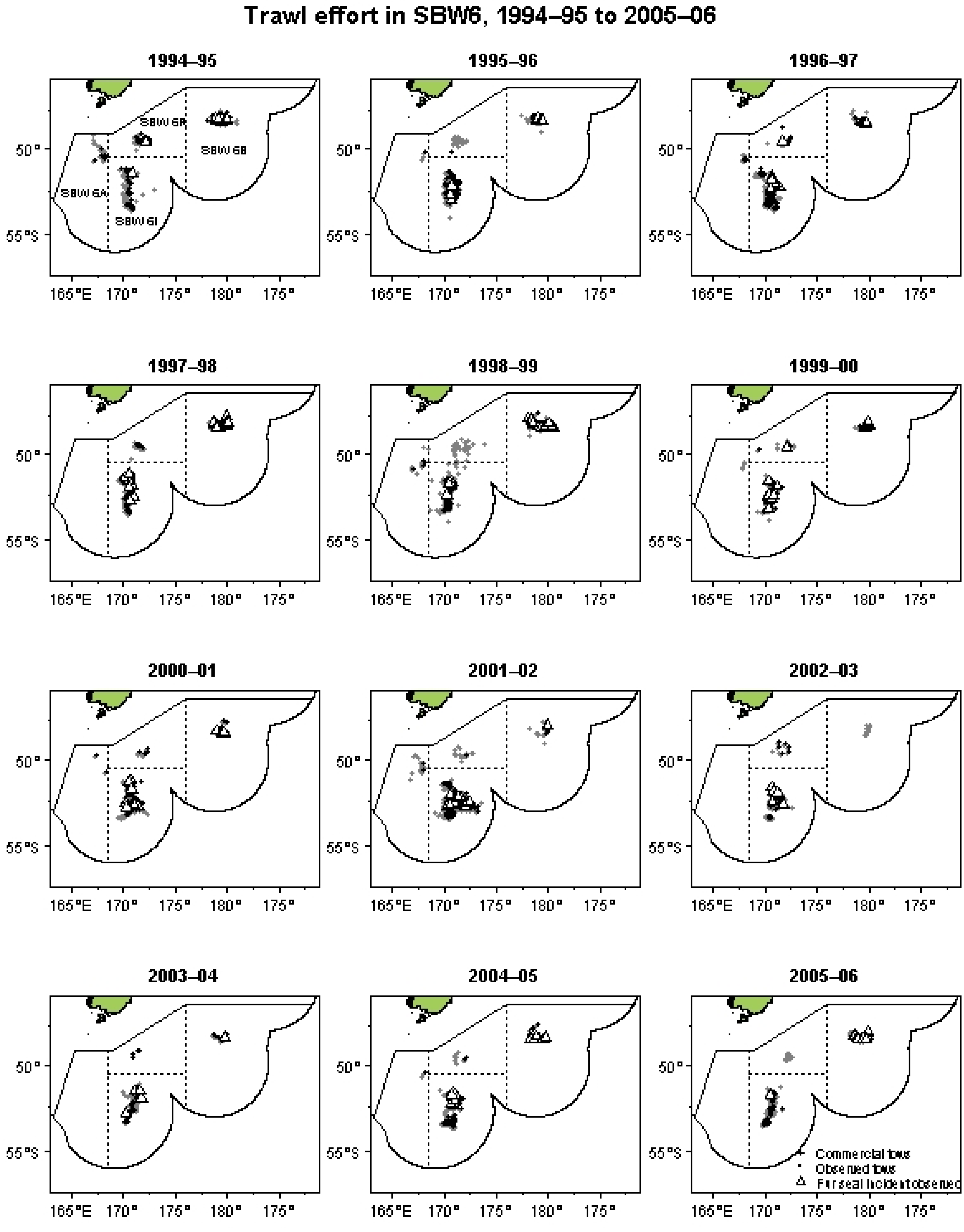


Figure G1: Plot of start positions of commercial tows, observed tows, and observed fur seal incidents by fishing year for the SBW6 fishery area. The dashed lines are the boundaries between the subareas: Auckland Islands (6A), Campbell Rise (6I), Pukaki Rise (6R), and Bounty Plateau (6B).

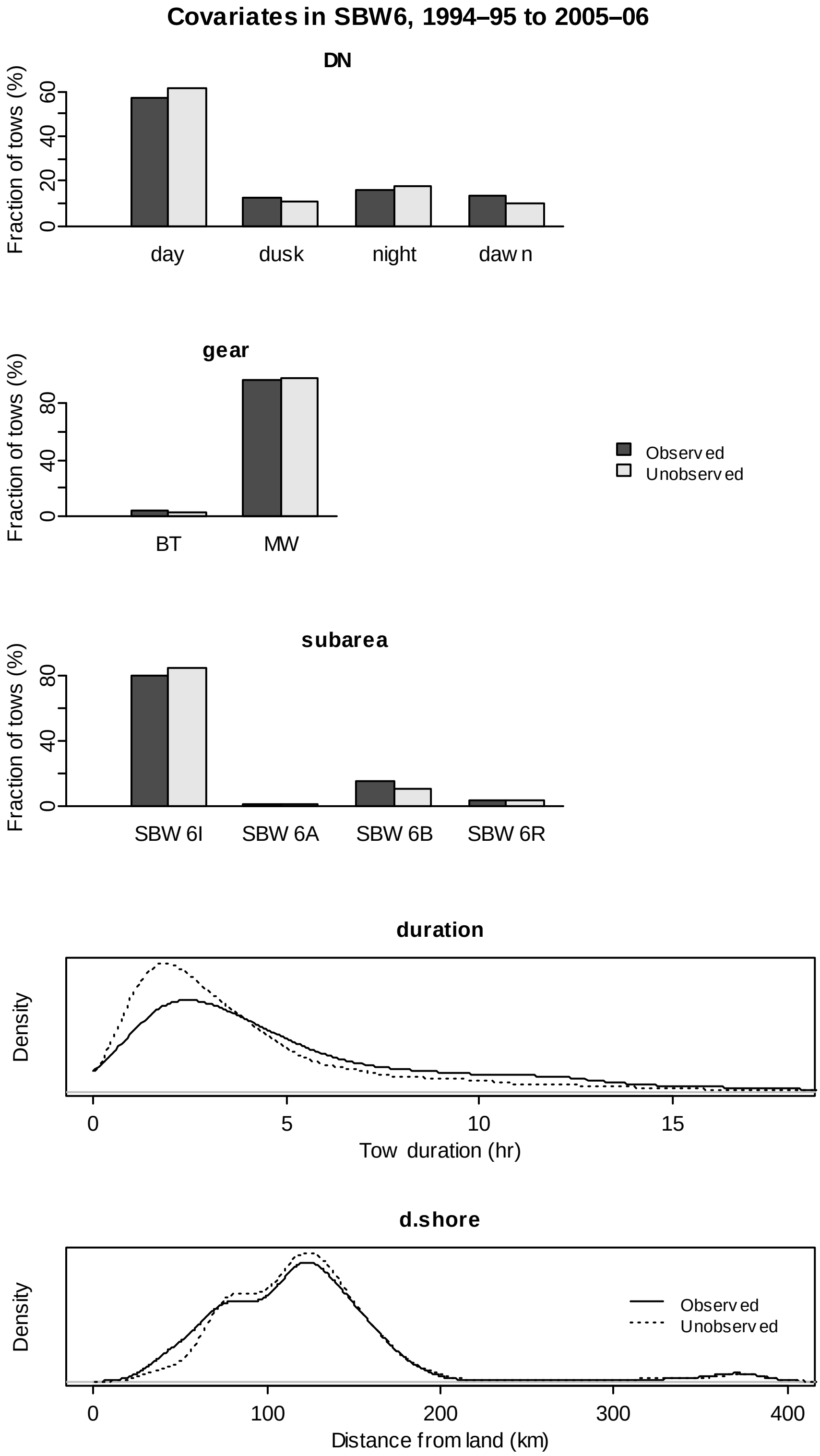


Figure G2: Bar and density plots for the fixed covariates used in the model for fur seal captures in the SBW6 fishery area.

APPENDIX G – *continued*

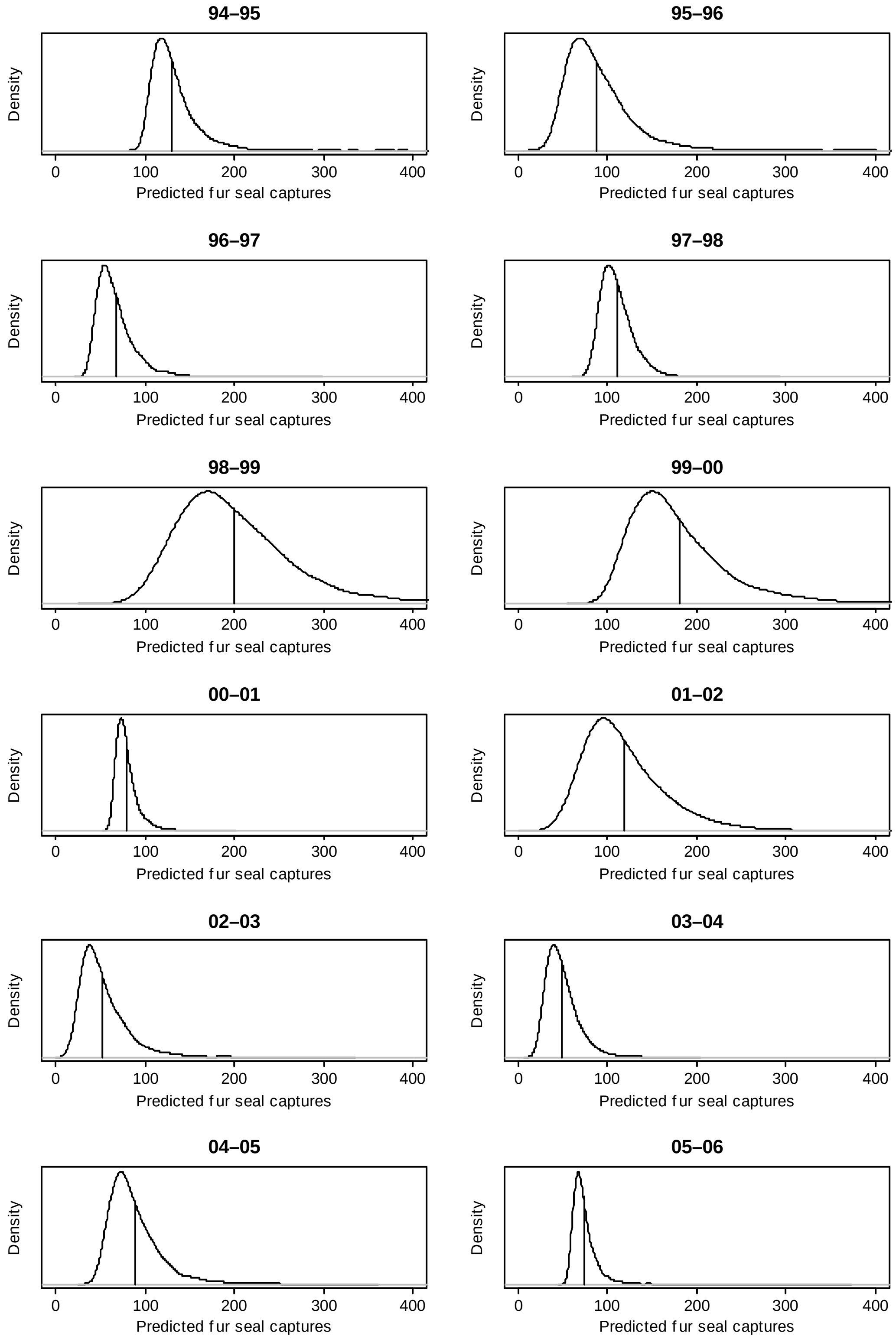


Figure G3: Plots of the predictive densities, by fishing year, for fur seal captures for tows in the SBW6 fishery area.

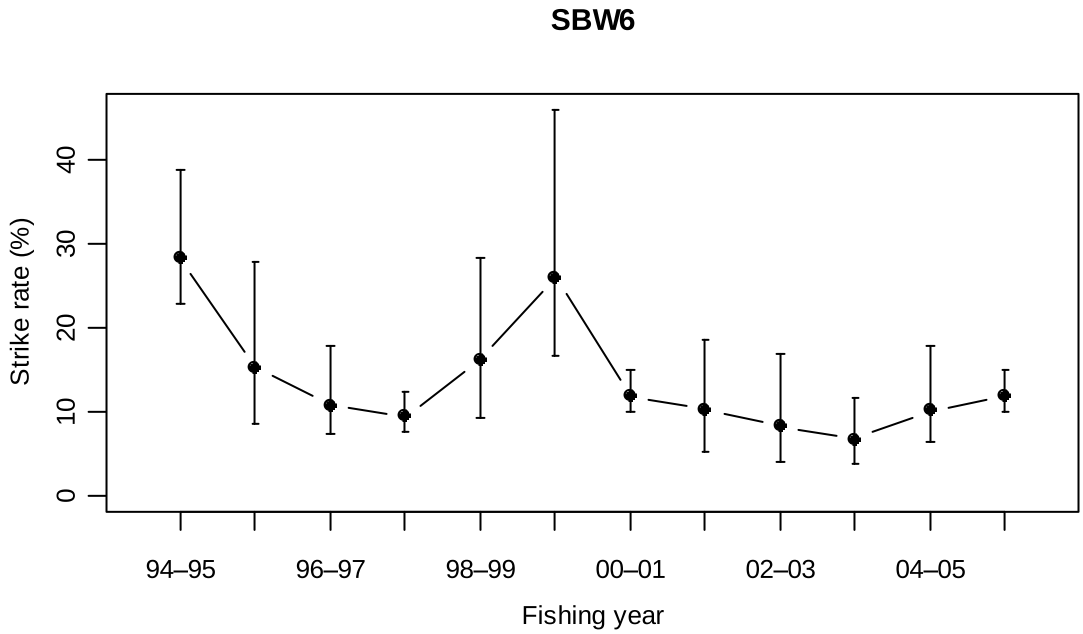


Figure G4: Predicted strike rates, with 95% prediction intervals, by fishing year, for tows in the SBW6 fishery area.