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Temporal and spatial distribution of non-target catch and non-target catch species in deepwater fisheries: supplementary information

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This supplement provides detailed model selection diagnostics, fits, and model outputs for each of the applications detailed in the main report (Edwards & Mormede 2023).

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S1. INTRODUCTION AND METHODS SUMMARY

We provide detailed results for each of the non-target species selected for analysis (Table S1), as described by Edwards & Mormede (2023). Visual and tabulated representations of the empirical data, model selection results, convergence diagnostics, model fits to the data, and predicted catches are shown.

Table S1: Non-Target species comprising the top 90% of observer recorded catches, plus hydrocorals, in order of decreasing observed catch biomass.

Species code	Common name	Scientific name	Family
BAR	Barracouta	*Thyrsites atun*	Gempylidae
RAT	Rattails	Macrouridae	Macrouridae
SPD	Spiny dogfish	*Squalus acanthias*	Squalidae
FRO	Frostfish	*Lepidopus caudatus*	Trichiuridae
EMA	Blue mackerel	*Scomber australasicus*	Scombridae
MOD	Morid cods	Moridae	Moridae
RBT	Redbait	*Emmelichthys nitidus*	Emmelichthyidae
WAR	Common warehou	*Seriolella brama*	Centrolophidae
NCB	Smooth red swimming crab	*Nectocarcinus bennetti*	Portunidae
SPE	Sea perch	*Helicolenus* spp.	Scorpaenidae
GSP	Pale ghost shark	*Hydrolagus bemisi*	Chimaeridae
RSO	Gemfish	*Rexea solandri*	Gempylidae
GSH	Ghost shark	*Hydrolagus novaezealandiae*	Chimaeridae
SDO	Silver dory	*Cyttus novaezealandiae*	Zeidae
STA	Giant stargazer	*Kathetostoma* spp.	Uranoscopidae
SND	Shovelnose spiny dogfish	*Deania calcea*	Centrophoridae
LDO	Lookdown dory	*Cyttus traversi*	Zeidae
SSK	Smooth skate	*Dipturus innominatus*	Rajidae
STU	Slender tuna	*Allothunnus fallai*	Scombridae
RBM	Rays bream	*Brama brama*	Bramidae
RSK	Rough skate	*Zearaja nasuta*	Rajidae
GSC	Giant spider crab	*Jacquinotia edwardsii*	Majidae
ETB	Baxters lantern dogfish	*Etmopterus baxteri*	Etmopteridae
COR	Hydrocorals	Stylasteridae	Stylasteridae

S1.1 Model selection

The density d_{kl} per grid cell k and season l was modelled as a regression on coefficient vector $\boldsymbol{\alpha}$, a spatial random effect by season, $\boldsymbol{\phi}_l$:

$$d_{kl} = \underbrace{\mathbf{x}_k' \cdot \boldsymbol{\alpha}}_{\bar{d}_k} + \phi_{kl}$$

As part of the model development process, six model runs were completed per species, each with a different representation of the density as a function of depth and latitude covariates:

Model 1: $\bar{d}_k = \alpha_0$ (with no seasonal partition for $\boldsymbol{\phi}$)

Model 2: $\bar{d}_k = \alpha_0$

Model 3: $\bar{d}_k = \alpha_0 + x_{\text{depth}} \cdot \alpha_{\text{depth}} + x_{\text{lat}} \cdot \alpha_{\text{lat}}$

Model 4: $\bar{d}_k = \alpha_0 + x_{\text{depth}} \cdot \alpha_{\text{depth},1} + x_{\text{depth}}^2 \cdot \alpha_{\text{depth},2} + x_{\text{lat}} \cdot \alpha_{\text{lat}}$

Model 5: $\bar{d}_k = \alpha_0 + x_{\text{depth}} \cdot \alpha_{\text{depth}} + x_{\text{lat}} \cdot \alpha_{\text{lat},1} + x_{\text{lat}}^2 \cdot \alpha_{\text{lat},2}$

Model 6: $\bar{d}_k = \alpha_0 + x_{\text{depth}} \cdot \alpha_{\text{depth}} + x_{\text{depth}}^2 \cdot \alpha_{\text{depth},2} + x_{\text{lat}} \cdot \alpha_{\text{lat},1} + x_{\text{lat}}^2 \cdot \alpha_{\text{lat},2}$

A comparison between models 1 and 2 was used to illustrate the benefit (or not) of including a seasonal partition in the biomass density surface. However for reasons of expediency, the seasonal model was always given preference (unless it did not converge). Comparison of models 2 to 6 was used to identify which environmental covariates should be retained for prediction of the density. In the current setting, only first and second order polynomial terms were included. This could easily be expanded to more complicated structural forms and include additional environmental data (Mormede 2023, for example, included a much broader range of environmental covariates when modelling inshore species). The best performing of these models was used for the final run.

The convergence of all parameter chains was first verified using visual inspection and consideration of the $\hat{R}$ statistic (Gelman & Rubin 1992), with values close to one indicative of convergence. When evaluating convergence of parameter vectors, we examined the Euclidean norm of the vector, i.e. $||\boldsymbol{x}|| = \sqrt{x_1^2 + x_2^2 + \ldots}$. Experience suggests that convergence of this summary statistic indicates convergence of each component of the vector. Convergence of $||\boldsymbol{\alpha}||$, $||\boldsymbol{\gamma}||$ and $||\boldsymbol{\pi}||$ was examined formally using the $\hat{R}$ value and is listed for each model. For the selected model we also show trace plots of the posterior samples for the regression coefficients $||\boldsymbol{\alpha}||$, random effects $||\boldsymbol{\phi}||$, encounter rate $||\boldsymbol{\gamma}||$, efficiency $||\boldsymbol{\pi}||$, observation error $||\boldsymbol{\sigma}||$ and conditional autoregressive prior parameters $||\tau, \rho||$.

To select the best performing model out of those that had successfully converged, each was compared using the mean prediction error (MPE), and the L^2 (Ibrahim & Laud 1994) and WAIC (Wantabe 2010, Vehtari et al. 2017) measures of model fit. Model selection diagnostics were calculated using posterior predictions of the observer catch data, which we denote $\tilde{X}_i$. Where applicable, the expectation and variance of $\tilde{X}_i$ was taken across the full posterior.

For n observed fishing events, we calculated the mean prediction error as:

$$\mathrm{MPE} = \sqrt{\frac{1}{n} \cdot \sum_n (X_i - \mathbb{E}\left[\tilde{X}_i\right])^2}$$

The L^2 statistic of Ibrahim & Laud (1994) is similar, but includes a penalty that is proportional to the variance of the simulated values:

$$L^2 = \sqrt{\frac{1}{n} \cdot \sum_n (X_i - \mathbb{E}\left[\tilde{X}_i\right])^2 + \frac{1}{n} \cdot \mathbb{VAR}\left[\tilde{X}_i\right]}$$

In both cases, the preferred model is that which minimises the value of the summary statistic. For the WAIC (Wantabe 2010), we use the likelihood value per data point $\mathbb{L}[X_i]$. Following the description given by Vehtari et al. (2017), we calculated the WAIC as:

$$\mathrm{WAIC} = \sum_n \log\left(\mathbb{E}\left[\mathbb{L}\left[X_i\right]\right]\right) - \sum_n \mathbb{VAR}\left[\log\left(\mathbb{L}\left[X_i\right]\right)\right]$$

in this case selecting the model with the highest value (this differs from the standard application, in which the lowest WAIC is typically preferred). In addition, we calculated a density residual summary statistic to measure the deviation of random effect terms ϕ_{kl} around the density predicted from the regression on depth and latitude. We refer to this as the density residual error (DRE), calculated as the square-root of the squared mean value of ϕ_{kl}. All of these summary statistics were considered when selecting the best performing model.

S1.2 Presentation of data and results

For each species we present a summary of the empirical catch, effort and catch rate data for each of the gear types listed in Table S2. We would expect that vessel reported catches would be much greater than observed catches, because the former should represent a higher proportion of the fishing effort. Through comparison of the observed with the vessel reported catches, we can also see how representative the observer data are. The catch rate provides an intuitive indication of the catchability per gear type. Large differences in the empirical catch rates can occur when vessel reported catches do not include the species in question. For example, if the species is caught only in small quantities it will less frequently be reported and vessel reported catch rates will be an underestimate. This is to be expected for rare bycatch species. However if vessel reported catch rates are higher than the observed catch rates (e.g., barracouta, Figure S1), this could indicate that the observer data are not representative of where and when the species is caught and will likely lead to poor model performance. When catch rates are similar, it suggests that we can use the vessel reported catches as a diagnostic to assess predictive ability of the model. For abundant species, where we can be sure that the catch is always recorded, it may be possible to include the vessel reported catches as part of the model fit (as was done by Edwards 2021).

The observer catch rate data are also presented spatially, to give an indication of where the species are caught. When co-estimating the catchability parameters and the biomass density surface it is important that catches by the different gear types overlap spatially. In most instances coverage is good. The commercial effort is also mapped. The spatial coverage of the effort will be different between species because only those grids with positive catches are retained. When combined with the observed catch rates the effort provides an indication of where the highest catches are likely to occur.

Table S2: Notation and description for fishing methods and gear types.

Method	Gear	Description
BLL	AUT	Bottom autoline
BLL	MAN	Bottom manual longline
TWL	BT	Bottom trawl
TWL	MB	Mid-water trawl within 5 m of the bottom
TWL	MW	Mid-water trawl
TWL	PRB	Precision trawl harvesting (bottom)
TWL	PRM	Precision trawl harvesting (mid-water)
TWL	TAN	RV *Tangaroa* trawl survey
TWL	KAH	RV *Kaharoa* trawl survey

Model selection summary statistics are given for each model run. There was typically little noticeable difference between the model runs. By default we selected the model with the highest WAIC score out of those models for which posterior samples had converged. However, this was not a strict criteria. In some instances where the WAIC was similar between models, preference was given according to one of the other model selection criteria (e.g., the DRE). For the best performing model we provide trace diagnostics for parameter summary statistics and posterior distributions for the encounter rate and efficiency parameters. Regression relationships of the estimated posterior densities per grid cell and season are plotted against each covariate. These illustrate the distribution of cell-specific random effects around the covariate prediction.

Fit of the model to the observed data is shown as a scatter plot of the relationship between the annual average of the empirical catches and the annual average of the model estimated catches per grid cell and gear type. Estimated values are given as the median of the posterior. For clarity of presentation credibility intervals are omitted. A good model fit is indicated by points along the one-to-one line of equivalence. The fit is generally better for grids and gear types with high catches and a large number of observed fishing events. Fit is also shown spatially, to demonstrate how model predicted catches map closely to the observations.

From the model fit, we predict the total commercial catches, which are shown spatially by season and method, and also as the sum per year in tabulated form. We also report the predicted biomass density across space for each season. Since the density is an estimated parameter rather than a model input, we provide a measure of the uncertainty for illustrative purposes, noting that a similar measure could have also been produced for the catches.

Finally, we compare the annual sum of the model estimated catches against the sum of the vessel reported catches and the landings. The reported catches only include the top five species caught in each fishing event (sometimes top 8 depending on the reporting requirement) and therefore are likely to under-represent actual catches, particularly for non-target species. In contrast, the landings accurately report all catches that have been landed, but not discards, and therefore might not be representative of the total catch in particular for species which can be discarded (non-Quota Management System (QMS) species and QMS species under limited circumstances). Landings are also only available in aggregated form (per trip and fish stock) and are not suitable for spatial-temporal modelling. Comparison of the model estimates with the landings can therefore be used to validate the model outputs for species that are not discarded.

S2. SPECIES SPECIFIC DATA AND RESULTS

S2.1 Barracouta (*Thyrsites atun*)

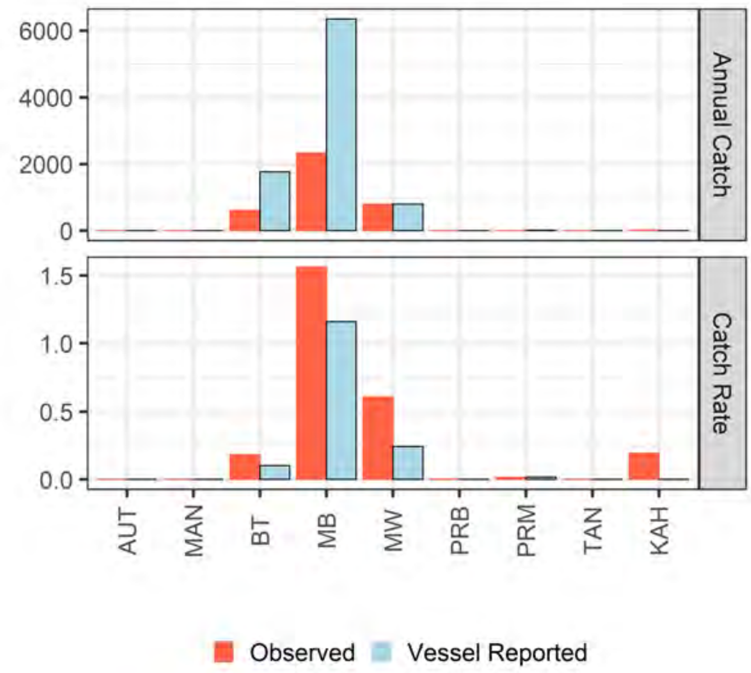


Figure S1: Empirical catch and catch rate data per gear type for barracouta. Annual catch is given in tonnes as an average across years. The catch rate is an average calculated as the sum of the observed catch in kilograms (i.e., $\sum X_i$) over the sum of the effort count (number of fishing events). Effort was calculated as a count to allow comparability between methods. There are no vessel reported catches for TAN and KAH surveys.

Table S3: Summary data for barracouta across 373 grid cells, removing 191 853 commercial events that were outside the selected cells. The total landings associated with retained commercial effort equal 384 523 tonnes. Catch is in units of tonnes, effort in the number of fishing events. "Obs." is observed; "Com." is commercial.

Method	Gear	Obs. catch	Obs. effort	Com. catch	Com. effort
BLL	AUT	0	4 797	0	31 033
BLL	MAN	0	587	0	15 245
TWL	BT	11 704	63 911	33 630	329 401
TWL	MB	44 254	28 335	120 632	104 064
TWL	MW	15 071	24 730	15 223	62 519
TWL	PRB	2	723	4	2 614
TWL	PRM	6	388	35	2 027
TWL	TAN	3	2 061		
TWL	KAH	270	1 388		
Total		71 311	126 920	169 525	546 903

Table S4: Model selection summary statistics for barracouta. Model 4 was selected for prediction of the catches.

Model	$\mathbb{L}[X]$	MPE	L^2	WAIC	$\hat{R}(\alpha)$	$\hat{R}(\gamma)$	$\hat{R}(\pi)$	DRE
1	-0.061	0.653	2.840	-4989.544	1.002	1.009	1.005	2.310
2	-0.059	0.699	3.362	-4880.256	1.003	1.006	1.005	2.397
3	-0.058	0.683	3.072	-4886.558	0.999	1.001	1.001	1.921
4	-0.058	0.695	3.248	-4879.948	1.000	1.003	1.004	1.808
5	-0.058	0.701	4.297	-4886.894	1.011	1.006	1.006	1.932
6	-0.058	0.682	2.648	-4880.014	1.018	1.010	1.007	1.826

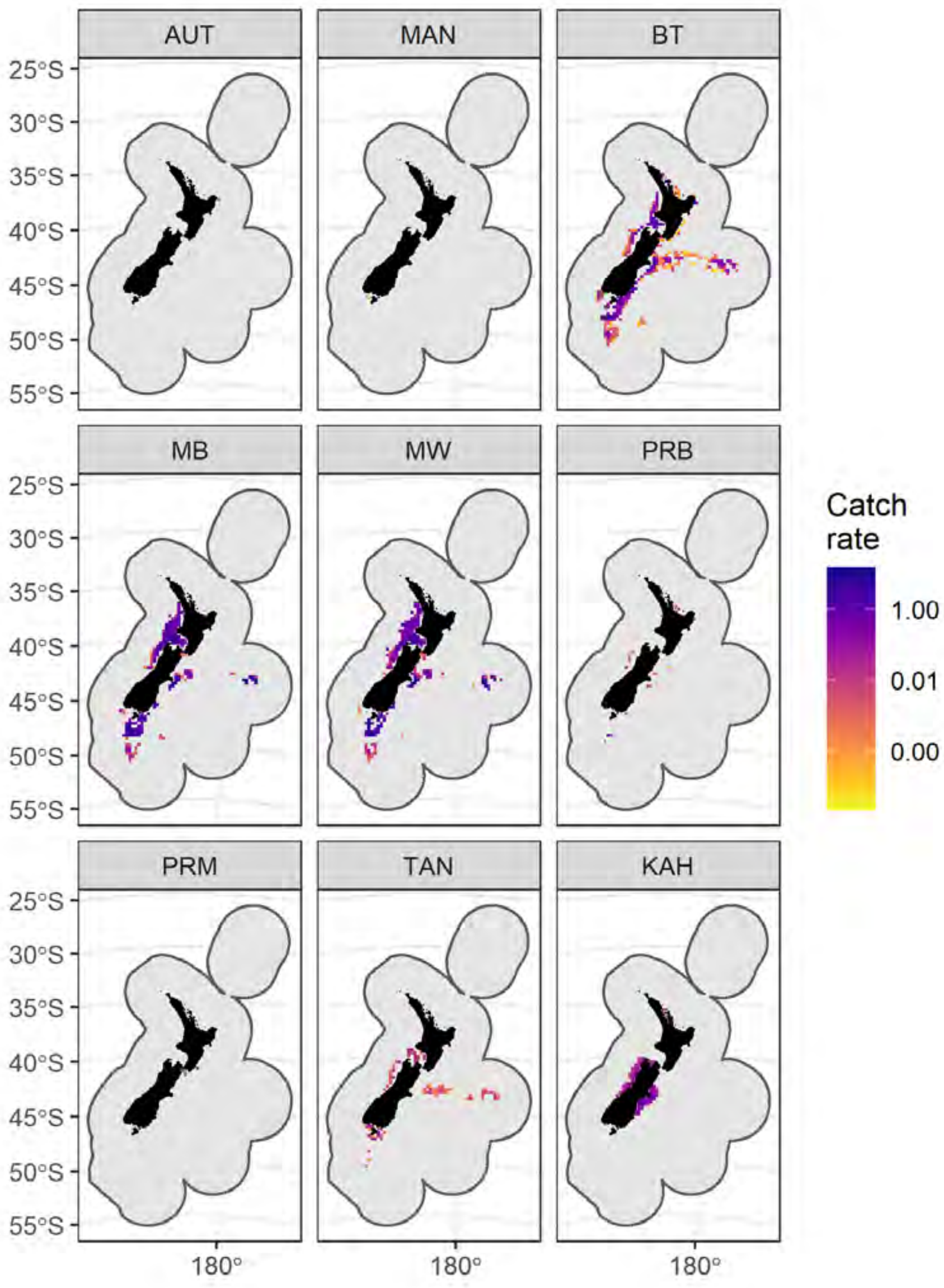


Figure S2: Observer catch rate data for barracouta on a log10-scale. The catch rate is an average calculated as the sum of the observed catch $\sum X_i$ over the number of observed fishing events per grid cell and gear type. Effort was calculated as a count to allow comparability between methods.

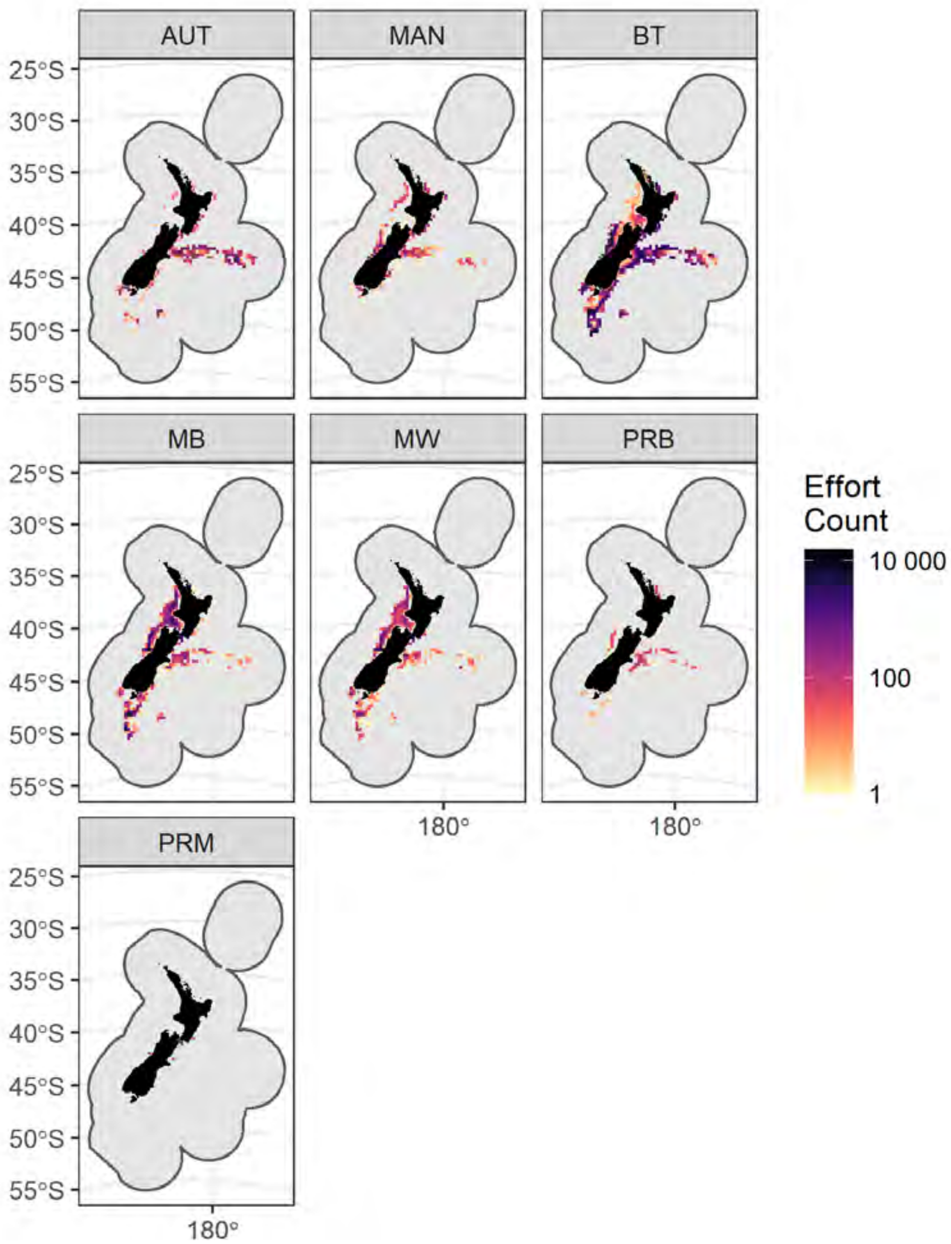


Figure S3: Commercial fishing effort (number of events) for barracouta summed across all years and presented on a log10-scale per grid cell and gear type. Effort was calculated as a count to allow comparability between methods.

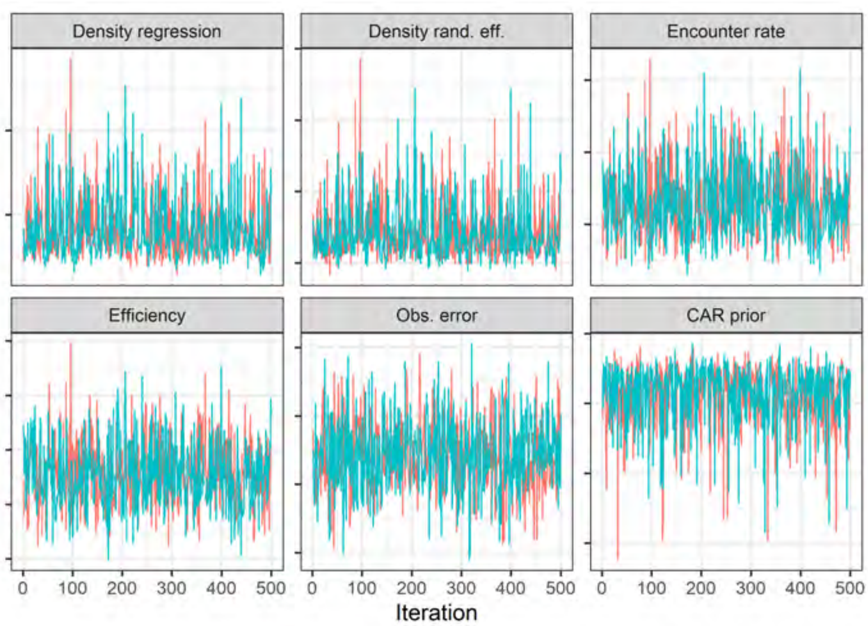


Figure S4: Posterior density sample traces for barracouta, for the regression coefficients $||\boldsymbol{\alpha}||$, random effects $||\boldsymbol{\phi}||$, encounter rate $||\boldsymbol{\gamma}||$, efficiency $||\boldsymbol{\pi}||$, observation error $||\boldsymbol{\sigma}||$ and conditional autoregressive prior parameters $||\tau,\rho||$. Colours represent independent sample chains.

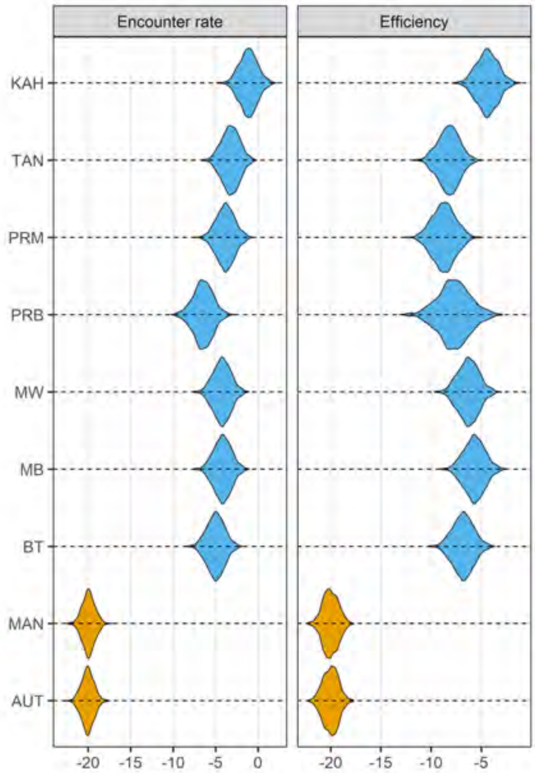


Figure S5: Violin plots of the posterior density for the encounter rate (γ_j) and the efficiency (π_j) per gear type for barracouta. Catchability terms for bottom longline gear types (see Table S2) are presented in a different colour as they are not comparable to the trawl gear types because they are dependent on different measures of effort (i.e., thousand hooks and distance, respectively).

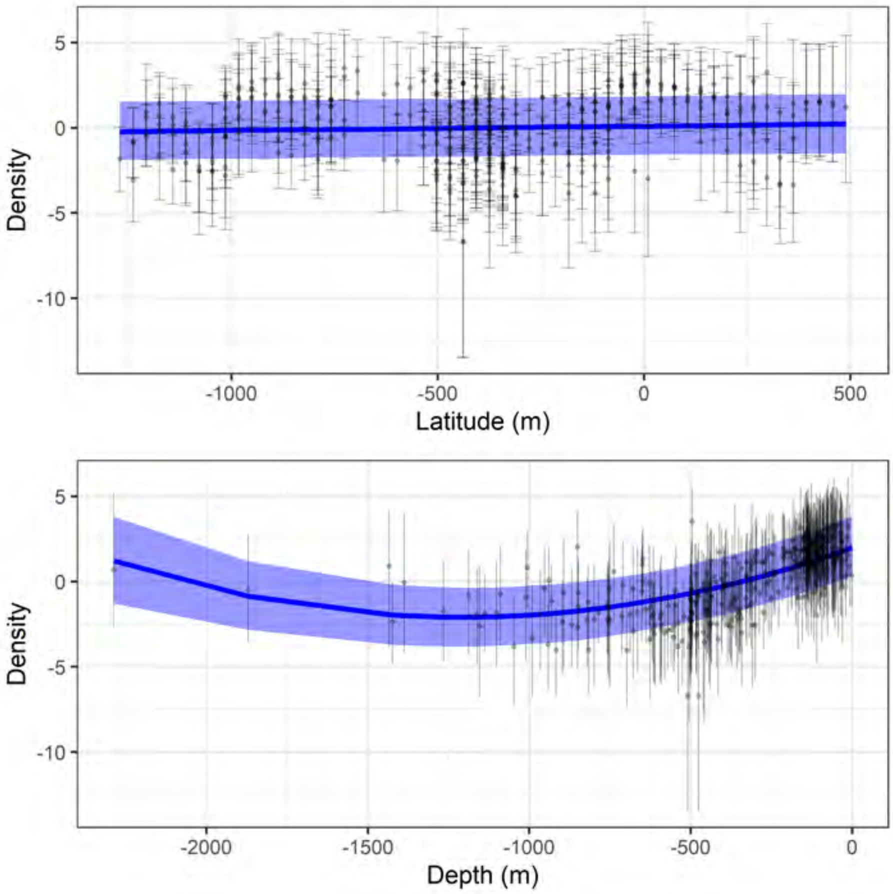


Figure S6: Estimated relationship between biomass density per grid cell and environmental covariates for barracouta. Points and error bars show the median and 90% credibility intervals per cell. The blue ribbon shows the estimated marginal relationship.

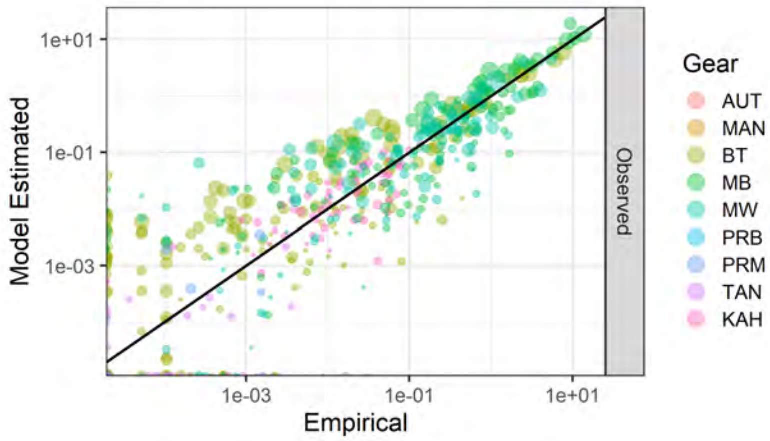


Figure S7: Fit of model to empirical observer catches. Total catches are summed per grid cell and gear type for barracouta. Model estimates are the median of the posterior predicted distribution. The size of the point is representative of the number of observed events. Catches are shown in tonnes on a log10 scale.

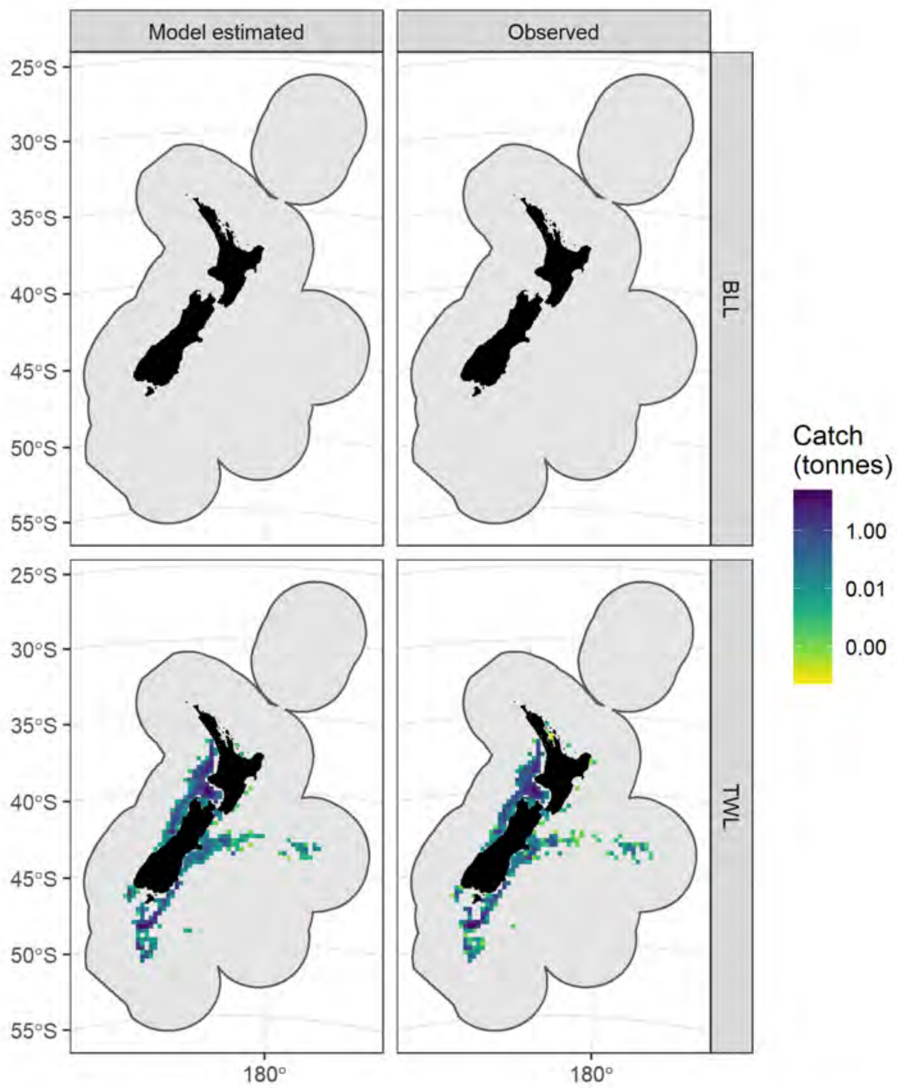


Figure S8: Spatial fit of model to empirical observer catches by grid cell and method for barracouta. Average annual catches were calculated as the sum across gear types per cell and method. Posterior median values are shown, with catches in tonnes on a log10 scale.

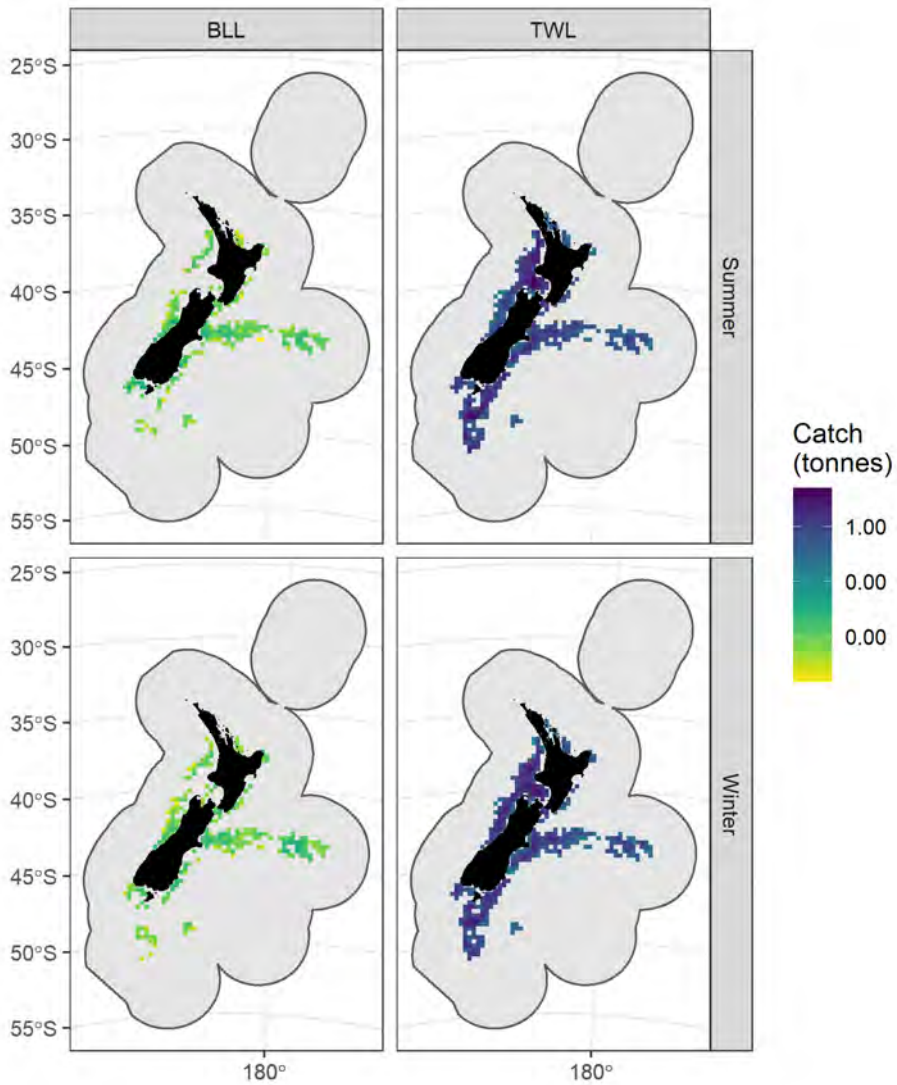


Figure S9: Posterior prediction of the total catches by grid cell, method and season for barracouta. Average annual catches per season were calculated as the sum across gear types per cell and method. Posterior median values are shown, with catches in tonnes on a log10 scale.

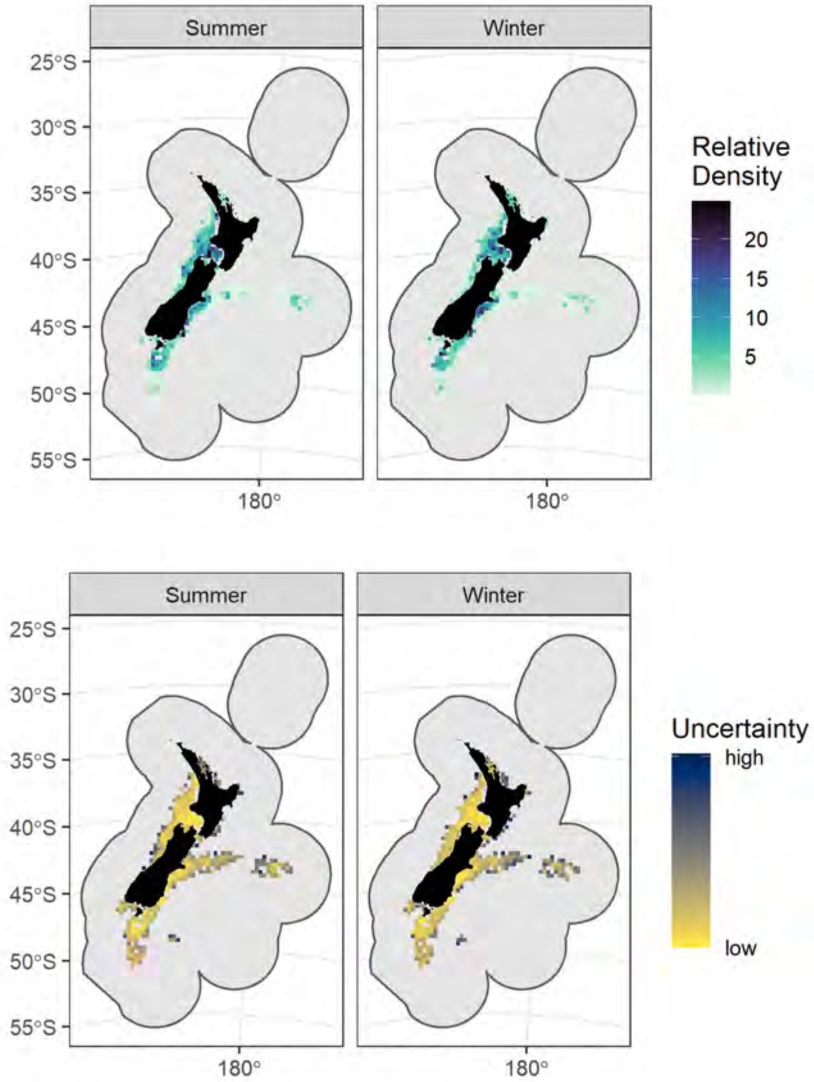


Figure S10: Posterior prediction of the relative density per grid cell and season for barracouta. Posterior median values are shown on a natural scale in tonnes per square kilometre. Uncertainty is measured using the difference between the upper and lower 95% equal-tailed posterior density interval.

Table S5: **Total predicted bycatch (tonnes) per method for barracouta. Posterior median values are given, with the 95% equal-tailed credibility intervals in brackets.**

Fishing year	BLL	TWL	Total
2000/01	0 (0 - 0)	5 965 (4 999 - 8 151)	5 965 (4 999 - 8 151)
2001/02	0 (0 - 0)	6 167 (5 169 - 7 931)	6 167 (5 169 - 7 931)
2002/03	0 (0 - 0)	6 926 (5 844 - 8 594)	6 926 (5 844 - 8 594)
2003/04	0 (0 - 0)	5 099 (4 276 - 6 395)	5 099 (4 276 - 6 395)
2004/05	0 (0 - 0)	5 410 (4 605 - 6 689)	5 410 (4 605 - 6 689)
2005/06	0 (0 - 0)	5 915 (5 055 - 7 482)	5 915 (5 055 - 7 482)
2006/07	0 (0 - 0)	5 268 (4 413 - 6 756)	5 268 (4 413 - 6 756)
2007/08	0 (0 - 0)	4 916 (4 088 - 6 156)	4 916 (4 088 - 6 156)
2008/09	0 (0 - 0)	4 482 (3 633 - 6 098)	4 482 (3 633 - 6 098)
2009/10	0 (0 - 0)	5 653 (4 547 - 7 799)	5 653 (4 547 - 7 799)
2010/11	0 (0 - 0)	4 238 (3 407 - 5 639)	4 238 (3 407 - 5 639)
2011/12	0 (0 - 0)	4 931 (3 928 - 6 743)	4 931 (3 928 - 6 743)
2012/13	0 (0 - 0)	4 109 (3 327 - 5 385)	4 109 (3 327 - 5 385)
2013/14	0 (0 - 0)	4 072 (3 289 - 5 524)	4 072 (3 289 - 5 524)
2014/15	0 (0 - 0)	3 515 (2 704 - 5 049)	3 515 (2 704 - 5 049)
2015/16	0 (0 - 0)	3 293 (2 520 - 4 637)	3 293 (2 520 - 4 637)
2016/17	0 (0 - 0)	3 791 (2 873 - 5 629)	3 791 (2 873 - 5 629)
2017/18	0 (0 - 0)	3 898 (3 029 - 5 523)	3 898 (3 029 - 5 523)
2018/19	0 (0 - 0)	4 255 (3 463 - 5 782)	4 255 (3 463 - 5 782)

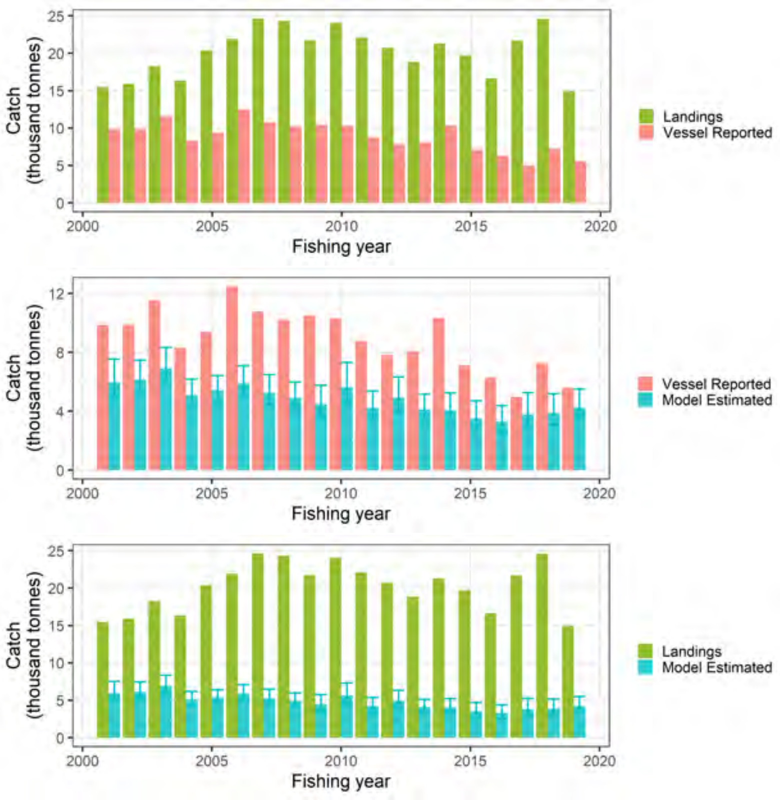


Figure S11: **Relationships between landings, vessel reported catches and model estimated catches for barracouta.**

S2.2 Rattails (Macrouridae)

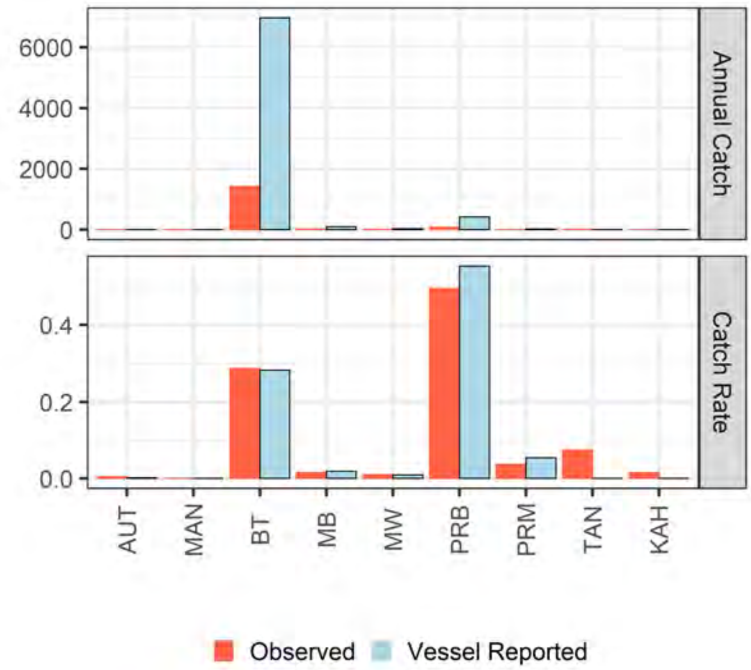


Figure S12: Empirical catch and catch rate data per gear type for rattails. Annual catch is given in tonnes as an average across years. The catch rate is an average calculated as the sum of the observed catch in kilograms (i.e., $\sum X_i$) over the sum of the effort count (number of fishing events). Effort was calculated as a count to allow comparability between methods. There are no vessel reported catches for TAN and KAH surveys.

Table S6: Summary data for rattails across 1 004 grid cells, removing 22 994 commercial events that were outside the selected cells. The total landings associated with retained commercial effort equal 175 146 tonnes. Catch is in units of tonnes, effort in the number of fishing events. “Obs.” is observed; “Com.” is commercial.

Method	Gear	Obs. catch	Obs. effort	Com. catch	Com. effort
BLL	AUT	41	8 442	91	50 548
BLL	MAN	0	756	1	23 704
TWL	BT	27 093	94 174	132 206	466 971
TWL	MB	472	29 571	1 989	104 770
TWL	MW	288	27 121	622	64 647
TWL	PRB	414	837	1 692	3 059
TWL	PRM	15	401	112	2 063
TWL	TAN	334	4 462		
TWL	KAH	20	1 277		
Total		28 678	167 041	136 713	715 762

Table S7: Model selection summary statistics for rattails. Model 5 was selected for prediction of the catches.

Model	$\mathbb{L}[X]$	MPE	L^2	WAIC	$\hat{R}(\alpha)$	$\hat{R}(\gamma)$	$\hat{R}(\pi)$	DRE
1	-0.007	0.252	0.972	17325.592	1.021	1.014	1.013	1.341
2	-0.007	0.262	1.068	17658.948	0.997	1.003	1.004	1.420
3	-0.007	0.259	1.031	17662.599	1.008	1.007	1.009	1.302
4	-0.008	0.258	1.053	17665.159	1.006	1.004	1.005	1.225
5	-0.007	0.259	1.027	17670.580	1.005	1.007	1.009	1.267
6	-0.008	0.257	1.010	17669.038	1.005	1.012	1.015	1.195

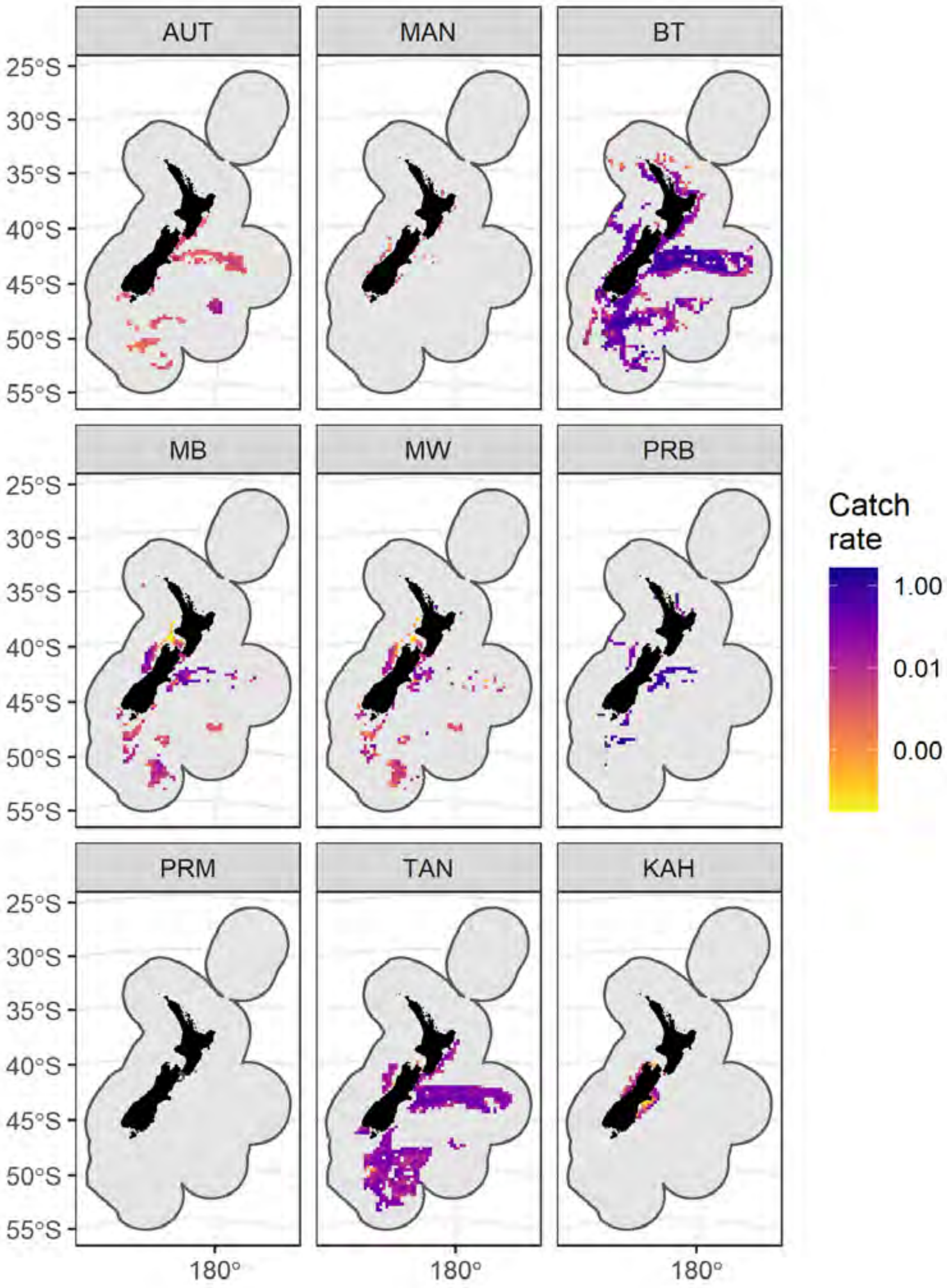


Figure S13: Observer catch rate data for rattails on a log10-scale. The catch rate is an average calculated as the sum of the observed catch $\sum X_i$ over the number of observed fishing events per grid cell and gear type. Effort was calculated as a count to allow comparability between methods.

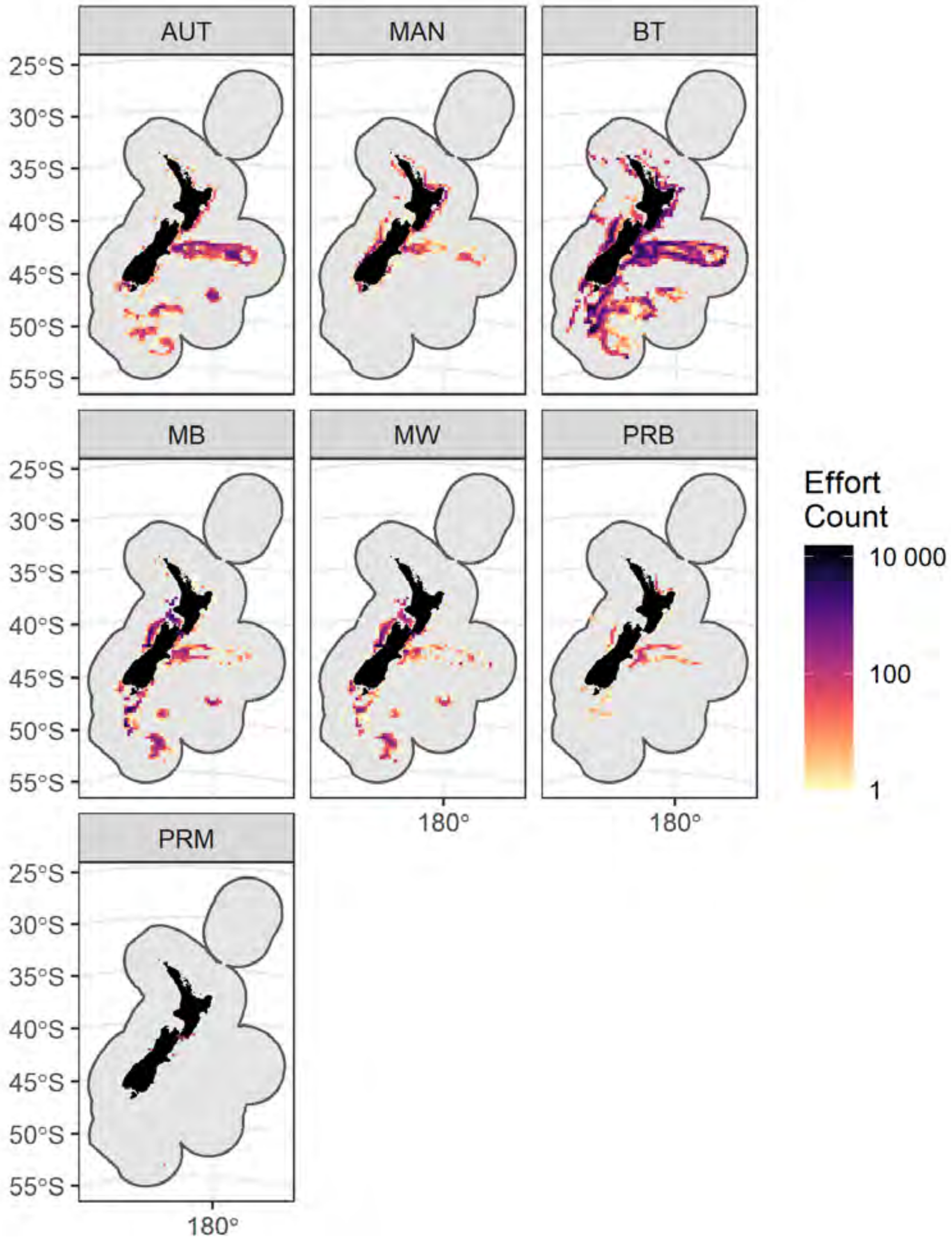


Figure S14: Commercial fishing effort (number of events) for rattails summed across all years and presented on a log10-scale per grid cell and gear type. Effort was calculated as a count to allow comparability between methods.

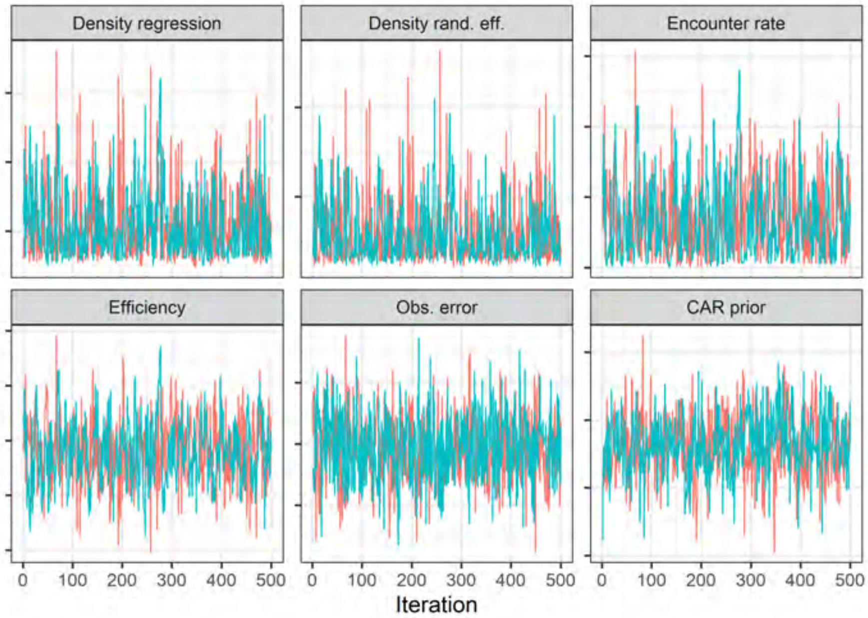


Figure S15: Posterior density sample traces for rattails, for the regression coefficients $||\boldsymbol{\alpha}||$, random effects $||\boldsymbol{\phi}||$, encounter rate $||\boldsymbol{\gamma}||$, efficiency $||\boldsymbol{\pi}||$, observation error $||\boldsymbol{\sigma}||$ and conditional autoregressive prior parameters $||\tau, \rho||$. Colours represent independent sample chains.

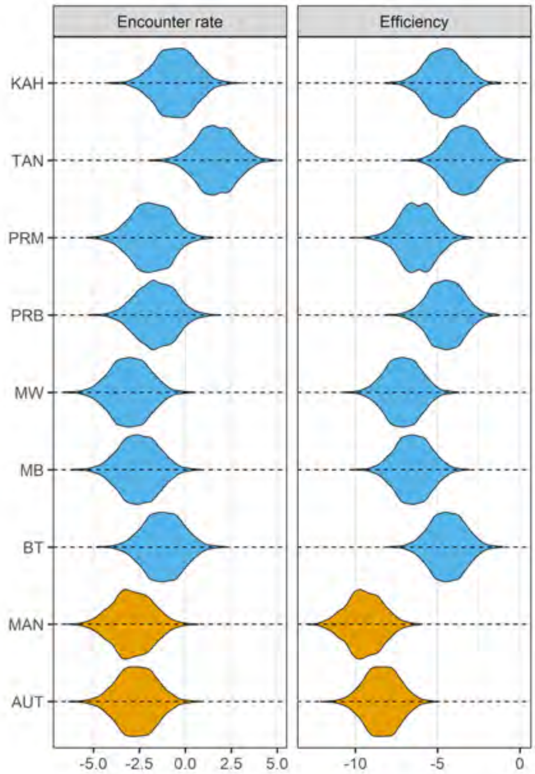


Figure S16: Violin plots of the posterior density for the encounter rate (γ_j) and the efficiency (π_j) per gear type for rattails. Catchability terms for bottom longline gear types (see Table S2) are presented in a different colour as they are not comparable to the trawl gear types because they are dependent on different measures of effort (i.e., thousand hooks and distance, respectively).

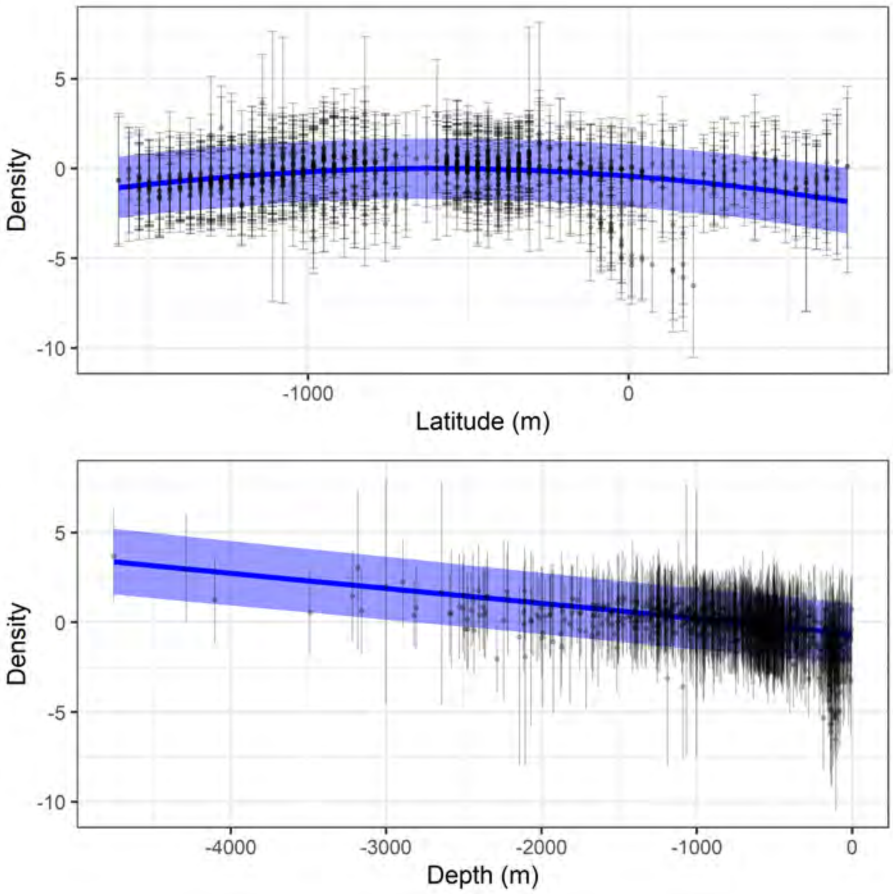


Figure S17: Estimated relationship between biomass density per grid cell and environmental covariates for rattails. Points and error bars show the median and 90% credibility intervals per cell. The blue ribbon shows the estimated marginal relationship.

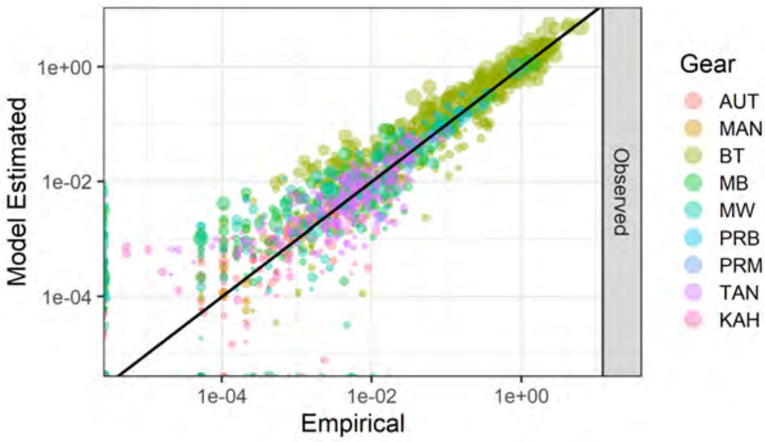


Figure S18: Fit of model to empirical observer catches. Total catches are summed per grid cell and gear type for rattails. Model estimates are the median of the posterior predicted distribution. The size of the point is representative of the number of observed events. Catches are shown in tonnes on a log10 scale.

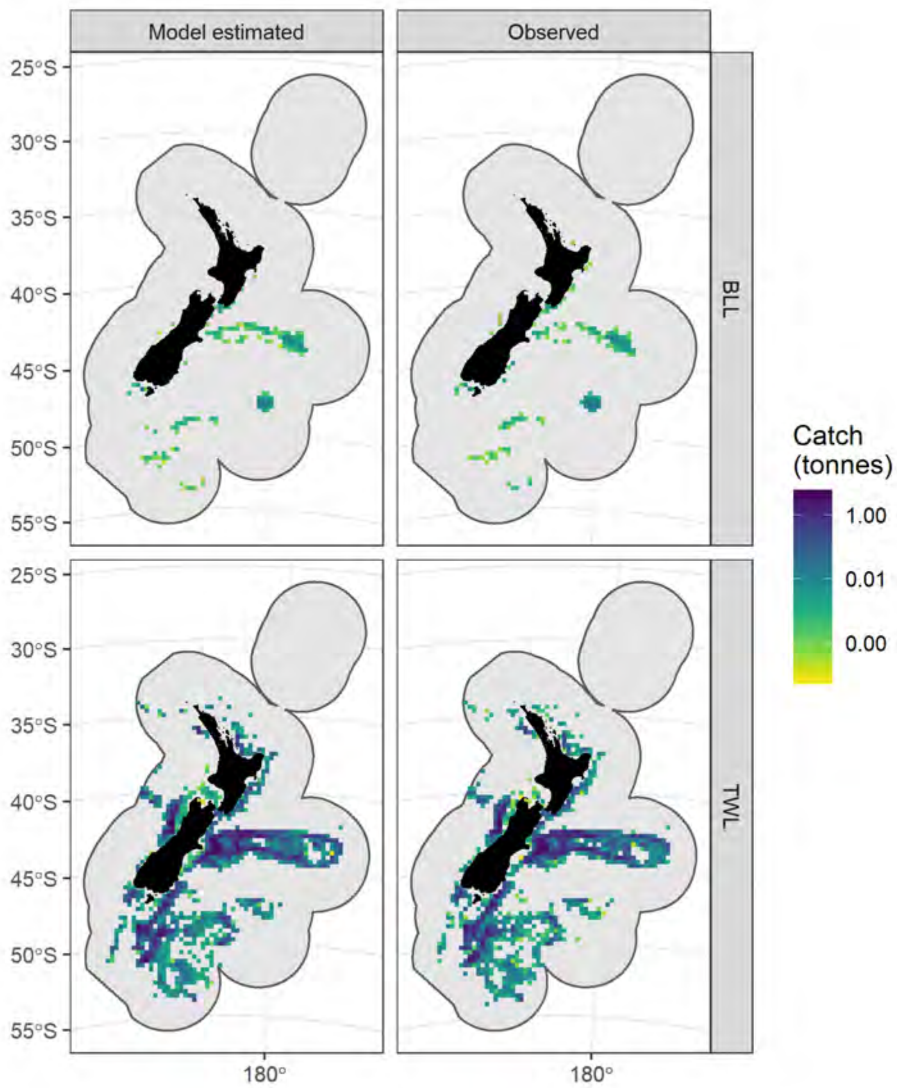


Figure S19: Spatial fit of model to empirical observer catches by grid cell and method for rattails. Average annual catches were calculated as the sum across gear types per cell and method. Posterior median values are shown, with catches in tonnes on a log10 scale.

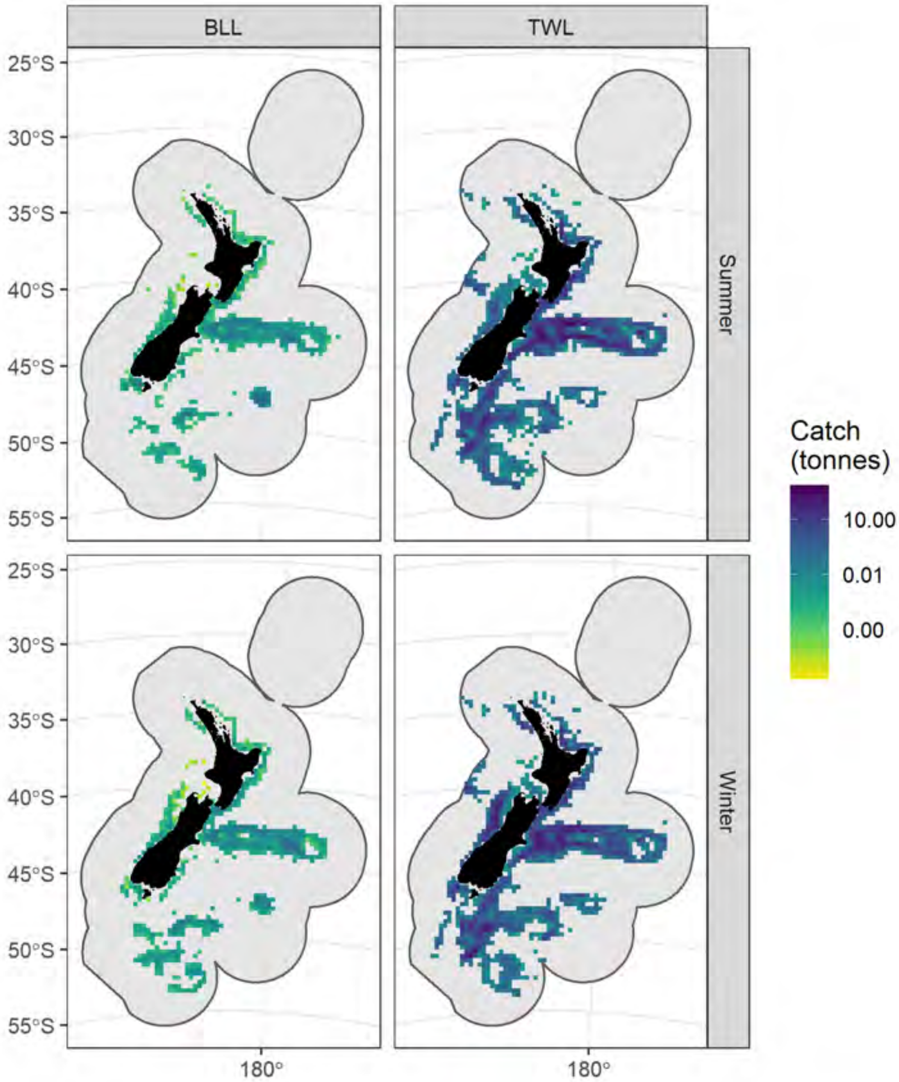


Figure S20: Posterior prediction of the total catches by grid cell, method and season for rattails. Average annual catches per season were calculated as the sum across gear types per cell and method. Posterior median values are shown, with catches in tonnes on a log10 scale.

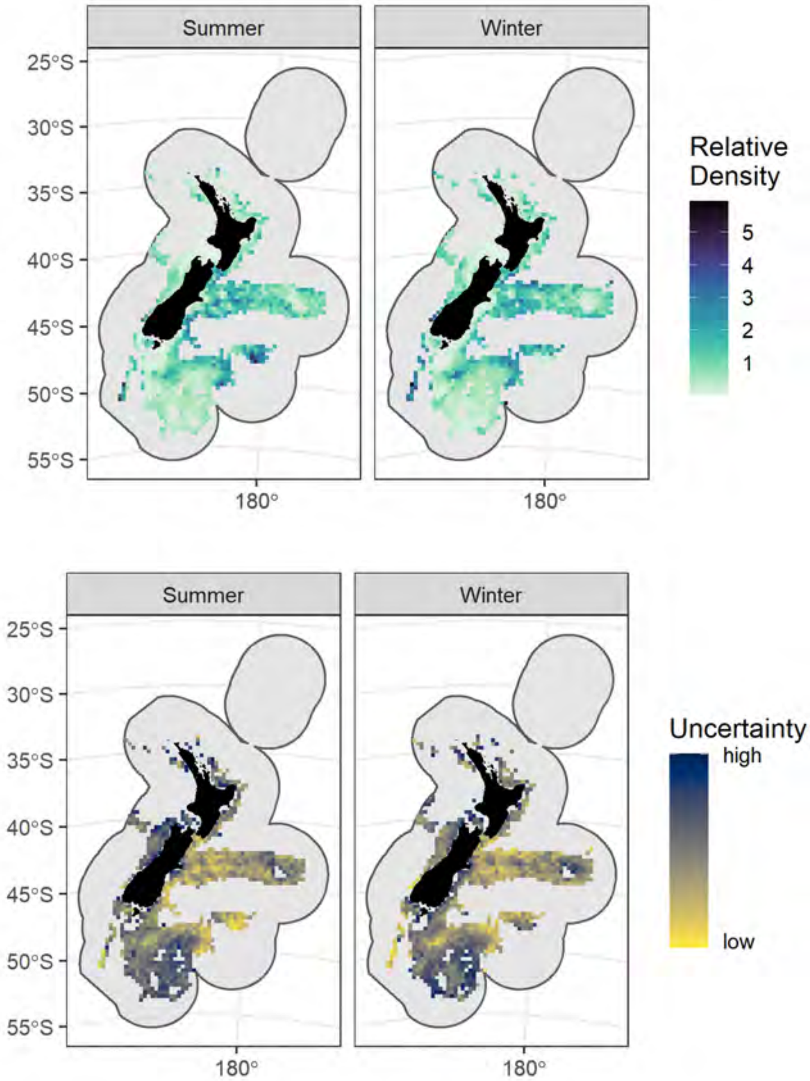


Figure S21: Posterior prediction of the relative density per grid cell and season for rattails. Posterior median values are shown on a natural scale in tonnes per square kilometre. Uncertainty is measured using the difference between the upper and lower 95% equal-tailed posterior density interval.

Table S8: Total predicted bycatch (tonnes) per method for rattails. Posterior median values are given, with the 95% equal-tailed credibility intervals in brackets.

Fishing year	BLL	TWL	Total
2000/01	13 (11 - 14)	14 482 (13 442 - 15 694)	14 495 (13 454 - 15 708)
2001/02	12 (11 - 14)	14 421 (13 378 - 15 708)	14 433 (13 391 - 15 720)
2002/03	8 (7 - 9)	14 830 (13 716 - 16 230)	14 838 (13 724 - 16 239)
2003/04	11 (10 - 12)	11 784 (10 881 - 12 773)	11 795 (10 891 - 12 784)
2004/05	8 (7 - 9)	9 464 (8 756 - 10 276)	9 473 (8 763 - 10 283)
2005/06	6 (5 - 6)	9 219 (8 509 - 9 977)	9 224 (8 514 - 9 983)
2006/07	7 (6 - 8)	9 135 (8 388 - 9 964)	9 142 (8 394 - 9 970)
2007/08	7 (6 - 8)	10 549 (9 633 - 11 561)	10 556 (9 640 - 11 568)
2008/09	7 (6 - 8)	10 263 (9 397 - 11 288)	10 270 (9 404 - 11 296)
2009/10	6 (5 - 7)	11 362 (10 485 - 12 475)	11 368 (10 491 - 12 481)
2010/11	6 (5 - 6)	11 268 (10 342 - 12 435)	11 273 (10 348 - 12 441)
2011/12	5 (4 - 5)	11 815 (10 793 - 13 033)	11 820 (10 798 - 13 038)
2012/13	4 (3 - 4)	11 391 (10 348 - 12 634)	11 395 (10 351 - 12 638)
2013/14	7 (6 - 8)	12 320 (11 193 - 13 571)	12 328 (11 201 - 13 579)
2014/15	5 (4 - 6)	13 125 (11 959 - 14 548)	13 130 (11 964 - 14 553)
2015/16	6 (6 - 7)	13 269 (12 079 - 14 613)	13 275 (12 085 - 14 619)
2016/17	9 (8 - 10)	12 808 (11 658 - 16 793)	12 817 (11 667 - 16 802)
2017/18	8 (7 - 9)	13 146 (12 088 - 14 509)	13 153 (12 098 - 14 517)
2018/19	7 (6 - 8)	12 658 (11 558 - 14 044)	12 665 (11 566 - 14 052)

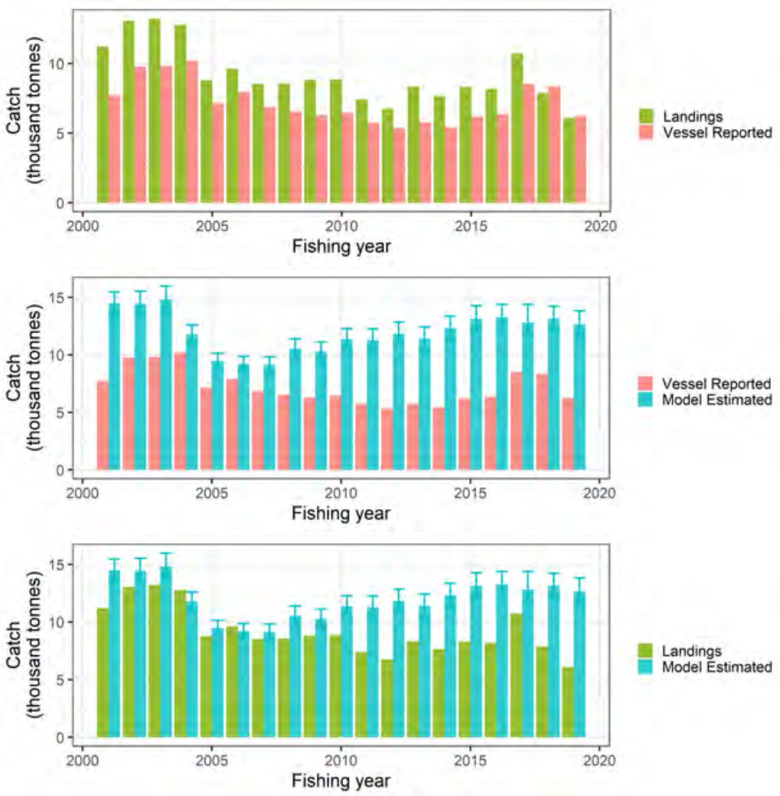


Figure S22: Relationships between landings, vessel reported catches and model estimated catches for rattails.

S2.3 Spiny dogfish (*Squalus acanthias*)

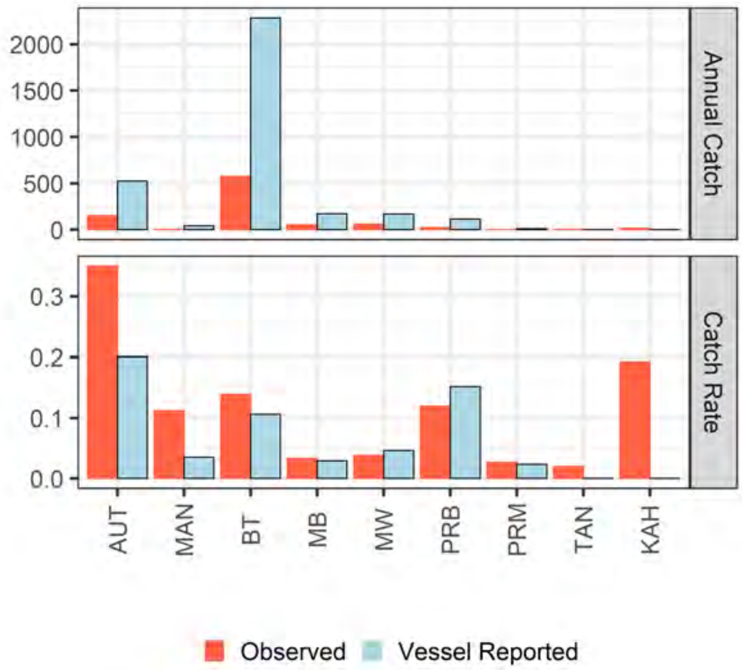


Figure S23: Empirical catch and catch rate data per gear type for spiny dogfish. Annual catch is given in tonnes as an average across years. The catch rate is an average calculated as the sum of the observed catch in kilograms (i.e., $\sum X_i$) over the sum of the effort count (number of fishing events). Effort was calculated as a count to allow comparability between methods. There are no vessel reported catches for TAN and KAH surveys.

Table S9: Summary data for spiny dogfish across 721 grid cells, removing 72 214 commercial events that were outside the selected cells. The total landings associated with retained commercial effort equal 90 496 tonnes. Catch is in units of tonnes, effort in the number of fishing events. "Obs." is observed; "Com." is commercial.

Method	Gear	Obs. catch	Obs. effort	Com. catch	Com. effort
BLL	AUT	2 924	8 360	9 968	49 633
BLL	MAN	83	741	767	21 858
TWL	BT	10 935	78 485	43 386	408 220
TWL	MB	1 057	31 606	3 290	112 740
TWL	MW	1 147	29 909	3 209	69 019
TWL	PRB	99	829	457	3 011
TWL	PRM	11	402	49	2 061
TWL	TAN	77	3 847		
TWL	KAH	262	1 357		
Total		16 595	155 536	61 126	666 542

Table S10: Model selection summary statistics for spiny dogfish. Model 4 was selected for prediction of the catches.

Model	$\mathbb{L}[X]$	MPE	L^2	WAIC	$\hat{R}(\alpha)$	$\hat{R}(\gamma)$	$\hat{R}(\pi)$	DRE
1	-0.076	0.167	0.480	7889.396	1.008	1.040	1.039	1.285
2	-0.075	0.164	0.463	7972.895	1.003	1.016	1.016	1.318
3	-0.074	0.163	0.453	7992.528	1.009	1.011	1.012	1.179
4	-0.074	0.163	0.453	7992.798	0.999	1.025	1.026	1.176
5	-0.075	0.163	0.463	7989.050	1.006	1.011	1.013	1.095
6	-0.075	0.163	0.491	7988.533	1.003	1.031	1.036	1.089

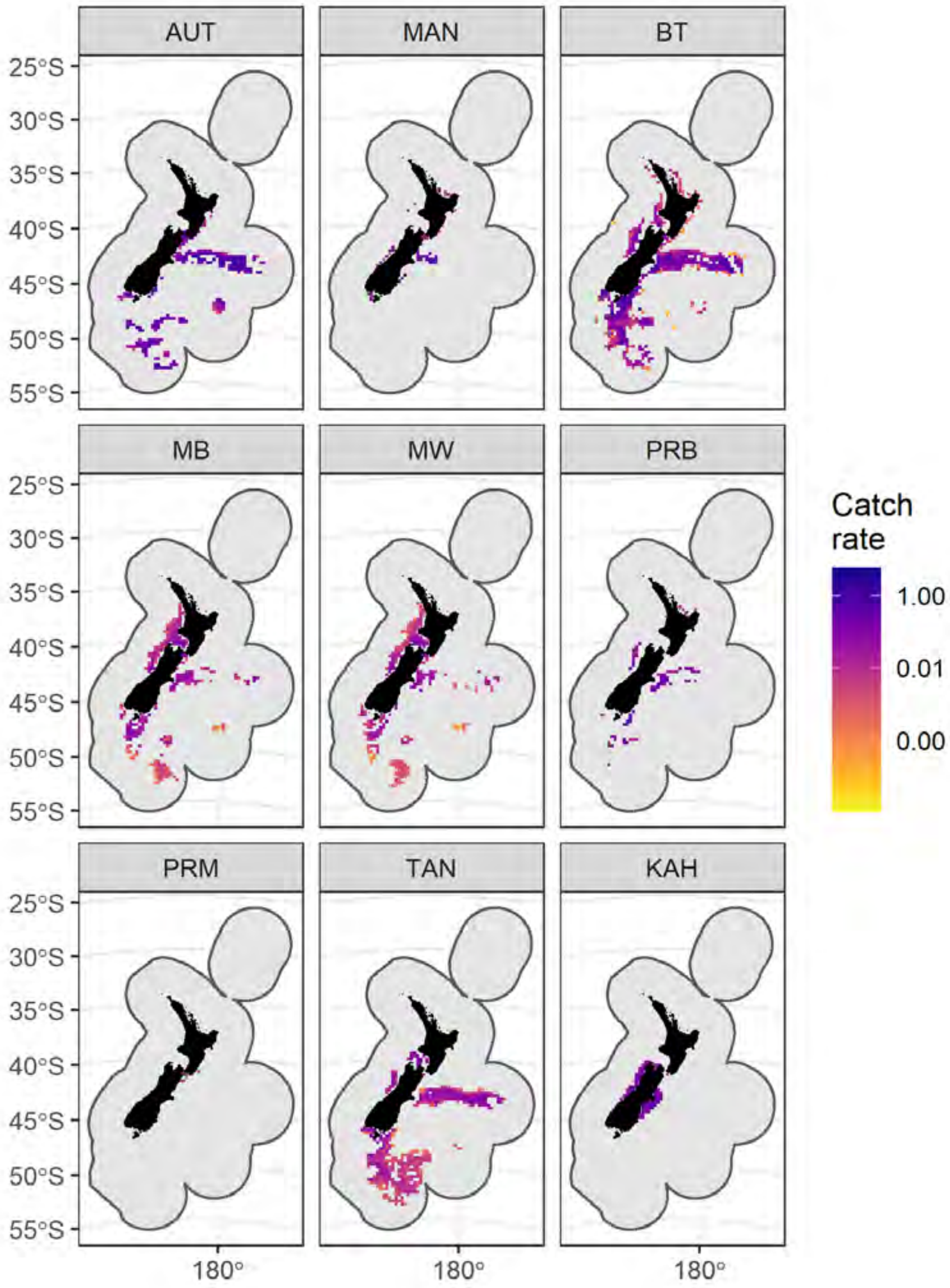


Figure S24: Observer catch rate data for spiny dogfish on a log10-scale. The catch rate is an average calculated as the sum of the observed catch $\sum X_i$ over the number of observed fishing events per grid cell and gear type. Effort was calculated as a count to allow comparability between methods.

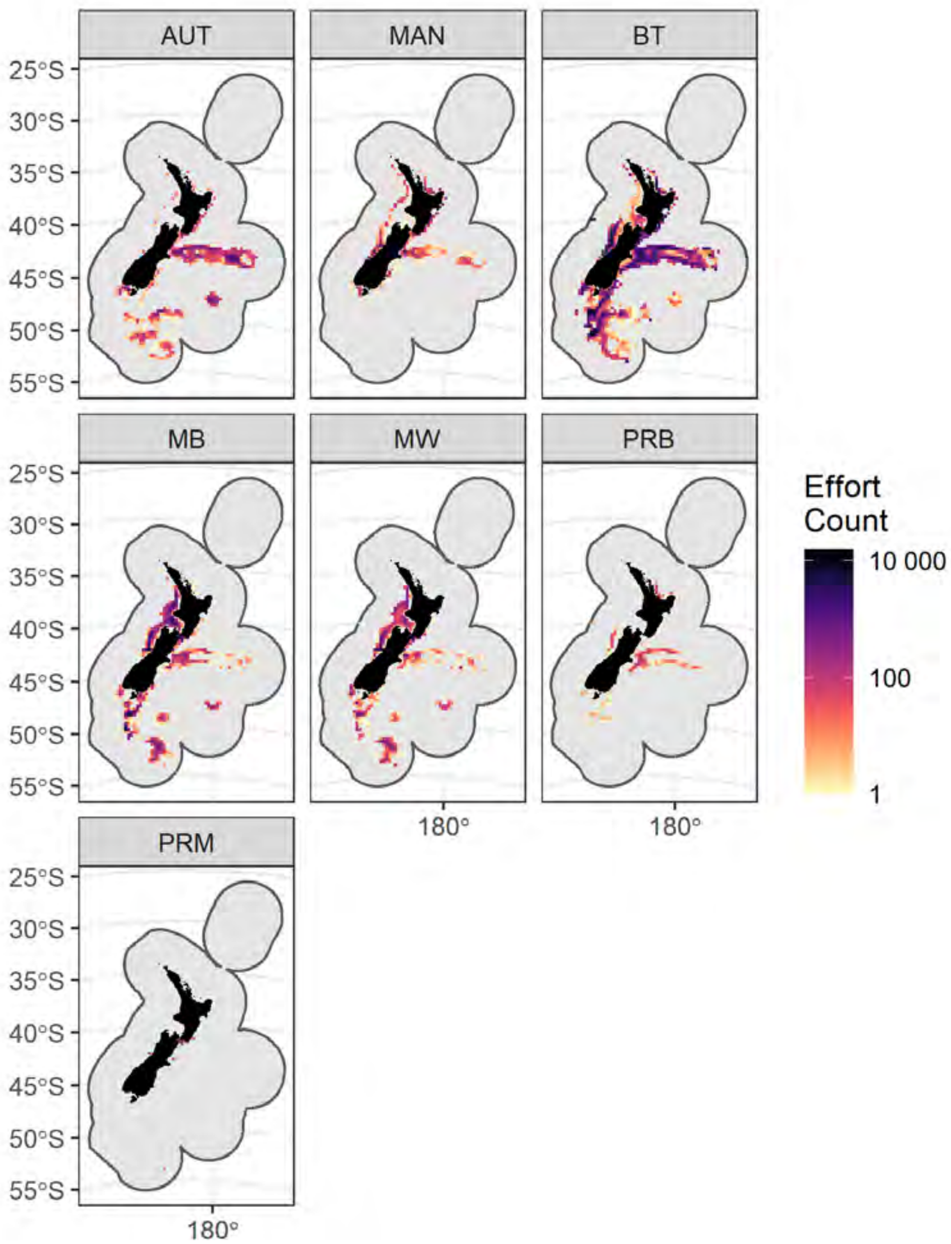


Figure S25: Commercial fishing effort (number of events) for spiny dogfish summed across all years and presented on a log10-scale per grid cell and gear type. Effort was calculated as a count to allow comparability between methods.

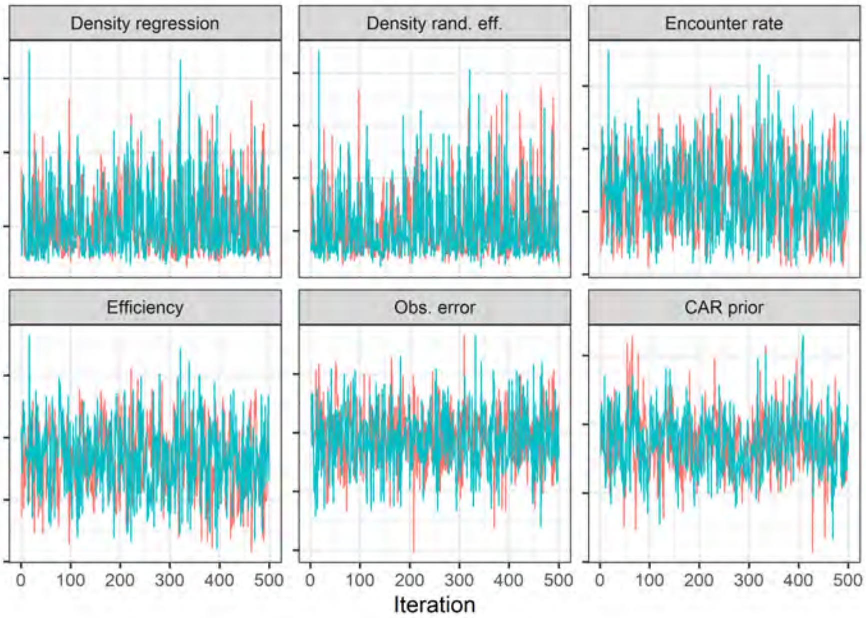


Figure S26: Posterior density sample traces for spiny dogfish, for the regression coefficients $||\boldsymbol{\alpha}||$, random effects $||\boldsymbol{\phi}||$, encounter rate $||\boldsymbol{\gamma}||$, efficiency $||\boldsymbol{\pi}||$, observation error $||\boldsymbol{\sigma}||$ and conditional autoregressive prior parameters $||\tau,\rho||$. Colours represent independent sample chains.

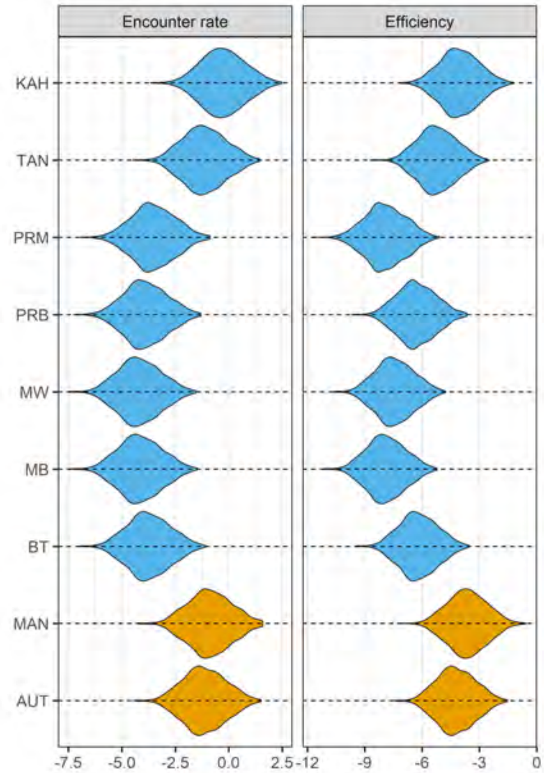


Figure S27: Violin plots of the posterior density for the encounter rate (γ_j) and the efficiency (π_j) per gear type for spiny dogfish. Catchability terms for bottom longline gear types (see Table S2) are presented in a different colour as they are not comparable to the trawl gear types because they are dependent on different measures of effort (i.e., thousand hooks and distance, respectively).

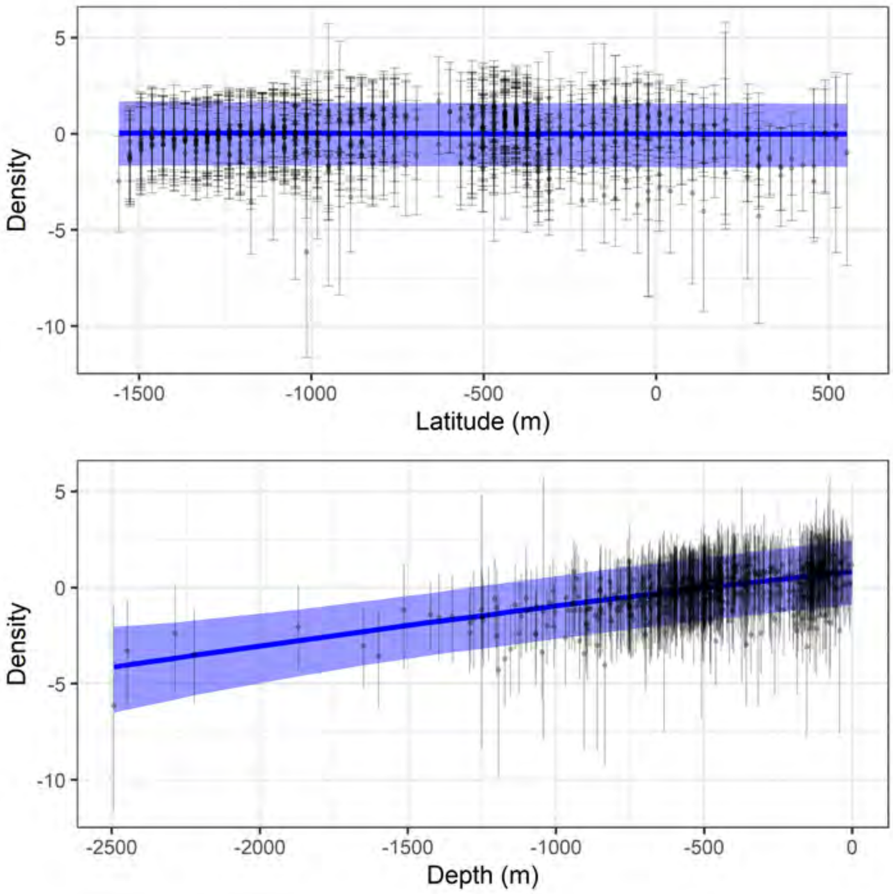


Figure S28: Estimated relationship between biomass density per grid cell and environmental covariates for spiny dogfish. Points and error bars show the median and 90% credibility intervals per cell. The blue ribbon shows the estimated marginal relationship.

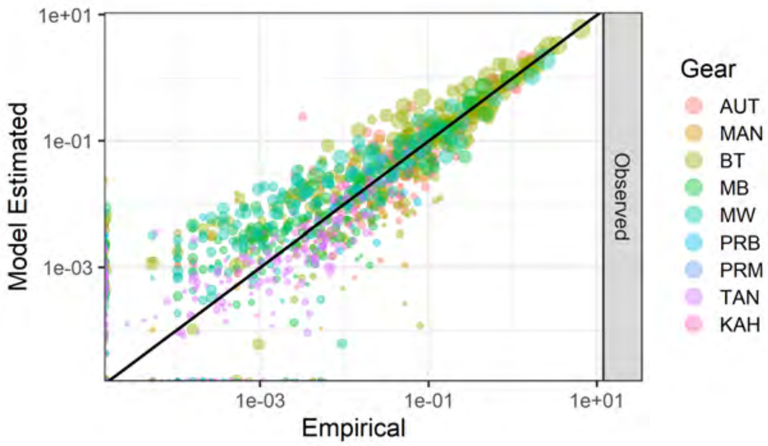


Figure S29: Fit of model to empirical observer catches. Total catches are summed per grid cell and gear type for spiny dogfish. Model estimates are the median of the posterior predicted distribution. The size of the point is representative of the number of observed events. Catches are shown in tonnes on a log10 scale.

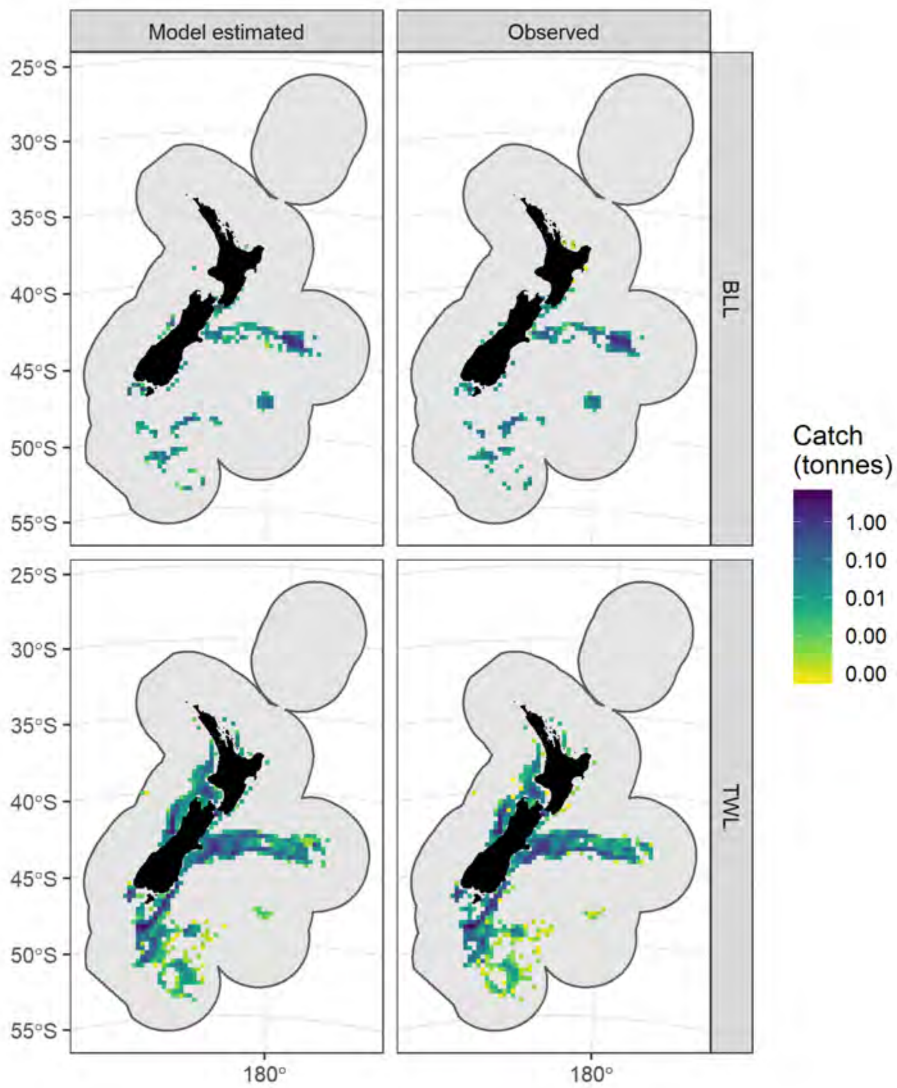


Figure S30: Spatial fit of model to empirical observer catches by grid cell and method for spiny dogfish. Average annual catches were calculated as the sum across gear types per cell and method. Posterior median values are shown, with catches in tonnes on a log10 scale.

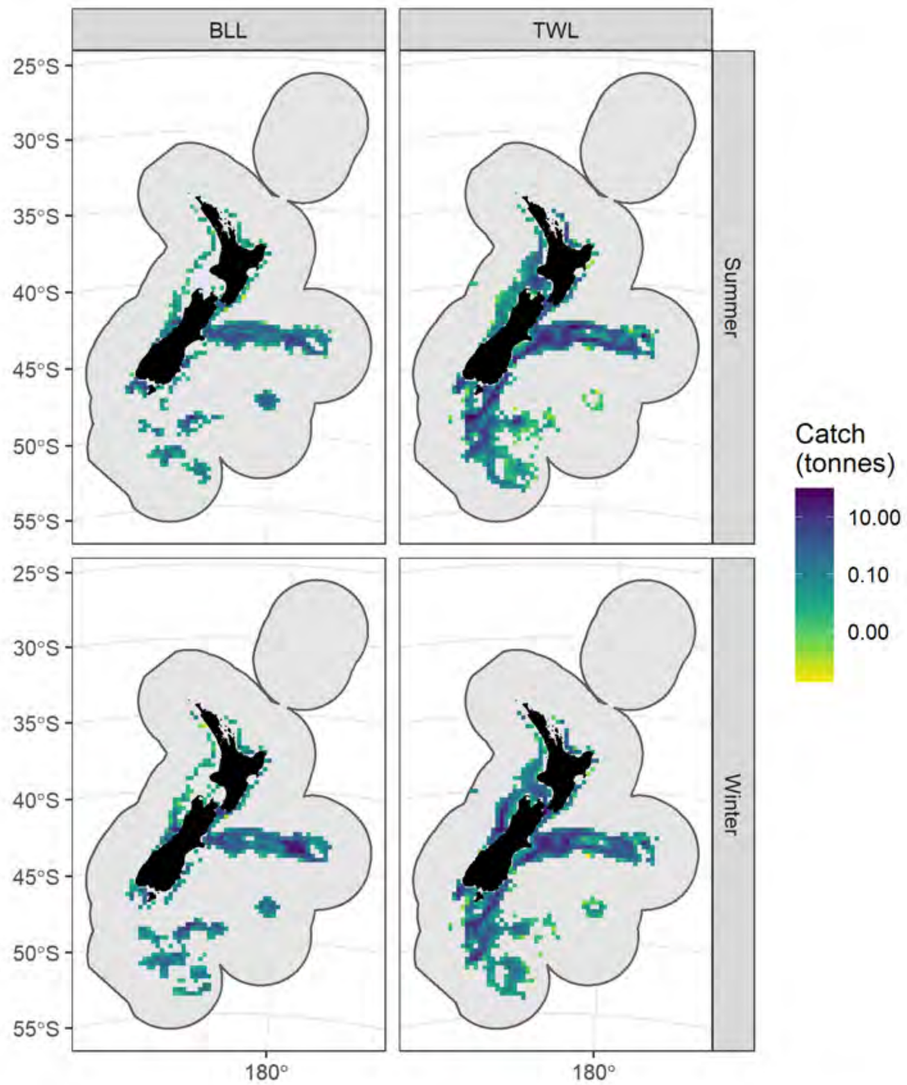


Figure S31: Posterior prediction of the total catches by grid cell, method and season for spiny dogfish. Average annual catches per season were calculated as the sum across gear types per cell and method. Posterior median values are shown, with catches in tonnes on a log10 scale.

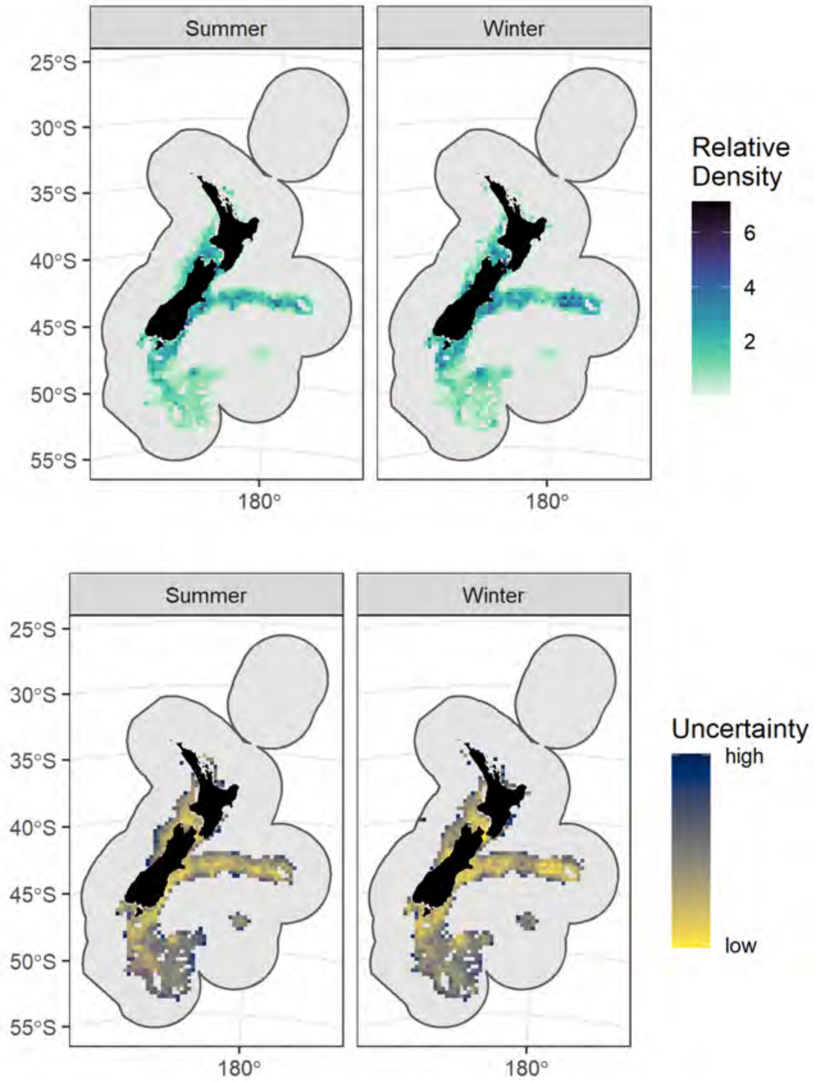


Figure S32: Posterior prediction of the relative density per grid cell and season for spiny dogfish. Posterior median values are shown on a natural scale in tonnes per square kilometre. Uncertainty is measured using the difference between the upper and lower 95% equal-tailed posterior density interval.

Table S11: Total predicted bycatch (tonnes) per method for spiny dogfish. Posterior median values are given, with the 95% equal-tailed credibility intervals in brackets.

Fishing year	BLL	TWL	Total
2000/01	897 (768 - 1 163)	3 739 (3 457 - 4 561)	4 639 (4 300 - 5 663)
2001/02	994 (851 - 1 200)	3 388 (3 142 - 3 728)	4 392 (4 103 - 4 782)
2002/03	664 (551 - 808)	3 773 (3 469 - 4 199)	4 440 (4 115 - 4 877)
2003/04	932 (784 - 1 127)	2 860 (2 636 - 3 094)	3 800 (3 529 - 4 105)
2004/05	716 (595 - 882)	2 969 (2 740 - 3 376)	3 687 (3 437 - 4 098)
2005/06	599 (499 - 743)	2 773 (2 581 - 3 006)	3 377 (3 157 - 3 658)
2006/07	539 (449 - 658)	2 572 (2 363 - 2 872)	3 118 (2 882 - 3 443)
2007/08	740 (593 - 1 831)	2 739 (2 529 - 3 042)	3 494 (3 201 - 4 905)
2008/09	764 (617 - 1 097)	2 335 (2 160 - 2 575)	3 114 (2 867 - 3 503)
2009/10	773 (649 - 1 044)	2 695 (2 503 - 2 970)	3 479 (3 242 - 3 858)
2010/11	875 (705 - 1 617)	2 582 (2 379 - 2 820)	3 465 (3 192 - 4 214)
2011/12	834 (678 - 1 650)	2 571 (2 379 - 2 779)	3 418 (3 142 - 4 258)
2012/13	709 (557 - 1 050)	2 433 (2 225 - 2 646)	3 147 (2 882 - 3 562)
2013/14	994 (788 - 1 566)	2 551 (2 367 - 2 791)	3 551 (3 258 - 4 204)
2014/15	873 (702 - 1 581)	2 664 (2 461 - 2 923)	3 552 (3 262 - 4 324)
2015/16	1 036 (848 - 1 816)	2 535 (2 336 - 2 792)	3 574 (3 284 - 4 423)
2016/17	1 131 (923 - 1 642)	2 566 (2 378 - 2 778)	3 700 (3 418 - 4 235)
2017/18	1 097 (902 - 1 584)	2 530 (2 342 - 2 724)	3 630 (3 351 - 4 126)
2018/19	1 004 (827 - 1 360)	2 561 (2 356 - 2 765)	3 570 (3 300 - 3 972)

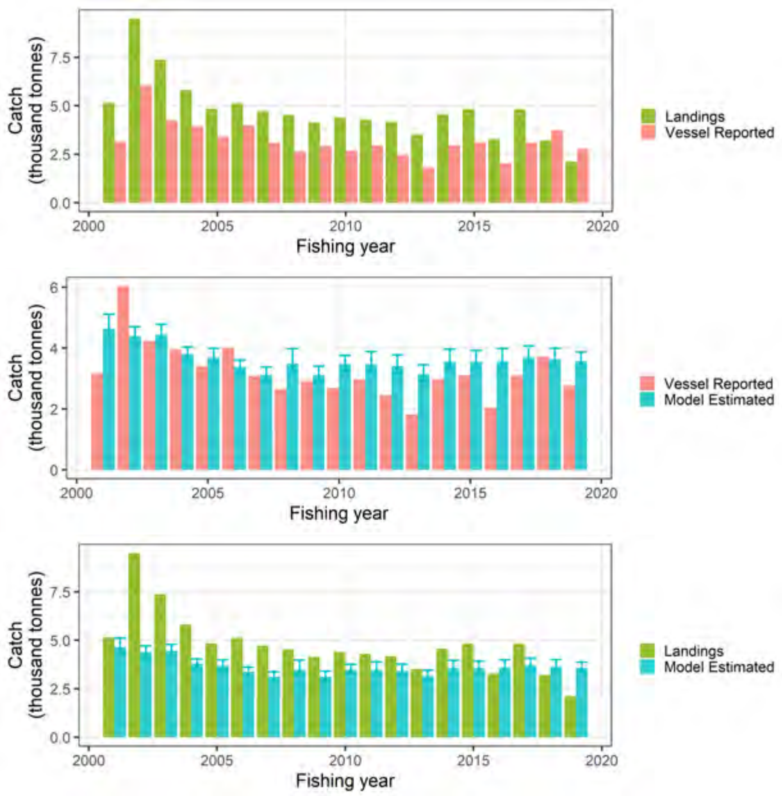


Figure S33: Relationships between landings, vessel reported catches and model estimated catches for spiny dogfish.

S2.4 Frostfish (*Lepidopus caudatus*)

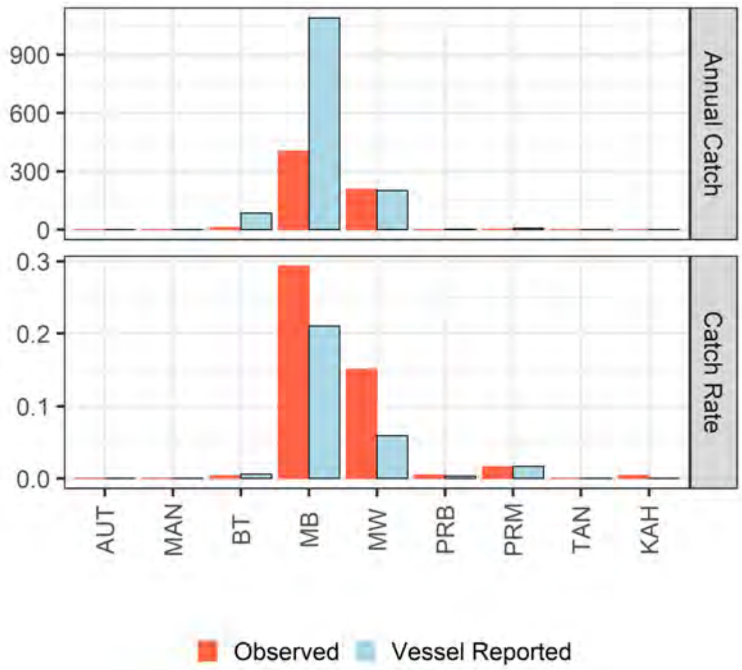


Figure S34: Empirical catch and catch rate data per gear type for frostfish. Annual catch is given in tonnes as an average across years. The catch rate is an average calculated as the sum of the observed catch in kilograms (i.e., $\sum X_i$) over the sum of the effort count (number of fishing events). Effort was calculated as a count to allow comparability between methods. There are no vessel reported catches for TAN and KAH surveys.

Table S12: Summary data for frostfish across 298 grid cells, removing 257 423 commercial events that were outside the selected cells. The total landings associated with retained commercial effort equal 38 437 tonnes. Catch is in units of tonnes, effort in the number of fishing events. "Obs." is observed; "Com." is commercial.

Method	Gear	Obs. catch	Obs. effort	Com. catch	Com. effort
BLL	AUT	0	2 854	0	19 950
BLL	MAN	0	556	0	16 789
TWL	BT	201	53 266	1 623	277 604
TWL	MB	7 669	26 156	20 663	98 202
TWL	MW	3 936	26 053	3 837	64 719
TWL	PRB	3	589	7	2 049
TWL	PRM	6	386	34	2 020
TWL	TAN	0	1 566		
TWL	KAH	3	754		
Total		11 819	112 180	26 164	481 333

Table S13: Model selection summary statistics for frostfish. Model 4 was selected for prediction of the catches.

Model	$\mathbb{L}[X]$	MPE	L^2	WAIC	$\hat{R}(\alpha)$	$\hat{R}(\gamma)$	$\hat{R}(\pi)$	DRE
1	-0.029	0.191	0.556	1338.825	1.002	1.000	1.000	1.953
2	-0.027	0.196	0.654	1383.389	0.998	1.005	1.006	1.992
3	-0.027	0.194	0.634	1384.320	1.005	1.004	1.005	1.430
4	-0.027	0.193	0.588	1387.225	1.012	1.001	1.001	1.372
5	-0.027	0.193	0.606	1381.215	1.036	1.026	1.025	1.403
6	-0.027	0.194	0.642	1385.781	1.009	1.008	1.009	1.381

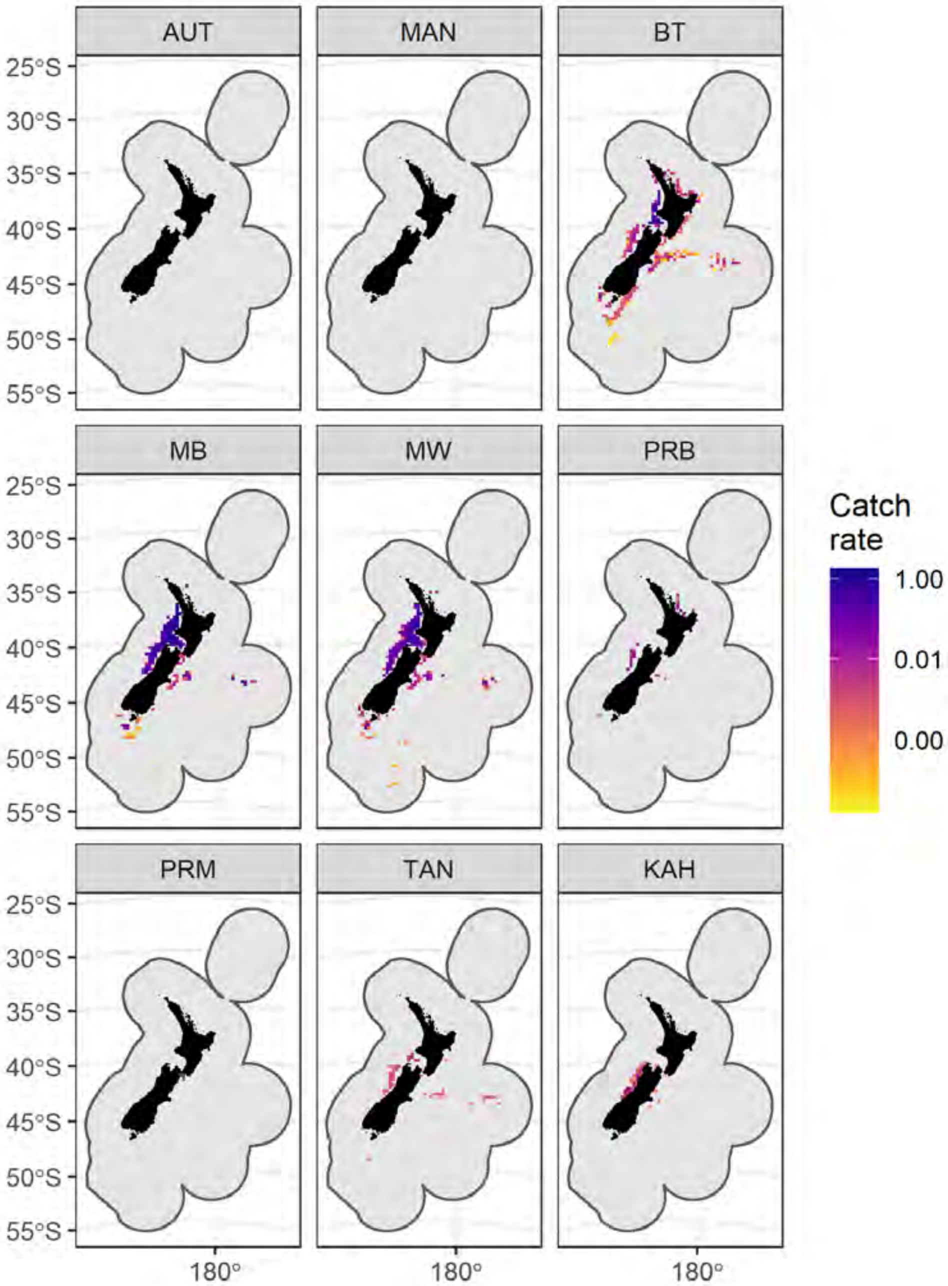


Figure S35: Observer catch rate data for frostfish on a log10-scale. The catch rate is an average calculated as the sum of the observed catch $\sum X_i$ over the number of observed fishing events per grid cell and gear type. Effort was calculated as a count to allow comparability between methods.

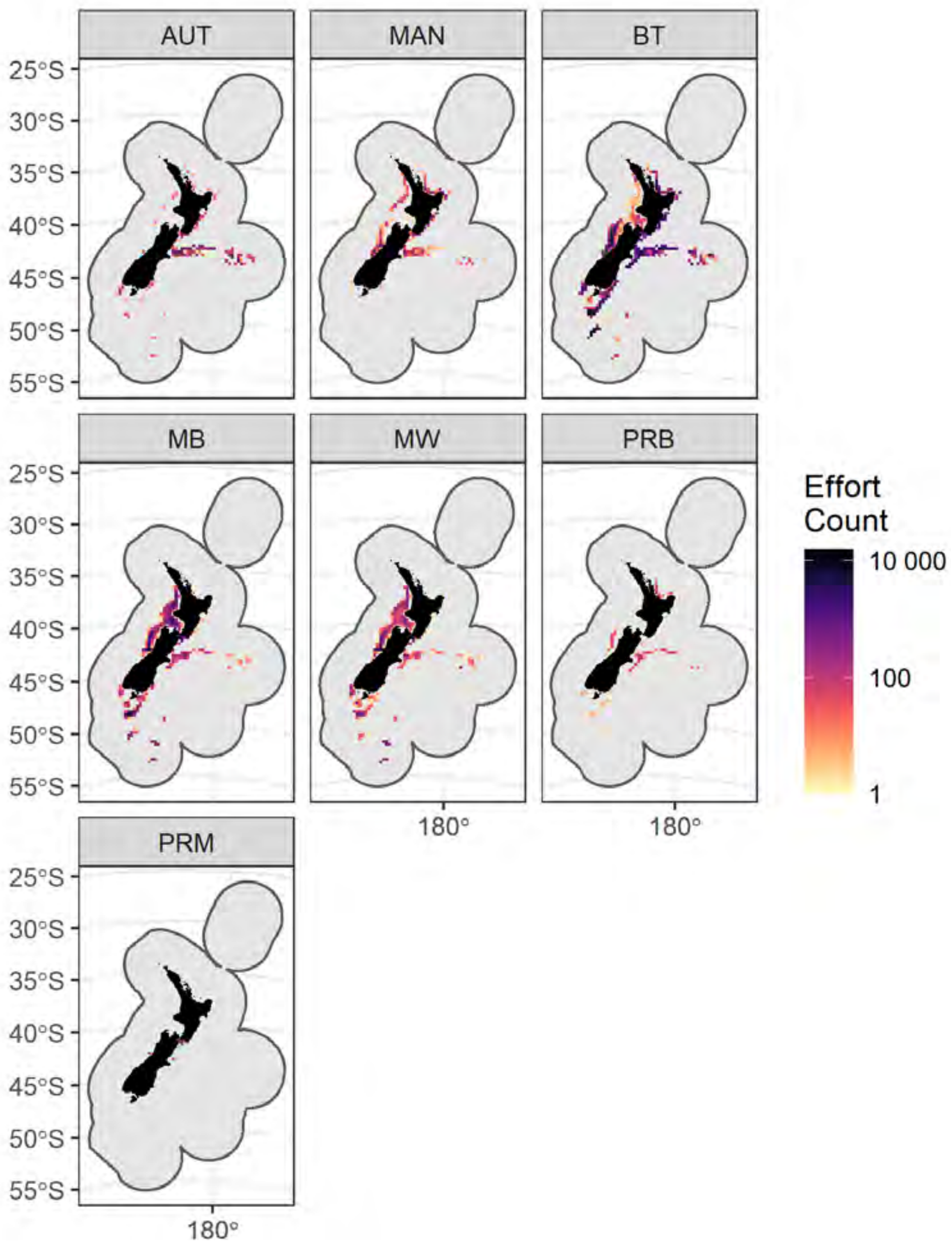


Figure S36: Commercial fishing effort (number of events) for frostfish summed across all years and presented on a log10-scale per grid cell and gear type. Effort was calculated as a count to allow comparability between methods.

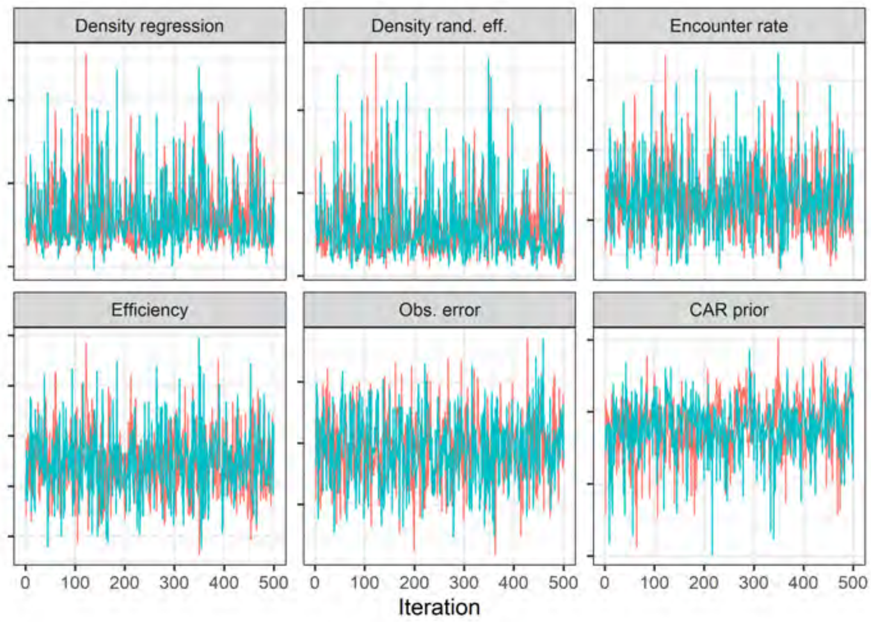


Figure S37: Posterior density sample traces for frostfish, for the regression coefficients $||\boldsymbol{\alpha}||$, random effects $||\boldsymbol{\phi}||$, encounter rate $||\boldsymbol{\gamma}||$, efficiency $||\boldsymbol{\pi}||$, observation error $||\boldsymbol{\sigma}||$ and conditional autoregressive prior parameters $||\tau, \rho||$. Colours represent independent sample chains.

Figure S38: Violin plots of the posterior density for the encounter rate (γ_j) and the efficiency (π_j) per gear type for frostfish. Catchability terms for bottom longline gear types (see Table S2) are presented in a different colour as they are not comparable to the trawl gear types because they are dependent on different measures of effort (i.e., thousand hooks and distance, respectively).

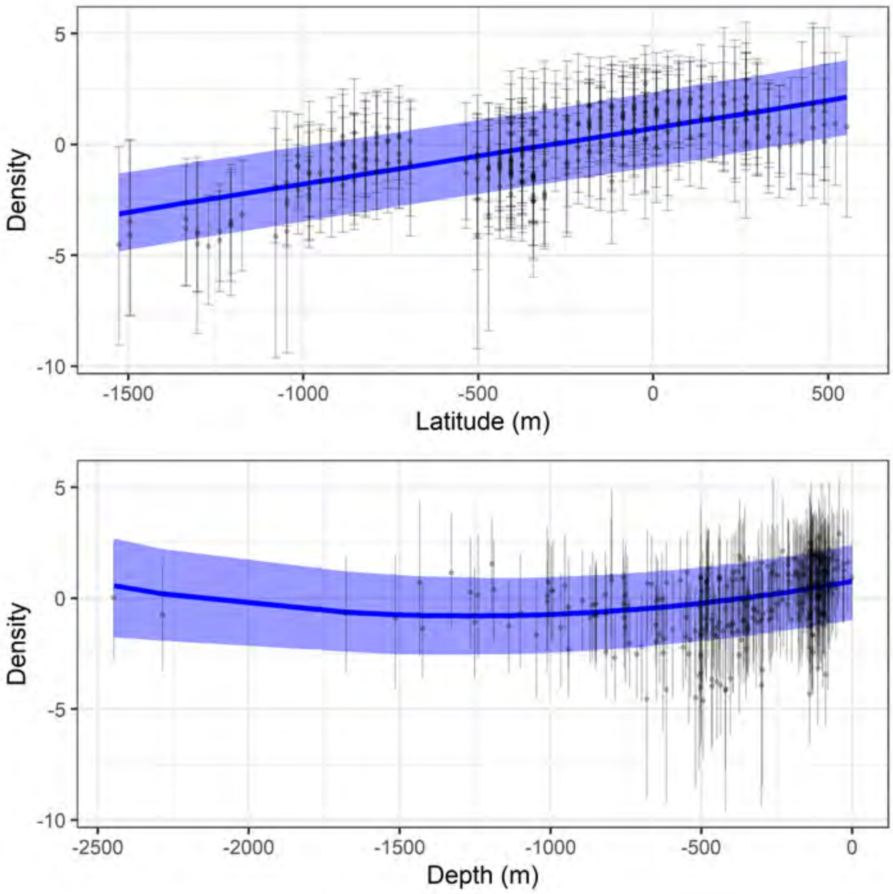


Figure S39: Estimated relationship between biomass density per grid cell and environmental covariates for frostfish. Points and error bars show the median and 90% credibility intervals per cell. The blue ribbon shows the estimated marginal relationship.

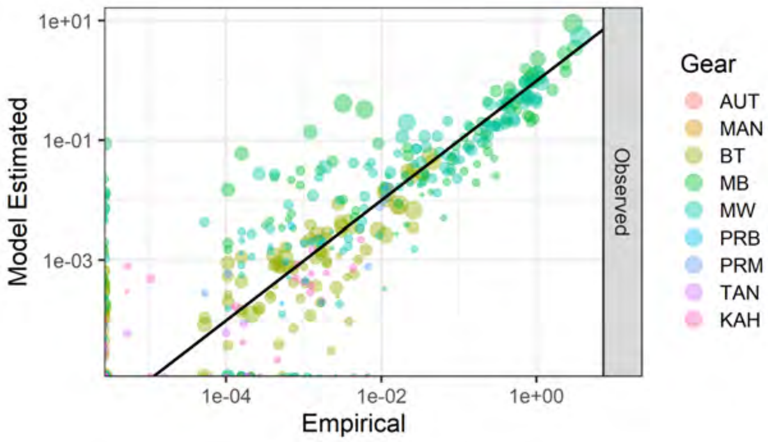


Figure S40: Fit of model to empirical observer catches. Total catches are summed per grid cell and gear type for frostfish. Model estimates are the median of the posterior predicted distribution. The size of the point is representative of the number of observed events. Catches are shown in tonnes on a log10 scale.

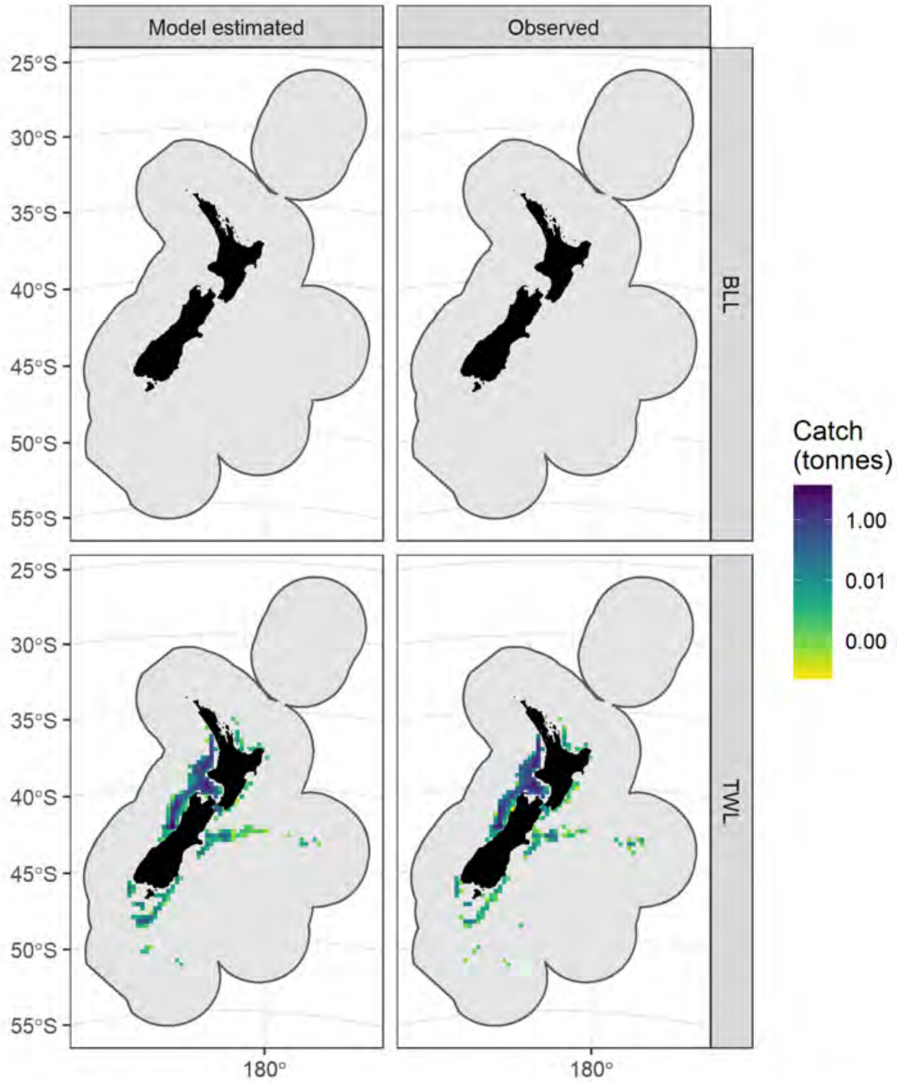


Figure S41: Spatial fit of model to empirical observer catches by grid cell and method for frostfish. Average annual catches were calculated as the sum across gear types per cell and method. Posterior median values are shown, with catches in tonnes on a log10 scale.

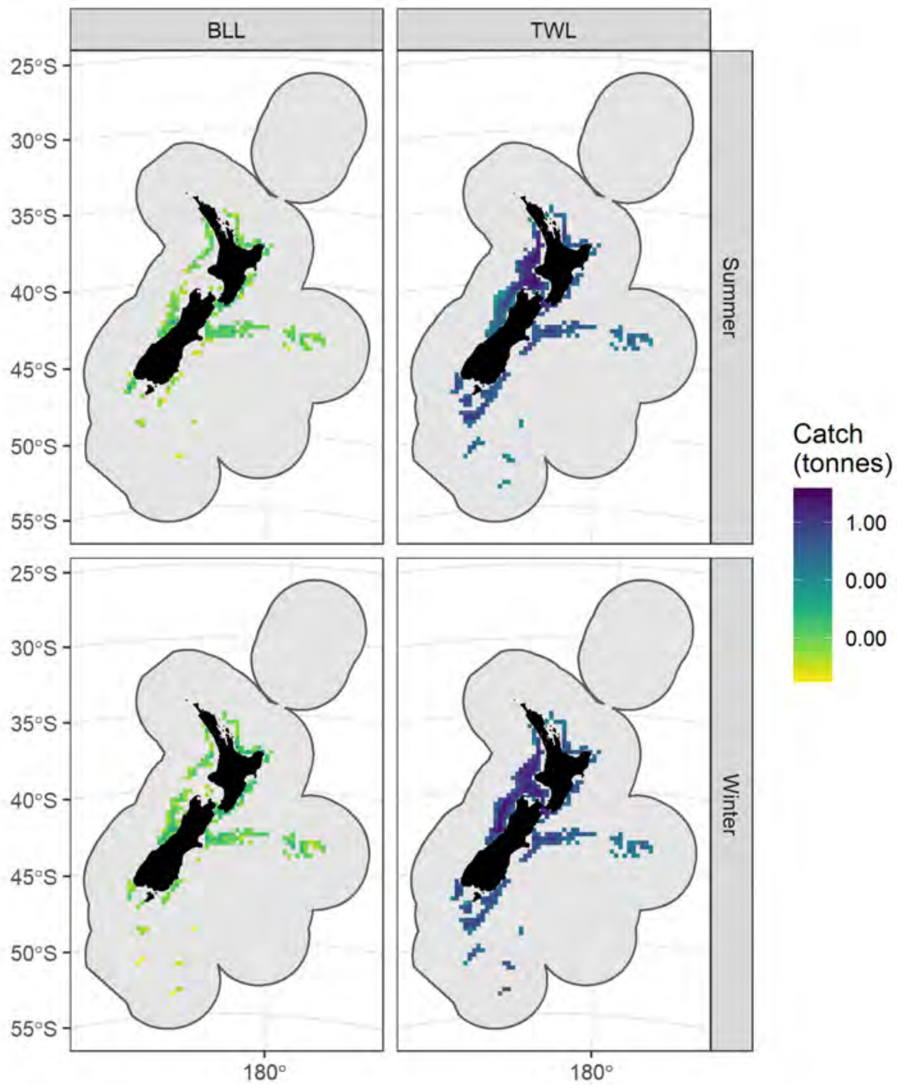
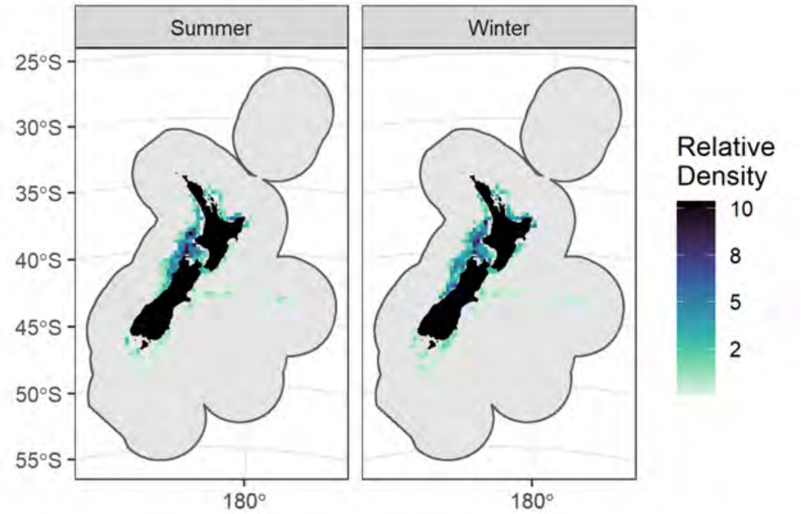


Figure S42: Posterior prediction of the total catches by grid cell, method and season for frostfish. Average annual catches per season were calculated as the sum across gear types per cell and method. Posterior median values are shown, with catches in tonnes on a log10 scale.



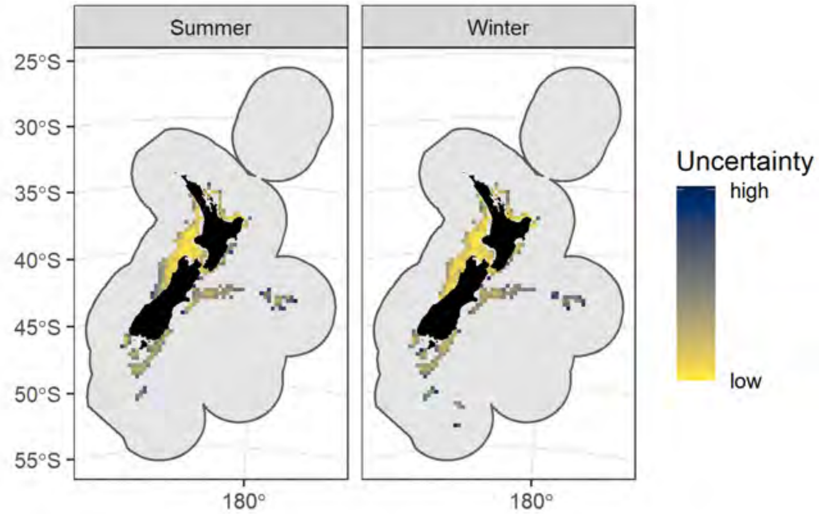


Figure S43: Posterior prediction of the relative density per grid cell and season for frostfish. Posterior median values are shown on a natural scale in tonnes per square kilometre. Uncertainty is measured using the difference between the upper and lower 95% equal-tailed posterior density interval.

Table S14: Total predicted bycatch (tonnes) per method for frostfish. Posterior median values are given, with the 95% equal-tailed credibility intervals in brackets.

Fishing year	BLL	TWL	Total
2000/01	0 (0 - 0)	1 536 (1 383 - 1 724)	1 536 (1 383 - 1 724)
2001/02	0 (0 - 0)	1 504 (1 335 - 1 712)	1 504 (1 335 - 1 712)
2002/03	0 (0 - 0)	1 894 (1 674 - 2 169)	1 894 (1 674 - 2 169)
2003/04	0 (0 - 0)	1 694 (1 470 - 2 024)	1 694 (1 470 - 2 024)
2004/05	0 (0 - 0)	1 256 (1 099 - 1 451)	1 256 (1 099 - 1 451)
2005/06	0 (0 - 0)	1 297 (1 121 - 1 547)	1 297 (1 121 - 1 547)
2006/07	0 (0 - 0)	1 222 (1 045 - 1 457)	1 222 (1 045 - 1 457)
2007/08	0 (0 - 0)	1 103 (922 - 1 303)	1 103 (922 - 1 303)
2008/09	0 (0 - 0)	1 082 (911 - 1 333)	1 082 (911 - 1 333)
2009/10	0 (0 - 0)	1 266 (1 086 - 1 507)	1 266 (1 086 - 1 507)
2010/11	0 (0 - 0)	941 (800 - 1 117)	941 (800 - 1 117)
2011/12	0 (0 - 0)	1 068 (917 - 1 274)	1 068 (917 - 1 274)
2012/13	0 (0 - 0)	1 152 (1 000 - 1 353)	1 152 (1 000 - 1 353)
2013/14	0 (0 - 0)	1 312 (1 152 - 1 514)	1 312 (1 152 - 1 514)
2014/15	0 (0 - 0)	1 160 (1 032 - 1 340)	1 160 (1 032 - 1 340)
2015/16	0 (0 - 0)	1 085 (943 - 1 251)	1 085 (943 - 1 251)
2016/17	0 (0 - 0)	1 151 (983 - 1 383)	1 151 (983 - 1 383)
2017/18	0 (0 - 0)	1 116 (956 - 1 320)	1 116 (956 - 1 320)
2018/19	0 (0 - 0)	1 149 (1 001 - 1 348)	1 149 (1 001 - 1 348)

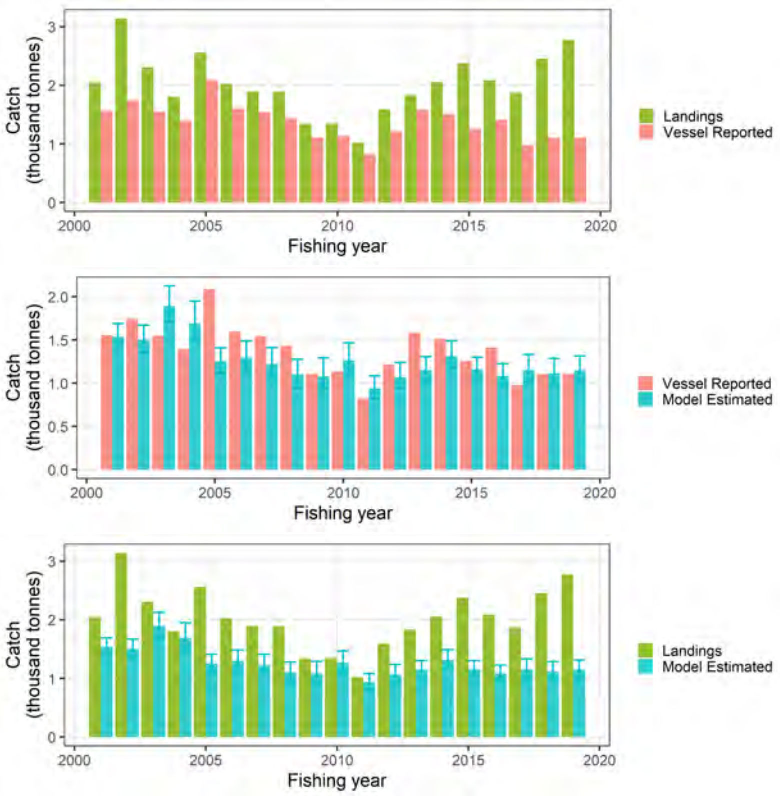


Figure S44: Relationships between landings, vessel reported catches and model estimated catches for frostfish.

S2.5 Blue mackerel (*Scomber australasicus*)

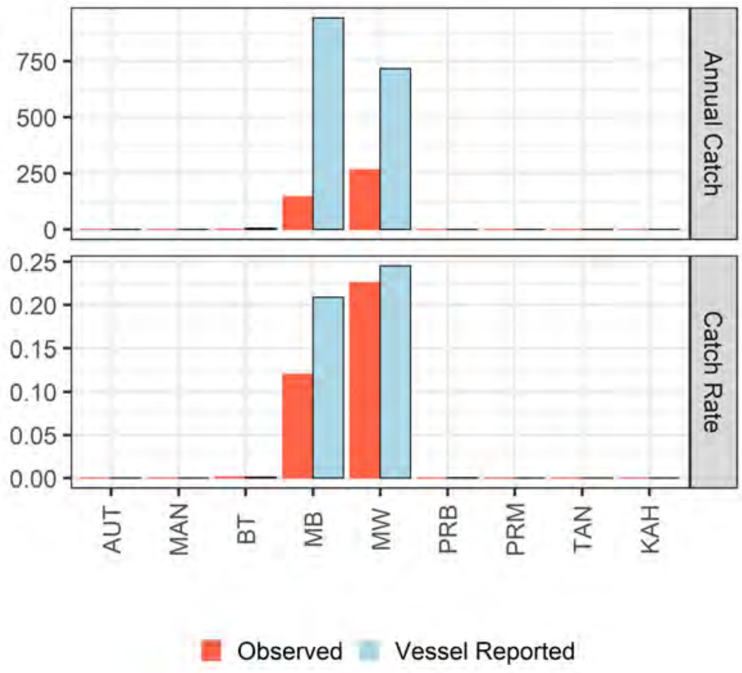


Figure S45: Empirical catch and catch rate data per gear type for blue mackerel. Annual catch is given in tonnes as an average across years. The catch rate is an average calculated as the sum of the observed catch in kilograms (i.e., $\sum X_i$) over the sum of the effort count (number of fishing events). Effort was calculated as a count to allow comparability between methods. There are no vessel reported catches for TAN and KAH surveys.

Table S15: Summary data for blue mackerel across 151 grid cells, removing 461 975 commercial events that were outside the selected cells. The total landings associated with retained commercial effort equal 48 485 tonnes. Catch is in units of tonnes, effort in the number of fishing events. "Obs." is observed; "Com." is commercial.

Method	Gear	Obs. catch	Obs. effort	Com. catch	Com. effort
BLL	AUT	0	1 173	0	8 497
BLL	MAN	0	344	0	5 561
TWL	BT	47	28 410	118	118 785
TWL	MB	2 771	22 994	17 898	85 628
TWL	MW	5 054	22 366	13 607	55 476
TWL	PRB	0	424	0	1 184
TWL	PRM	0	341	0	1 650
TWL	TAN	0	688		
TWL	KAH	0	564		
Total		7 873	77 304	31 623	276 781

Table S16: Model selection summary statistics for blue mackerel. Model 6 was selected for prediction of the catches.

Model	$\mathbb{L}[X]$	MPE	L^2	WAIC	$\hat{R}(\alpha)$	$\hat{R}(\gamma)$	$\hat{R}(\pi)$	DRE
1	-0.000	0.320	6.800	-906.608	1.002	1.010	1.010	2.801
2	-0.000	0.215	2.214	-891.003	1.005	1.006	1.008	2.508
3	-0.000	0.210	1.819	-896.322	1.006	1.004	1.000	1.705
4	-0.001	0.212	1.395	-893.242	1.015	1.003	1.002	1.635
5	-0.000	0.205	1.563	-898.547	1.051	1.019	1.011	1.679
6	-0.000	0.206	1.290	-892.219	1.006	1.013	1.017	1.590

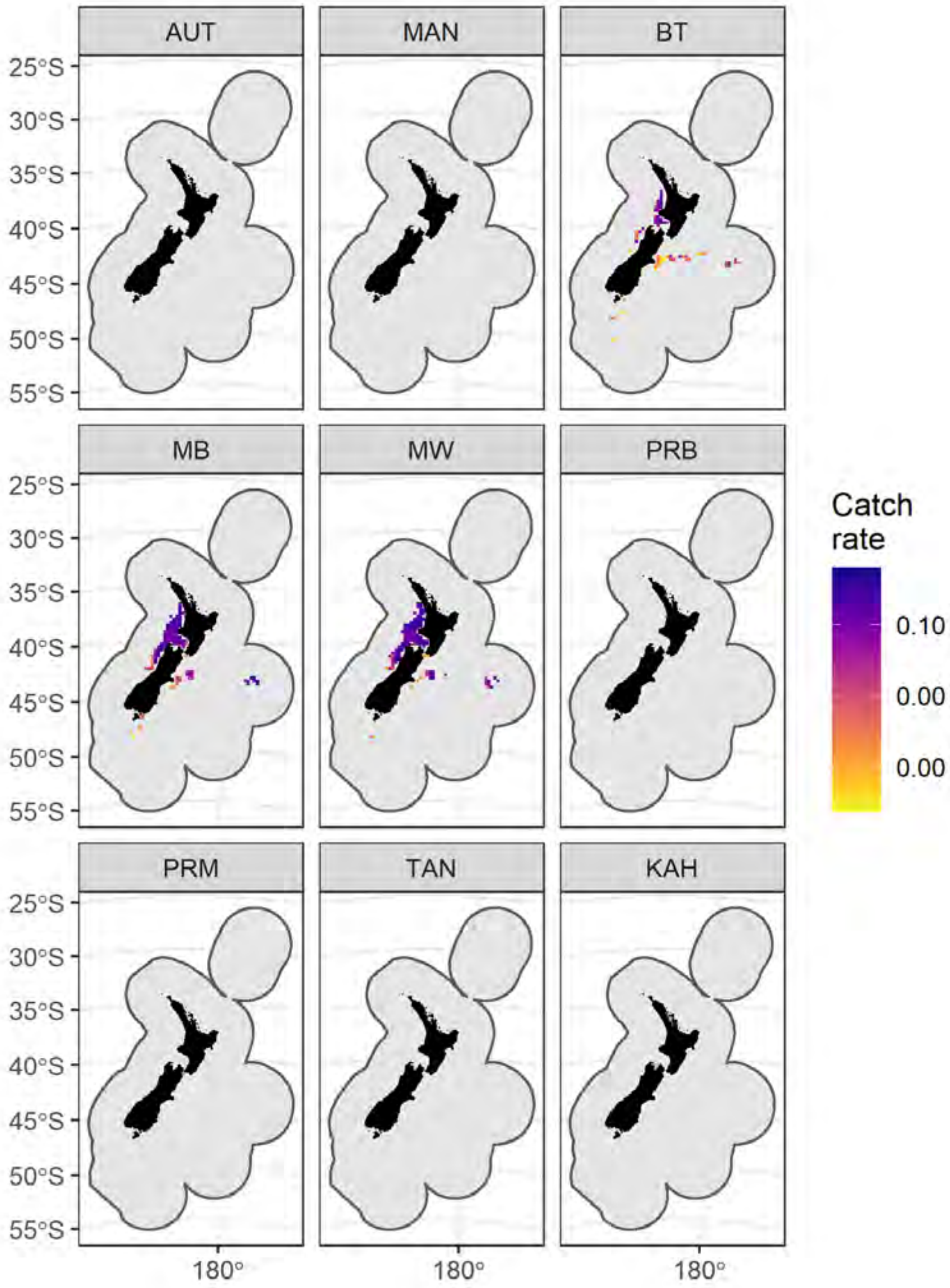


Figure S46: Observer catch rate data for blue mackerel on a log10-scale. The catch rate is an average calculated as the sum of the observed catch $\sum X_i$ over the number of observed fishing events per grid cell and gear type. Effort was calculated as a count to allow comparability between methods.

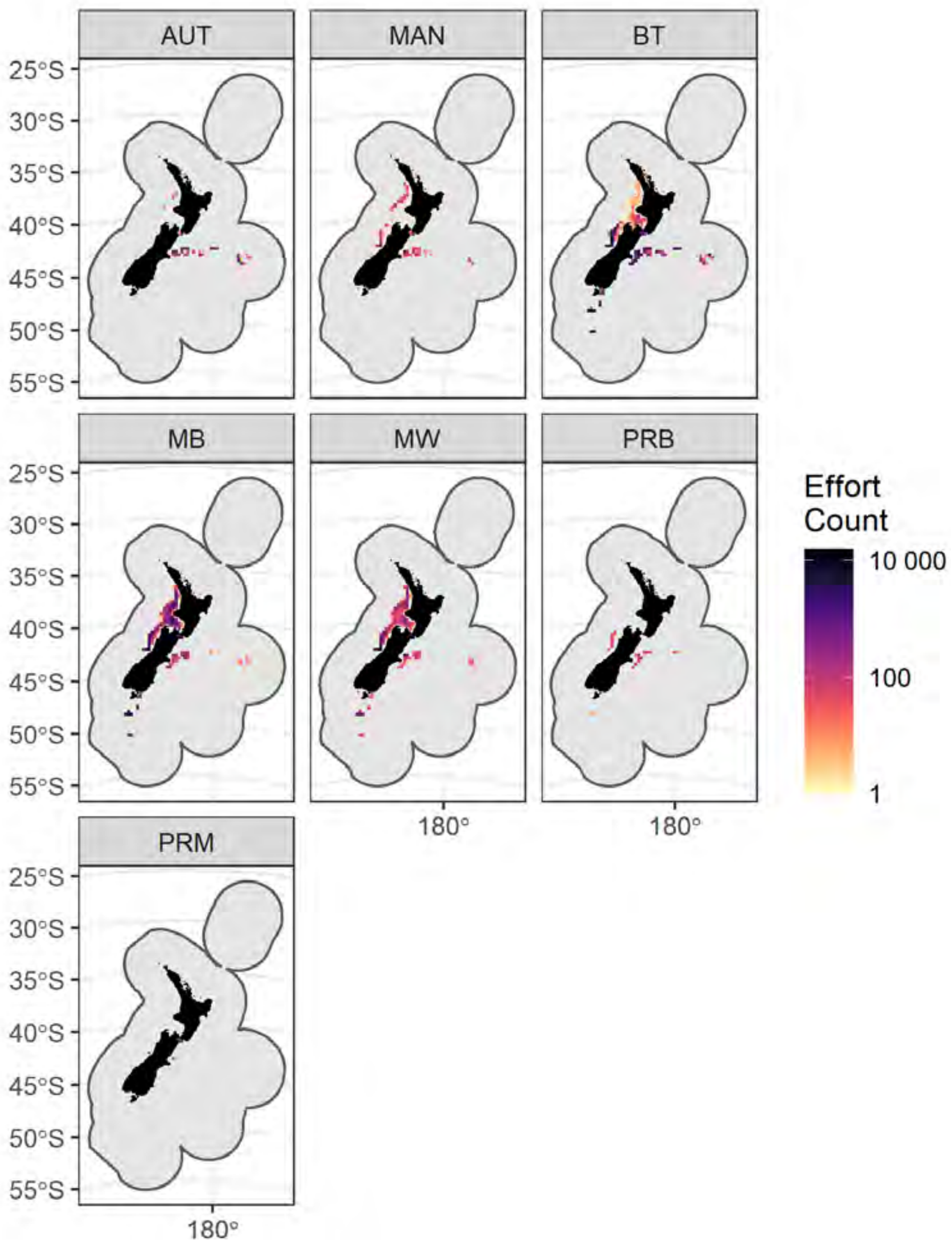


Figure S47: Commercial fishing effort (number of events) for blue mackerel summed across all years and presented on a log10-scale per grid cell and gear type. Effort was calculated as a count to allow comparability between methods.

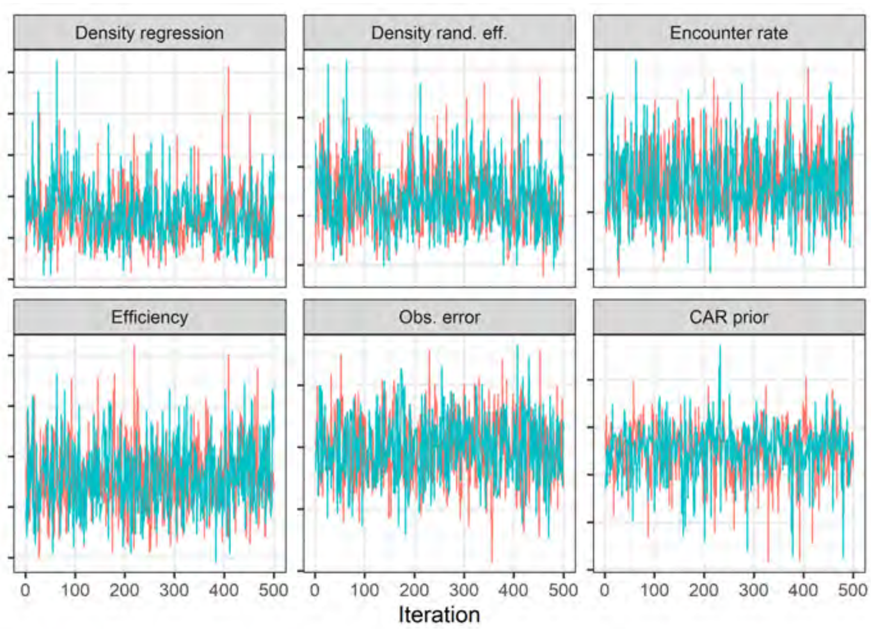


Figure S48: Posterior density sample traces for blue mackerel, for the regression coefficients $||\boldsymbol{\alpha}||$, random effects $||\boldsymbol{\phi}||$, encounter rate $||\boldsymbol{\gamma}||$, efficiency $||\boldsymbol{\pi}||$, observation error $||\boldsymbol{\sigma}||$ and conditional autoregressive prior parameters $||\tau, \rho||$. Colours represent independent sample chains.

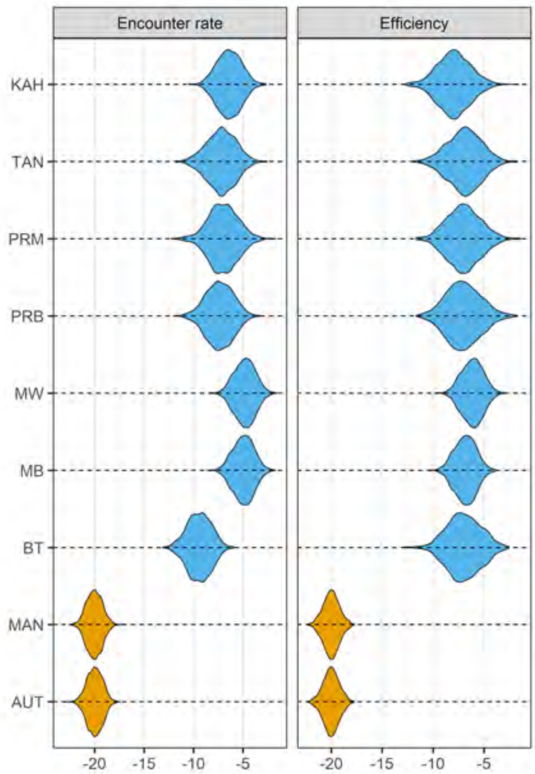


Figure S49: Violin plots of the posterior density for the encounter rate (γ_j) and the efficiency (π_j) per gear type for blue mackerel. Catchability terms for bottom longline gear types (see Table S2) are presented in a different colour as they are not comparable to the trawl gear types because they are dependent on different measures of effort (i.e., thousand hooks and distance, respectively).

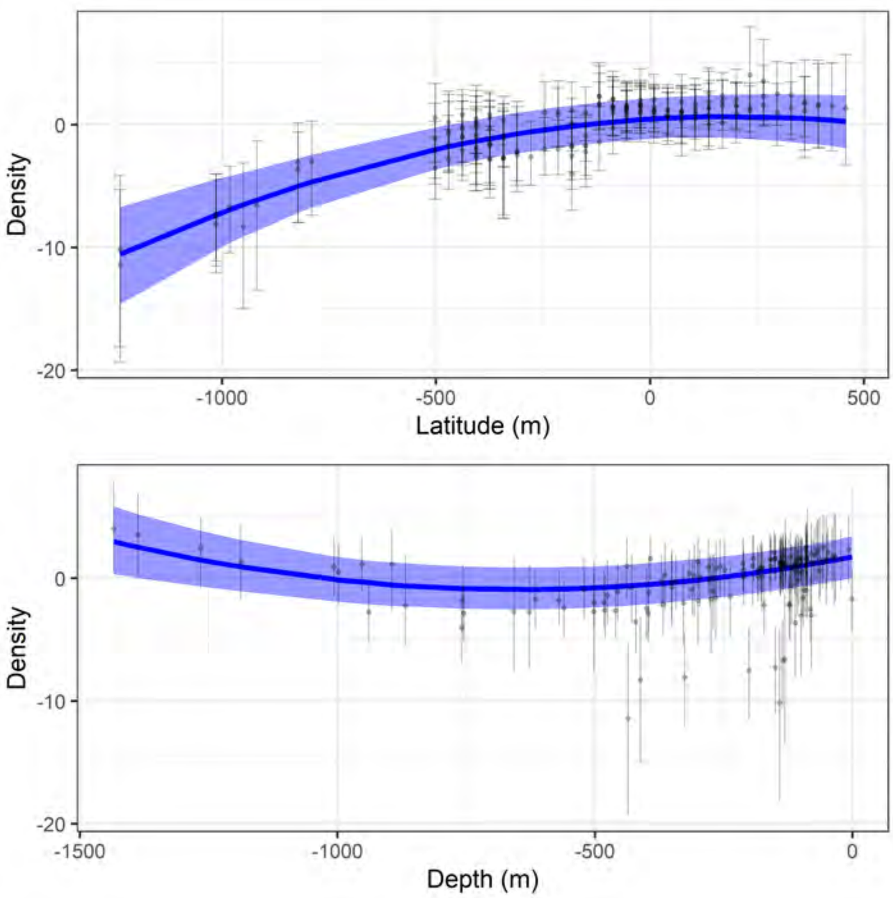


Figure S50: Estimated relationship between biomass density per grid cell and environmental covariates for blue mackerel. Points and error bars show the median and 90% credibility intervals per cell. The blue ribbon shows the estimated marginal relationship.

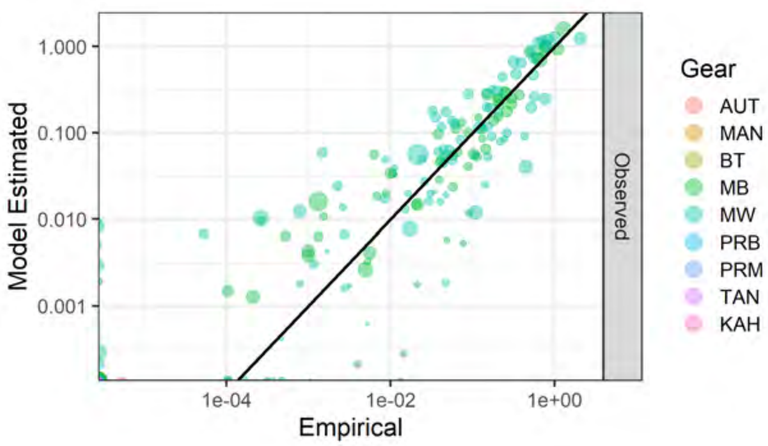


Figure S51: Fit of model to empirical observer catches. Total catches are summed per grid cell and gear type for blue mackerel. Model estimates are the median of the posterior predicted distribution. The size of the point is representative of the number of observed events. Catches are shown in tonnes on a log10 scale.

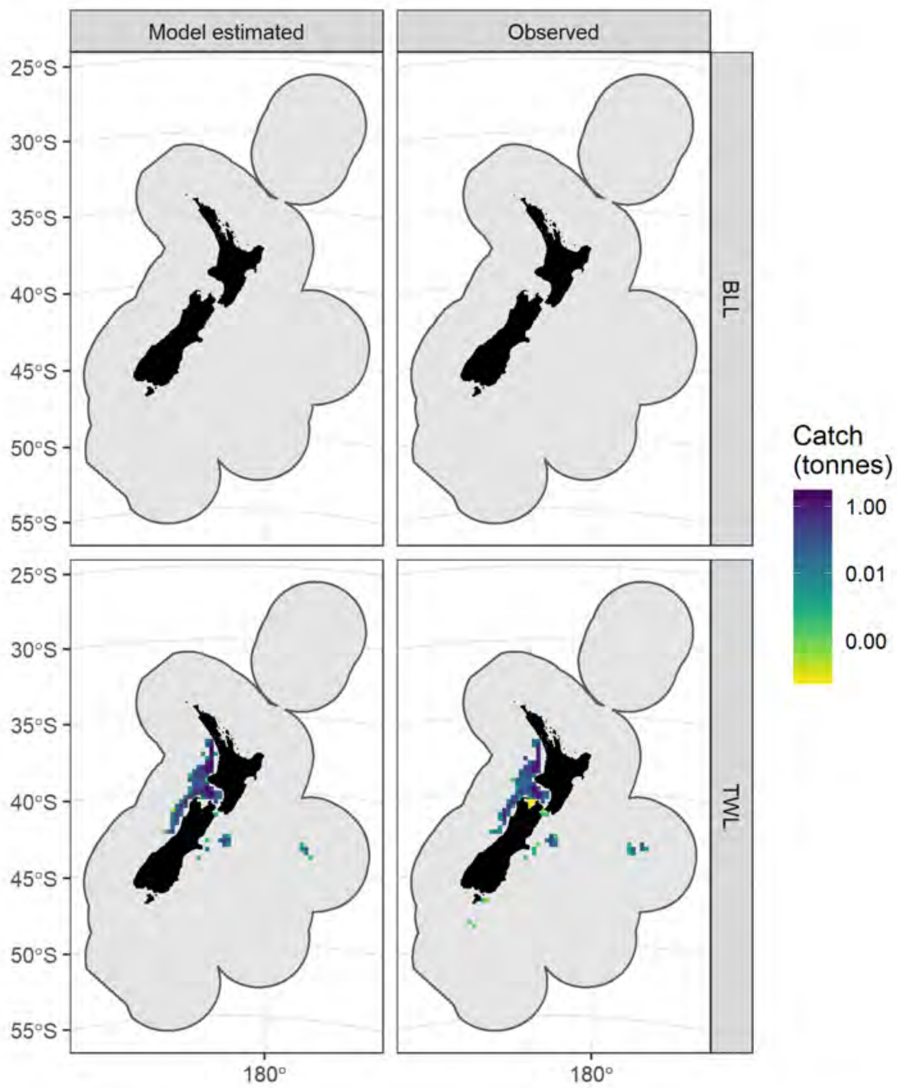


Figure S52: Spatial fit of model to empirical observer catches by grid cell and method for blue mackerel. Average annual catches were calculated as the sum across gear types per cell and method. Posterior median values are shown, with catches in tonnes on a log10 scale.

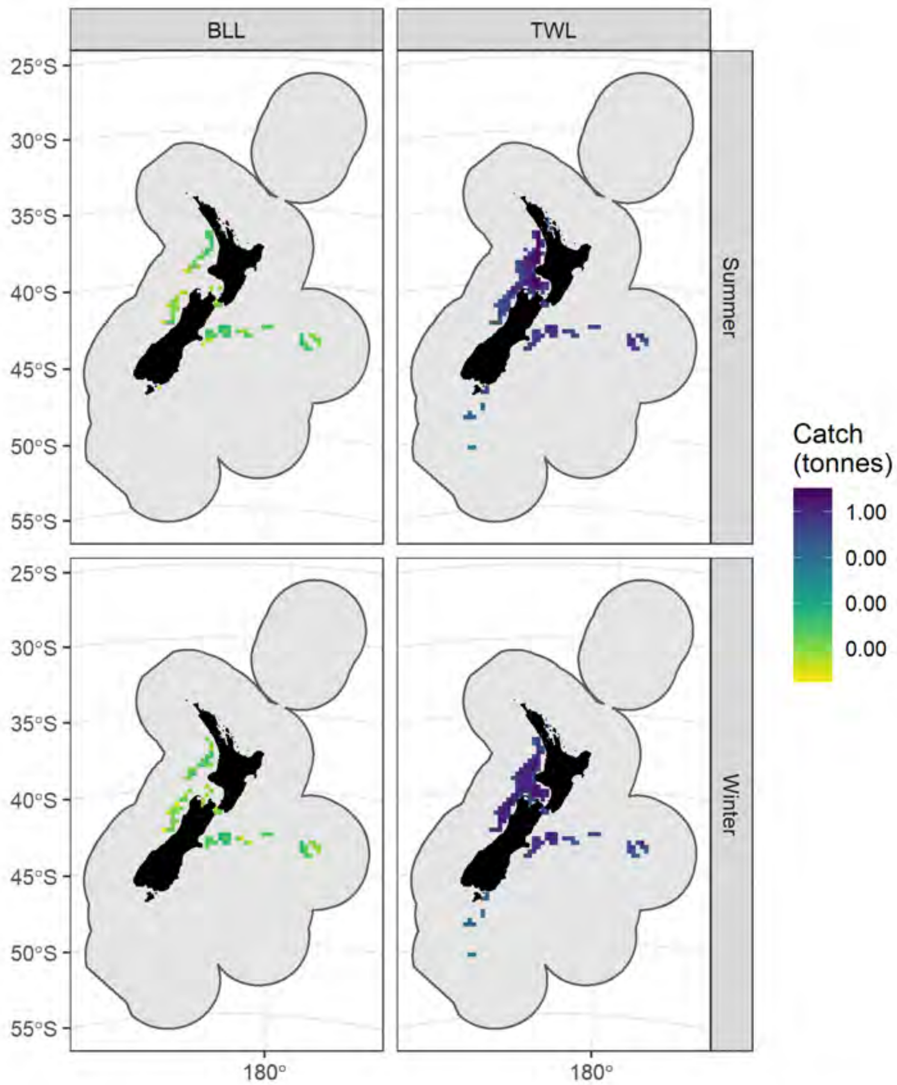


Figure S53: Posterior prediction of the total catches by grid cell, method and season for blue mackerel. Average annual catches per season were calculated as the sum across gear types per cell and method. Posterior median values are shown, with catches in tonnes on a log10 scale.

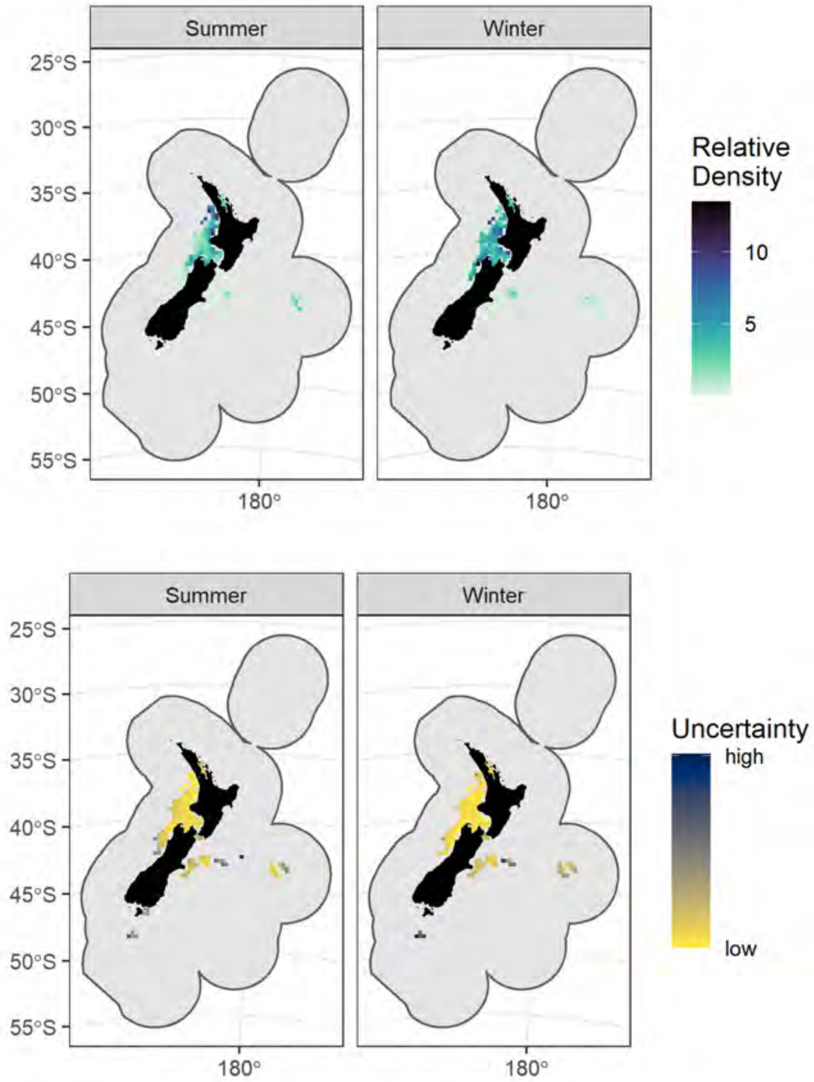


Figure S54: Posterior prediction of the relative density per grid cell and season for blue mackerel. Posterior median values are shown on a natural scale in tonnes per square kilometre. Uncertainty is measured using the difference between the upper and lower 95% equal-tailed posterior density interval.

Table S17: Total predicted bycatch (tonnes) per method for blue mackerel. Posterior median values are given, with the 95% equal-tailed credibility intervals in brackets.

Fishing year	BLL	TWL	Total
2000/01	0 (0 - 0)	408 (219 - 2 447)	408 (219 - 2 447)
2001/02	0 (0 - 0)	477 (292 - 2 308)	477 (292 - 2 308)
2002/03	0 (0 - 0)	539 (366 - 1 900)	539 (366 - 1 900)
2003/04	0 (0 - 0)	527 (374 - 1 137)	527 (374 - 1 137)
2004/05	0 (0 - 0)	686 (492 - 1 409)	686 (492 - 1 409)
2005/06	0 (0 - 0)	545 (392 - 1 293)	545 (392 - 1 293)
2006/07	0 (0 - 0)	713 (511 - 1 557)	713 (511 - 1 557)
2007/08	0 (0 - 0)	608 (422 - 1 804)	608 (422 - 1 804)
2008/09	0 (0 - 0)	450 (323 - 836)	450 (323 - 836)
2009/10	0 (0 - 0)	606 (442 - 1 078)	606 (442 - 1 078)
2010/11	0 (0 - 0)	586 (396 - 1 296)	586 (396 - 1 296)
2011/12	0 (0 - 0)	501 (341 - 1 282)	501 (341 - 1 282)
2012/13	0 (0 - 0)	618 (432 - 1 225)	618 (432 - 1 225)
2013/14	0 (0 - 0)	642 (458 - 1 444)	642 (458 - 1 444)
2014/15	0 (0 - 0)	579 (390 - 1 720)	579 (390 - 1 720)
2015/16	0 (0 - 0)	523 (330 - 1 908)	523 (330 - 1 908)
2016/17	0 (0 - 0)	488 (313 - 1 353)	488 (313 - 1 353)
2017/18	0 (0 - 0)	493 (336 - 1 210)	493 (336 - 1 210)
2018/19	0 (0 - 0)	478 (329 - 1 212)	478 (329 - 1 212)

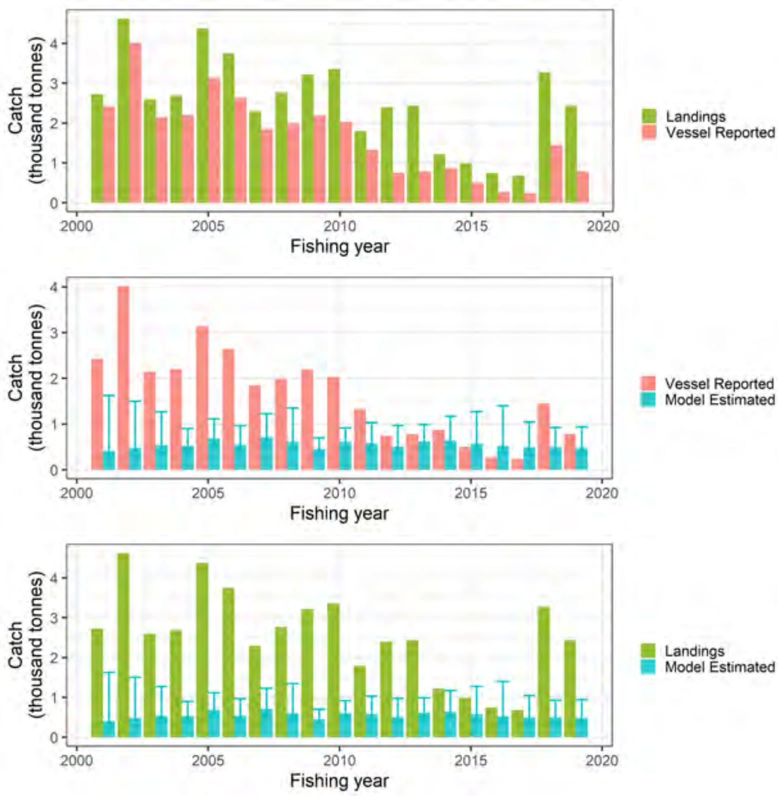


Figure S55: Relationships between landings, vessel reported catches and model estimated catches for blue mackerel.

S2.6 Morid cods (Moridae)

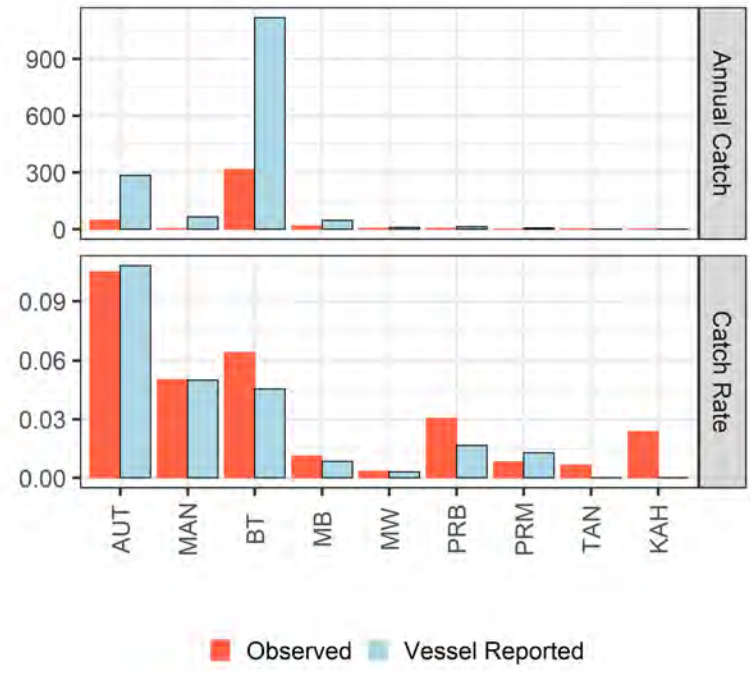


Figure S56: Empirical catch and catch rate data per gear type for morid cods. Annual catch is given in tonnes as an average across years. The catch rate is an average calculated as the sum of the observed catch in kilograms (i.e., $\sum X_i$) over the sum of the effort count (number of fishing events). Effort was calculated as a count to allow comparability between methods. There are no vessel reported catches for TAN and KAH surveys.

Table S18: Summary data for morid cods across 950 grid cells, removing 16 989 commercial events that were outside the selected cells. The total landings associated with retained commercial effort equal 54 391 tonnes. Catch is in units of tonnes, effort in the number of fishing events. "Obs." is observed; "Com." is commercial.

Method	Gear	Obs. catch	Obs. effort	Com. catch	Com. effort
BLL	AUT	883	8 406	5 417	50 078
BLL	MAN	43	846	1 257	25 171
TWL	BT	6 006	94 301	21 218	467 533
TWL	MB	339	30 361	909	107 903
TWL	MW	94	27 956	200	65 947
TWL	PRB	26	854	51	3 072
TWL	PRM	3	402	26	2 063
TWL	TAN	28	4 367		
TWL	KAH	32	1 358		
Total		7 454	168 851	29 078	721 767

Table S19: Model selection summary statistics for morid cods. Model 4 was selected for prediction of the catches.

Model	$\mathbb{L}[X]$	MPE	L^2	WAIC	$\hat{R}(\alpha)$	$\hat{R}(\gamma)$	$\hat{R}(\pi)$	DRE
1	-0.045	0.085	0.241	19147.766	1.009	1.040	1.037	1.400
2	-0.044	0.084	0.242	19312.112	1.009	1.037	1.038	1.437
3	-0.046	0.084	0.242	19325.019	1.010	1.046	1.045	1.160
4	-0.046	0.084	0.247	19329.053	1.011	1.021	1.021	1.146
5	-0.046	0.084	0.261	19330.474	1.006	1.024	1.024	1.165
6	-0.045	0.084	0.241	19328.603	1.011	1.013	1.011	1.146

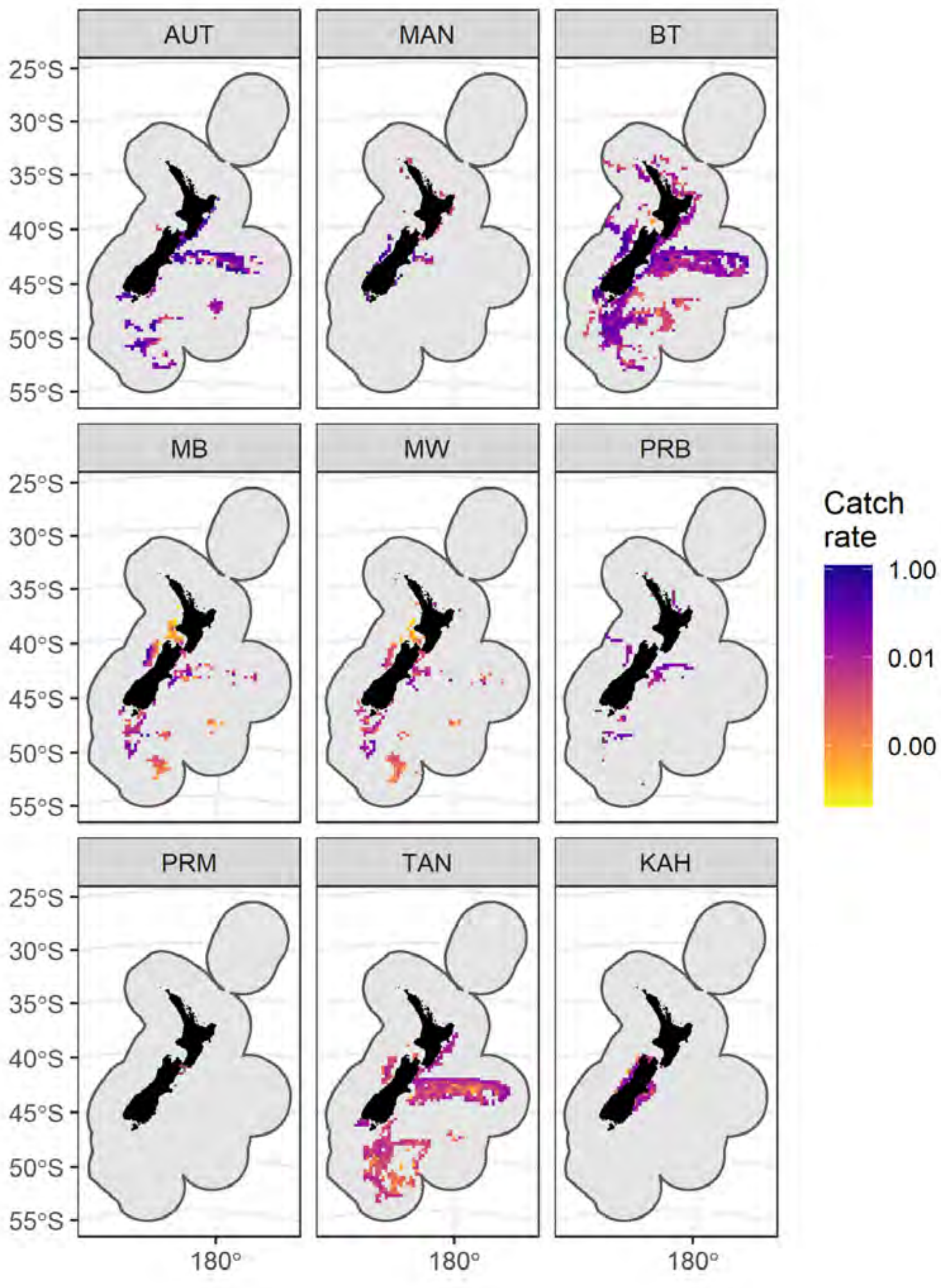


Figure S57: Observer catch rate data for morid cods on a log10-scale. The catch rate is an average calculated as the sum of the observed catch $\sum X_i$ over the number of observed fishing events per grid cell and gear type. Effort was calculated as a count to allow comparability between methods.

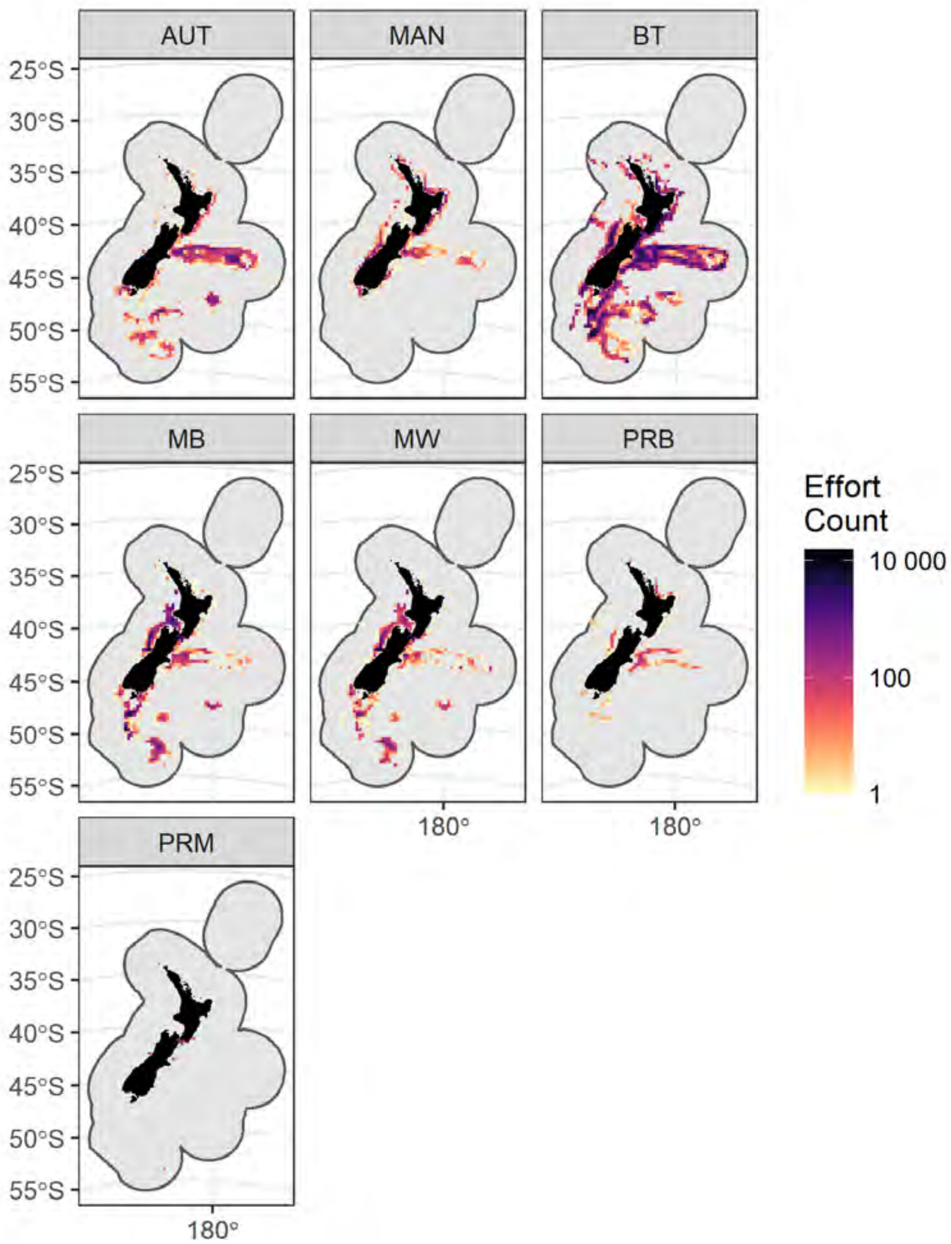


Figure S58: Commercial fishing effort (number of events) for morid cods summed across all years and presented on a log10-scale per grid cell and gear type. Effort was calculated as a count to allow comparability between methods.

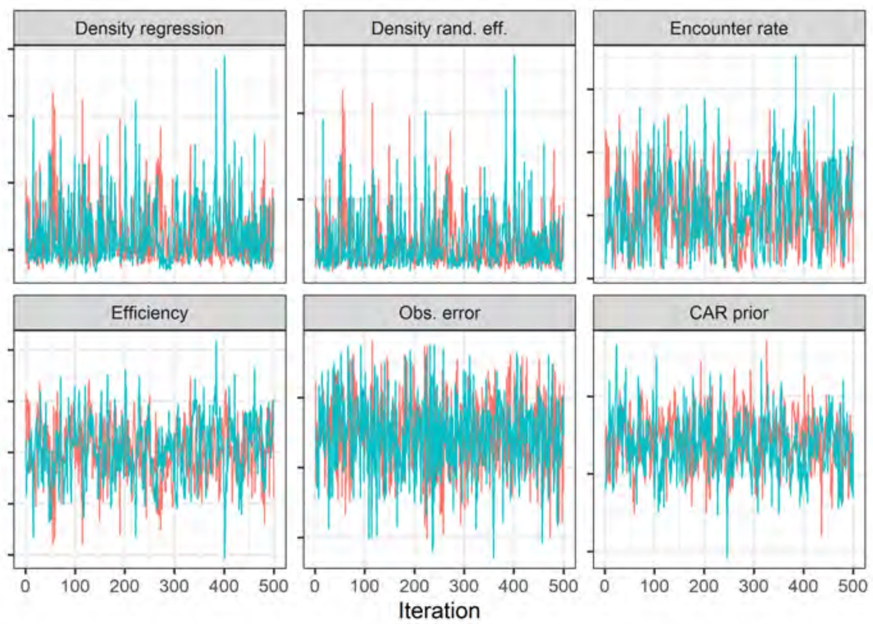


Figure S59: Posterior density sample traces for morid cods, for the regression coefficients $||\boldsymbol{\alpha}||$, random effects $||\boldsymbol{\phi}||$, encounter rate $||\boldsymbol{\gamma}||$, efficiency $||\boldsymbol{\pi}||$, observation error $||\boldsymbol{\sigma}||$ and conditional autoregressive prior parameters $||\tau,\rho||$. Colours represent independent sample chains.

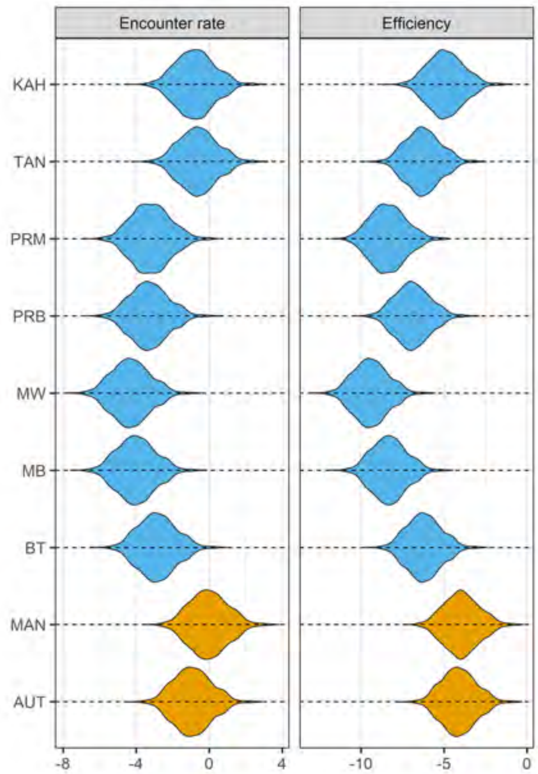


Figure S60: Violin plots of the posterior density for the encounter rate (γ_j) and the efficiency (π_j) per gear type for morid cods. Catchability terms for bottom longline gear types (see Table S2) are presented in a different colour as they are not comparable to the trawl gear types because they are dependent on different measures of effort (i.e., thousand hooks and distance, respectively).

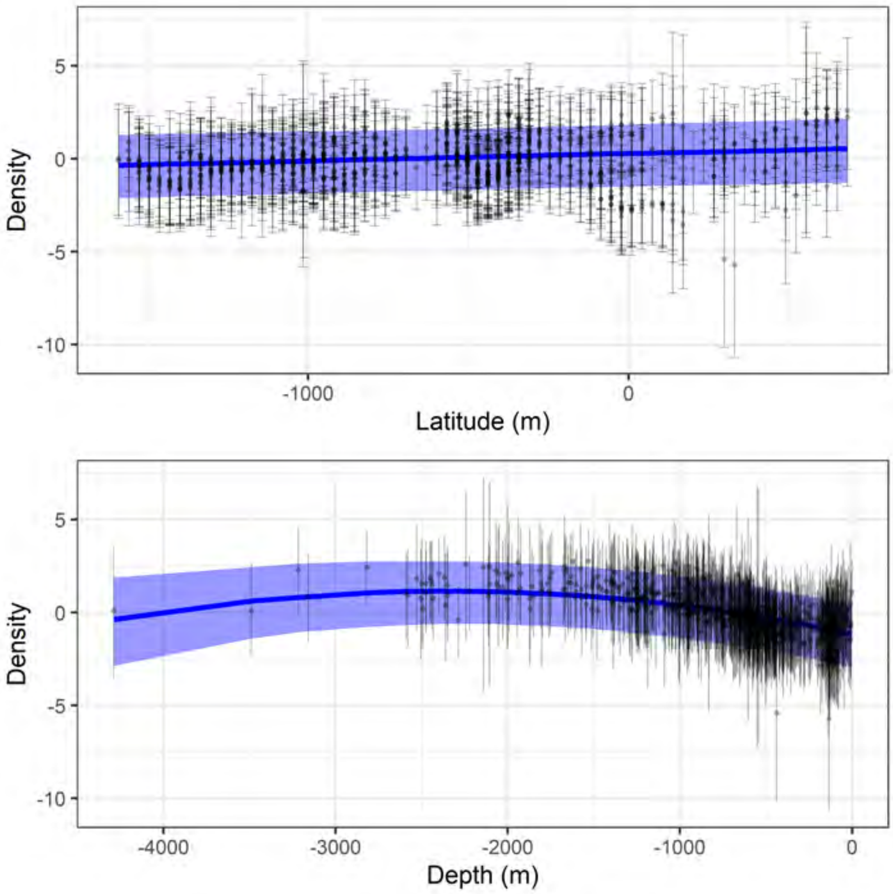


Figure S61: Estimated relationship between biomass density per grid cell and environmental covariates for morid cods. Points and error bars show the median and 90% credibility intervals per cell. The blue ribbon shows the estimated marginal relationship.

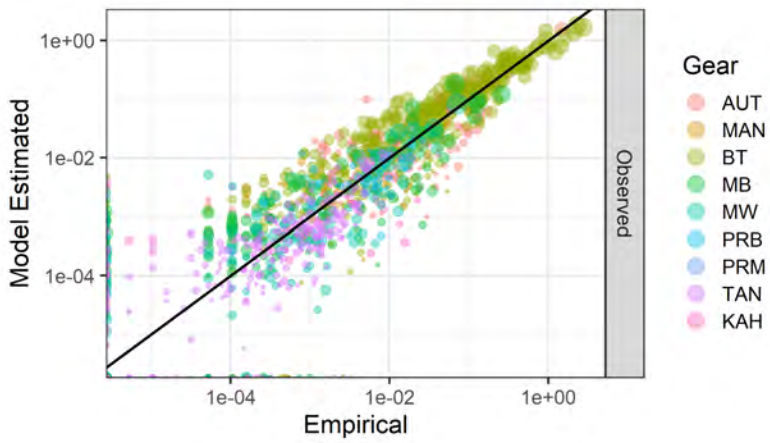


Figure S62: Fit of model to empirical observer catches. Total catches are summed per grid cell and gear type for morid cods. Model estimates are the median of the posterior predicted distribution. The size of the point is representative of the number of observed events. Catches are shown in tonnes on a log10 scale.

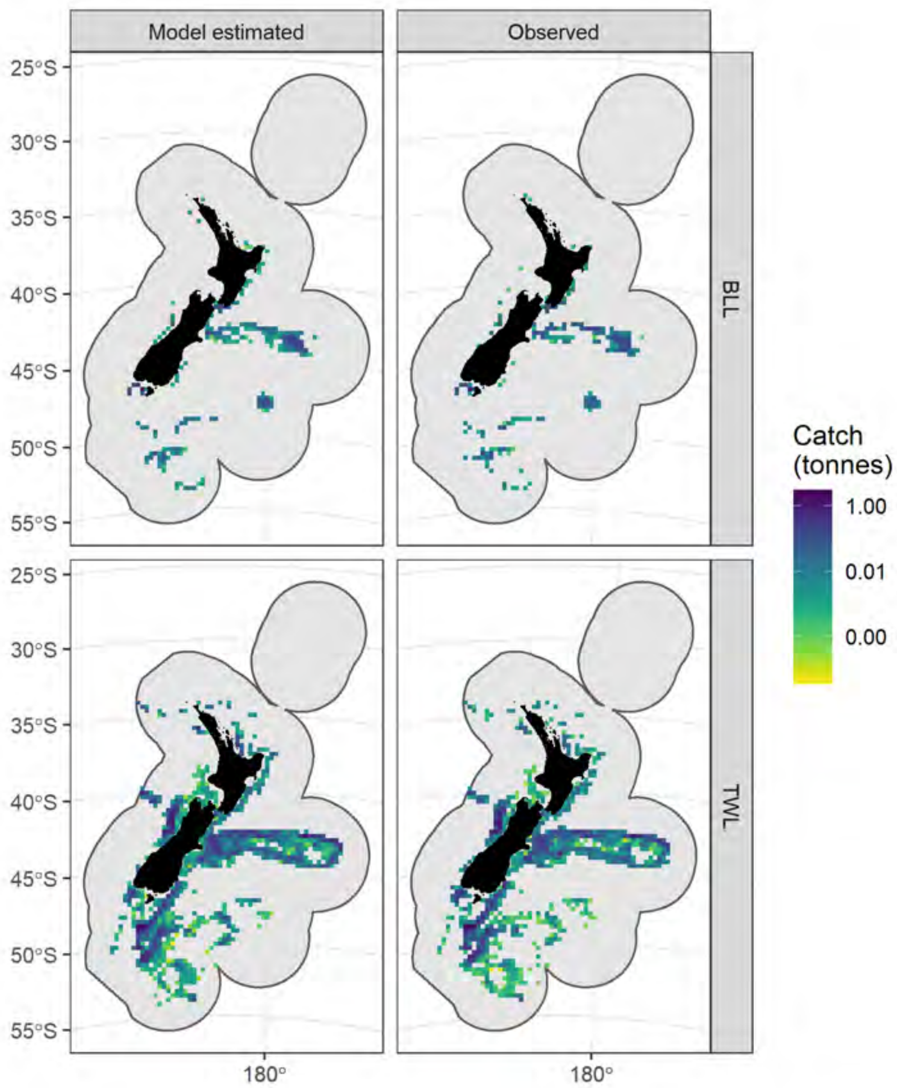


Figure S63: Spatial fit of model to empirical observer catches by grid cell and method for morid cods. Average annual catches were calculated as the sum across gear types per cell and method. Posterior median values are shown, with catches in tonnes on a log10 scale.

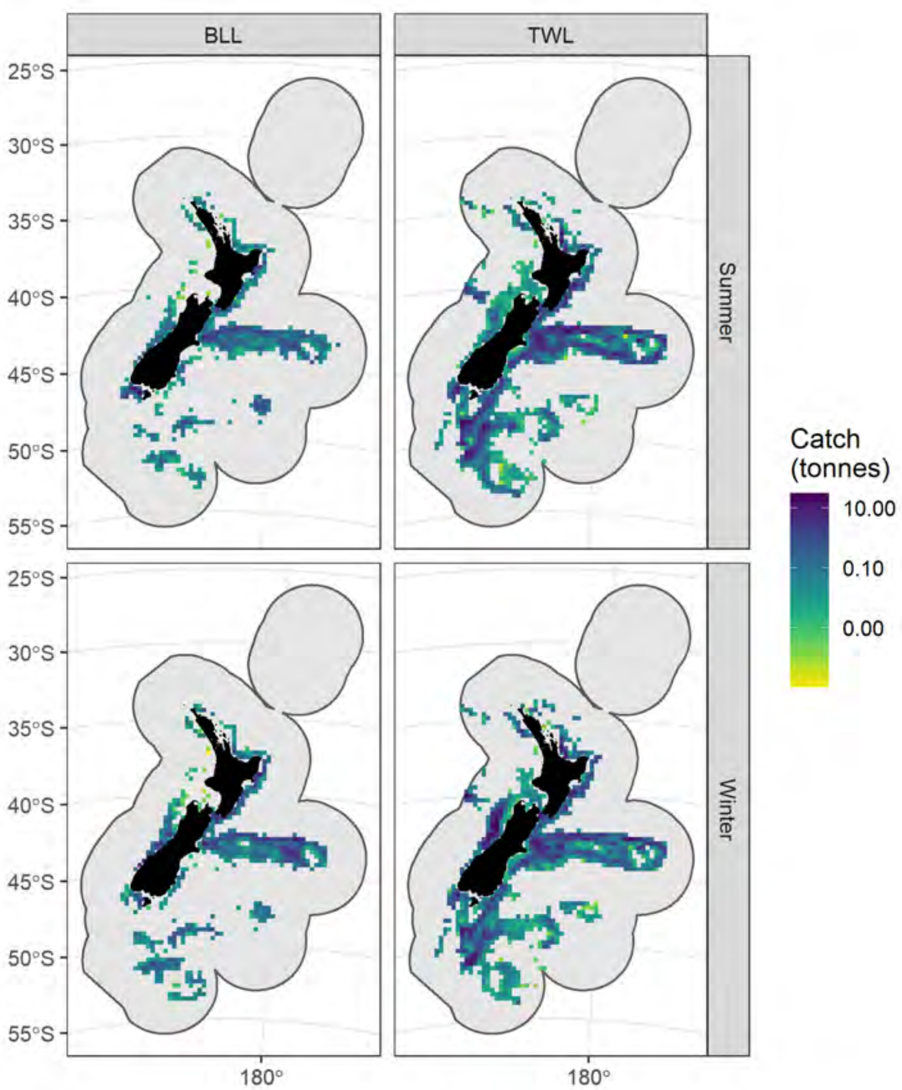


Figure S64: Posterior prediction of the total catches by grid cell, method and season for morid cods. Average annual catches per season were calculated as the sum across gear types per cell and method. Posterior median values are shown, with catches in tonnes on a log10 scale.

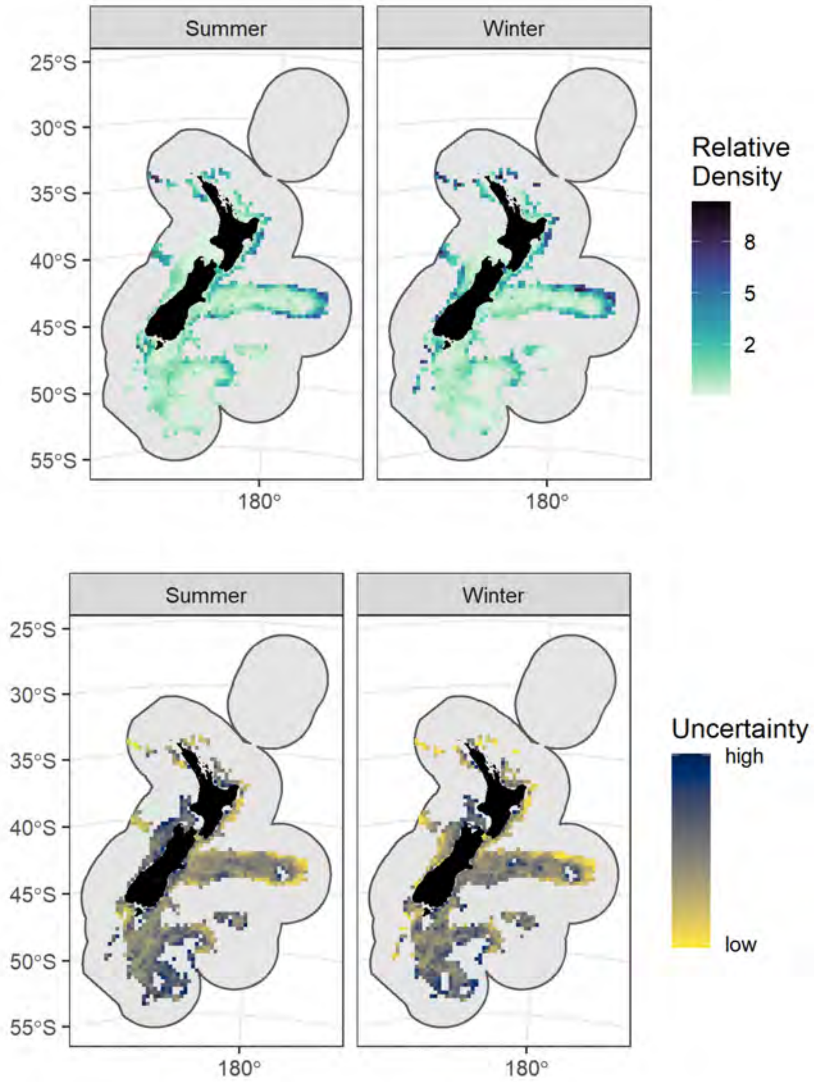


Figure S65: Posterior prediction of the relative density per grid cell and season for morid cods. Posterior median values are shown on a natural scale in tonnes per square kilometre. Uncertainty is measured using the difference between the upper and lower 95% equal-tailed posterior density interval.

Table S20: Total predicted bycatch (tonnes) per method for morid cods. Posterior median values are given, with the 95% equal-tailed credibility intervals in brackets.

Fishing year	BLL	TWL	Total
2000/01	429 (356 - 536)	1 977 (1 831 - 2 240)	2 408 (2 238 - 2 700)
2001/02	479 (382 - 661)	2 103 (1 962 - 2 759)	2 592 (2 400 - 3 287)
2002/03	216 (177 - 272)	2 013 (1 872 - 3 493)	2 236 (2 079 - 3 687)
2003/04	364 (290 - 902)	1 862 (1 746 - 2 007)	2 234 (2 086 - 2 783)
2004/05	326 (262 - 423)	1 673 (1 557 - 1 817)	2 004 (1 872 - 2 178)
2005/06	247 (203 - 312)	1 485 (1 389 - 1 657)	1 737 (1 625 - 1 932)
2006/07	283 (230 - 364)	1 350 (1 258 - 1 469)	1 637 (1 530 - 1 786)
2007/08	361 (289 - 470)	1 484 (1 377 - 1 620)	1 851 (1 710 - 2 015)
2008/09	355 (285 - 570)	1 494 (1 390 - 1 623)	1 856 (1 713 - 2 097)
2009/10	379 (300 - 556)	1 535 (1 428 - 1 679)	1 923 (1 762 - 2 166)
2010/11	407 (324 - 670)	1 424 (1 328 - 1 688)	1 836 (1 694 - 2 435)
2011/12	358 (284 - 505)	1 296 (1 201 - 1 394)	1 654 (1 538 - 1 851)
2012/13	323 (250 - 633)	1 255 (1 163 - 1 383)	1 589 (1 459 - 1 961)
2013/14	615 (464 - 907)	1 492 (1 380 - 1 628)	2 111 (1 921 - 2 408)
2014/15	456 (347 - 731)	1 608 (1 483 - 1 786)	2 078 (1 902 - 2 412)
2015/16	477 (379 - 945)	1 604 (1 487 - 1 778)	2 095 (1 922 - 2 697)
2016/17	474 (367 - 771)	1 802 (1 667 - 1 959)	2 281 (2 099 - 2 609)
2017/18	424 (332 - 712)	1 780 (1 645 - 4 712)	2 215 (2 039 - 5 118)
2018/19	433 (340 - 632)	1 495 (1 389 - 1 636)	1 935 (1 785 - 2 189)

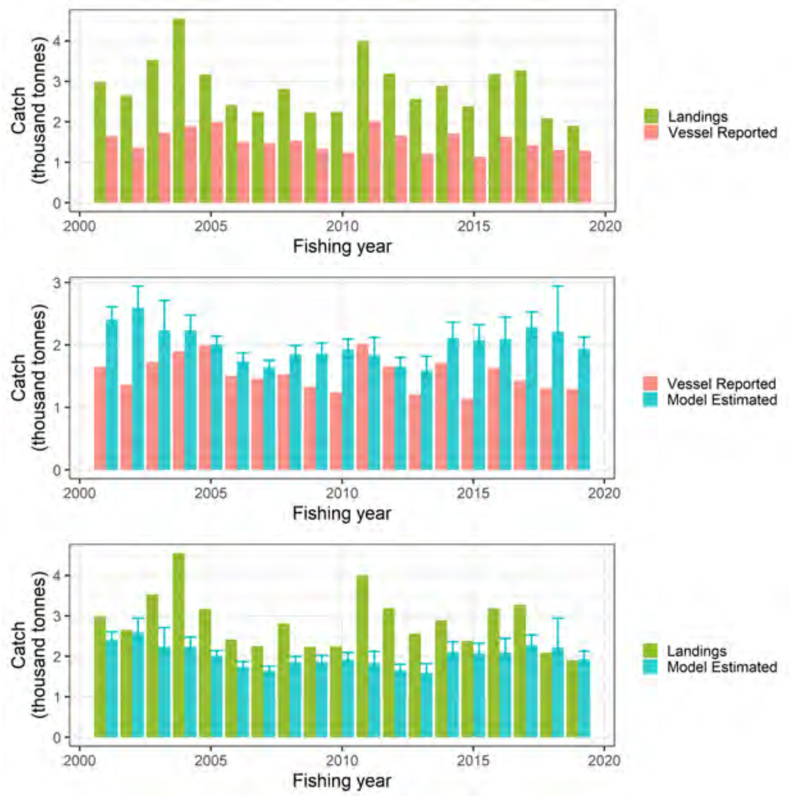


Figure S66: Relationships between landings, vessel reported catches and model estimated catches for morid cods.

S2.7 Redbait (*Emmelichthys nitidus*)

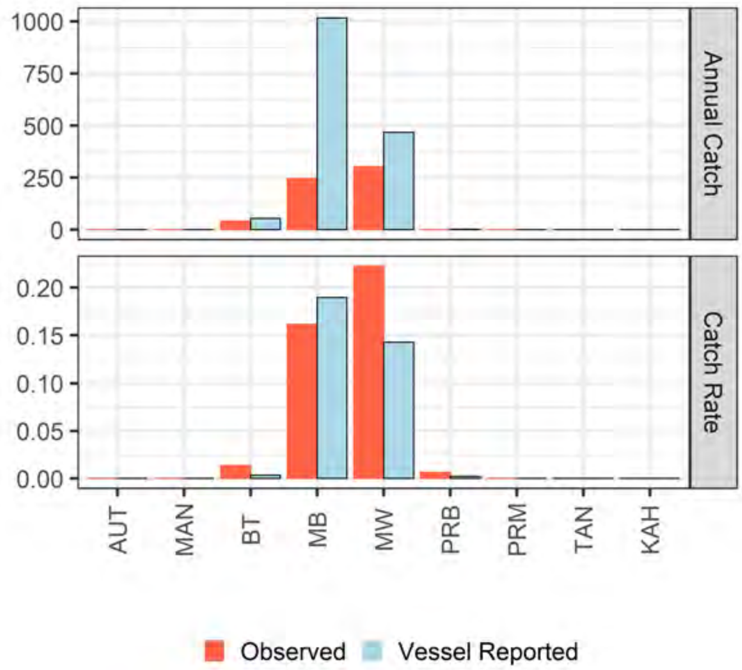


Figure S67: Empirical catch and catch rate data per gear type for redbait. Annual catch is given in tonnes as an average across years. The catch rate is an average calculated as the sum of the observed catch in kilograms (i.e., $\sum X_i$) over the sum of the effort count (number of fishing events). Effort was calculated as a count to allow comparability between methods. There are no vessel reported catches for TAN and KAH surveys.

Table S21: Summary data for redbait across 297 grid cells, removing 232 851 commercial events that were outside the selected cells. The total landings associated with retained commercial effort equal 48 795 tonnes. Catch is in units of tonnes, effort in the number of fishing events. "Obs." is observed; "Com." is commercial.

Method	Gear	Obs. catch	Obs. effort	Com. catch	Com. effort
BLL	AUT	0	4 498	0	29 415
BLL	MAN	0	517	0	12 116
TWL	BT	237	59 810	1 032	295 014
TWL	MB	2 132	28 818	19 334	102 569
TWL	MW	2 852	25 784	8 893	62 465
TWL	PRB	4	690	5	2 417
TWL	PRM	0	372	0	1 909
TWL	TAN	0	2 008		
TWL	KAH	0	715		
Total		5 226	123 212	29 264	505 905

Table S22: Model selection summary statistics for redbait. Model 6 was selected for prediction of the catches.

Model	$\mathbb{L}[X]$	MPE	L^2	WAIC	$\hat{R}(\alpha)$	$\hat{R}(\gamma)$	$\hat{R}(\pi)$	DRE
1	-0.053	0.059	0.074	6993.029	2.289	3.179	3.081	0.916
2	-0.056	0.059	0.076	7047.316	2.260	2.241	2.215	0.872
3	-0.022	0.059	0.075	7131.426	1.008	1.004	1.004	2.110
4	-0.022	0.059	0.076	7134.160	1.018	1.012	1.015	2.087
5	-0.023	0.059	0.076	7126.369	1.005	1.010	1.011	2.025
6	-0.022	0.059	0.076	7135.115	1.006	1.004	1.006	2.031

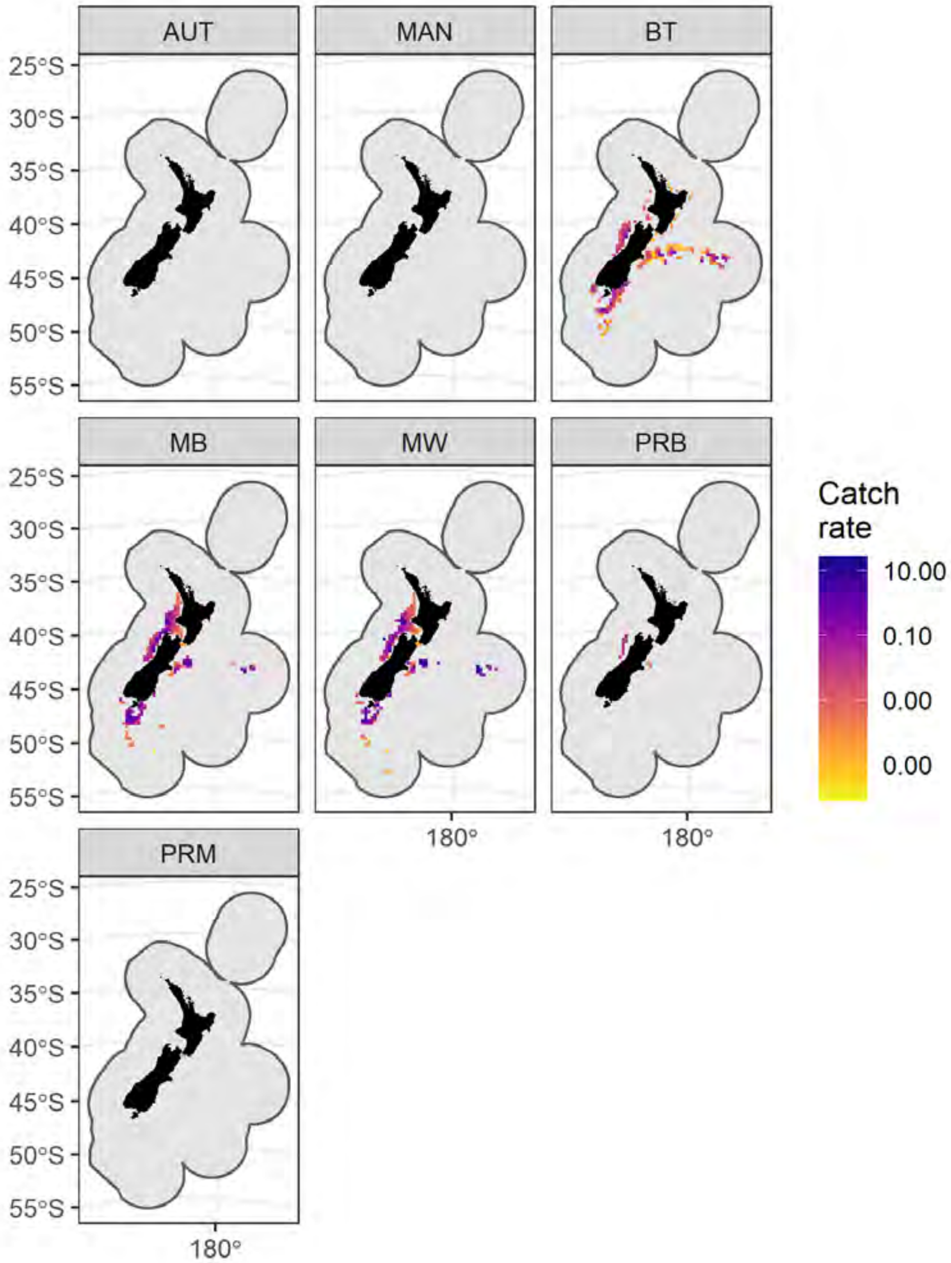


Figure S68: Observer catch rate data for redbait on a log10-scale. The catch rate is an average calculated as the sum of the observed catch $\sum X_i$ over the number of observed fishing events per grid cell and gear type. Effort was calculated as a count to allow comparability between methods.

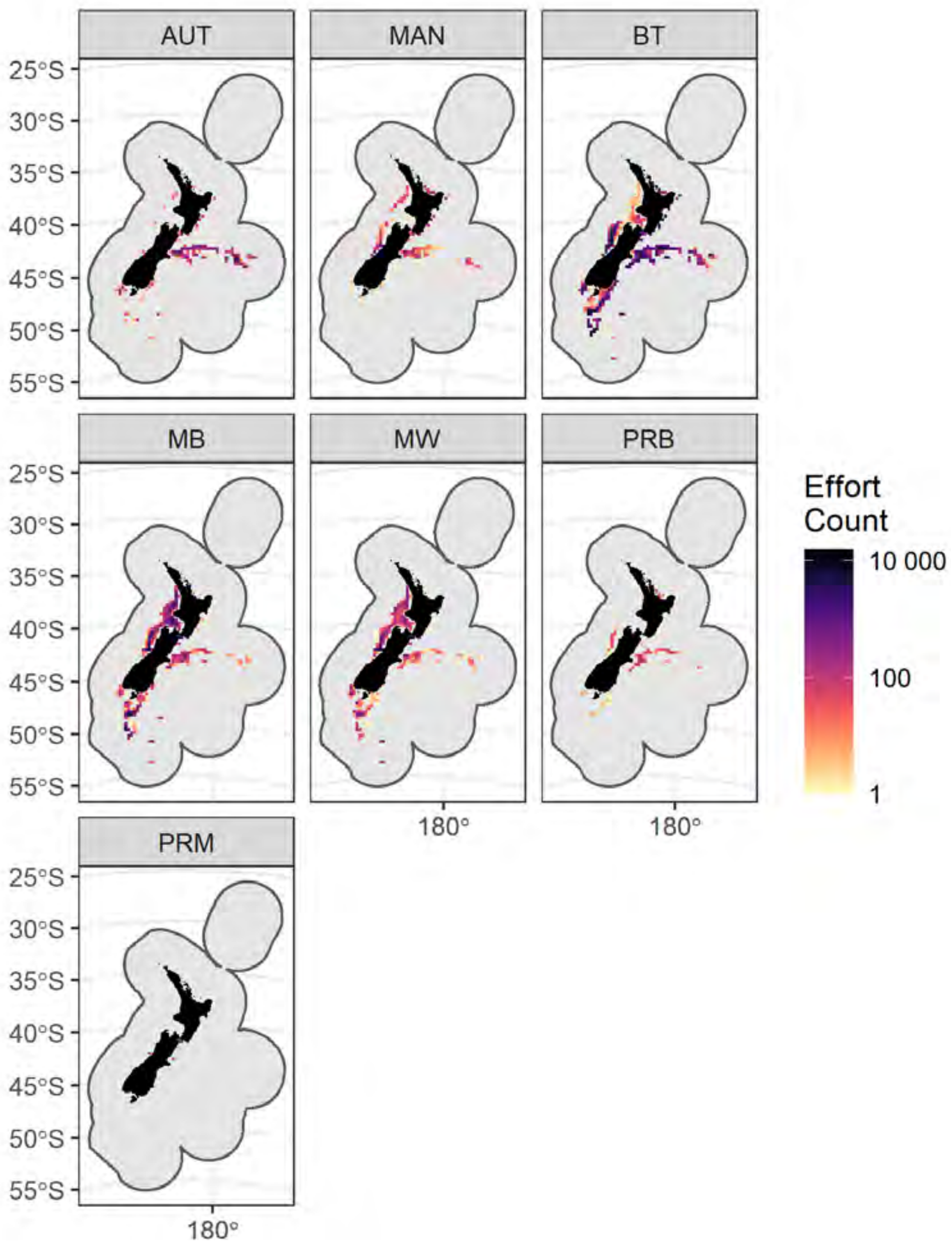


Figure S69: Commercial fishing effort (number of events) for redbait summed across all years and presented on a log10-scale per grid cell and gear type. Effort was calculated as a count to allow comparability between methods.

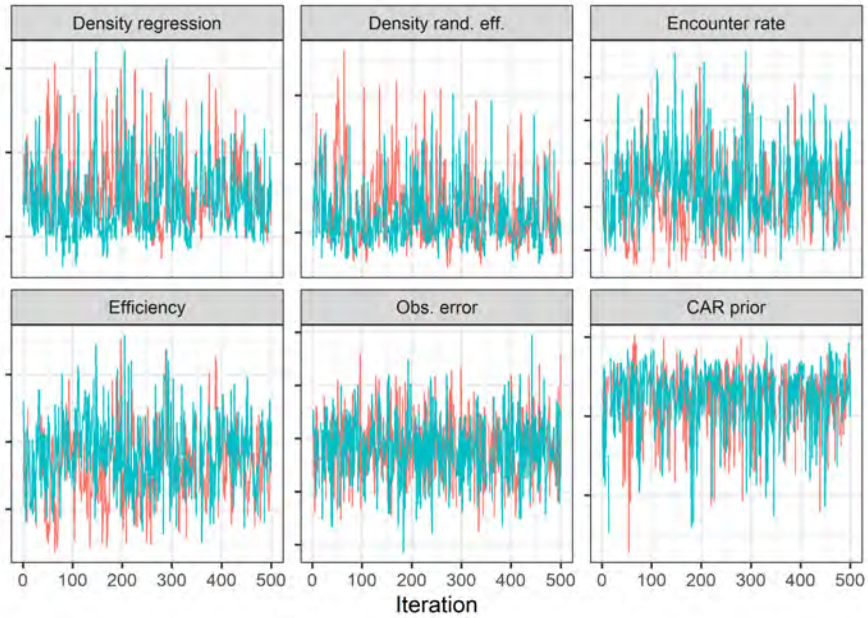


Figure S70: Posterior density sample traces for redbait, for the regression coefficients $||\boldsymbol{\alpha}||$, random effects $||\boldsymbol{\phi}||$, encounter rate $||\boldsymbol{\gamma}||$, efficiency $||\boldsymbol{\pi}||$, observation error $||\boldsymbol{\sigma}||$ and conditional autoregressive prior parameters $||\tau,\rho||$. Colours represent independent sample chains.

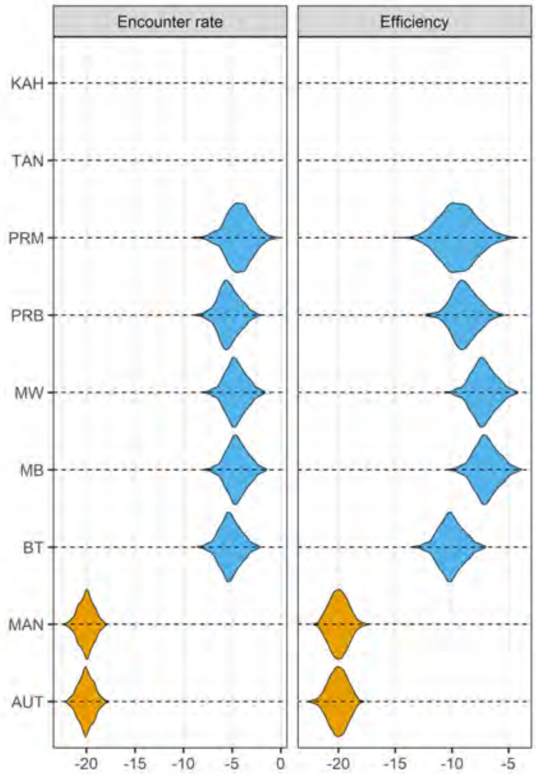


Figure S71: Violin plots of the posterior density for the encounter rate (γ_j) and the efficiency (π_j) per gear type for redbait. Catchability terms for bottom longline gear types (see Table S2) are presented in a different colour as they are not comparable to the trawl gear types because they are dependent on different measures of effort (i.e., thousand hooks and distance, respectively).

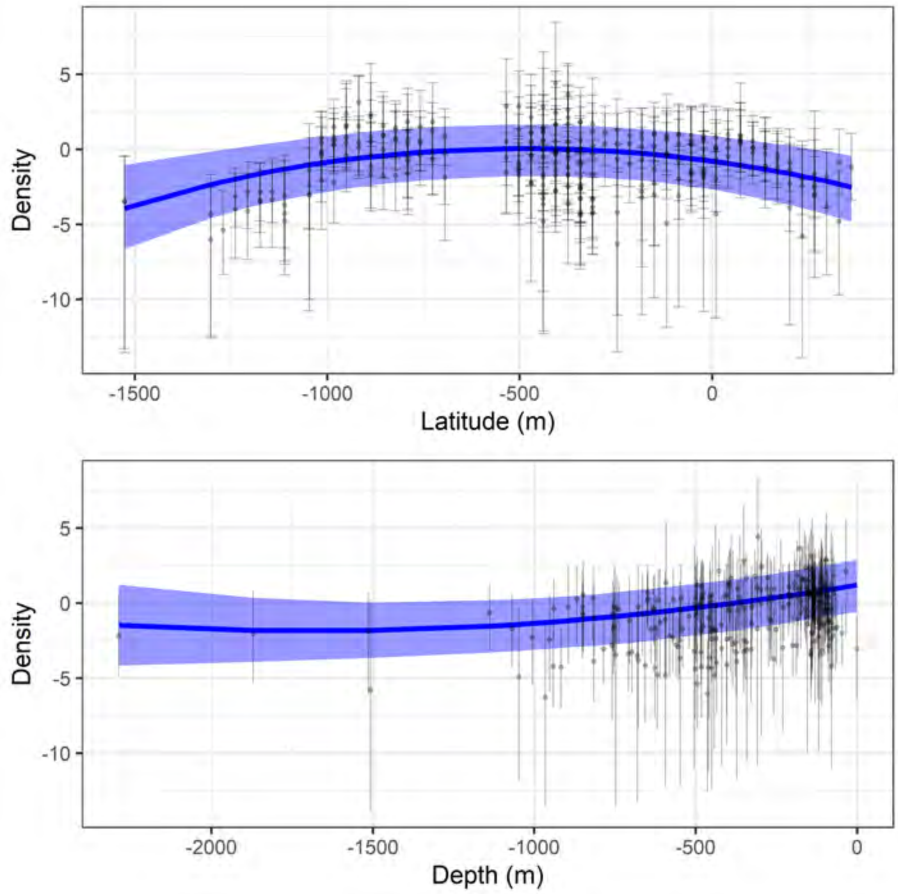


Figure S72: Estimated relationship between biomass density per grid cell and environmental covariates for redbait. Points and error bars show the median and 90% credibility intervals per cell. The blue ribbon shows the estimated marginal relationship.

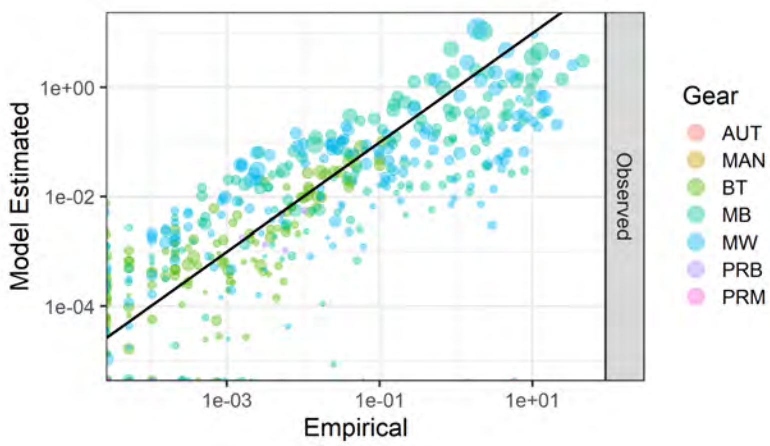


Figure S73: Fit of model to empirical observer catches. Total catches are summed per grid cell and gear type for redbait. Model estimates are the median of the posterior predicted distribution. The size of the point is representative of the number of observed events. Catches are shown in tonnes on a log10 scale.

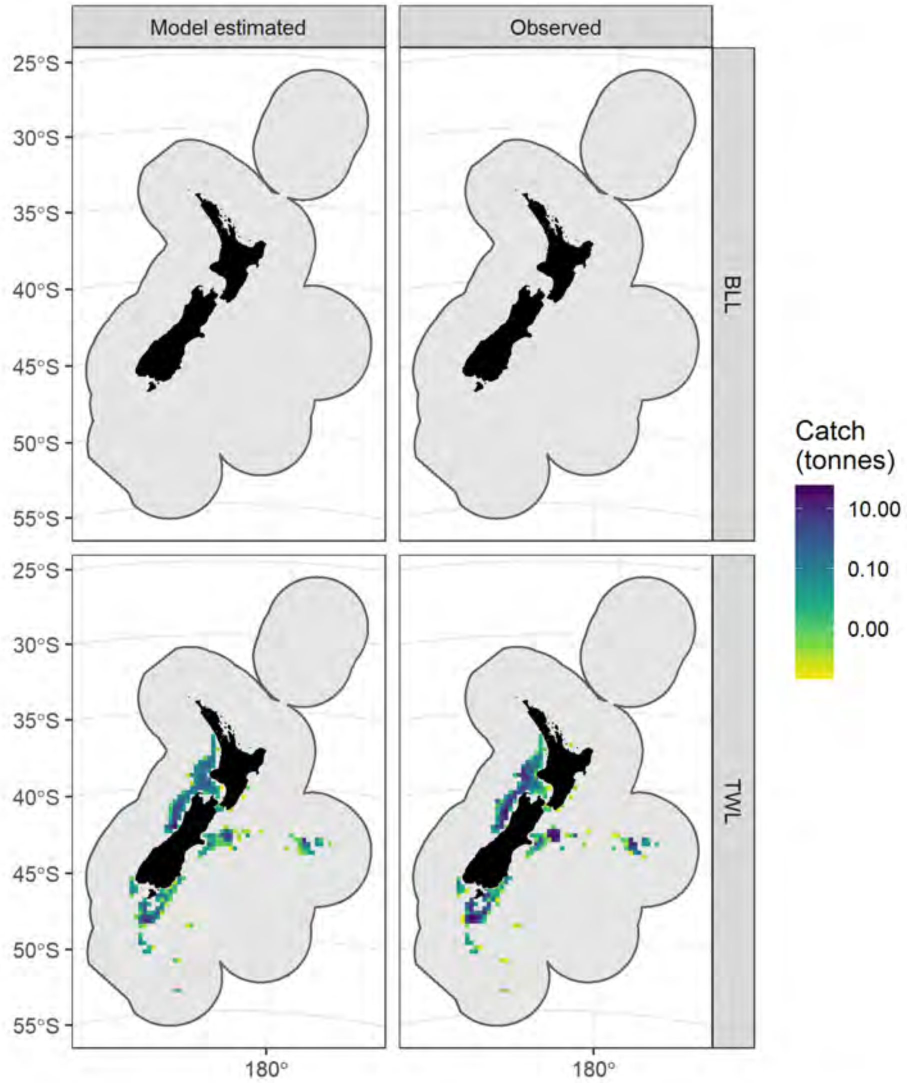


Figure S74: Spatial fit of model to empirical observer catches by grid cell and method for redbait. Average annual catches were calculated as the sum across gear types per cell and method. Posterior median values are shown, with catches in tonnes on a log10 scale.

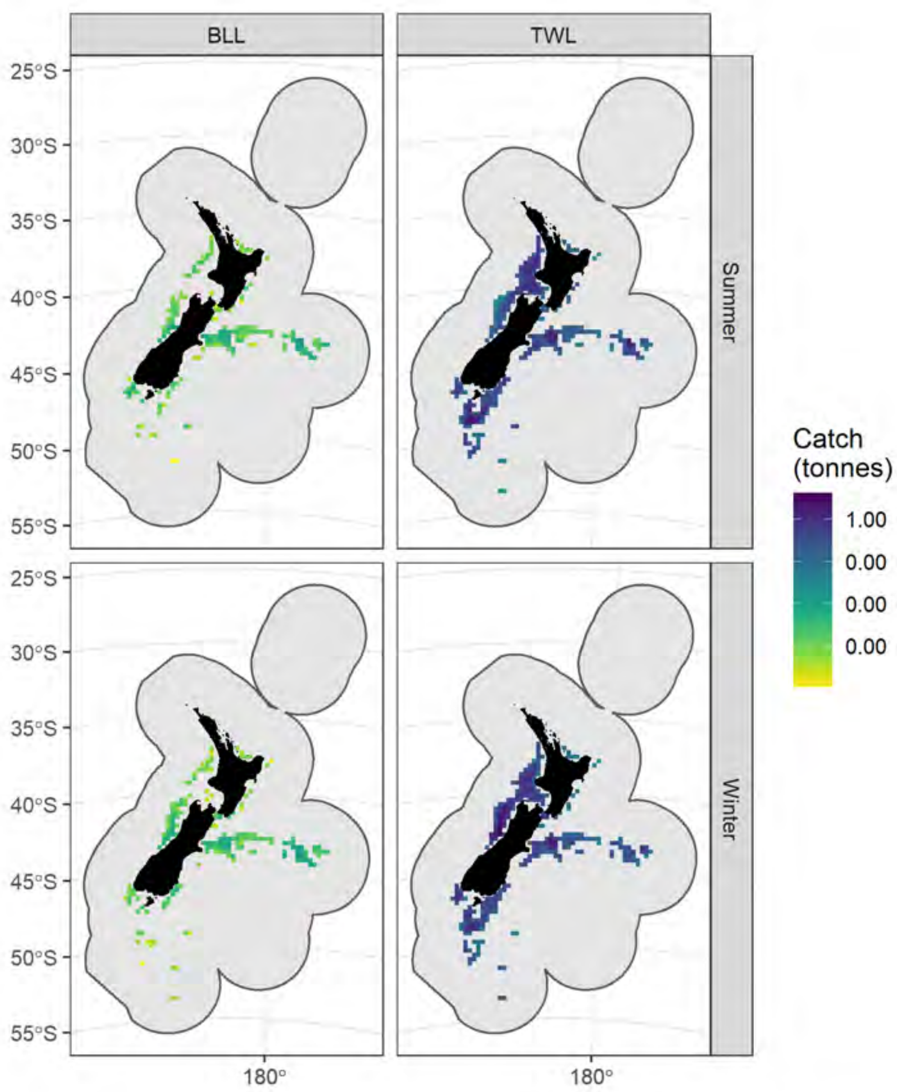
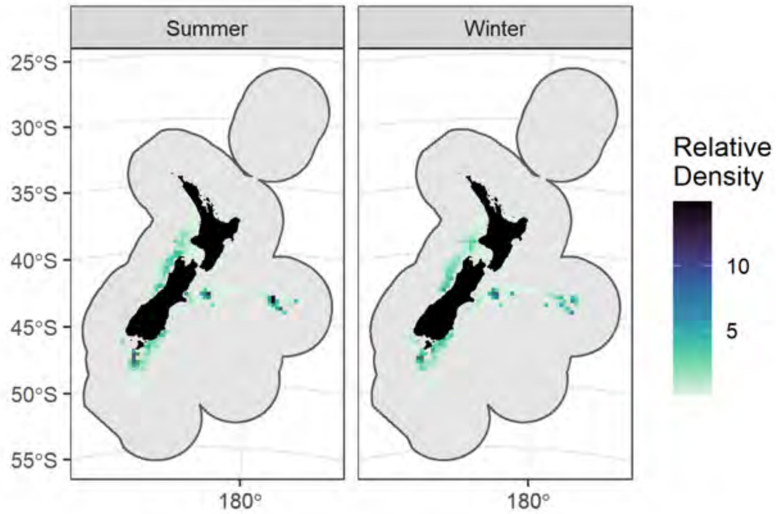


Figure S75: Posterior prediction of the total catches by grid cell, method and season for redbait. Average annual catches per season were calculated as the sum across gear types per cell and method. Posterior median values are shown, with catches in tonnes on a log10 scale.



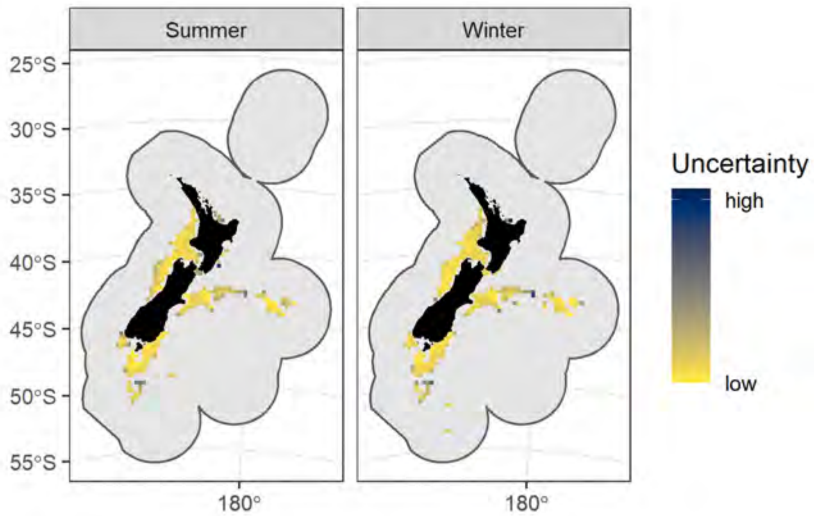


Figure S76: Posterior prediction of the relative density per grid cell and season for redbait. Posterior median values are shown on a natural scale in tonnes per square kilometre. Uncertainty is measured using the difference between the upper and lower 95% equal-tailed posterior density interval.

Table S23: Total predicted bycatch (tonnes) per method for redbait. Posterior median values are given, with the 95% equal-tailed credibility intervals in brackets.

Fishing year	BLL	TWL	Total
2000/01	0 (0 - 0)	588 (479 - 743)	588 (479 - 743)
2001/02	0 (0 - 0)	474 (381 - 608)	474 (381 - 608)
2002/03	0 (0 - 0)	547 (442 - 759)	547 (442 - 759)
2003/04	0 (0 - 0)	458 (367 - 599)	458 (367 - 599)
2004/05	0 (0 - 0)	326 (260 - 433)	326 (260 - 433)
2005/06	0 (0 - 0)	408 (303 - 718)	408 (303 - 718)
2006/07	0 (0 - 0)	266 (211 - 394)	266 (211 - 394)
2007/08	0 (0 - 0)	280 (209 - 401)	280 (209 - 401)
2008/09	0 (0 - 0)	211 (155 - 349)	211 (155 - 349)
2009/10	0 (0 - 0)	196 (145 - 314)	196 (145 - 314)
2010/11	0 (0 - 0)	180 (138 - 261)	180 (138 - 261)
2011/12	0 (0 - 0)	238 (181 - 350)	238 (181 - 350)
2012/13	0 (0 - 0)	277 (203 - 421)	277 (203 - 421)
2013/14	0 (0 - 0)	337 (251 - 588)	337 (251 - 588)
2014/15	0 (0 - 0)	349 (260 - 568)	349 (260 - 568)
2015/16	0 (0 - 0)	286 (223 - 412)	286 (223 - 412)
2016/17	0 (0 - 0)	355 (242 - 1 837)	355 (242 - 1 837)
2017/18	0 (0 - 0)	365 (240 - 2 020)	365 (240 - 2 020)
2018/19	0 (0 - 0)	510 (375 - 987)	510 (375 - 987)

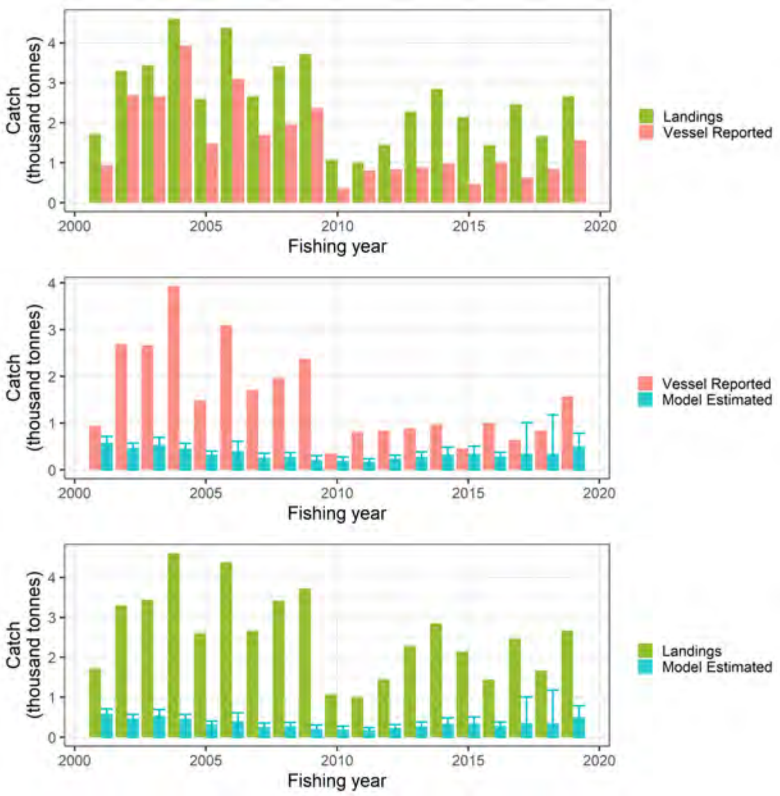


Figure S77: Relationships between landings, vessel reported catches and model estimated catches for redbait.

S2.8 Common warehou (*Seriolella brama*)

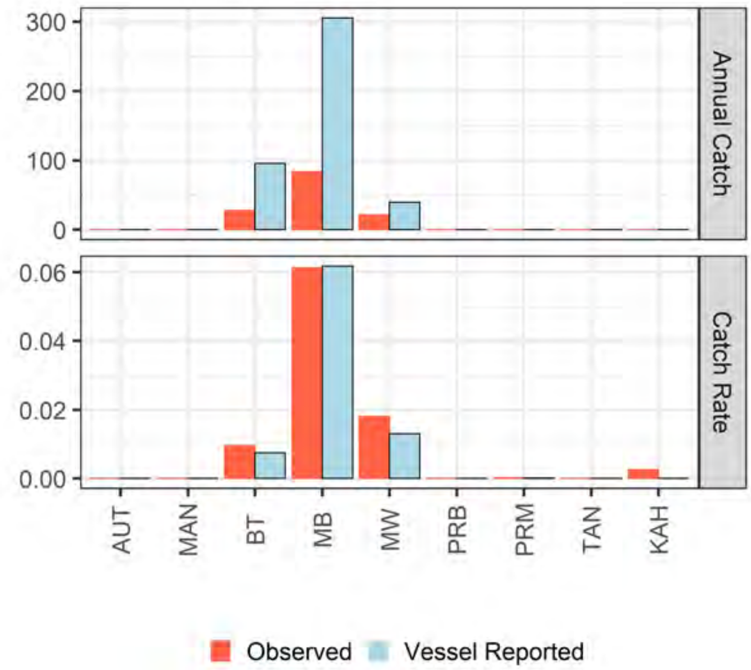


Figure S78: Empirical catch and catch rate data per gear type for common warehou. Annual catch is given in tonnes as an average across years. The catch rate is an average calculated as the sum of the observed catch in kilograms (i.e., $\sum X_i$) over the sum of the effort count (number of fishing events). Effort was calculated as a count to allow comparability between methods. There are no vessel reported catches for TAN and KAH surveys.

Table S24: Summary data for common warehou across 654 grid cells, removing 74 776 commercial events that were outside the selected cells. The total landings associated with retained commercial effort equal 251 024 tonnes. Catch is in units of tonnes, effort in the number of fishing events. "Obs." is observed; "Com." is commercial.

Method	Gear	Obs. catch	Obs. effort	Com. catch	Com. effort
BLL	AUT	0	7 733	1	47 527
BLL	MAN	0	636	1	16 460
TWL	BT	38 448	79 014	156 652	413 403
TWL	MB	3 523	31 591	24 835	112 572
TWL	MW	1 304	29 910	3 983	68 946
TWL	PRB	411	827	1 149	3 011
TWL	PRM	12	402	46	2 061
TWL	TAN	78	3 784		
TWL	KAH	8	1 357		
Total		43 785	155 254	186 666	663 980

Table S25: Model selection summary statistics for common warehou. Model 4 was selected for prediction of the catches.

Model	$\mathbb{L}[X]$	MPE	L^2	WAIC	$\hat{R}(\alpha)$	$\hat{R}(\gamma)$	$\hat{R}(\pi)$	DRE
1	-0.012	0.032	0.068	-838.685	0.998	1.003	0.999	2.025
2	-0.012	0.031	0.068	-812.336	1.008	0.999	1.001	2.226
3	-0.012	0.031	0.067	-814.994	1.006	1.004	1.005	1.954
4	-0.012	0.031	0.072	-811.652	1.019	1.007	1.010	1.880
5	-0.012	0.031	0.065	-814.965	0.999	0.998	0.998	1.894
6	-0.012	0.031	0.066	-811.667	1.022	1.002	0.999	1.815

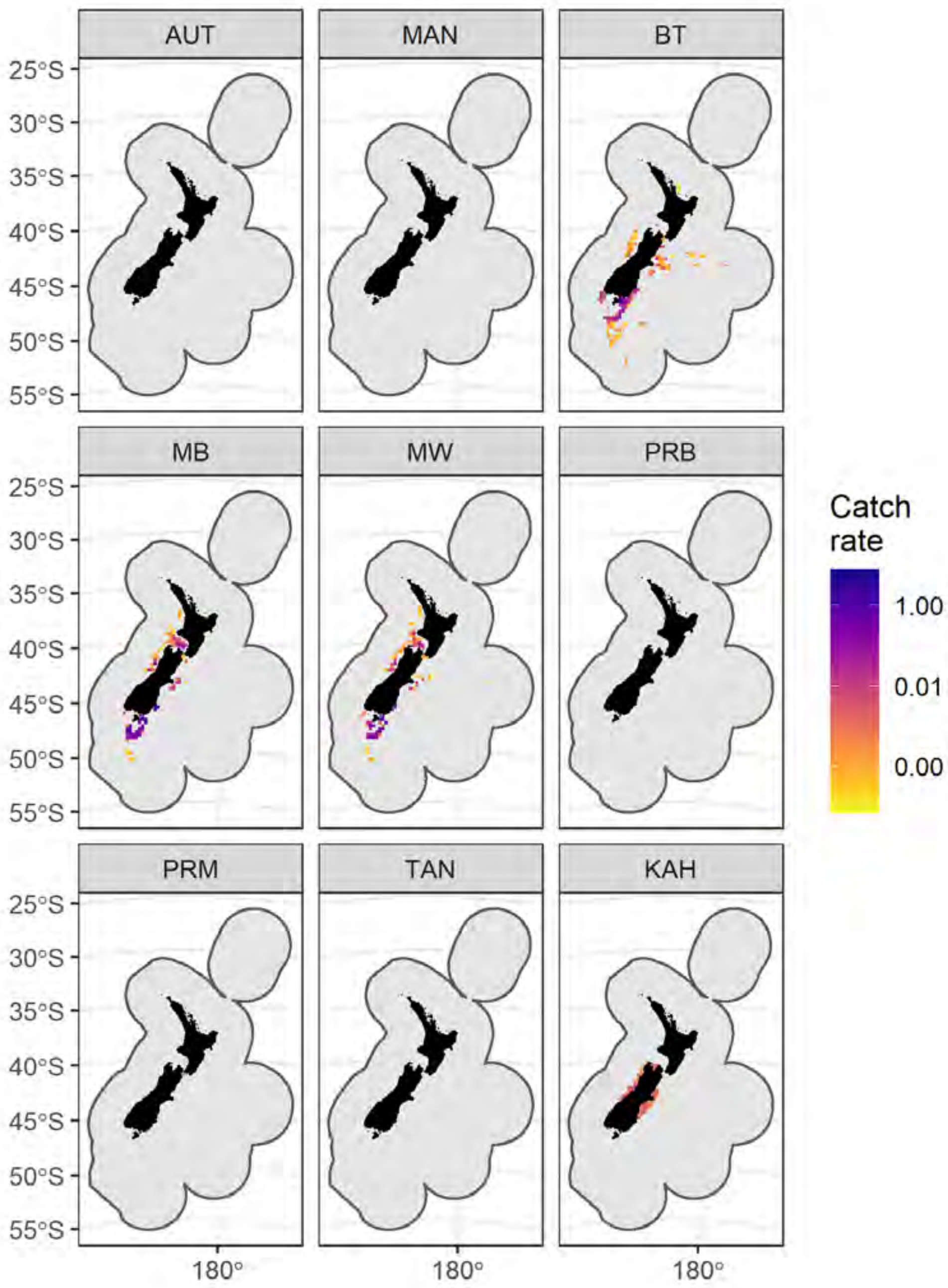


Figure S79: Observer catch rate data for common warehou on a log10-scale. The catch rate is an average calculated as the sum of the observed catch $\sum X_i$ over the number of observed fishing events per grid cell and gear type. Effort was calculated as a count to allow comparability between methods.

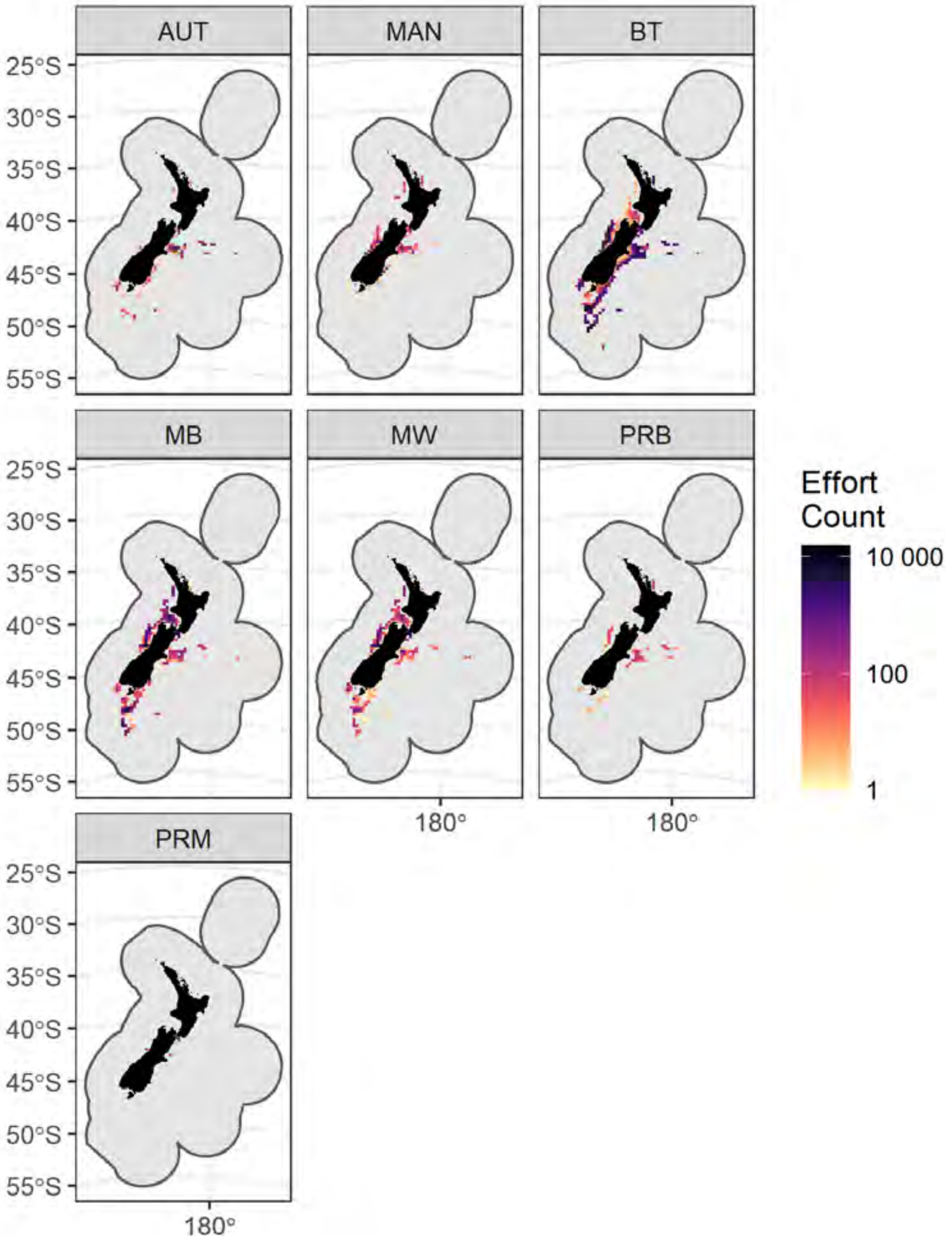


Figure S80: Commercial fishing effort (number of events) for common warehou summed across all years and presented on a log10-scale per grid cell and gear type. Effort was calculated as a count to allow comparability between methods.

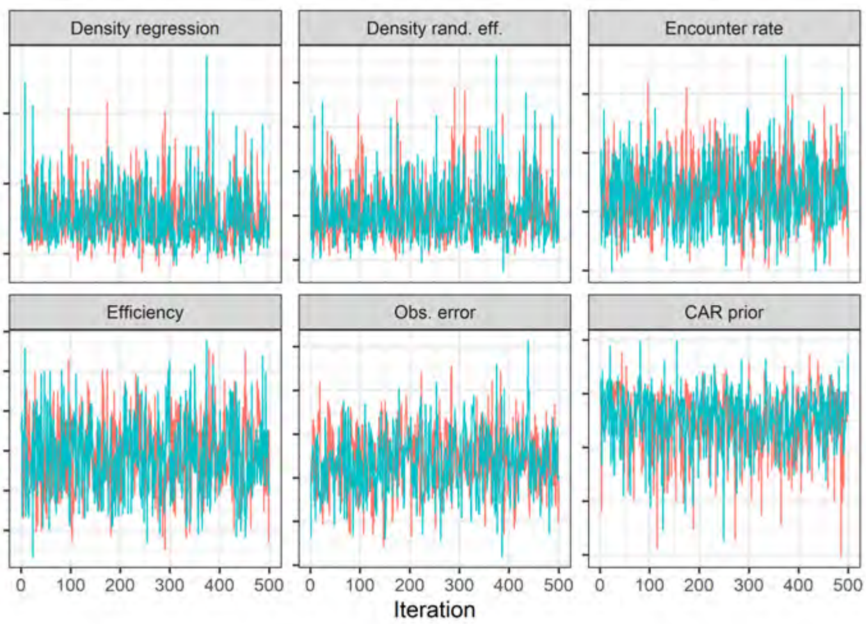


Figure S81: Posterior density sample traces for common warehou, for the regression coefficients $||\boldsymbol{\alpha}||$, random effects $||\boldsymbol{\phi}||$, encounter rate $||\boldsymbol{\gamma}||$, efficiency $||\boldsymbol{\pi}||$, observation error $||\boldsymbol{\sigma}||$ and conditional autoregressive prior parameters $||\tau, \rho||$. Colours represent independent sample chains.

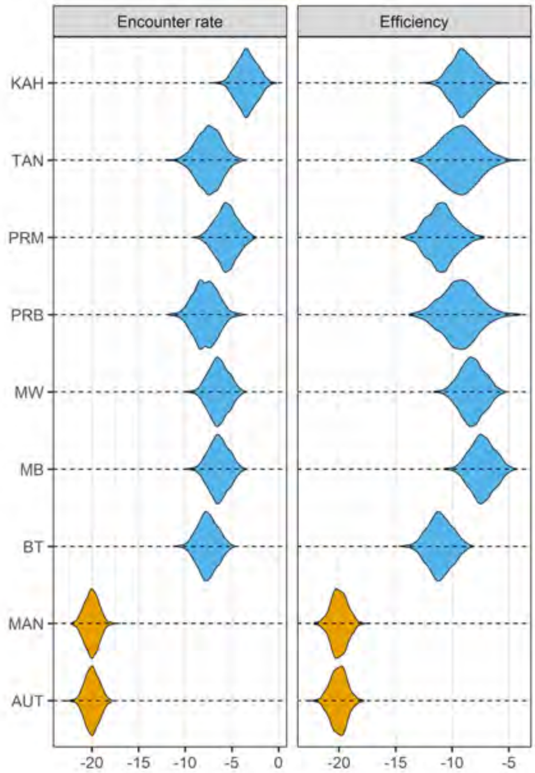


Figure S82: Violin plots of the posterior density for the encounter rate (γ_j) and the efficiency (π_j) per gear type for common warehou. Catchability terms for bottom longline gear types (see Table S2) are presented in a different colour as they are not comparable to the trawl gear types because they are dependent on different measures of effort (i.e., thousand hooks and distance, respectively).

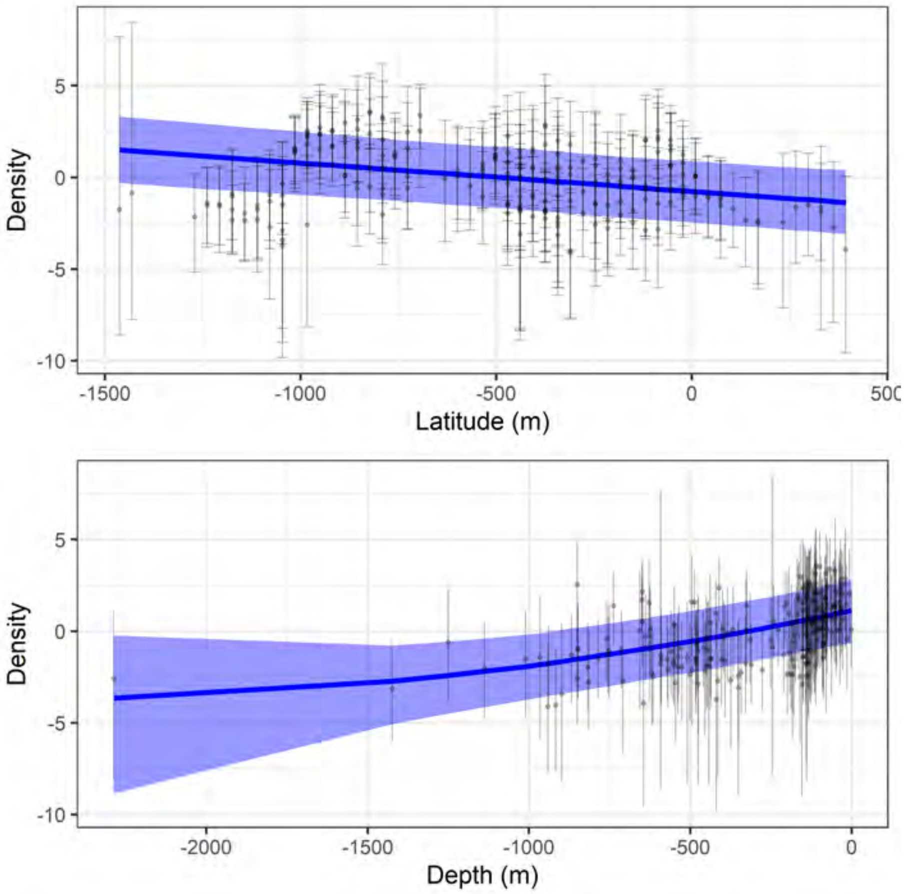


Figure S83: Estimated relationship between biomass density per grid cell and environmental covariates for common warehou. Points and error bars show the median and 90% credibility intervals per cell. The blue ribbon shows the estimated marginal relationship.

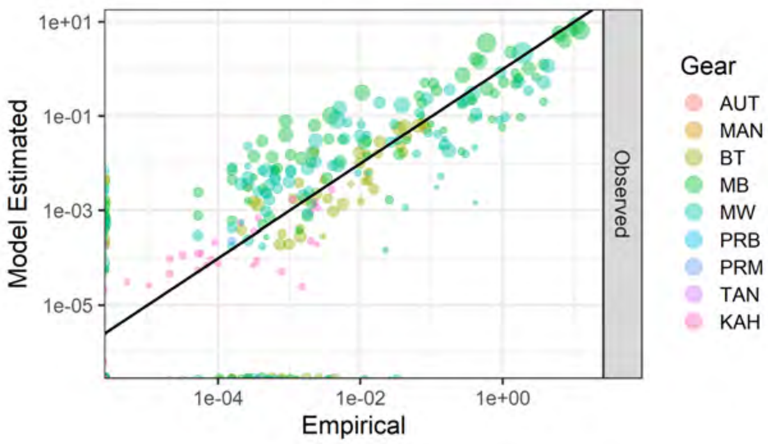


Figure S84: Fit of model to empirical observer catches. Total catches are summed per grid cell and gear type for common warehou. Model estimates are the median of the posterior predicted distribution. The size of the point is representative of the number of observed events. Catches are shown in tonnes on a log10 scale.

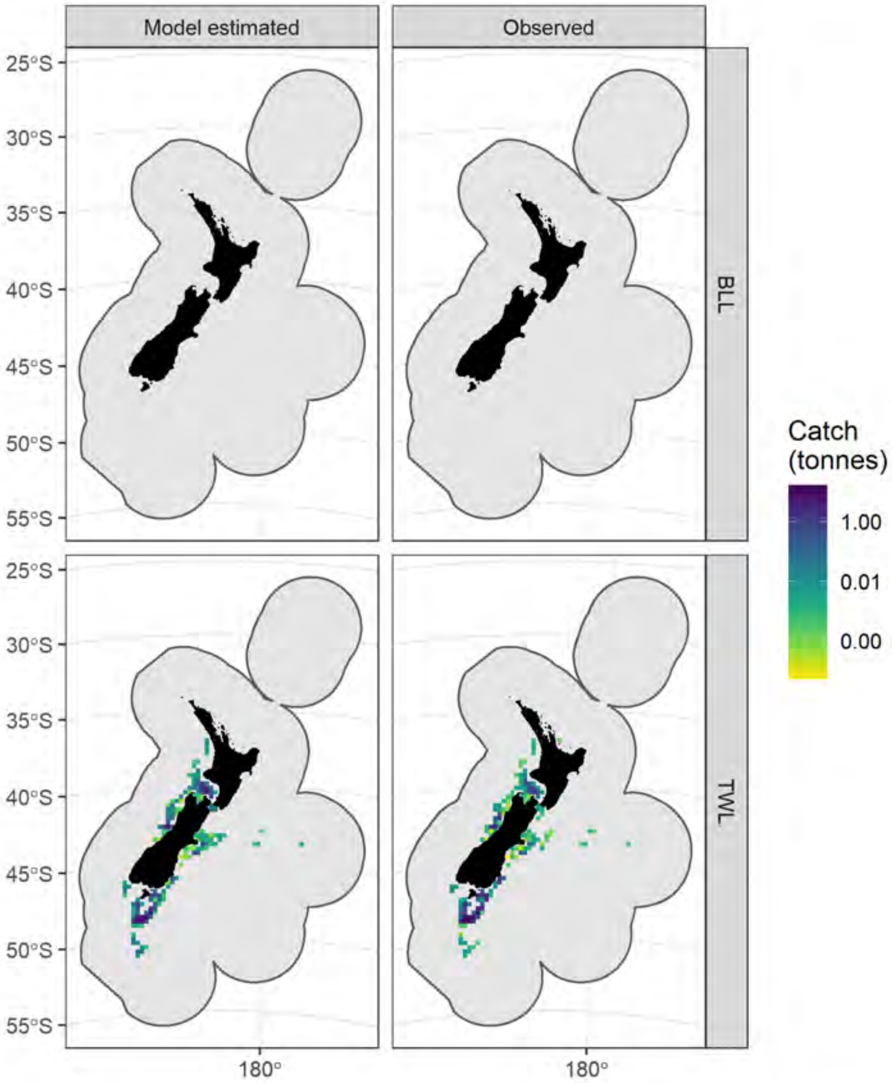


Figure S85: Spatial fit of model to empirical observer catches by grid cell and method for common warehou. Average annual catches were calculated as the sum across gear types per cell and method. Posterior median values are shown, with catches in tonnes on a log10 scale.

Table S26: Total predicted bycatch (tonnes) per method for common warehou. Posterior median values are given, with the 95% equal-tailed credibility intervals in brackets.

Fishing year	BLL	TWL	Total
2000/01	0 (0 - 0)	424 (309 - 730)	424 (309 - 730)
2001/02	0 (0 - 0)	342 (259 - 595)	342 (259 - 595)
2002/03	0 (0 - 0)	336 (245 - 659)	336 (245 - 659)
2003/04	0 (0 - 0)	343 (242 - 646)	343 (242 - 646)
2004/05	0 (0 - 0)	304 (230 - 471)	304 (230 - 471)
2005/06	0 (0 - 0)	283 (202 - 447)	283 (202 - 447)
2006/07	0 (0 - 0)	233 (165 - 414)	233 (165 - 414)
2007/08	0 (0 - 0)	244 (162 - 409)	244 (162 - 409)
2008/09	0 (0 - 0)	176 (118 - 297)	176 (118 - 297)
2009/10	0 (0 - 0)	157 (110 - 279)	157 (110 - 279)
2010/11	0 (0 - 0)	148 (103 - 256)	148 (103 - 256)
2011/12	0 (0 - 0)	200 (137 - 334)	200 (137 - 334)
2012/13	0 (0 - 0)	147 (101 - 268)	147 (101 - 268)
2013/14	0 (0 - 0)	146 (107 - 236)	146 (107 - 236)
2014/15	0 (0 - 0)	137 (98 - 244)	137 (98 - 244)
2015/16	0 (0 - 0)	128 (91 - 202)	128 (91 - 202)
2016/17	0 (0 - 0)	137 (94 - 296)	137 (94 - 296)
2017/18	0 (0 - 0)	215 (156 - 347)	215 (156 - 347)
2018/19	0 (0 - 0)	265 (181 - 473)	265 (181 - 473)

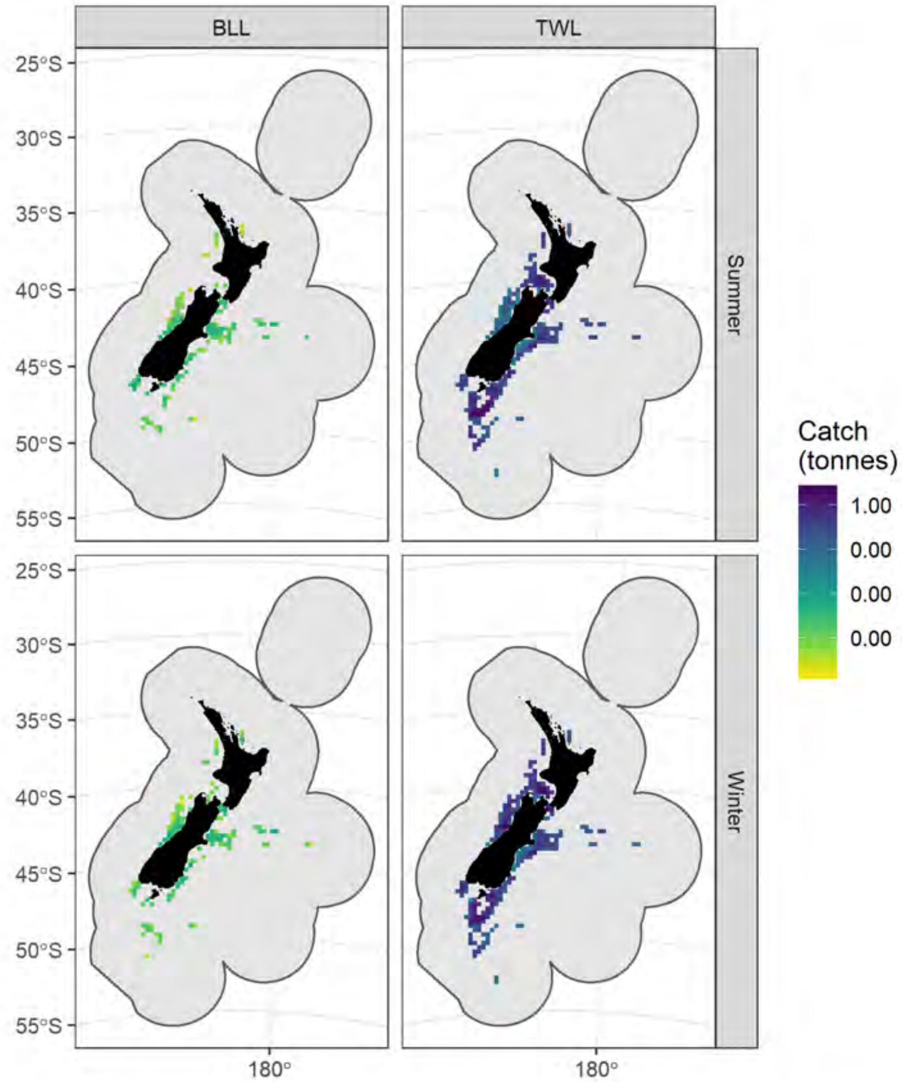


Figure S86: Posterior prediction of the total catches by grid cell, method and season for common warehou. Average annual catches per season were calculated as the sum across gear types per cell and method. Posterior median values are shown, with catches in tonnes on a log10 scale.

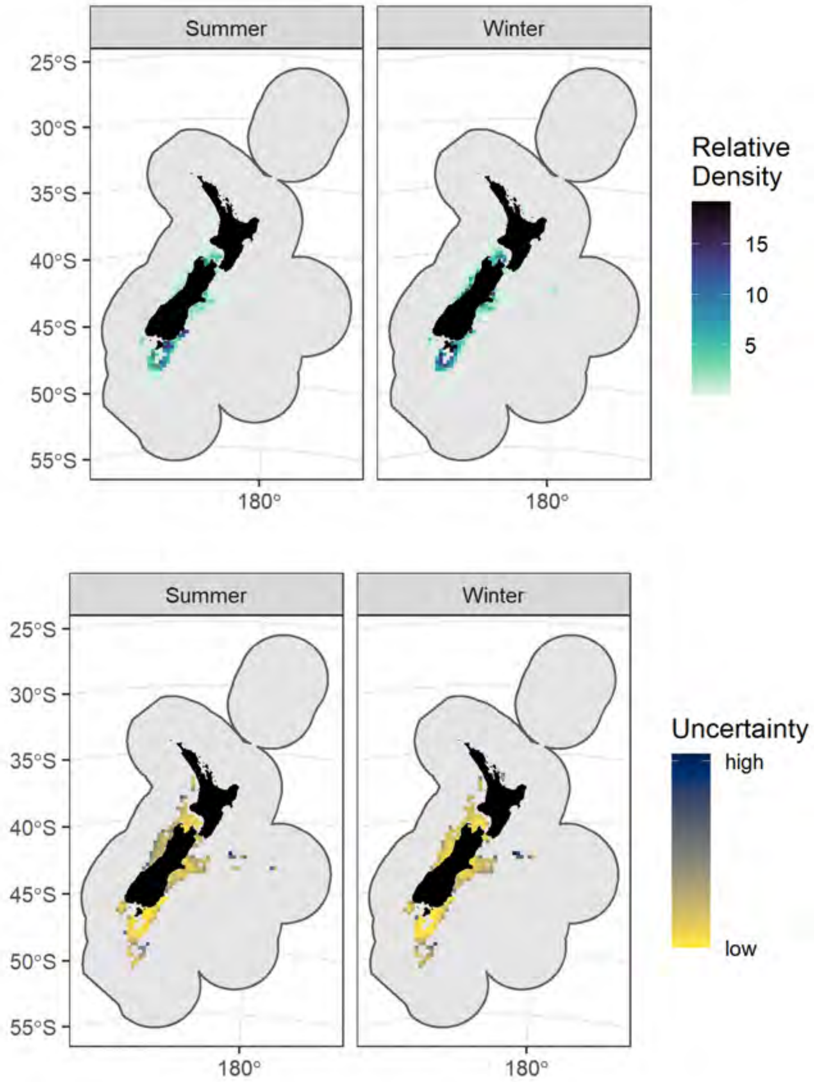


Figure S87: Posterior prediction of the relative density per grid cell and season for common warehou. Posterior median values are shown on a natural scale in tonnes per square kilometre. Uncertainty is measured using the difference between the upper and lower 95% equal-tailed posterior density interval.

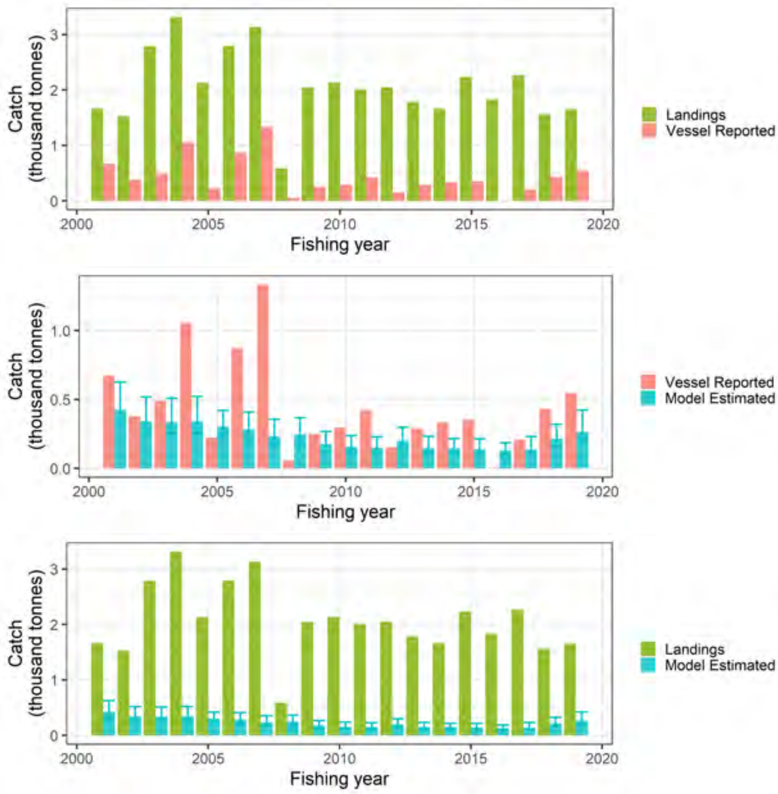


Figure S88: Relationships between landings, vessel reported catches and model estimated catches for common warehou.

S2.9 Smooth red swimming crab (*Nectocarcinus bennetti*)

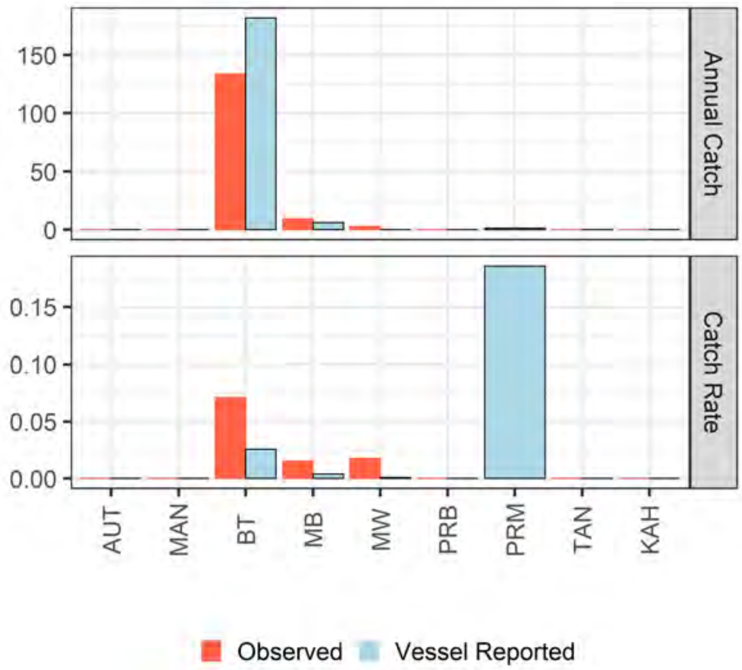


Figure S89: Empirical catch and catch rate data per gear type for smooth red swimming crab. Annual catch is given in tonnes as an average across years. The catch rate is an average calculated as the sum of the observed catch in kilograms (i.e., $\sum X_i$) over the sum of the effort count (number of fishing events). Effort was calculated as a count to allow comparability between methods. There are no vessel reported catches for TAN and KAH surveys.

Table S27: Summary data for smooth red swimming crab across 75 grid cells, removing 567 692 commercial events that were outside the selected cells. The total landings associated with retained commercial effort equal 3 841 tonnes. Catch is in units of tonnes, effort in the number of fishing events. "Obs." is observed; "Com." is commercial.

Method	Gear	Obs. catch	Obs. effort	Com. catch	Com. effort
BLL	AUT	0	452	0	2 591
BLL	MAN	0	44	0	368
TWL	BT	2 541	35 748	3 454	134 470
TWL	MB	181	11 699	116	29 268
TWL	MW	57	3 239	4	4 054
TWL	PRB	0	102	0	306
TWL	PRM			1	7
TWL	TAN	0	426		
TWL	KAH	0	68		
Total		2 779	51 778	3 575	171 064

Table S28: Model selection summary statistics for smooth red swimming crab. Model 6 was selected for prediction of the catches.

Model	$\mathbb{L}[X]$	MPE	L^2	WAIC	$\hat{R}(\alpha)$	$\hat{R}(\gamma)$	$\hat{R}(\pi)$	DRE
1	-0.026	0.118	1.367	165.946	1.005	1.014	1.029	3.229
2	-0.025	0.106	0.728	185.830	1.020	1.007	1.015	3.443
3	-0.026	0.108	0.963	186.625	1.020	1.005	1.018	2.263
4	-0.026	0.104	0.738	186.684	1.023	1.000	1.002	2.229
5	-0.026	0.107	0.647	185.394	1.036	1.014	1.013	2.263
6	-0.026	0.106	0.692	186.715	1.022	1.004	1.001	2.290

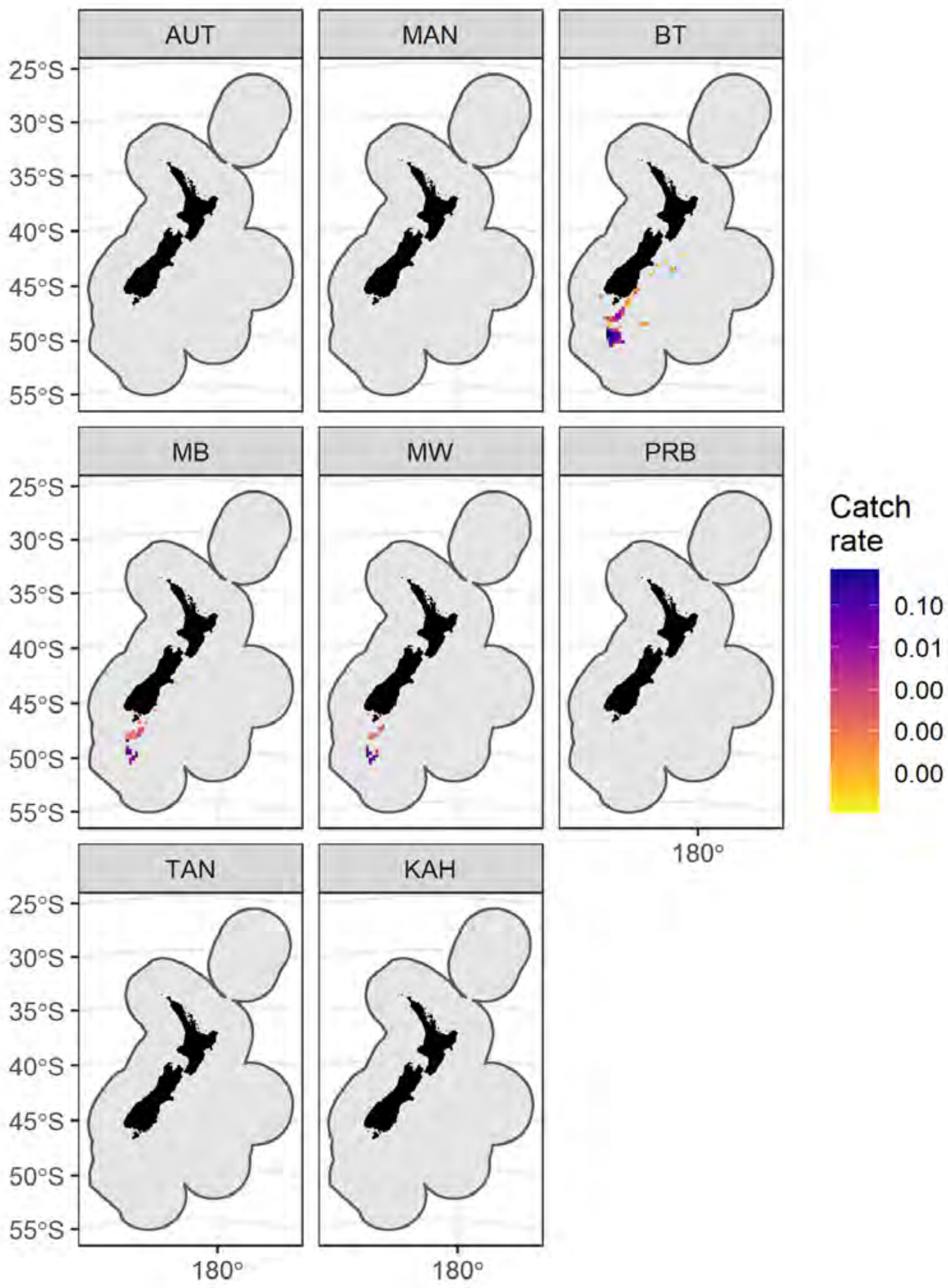


Figure S90: Observer catch rate data for smooth red swimming crab on a log10-scale. The catch rate is an average calculated as the sum of the observed catch $\sum X_i$ over the number of observed fishing events per grid cell and gear type. Effort was calculated as a count to allow comparability between methods.

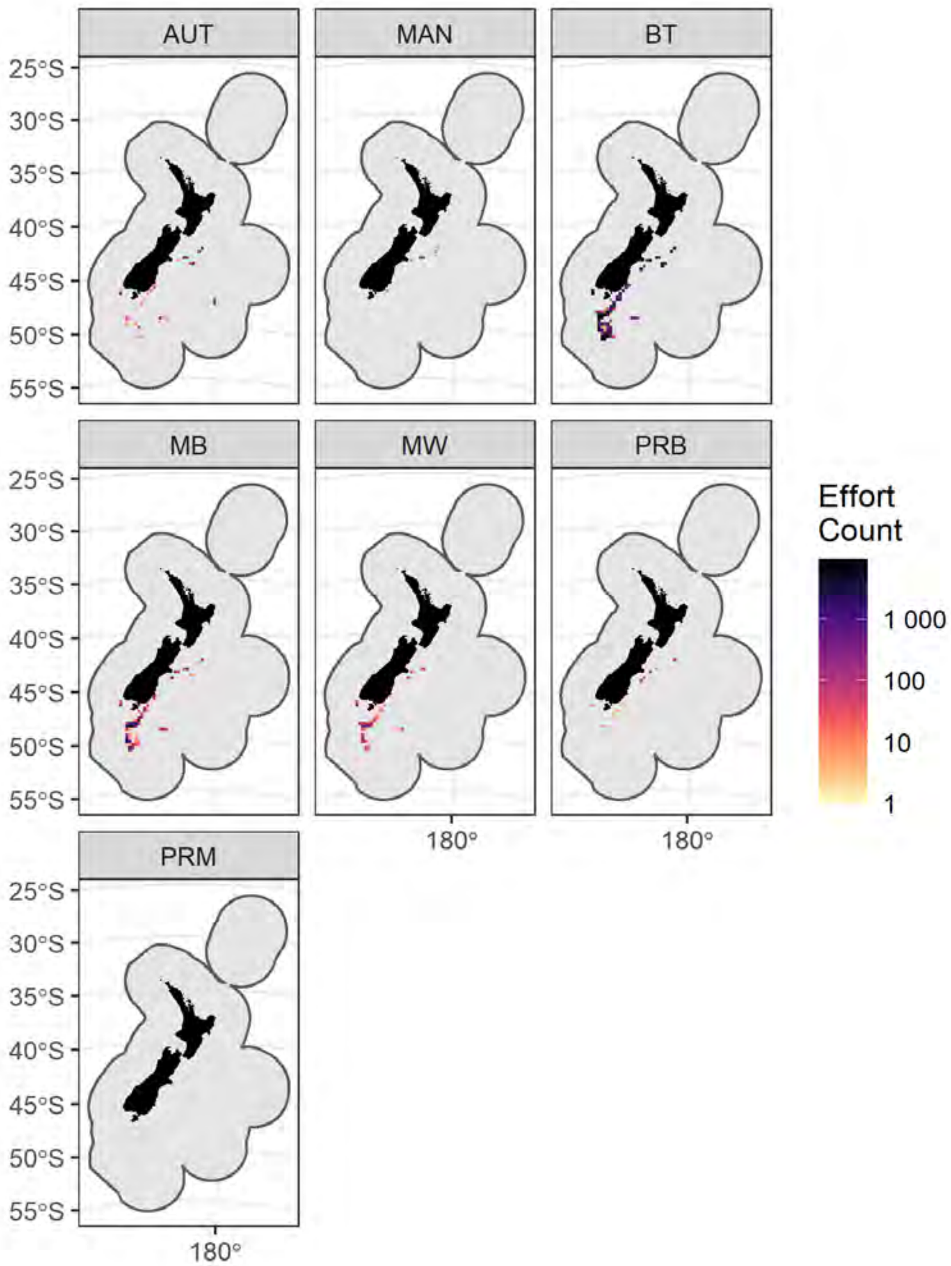


Figure S91: Commercial fishing effort (number of events) for smooth red swimming crab summed across all years and presented on a log10-scale per grid cell and gear type. Effort was calculated as a count to allow comparability between methods.

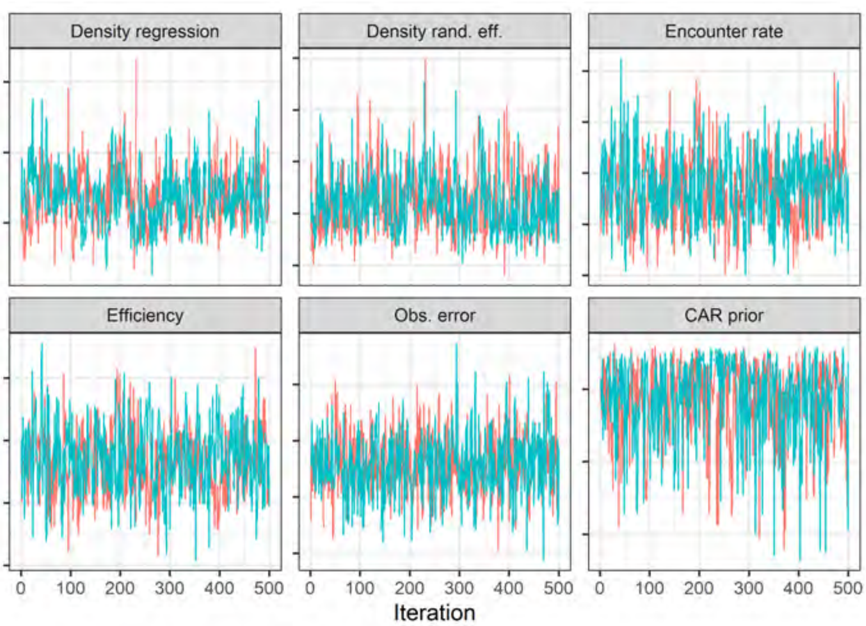


Figure S92: Posterior density sample traces for smooth red swimming crab, for the regression coefficients $||\boldsymbol{\alpha}||$, random effects $||\boldsymbol{\phi}||$, encounter rate $||\boldsymbol{\gamma}||$, efficiency $||\boldsymbol{\pi}||$, observation error $||\boldsymbol{\sigma}||$ and conditional autoregressive prior parameters $||\tau, \rho||$. Colours represent independent sample chains.

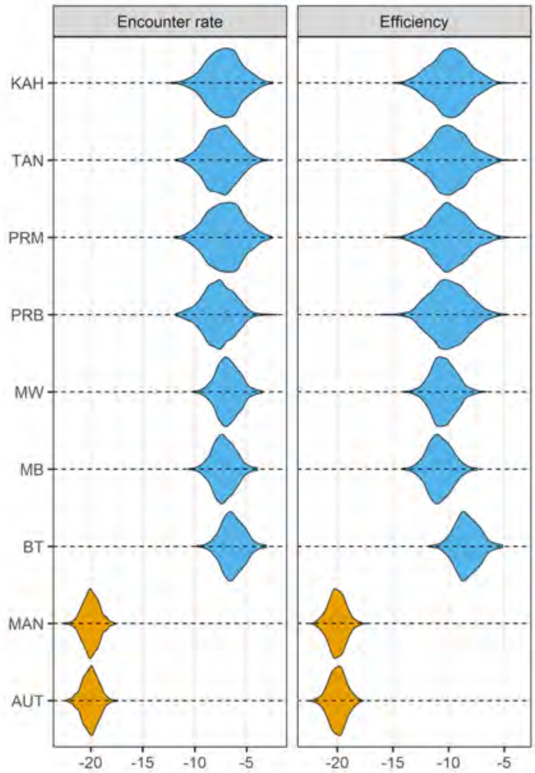


Figure S93: Violin plots of the posterior density for the encounter rate (γ_j) and the efficiency (π_j) per gear type for smooth red swimming crab. Catchability terms for bottom longline gear types (see Table S2) are presented in a different colour as they are not comparable to the trawl gear types because they are dependent on different measures of effort (i.e., thousand hooks and distance, respectively).

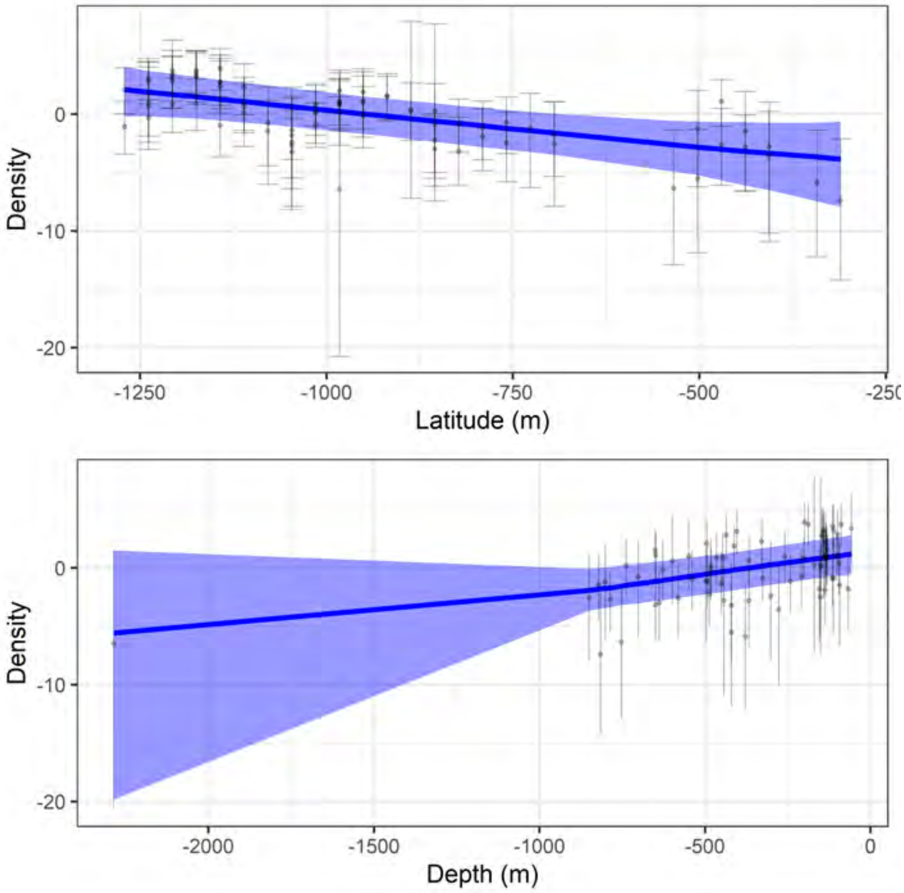


Figure S94: Estimated relationship between biomass density per grid cell and environmental covariates for smooth red swimming crab. Points and error bars show the median and 90% credibility intervals per cell. The blue ribbon shows the estimated marginal relationship.

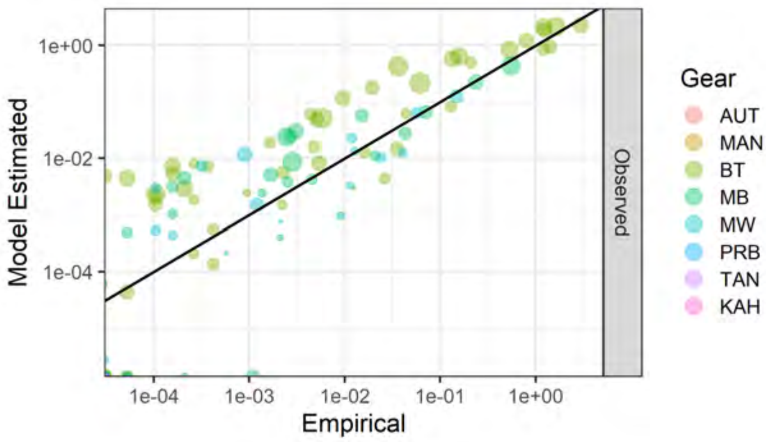


Figure S95: Fit of model to empirical observer catches. Total catches are summed per grid cell and gear type for smooth red swimming crab. Model estimates are the median of the posterior predicted distribution. The size of the point is representative of the number of observed events. Catches are shown in tonnes on a log10 scale.

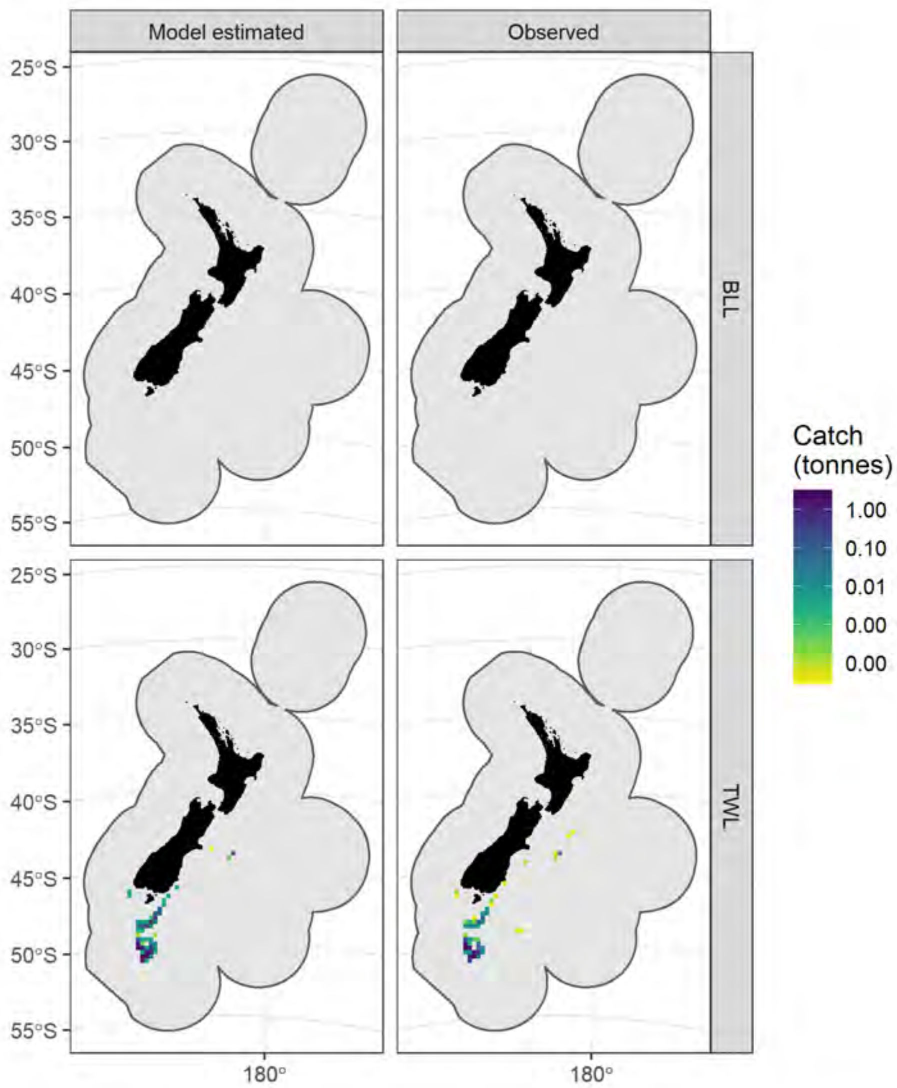


Figure S96: Spatial fit of model to empirical observer catches by grid cell and method for smooth red swimming crab. Average annual catches were calculated as the sum across gear types per cell and method. Posterior median values are shown, with catches in tonnes on a log10 scale.

Table S29: Total predicted bycatch (tonnes) per method for smooth red swimming crab. Posterior median values are given, with the 95% equal-tailed credibility intervals in brackets.

Fishing year	BLL	TWL	Total
2000/01	0 (0 - 0)	163 (119 - 240)	163 (119 - 240)
2001/02	0 (0 - 0)	289 (211 - 415)	289 (211 - 415)
2002/03	0 (0 - 0)	306 (232 - 455)	306 (232 - 455)
2003/04	0 (0 - 0)	506 (365 - 726)	506 (365 - 726)
2004/05	0 (0 - 0)	593 (448 - 829)	593 (448 - 829)
2005/06	0 (0 - 0)	642 (477 - 901)	642 (477 - 901)
2006/07	0 (0 - 0)	345 (252 - 518)	345 (252 - 518)
2007/08	0 (0 - 0)	349 (248 - 543)	349 (248 - 543)
2008/09	0 (0 - 0)	615 (457 - 887)	615 (457 - 887)
2009/10	0 (0 - 0)	458 (333 - 693)	458 (333 - 693)
2010/11	0 (0 - 0)	509 (379 - 739)	509 (379 - 739)
2011/12	0 (0 - 0)	429 (307 - 668)	429 (307 - 668)
2012/13	0 (0 - 0)	376 (258 - 579)	376 (258 - 579)
2013/14	0 (0 - 0)	289 (191 - 443)	289 (191 - 443)
2014/15	0 (0 - 0)	208 (139 - 347)	208 (139 - 347)
2015/16	0 (0 - 0)	366 (262 - 548)	366 (262 - 548)
2016/17	0 (0 - 0)	624 (455 - 927)	624 (455 - 927)
2017/18	0 (0 - 0)	459 (328 - 656)	459 (328 - 656)
2018/19	0 (0 - 0)	369 (261 - 548)	369 (261 - 548)

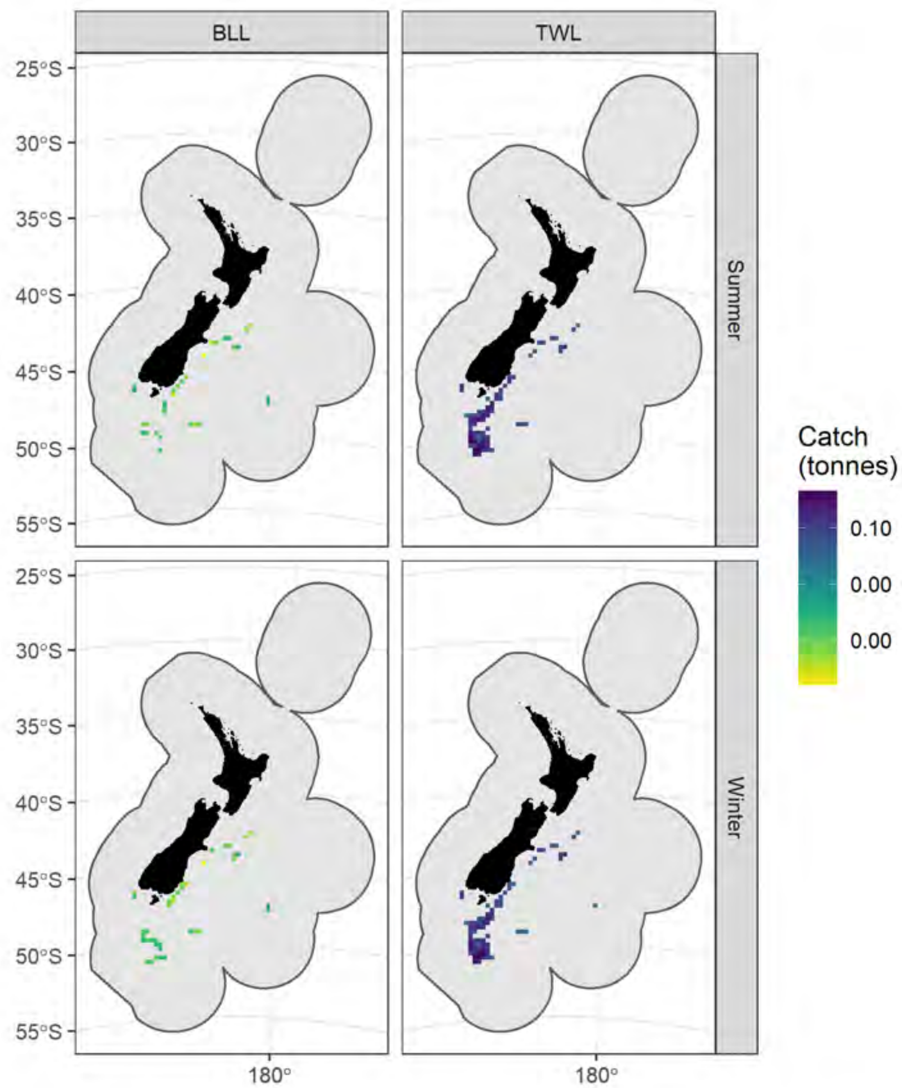


Figure S97: Posterior prediction of the total catches by grid cell, method and season for smooth red swimming crab. Average annual catches per season were calculated as the sum across gear types per cell and method. Posterior median values are shown, with catches in tonnes on a log10 scale.

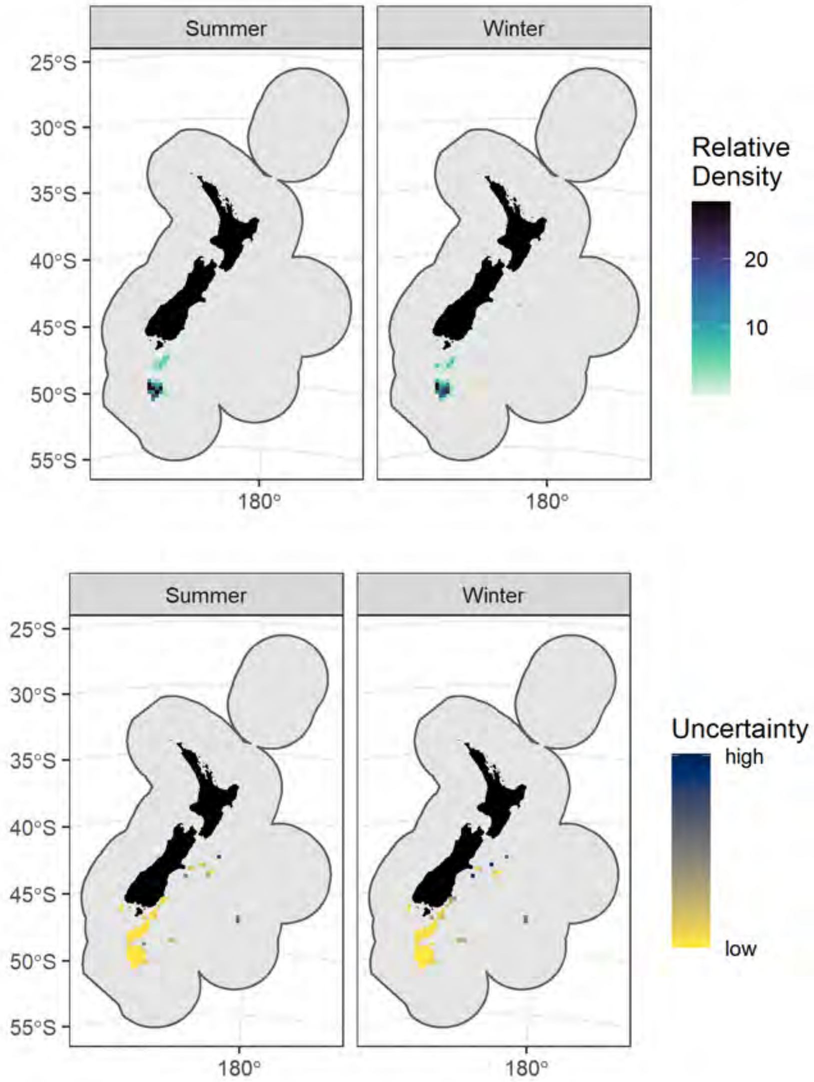


Figure S98: Posterior prediction of the relative density per grid cell and season for smooth red swimming crab. Posterior median values are shown on a natural scale in tonnes per square kilometre. Uncertainty is measured using the difference between the upper and lower 95% equal-tailed posterior density interval.

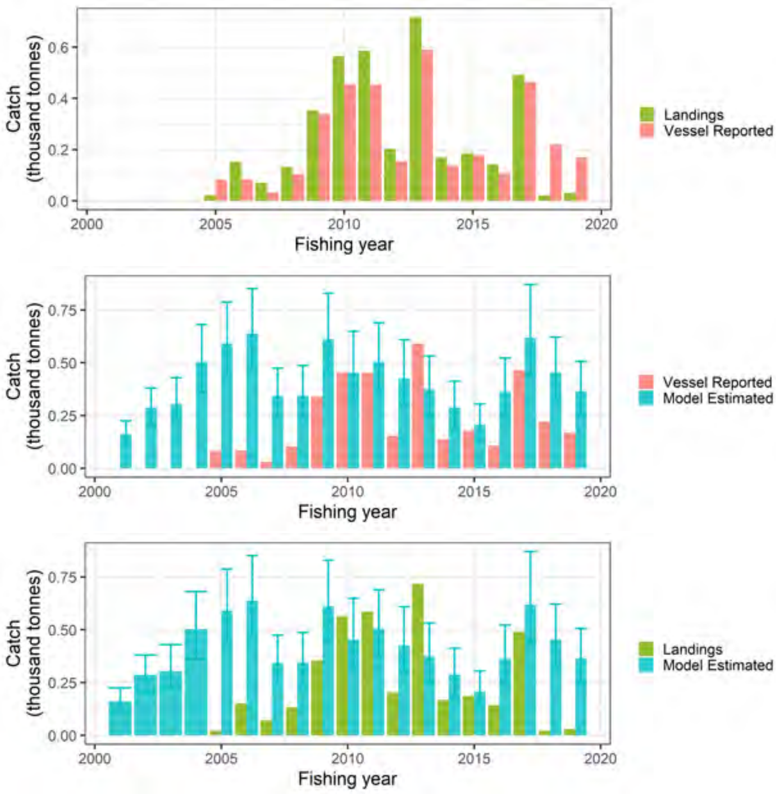


Figure S99: Relationships between landings, vessel reported catches and model estimated catches for smooth red swimming crab.

S2.10 Sea perch (*Helicolenus* spp.)

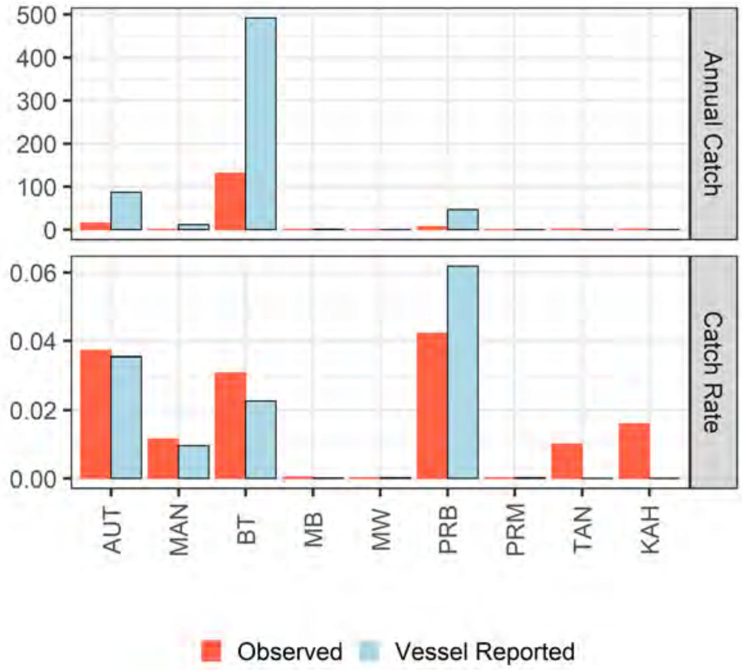


Figure S100: Empirical catch and catch rate data per gear type for sea perch. Annual catch is given in tonnes as an average across years. The catch rate is an average calculated as the sum of the observed catch in kilograms (i.e., $\sum X_i$) over the sum of the effort count (number of fishing events). Effort was calculated as a count to allow comparability between methods. There are no vessel reported catches for TAN and KAH surveys.

Table S30: Summary data for sea perch across 548 grid cells, removing 85 746 commercial events that were outside the selected cells. The total landings associated with retained commercial effort equal 21 533 tonnes. Catch is in units of tonnes, effort in the number of fishing events. "Obs." is observed; "Com." is commercial.

Method	Gear	Obs. catch	Obs. effort	Com. catch	Com. effort
BLL	AUT	288	7 720	1 658	46 710
BLL	MAN	10	835	233	24 266
TWL	BT	2 492	80 698	9 343	412 285
TWL	MB	14	28 445	14	103 070
TWL	MW	5	24 453	10	61 594
TWL	PRB	35	828	188	3 038
TWL	PRM	0	389	0	2 047
TWL	TAN	34	3 355		
TWL	KAH	22	1 357		
Total		2 899	148 080	11 446	653 010

Table S31: Model selection summary statistics for sea perch. Model 3 was selected for prediction of the catches.

Model	$\mathbb{L}[X]$	MPE	L^2	WAIC	$\hat{R}(\alpha)$	$\hat{R}(\gamma)$	$\hat{R}(\pi)$	DRE
1	-0.017	0.037	0.103	12215.162	1.003	1.010	1.010	1.990
2	-0.017	0.038	0.109	12254.523	1.003	1.016	1.017	2.044
3	-0.018	0.038	0.111	12261.119	1.008	1.016	1.018	1.862
4	-0.017	0.038	0.139	12254.497	1.007	1.019	1.018	1.870
5	-0.017	0.037	0.109	12252.251	1.050	1.017	1.018	1.609
6	-0.017	0.037	0.113	12247.943	1.009	1.002	1.002	1.629

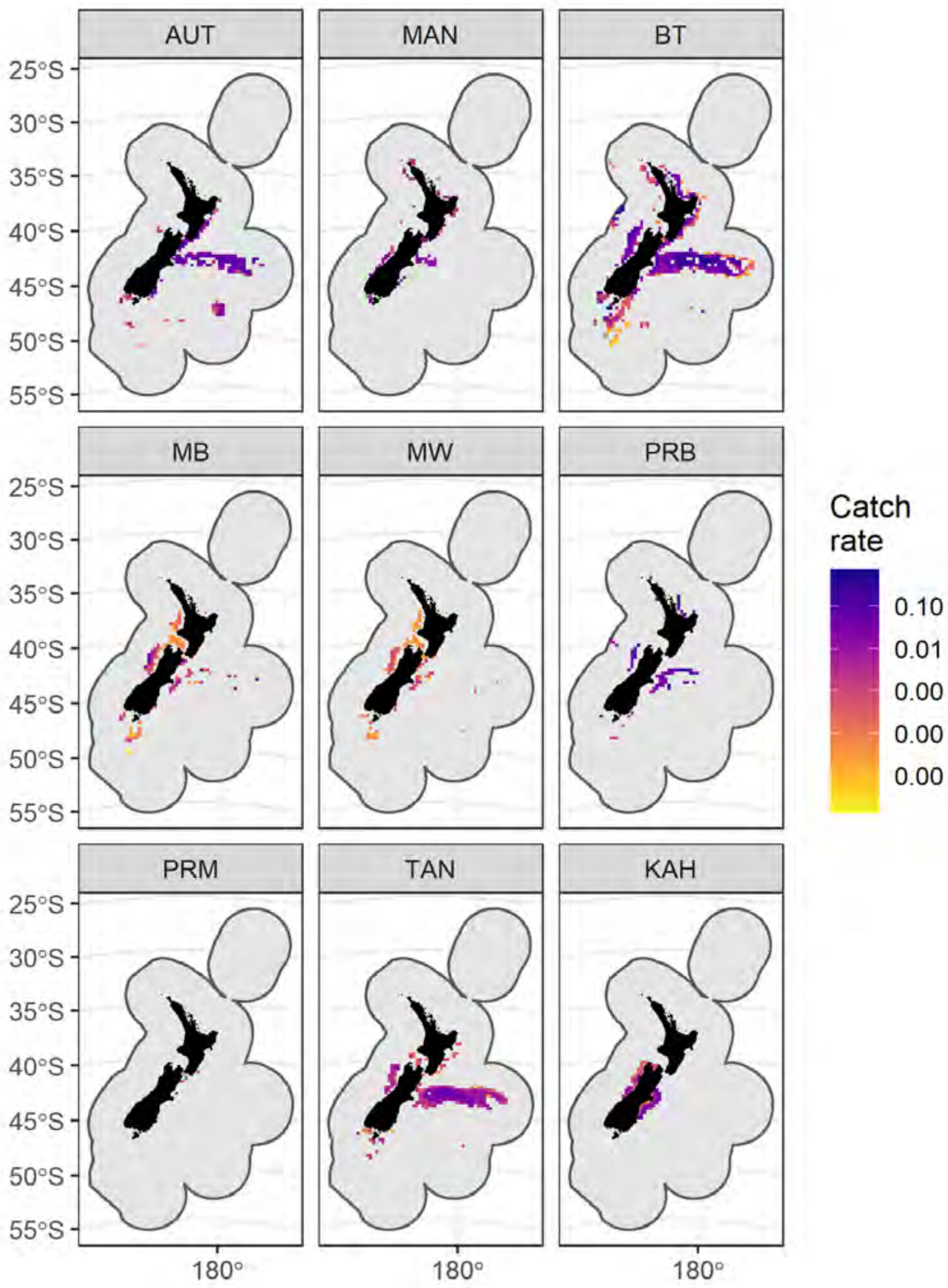


Figure S101: Observer catch rate data for sea perch on a log10-scale. The catch rate is an average calculated as the sum of the observed catch $\sum X_i$ over the number of observed fishing events per grid cell and gear type. Effort was calculated as a count to allow comparability between methods.

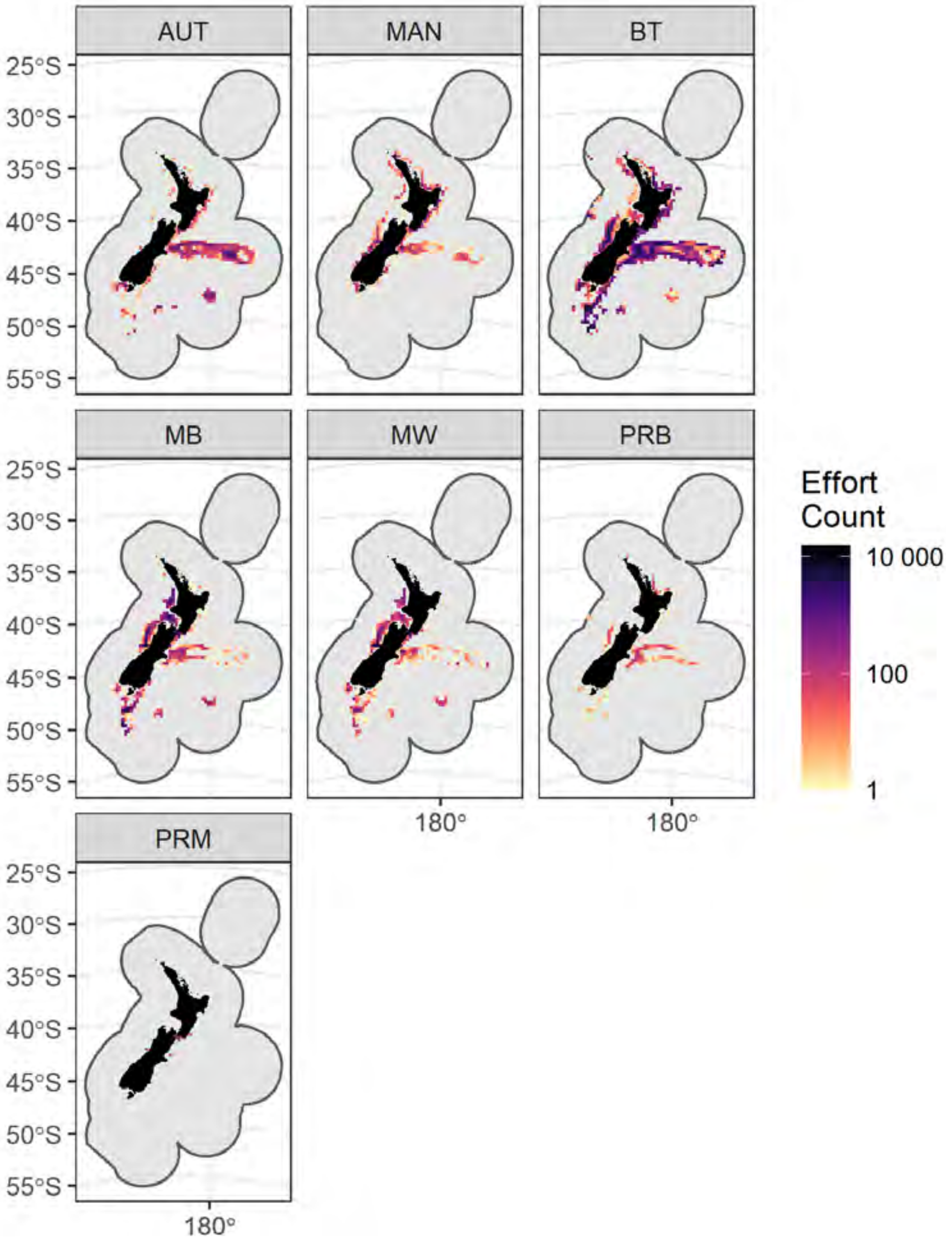


Figure S102: Commercial fishing effort (number of events) for sea perch summed across all years and presented on a log10-scale per grid cell and gear type. Effort was calculated as a count to allow comparability between methods.

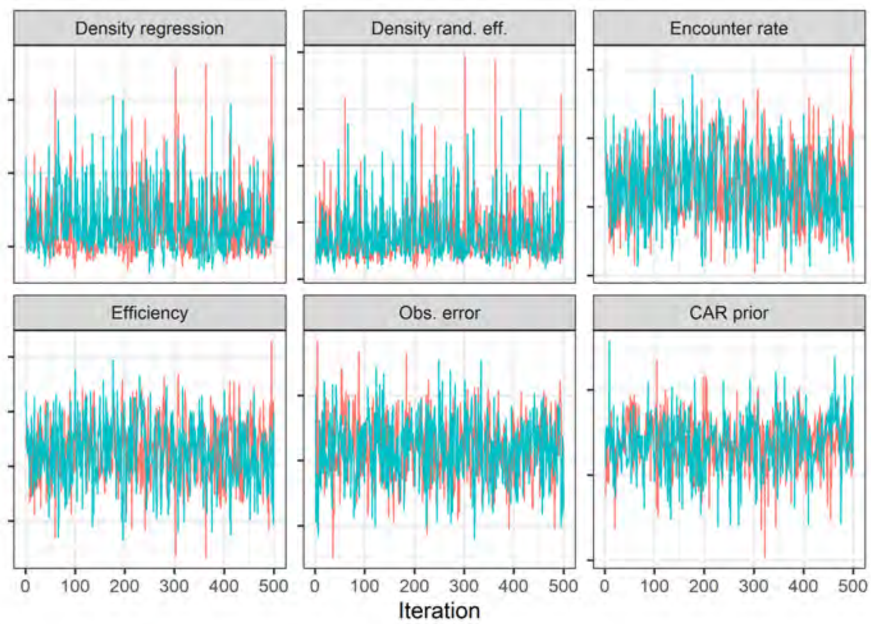


Figure S103: Posterior density sample traces for sea perch, for the regression coefficients $||\boldsymbol{\alpha}||$, random effects $||\boldsymbol{\phi}||$, encounter rate $||\boldsymbol{\gamma}||$, efficiency $||\boldsymbol{\pi}||$, observation error $||\boldsymbol{\sigma}||$ and conditional autoregressive prior parameters $||\tau,\rho||$. Colours represent independent sample chains.

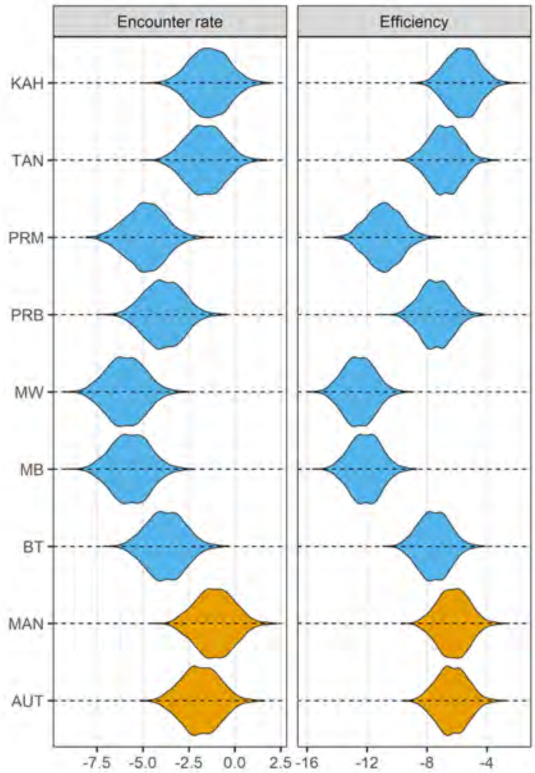


Figure S104: Violin plots of the posterior density for the encounter rate (γ_j) and the efficiency (π_j) per gear type for sea perch. Catchability terms for bottom longline gear types (see Table S2) are presented in a different colour as they are not comparable to the trawl gear types because they are dependent on different measures of effort (i.e., thousand hooks and distance, respectively).

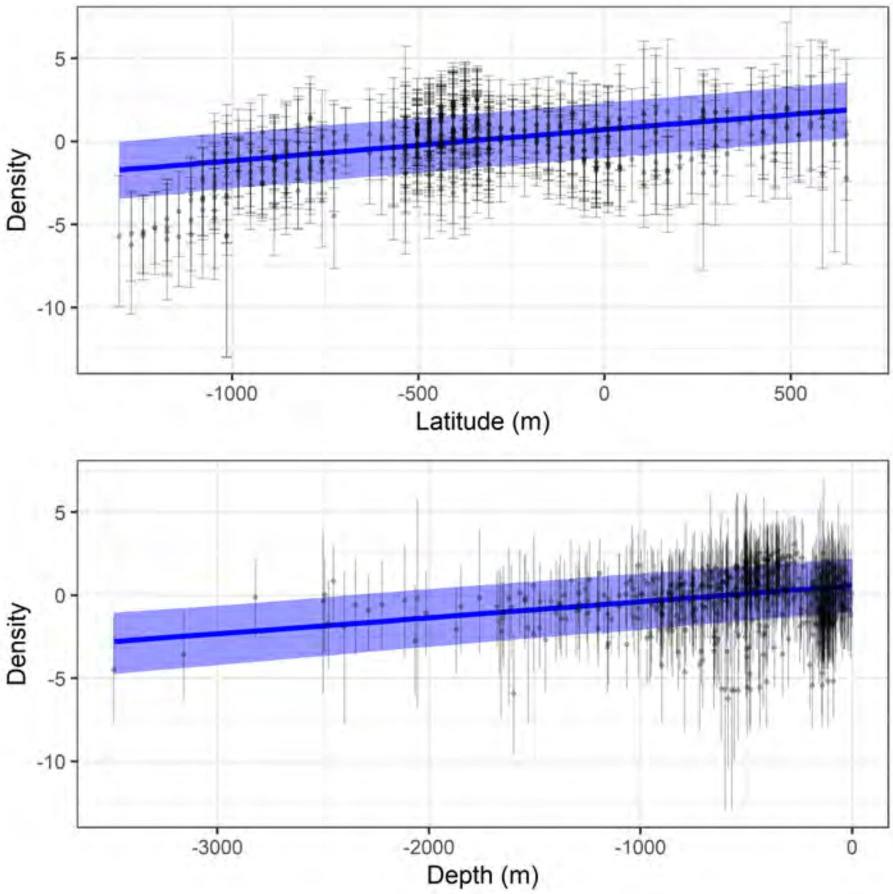


Figure S105: Estimated relationship between biomass density per grid cell and environmental covariates for sea perch. Points and error bars show the median and 90% credibility intervals per cell. The blue ribbon shows the estimated marginal relationship.

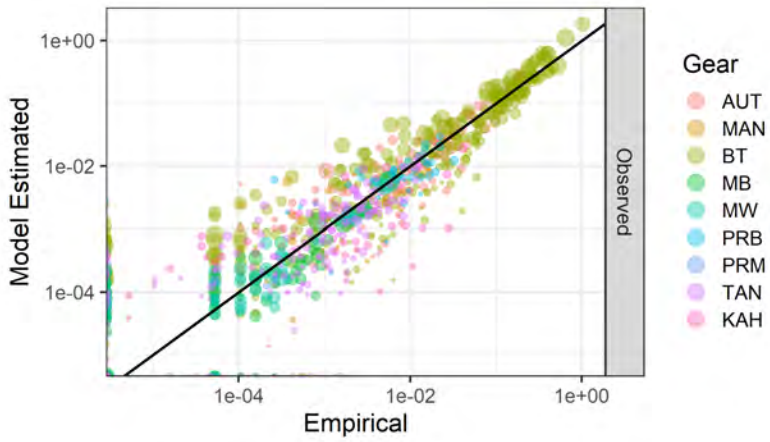


Figure S106: Fit of model to empirical observer catches. Total catches are summed per grid cell and gear type for sea perch. Model estimates are the median of the posterior predicted distribution. The size of the point is representative of the number of observed events. Catches are shown in tonnes on a log10 scale.

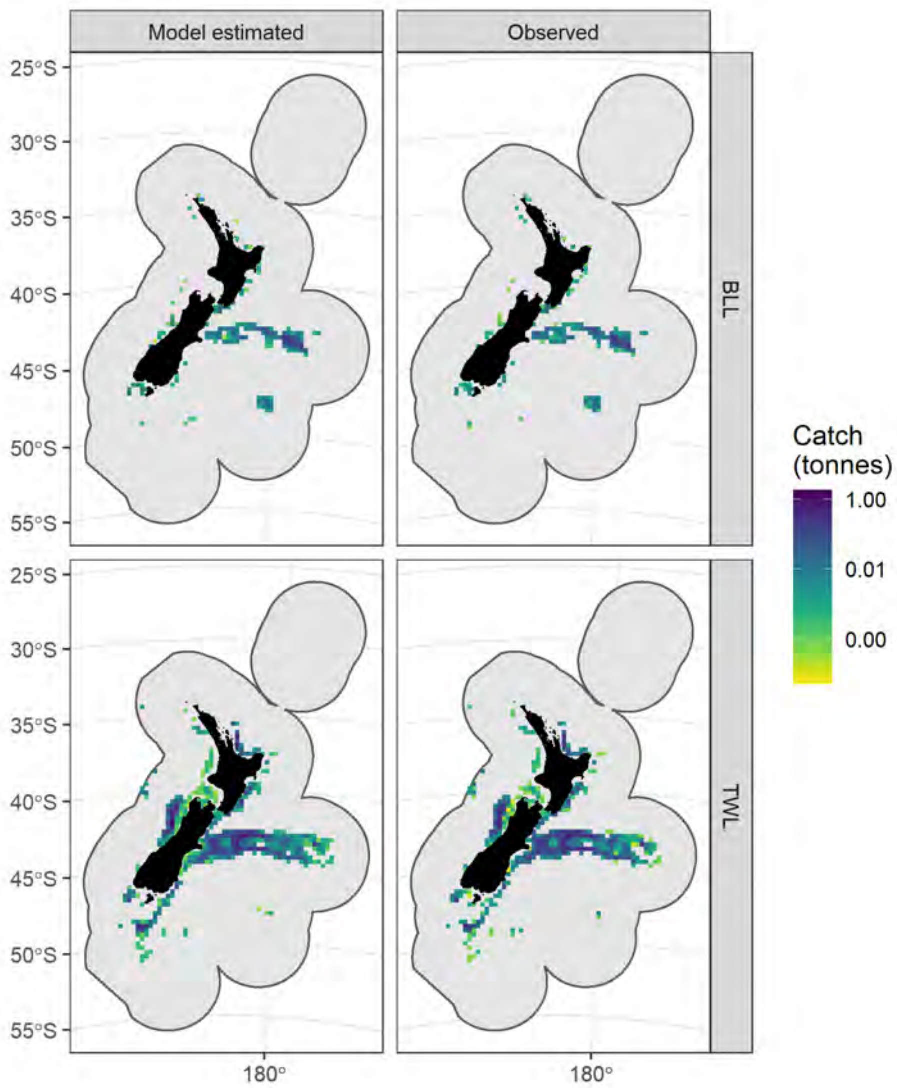


Figure S107: Spatial fit of model to empirical observer catches by grid cell and method for sea perch. Average annual catches were calculated as the sum across gear types per cell and method. Posterior median values are shown, with catches in tonnes on a log10 scale.

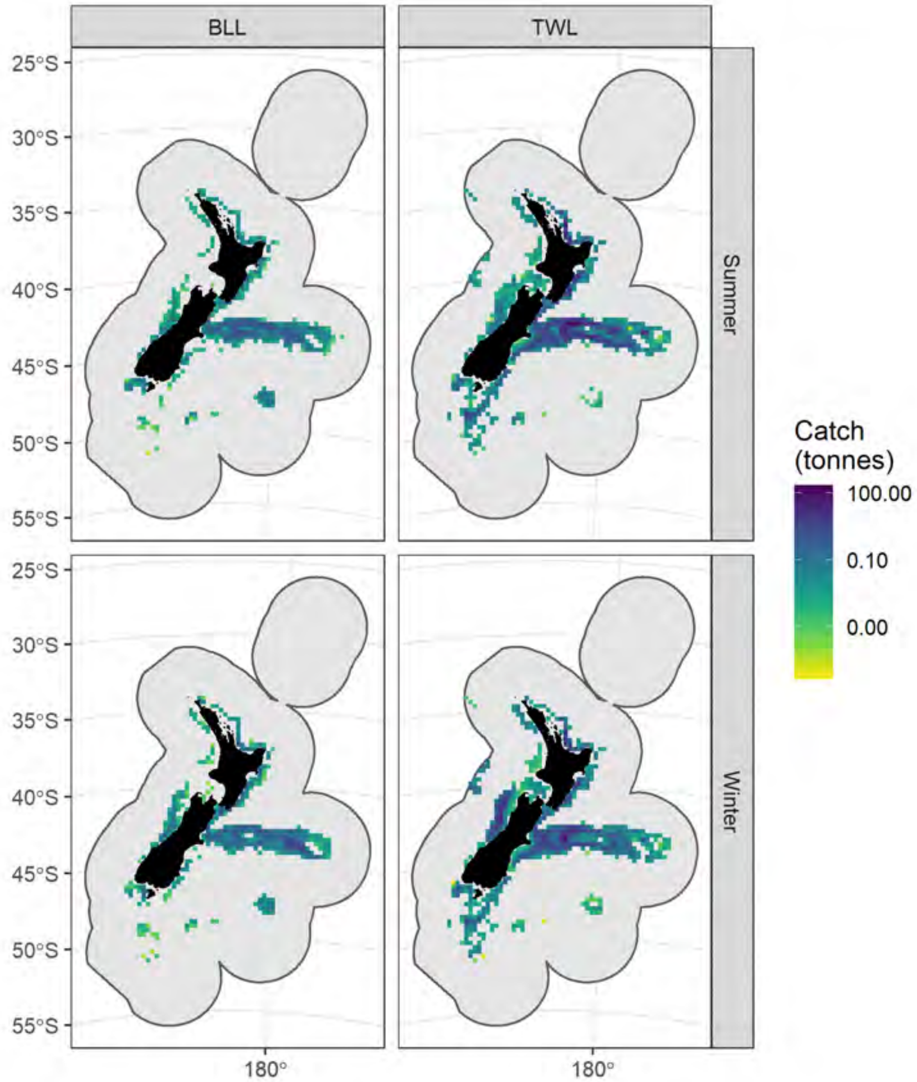


Figure S108: Posterior prediction of the total catches by grid cell, method and season for sea perch. Average annual catches per season were calculated as the sum across gear types per cell and method. Posterior median values are shown, with catches in tonnes on a log10 scale.

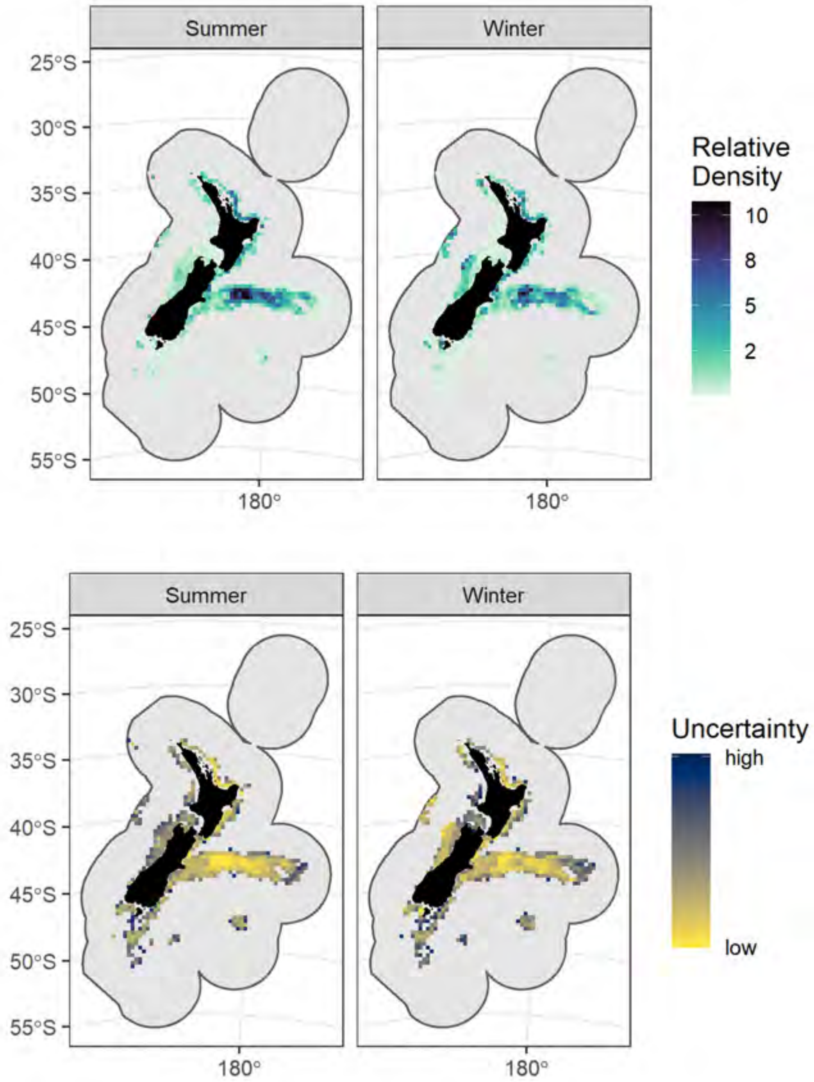


Figure S109: Posterior prediction of the relative density per grid cell and season for sea perch. Posterior median values are shown on a natural scale in tonnes per square kilometre. Uncertainty is measured using the difference between the upper and lower 95% equal-tailed posterior density interval.

Table S32: **Total predicted bycatch (tonnes) per method for sea perch. Posterior median values are given, with the 95% equal-tailed credibility intervals in brackets.**

Fishing year	BLL	TWL	Total
2000/01	144 (123 - 170)	1 323 (1 227 - 1 459)	1 468 (1 371 - 1 607)
2001/02	173 (150 - 206)	1 392 (1 285 - 1 638)	1 565 (1 456 - 1 820)
2002/03	87 (75 - 104)	1 398 (1 302 - 1 514)	1 487 (1 385 - 1 605)
2003/04	105 (90 - 125)	1 110 (1 020 - 1 243)	1 216 (1 120 - 1 346)
2004/05	174 (148 - 209)	1 072 (993 - 1 187)	1 250 (1 159 - 1 360)
2005/06	127 (108 - 151)	1 087 (1 000 - 1 400)	1 214 (1 125 - 1 515)
2006/07	115 (98 - 136)	1 051 (962 - 1 186)	1 166 (1 073 - 1 301)
2007/08	127 (104 - 194)	1 399 (1 287 - 1 550)	1 531 (1 405 - 1 695)
2008/09	116 (100 - 149)	1 337 (1 217 - 1 527)	1 455 (1 330 - 1 653)
2009/10	149 (126 - 192)	1 582 (1 436 - 1 780)	1 732 (1 581 - 1 940)
2010/11	137 (114 - 236)	1 558 (1 410 - 1 752)	1 701 (1 540 - 1 920)
2011/12	124 (103 - 222)	1 813 (1 637 - 2 034)	1 943 (1 762 - 2 202)
2012/13	107 (89 - 162)	1 793 (1 606 - 2 045)	1 904 (1 708 - 2 169)
2013/14	143 (120 - 237)	1 774 (1 609 - 1 988)	1 920 (1 749 - 2 163)
2014/15	132 (106 - 276)	2 074 (1 862 - 2 342)	2 215 (1 991 - 2 529)
2015/16	174 (148 - 245)	1 986 (1 778 - 2 256)	2 166 (1 951 - 2 445)
2016/17	195 (164 - 324)	1 650 (1 492 - 1 857)	1 850 (1 678 - 2 084)
2017/18	147 (125 - 206)	1 613 (1 468 - 1 853)	1 765 (1 615 - 2 064)
2018/19	153 (124 - 323)	1 853 (1 652 - 2 100)	2 016 (1 809 - 2 313)

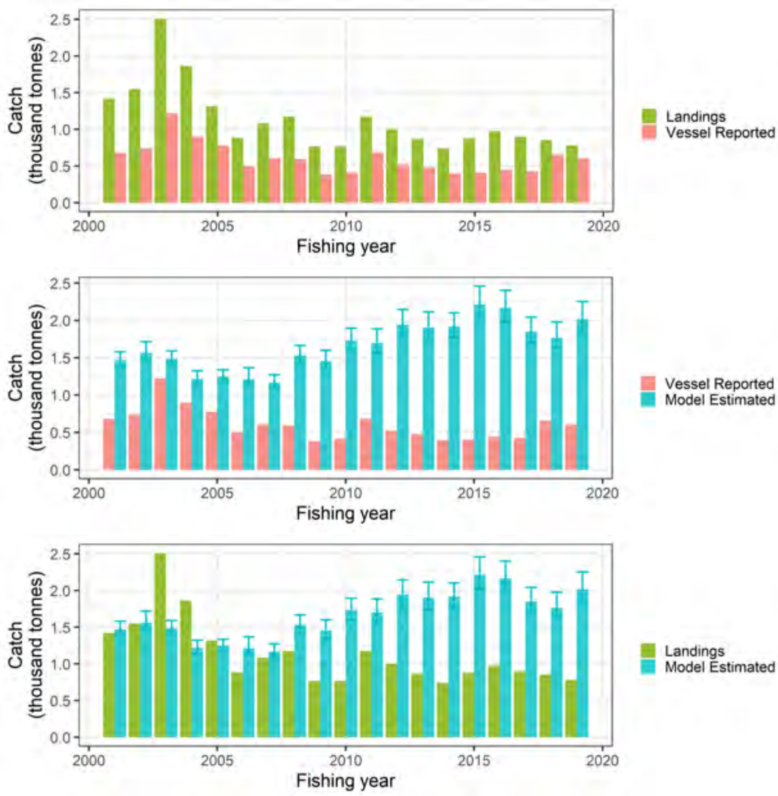


Figure S110: **Relationships between landings, vessel reported catches and model estimated catches for sea perch.**

S2.11 Pale ghost shark (*Hydrolagus bemisi*)

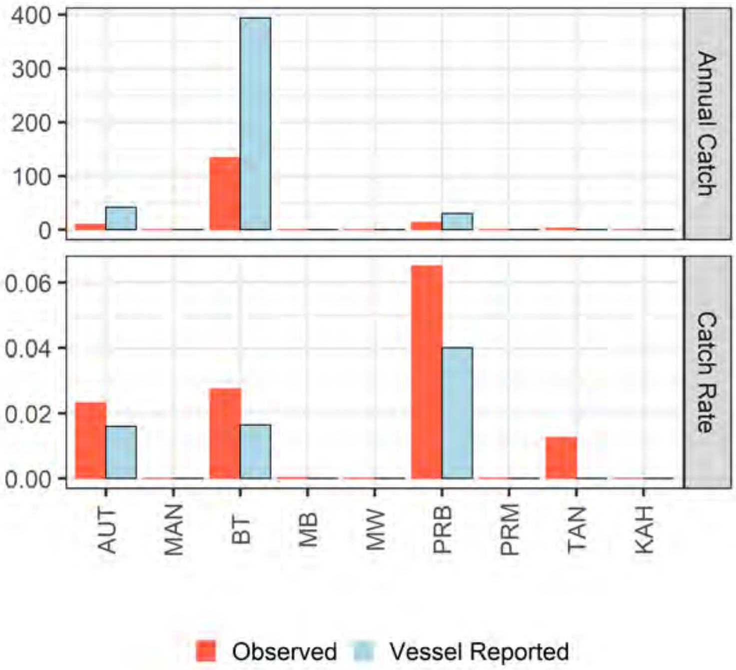


Figure S111: Empirical catch and catch rate data per gear type for pale ghost shark. Annual catch is given in tonnes as an average across years. The catch rate is an average calculated as the sum of the observed catch in kilograms (i.e., $\sum X_i$) over the sum of the effort count (number of fishing events). Effort was calculated as a count to allow comparability between methods. There are no vessel reported catches for TAN and KAH surveys.

Table S33: Summary data for pale ghost shark across 793 grid cells, removing 54 251 commercial events that were outside the selected cells. The total landings associated with retained commercial effort equal 18 985 tonnes. Catch is in units of tonnes, effort in the number of fishing events. "Obs." is observed; "Com." is commercial.

Method	Gear	Obs. catch	Obs. effort	Com. catch	Com. effort
BLL	AUT	195	8 402	790	49 365
BLL	MAN	0	597	0	16 756
TWL	BT	2 547	92 669	7 481	453 451
TWL	MB	8	28 017	4	99 656
TWL	MW	4	25 197	2	60 202
TWL	PRB	54	833	121	3 026
TWL	PRM	0	404	0	2 049
TWL	TAN	55	4 358		
TWL	KAH	0	494		
Total		2 864	160 971	8 398	684 505

Table S34: Model selection summary statistics for pale ghost shark. Model 3 was selected for prediction of the catches.

Model	$\mathbb{L}[X]$	MPE	L^2	WAIC	$\hat{R}(\alpha)$	$\hat{R}(\gamma)$	$\hat{R}(\pi)$	DRE
1	-0.015	0.036	0.109	4520.795	1.003	1.008	1.009	1.413
2	-0.015	0.036	0.114	4561.049	1.017	1.016	1.015	1.520
3	-0.015	0.037	0.115	4573.844	1.008	1.006	1.014	1.415
4	-0.015	0.037	0.113	4567.529	1.017	1.009	1.008	1.342
5	-0.015	0.037	0.113	4572.158	1.006	1.001	1.000	1.422
6	-0.015	0.037	0.113	4566.068	1.017	1.054	1.048	1.353

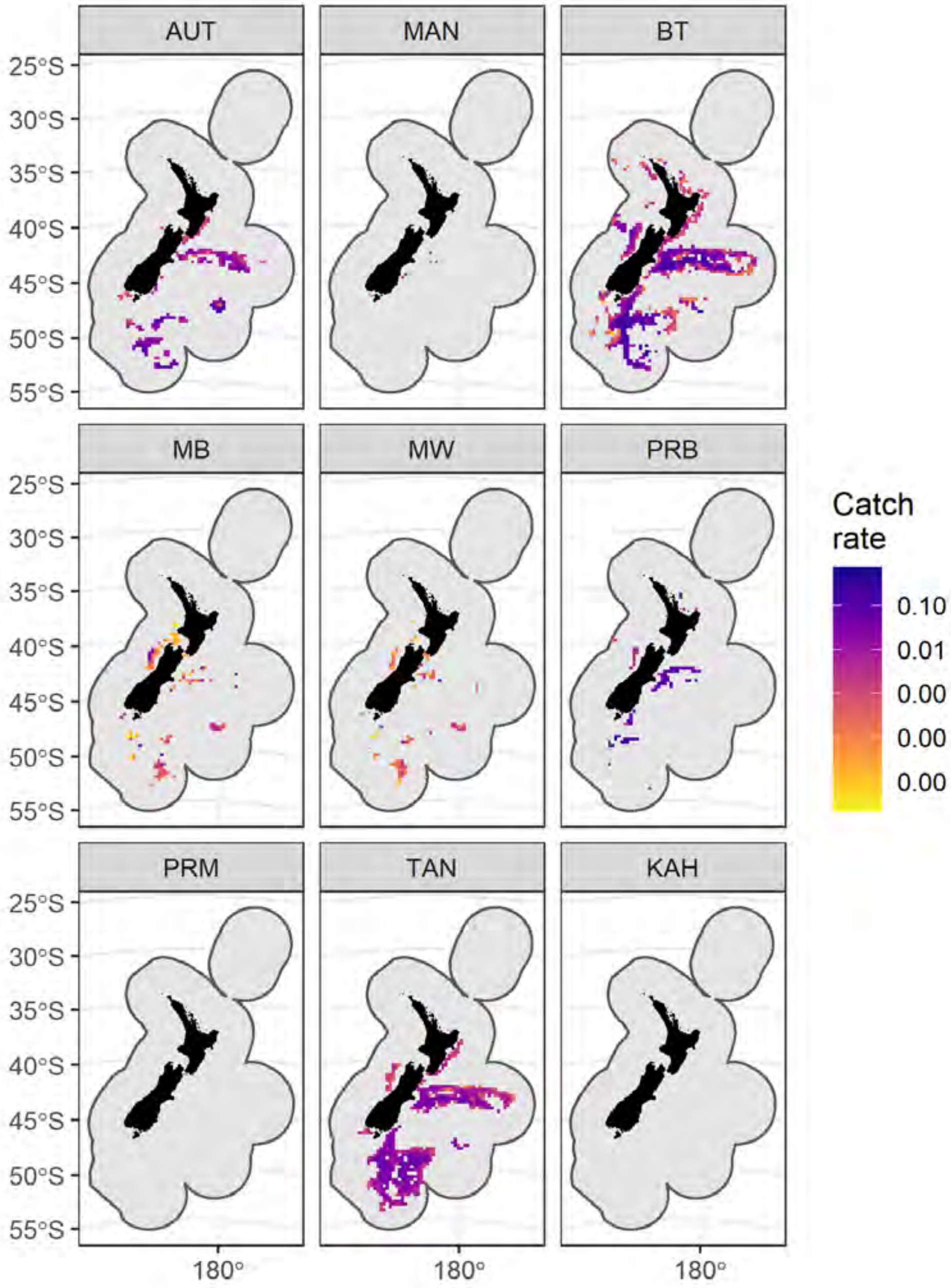


Figure S112: Observer catch rate data for pale ghost shark on a log10-scale. The catch rate is an average calculated as the sum of the observed catch $\sum X_i$ over the number of observed fishing events per grid cell and gear type. Effort was calculated as a count to allow comparability between methods.

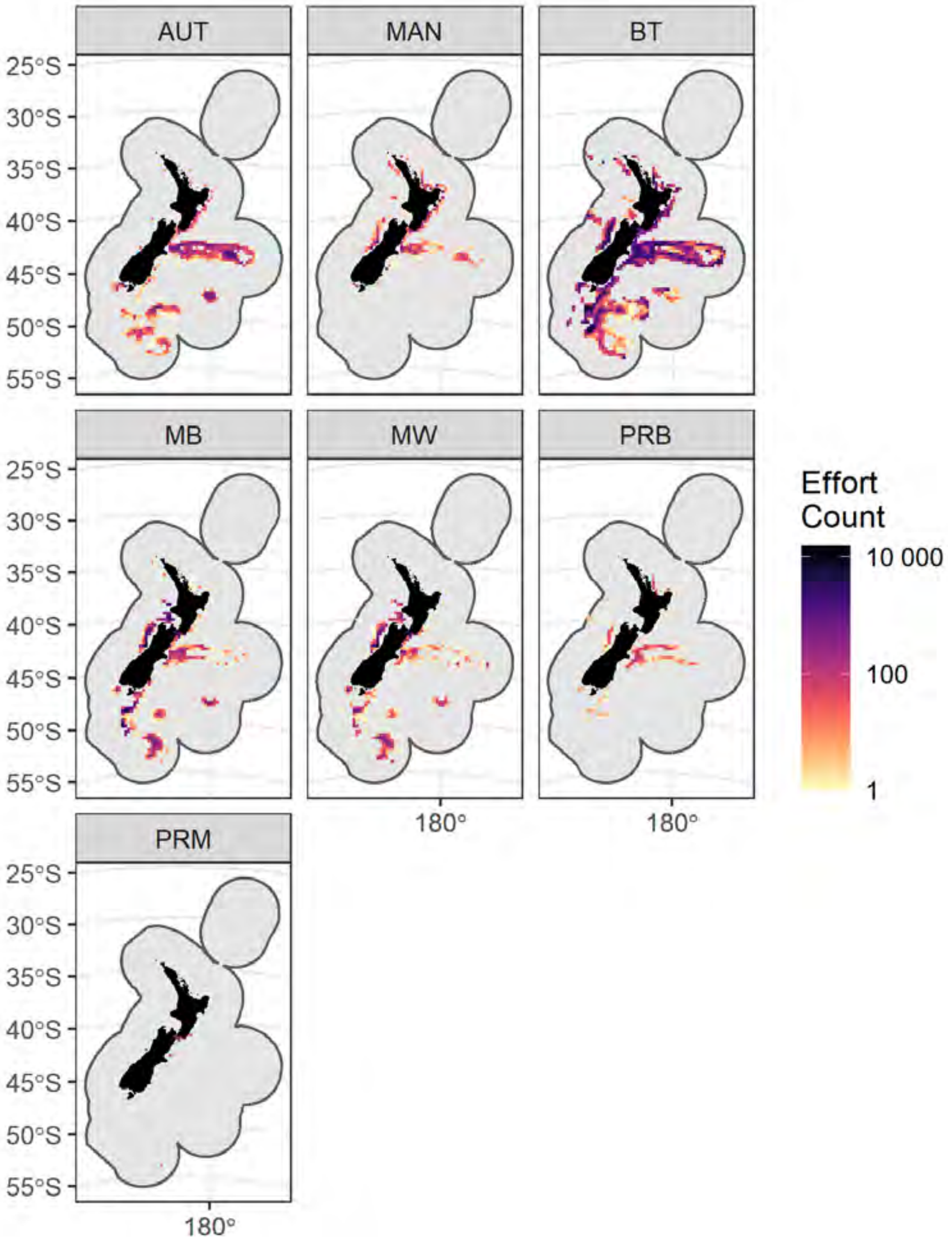


Figure S113: Commercial fishing effort (number of events) for pale ghost shark summed across all years and presented on a log10-scale per grid cell and gear type. Effort was calculated as a count to allow comparability between methods.

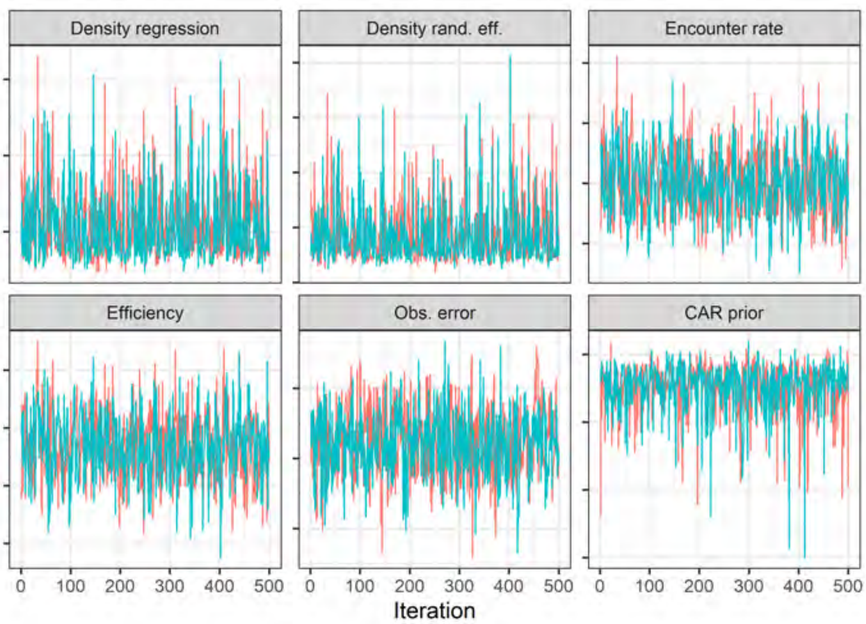


Figure S114: Posterior density sample traces for pale ghost shark, for the regression coefficients $||\boldsymbol{\alpha}||$, random effects $||\boldsymbol{\phi}||$, encounter rate $||\boldsymbol{\gamma}||$, efficiency $||\boldsymbol{\pi}||$, observation error $||\boldsymbol{\sigma}||$ and conditional autoregressive prior parameters $||\tau, \rho||$. Colours represent independent sample chains.

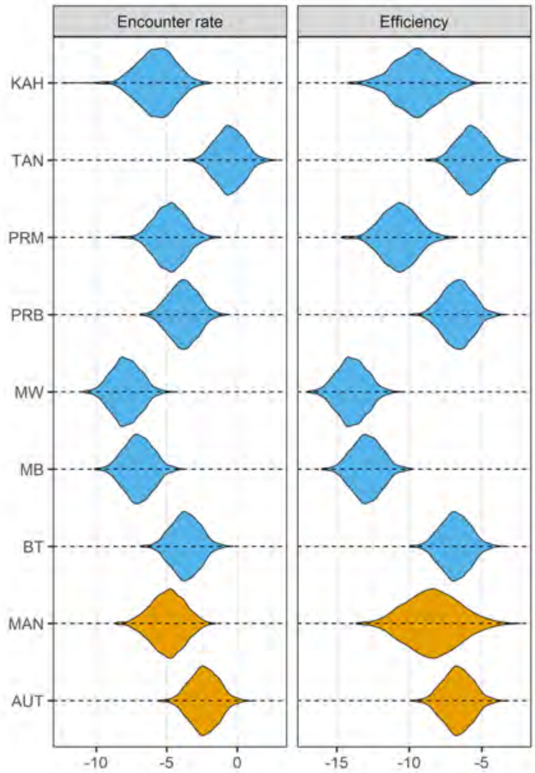


Figure S115: Violin plots of the posterior density for the encounter rate (γ_j) and the efficiency (π_j) per gear type for pale ghost shark. Catchability terms for bottom longline gear types (see Table S2) are presented in a different colour as they are not comparable to the trawl gear types because they are dependent on different measures of effort (i.e., thousand hooks and distance, respectively).

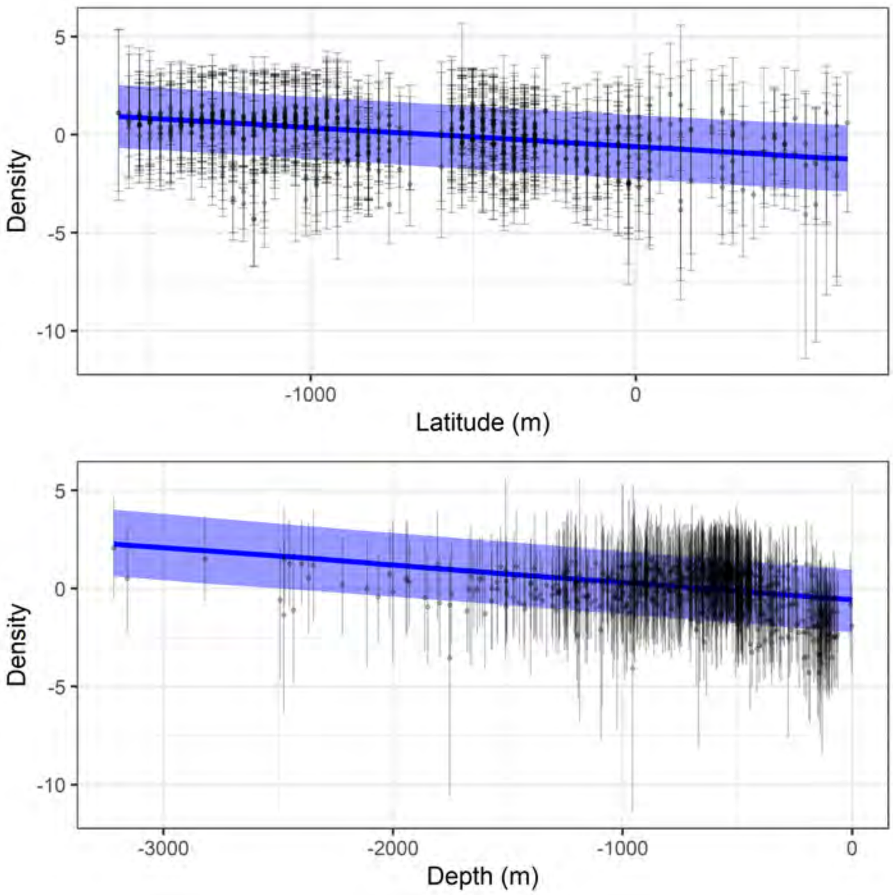


Figure S116: Estimated relationship between biomass density per grid cell and environmental covariates for pale ghost shark. Points and error bars show the median and 90% credibility intervals per cell. The blue ribbon shows the estimated marginal relationship.

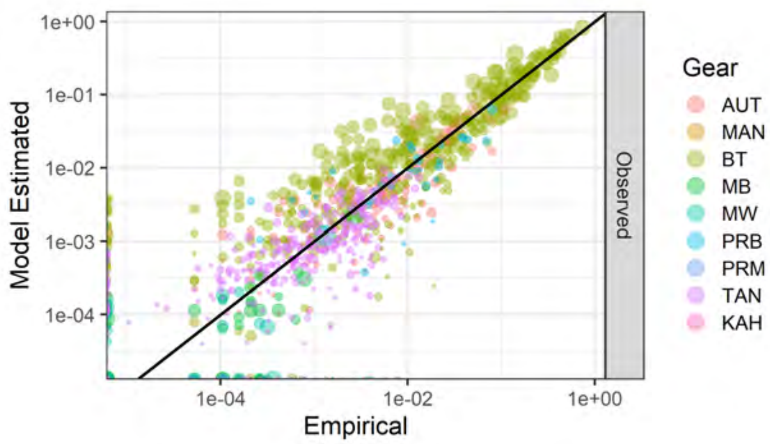


Figure S117: Fit of model to empirical observer catches. Total catches are summed per grid cell and gear type for pale ghost shark. Model estimates are the median of the posterior predicted distribution. The size of the point is representative of the number of observed events. Catches are shown in tonnes on a log10 scale.

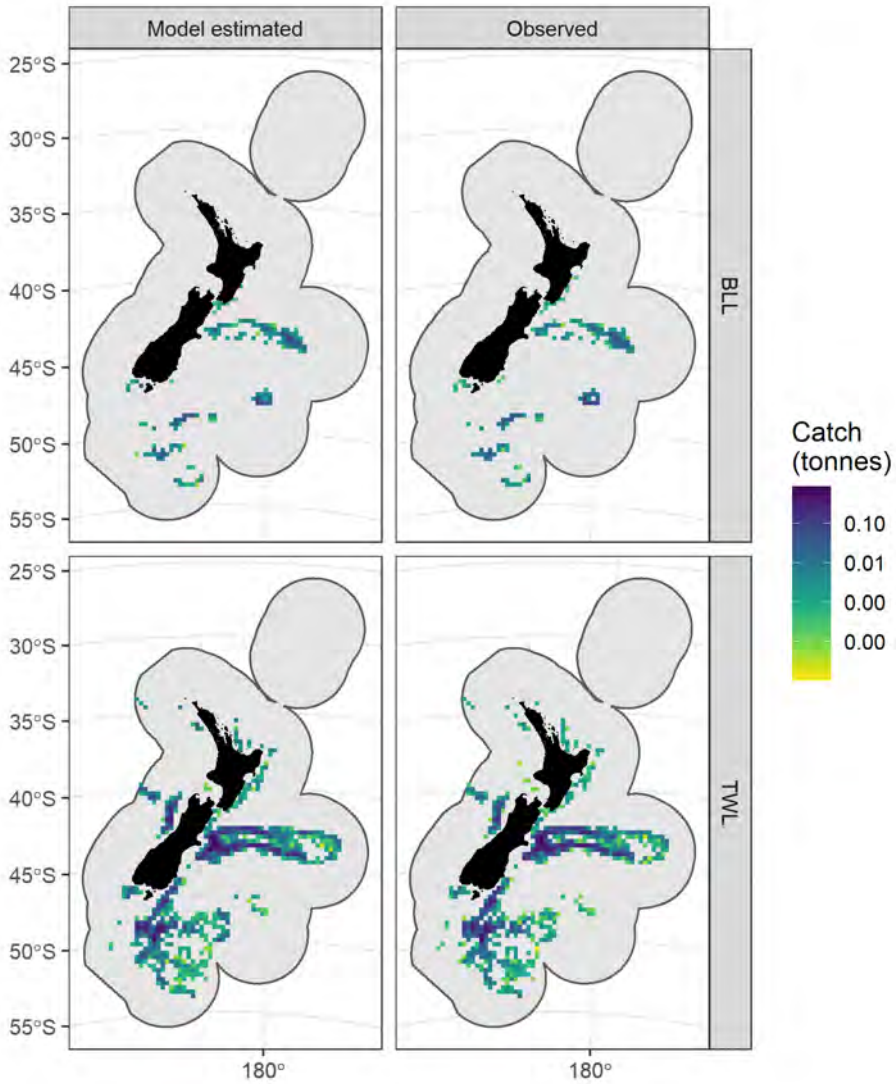


Figure S118: Spatial fit of model to empirical observer catches by grid cell and method for pale ghost shark. Average annual catches were calculated as the sum across gear types per cell and method. Posterior median values are shown, with catches in tonnes on a log10 scale.

Table S35: Total predicted bycatch (tonnes) per method for pale ghost shark. Posterior median values are given, with the 95% equal-tailed credibility intervals in brackets.

Fishing year	BLL	TWL	Total
2000/01	62 (53 - 76)	1 380 (1 278 - 1 510)	1 442 (1 342 - 1 576)
2001/02	63 (54 - 75)	1 429 (1 323 - 1 563)	1 492 (1 385 - 1 629)
2002/03	43 (36 - 52)	1 494 (1 383 - 1 633)	1 537 (1 425 - 1 672)
2003/04	62 (53 - 74)	1 162 (1 067 - 1 277)	1 225 (1 131 - 1 340)
2004/05	45 (38 - 55)	841 (768 - 927)	886 (812 - 971)
2005/06	30 (26 - 37)	692 (634 - 766)	722 (663 - 797)
2006/07	25 (21 - 33)	676 (621 - 747)	701 (647 - 772)
2007/08	33 (27 - 45)	786 (723 - 863)	818 (753 - 900)
2008/09	33 (27 - 48)	802 (733 - 883)	836 (765 - 919)
2009/10	39 (32 - 54)	848 (771 - 940)	888 (810 - 992)
2010/11	37 (31 - 56)	798 (726 - 880)	836 (764 - 922)
2011/12	42 (34 - 58)	769 (702 - 847)	812 (741 - 893)
2012/13	17 (14 - 31)	738 (674 - 816)	757 (691 - 835)
2013/14	50 (40 - 80)	871 (798 - 968)	922 (847 - 1 030)
2014/15	32 (25 - 49)	887 (813 - 983)	920 (846 - 1 022)
2015/16	48 (40 - 64)	824 (752 - 909)	873 (800 - 962)
2016/17	70 (57 - 96)	880 (804 - 962)	951 (871 - 1 033)
2017/18	53 (44 - 72)	946 (866 - 1 045)	1 000 (917 - 1 108)
2018/19	63 (53 - 85)	782 (713 - 877)	848 (775 - 943)

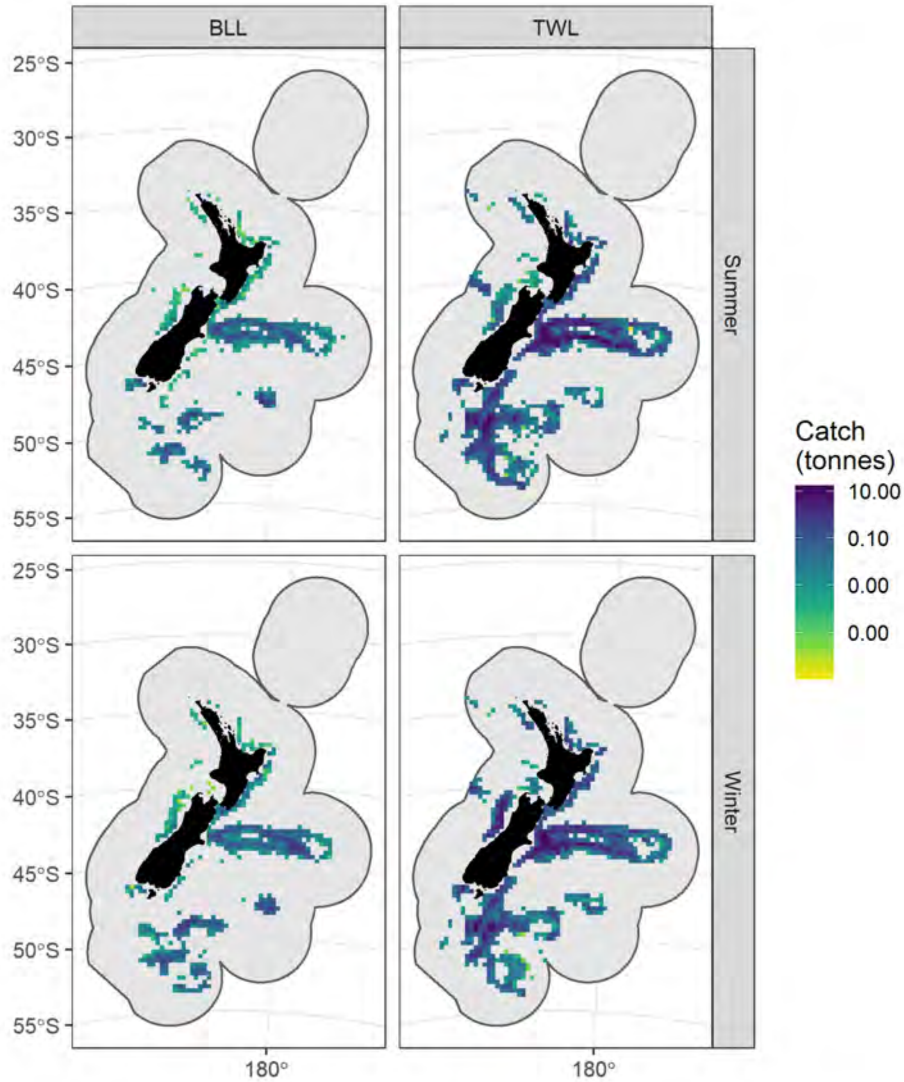


Figure S119: Posterior prediction of the total catches by grid cell, method and season for pale ghost shark. Average annual catches per season were calculated as the sum across gear types per cell and method. Posterior median values are shown, with catches in tonnes on a log10 scale.

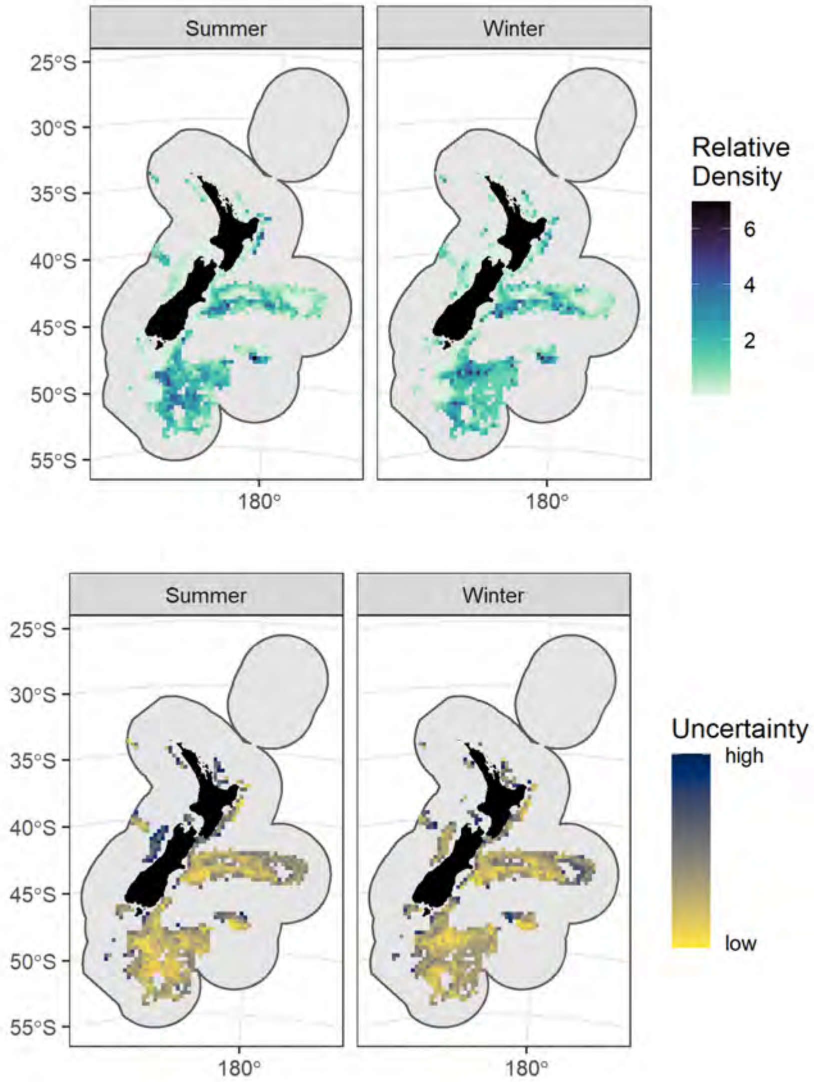


Figure S120: Posterior prediction of the relative density per grid cell and season for pale ghost shark. Posterior median values are shown on a natural scale in tonnes per square kilometre. Uncertainty is measured using the difference between the upper and lower 95% equal-tailed posterior density interval.

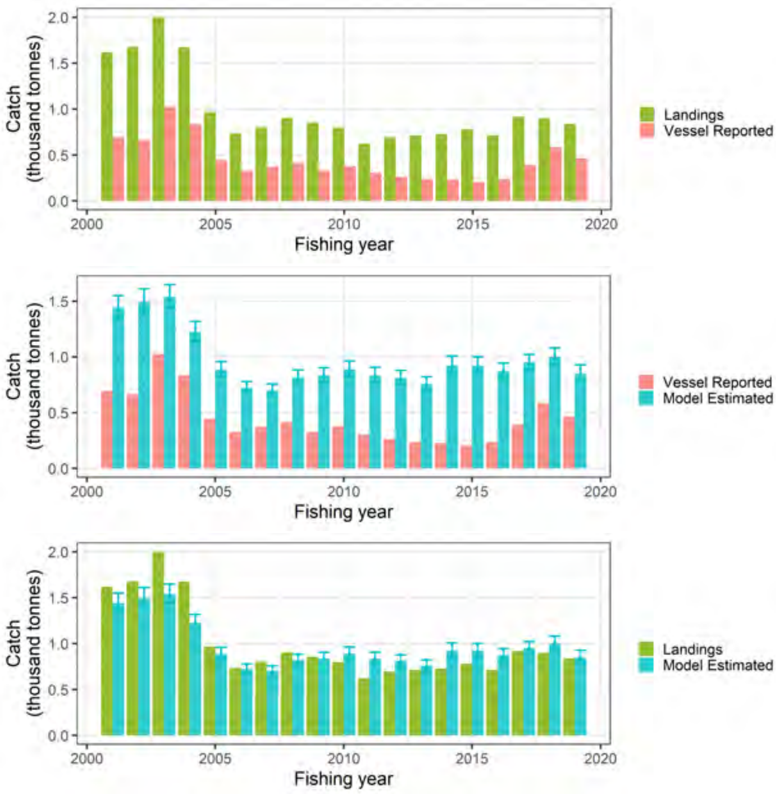


Figure S121: Relationships between landings, vessel reported catches and model estimated catches for pale ghost shark.

S2.12 Gemfish (*Rexea solandri*)

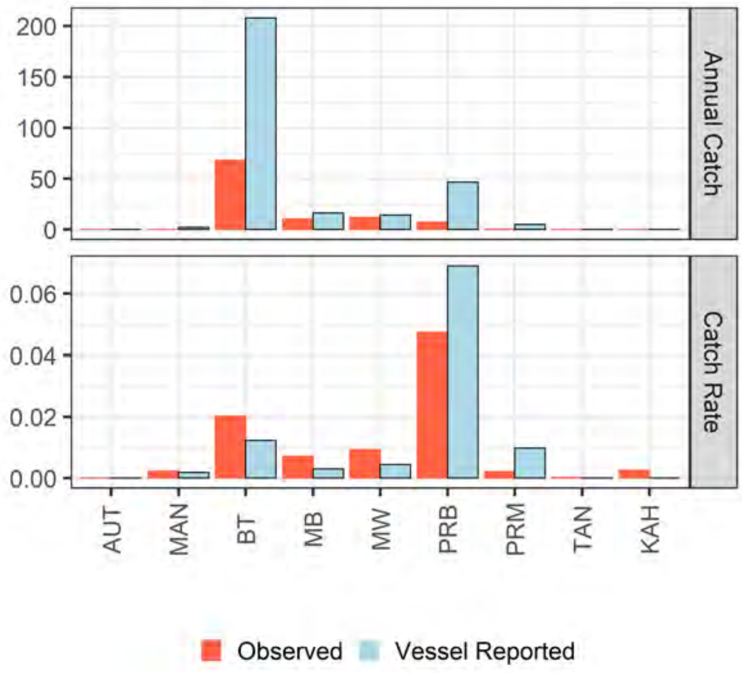


Figure S122: Empirical catch and catch rate data per gear type for gemfish. Annual catch is given in tonnes as an average across years. The catch rate is an average calculated as the sum of the observed catch in kilograms (i.e., $\sum X_i$) over the sum of the effort count (number of fishing events). Effort was calculated as a count to allow comparability between methods. There are no vessel reported catches for TAN and KAH surveys.

Table S36: Summary data for gemfish across 320 grid cells, removing 209 024 commercial events that were outside the selected cells. The total landings associated with retained commercial effort equal 10 695 tonnes. Catch is in units of tonnes, effort in the number of fishing events. "Obs." is observed; "Com." is commercial.

Method	Gear	Obs. catch	Obs. effort	Com. catch	Com. effort
BLL	AUT	0	2 688	1	18 172
BLL	MAN	2	770	42	22 240
TWL	BT	1 298	64 104	3 951	320 780
TWL	MB	200	27 960	308	102 136
TWL	MW	226	24 147	272	61 656
TWL	PRB	37	788	187	2 703
TWL	PRM	1	389	20	2 045
TWL	TAN	0	1 671		
TWL	KAH	2	866		
Total		1 766	123 383	4 780	529 732

Table S37: Model selection summary statistics for gemfish. Model 5 was selected for prediction of the catches.

Model	$\mathbb{L}[X]$	MPE	L^2	WAIC	$\hat{R}(\alpha)$	$\hat{R}(\gamma)$	$\hat{R}(\pi)$	DRE
1	-0.036	0.033	0.081	1092.098	1.001	1.002	1.002	1.857
2	-0.037	0.033	0.096	1114.129	1.001	1.012	1.012	1.964
3	-0.036	0.033	0.124	1117.266	1.005	1.006	1.007	1.861
4	-0.037	0.033	0.089	1116.123	1.010	1.009	1.007	1.875
5	-0.037	0.033	0.123	1117.560	1.016	1.014	1.012	1.867
6	-0.037	0.033	0.099	1117.531	1.012	1.009	1.008	1.876

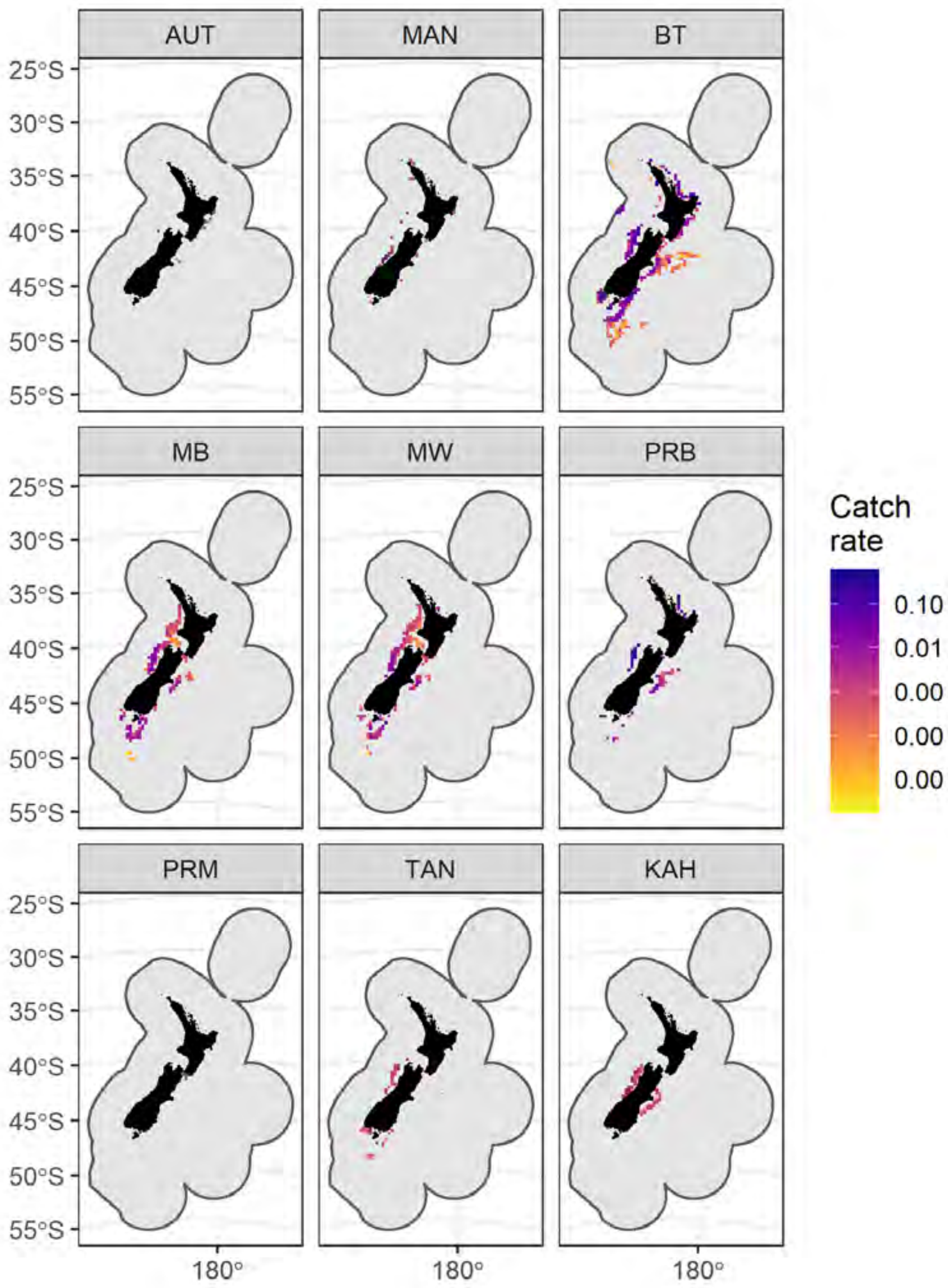


Figure S123: Observer catch rate data for gemfish on a log10-scale. The catch rate is an average calculated as the sum of the observed catch $\sum X_i$ over the number of observed fishing events per grid cell and gear type. Effort was calculated as a count to allow comparability between methods.

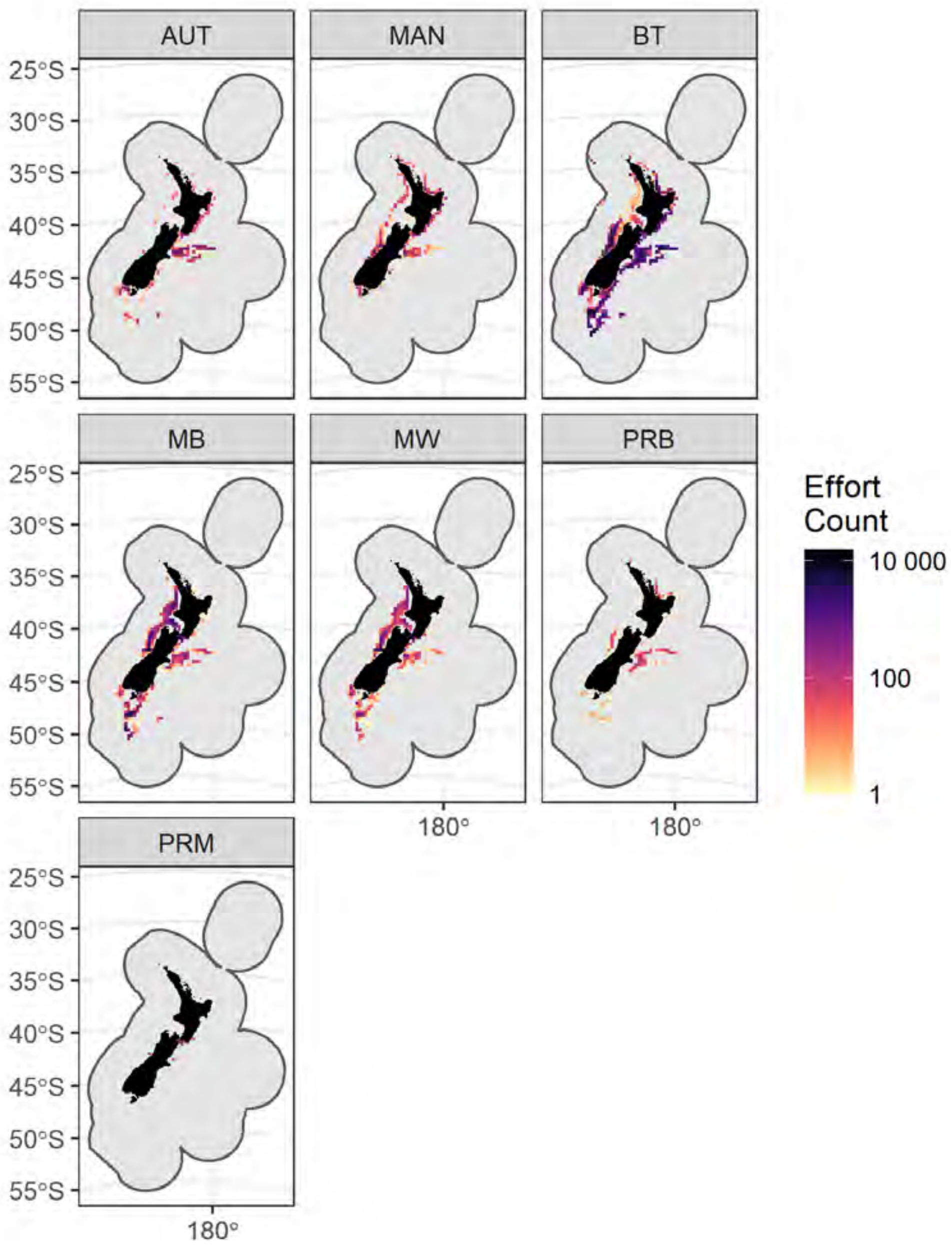


Figure S124: Commercial fishing effort (number of events) for gemfish summed across all years and presented on a log10-scale per grid cell and gear type. Effort was calculated as a count to allow comparability between methods.

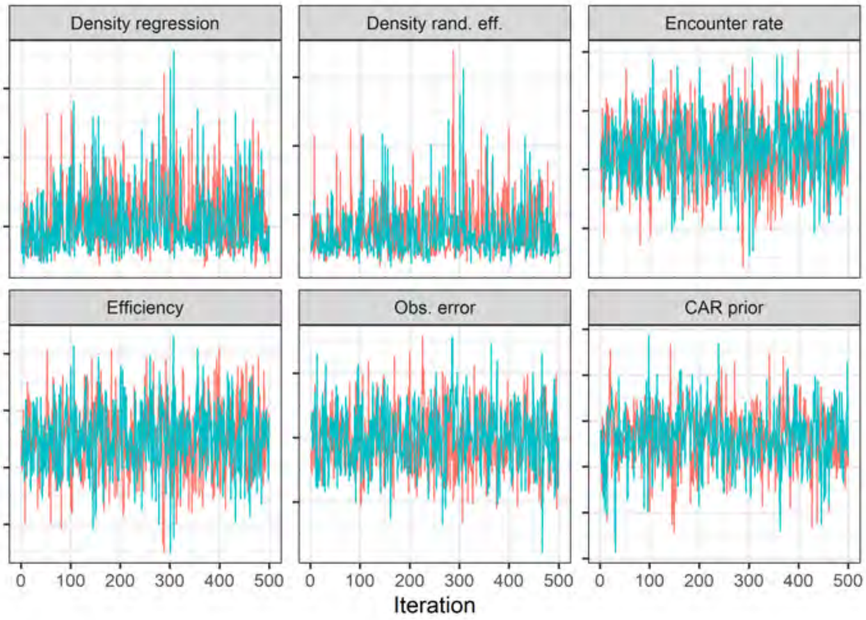


Figure S125: Posterior density sample traces for gemfish, for the regression coefficients $||\boldsymbol{\alpha}||$, random effects $||\boldsymbol{\phi}||$, encounter rate $||\boldsymbol{\gamma}||$, efficiency $||\boldsymbol{\pi}||$, observation error $||\boldsymbol{\sigma}||$ and conditional autoregressive prior parameters $||\tau, \rho||$. Colours represent independent sample chains.

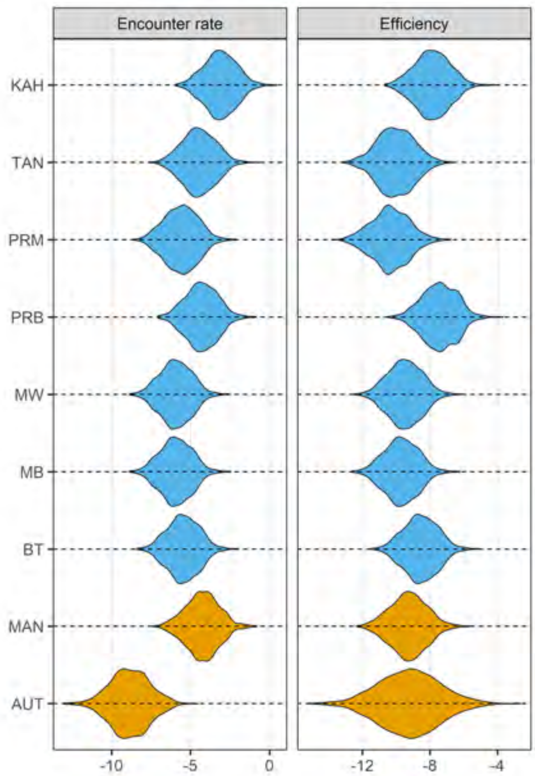


Figure S126: Violin plots of the posterior density for the encounter rate (γ_j) and the efficiency (π_j) per gear type for gemfish. Catchability terms for bottom longline gear types (see Table S2) are presented in a different colour as they are not comparable to the trawl gear types because they are dependent on different measures of effort (i.e., thousand hooks and distance, respectively).

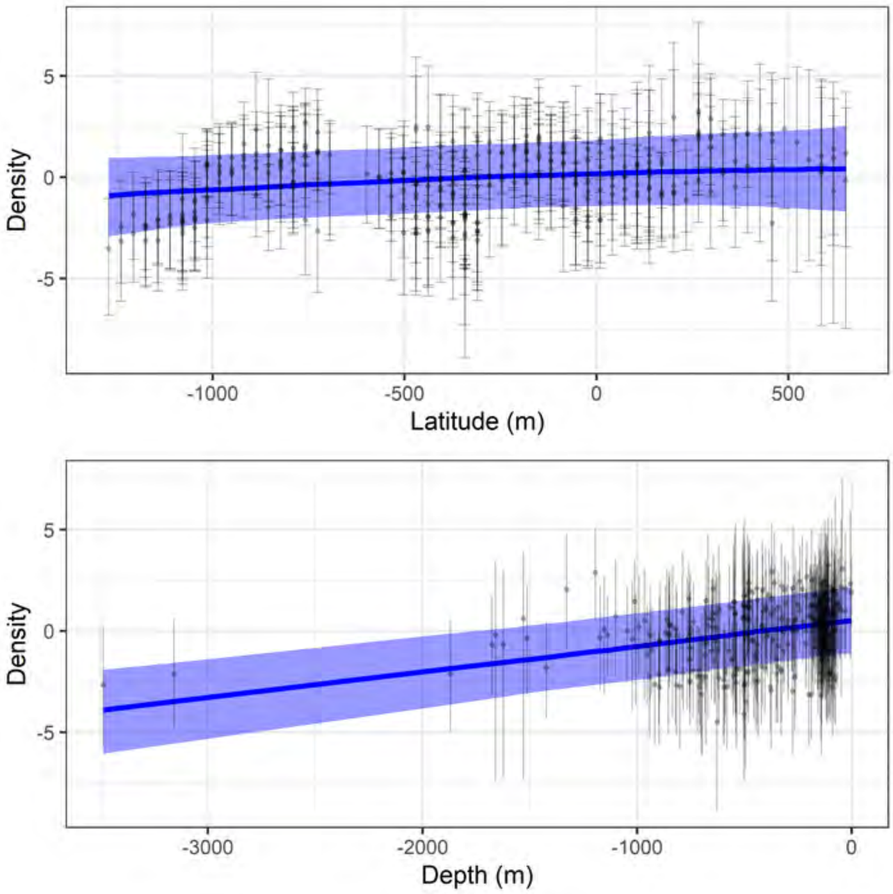


Figure S127: Estimated relationship between biomass density per grid cell and environmental covariates for gemfish. Points and error bars show the median and 90% credibility intervals per cell. The blue ribbon shows the estimated marginal relationship.

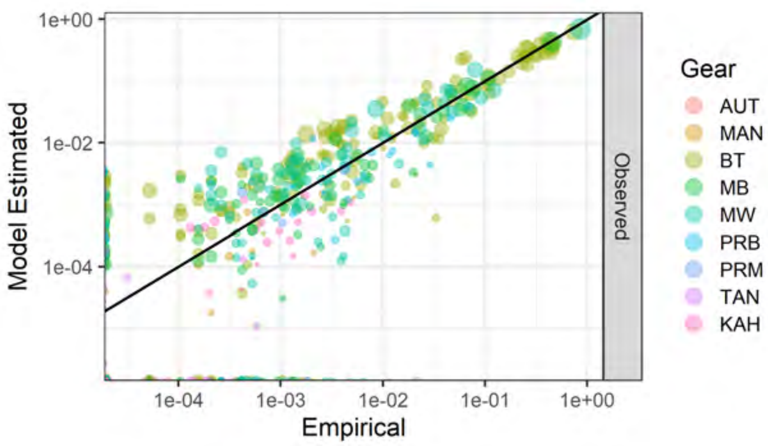


Figure S128: Fit of model to empirical observer catches. Total catches are summed per grid cell and gear type for gemfish. Model estimates are the median of the posterior predicted distribution. The size of the point is representative of the number of observed events. Catches are shown in tonnes on a log10 scale.

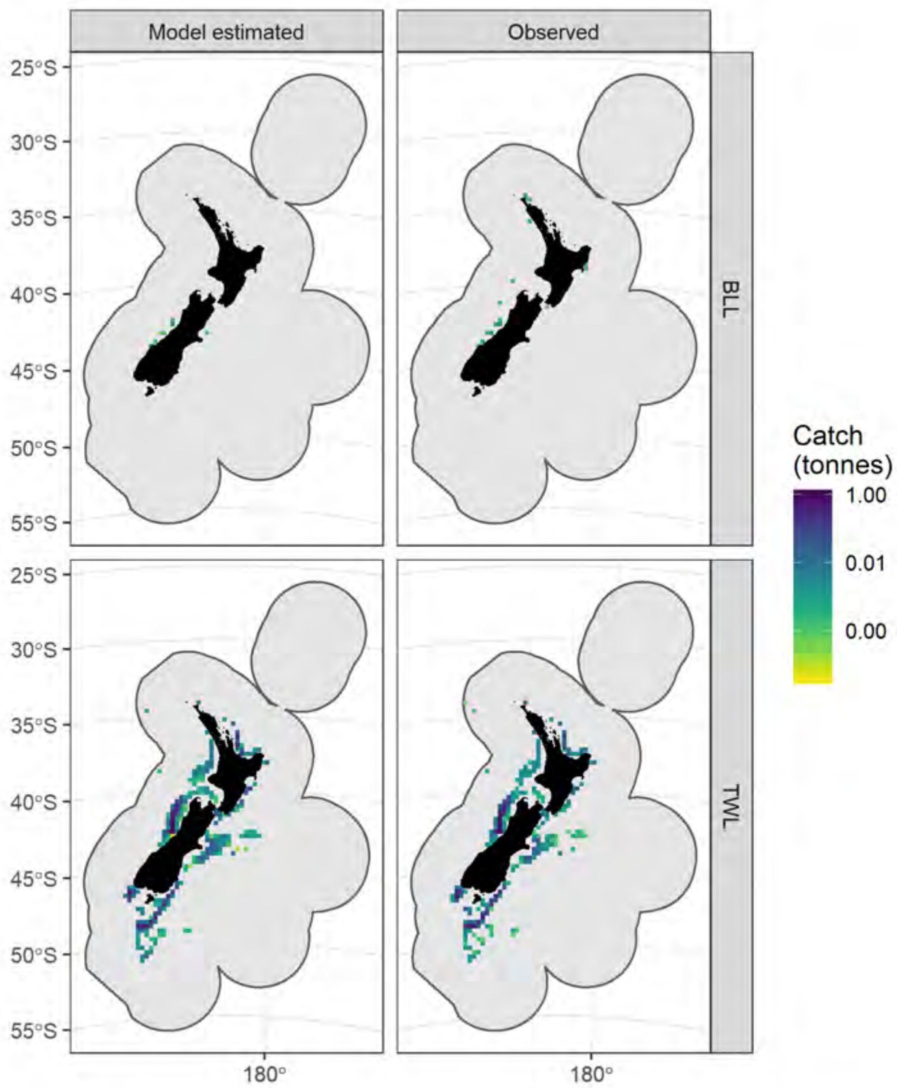


Figure S129: Spatial fit of model to empirical observer catches by grid cell and method for gemfish. Average annual catches were calculated as the sum across gear types per cell and method. Posterior median values are shown, with catches in tonnes on a log10 scale.

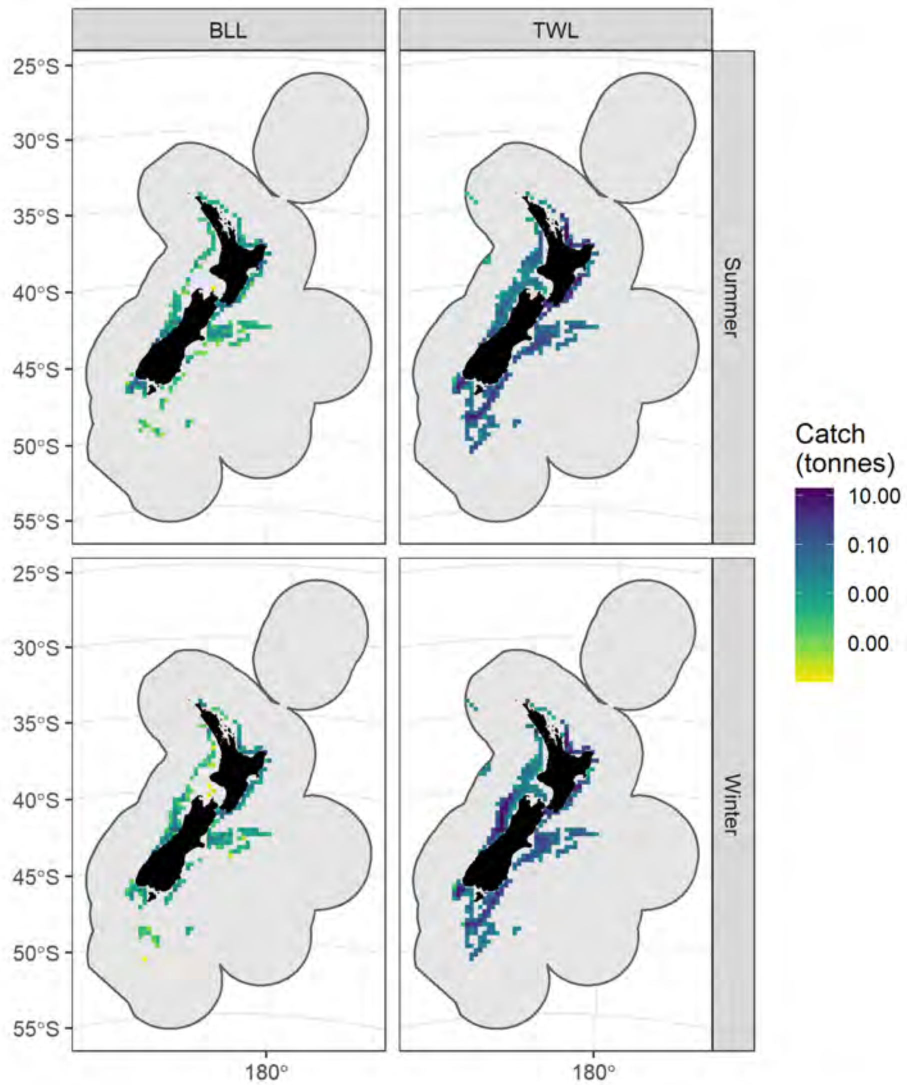


Figure S130: Posterior prediction of the total catches by grid cell, method and season for gemfish. Average annual catches per season were calculated as the sum across gear types per cell and method. Posterior median values are shown, with catches in tonnes on a log10 scale.

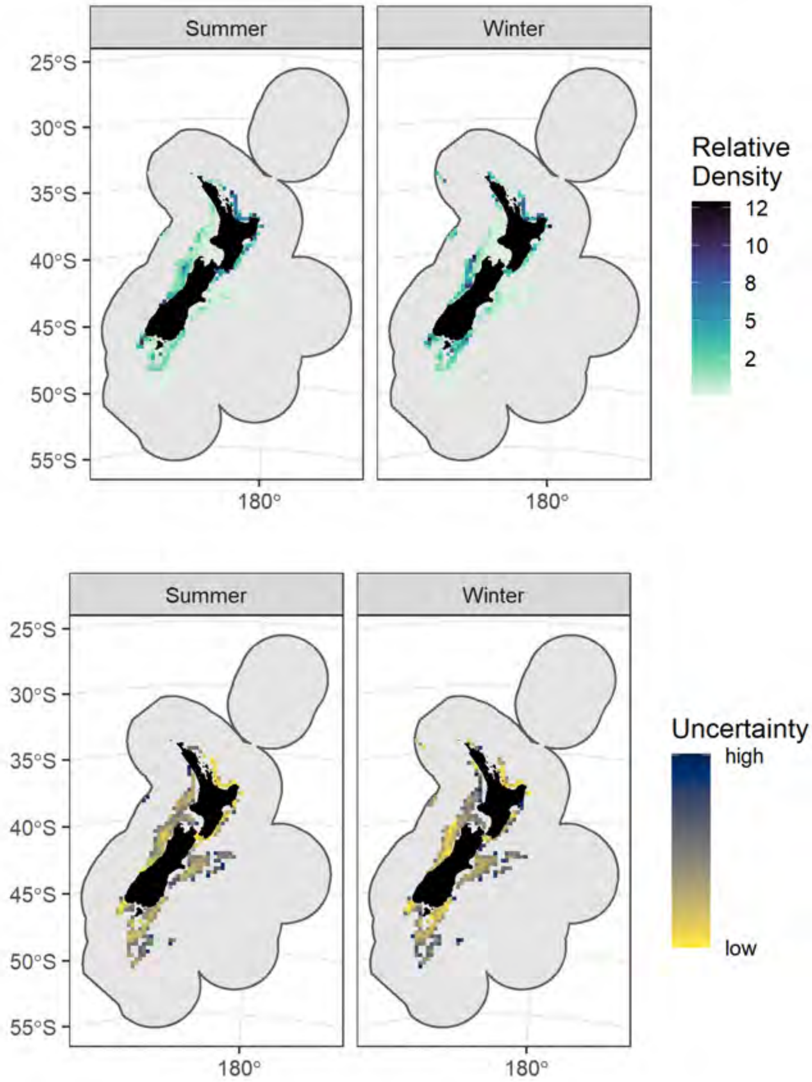


Figure S131: Posterior prediction of the relative density per grid cell and season for gemfish. Posterior median values are shown on a natural scale in tonnes per square kilometre. Uncertainty is measured using the difference between the upper and lower 95% equal-tailed posterior density interval.

Table S38: Total predicted bycatch (tonnes) per method for gemfish. Posterior median values are given, with the 95% equal-tailed credibility intervals in brackets.

Fishing year	BLL	TWL	Total
2000/01	2 (0 - 46)	463 (421 - 543)	469 (425 - 573)
2001/02	1 (0 - 29)	511 (463 - 601)	516 (465 - 630)
2002/03	1 (0 - 15)	561 (497 - 1 031)	563 (499 - 1 033)
2003/04	2 (0 - 39)	391 (352 - 489)	397 (355 - 544)
2004/05	3 (0 - 58)	378 (341 - 437)	386 (345 - 474)
2005/06	3 (0 - 51)	376 (339 - 437)	383 (341 - 463)
2006/07	3 (0 - 58)	269 (242 - 310)	276 (245 - 335)
2007/08	8 (2 - 169)	276 (242 - 341)	289 (250 - 528)
2008/09	5 (1 - 85)	295 (257 - 446)	303 (263 - 565)
2009/10	4 (1 - 127)	423 (368 - 560)	430 (372 - 639)
2010/11	6 (2 - 125)	378 (331 - 767)	386 (336 - 859)
2011/12	4 (2 - 37)	315 (276 - 498)	320 (280 - 535)
2012/13	4 (2 - 50)	330 (289 - 540)	336 (293 - 579)
2013/14	5 (2 - 64)	362 (316 - 480)	372 (322 - 534)
2014/15	6 (2 - 89)	376 (327 - 541)	385 (333 - 610)
2015/16	6 (2 - 93)	369 (320 - 490)	379 (326 - 584)
2016/17	6 (2 - 106)	419 (367 - 489)	429 (374 - 562)
2017/18	5 (2 - 36)	450 (393 - 532)	457 (397 - 556)
2018/19	6 (2 - 48)	403 (356 - 470)	411 (363 - 506)

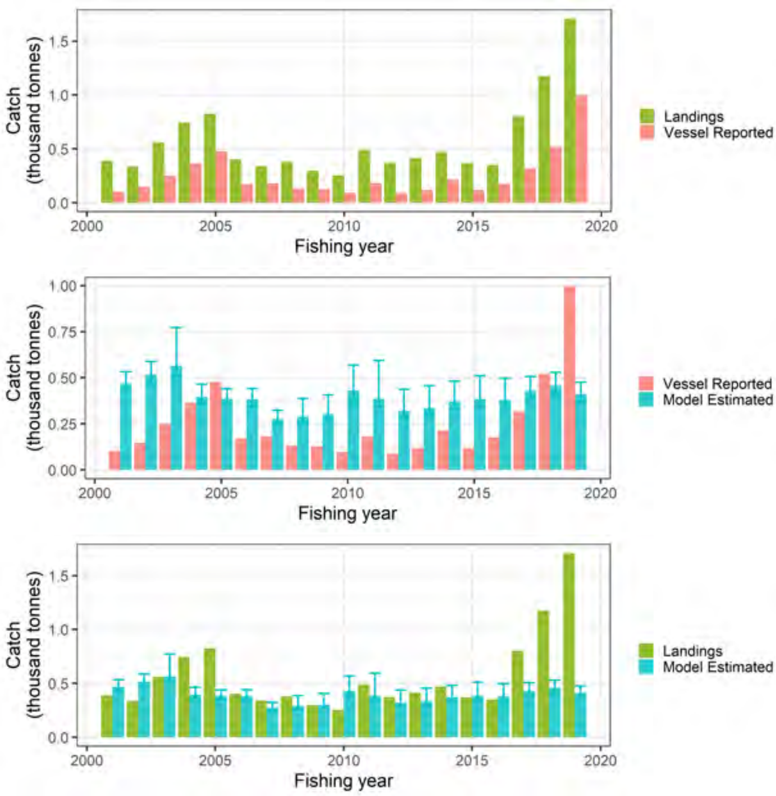


Figure S132: Relationships between landings, vessel reported catches and model estimated catches for gemfish.

S2.13 Ghost shark (*Hydrolagus novaezealandiae*)

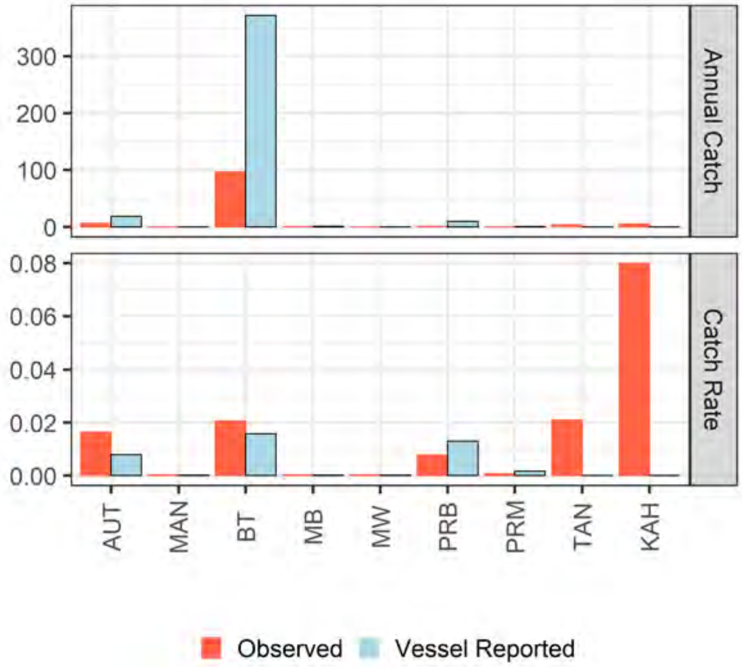


Figure S133: Empirical catch and catch rate data per gear type for ghost shark. Annual catch is given in tonnes as an average across years. The catch rate is an average calculated as the sum of the observed catch in kilograms (i.e., $\sum X_i$) over the sum of the effort count (number of fishing events). Effort was calculated as a count to allow comparability between methods. There are no vessel reported catches for TAN and KAH surveys.

Table S39: Summary data for ghost shark across 591 grid cells, removing 48 445 commercial events that were outside the selected cells. The total landings associated with retained commercial effort equal 16 159 tonnes. Catch is in units of tonnes, effort in the number of fishing events. "Obs." is observed; "Com." is commercial.

Method	Gear	Obs. catch	Obs. effort	Com. catch	Com. effort
BLL	AUT	120	7 301	359	45 511
BLL	MAN	0	693	2	19 836
TWL	BT	1 837	89 061	7 053	446 290
TWL	MB	10	30 345	22	108 279
TWL	MW	6	27 858	8	65 294
TWL	PRB	7	838	40	3 038
TWL	PRM	0	404	3	2 063
TWL	TAN	76	3 591		
TWL	KAH	84	1 047		
Total		2 139	161 138	7 487	690 311

Table S40: Model selection summary statistics for ghost shark. Model 4 was selected for prediction of the catches.

Model	$\mathbb{L}[X]$	MPE	L^2	WAIC	$\hat{R}(\alpha)$	$\hat{R}(\gamma)$	$\hat{R}(\pi)$	DRE
1	-0.021	0.029	0.076	4112.113	1.002	1.022	1.021	1.758
2	-0.021	0.029	0.076	4141.564	1.011	1.012	1.011	1.847
3	-0.020	0.029	0.076	4140.917	1.003	1.003	1.002	1.697
4	-0.020	0.029	0.077	4144.302	1.016	1.023	1.023	1.674
5	-0.020	0.030	0.083	4141.381	1.009	1.004	1.005	1.690
6	-0.020	0.029	0.090	4144.889	1.002	1.011	1.011	1.681

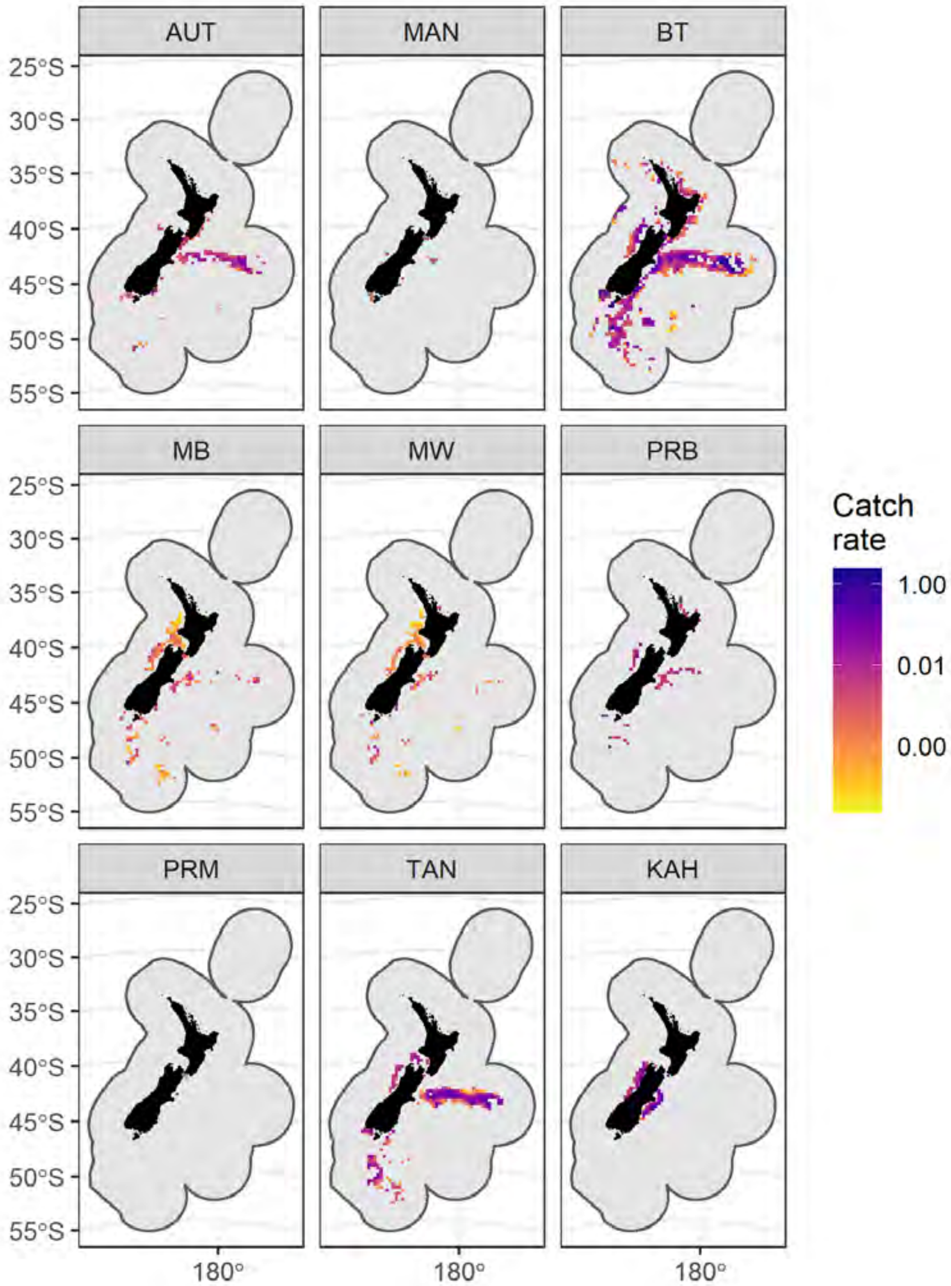


Figure S134: Observer catch rate data for ghost shark on a log10-scale. The catch rate is an average calculated as the sum of the observed catch $\sum X_i$ over the number of observed fishing events per grid cell and gear type. Effort was calculated as a count to allow comparability between methods.

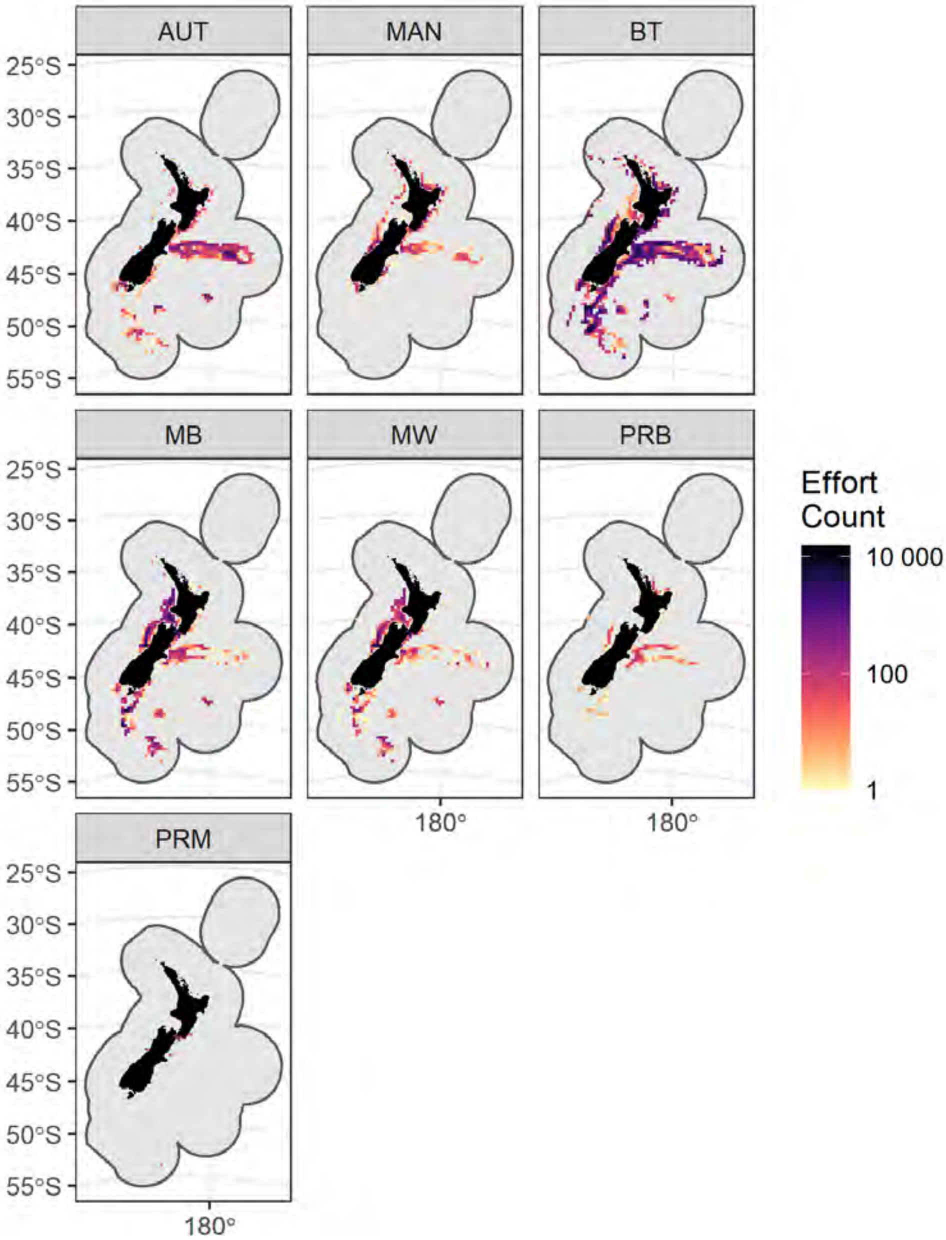


Figure S135: Commercial fishing effort (number of events) for ghost shark summed across all years and presented on a log10-scale per grid cell and gear type. Effort was calculated as a count to allow comparability between methods.

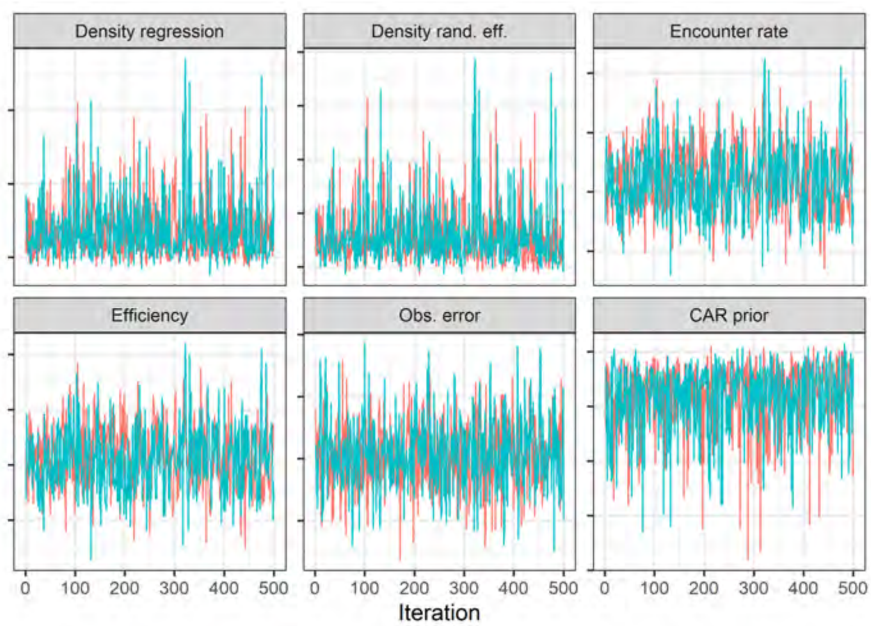


Figure S136: Posterior density sample traces for ghost shark, for the regression coefficients $||\boldsymbol{\alpha}||$, random effects $||\boldsymbol{\phi}||$, encounter rate $||\boldsymbol{\gamma}||$, efficiency $||\boldsymbol{\pi}||$, observation error $||\boldsymbol{\sigma}||$ and conditional autoregressive prior parameters $||\tau, \rho||$. Colours represent independent sample chains.

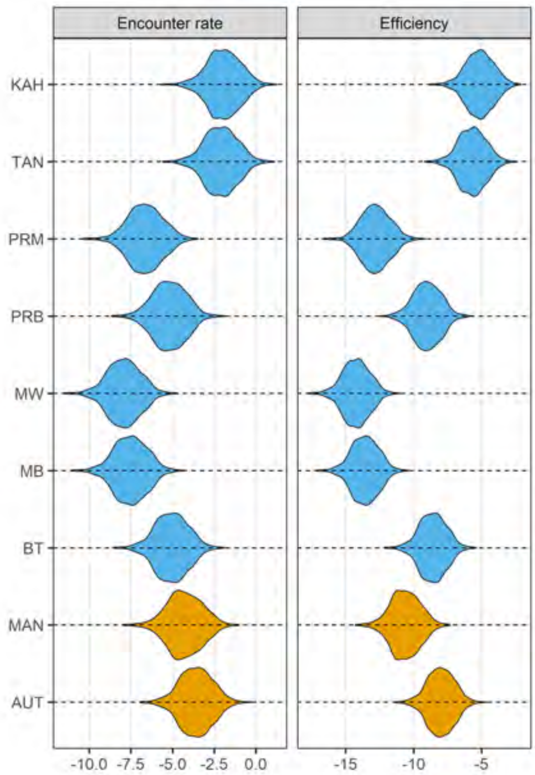


Figure S137: Violin plots of the posterior density for the encounter rate (γ_j) and the efficiency (π_j) per gear type for ghost shark. Catchability terms for bottom longline gear types (see Table S2) are presented in a different colour as they are not comparable to the trawl gear types because they are dependent on different measures of effort (i.e., thousand hooks and distance, respectively).

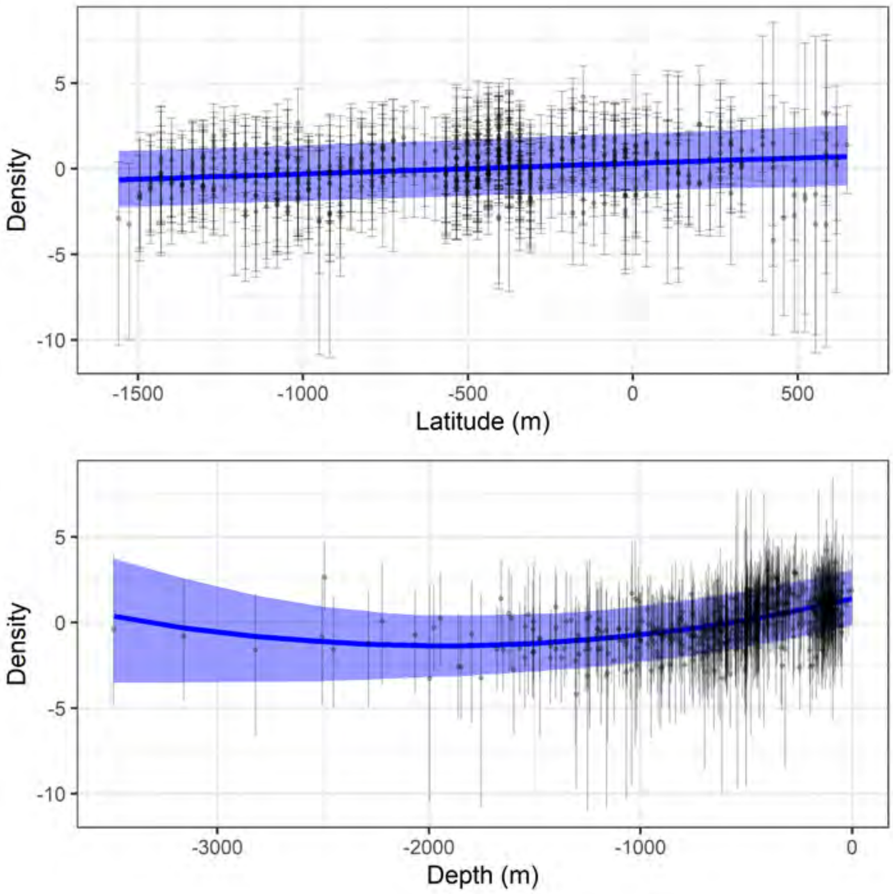


Figure S138: Estimated relationship between biomass density per grid cell and environmental covariates for ghost shark. Points and error bars show the median and 90% credibility intervals per cell. The blue ribbon shows the estimated marginal relationship.

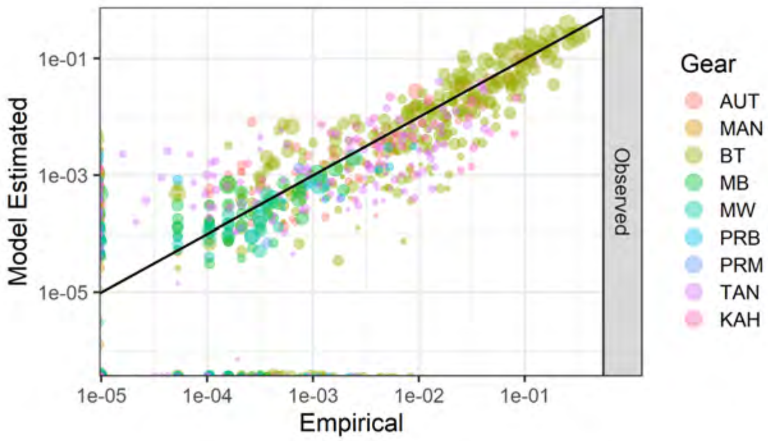


Figure S139: Fit of model to empirical observer catches. Total catches are summed per grid cell and gear type for ghost shark. Model estimates are the median of the posterior predicted distribution. The size of the point is representative of the number of observed events. Catches are shown in tonnes on a log10 scale.

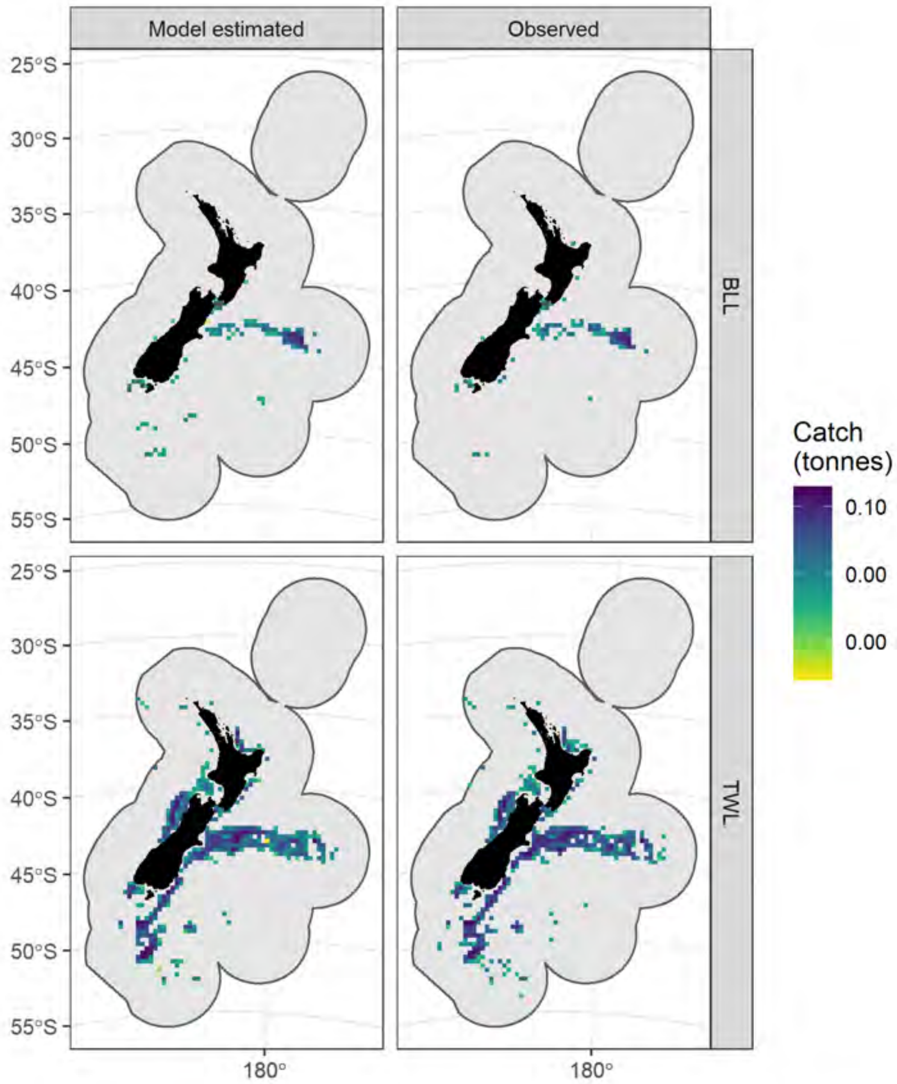


Figure S140: Spatial fit of model to empirical observer catches by grid cell and method for ghost shark. Average annual catches were calculated as the sum across gear types per cell and method. Posterior median values are shown, with catches in tonnes on a log10 scale.

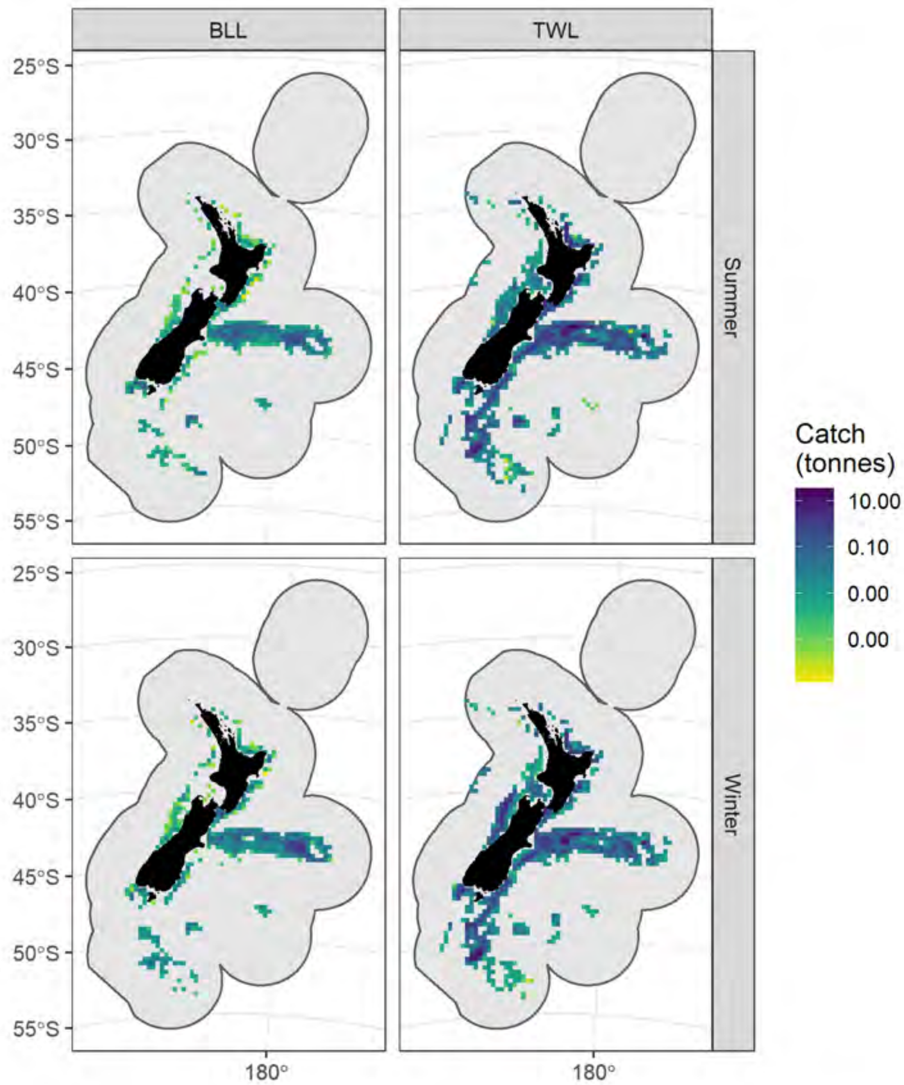


Figure S141: Posterior prediction of the total catches by grid cell, method and season for ghost shark. Average annual catches per season were calculated as the sum across gear types per cell and method. Posterior median values are shown, with catches in tonnes on a log10 scale.

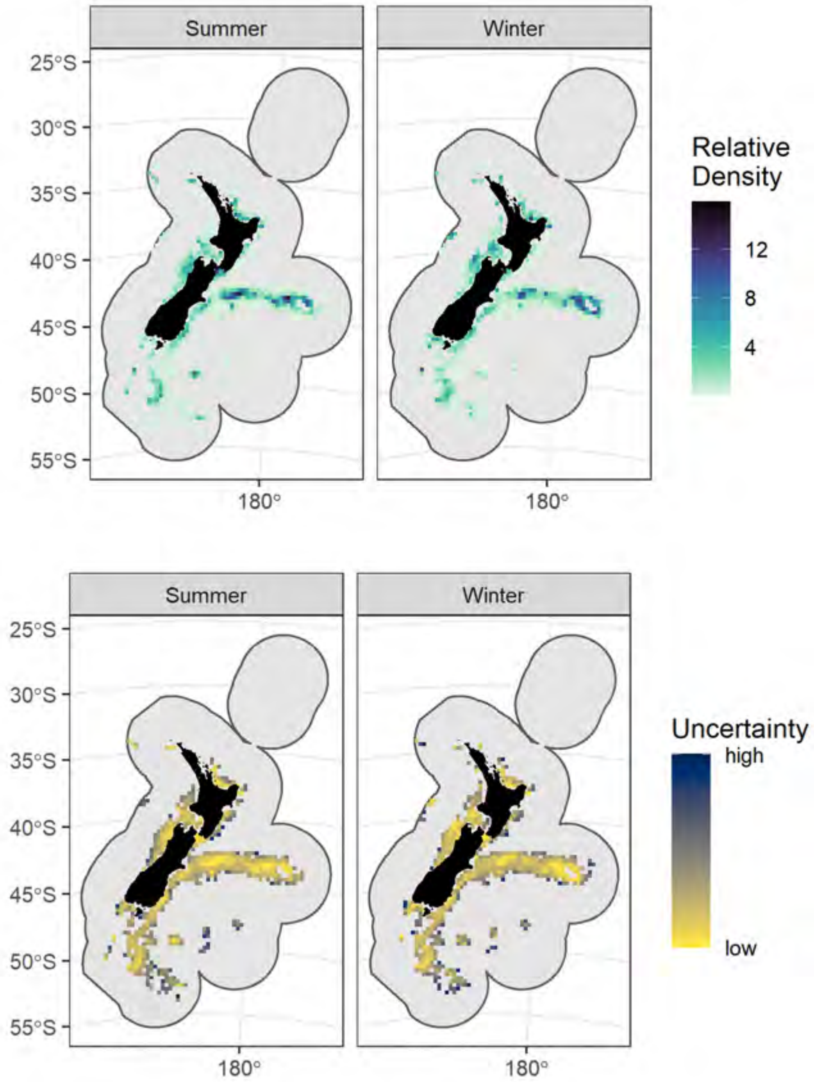


Figure S142: Posterior prediction of the relative density per grid cell and season for ghost shark. Posterior median values are shown on a natural scale in tonnes per square kilometre. Uncertainty is measured using the difference between the upper and lower 95% equal-tailed posterior density interval.

Table S41: Total predicted bycatch (tonnes) per method for ghost shark. Posterior median values are given, with the 95% equal-tailed credibility intervals in brackets.

Fishing year	BLL	TWL	Total
2000/01	31 (26 - 37)	395 (354 - 959)	426 (384 - 992)
2001/02	28 (24 - 34)	408 (365 - 537)	437 (393 - 567)
2002/03	21 (17 - 26)	430 (380 - 1 930)	452 (402 - 1 951)
2003/04	27 (22 - 33)	366 (326 - 521)	392 (351 - 549)
2004/05	26 (21 - 32)	368 (331 - 638)	394 (355 - 665)
2005/06	22 (18 - 27)	416 (366 - 2 456)	437 (388 - 2 478)
2006/07	19 (16 - 23)	409 (358 - 638)	428 (378 - 655)
2007/08	25 (20 - 375)	489 (430 - 772)	516 (455 - 1 354)
2008/09	24 (20 - 30)	456 (400 - 565)	480 (425 - 590)
2009/10	26 (21 - 38)	534 (456 - 3 441)	559 (481 - 3 466)
2010/11	23 (19 - 513)	511 (450 - 1 806)	538 (474 - 2 752)
2011/12	23 (19 - 73)	572 (504 - 1 383)	596 (527 - 1 436)
2012/13	19 (16 - 24)	518 (454 - 2 039)	537 (473 - 2 064)
2013/14	20 (16 - 76)	561 (488 - 1 763)	579 (508 - 2 045)
2014/15	29 (23 - 37)	579 (499 - 934)	608 (527 - 965)
2015/16	38 (32 - 48)	627 (539 - 1 320)	665 (575 - 1 360)
2016/17	33 (27 - 42)	566 (494 - 1 389)	599 (528 - 1 426)
2017/18	30 (25 - 75)	517 (456 - 1 093)	547 (485 - 1 171)
2018/19	23 (19 - 166)	551 (483 - 1 991)	575 (508 - 3 384)

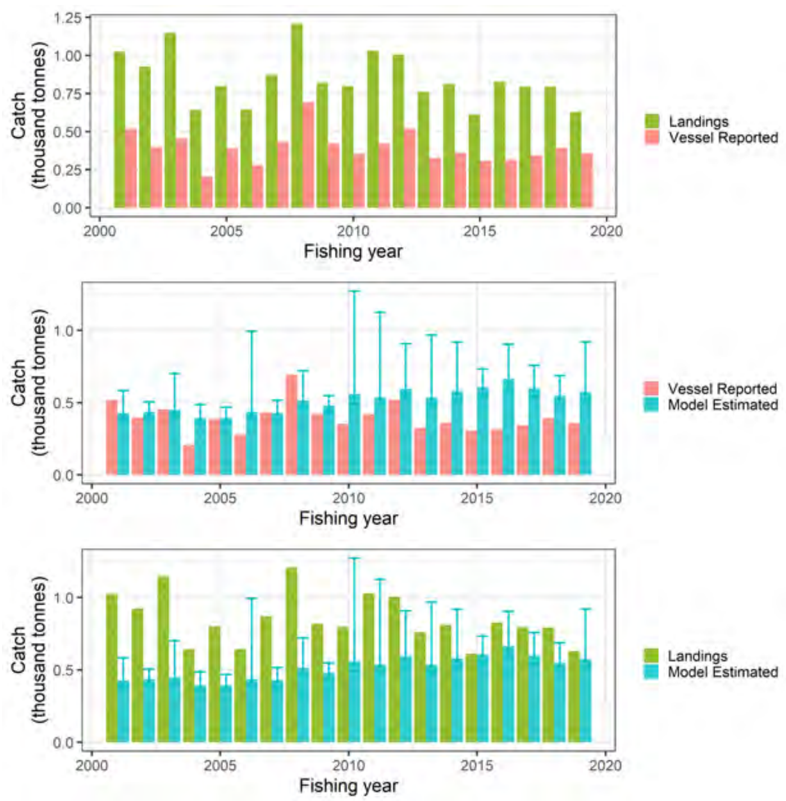


Figure S143: Relationships between landings, vessel reported catches and model estimated catches for ghost shark.

S2.14 Silver dory (*Cyttus novaezealandiae*)

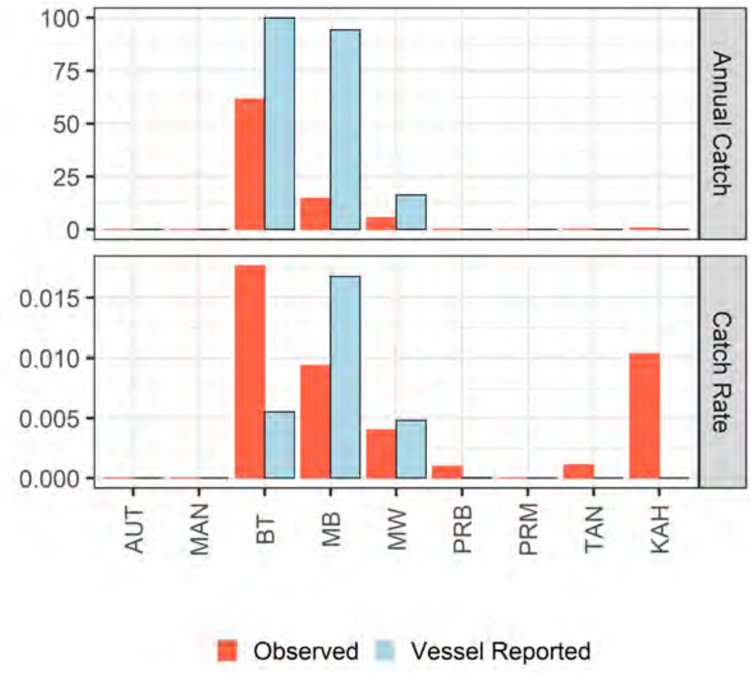


Figure S144: Empirical catch and catch rate data per gear type for silver dory. Annual catch is given in tonnes as an average across years. The catch rate is an average calculated as the sum of the observed catch in kilograms (i.e., $\sum X_i$) over the sum of the effort count (number of fishing events). Effort was calculated as a count to allow comparability between methods. There are no vessel reported catches for TAN and KAH surveys.

Table S42: Summary data for silver dory across 383 grid cells, removing 165 831 commercial events that were outside the selected cells. The total landings associated with retained commercial effort equal 7 803 tonnes. Catch is in units of tonnes, effort in the number of fishing events. "Obs." is observed; "Com." is commercial.

Method	Gear	Obs. catch	Obs. effort	Com. catch	Com. effort
BLL	AUT	0	6 429	0	38 576
BLL	MAN	0	602	0	14 483
TWL	BT	1 170	66 313	1 897	344 202
TWL	MB	279	29 732	1 791	106 714
TWL	MW	108	26 740	310	64 315
TWL	PRB	1	720	0	2 598
TWL	PRM	0	402	0	2 037
TWL	TAN	3	2 399		
TWL	KAH	12	1 172		
Total		1 573	134 509	3 998	572 925

Table S43: Model selection summary statistics for silver dory. Model 4 was selected for prediction of the catches.

Model	$\mathbb{L}[X]$	MPE	L^2	WAIC	$\hat{R}(\alpha)$	$\hat{R}(\gamma)$	$\hat{R}(\pi)$	DRE
1	-0.039	0.025	0.066	4990.642	1.008	1.007	1.008	1.860
2	-0.039	0.025	0.069	5037.486	1.003	1.016	1.016	2.000
3	-0.039	0.025	0.080	5034.722	1.001	1.003	1.003	1.761
4	-0.039	0.025	0.070	5041.835	1.002	1.003	1.005	1.731
5	-0.039	0.025	0.065	5034.180	1.002	1.003	1.004	1.760
6	-0.039	0.025	0.070	5038.479	1.006	1.003	1.004	1.709

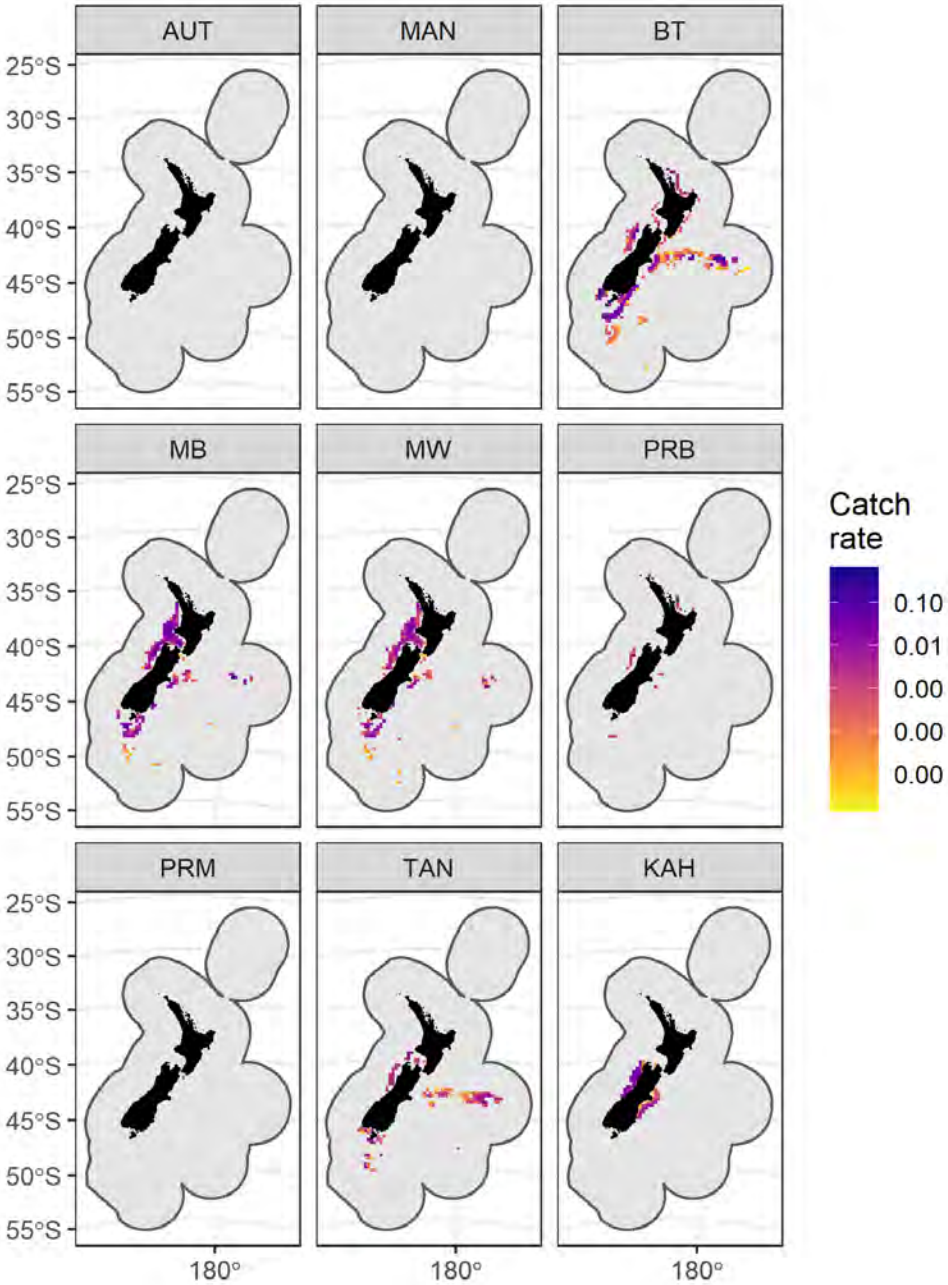


Figure S145: Observer catch rate data for silver dory on a log10-scale. The catch rate is an average calculated as the sum of the observed catch $\sum X_i$ over the number of observed fishing events per grid cell and gear type. Effort was calculated as a count to allow comparability between methods.

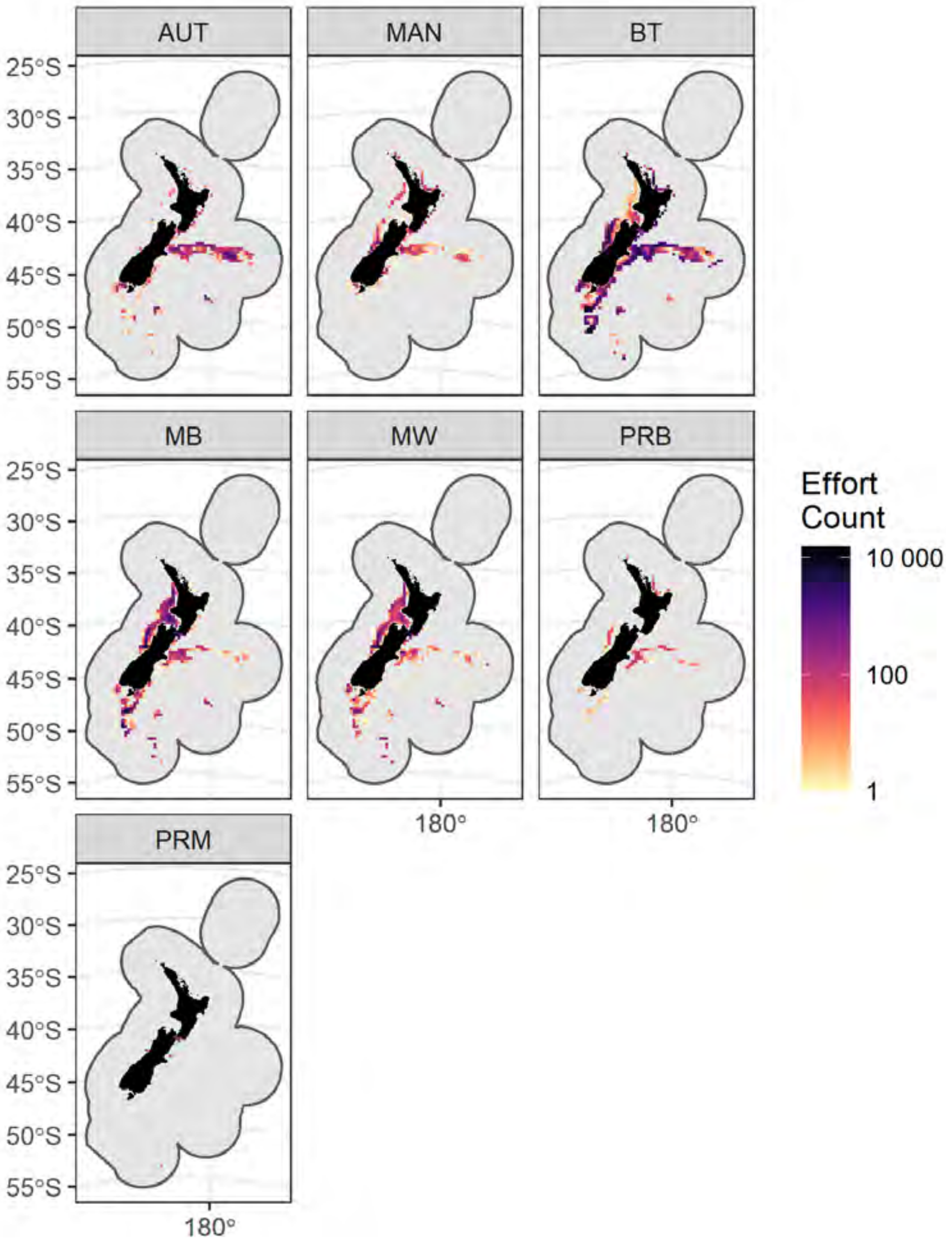


Figure S146: Commercial fishing effort (number of events) for silver dory summed across all years and presented on a log10-scale per grid cell and gear type. Effort was calculated as a count to allow comparability between methods.

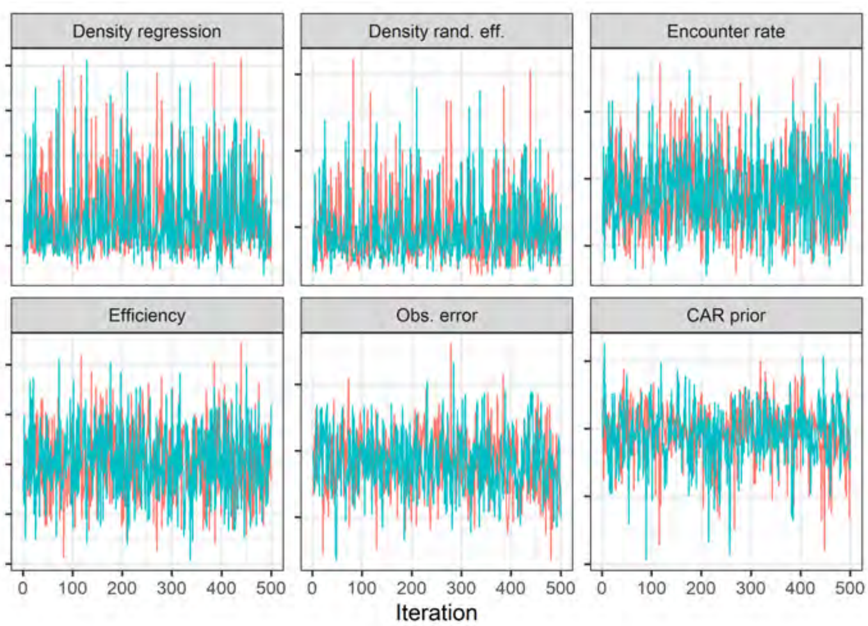


Figure S147: Posterior density sample traces for silver dory, for the regression coefficients $||\boldsymbol{\alpha}||$, random effects $||\boldsymbol{\phi}||$, encounter rate $||\boldsymbol{\gamma}||$, efficiency $||\boldsymbol{\pi}||$, observation error $||\boldsymbol{\sigma}||$ and conditional autoregressive prior parameters $||\tau, \rho||$. Colours represent independent sample chains.

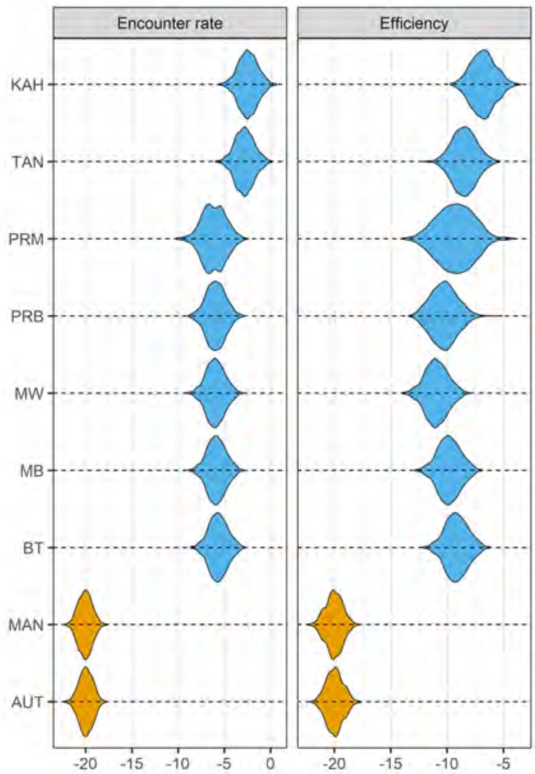


Figure S148: Violin plots of the posterior density for the encounter rate (γ_j) and the efficiency (π_j) per gear type for silver dory. Catchability terms for bottom longline gear types (see Table S2) are presented in a different colour as they are not comparable to the trawl gear types because they are dependent on different measures of effort (i.e., thousand hooks and distance, respectively).

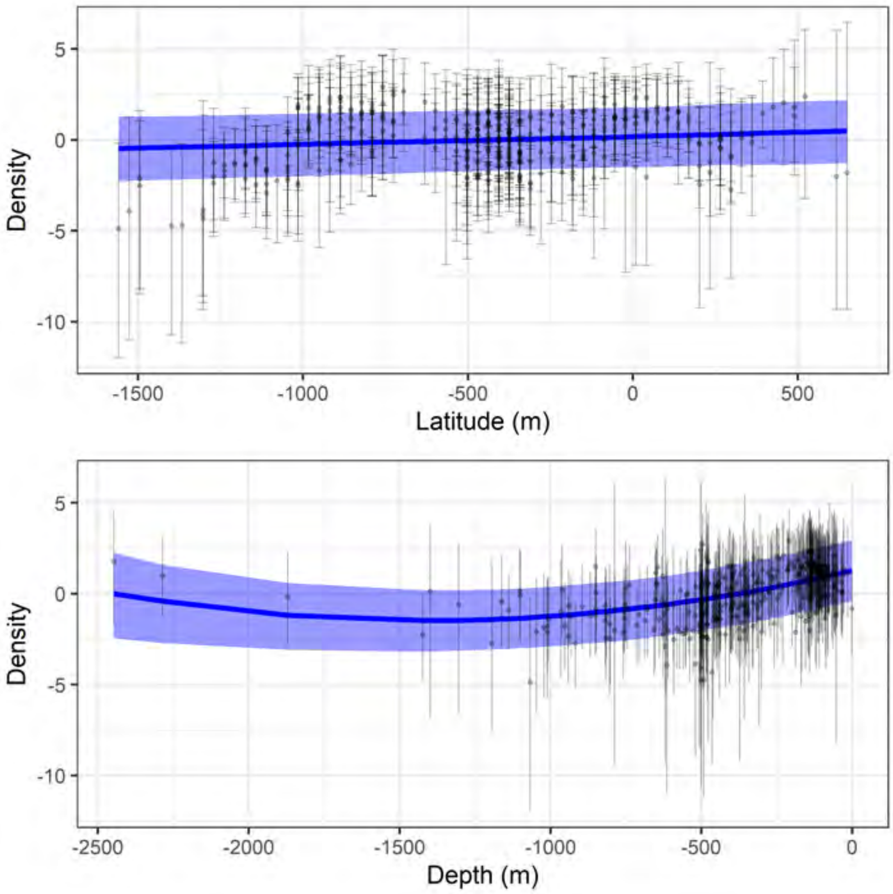


Figure S149: Estimated relationship between biomass density per grid cell and environmental covariates for silver dory. Points and error bars show the median and 90% credibility intervals per cell. The blue ribbon shows the estimated marginal relationship.

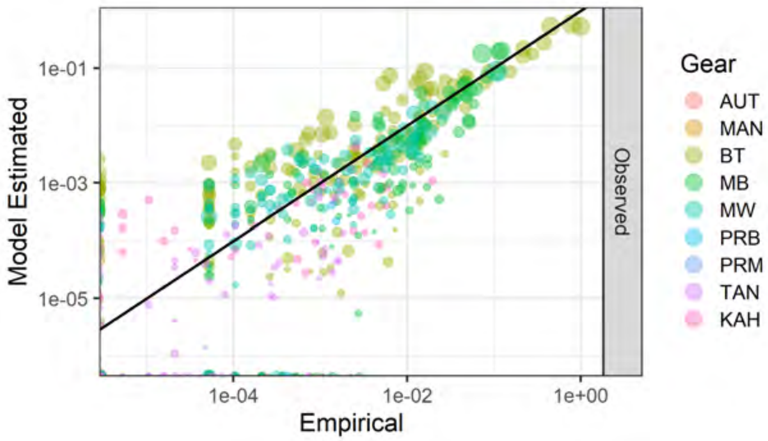


Figure S150: Fit of model to empirical observer catches. Total catches are summed per grid cell and gear type for silver dory. Model estimates are the median of the posterior predicted distribution. The size of the point is representative of the number of observed events. Catches are shown in tonnes on a log10 scale.

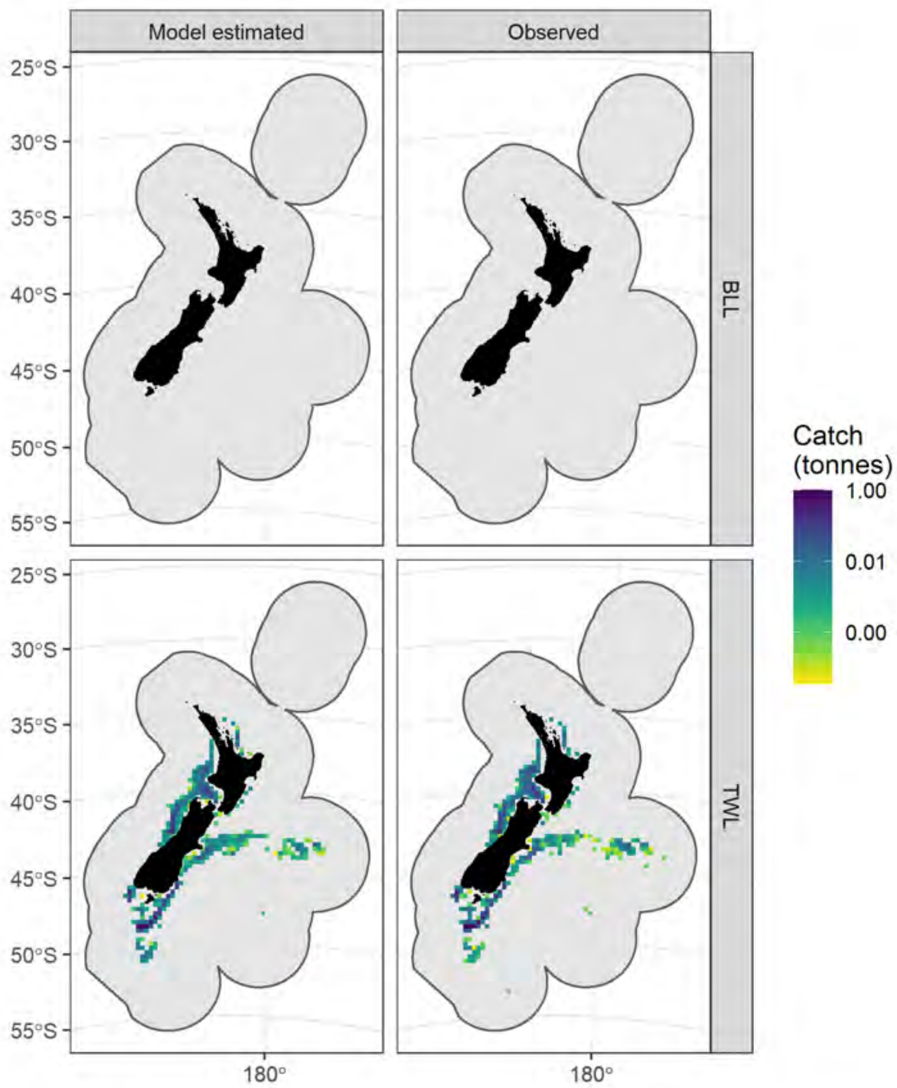


Figure S151: Spatial fit of model to empirical observer catches by grid cell and method for silver dory. Average annual catches were calculated as the sum across gear types per cell and method. Posterior median values are shown, with catches in tonnes on a log10 scale.

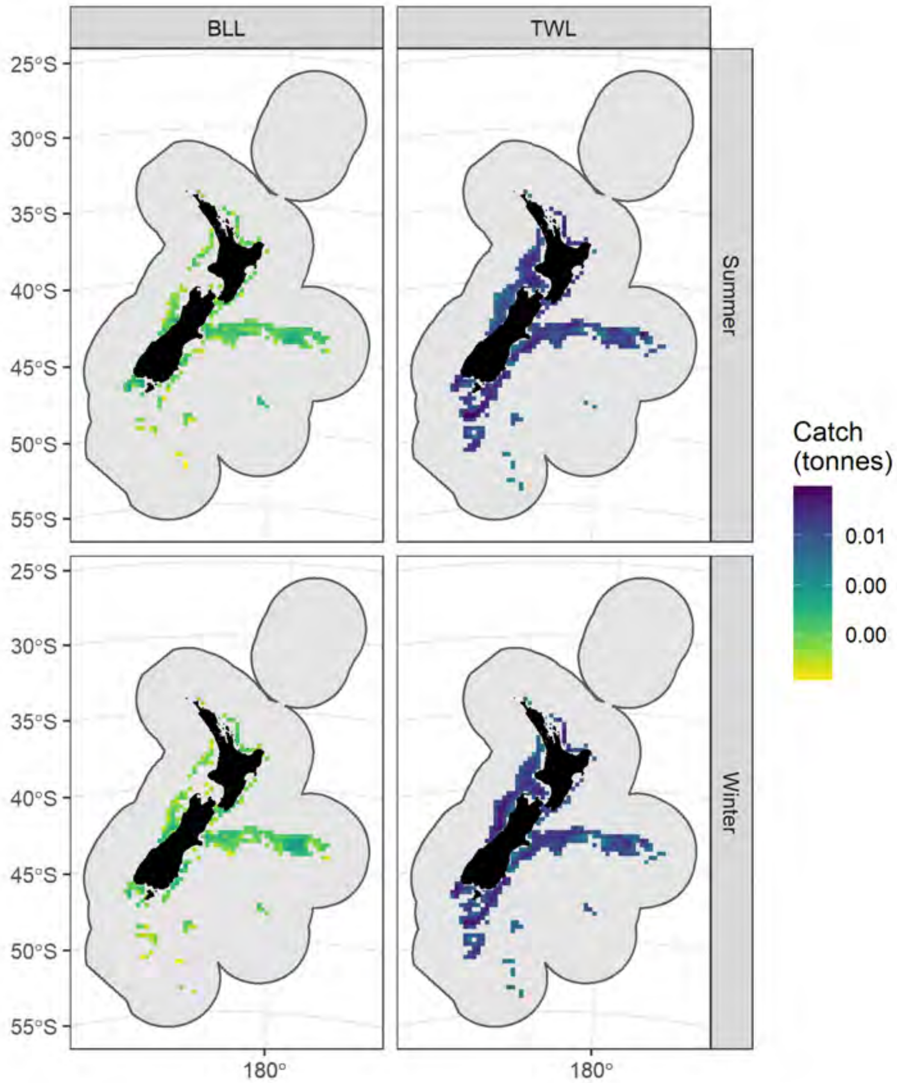


Figure S152: Posterior prediction of the total catches by grid cell, method and season for silver dory. Average annual catches per season were calculated as the sum across gear types per cell and method. Posterior median values are shown, with catches in tonnes on a log10 scale.

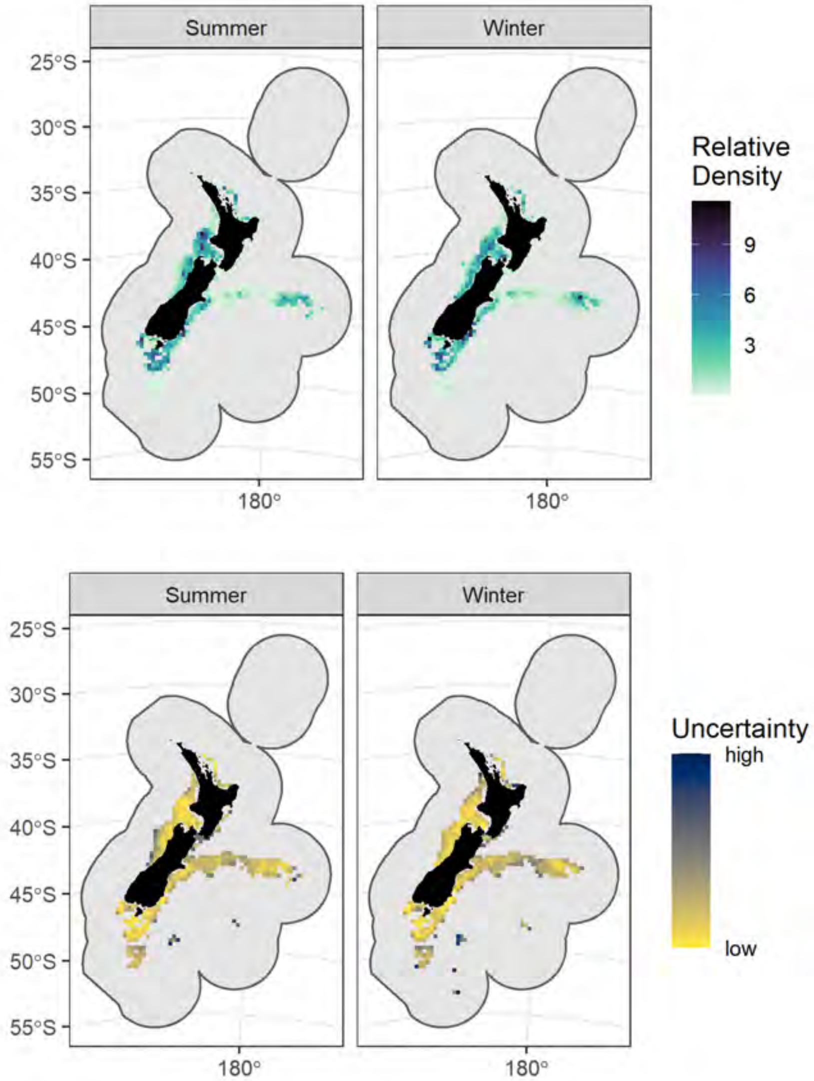


Figure S153: Posterior prediction of the relative density per grid cell and season for silver dory. Posterior median values are shown on a natural scale in tonnes per square kilometre. Uncertainty is measured using the difference between the upper and lower 95% equal-tailed posterior density interval.

Table S44: **Total predicted bycatch (tonnes) per method for silver dory. Posterior median values are given, with the 95% equal-tailed credibility intervals in brackets.**

Fishing year	BLL	TWL	Total
2000/01	0 (0 - 0)	197 (172 - 233)	197 (172 - 233)
2001/02	0 (0 - 0)	202 (178 - 238)	202 (178 - 238)
2002/03	0 (0 - 0)	232 (201 - 271)	232 (201 - 271)
2003/04	0 (0 - 0)	183 (161 - 216)	183 (161 - 216)
2004/05	0 (0 - 0)	216 (189 - 257)	216 (189 - 257)
2005/06	0 (0 - 0)	193 (166 - 275)	193 (166 - 275)
2006/07	0 (0 - 0)	148 (130 - 176)	148 (130 - 176)
2007/08	0 (0 - 0)	142 (123 - 199)	142 (123 - 199)
2008/09	0 (0 - 0)	121 (106 - 142)	121 (106 - 142)
2009/10	0 (0 - 0)	158 (137 - 196)	158 (137 - 196)
2010/11	0 (0 - 0)	154 (134 - 182)	154 (134 - 182)
2011/12	0 (0 - 0)	142 (124 - 167)	142 (124 - 167)
2012/13	0 (0 - 0)	141 (121 - 167)	141 (121 - 167)
2013/14	0 (0 - 0)	143 (122 - 187)	143 (122 - 187)
2014/15	0 (0 - 0)	137 (118 - 163)	137 (118 - 163)
2015/16	0 (0 - 0)	129 (110 - 174)	129 (110 - 174)
2016/17	0 (0 - 0)	146 (127 - 180)	146 (127 - 180)
2017/18	0 (0 - 0)	132 (115 - 154)	132 (115 - 154)
2018/19	0 (0 - 0)	139 (122 - 165)	139 (122 - 165)

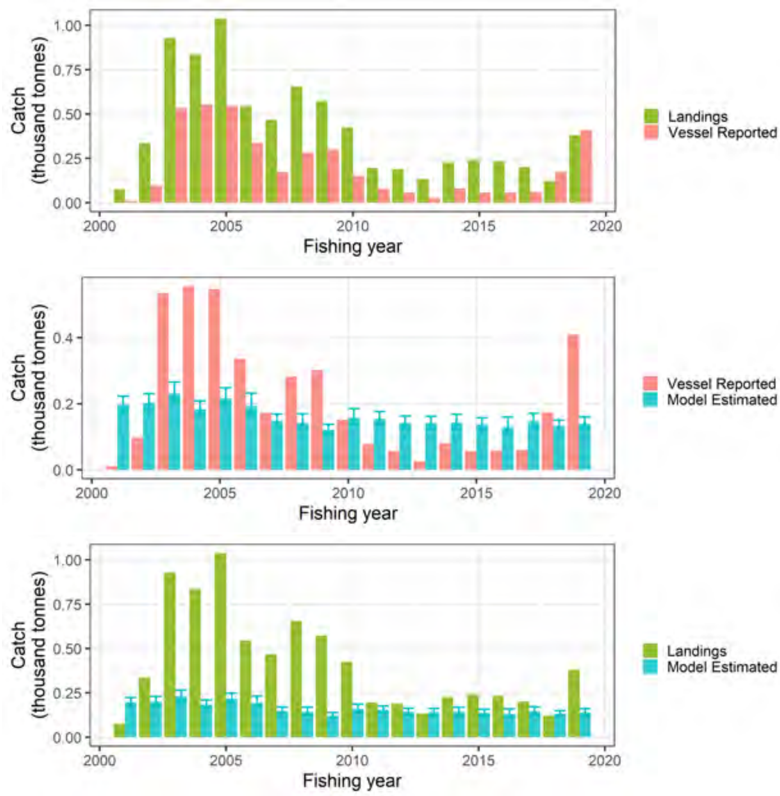


Figure S154: Relationships between landings, vessel reported catches and model estimated catches for silver dory.

S2.15 Giant stargazer (*Kathetostoma* spp.)

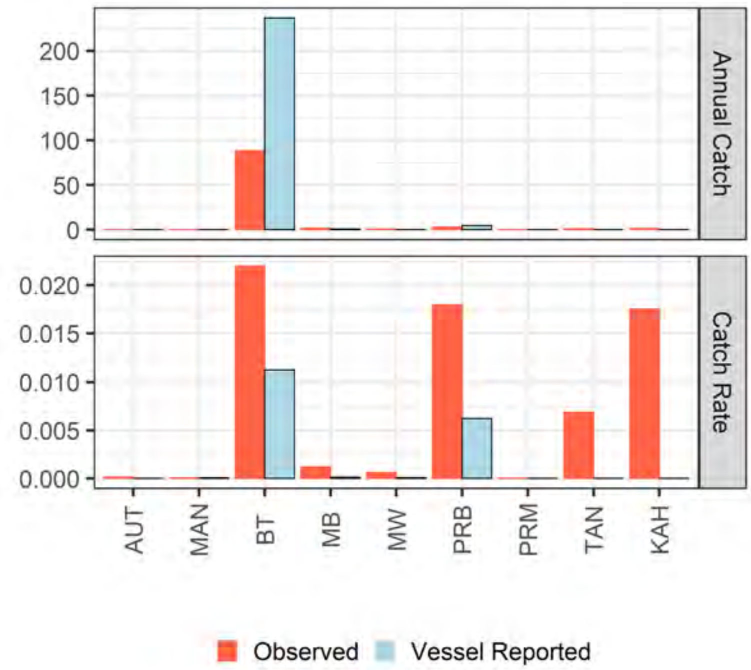


Figure S155: Empirical catch and catch rate data per gear type for giant stargazer. Annual catch is given in tonnes as an average across years. The catch rate is an average calculated as the sum of the observed catch in kilograms (i.e., $\sum X_i$) over the sum of the effort count (number of fishing events). Effort was calculated as a count to allow comparability between methods. There are no vessel reported catches for TAN and KAH surveys.

Table S45: Summary data for giant stargazer across 491 grid cells, removing 110 863 commercial events that were outside the selected cells. The total landings associated with retained commercial effort equal 18 488 tonnes. Catch is in units of tonnes, effort in the number of fishing events. “Obs.” is observed; “Com.” is commercial.

Method	Gear	Obs. catch	Obs. effort	Com. catch	Com. effort
BLL	AUT	1	7 566	0	45 821
BLL	MAN	0	729	2	17 850
TWL	BT	1 681	76 536	4 497	398 667
TWL	MB	35	28 491	14	100 398
TWL	MW	15	24 775	5	60 658
TWL	PRB	15	844	19	3 043
TWL	PRM	0	268	0	1 456
TWL	TAN	22	3 231		
TWL	KAH	23	1 333		
Total		1 793	143 773	4 537	627 893

Table S46: Model selection summary statistics for giant stargazer. Model 1 was selected for prediction of the catches.

Model	$\mathbb{L}[X]$	MPE	L^2	WAIC	$\hat{R}(\alpha)$	$\hat{R}(\gamma)$	$\hat{R}(\pi)$	DRE
1	-0.024	0.024	0.048	8960.315	1.000	1.012	1.015	1.297
2	-0.025	0.023	0.049	8943.229	1.003	1.000	1.000	1.315
3	-0.025	0.023	0.049	8950.854	1.004	1.021	1.015	1.261
4	-0.025	0.023	0.048	8954.203	1.005	1.033	1.038	1.256
5	-0.025	0.023	0.048	8949.646	1.009	1.021	1.017	1.105
6	-0.025	0.023	0.050	8948.042	1.023	1.012	1.013	1.117

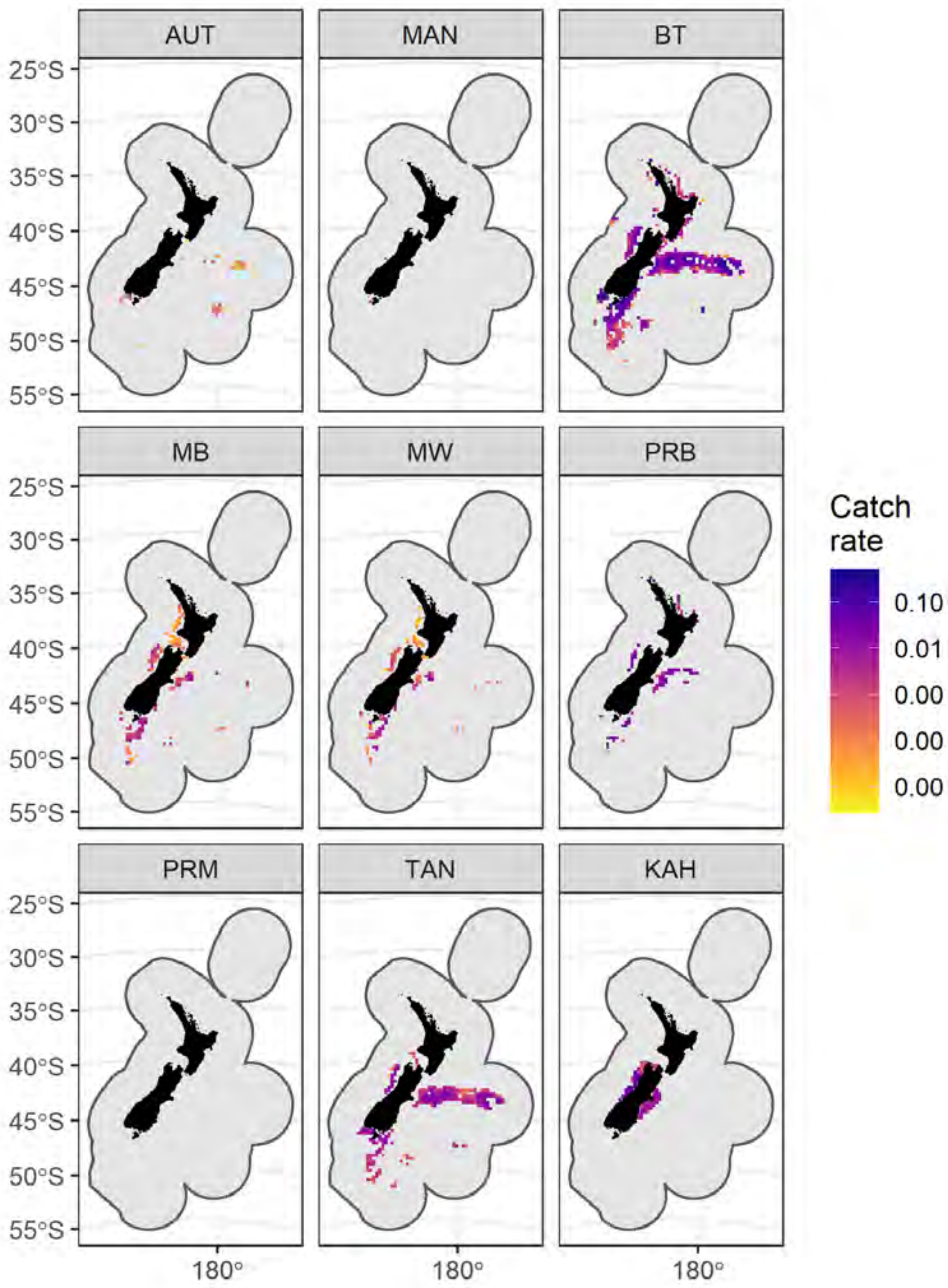


Figure S156: Observer catch rate data for giant stargazer on a log10-scale. The catch rate is an average calculated as the sum of the observed catch $\sum X_i$ over the number of observed fishing events per grid cell and gear type. Effort was calculated as a count to allow comparability between methods.

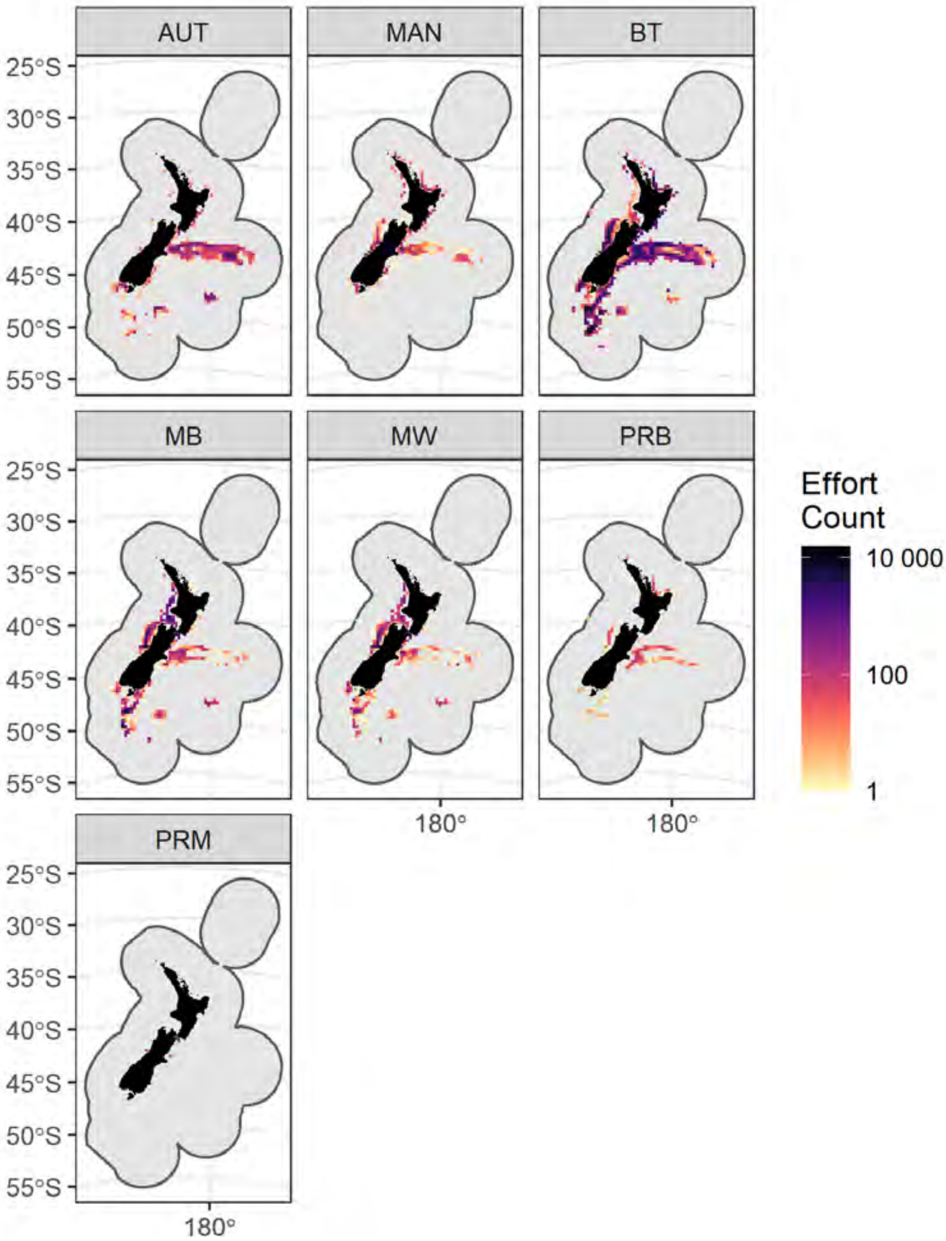


Figure S157: Commercial fishing effort (number of events) for giant stargazer summed across all years and presented on a log10-scale per grid cell and gear type. Effort was calculated as a count to allow comparability between methods.

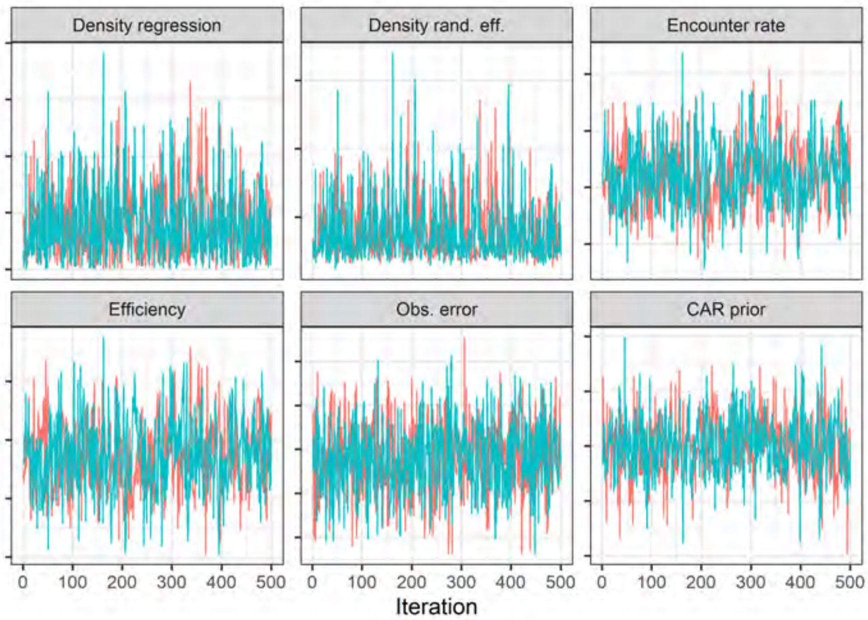


Figure S158: Posterior density sample traces for giant stargazer, for the regression coefficients $||\boldsymbol{\alpha}||$, random effects $||\boldsymbol{\phi}||$, encounter rate $||\boldsymbol{\gamma}||$, efficiency $||\boldsymbol{\pi}||$, observation error $||\boldsymbol{\sigma}||$ and conditional autoregressive prior parameters $||\tau,\rho||$. Colours represent independent sample chains.

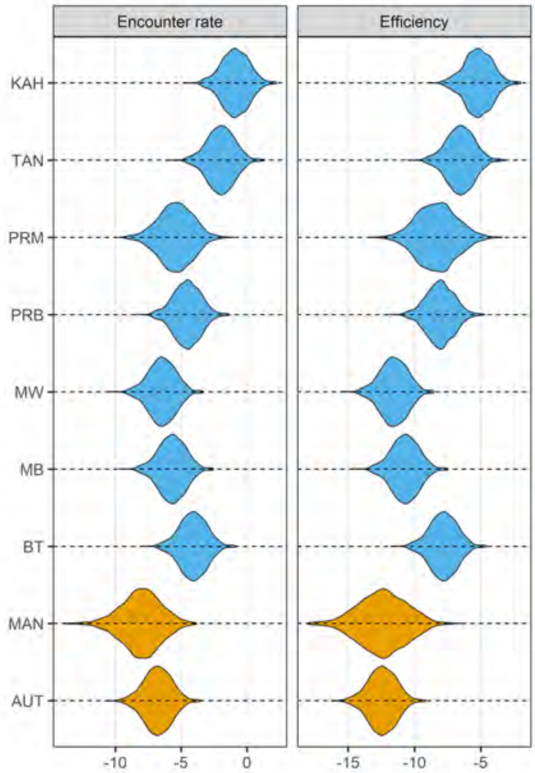


Figure S159: Violin plots of the posterior density for the encounter rate (γ_j) and the efficiency (π_j) per gear type for giant stargazer. Catchability terms for bottom longline gear types (see Table S2) are presented in a different colour as they are not comparable to the trawl gear types because they are dependent on different measures of effort (i.e., thousand hooks and distance, respectively).

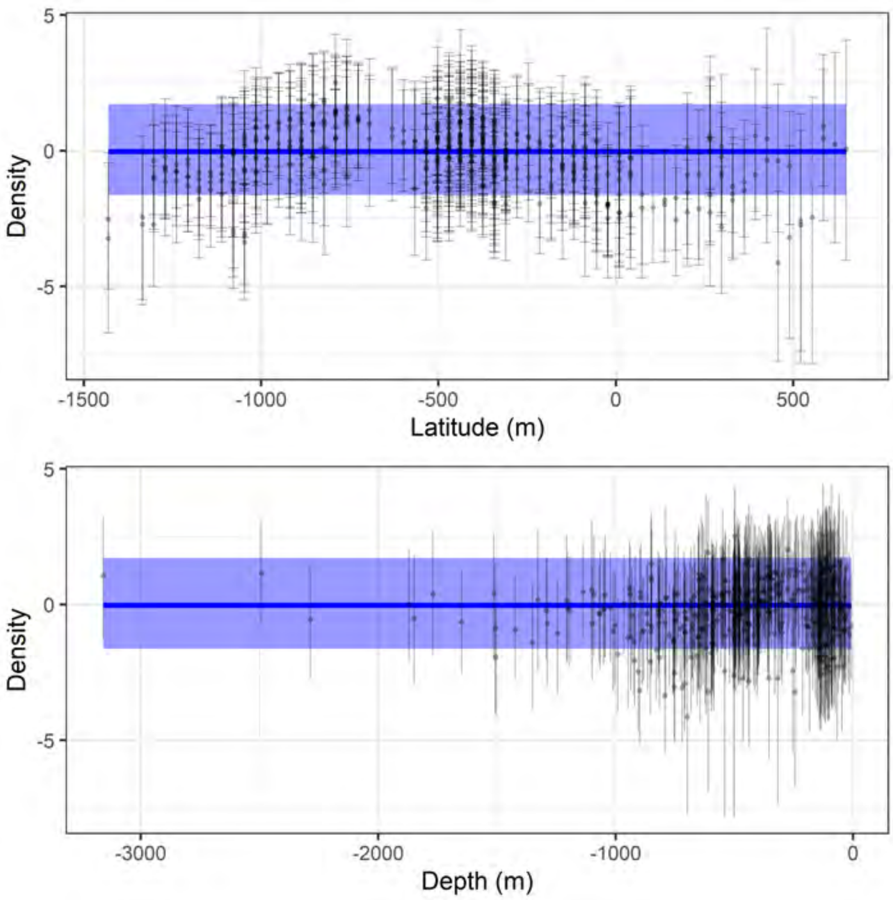


Figure S160: Estimated relationship between biomass density per grid cell and environmental covariates for giant stargazer. Points and error bars show the median and 90% credibility intervals per cell. The blue ribbon shows the estimated marginal relationship.

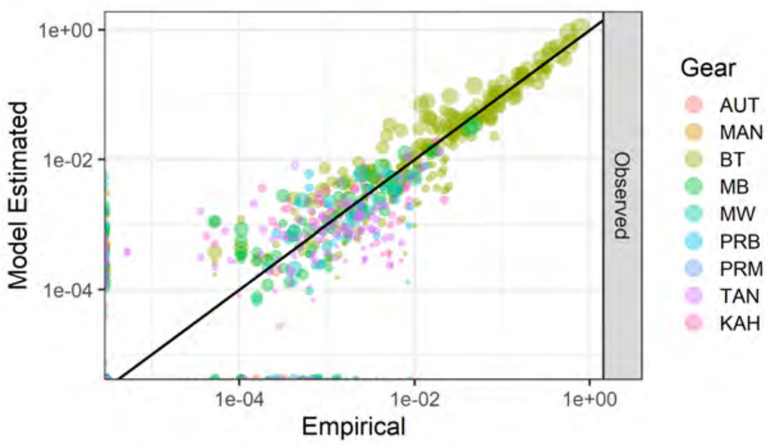


Figure S161: Fit of model to empirical observer catches. Total catches are summed per grid cell and gear type for giant stargazer. Model estimates are the median of the posterior predicted distribution. The size of the point is representative of the number of observed events. Catches are shown in tonnes on a log10 scale.

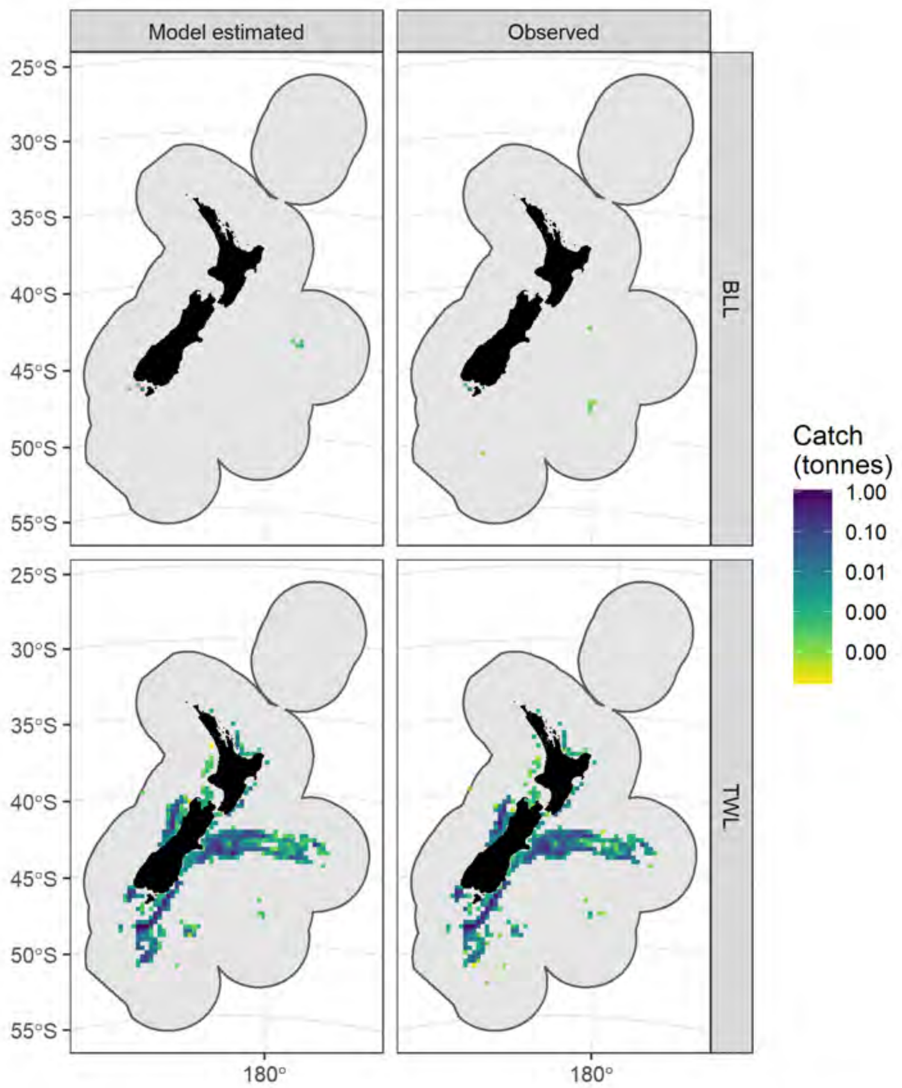


Figure S162: Spatial fit of model to empirical observer catches by grid cell and method for giant stargazer. Average annual catches were calculated as the sum across gear types per cell and method. Posterior median values are shown, with catches in tonnes on a log10 scale.

Table S47: Total predicted bycatch (tonnes) per method for giant stargazer. Posterior median values are given, with the 95% equal-tailed credibility intervals in brackets.

Fishing year	BLL	TWL	Total
2000/01	0 (0 - 0)	641 (603 - 682)	641 (603 - 682)
2001/02	0 (0 - 0)	603 (569 - 643)	603 (569 - 643)
2002/03	0 (0 - 0)	658 (622 - 700)	659 (622 - 700)
2003/04	0 (0 - 0)	456 (433 - 483)	456 (434 - 483)
2004/05	0 (0 - 0)	509 (482 - 538)	510 (482 - 538)
2005/06	0 (0 - 0)	519 (490 - 556)	519 (490 - 556)
2006/07	0 (0 - 0)	465 (437 - 495)	465 (437 - 495)
2007/08	0 (0 - 1)	485 (455 - 526)	485 (455 - 527)
2008/09	0 (0 - 1)	431 (406 - 465)	431 (407 - 465)
2009/10	0 (0 - 1)	522 (491 - 563)	522 (491 - 563)
2010/11	0 (0 - 1)	511 (482 - 541)	512 (482 - 541)
2011/12	0 (0 - 1)	524 (493 - 559)	524 (493 - 559)
2012/13	0 (0 - 1)	496 (466 - 531)	496 (467 - 531)
2013/14	0 (0 - 1)	497 (465 - 535)	497 (466 - 535)
2014/15	0 (0 - 1)	545 (513 - 583)	546 (513 - 583)
2015/16	0 (0 - 1)	517 (484 - 550)	517 (484 - 551)
2016/17	0 (0 - 1)	531 (500 - 569)	532 (500 - 569)
2017/18	0 (0 - 1)	479 (453 - 510)	479 (453 - 510)
2018/19	0 (0 - 1)	500 (470 - 532)	500 (470 - 532)

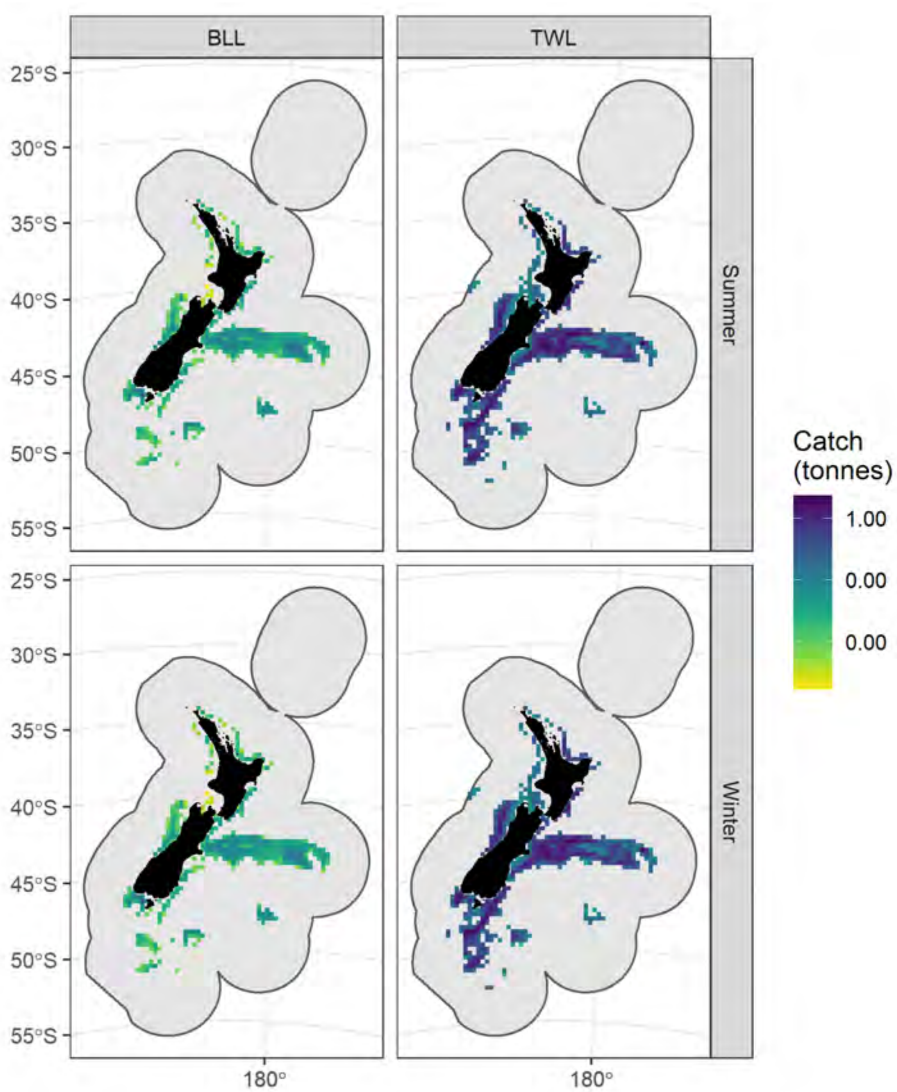


Figure S163: Posterior prediction of the total catches by grid cell, method and season for giant stargazer. Average annual catches per season were calculated as the sum across gear types per cell and method. Posterior median values are shown, with catches in tonnes on a log10 scale.

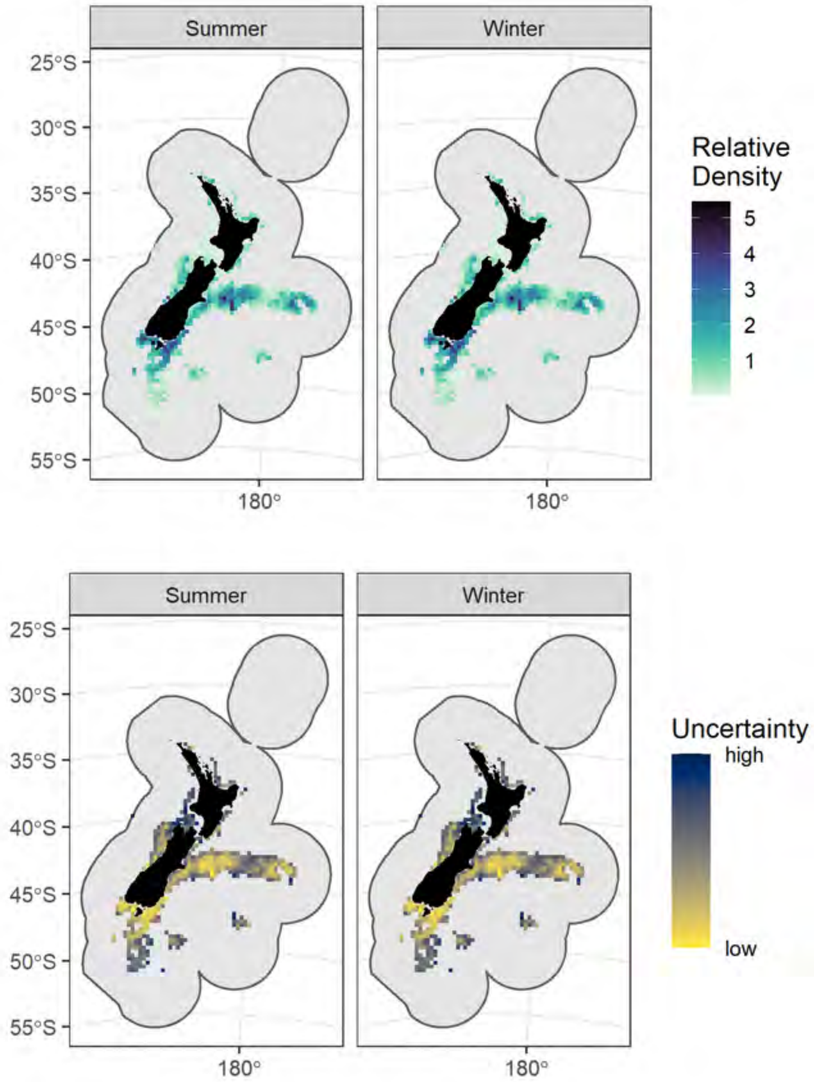


Figure S164: Posterior prediction of the relative density per grid cell and season for giant stargazer. Posterior median values are shown on a natural scale in tonnes per square kilometre. Uncertainty is measured using the difference between the upper and lower 95% equal-tailed posterior density interval.

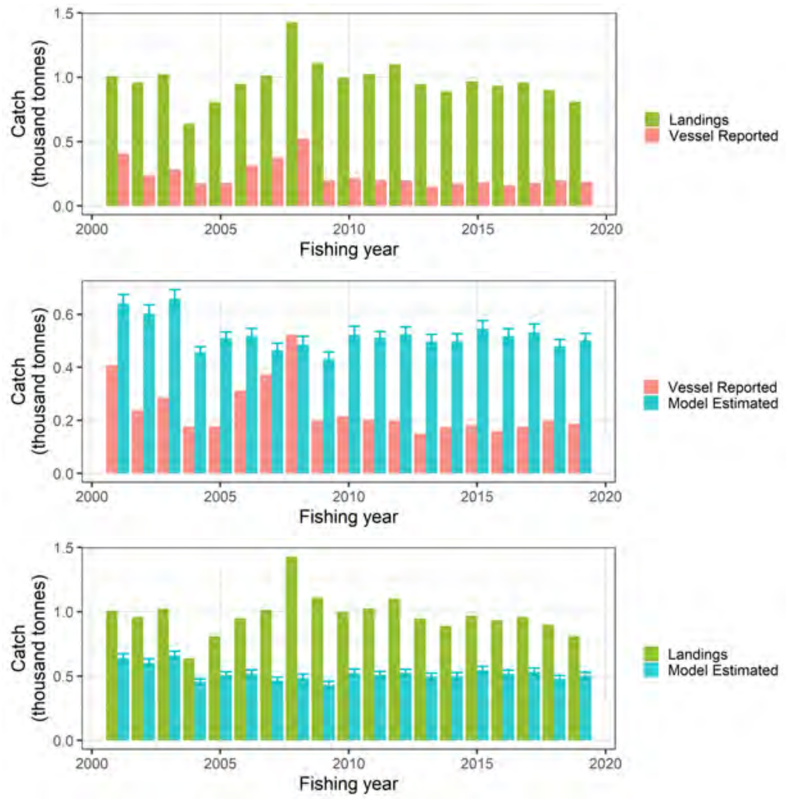


Figure S165: Relationships between landings, vessel reported catches and model estimated catches for giant stargazer.

S2.16 Shovelnose spiny dogfish (*Deania calcea*)

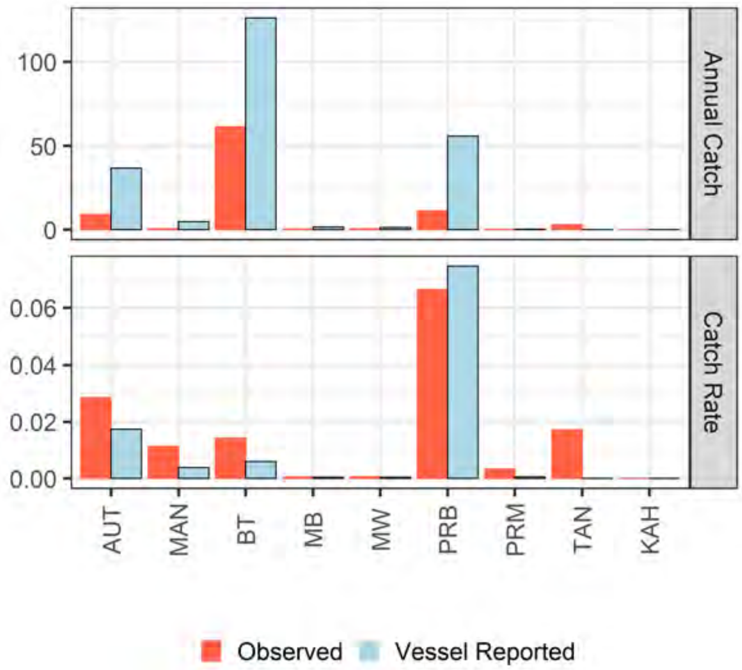


Figure S166: Empirical catch and catch rate data per gear type for shovelnose spiny dogfish. Annual catch is given in tonnes as an average across years. The catch rate is an average calculated as the sum of the observed catch in kilograms (i.e., $\sum X_i$) over the sum of the effort count (number of fishing events). Effort was calculated as a count to allow comparability between methods. There are no vessel reported catches for TAN and KAH surveys.

Table S48: Summary data for shovelnose spiny dogfish across 523 grid cells, removing 139 164 commercial events that were outside the selected cells. The total landings associated with retained commercial effort equal 5 378 tonnes. Catch is in units of tonnes, effort in the number of fishing events. "Obs." is observed; "Com." is commercial.

Method	Gear	Obs. catch	Obs. effort	Com. catch	Com. effort
BLL	AUT	176	6 174	698	40 330
BLL	MAN	9	803	91	23 278
TWL	BT	1 166	81 895	2 398	403 665
TWL	MB	10	17 327	33	72 209
TWL	MW	13	18 327	24	55 056
TWL	PRB	56	847	224	2 993
TWL	PRM	1	404	1	2 061
TWL	TAN	59	3 423		
TWL	KAH	0	459		
Total		1 489	129 659	3 469	599 592

Table S49: Model selection summary statistics for shovelnose spiny dogfish. Model 4 was selected for prediction of the catches.

Model	$\mathbb{L}[X]$	MPE	L^2	WAIC	$\hat{R}(\alpha)$	$\hat{R}(\gamma)$	$\hat{R}(\pi)$	DRE
1	-0.021	0.027	0.054	777.556	1.019	1.019	1.013	2.145
2	-0.021	0.027	0.059	863.973	1.010	1.022	1.029	2.244
3	-0.021	0.027	0.059	877.474	1.014	1.005	1.003	1.761
4	-0.021	0.027	0.061	877.730	1.063	1.011	1.011	1.674
5	-0.021	0.027	0.058	872.246	1.023	1.029	1.033	1.745
6	-0.021	0.027	0.057	874.510	1.019	1.007	1.009	1.653

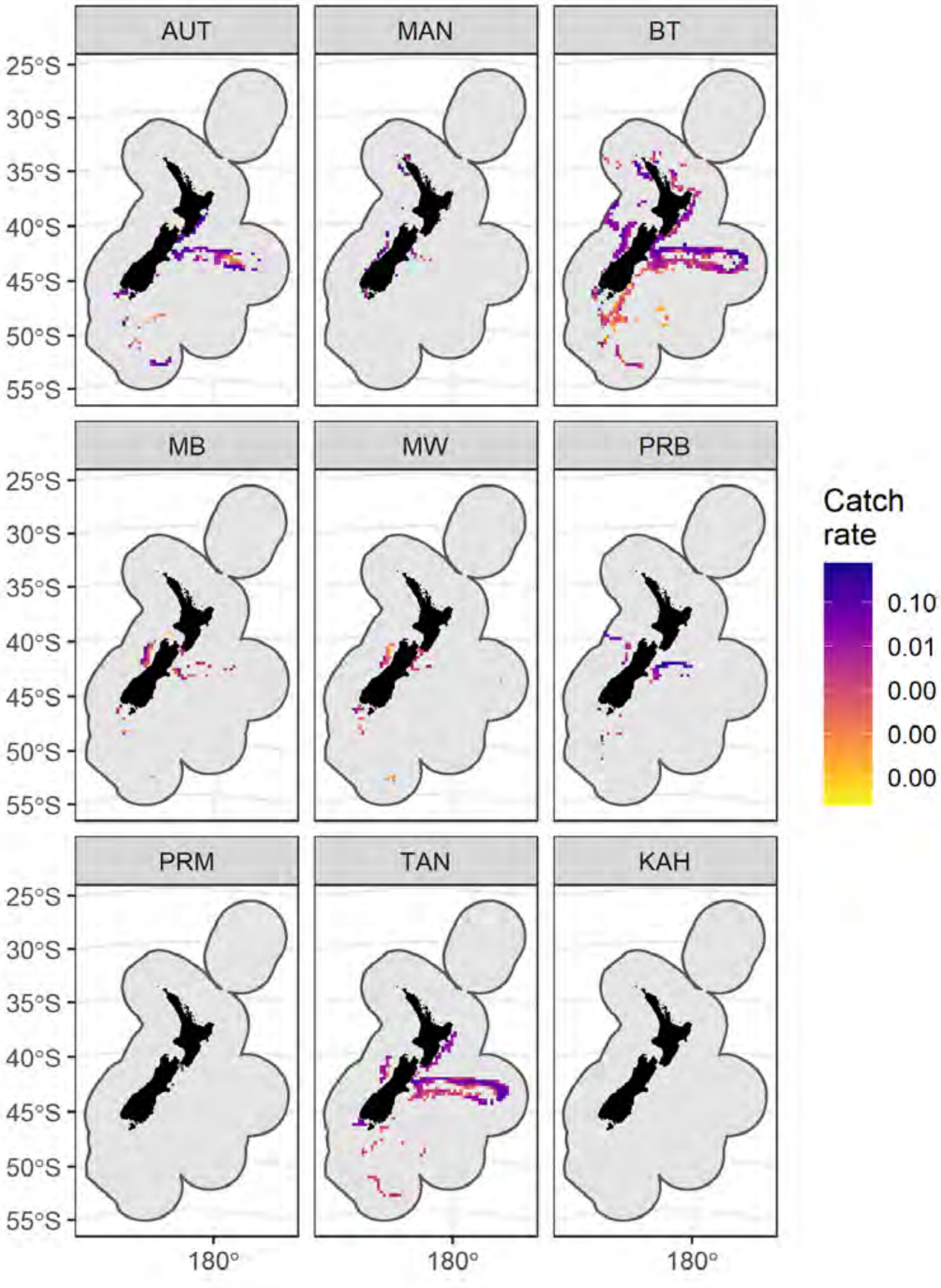


Figure S167: Observer catch rate data for shovelnose spiny dogfish on a log10-scale. The catch rate is an average calculated as the sum of the observed catch $\sum X_i$ over the number of observed fishing events per grid cell and gear type. Effort was calculated as a count to allow comparability between methods.

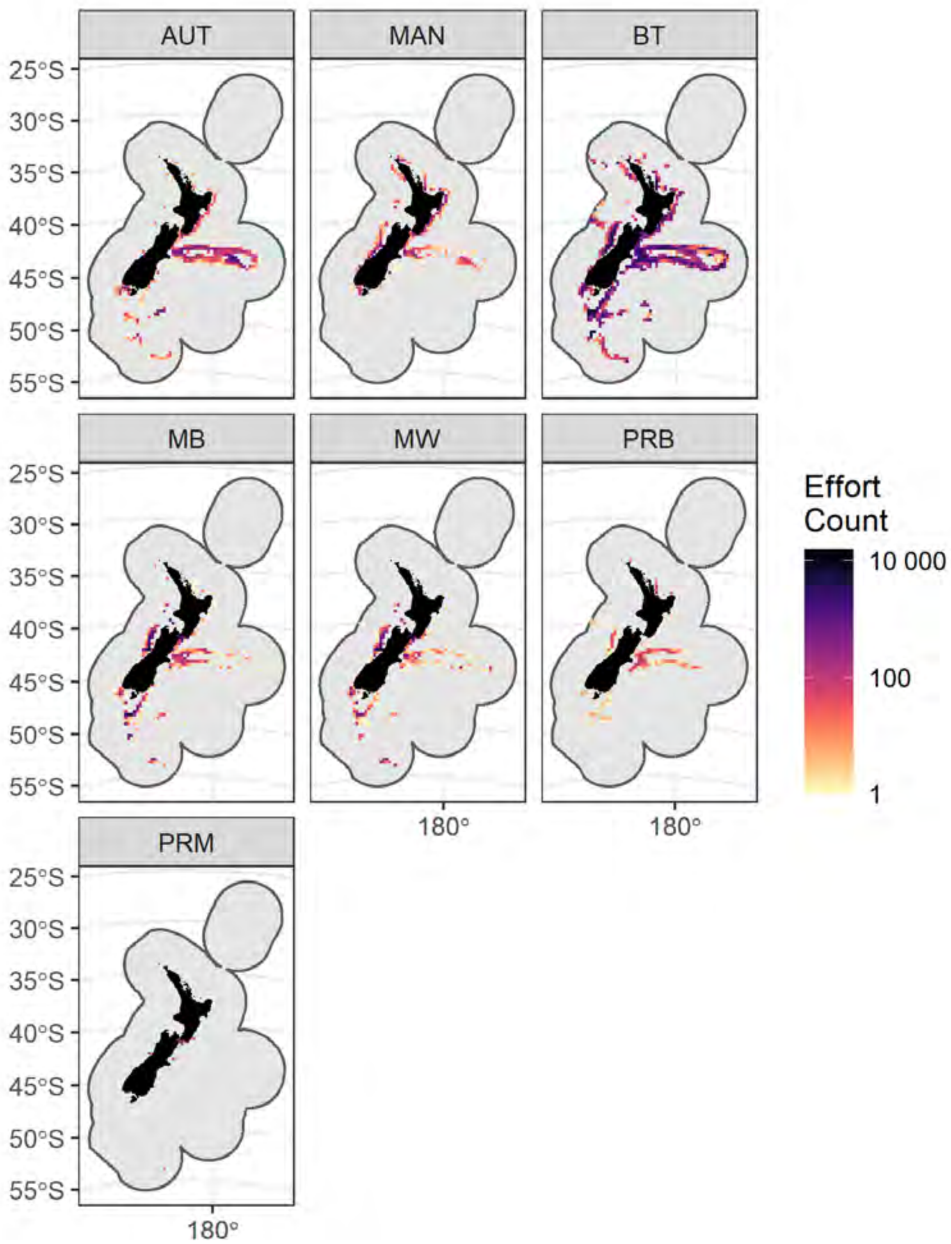


Figure S168: Commercial fishing effort (number of events) for shovelnose spiny dogfish summed across all years and presented on a log10-scale per grid cell and gear type. Effort was calculated as a count to allow comparability between methods.

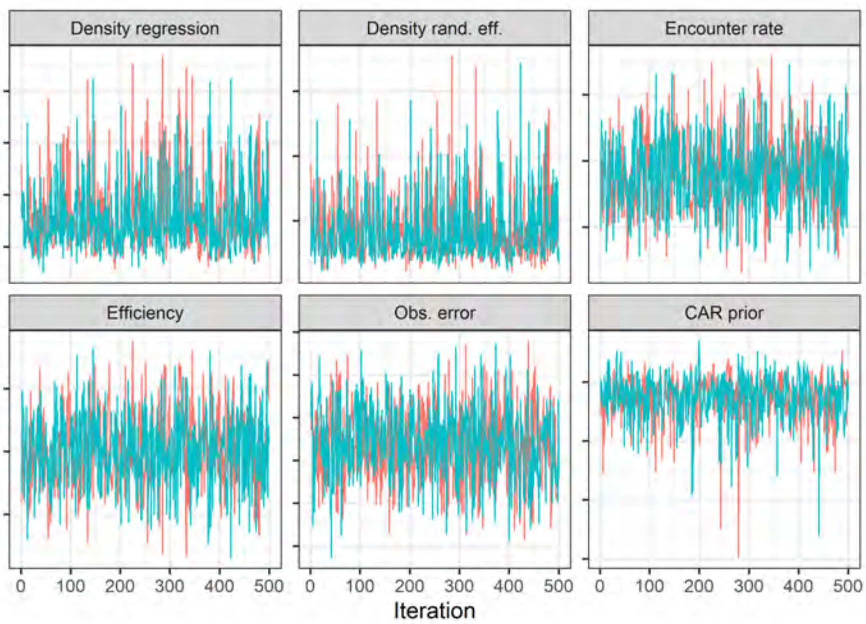


Figure S169: Posterior density sample traces for shovelnose spiny dogfish, for the regression coefficients $||\boldsymbol{\alpha}||$, random effects $||\boldsymbol{\phi}||$, encounter rate $||\boldsymbol{\gamma}||$, efficiency $||\boldsymbol{\pi}||$, observation error $||\boldsymbol{\sigma}||$ and conditional autoregressive prior parameters $||\tau, \rho||$. Colours represent independent sample chains.

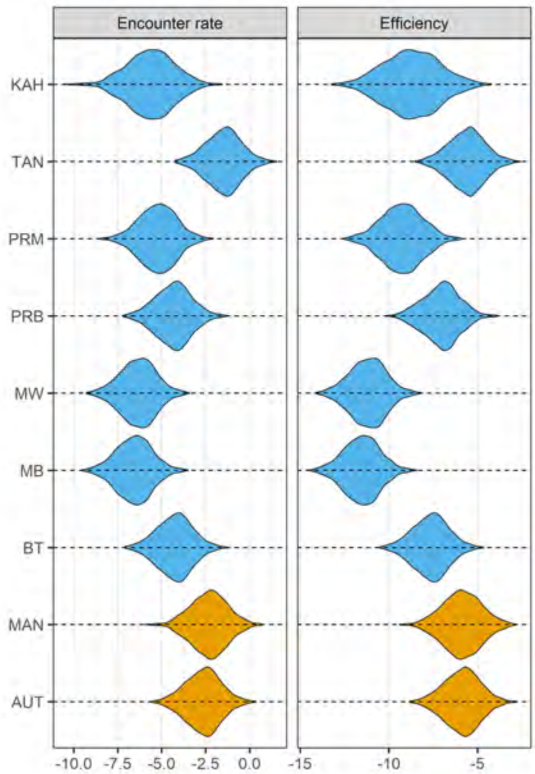


Figure S170: Violin plots of the posterior density for the encounter rate (γ_j) and the efficiency (π_j) per gear type for shovelnose spiny dogfish. Catchability terms for bottom longline gear types (see Table S2) are presented in a different colour as they are not comparable to the trawl gear types because they are dependent on different measures of effort (i.e., thousand hooks and distance, respectively).

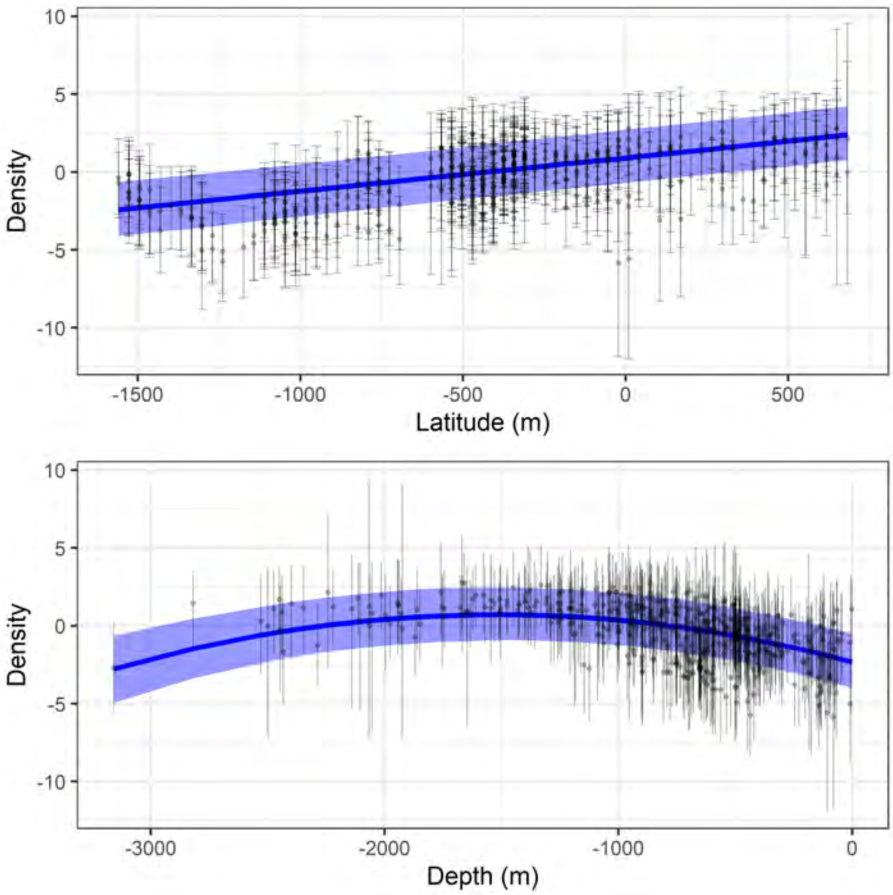


Figure S171: Estimated relationship between biomass density per grid cell and environmental covariates for shovelnose spiny dogfish. Points and error bars show the median and 90% credibility intervals per cell. The blue ribbon shows the estimated marginal relationship.

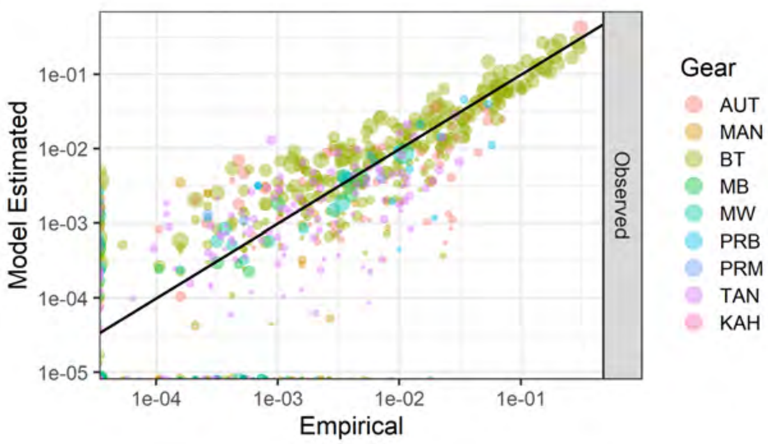


Figure S172: Fit of model to empirical observer catches. Total catches are summed per grid cell and gear type for shovelnose spiny dogfish. Model estimates are the median of the posterior predicted distribution. The size of the point is representative of the number of observed events. Catches are shown in tonnes on a log10 scale.

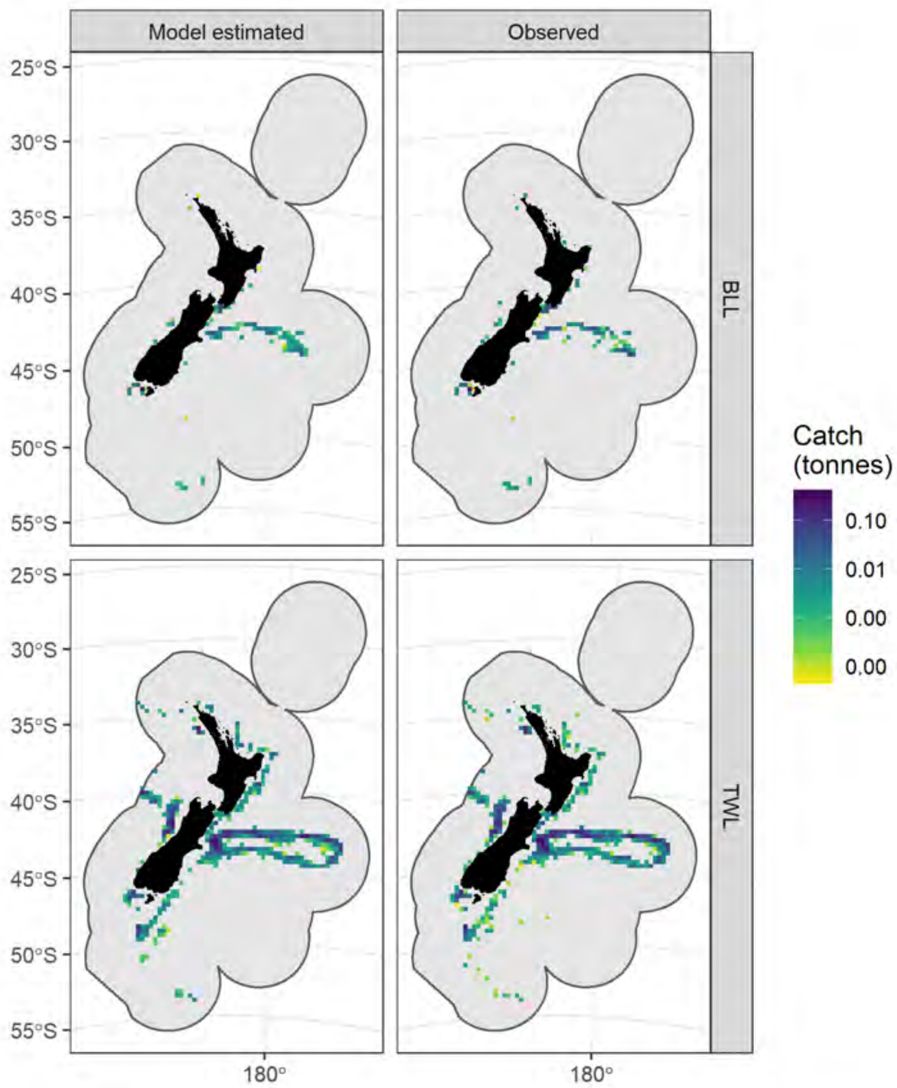


Figure S173: Spatial fit of model to empirical observer catches by grid cell and method for shovelnose spiny dogfish. Average annual catches were calculated as the sum across gear types per cell and method. Posterior median values are shown, with catches in tonnes on a log10 scale.

Table S50: Total predicted bycatch (tonnes) per method for shovelnose spiny dogfish. Posterior median values are given, with the 95% equal-tailed credibility intervals in brackets.

Fishing year	BLL	TWL	Total
2000/01	59 (47 - 80)	398 (361 - 443)	457 (421 - 507)
2001/02	75 (58 - 104)	363 (330 - 407)	440 (398 - 496)
2002/03	30 (24 - 39)	381 (350 - 421)	411 (380 - 452)
2003/04	48 (36 - 65)	344 (314 - 426)	392 (361 - 475)
2004/05	59 (45 - 78)	276 (251 - 306)	335 (307 - 368)
2005/06	45 (36 - 58)	257 (234 - 296)	303 (276 - 345)
2006/07	60 (47 - 78)	228 (208 - 252)	288 (264 - 318)
2007/08	68 (50 - 108)	255 (232 - 284)	324 (292 - 376)
2008/09	64 (48 - 106)	263 (241 - 293)	328 (298 - 378)
2009/10	67 (49 - 117)	235 (214 - 272)	304 (273 - 374)
2010/11	74 (54 - 136)	218 (199 - 245)	294 (264 - 364)
2011/12	60 (42 - 115)	189 (170 - 2 172)	252 (220 - 2 231)
2012/13	55 (40 - 94)	192 (174 - 235)	249 (224 - 309)
2013/14	101 (73 - 148)	233 (208 - 279)	336 (297 - 406)
2014/15	71 (50 - 123)	258 (230 - 323)	333 (294 - 412)
2015/16	80 (58 - 132)	292 (261 - 389)	375 (333 - 485)
2016/17	73 (51 - 135)	288 (260 - 335)	361 (324 - 442)
2017/18	64 (45 - 113)	291 (258 - 373)	358 (315 - 459)
2018/19	77 (55 - 126)	287 (247 - 369)	369 (320 - 457)

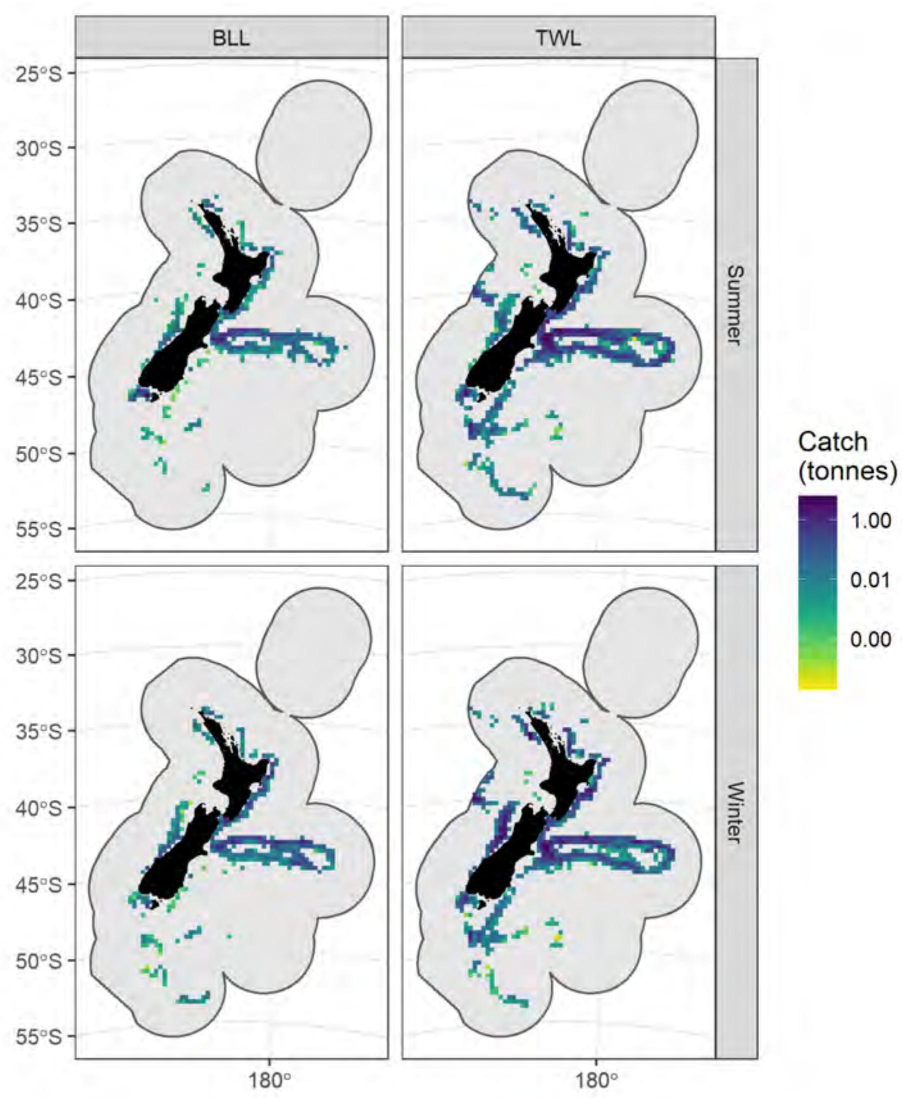


Figure S174: Posterior prediction of the total catches by grid cell, method and season for shovelnose spiny dogfish. Average annual catches per season were calculated as the sum across gear types per cell and method. Posterior median values are shown, with catches in tonnes on a log10 scale.

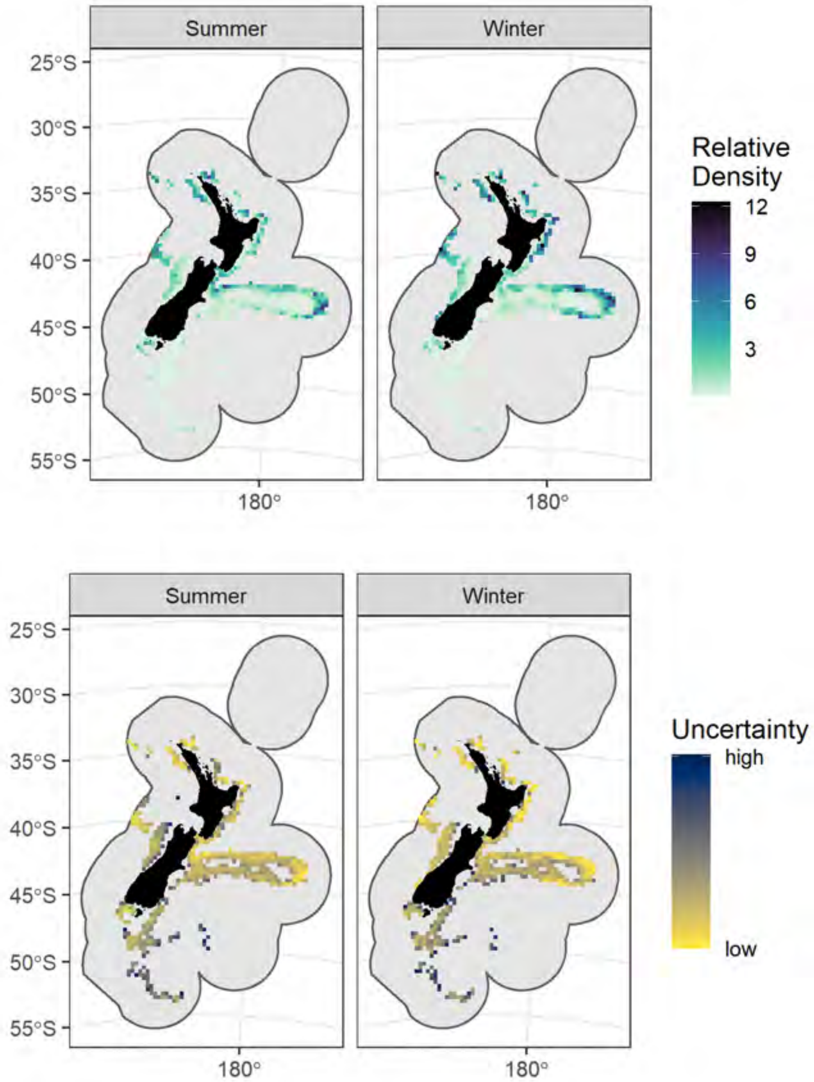


Figure S175: Posterior prediction of the relative density per grid cell and season for shovelnose spiny dogfish. Posterior median values are shown on a natural scale in tonnes per square kilometre. Uncertainty is measured using the difference between the upper and lower 95% equal-tailed posterior density interval.

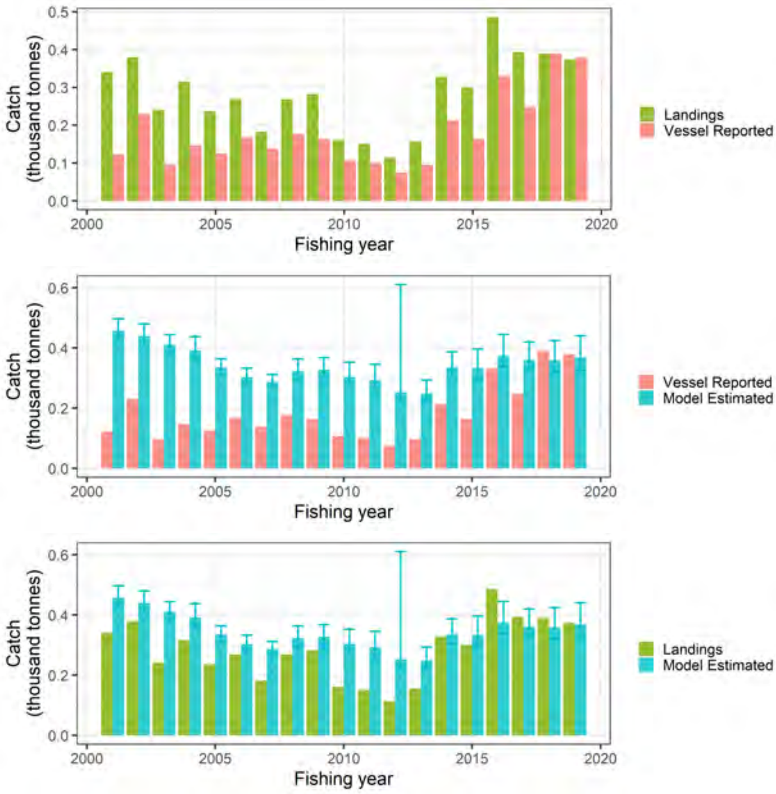


Figure S176: Relationships between landings, vessel reported catches and model estimated catches for shovelnose spiny dogfish.

S2.17 Lookdown dory (*Cyttus traversi*)

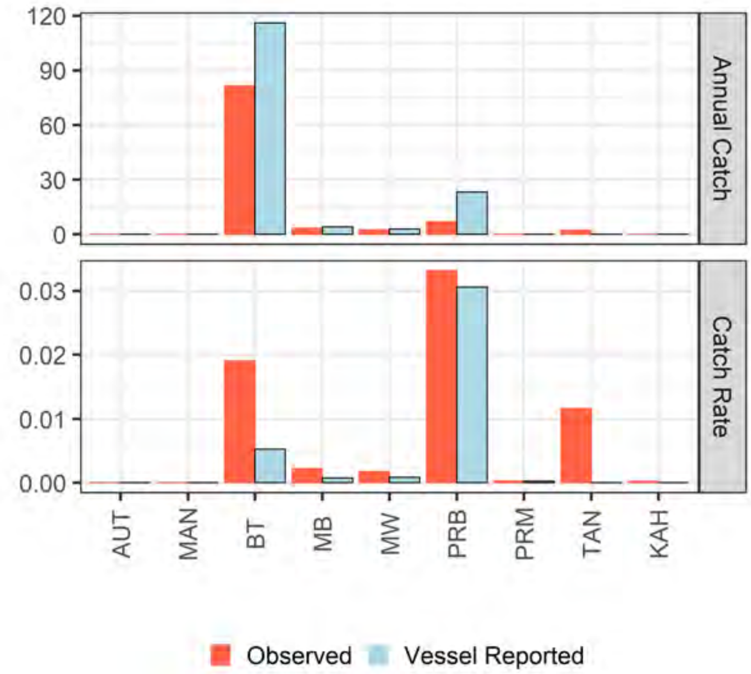


Figure S177: Empirical catch and catch rate data per gear type for lookdown dory. Annual catch is given in tonnes as an average across years. The catch rate is an average calculated as the sum of the observed catch in kilograms (i.e., $\sum X_i$) over the sum of the effort count (number of fishing events). Effort was calculated as a count to allow comparability between methods. There are no vessel reported catches for TAN and KAH surveys.

Table S51: Summary data for lookdown dory across 612 grid cells, removing 82 092 commercial events that were outside the selected cells. The total landings associated with retained commercial effort equal 9 818 tonnes. Catch is in units of tonnes, effort in the number of fishing events. "Obs." is observed; "Com." is commercial.

Method	Gear	Obs. catch	Obs. effort	Com. catch	Com. effort
BLL	AUT	0	7 718	0	47 661
BLL	MAN	0	666	0	16 166
TWL	BT	1 549	81 519	2 205	418 211
TWL	MB	65	29 185	77	104 451
TWL	MW	48	27 488	56	65 093
TWL	PRB	28	847	93	3 041
TWL	PRM	0	402	0	2 041
TWL	TAN	45	3 874		
TWL	KAH	0	675		
Total		1 736	152 374	2 431	656 664

Table S52: Model selection summary statistics for lookdown dory. Model 2 was selected for prediction of the catches.

Model	$\mathbb{L}[X]$	MPE	L^2	WAIC	$\hat{R}(\alpha)$	$\hat{R}(\gamma)$	$\hat{R}(\pi)$	DRE
1	-0.013	0.022	0.051	9725.884	0.999	1.009	1.010	1.672
2	-0.013	0.022	0.051	9732.751	1.001	1.004	1.004	1.734
3	-0.013	0.022	0.051	9731.802	1.012	1.006	1.006	1.708
4	-0.013	0.022	0.050	9728.362	1.000	1.000	1.000	1.595
5	-0.013	0.022	0.051	9726.735	1.022	1.022	1.022	1.631
6	-0.012	0.022	0.050	9725.325	1.002	1.000	1.000	1.492

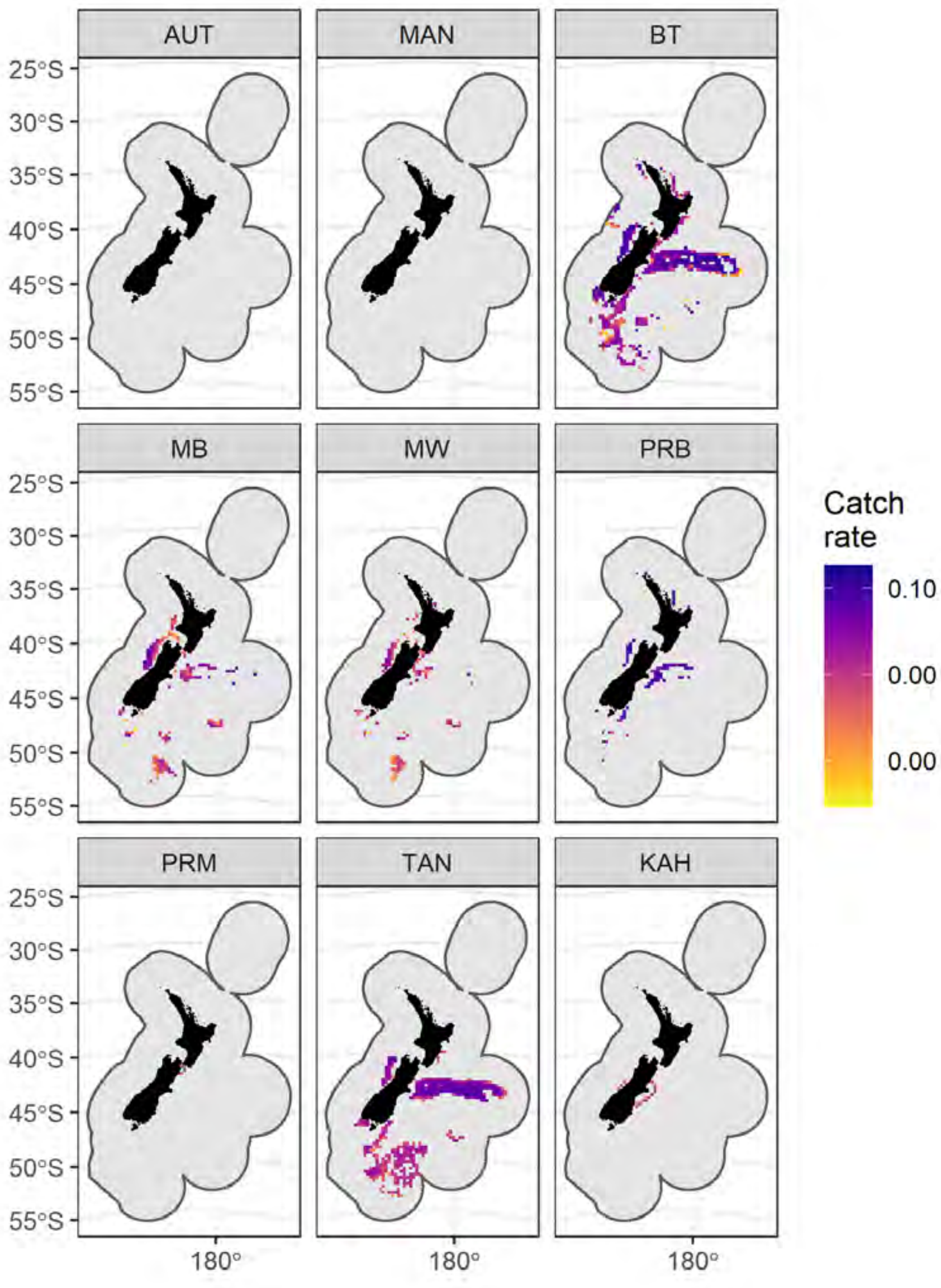


Figure S178: Observer catch rate data for lookdown dory on a log10-scale. The catch rate is an average calculated as the sum of the observed catch $\sum X_i$ over the number of observed fishing events per grid cell and gear type. Effort was calculated as a count to allow comparability between methods.

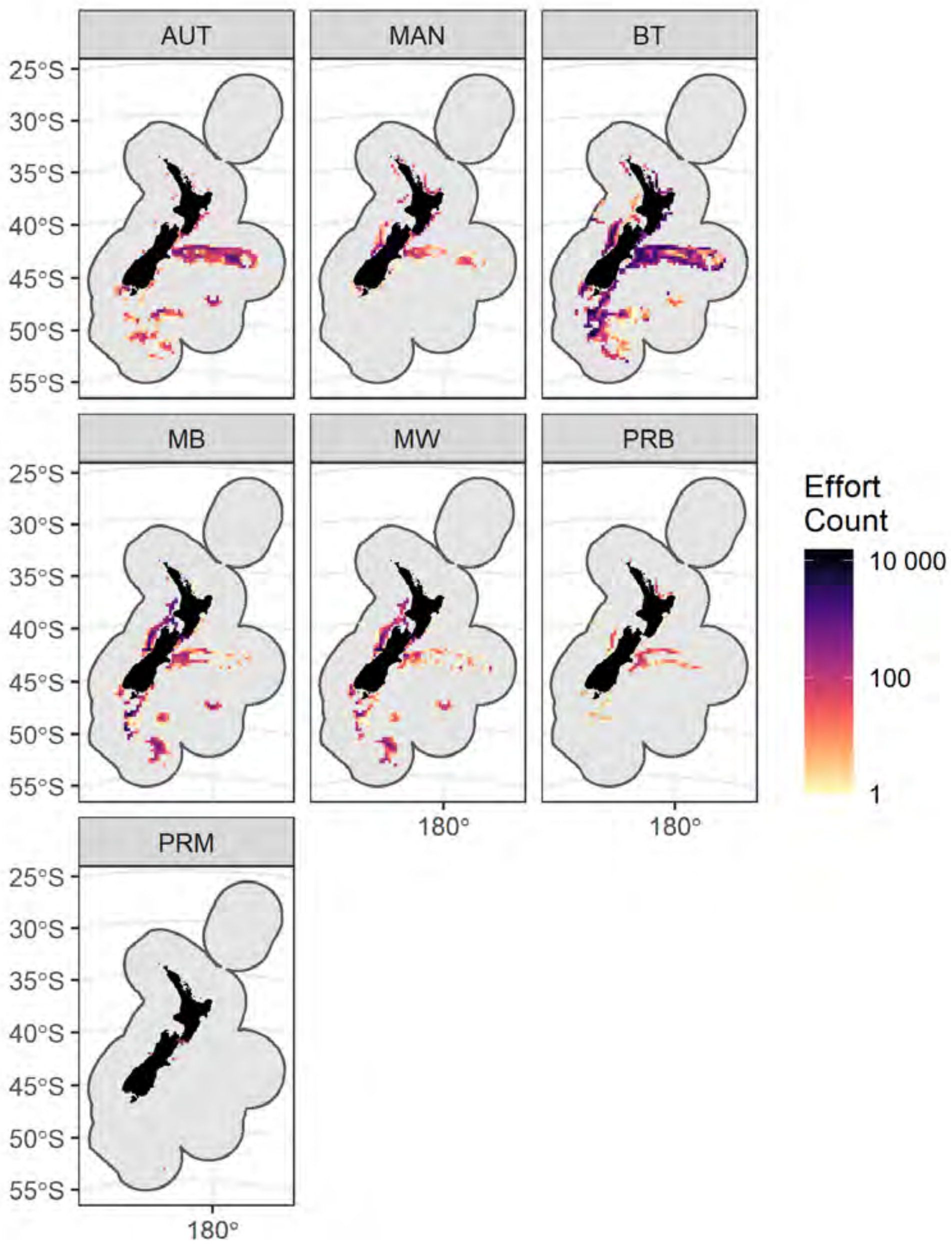


Figure S179: Commercial fishing effort (number of events) for lookdown dory summed across all years and presented on a log10-scale per grid cell and gear type. Effort was calculated as a count to allow comparability between methods.

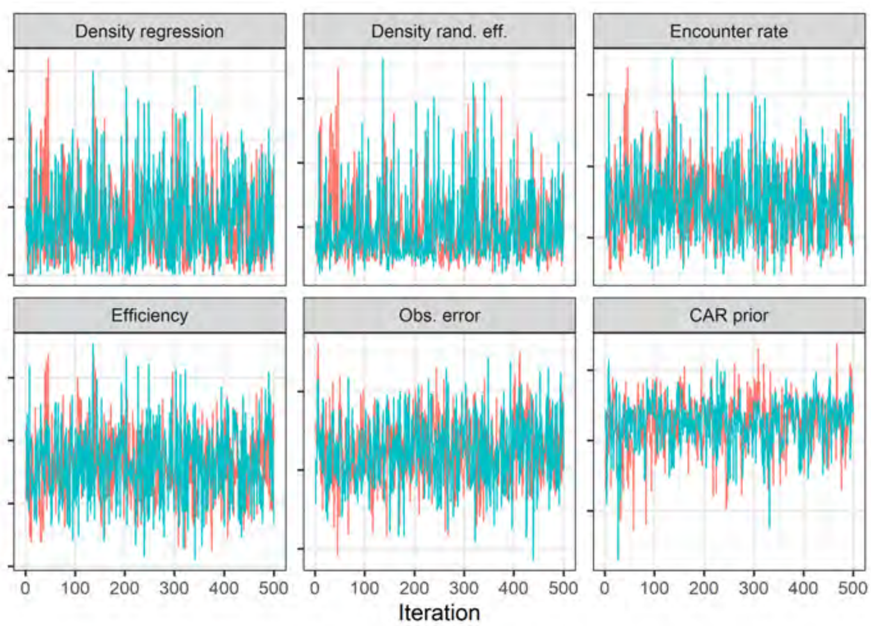


Figure S180: Posterior density sample traces for lookdown dory, for the regression coefficients $||\boldsymbol{\alpha}||$, random effects $||\boldsymbol{\phi}||$, encounter rate $||\boldsymbol{\gamma}||$, efficiency $||\boldsymbol{\pi}||$, observation error $||\boldsymbol{\sigma}||$ and conditional autoregressive prior parameters $||\tau,\rho||$. Colours represent independent sample chains.

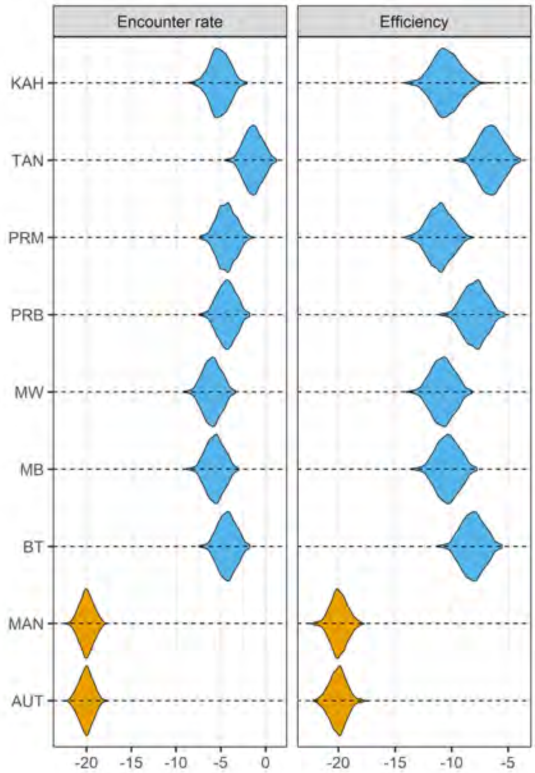


Figure S181: Violin plots of the posterior density for the encounter rate (γ_j) and the efficiency (π_j) per gear type for lookdown dory. Catchability terms for bottom longline gear types (see Table S2) are presented in a different colour as they are not comparable to the trawl gear types because they are dependent on different measures of effort (i.e., thousand hooks and distance, respectively).

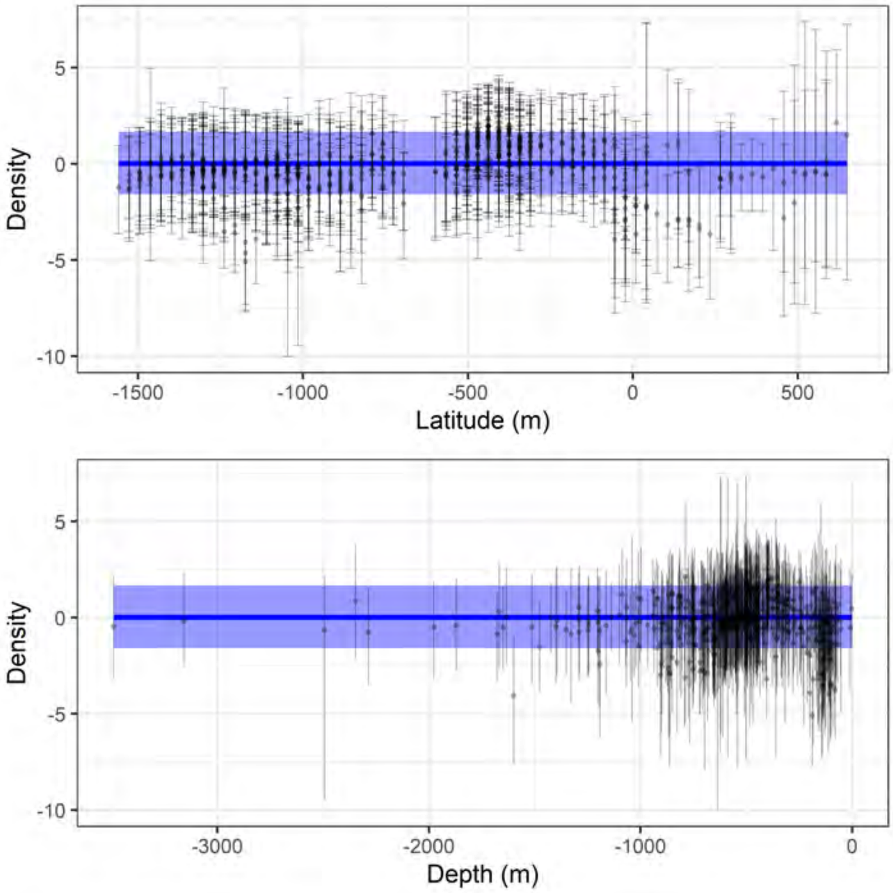


Figure S182: Estimated relationship between biomass density per grid cell and environmental covariates for lookdown dory. Points and error bars show the median and 90% credibility intervals per cell. The blue ribbon shows the estimated marginal relationship.

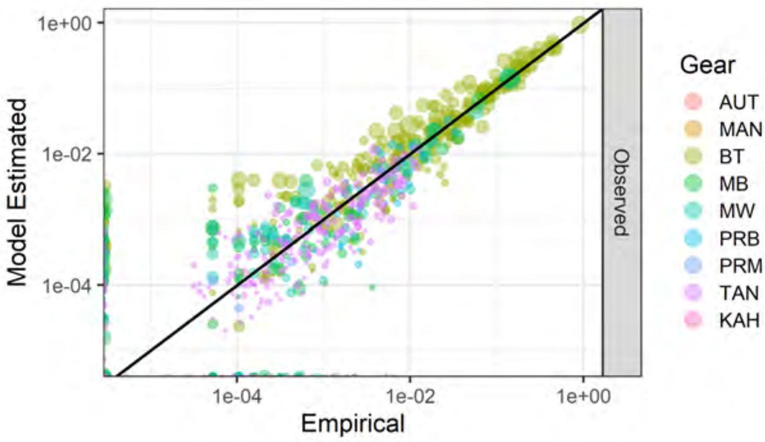


Figure S183: Fit of model to empirical observer catches. Total catches are summed per grid cell and gear type for lookdown dory. Model estimates are the median of the posterior predicted distribution. The size of the point is representative of the number of observed events. Catches are shown in tonnes on a log10 scale.

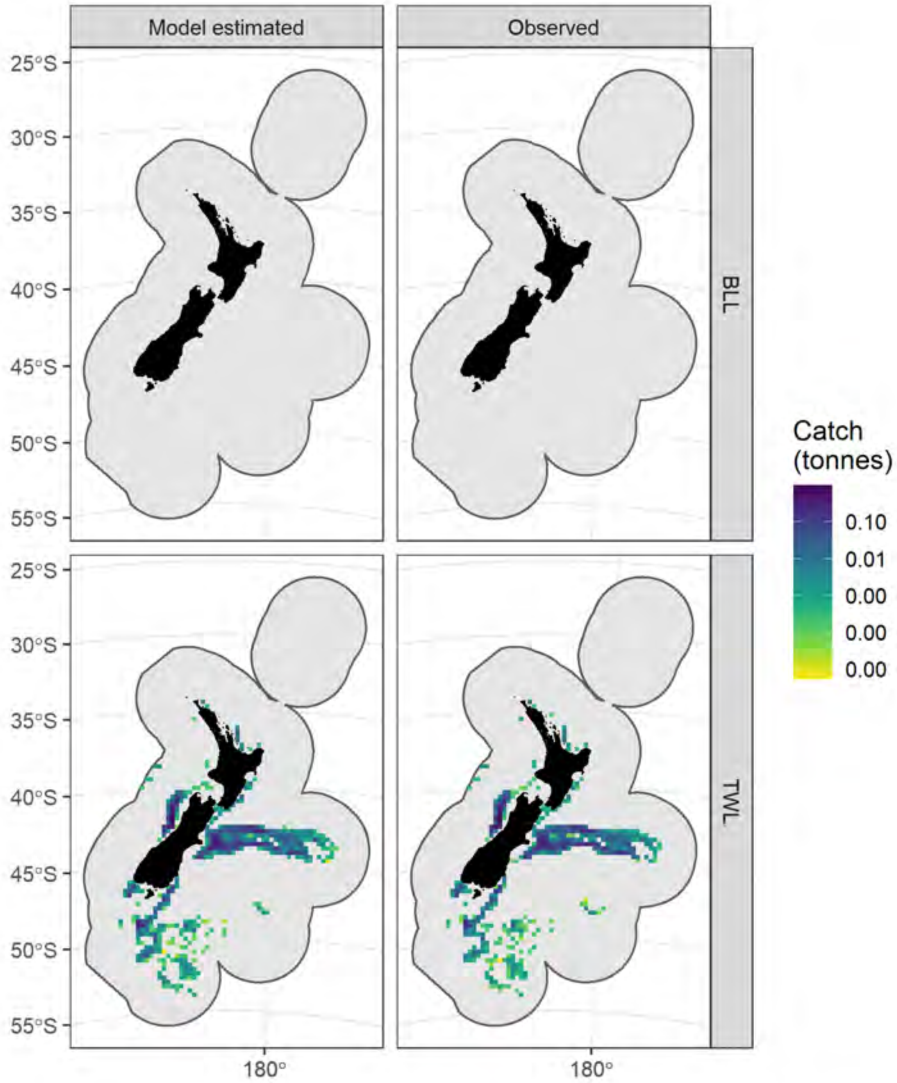


Figure S184: Spatial fit of model to empirical observer catches by grid cell and method for lookdown dory. Average annual catches were calculated as the sum across gear types per cell and method. Posterior median values are shown, with catches in tonnes on a log10 scale.

Table S53: Total predicted bycatch (tonnes) per method for lookdown dory. Posterior median values are given, with the 95% equal-tailed credibility intervals in brackets.

Fishing year	BLL	TWL	Total
2000/01	0 (0 - 0)	782 (727 - 1 658)	782 (727 - 1 658)
2001/02	0 (0 - 0)	754 (698 - 844)	754 (698 - 844)
2002/03	0 (0 - 0)	838 (781 - 1 509)	838 (781 - 1 509)
2003/04	0 (0 - 0)	719 (651 - 847)	719 (651 - 847)
2004/05	0 (0 - 0)	573 (525 - 961)	573 (525 - 961)
2005/06	0 (0 - 0)	549 (499 - 3 506)	549 (499 - 3 506)
2006/07	0 (0 - 0)	491 (453 - 642)	491 (453 - 642)
2007/08	0 (0 - 0)	601 (548 - 1 064)	601 (548 - 1 064)
2008/09	0 (0 - 0)	555 (501 - 757)	555 (501 - 757)
2009/10	0 (0 - 0)	560 (516 - 1 374)	560 (516 - 1 374)
2010/11	0 (0 - 0)	527 (493 - 616)	527 (493 - 616)
2011/12	0 (0 - 0)	592 (551 - 643)	592 (551 - 643)
2012/13	0 (0 - 0)	559 (521 - 942)	559 (521 - 942)
2013/14	0 (0 - 0)	571 (528 - 1 070)	571 (528 - 1 070)
2014/15	0 (0 - 0)	642 (595 - 1 185)	642 (595 - 1 185)
2015/16	0 (0 - 0)	633 (579 - 2 861)	633 (579 - 2 861)
2016/17	0 (0 - 0)	643 (596 - 1 267)	643 (596 - 1 267)
2017/18	0 (0 - 0)	639 (593 - 3 408)	639 (593 - 3 408)
2018/19	0 (0 - 0)	559 (519 - 620)	559 (519 - 620)

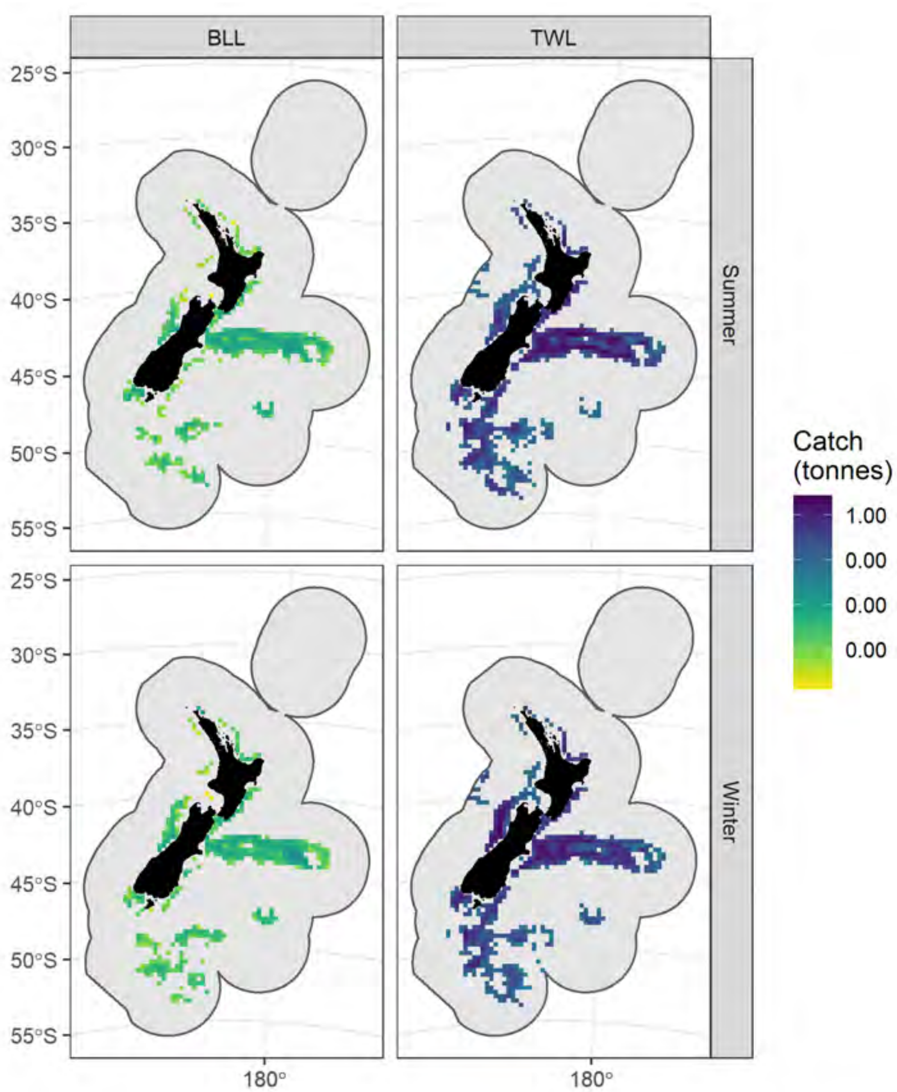


Figure S185: Posterior prediction of the total catches by grid cell, method and season for lookdown dory. Average annual catches per season were calculated as the sum across gear types per cell and method. Posterior median values are shown, with catches in tonnes on a log10 scale.

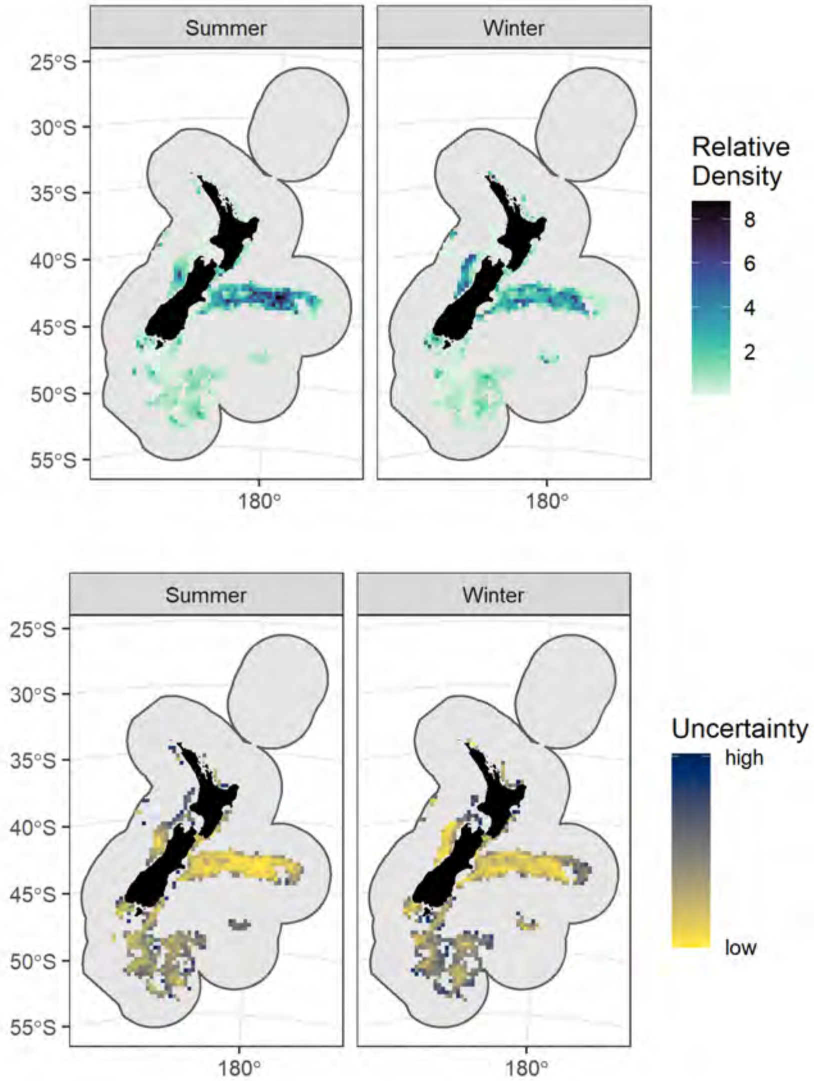


Figure S186: Posterior prediction of the relative density per grid cell and season for lookdown dory. Posterior median values are shown on a natural scale in tonnes per square kilometre. Uncertainty is measured using the difference between the upper and lower 95% equal-tailed posterior density interval.

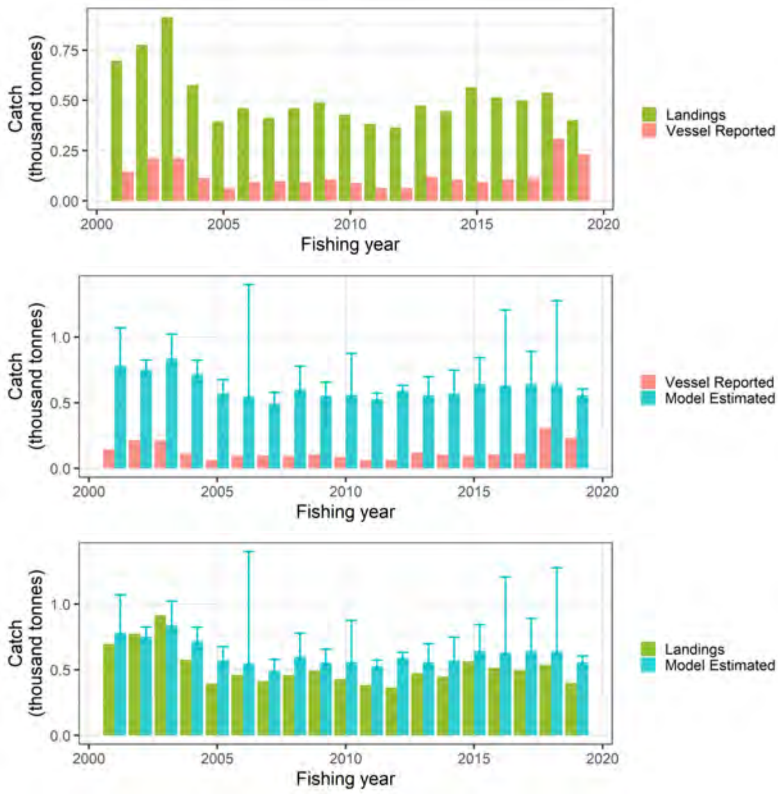


Figure S187: Relationships between landings, vessel reported catches and model estimated catches for lookdown dory.

S2.18 Smooth skate (*Dipturus innominatus*)

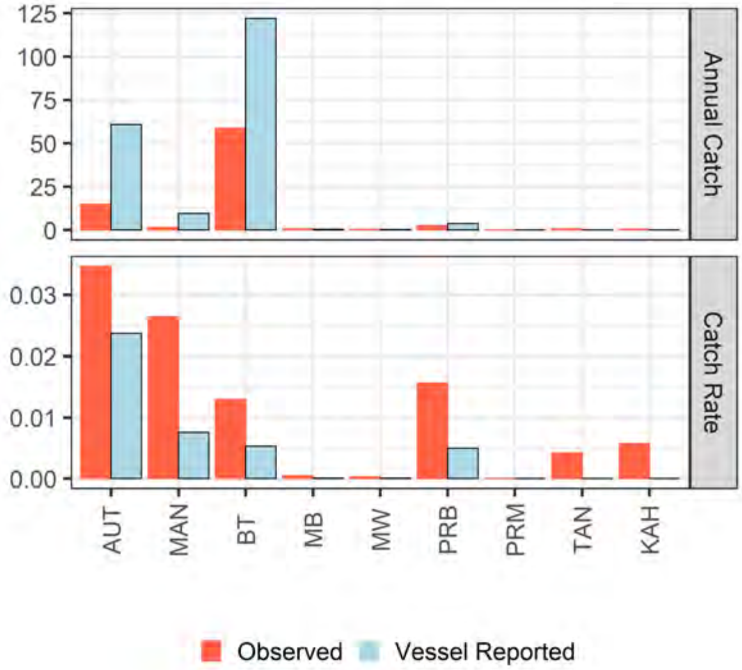


Figure S188: Empirical catch and catch rate data per gear type for smooth skate. Annual catch is given in tonnes as an average across years. The catch rate is an average calculated as the sum of the observed catch in kilograms (i.e., $\sum X_i$) over the sum of the effort count (number of fishing events). Effort was calculated as a count to allow comparability between methods. There are no vessel reported catches for TAN and KAH surveys.

Table S54: Summary data for smooth skate across 631 grid cells, removing 49 511 commercial events that were outside the selected cells. The total landings associated with retained commercial effort equal 9 715 tonnes. Catch is in units of tonnes, effort in the number of fishing events. "Obs." is observed; "Com." is commercial.

Method	Gear	Obs. catch	Obs. effort	Com. catch	Com. effort
BLL	AUT	284	8 187	1 155	48 802
BLL	MAN	22	826	181	23 836
TWL	BT	1 116	86 012	2 317	434 651
TWL	MB	15	30 714	9	109 699
TWL	MW	8	28 732	4	67 137
TWL	PRB	13	850	15	3 058
TWL	PRM	0	403	0	2 062
TWL	TAN	16	3 781		
TWL	KAH	8	1 310		
Total		1 481	160 815	3 682	689 245

Table S55: Model selection summary statistics for smooth skate. Model 6 was selected for prediction of the catches.

Model	$\mathbb{L}[X]$	MPE	L^2	WAIC	$\hat{R}(\alpha)$	$\hat{R}(\gamma)$	$\hat{R}(\pi)$	DRE
1	-0.020	0.023	0.041	1516.675	1.001	1.000	1.001	0.945
2	-0.020	0.023	0.041	1550.076	1.008	1.001	1.003	1.003
3	-0.019	0.023	0.041	1564.497	1.003	1.011	1.015	0.860
4	-0.019	0.023	0.041	1565.618	1.008	1.006	1.006	0.846
5	-0.019	0.023	0.041	1565.077	1.004	1.002	1.003	0.840
6	-0.019	0.023	0.041	1567.089	1.004	1.001	1.002	0.821

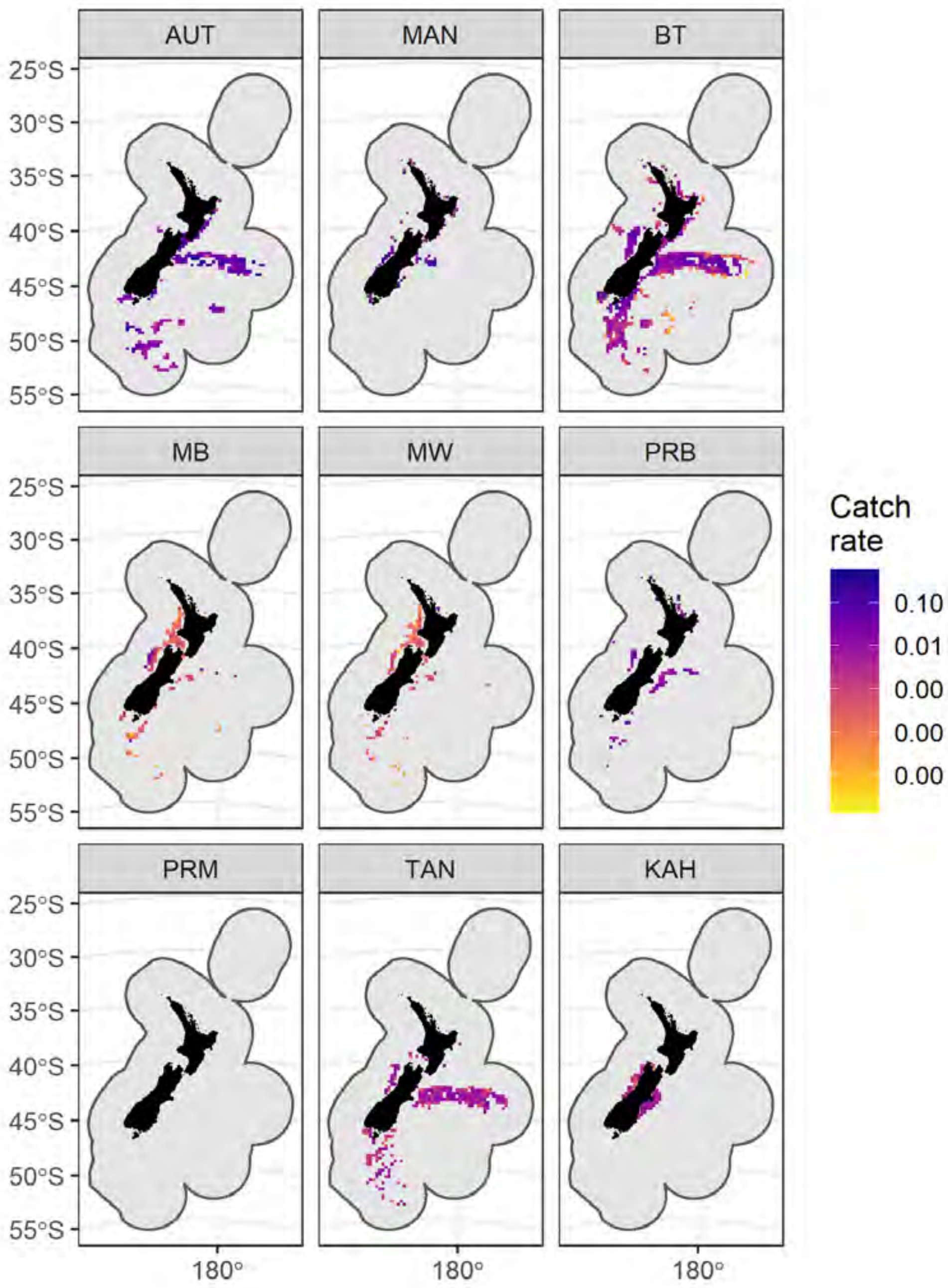


Figure S189: Observer catch rate data for smooth skate on a log10-scale. The catch rate is an average calculated as the sum of the observed catch $\sum X_i$ over the number of observed fishing events per grid cell and gear type. Effort was calculated as a count to allow comparability between methods.

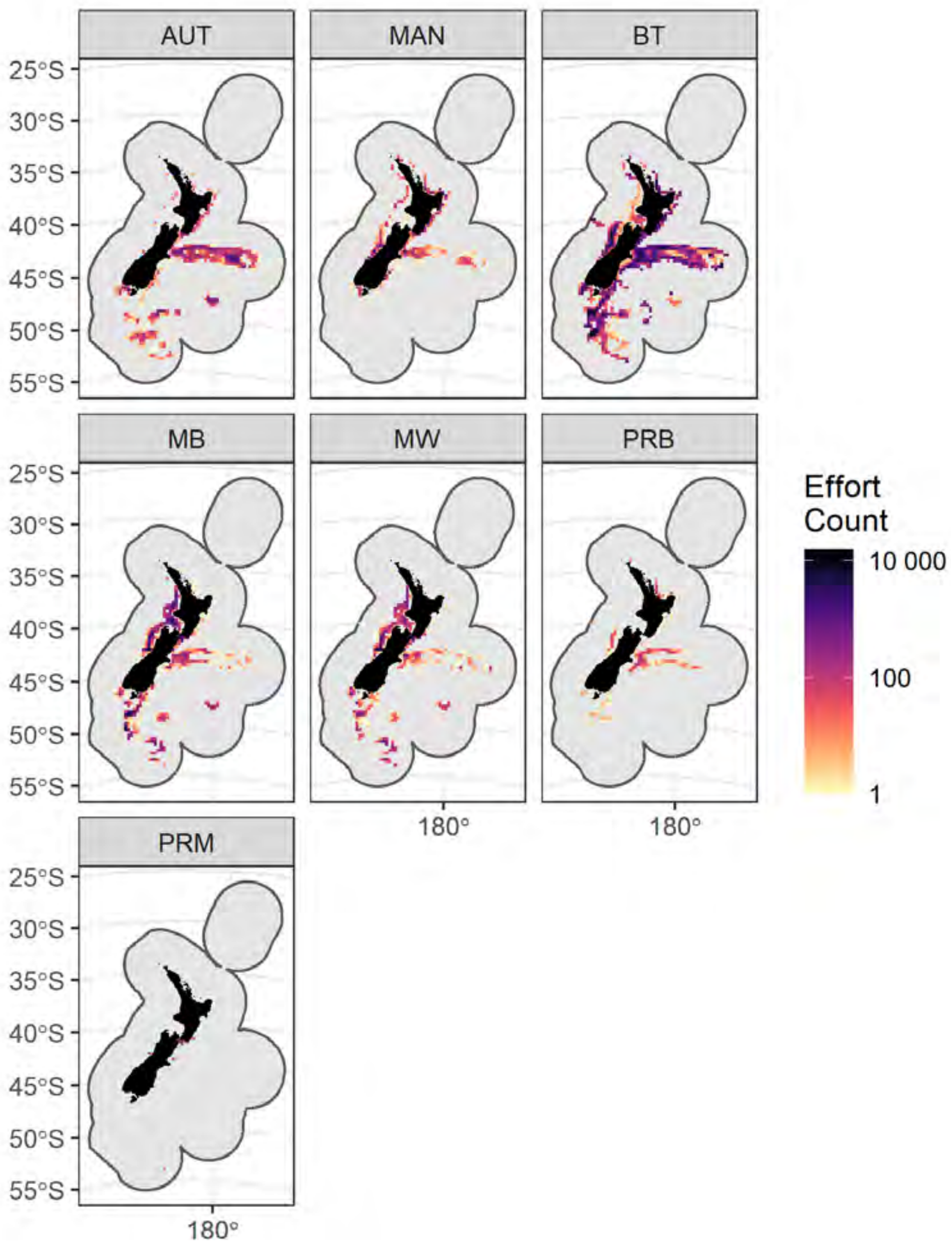


Figure S190: Commercial fishing effort (number of events) for smooth skate summed across all years and presented on a log10-scale per grid cell and gear type. Effort was calculated as a count to allow comparability between methods.

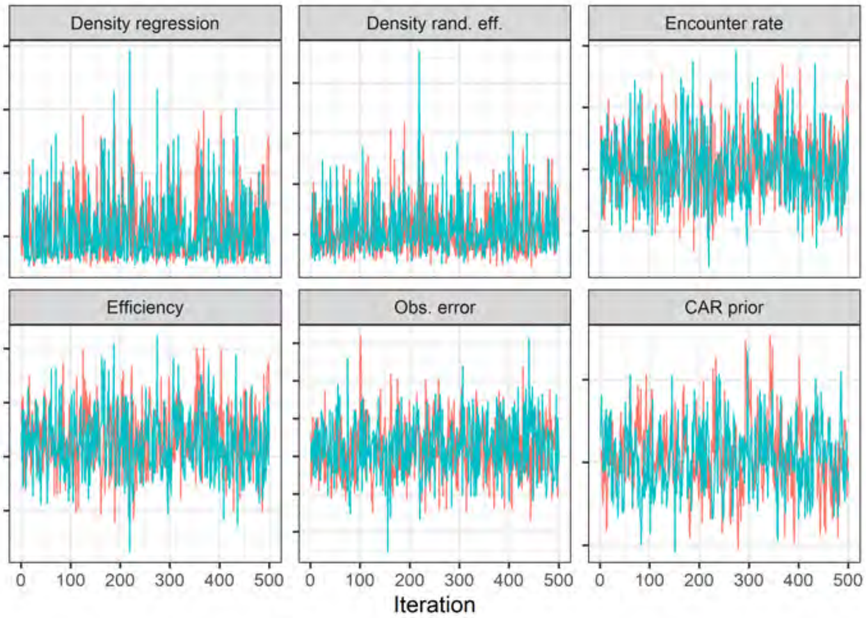


Figure S191: Posterior density sample traces for smooth skate, for the regression coefficients $||\boldsymbol{\alpha}||$, random effects $||\boldsymbol{\phi}||$, encounter rate $||\boldsymbol{\gamma}||$, efficiency $||\boldsymbol{\pi}||$, observation error $||\boldsymbol{\sigma}||$ and conditional autoregressive prior parameters $||\tau,\rho||$. Colours represent independent sample chains.

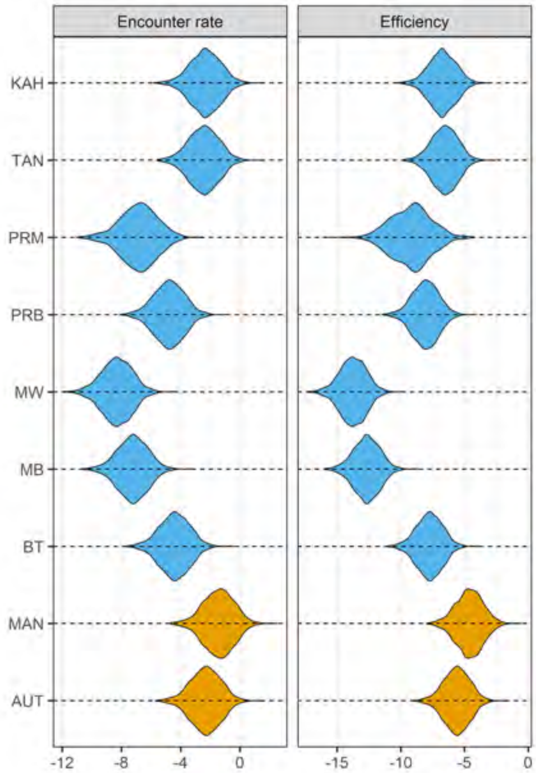


Figure S192: Violin plots of the posterior density for the encounter rate (γ_j) and the efficiency (π_j) per gear type for smooth skate. Catchability terms for bottom longline gear types (see Table S2) are presented in a different colour as they are not comparable to the trawl gear types because they are dependent on different measures of effort (i.e., thousand hooks and distance, respectively).

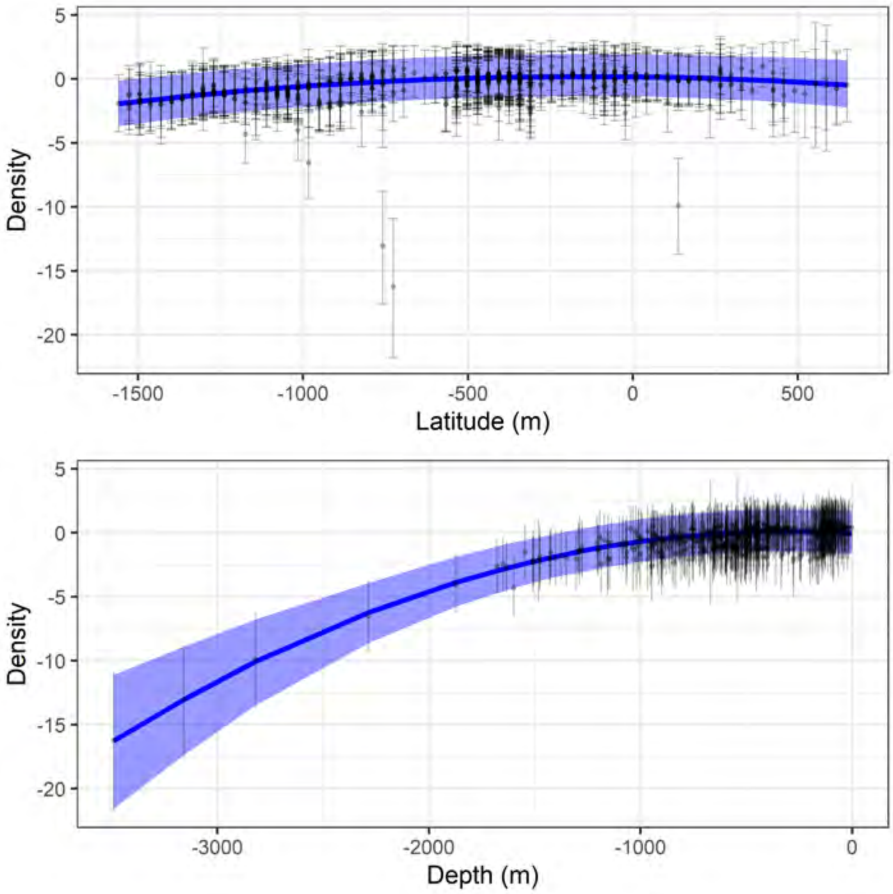


Figure S193: Estimated relationship between biomass density per grid cell and environmental covariates for smooth skate. Points and error bars show the median and 90% credibility intervals per cell. The blue ribbon shows the estimated marginal relationship.

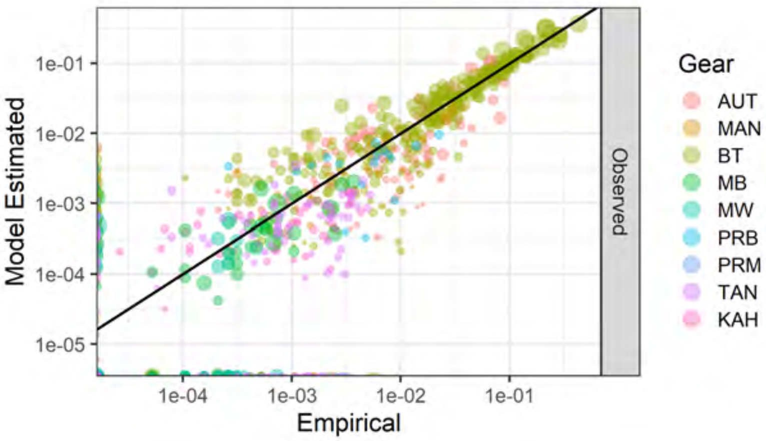


Figure S194: Fit of model to empirical observer catches. Total catches are summed per grid cell and gear type for smooth skate. Model estimates are the median of the posterior predicted distribution. The size of the point is representative of the number of observed events. Catches are shown in tonnes on a log10 scale.

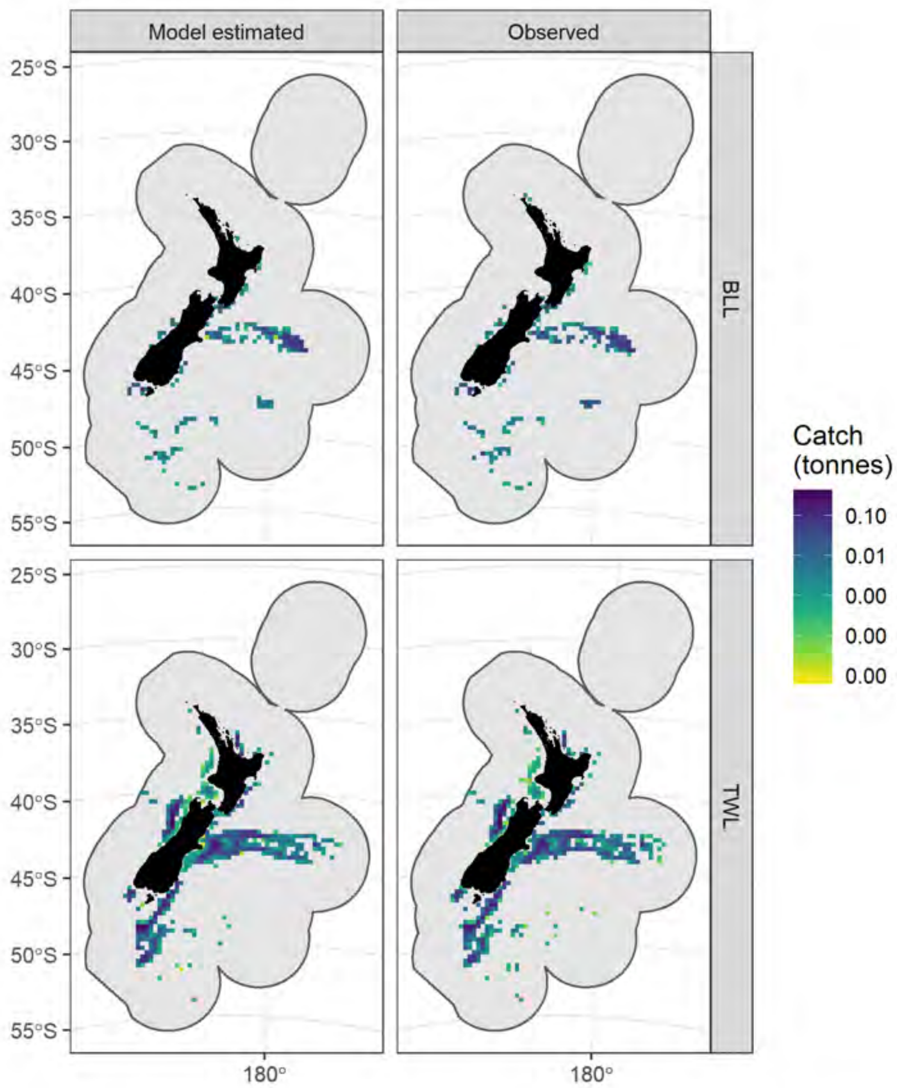


Figure S195: Spatial fit of model to empirical observer catches by grid cell and method for smooth skate. Average annual catches were calculated as the sum across gear types per cell and method. Posterior median values are shown, with catches in tonnes on a log10 scale.

Table S56: Total predicted bycatch (tonnes) per method for smooth skate. Posterior median values are given, with the 95% equal-tailed credibility intervals in brackets.

Fishing year	BLL	TWL	Total
2000/01	91 (79 - 106)	511 (475 - 555)	604 (563 - 648)
2001/02	95 (83 - 109)	522 (485 - 566)	617 (577 - 666)
2002/03	58 (50 - 67)	502 (470 - 538)	560 (527 - 597)
2003/04	80 (69 - 93)	399 (373 - 426)	479 (450 - 509)
2004/05	88 (76 - 104)	382 (358 - 405)	470 (443 - 499)
2005/06	68 (59 - 80)	382 (357 - 408)	450 (424 - 478)
2006/07	65 (56 - 77)	340 (318 - 362)	405 (380 - 430)
2007/08	107 (88 - 137)	364 (341 - 390)	473 (440 - 511)
2008/09	103 (86 - 126)	365 (340 - 391)	469 (437 - 507)
2009/10	112 (93 - 141)	432 (402 - 477)	545 (506 - 596)
2010/11	126 (103 - 164)	404 (378 - 432)	531 (493 - 577)
2011/12	108 (90 - 142)	406 (379 - 437)	515 (480 - 558)
2012/13	105 (84 - 138)	398 (371 - 432)	503 (467 - 552)
2013/14	137 (111 - 178)	413 (384 - 447)	551 (510 - 603)
2014/15	136 (109 - 179)	444 (413 - 492)	582 (537 - 645)
2015/16	152 (125 - 195)	451 (416 - 511)	604 (560 - 676)
2016/17	157 (130 - 200)	462 (431 - 510)	621 (577 - 680)
2017/18	144 (117 - 186)	438 (407 - 484)	582 (541 - 642)
2018/19	162 (129 - 243)	400 (370 - 437)	565 (518 - 653)

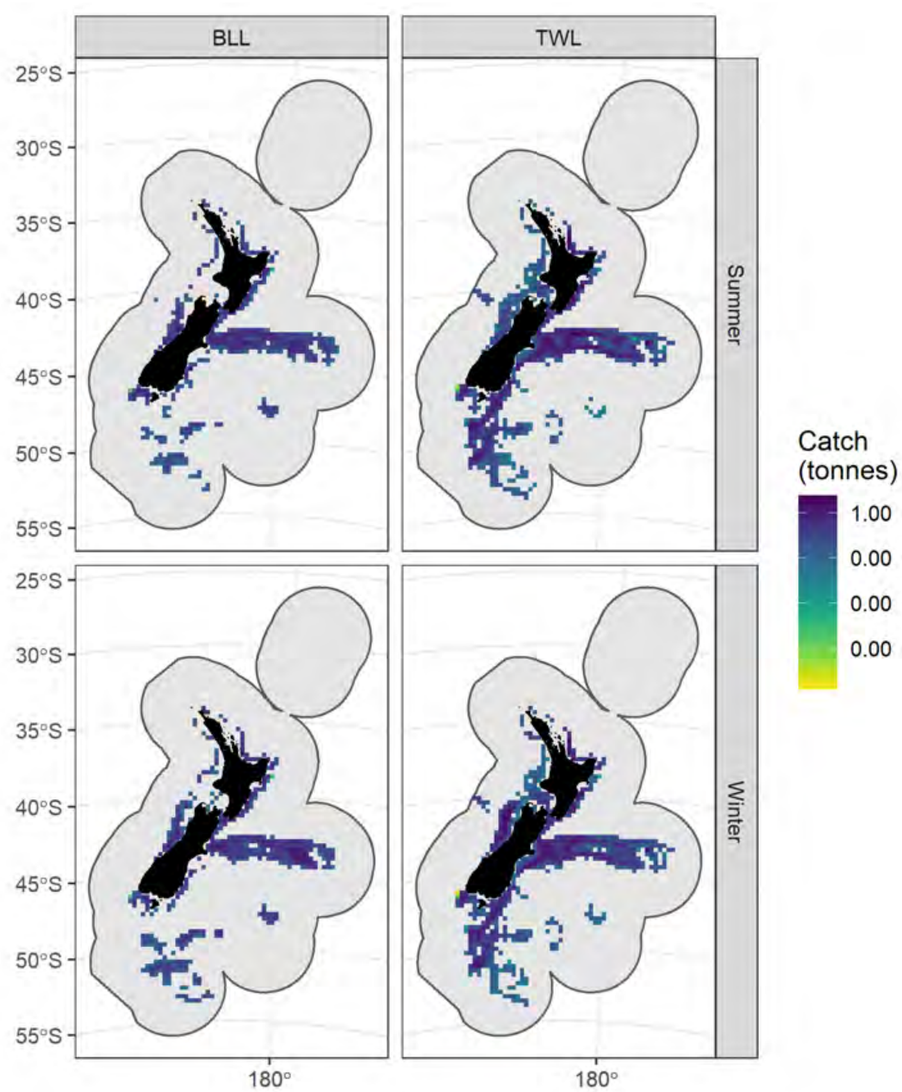


Figure S196: Posterior prediction of the total catches by grid cell, method and season for smooth skate. Average annual catches per season were calculated as the sum across gear types per cell and method. Posterior median values are shown, with catches in tonnes on a log10 scale.

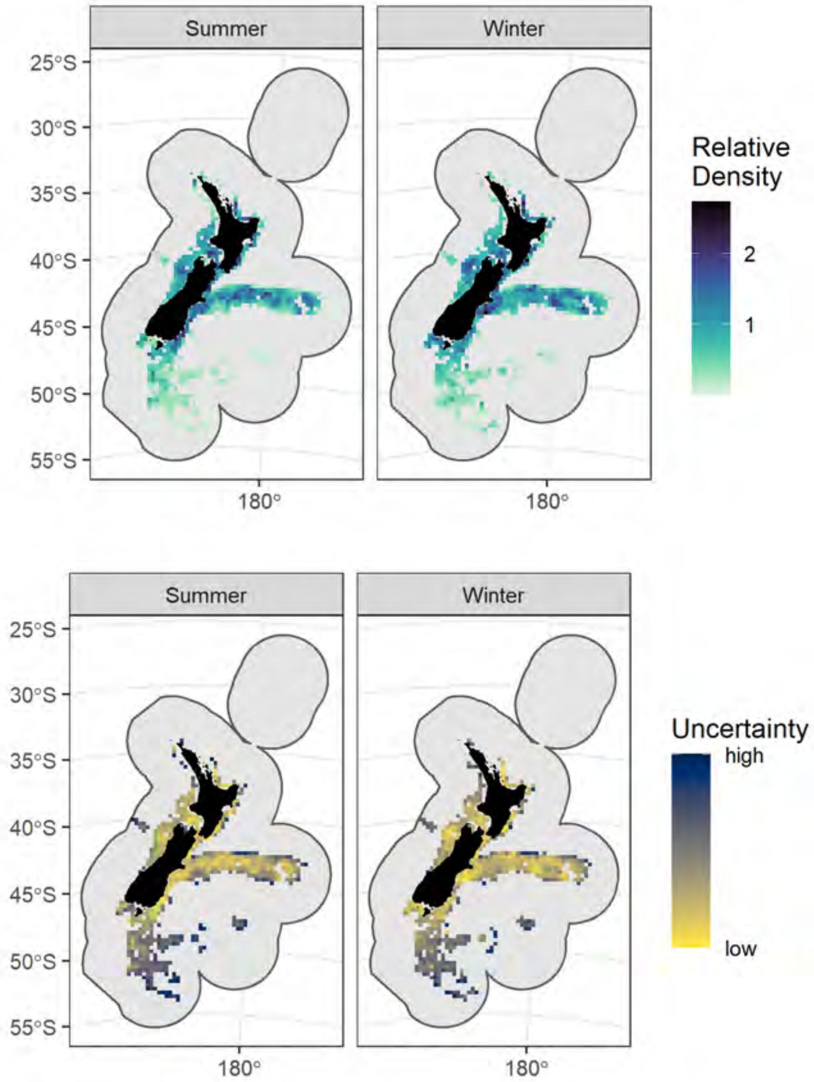


Figure S197: Posterior prediction of the relative density per grid cell and season for smooth skate. Posterior median values are shown on a natural scale in tonnes per square kilometre. Uncertainty is measured using the difference between the upper and lower 95% equal-tailed posterior density interval.

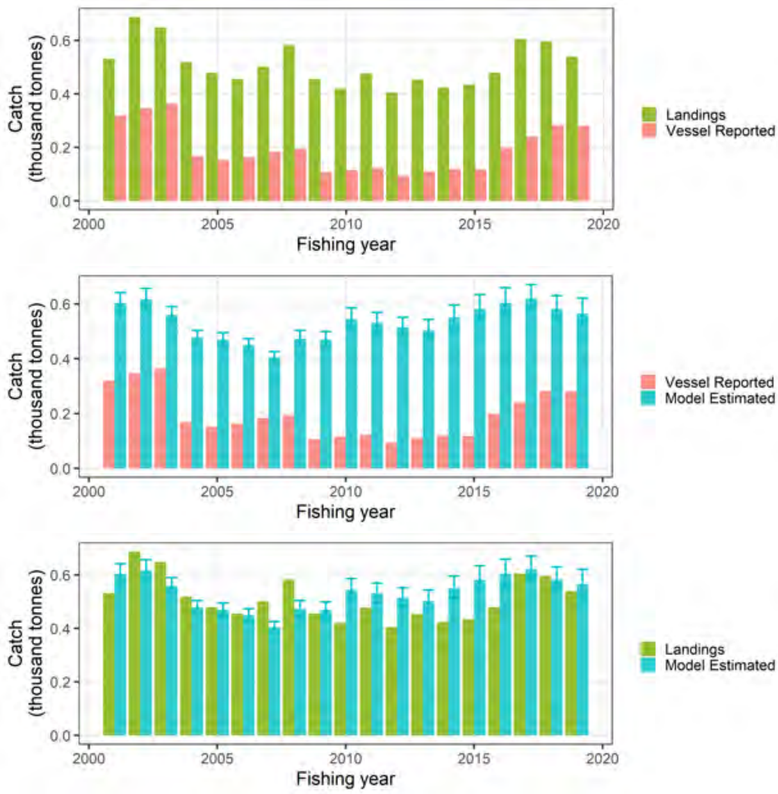


Figure S198: Relationships between landings, vessel reported catches and model estimated catches for smooth skate.

S2.19 Slender tuna (*Allothunnus fallai*)

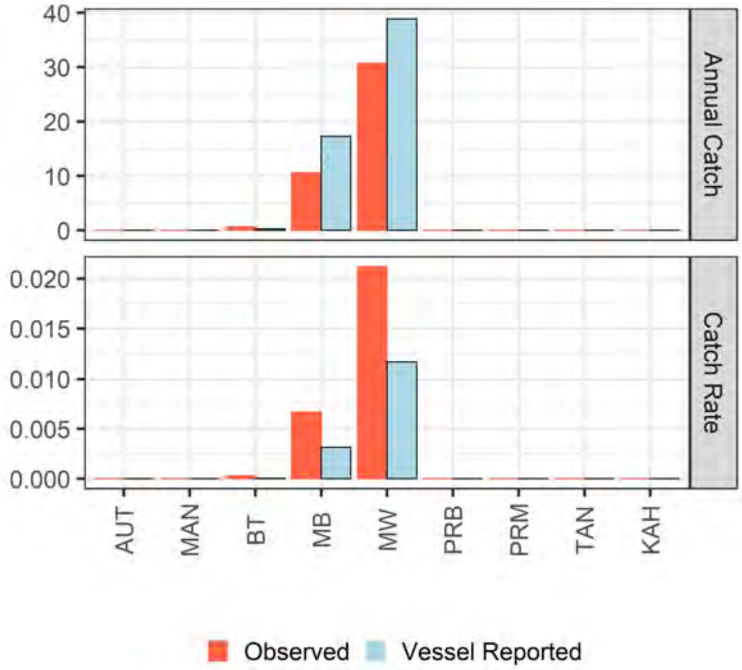


Figure S199: Empirical catch and catch rate data per gear type for slender tuna. Annual catch is given in tonnes as an average across years. The catch rate is an average calculated as the sum of the observed catch in kilograms (i.e., $\sum X_i$) over the sum of the effort count (number of fishing events). Effort was calculated as a count to allow comparability between methods. There are no vessel reported catches for TAN and KAH surveys.

Table S57: Summary data for slender tuna across 200 grid cells, removing 381 101 commercial events that were outside the selected cells. The total landings associated with retained commercial effort equal 3 024 tonnes. Catch is in units of tonnes, effort in the number of fishing events. "Obs." is observed; "Com." is commercial.

Method	Gear	Obs. catch	Obs. effort	Com. catch	Com. effort
BLL	AUT	0	1 781	0	11 611
BLL	MAN	0	339	0	6 007
TWL	BT	13	42 418	6	170 541
TWL	MB	201	30 103	329	103 710
TWL	MW	584	27 570	738	62 953
TWL	PRB	0	438	0	1 167
TWL	PRM	0	342	0	1 666
TWL	TAN	0	895		
TWL	KAH	0	413		
Total		798	104 299	1 073	357 655

Table S58: Model selection summary statistics for slender tuna. Model 6 was selected for prediction of the catches.

Model	$\mathbb{L}[X]$	MPE	L^2	WAIC	$\hat{R}(\alpha)$	$\hat{R}(\gamma)$	$\hat{R}(\pi)$	DRE
1	-0.010	0.011	0.018	-57.255	1.019	1.040	1.047	1.341
2	-0.009	0.011	0.022	-32.589	1.004	1.004	1.006	1.345
3	-0.009	0.011	0.019	-32.302	1.005	1.004	1.009	1.235
4	-0.009	0.011	0.018	-29.104	1.010	1.032	1.042	1.186
5	-0.009	0.011	0.019	-28.763	1.016	1.003	1.006	1.185
6	-0.009	0.011	0.020	-26.339	1.040	1.046	1.070	1.140

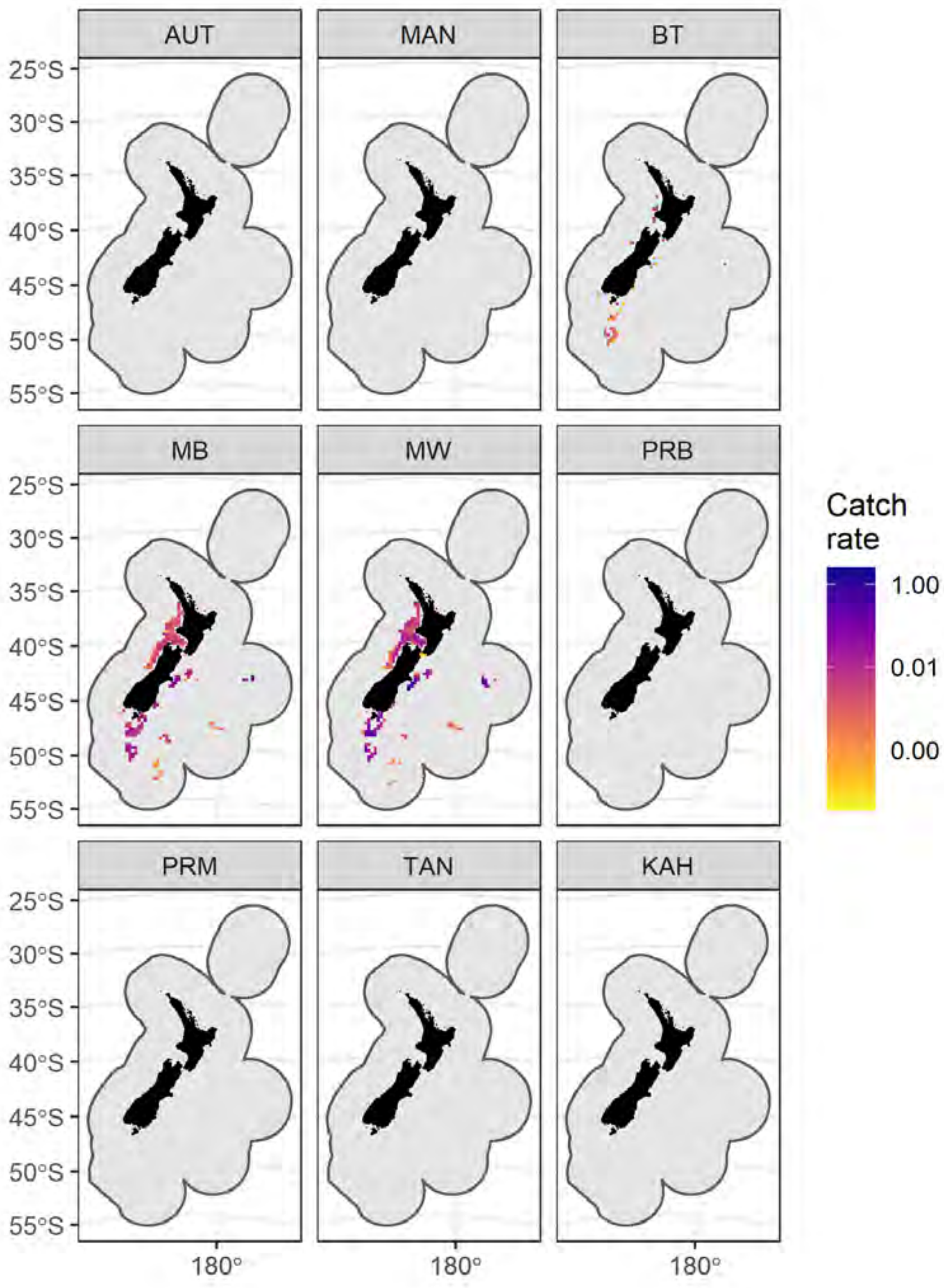


Figure S200: Observer catch rate data for slender tuna on a log10-scale. The catch rate is an average calculated as the sum of the observed catch $\sum X_i$ over the number of observed fishing events per grid cell and gear type. Effort was calculated as a count to allow comparability between methods.

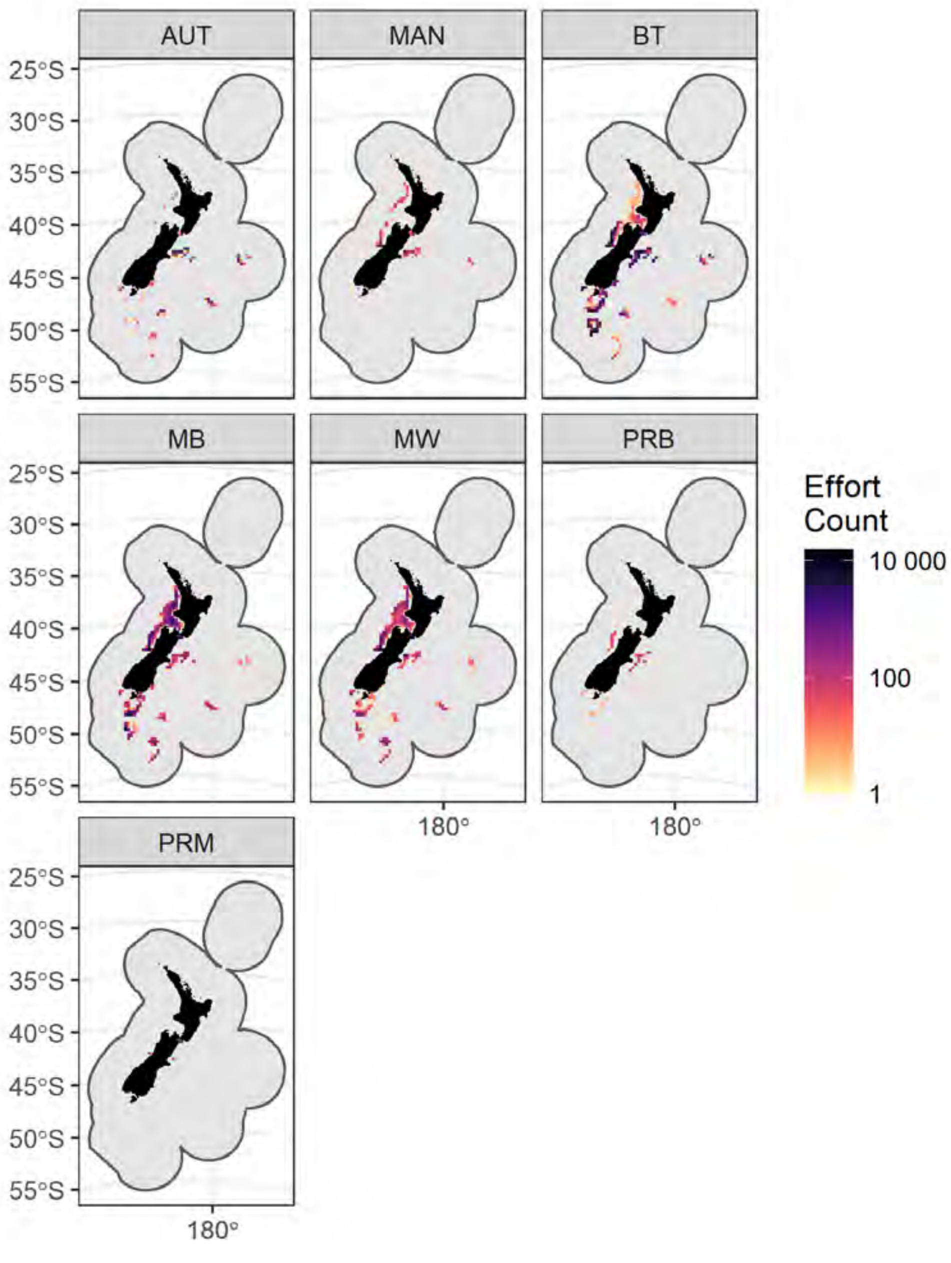


Figure S201: Commercial fishing effort (number of events) for slender tuna summed across all years and presented on a log10-scale per grid cell and gear type. Effort was calculated as a count to allow comparability between methods.

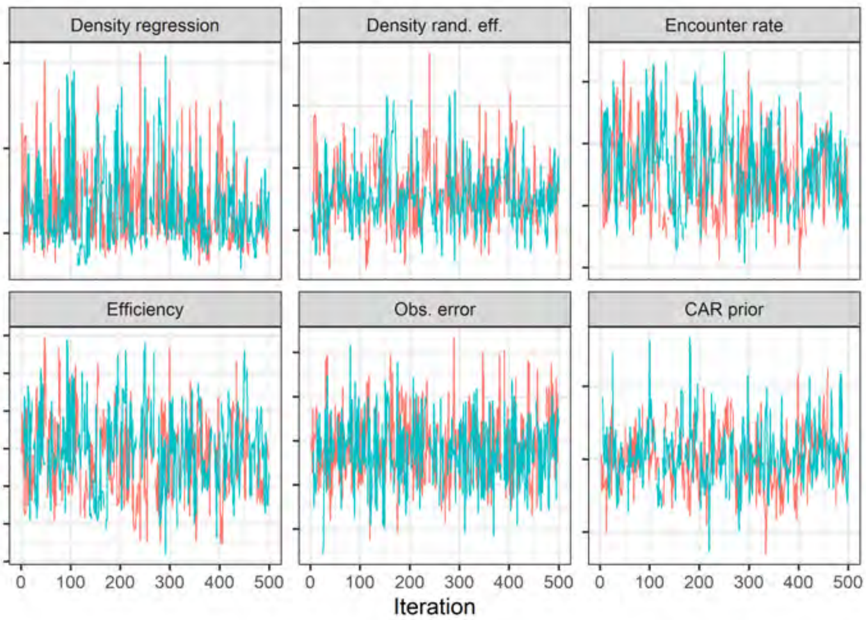


Figure S202: Posterior density sample traces for slender tuna, for the regression coefficients $||\boldsymbol{\alpha}||$, random effects $||\boldsymbol{\phi}||$, encounter rate $||\boldsymbol{\gamma}||$, efficiency $||\boldsymbol{\pi}||$, observation error $||\boldsymbol{\sigma}||$ and conditional autoregressive prior parameters $||\tau, \rho||$. Colours represent independent sample chains.

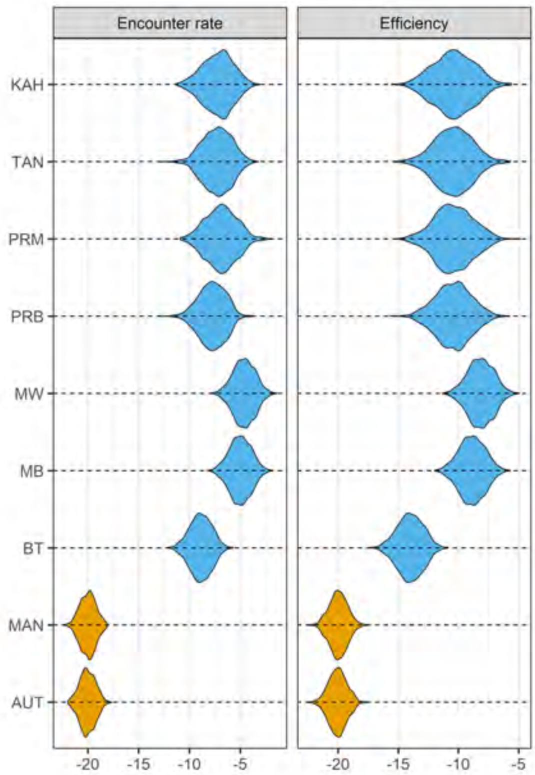


Figure S203: Violin plots of the posterior density for the encounter rate (γ_j) and the efficiency (π_j) per gear type for slender tuna. Catchability terms for bottom longline gear types (see Table S2) are presented in a different colour as they are not comparable to the trawl gear types because they are dependent on different measures of effort (i.e., thousand hooks and distance, respectively).

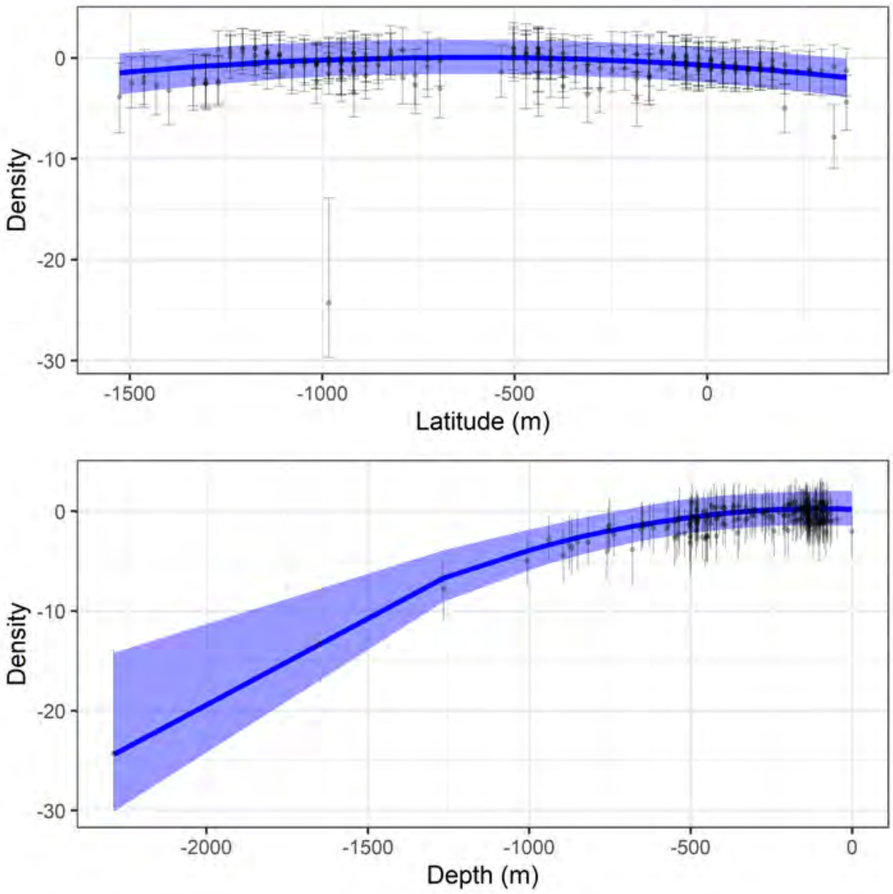


Figure S204: Estimated relationship between biomass density per grid cell and environmental covariates for slender tuna. Points and error bars show the median and 90% credibility intervals per cell. The blue ribbon shows the estimated marginal relationship.

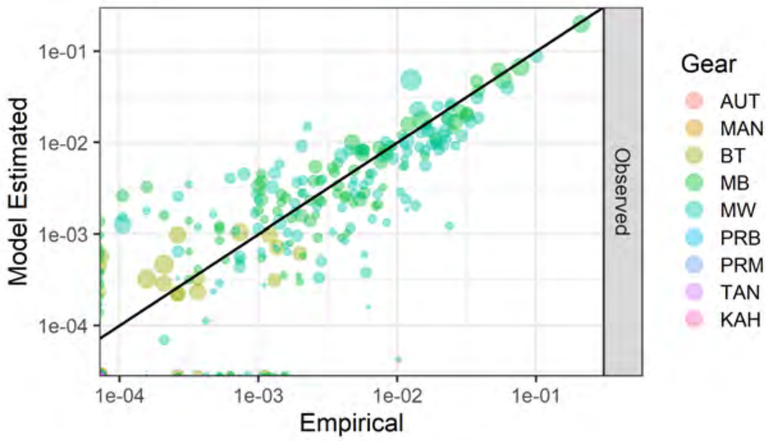


Figure S205: Fit of model to empirical observer catches. Total catches are summed per grid cell and gear type for slender tuna. Model estimates are the median of the posterior predicted distribution. The size of the point is representative of the number of observed events. Catches are shown in tonnes on a log10 scale.

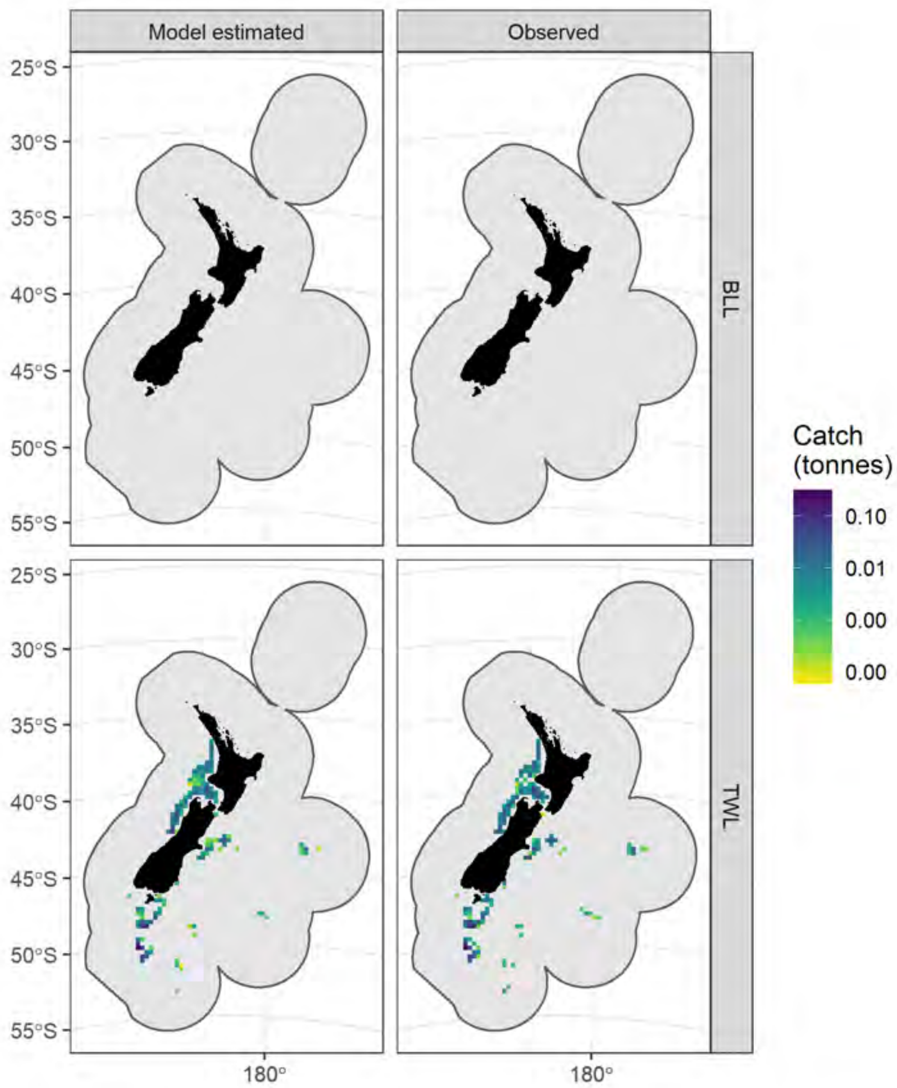


Figure S206: Spatial fit of model to empirical observer catches by grid cell and method for slender tuna. Average annual catches were calculated as the sum across gear types per cell and method. Posterior median values are shown, with catches in tonnes on a log10 scale.

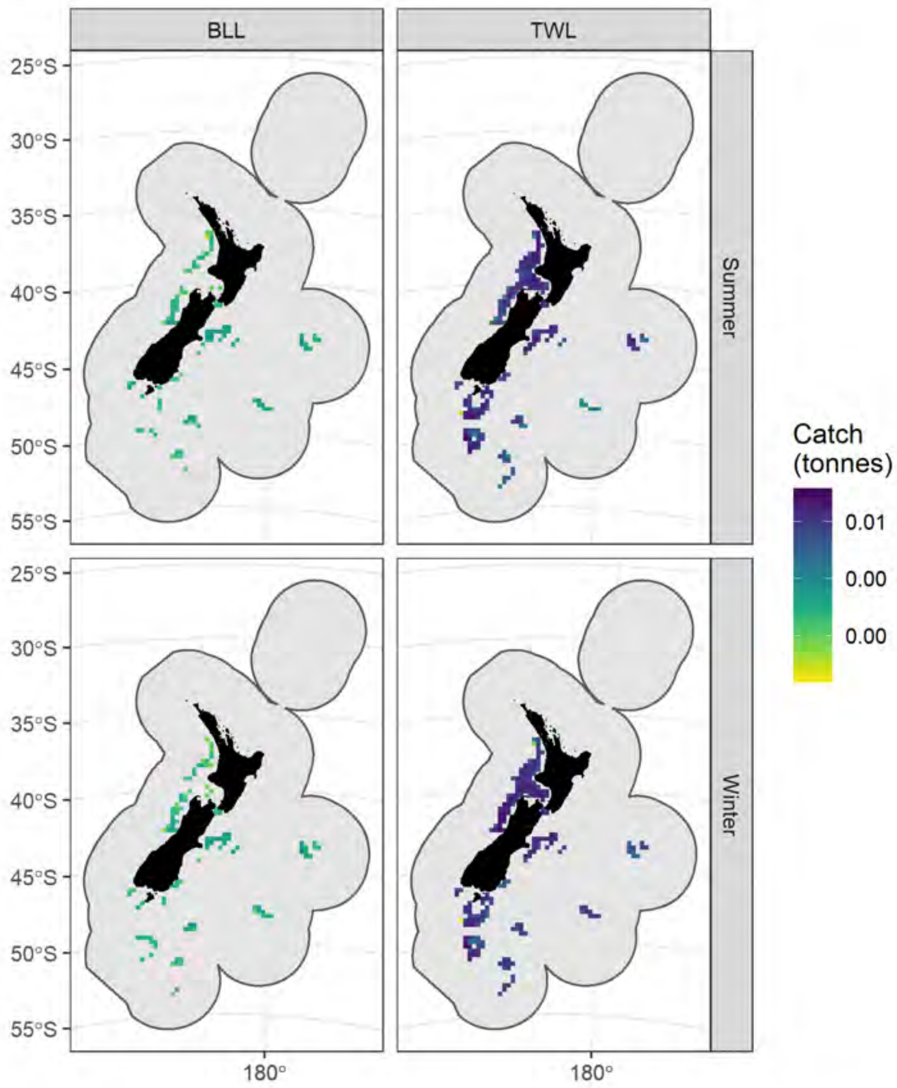


Figure S207: Posterior prediction of the total catches by grid cell, method and season for slender tuna. Average annual catches per season were calculated as the sum across gear types per cell and method. Posterior median values are shown, with catches in tonnes on a log10 scale.

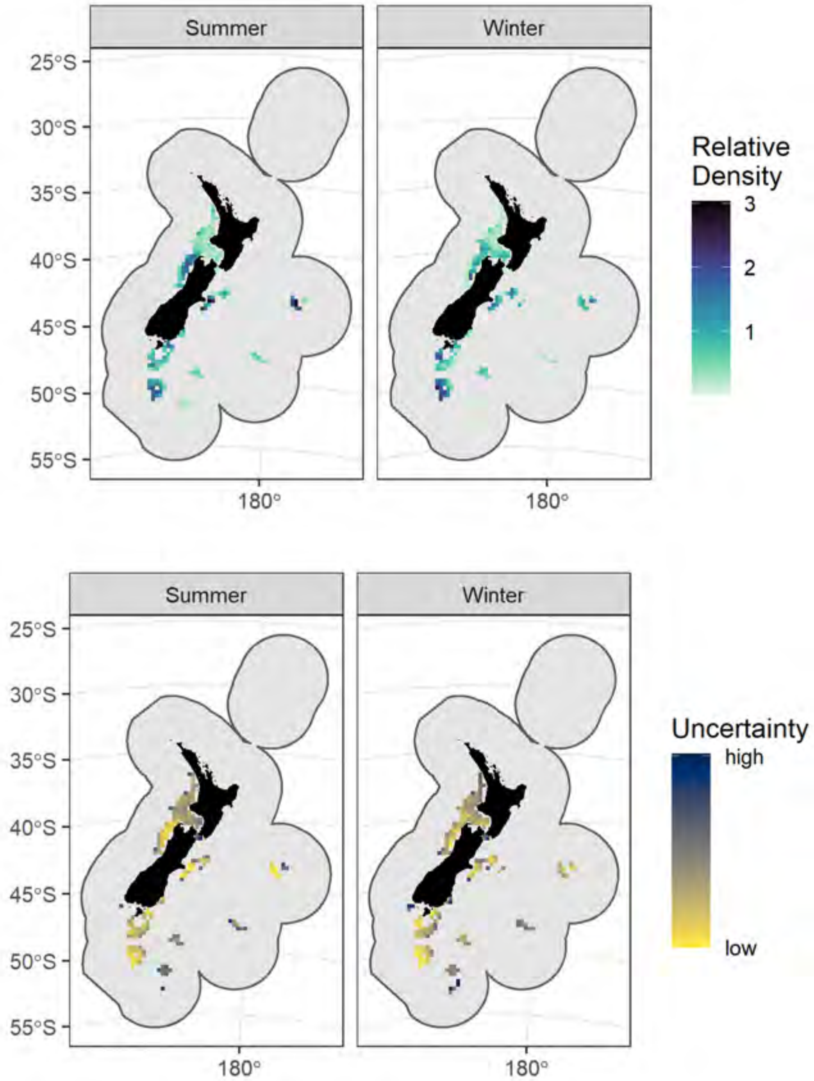


Figure S208: Posterior prediction of the relative density per grid cell and season for slender tuna. Posterior median values are shown on a natural scale in tonnes per square kilometre. Uncertainty is measured using the difference between the upper and lower 95% equal-tailed posterior density interval.

Table S59: Total predicted bycatch (tonnes) per method for slender tuna. Posterior median values are given, with the 95% equal-tailed credibility intervals in brackets.

Fishing year	BLL	TWL	Total
2000/01	0 (0 - 0)	26 (23 - 29)	26 (23 - 29)
2001/02	0 (0 - 0)	31 (28 - 35)	31 (28 - 35)
2002/03	0 (0 - 0)	29 (26 - 33)	29 (26 - 33)
2003/04	0 (0 - 0)	30 (27 - 35)	30 (27 - 35)
2004/05	0 (0 - 0)	31 (28 - 35)	31 (28 - 35)
2005/06	0 (0 - 0)	24 (22 - 28)	24 (22 - 28)
2006/07	0 (0 - 0)	25 (22 - 28)	25 (22 - 28)
2007/08	0 (0 - 0)	22 (20 - 25)	22 (20 - 25)
2008/09	0 (0 - 0)	25 (22 - 28)	25 (22 - 28)
2009/10	0 (0 - 0)	14 (12 - 16)	14 (12 - 16)
2010/11	0 (0 - 0)	16 (14 - 18)	16 (14 - 18)
2011/12	0 (0 - 0)	17 (15 - 20)	17 (15 - 20)
2012/13	0 (0 - 0)	17 (15 - 19)	17 (15 - 19)
2013/14	0 (0 - 0)	24 (21 - 28)	24 (21 - 28)
2014/15	0 (0 - 0)	20 (18 - 23)	20 (18 - 23)
2015/16	0 (0 - 0)	19 (17 - 22)	19 (17 - 22)
2016/17	0 (0 - 0)	17 (15 - 20)	17 (15 - 20)
2017/18	0 (0 - 0)	18 (16 - 22)	18 (16 - 22)
2018/19	0 (0 - 0)	22 (19 - 28)	22 (19 - 28)

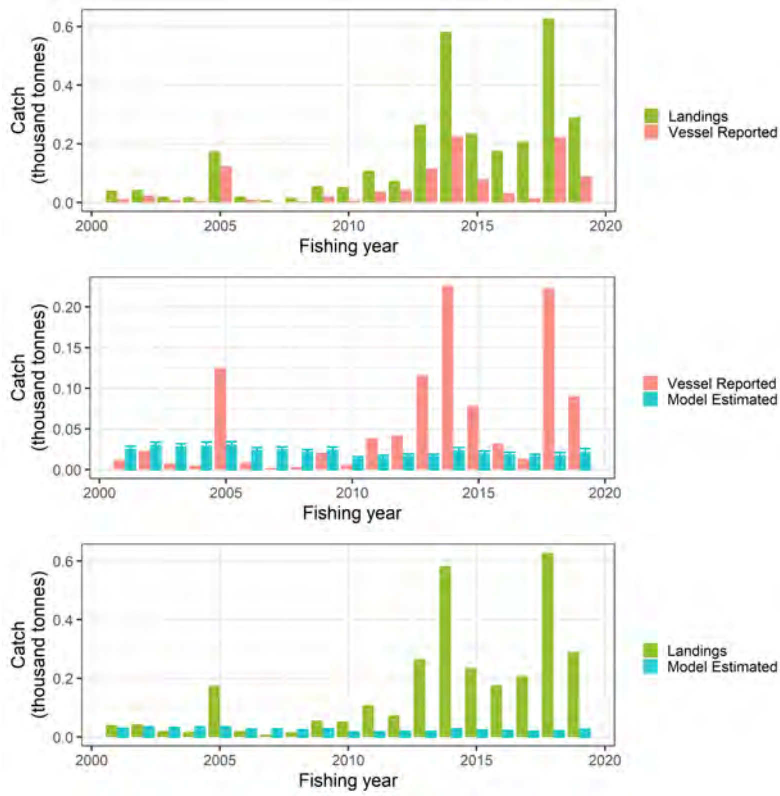


Figure S209: Relationships between landings, vessel reported catches and model estimated catches for slender tuna.

S2.20 Ray's bream (*Brama brama*)

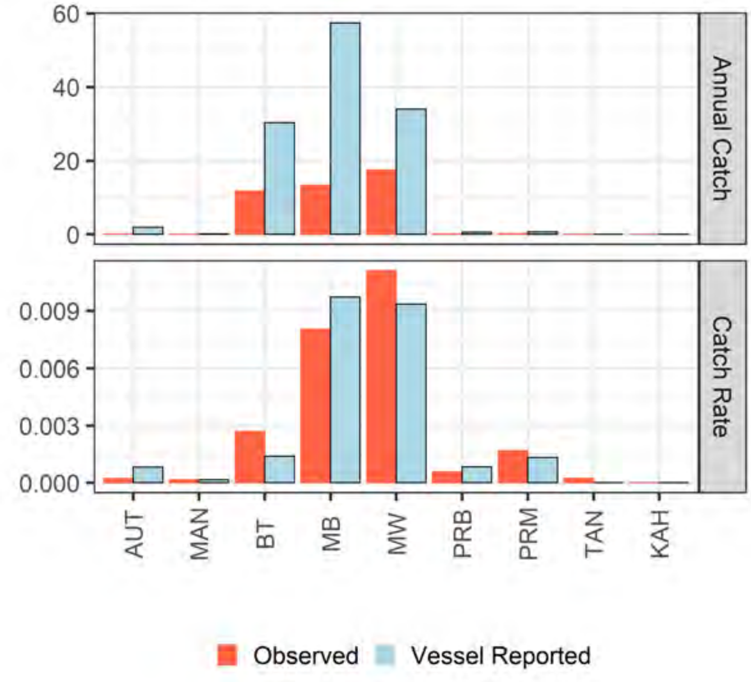


Figure S210: Empirical catch and catch rate data per gear type for Ray's bream. Annual catch is given in tonnes as an average across years. The catch rate is an average calculated as the sum of the observed catch in kilograms (i.e., $\sum X_i$) over the sum of the effort count (number of fishing events). Effort was calculated as a count to allow comparability between methods. There are no vessel reported catches for TAN and KAH surveys.

Table S60: Summary data for Ray's bream across 537 grid cells, removing 77 417 commercial events that were outside the selected cells. The total landings associated with retained commercial effort equal 5 143 tonnes. Catch is in units of tonnes, effort in the number of fishing events. "Obs." is observed; "Com." is commercial.

Method	Gear	Obs. catch	Obs. effort	Com. catch	Com. effort
BLL	AUT	2	7 639	38	45 746
BLL	MAN	0	619	3	16 155
TWL	BT	223	82 425	577	413 154
TWL	MB	254	31 605	1 090	112 175
TWL	MW	333	29 985	645	69 053
TWL	PRB	0	825	3	2 995
TWL	PRM	1	403	3	2 061
TWL	TAN	1	3 568		
TWL	KAH	0	572		
Total		814	157 641	2 358	661 339

Table S61: Model selection summary statistics for Ray's bream. Model 4 was selected for prediction of the catches.

Model	$\mathbb{L}[X]$	MPE	L^2	WAIC	$\hat{R}(\alpha)$	$\hat{R}(\gamma)$	$\hat{R}(\pi)$	DRE
1	-0.062	0.011	0.018	3669.697	1.004	1.016	1.018	1.155
2	-0.059	0.011	0.018	3714.690	1.000	1.011	1.007	1.236
3	-0.059	0.011	0.018	3718.022	1.004	1.007	1.008	1.206
4	-0.059	0.011	0.018	3720.807	1.004	1.004	1.004	1.215
5	-0.059	0.011	0.018	3715.861	1.001	1.003	1.003	1.211
6	-0.059	0.011	0.018	3720.561	1.006	1.010	1.010	1.195

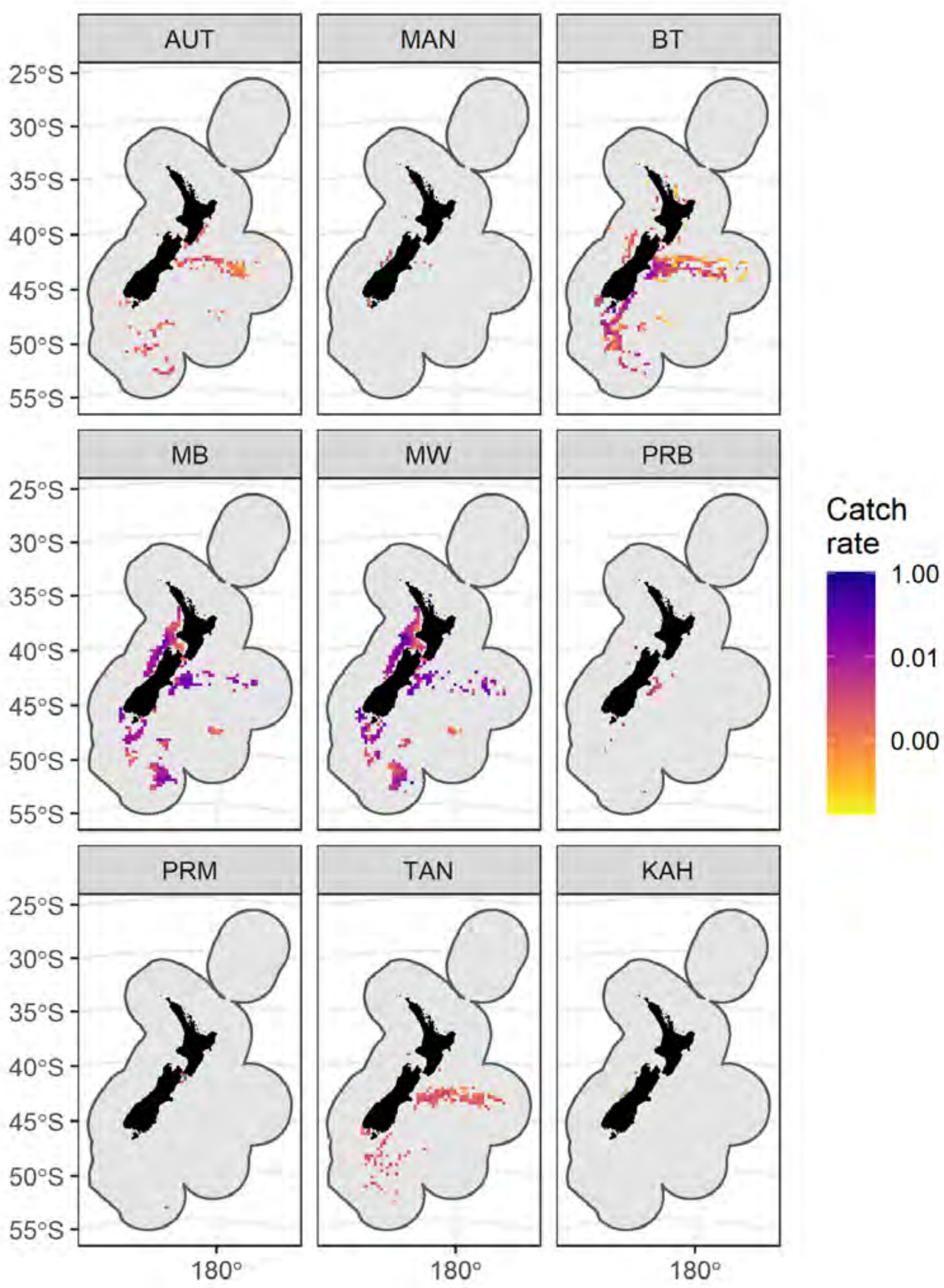


Figure S211: Observer catch rate data for Ray's bream on a log10-scale. The catch rate is an average calculated as the sum of the observed catch $\sum X_i$ over the number of observed fishing events per grid cell and gear type. Effort was calculated as a count to allow comparability between methods.

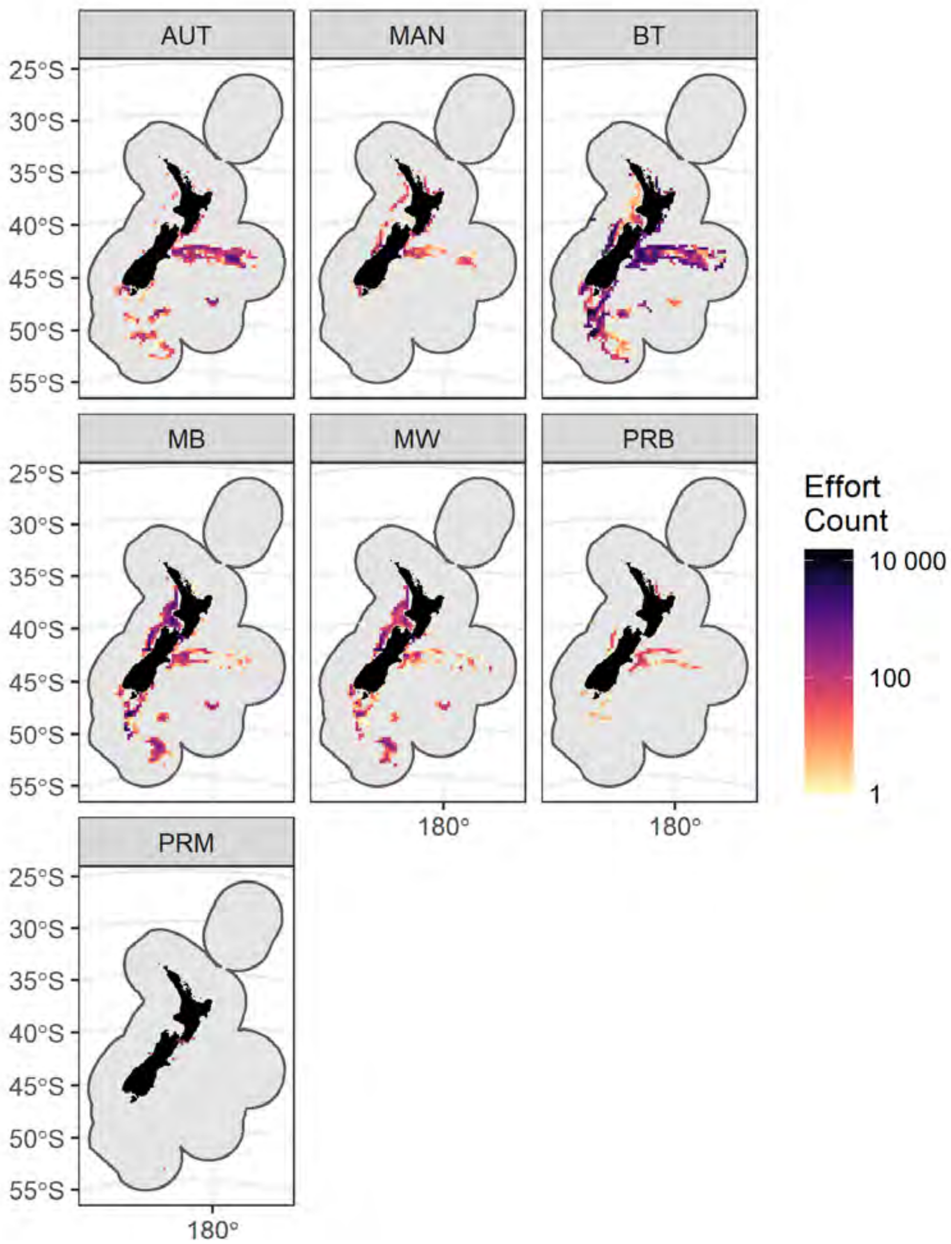


Figure S212: Commercial fishing effort (number of events) for Ray's bream summed across all years and presented on a log10-scale per grid cell and gear type. Effort was calculated as a count to allow comparability between methods.

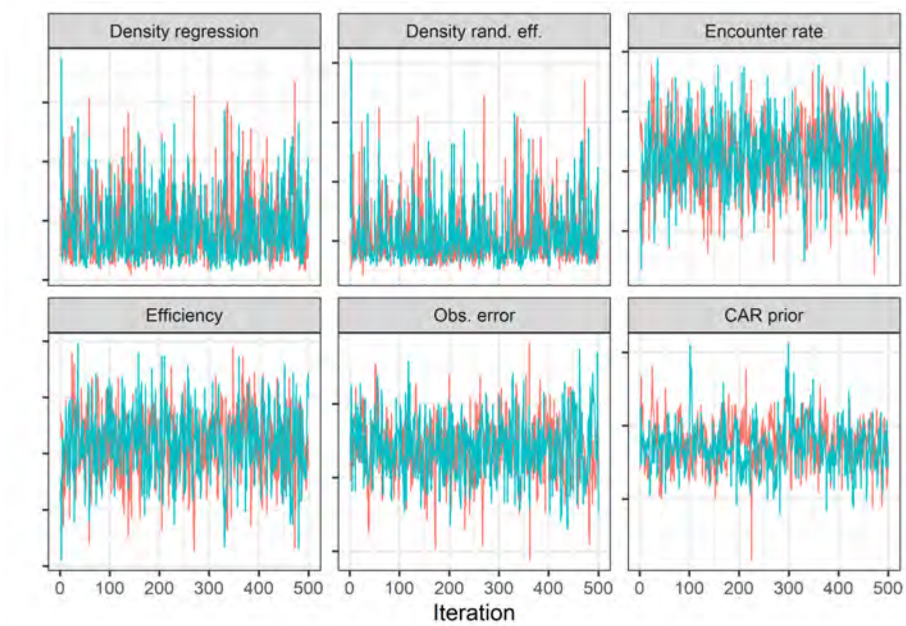


Figure S213: Posterior density sample traces for Ray's bream, for the regression coefficients $||\boldsymbol{\alpha}||$, random effects $||\boldsymbol{\phi}||$, encounter rate $||\boldsymbol{\gamma}||$, efficiency $||\boldsymbol{\pi}||$, observation error $||\boldsymbol{\sigma}||$ and conditional autoregressive prior parameters $||\tau, \rho||$. Colours represent independent sample chains.

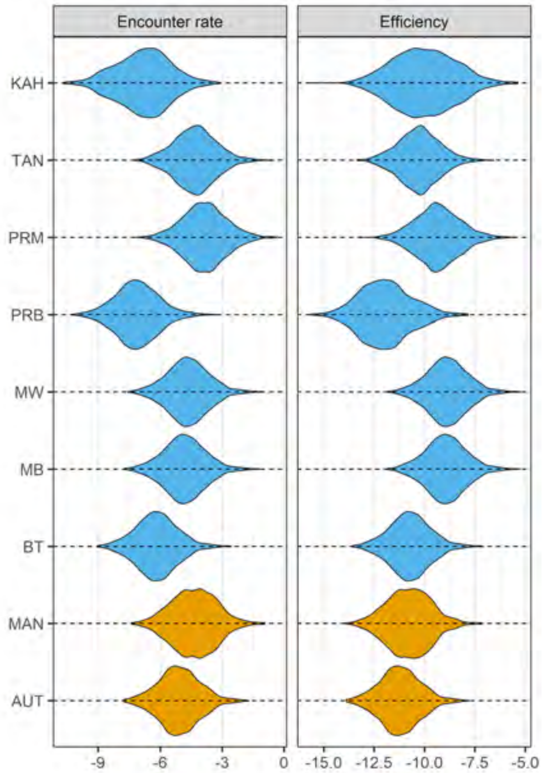


Figure S214: Violin plots of the posterior density for the encounter rate (γ_j) and the efficiency (π_j) per gear type for Ray's bream. Catchability terms for bottom longline gear types (see Table S2) are presented in a different colour as they are not comparable to the trawl gear types because they are dependent on different measures of effort (i.e., thousand hooks and distance, respectively).

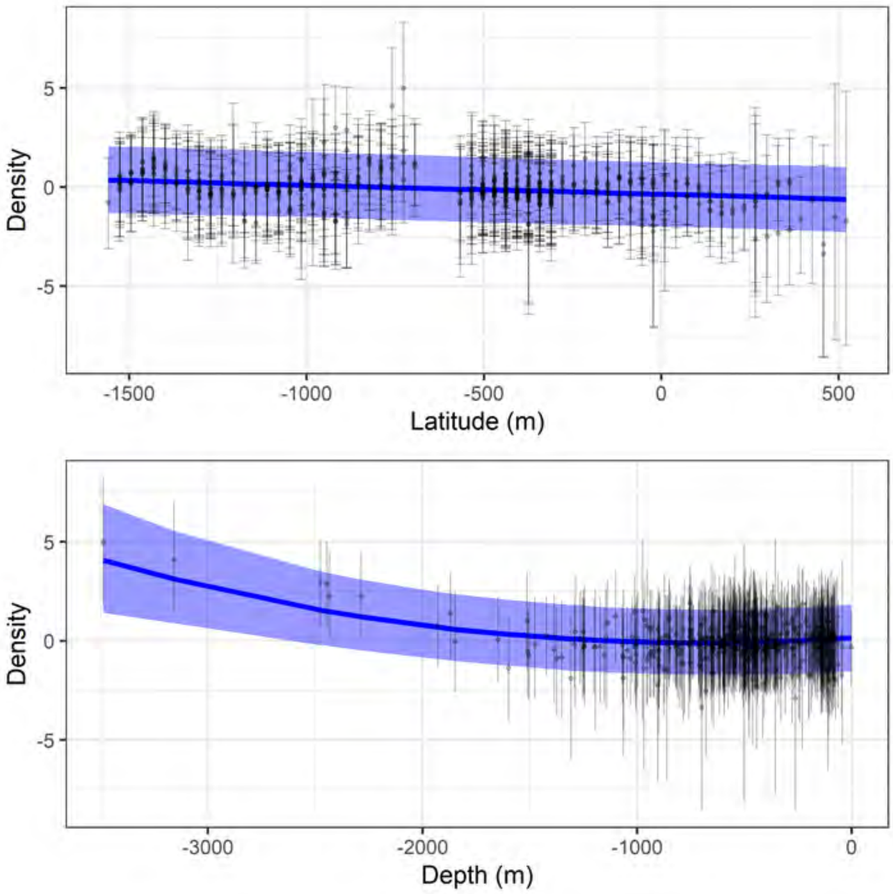


Figure S215: Estimated relationship between biomass density per grid cell and environmental covariates for Ray's bream. Points and error bars show the median and 90% credibility intervals per cell. The blue ribbon shows the estimated marginal relationship.

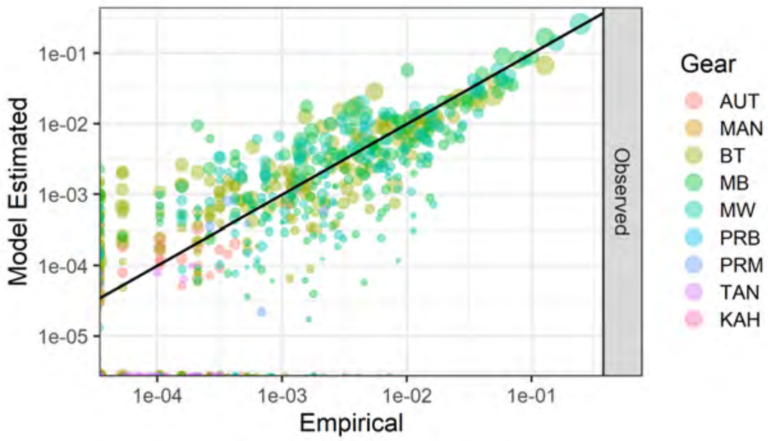


Figure S216: Fit of model to empirical observer catches. Total catches are summed per grid cell and gear type for Ray's bream. Model estimates are the median of the posterior predicted distribution. The size of the point is representative of the number of observed events. Catches are shown in tonnes on a log10 scale.

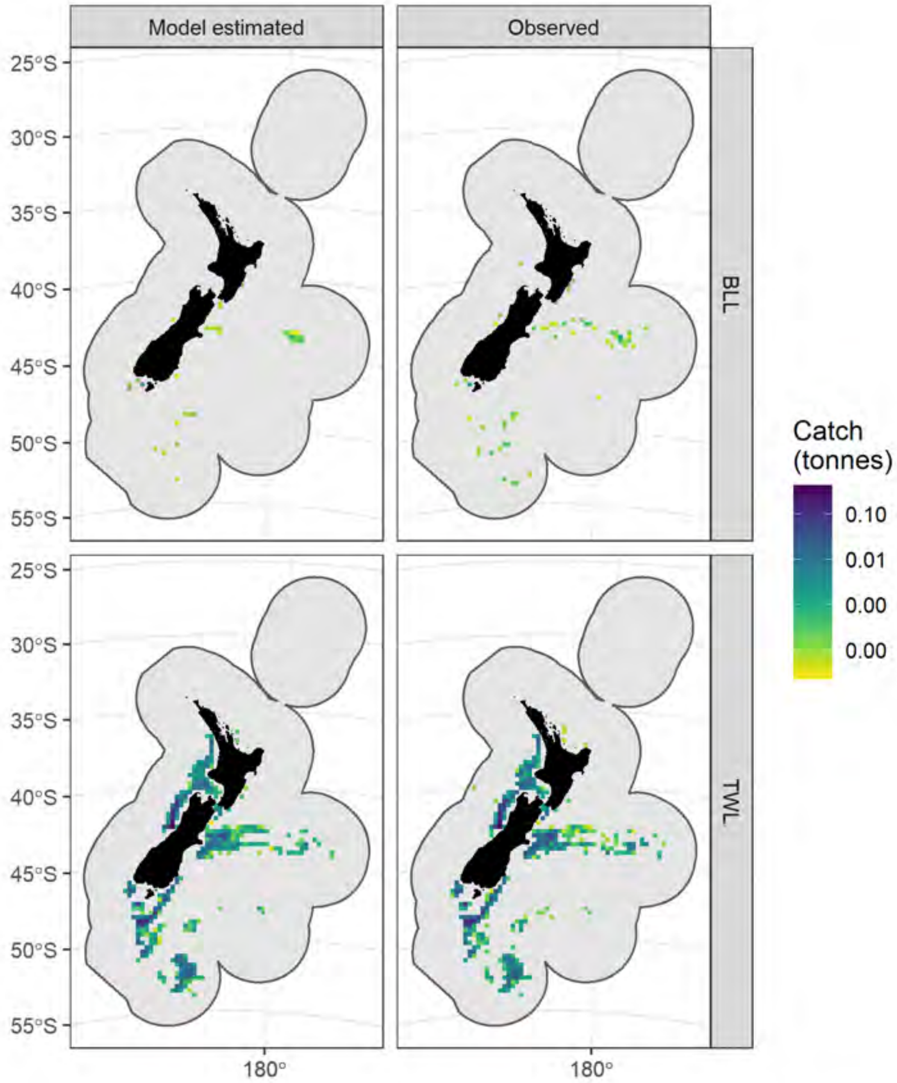


Figure S217: Spatial fit of model to empirical observer catches by grid cell and method for Ray's bream. Average annual catches were calculated as the sum across gear types per cell and method. Posterior median values are shown, with catches in tonnes on a log10 scale.

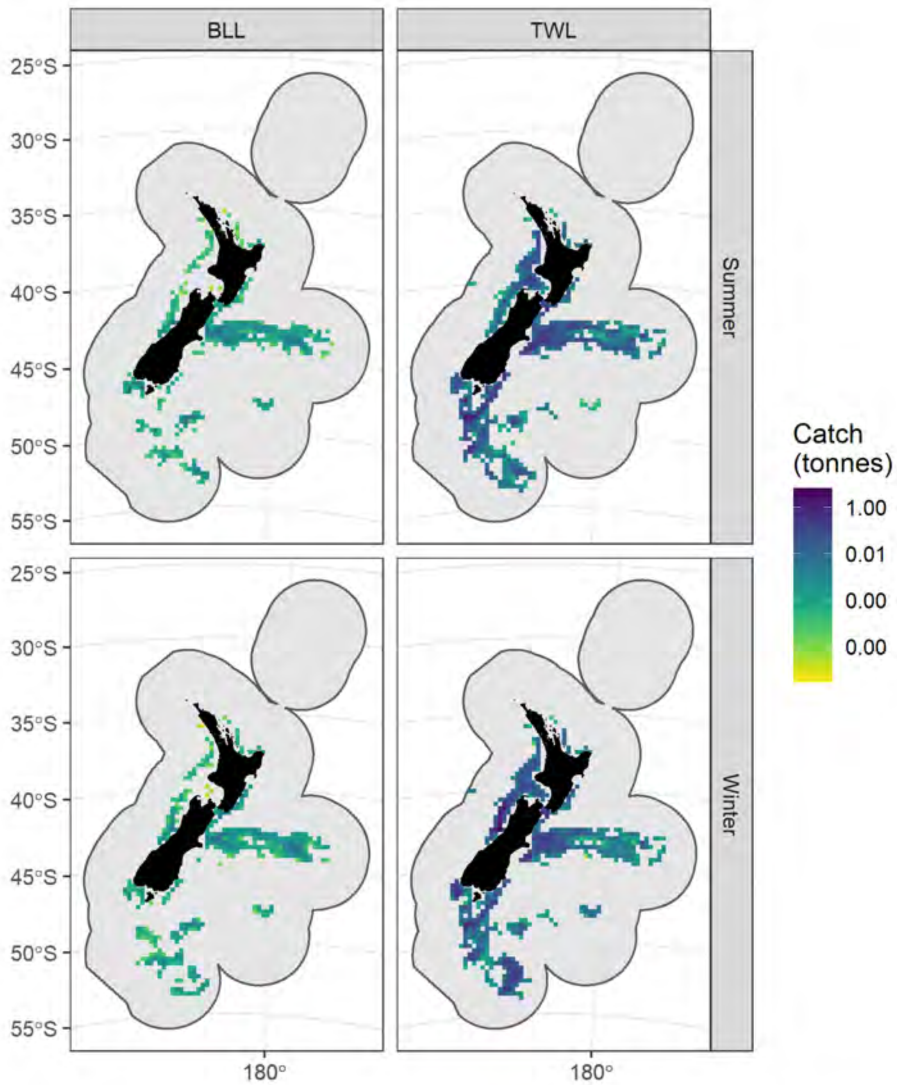


Figure S218: Posterior prediction of the total catches by grid cell, method and season for Ray's bream. Average annual catches per season were calculated as the sum across gear types per cell and method. Posterior median values are shown, with catches in tonnes on a log10 scale.

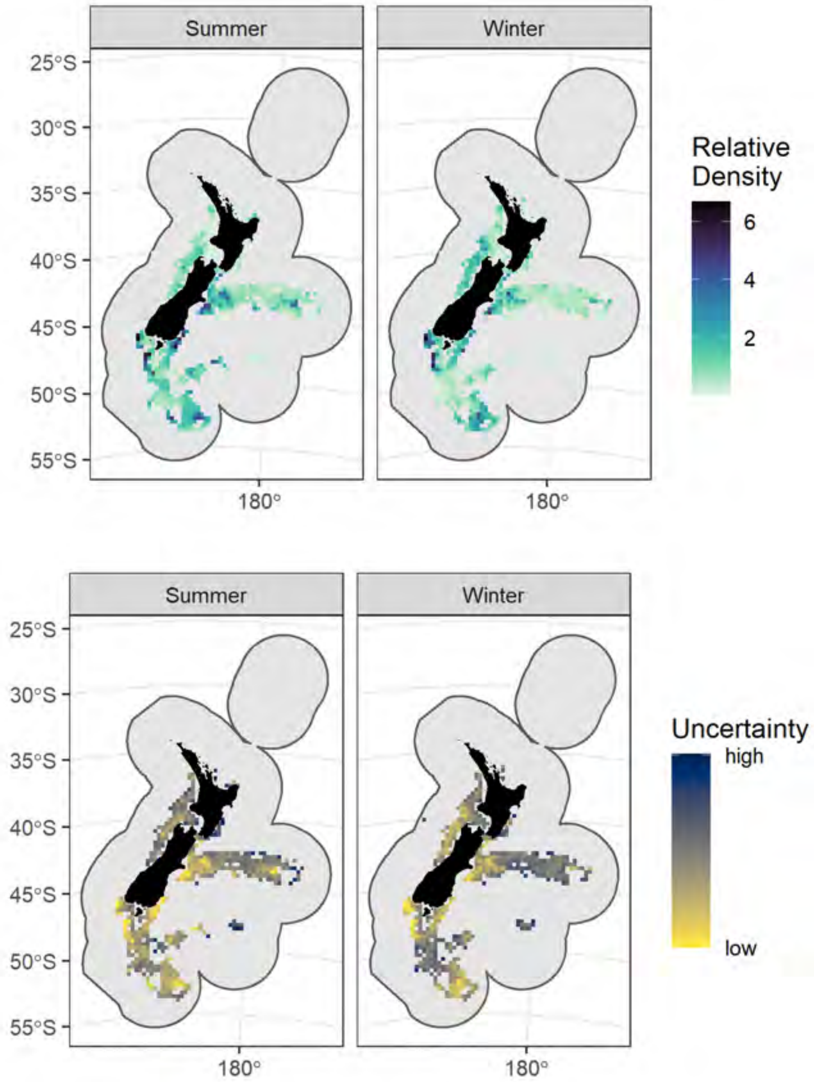


Figure S219: Posterior prediction of the relative density per grid cell and season for Ray's bream. Posterior median values are shown on a natural scale in tonnes per square kilometre. Uncertainty is measured using the difference between the upper and lower 95% equal-tailed posterior density interval.

Table S62: Total predicted bycatch (tonnes) per method for Ray's bream. Posterior median values are given, with the 95% equal-tailed credibility intervals in brackets.

Fishing year	BLL	TWL	Total
2000/01	0 (0 - 1)	128 (117 - 179)	128 (117 - 179)
2001/02	0 (0 - 1)	106 (98 - 116)	106 (98 - 116)
2002/03	0 (0 - 0)	107 (98 - 123)	107 (98 - 123)
2003/04	0 (0 - 1)	97 (89 - 127)	98 (89 - 128)
2004/05	0 (0 - 0)	78 (72 - 84)	78 (73 - 84)
2005/06	0 (0 - 0)	66 (61 - 71)	66 (61 - 72)
2006/07	0 (0 - 0)	61 (56 - 66)	61 (56 - 66)
2007/08	0 (0 - 1)	51 (47 - 55)	51 (47 - 56)
2008/09	0 (0 - 1)	51 (47 - 56)	51 (48 - 57)
2009/10	0 (0 - 1)	53 (49 - 59)	54 (49 - 60)
2010/11	0 (0 - 1)	55 (51 - 61)	56 (51 - 61)
2011/12	0 (0 - 1)	57 (53 - 63)	57 (53 - 63)
2012/13	0 (0 - 1)	55 (51 - 60)	55 (51 - 61)
2013/14	0 (0 - 1)	62 (57 - 67)	62 (58 - 68)
2014/15	0 (0 - 1)	67 (63 - 75)	68 (63 - 75)
2015/16	0 (0 - 1)	59 (55 - 64)	59 (55 - 64)
2016/17	1 (0 - 1)	59 (55 - 65)	59 (55 - 65)
2017/18	0 (0 - 1)	54 (50 - 60)	54 (50 - 60)
2018/19	0 (0 - 1)	63 (58 - 69)	63 (59 - 70)

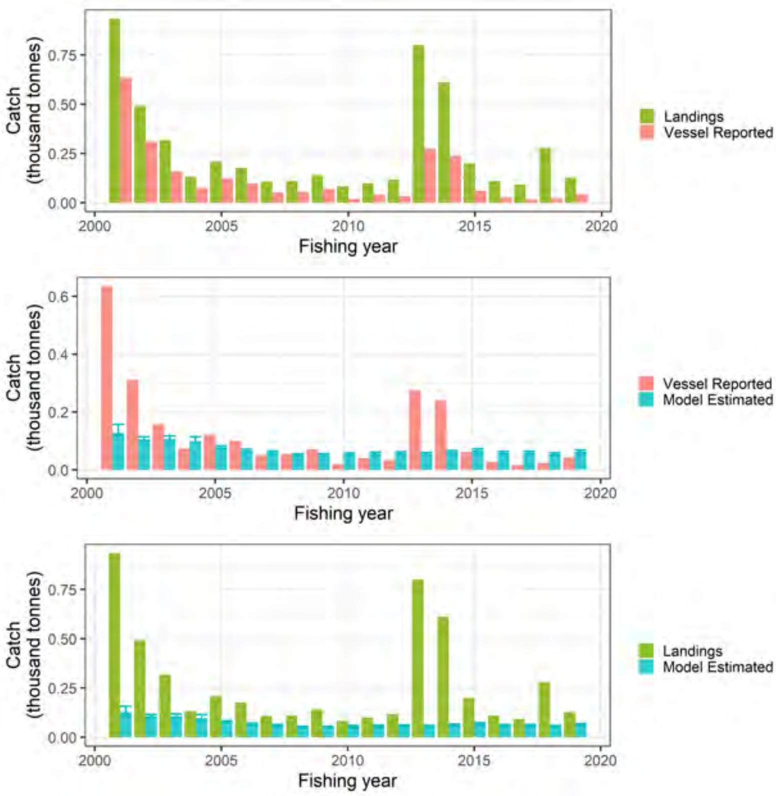


Figure S220: Relationships between landings, vessel reported catches and model estimated catches for Ray's bream.

S2.21 Rough skate (*Zearaja nasuta*)

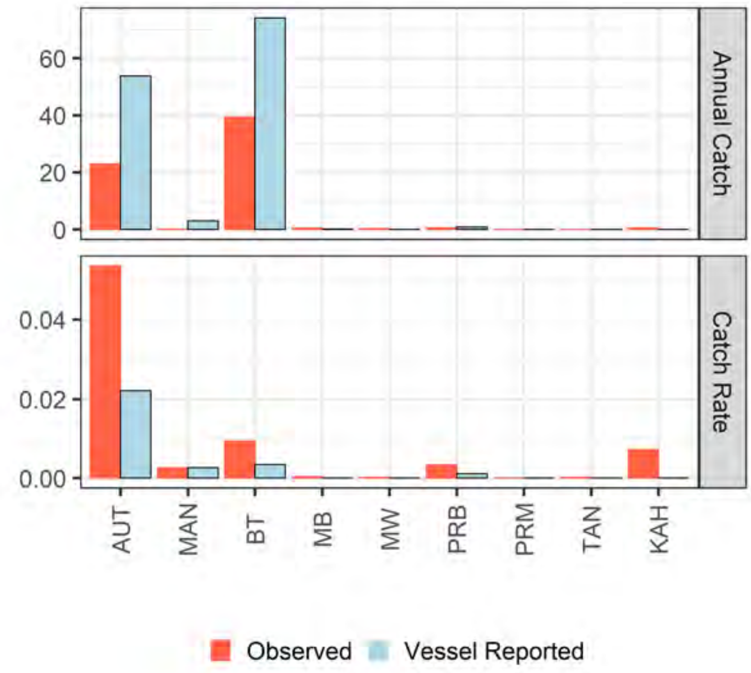


Figure S221: Empirical catch and catch rate data per gear type for rough skate. Annual catch is given in tonnes as an average across years. The catch rate is an average calculated as the sum of the observed catch in kilograms (i.e., $\sum X_i$) over the sum of the effort count (number of fishing events). Effort was calculated as a count to allow comparability between methods. There are no vessel reported catches for TAN and KAH surveys.

Table S63: Summary data for rough skate across 532 grid cells, removing 85 311 commercial events that were outside the selected cells. The total landings associated with retained commercial effort equal 5 862 tonnes. Catch is in units of tonnes, effort in the number of fishing events. “Obs.” is observed; “Com.” is commercial.

Method	Gear	Obs. catch	Obs. effort	Com. catch	Com. effort
BLL	AUT	437	8 151	1 021	46 172
BLL	MAN	2	675	54	20 300
TWL	BT	750	79 541	1 407	404 070
TWL	MB	12	31 164	4	110 793
TWL	MW	6	29 000	1	67 078
TWL	PRB	3	834	3	3 001
TWL	PRM	0	403	0	2 031
TWL	TAN	1	3 040		
TWL	KAH	10	1 359		
Total		1 220	154 167	2 490	653 445

Table S64: Model selection summary statistics for rough skate. Model 4 was selected for prediction of the catches.

Model	$\mathbb{L}[X]$	MPE	L^2	WAIC	$\hat{R}(\alpha)$	$\hat{R}(\gamma)$	$\hat{R}(\pi)$	DRE
1	-0.025	0.022	0.050	3102.709	1.012	1.009	1.011	1.623
2	-0.023	0.022	0.049	3183.272	1.006	1.005	1.004	1.763
3	-0.023	0.021	0.050	3199.227	1.005	1.003	1.004	1.436
4	-0.024	0.022	0.054	3204.783	1.006	1.030	1.029	1.406
5	-0.023	0.022	0.052	3201.039	1.026	1.011	1.017	1.430
6	-0.024	0.022	0.049	3204.141	1.003	0.999	1.000	1.386

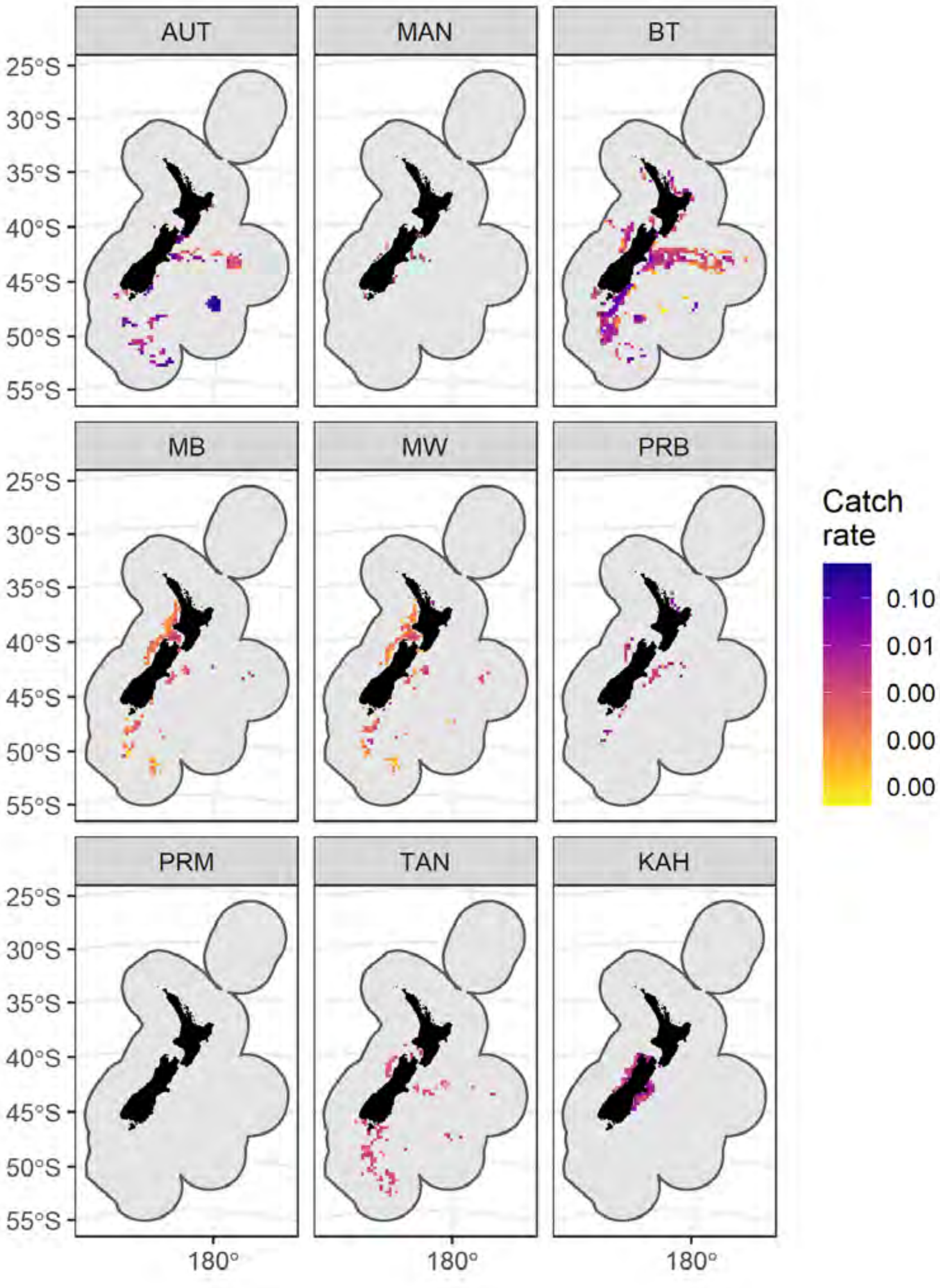


Figure S222: Observer catch rate data for rough skate on a log10-scale. The catch rate is an average calculated as the sum of the observed catch $\sum X_i$ over the number of observed fishing events per grid cell and gear type. Effort was calculated as a count to allow comparability between methods.

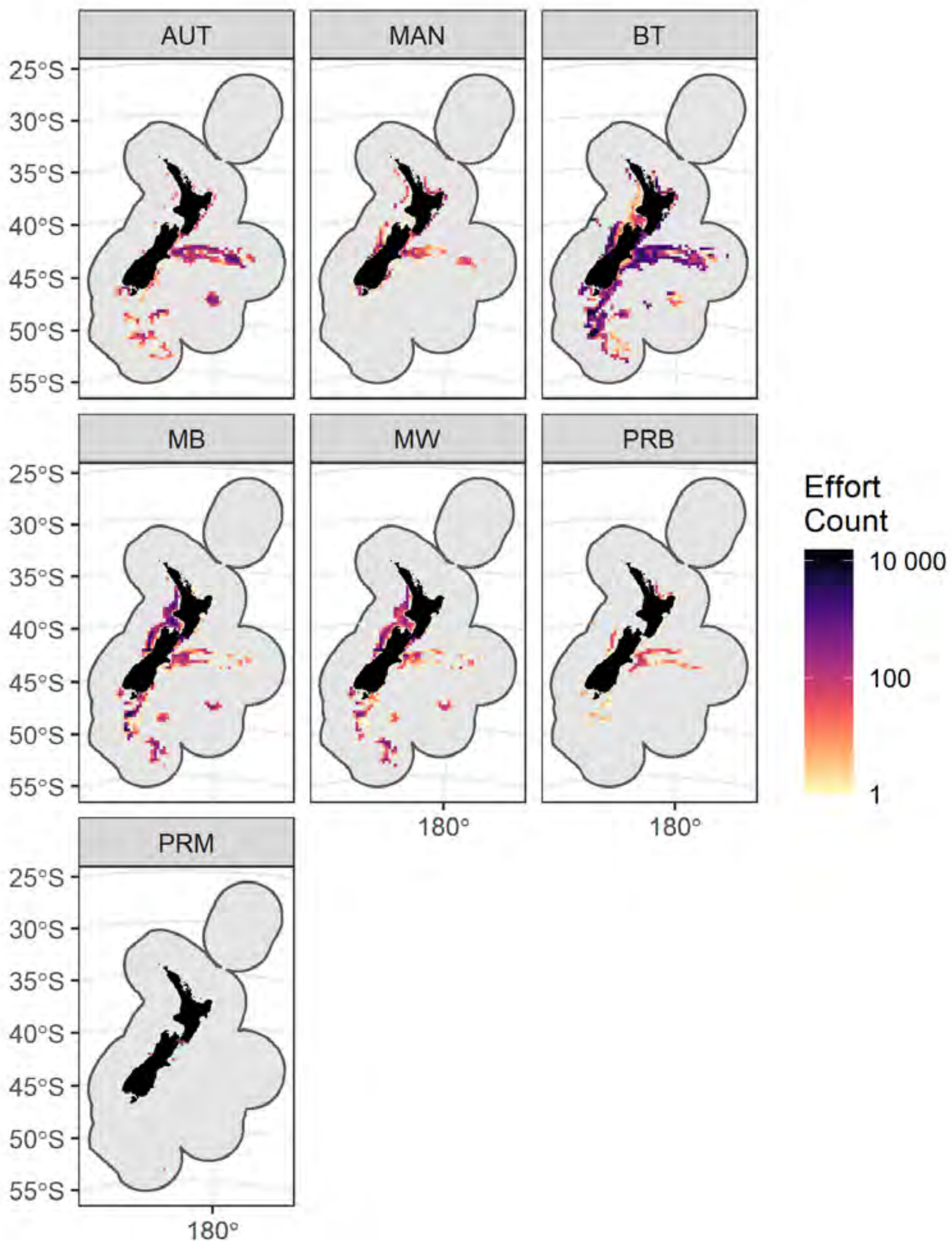


Figure S223: Commercial fishing effort (number of events) for rough skate summed across all years and presented on a log10-scale per grid cell and gear type. Effort was calculated as a count to allow comparability between methods.

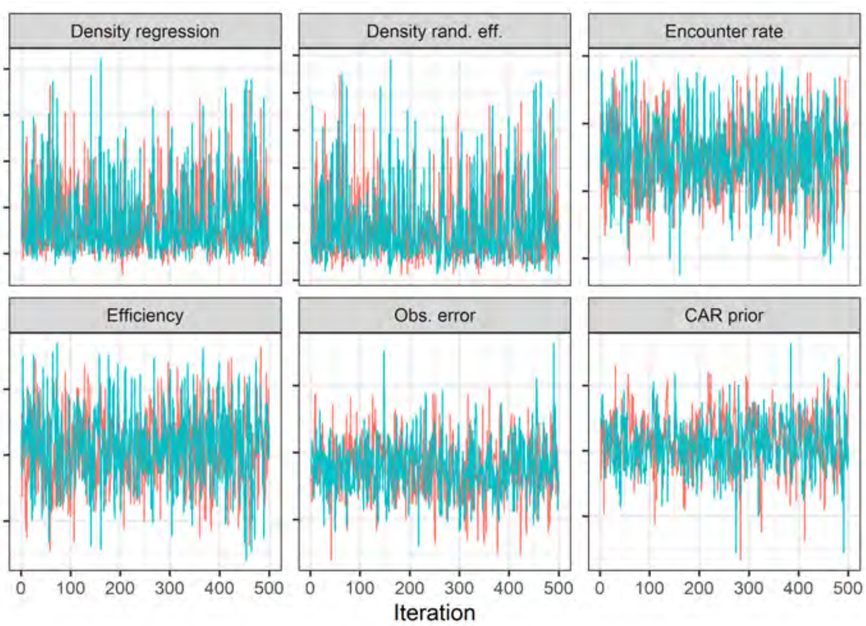


Figure S224: Posterior density sample traces for rough skate, for the regression coefficients $||\boldsymbol{\alpha}||$, random effects $||\boldsymbol{\phi}||$, encounter rate $||\boldsymbol{\gamma}||$, efficiency $||\boldsymbol{\pi}||$, observation error $||\boldsymbol{\sigma}||$ and conditional autoregressive prior parameters $||\tau, \rho||$. Colours represent independent sample chains.

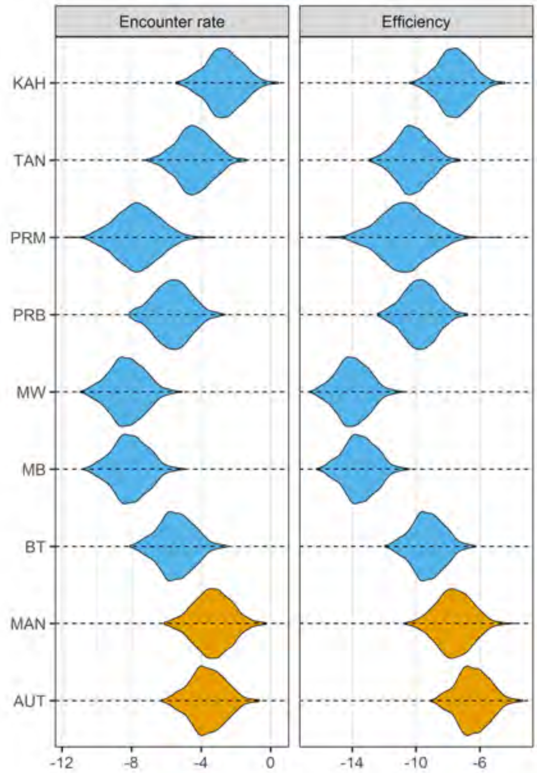


Figure S225: Violin plots of the posterior density for the encounter rate (γ_j) and the efficiency (π_j) per gear type for rough skate. Catchability terms for bottom longline gear types (see Table S2) are presented in a different colour as they are not comparable to the trawl gear types because they are dependent on different measures of effort (i.e., thousand hooks and distance, respectively).

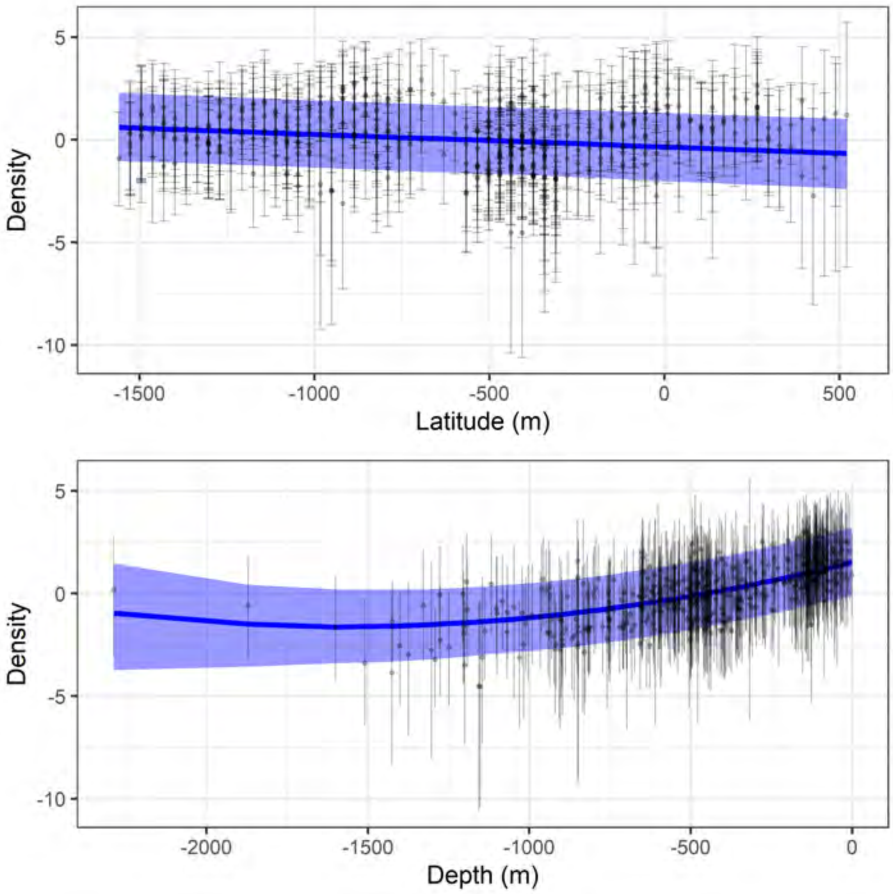


Figure S226: Estimated relationship between biomass density per grid cell and environmental covariates for rough skate. Points and error bars show the median and 90% credibility intervals per cell. The blue ribbon shows the estimated marginal relationship.

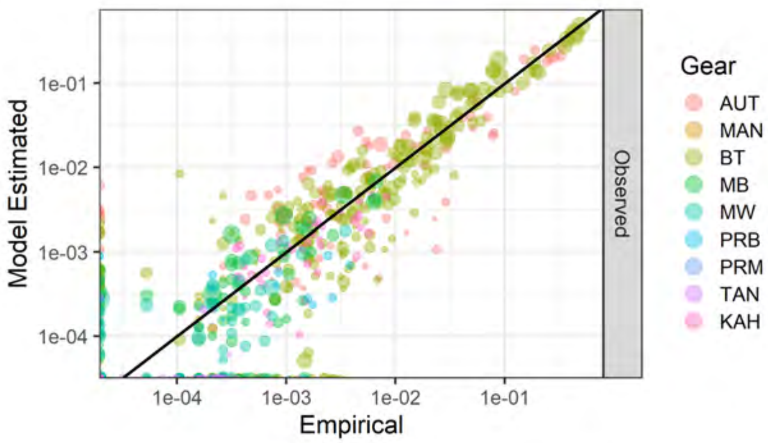


Figure S227: Fit of model to empirical observer catches. Total catches are summed per grid cell and gear type for rough skate. Model estimates are the median of the posterior predicted distribution. The size of the point is representative of the number of observed events. Catches are shown in tonnes on a log10 scale.

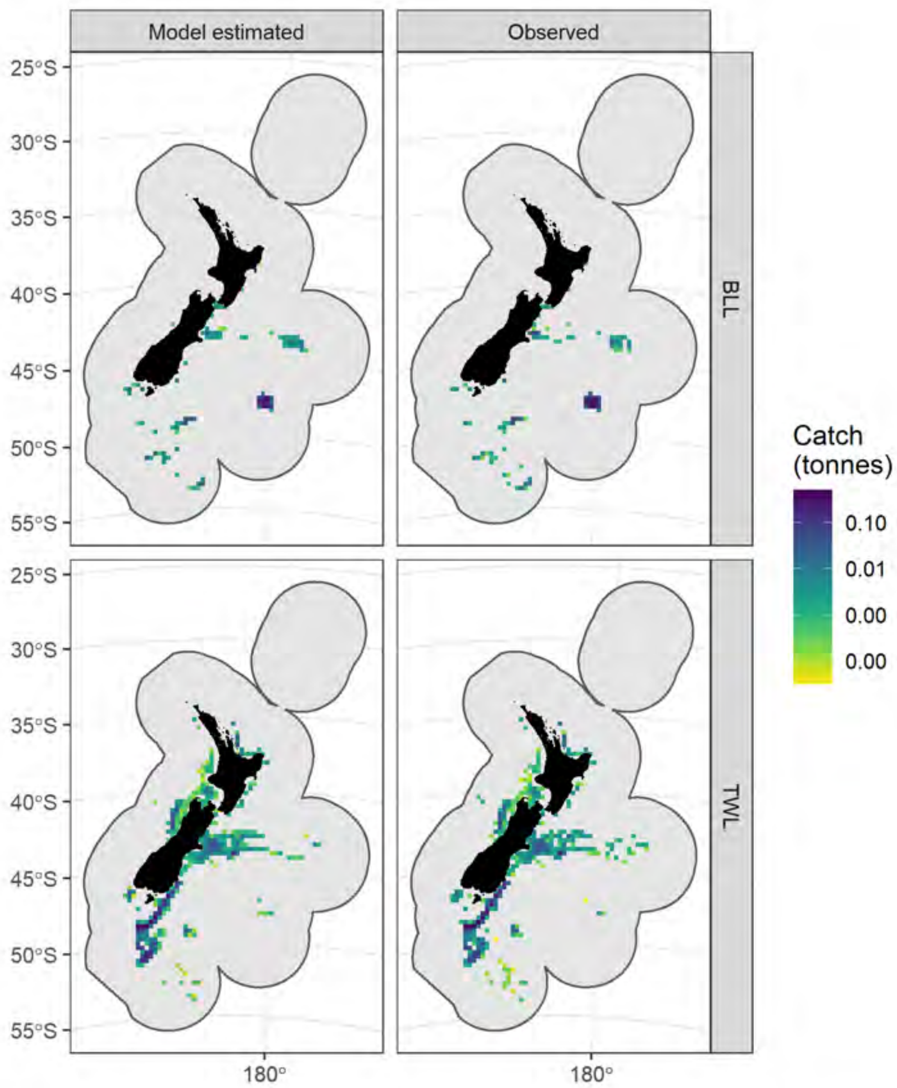


Figure S228: Spatial fit of model to empirical observer catches by grid cell and method for rough skate. Average annual catches were calculated as the sum across gear types per cell and method. Posterior median values are shown, with catches in tonnes on a log10 scale.

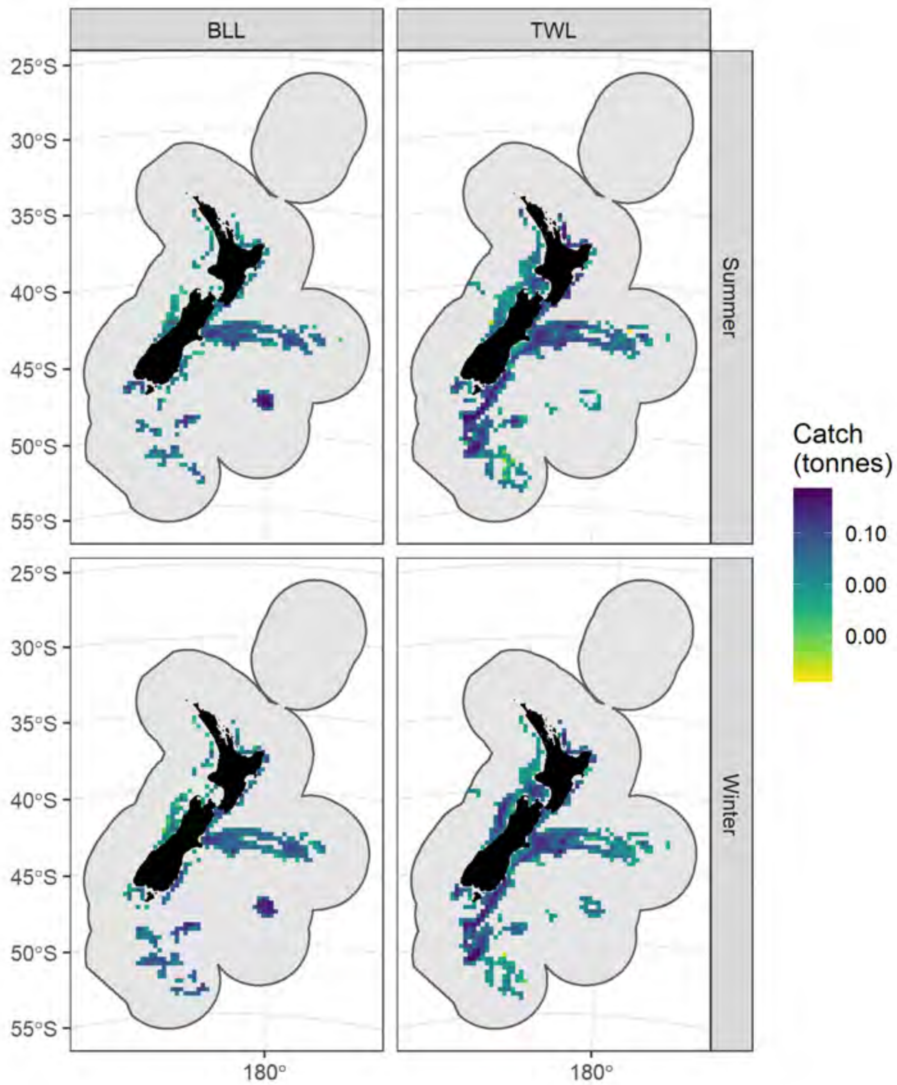


Figure S229: Posterior prediction of the total catches by grid cell, method and season for rough skate. Average annual catches per season were calculated as the sum across gear types per cell and method. Posterior median values are shown, with catches in tonnes on a log10 scale.

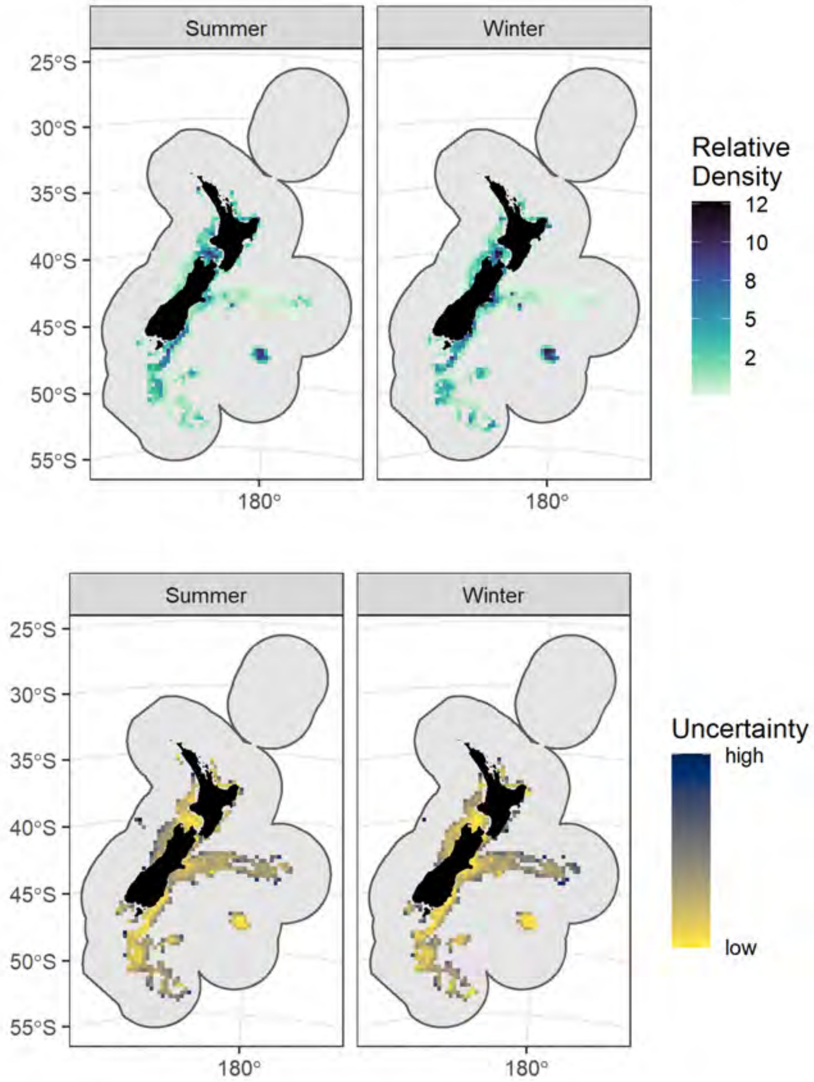


Figure S230: Posterior prediction of the relative density per grid cell and season for rough skate. Posterior median values are shown on a natural scale in tonnes per square kilometre. Uncertainty is measured using the difference between the upper and lower 95% equal-tailed posterior density interval.

Table S65: **Total predicted bycatch (tonnes) per method for rough skate. Posterior median values are given, with the 95% equal-tailed credibility intervals in brackets.**

Fishing year	BLL	TWL	Total
2000/01	131 (105 - 168)	186 (169 - 213)	319 (285 - 361)
2001/02	93 (75 - 122)	192 (175 - 216)	285 (257 - 323)
2002/03	90 (72 - 118)	175 (161 - 193)	265 (241 - 297)
2003/04	113 (92 - 142)	157 (146 - 172)	270 (246 - 305)
2004/05	32 (24 - 43)	175 (163 - 189)	207 (193 - 225)
2005/06	29 (21 - 39)	172 (159 - 186)	200 (186 - 218)
2006/07	53 (40 - 74)	150 (139 - 162)	203 (185 - 228)
2007/08	98 (73 - 147)	143 (132 - 156)	242 (213 - 292)
2008/09	64 (48 - 93)	158 (146 - 172)	222 (202 - 253)
2009/10	35 (26 - 53)	190 (176 - 217)	227 (208 - 261)
2010/11	42 (30 - 62)	189 (177 - 207)	231 (213 - 257)
2011/12	31 (24 - 43)	176 (164 - 192)	207 (193 - 228)
2012/13	14 (10 - 22)	160 (148 - 181)	174 (162 - 195)
2013/14	49 (36 - 69)	148 (136 - 170)	197 (178 - 232)
2014/15	31 (21 - 53)	149 (136 - 191)	180 (162 - 228)
2015/16	55 (40 - 80)	152 (139 - 208)	208 (185 - 267)
2016/17	115 (82 - 178)	182 (167 - 208)	298 (261 - 367)
2017/18	54 (42 - 73)	175 (162 - 195)	229 (210 - 255)
2018/19	49 (37 - 64)	186 (172 - 202)	235 (215 - 257)

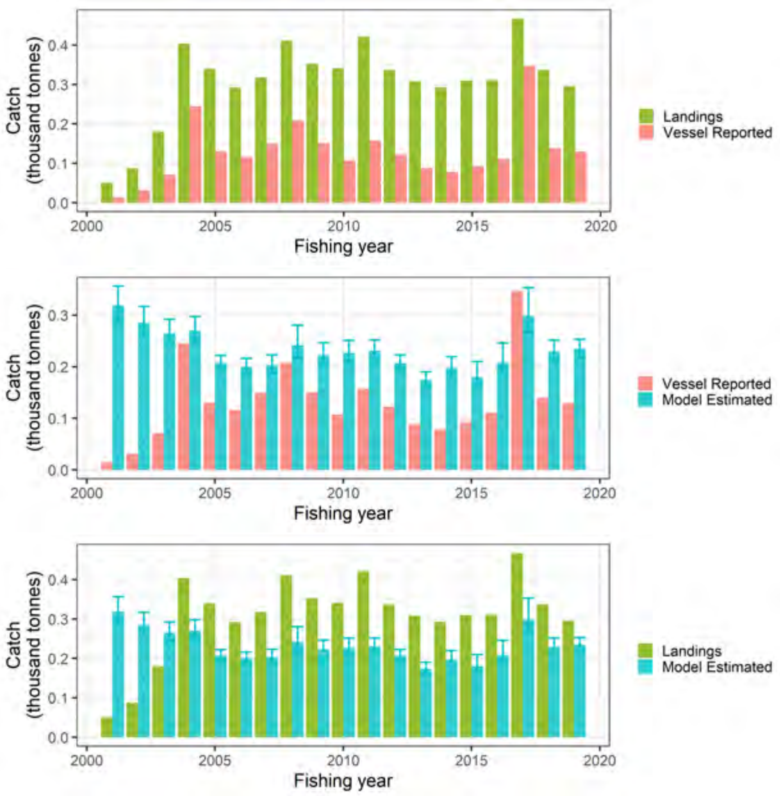


Figure S231: Relationships between landings, vessel reported catches and model estimated catches for rough skate.

S2.22 Baxter's lantern dogfish (*Etmopterus baxteri*)

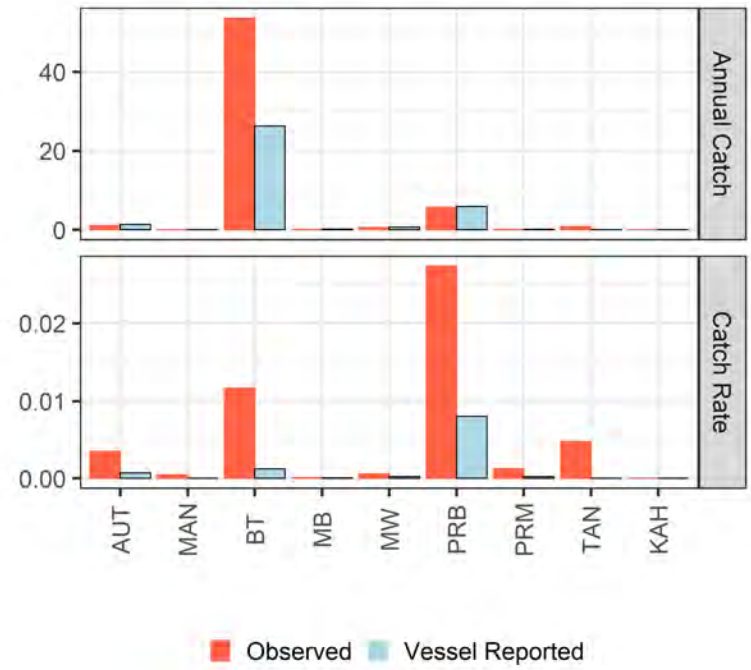


Figure S232: Empirical catch and catch rate data per gear type for Baxter's lantern dogfish. Annual catch is given in tonnes as an average across years. The catch rate is an average calculated as the sum of the observed catch in kilograms (i.e., $\sum X_i$) over the sum of the effort count (number of fishing events). Effort was calculated as a count to allow comparability between methods. There are no vessel reported catches for TAN and KAH surveys.

Table S66: Summary data for Baxter's lantern dogfish across 612 grid cells, removing 146 424 commercial events that were outside the selected cells. The total landings associated with retained commercial effort equal 1 996 tonnes. Catch is in units of tonnes, effort in the number of fishing events. "Obs." is observed; "Com." is commercial.

Method	Gear	Obs. catch	Obs. effort	Com. catch	Com. effort
BLL	AUT	21	5 912	27	37 365
BLL	MAN	0	485	0	12 697
TWL	BT	1 018	87 057	499	409 969
TWL	MB	2	19 431	4	75 842
TWL	MW	10	17 846	13	51 454
TWL	PRB	23	836	24	2 958
TWL	PRM	1	403	1	2 047
TWL	TAN	16	3 437		
TWL	KAH	0	380		
Total		1 091	135 787	567	592 332

Table S67: Model selection summary statistics for Baxter's lantern dogfish. Model 6 was selected for prediction of the catches.

Model	$\mathbb{L}[X]$	MPE	L^2	WAIC	$\hat{R}(\alpha)$	$\hat{R}(\gamma)$	$\hat{R}(\pi)$	DRE
1	-0.014	0.023	0.078	199.909	1.002	1.040	1.047	2.368
2	-0.014	0.023	0.078	199.909	1.002	1.040	1.047	2.368
3	-0.015	0.024	0.053	374.091	1.037	1.766	1.907	1.806
4	-0.014	0.026	0.315	201.311	1.016	1.009	1.003	1.655
5	-0.015	0.023	0.052	326.605	1.907	1.074	1.048	1.664
6	-0.014	0.024	0.070	205.186	1.044	1.037	1.028	1.681

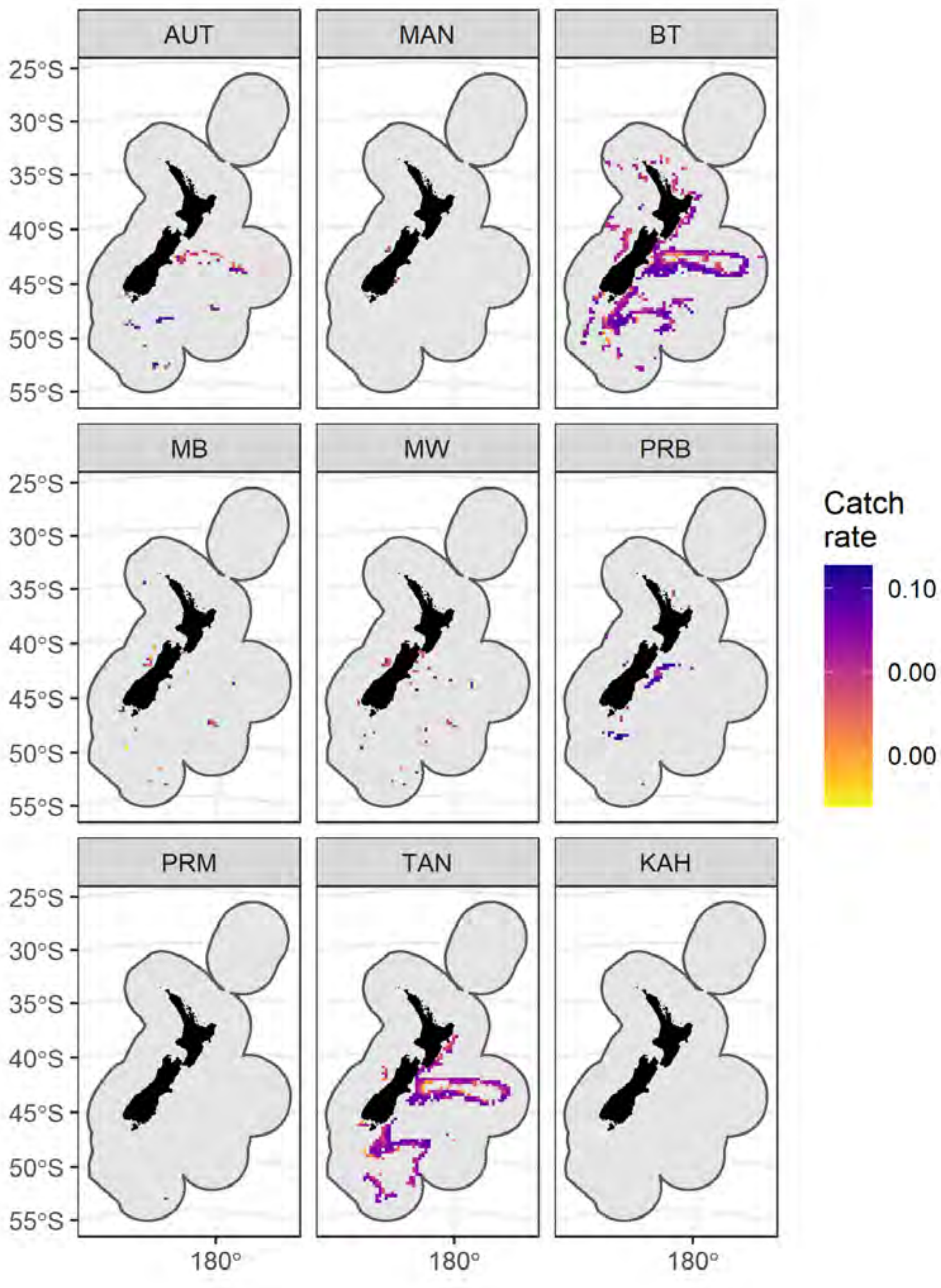


Figure S233: Observer catch rate data for Baxter's lantern dogfish on a log10-scale. The catch rate is an average calculated as the sum of the observed catch $\sum X_i$ over the number of observed fishing events per grid cell and gear type. Effort was calculated as a count to allow comparability between methods.

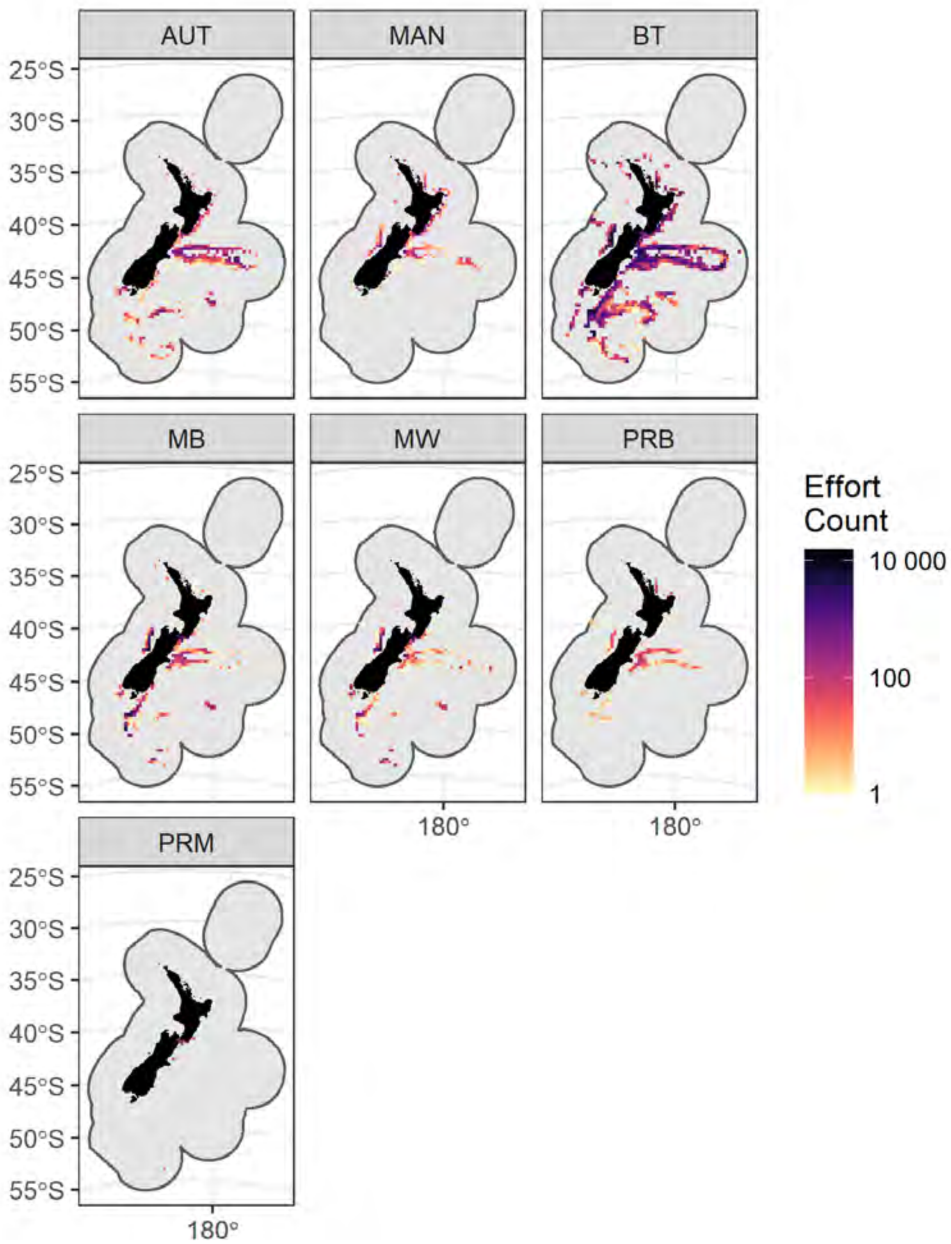


Figure S234: Commercial fishing effort (number of events) for Baxter's lantern dogfish summed across all years and presented on a log10-scale per grid cell and gear type. Effort was calculated as a count to allow comparability between methods.

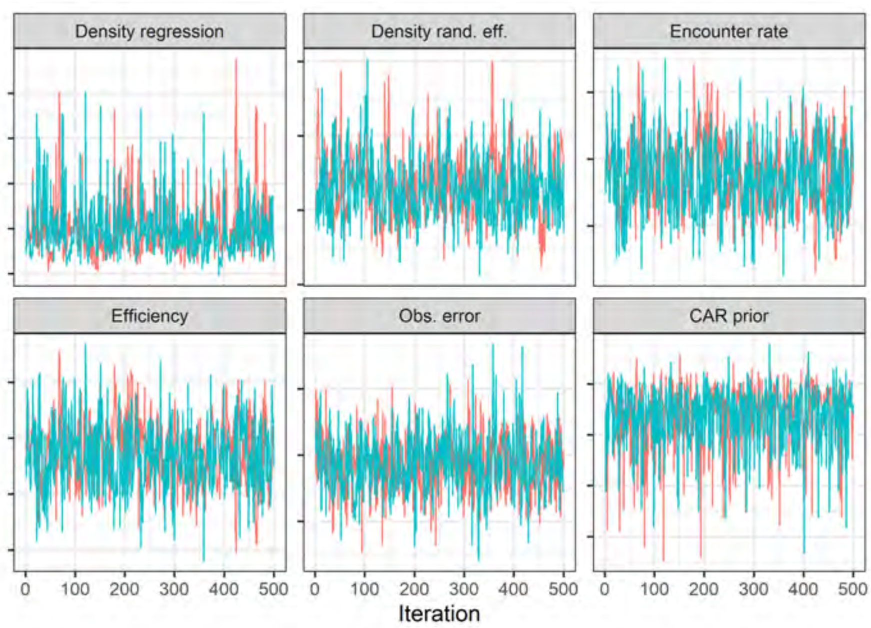


Figure S235: Posterior density sample traces for Baxter's lantern dogfish, for the regression coefficients $||\boldsymbol{\alpha}||$, random effects $||\boldsymbol{\phi}||$, encounter rate $||\boldsymbol{\gamma}||$, efficiency $||\boldsymbol{\pi}||$, observation error $||\boldsymbol{\sigma}||$ and conditional autoregressive prior parameters $||\tau, \rho||$. Colours represent independent sample chains.

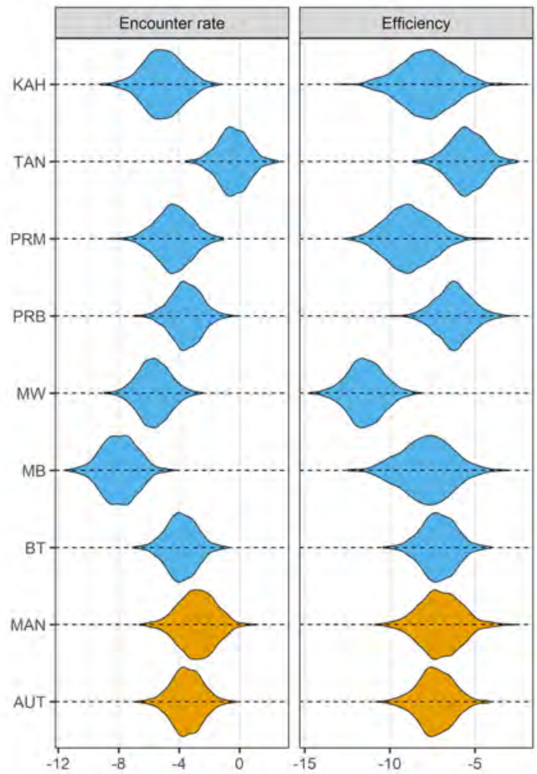


Figure S236: Violin plots of the posterior density for the encounter rate (γ_j) and the efficiency (π_j) per gear type for Baxter's lantern dogfish. Catchability terms for bottom longline gear types (see Table S2) are presented in a different colour as they are not comparable to the trawl gear types because they are dependent on different measures of effort (i.e., thousand hooks and distance, respectively).

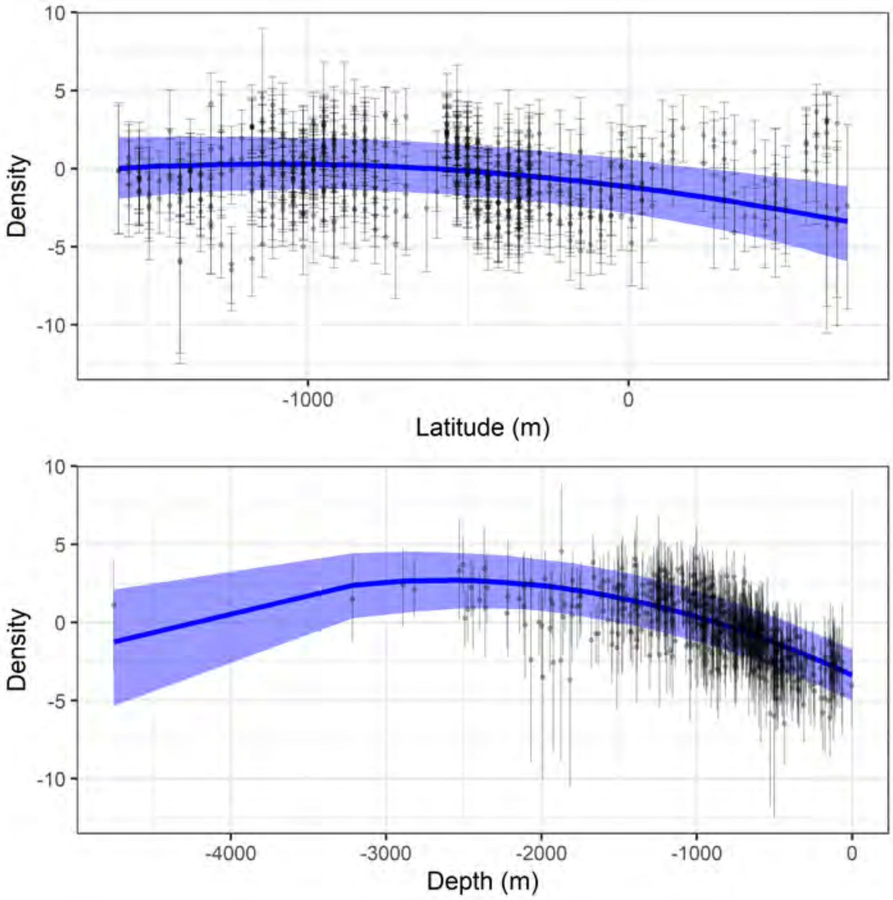


Figure S237: Estimated relationship between biomass density per grid cell and environmental covariates for Baxter's lantern dogfish. Points and error bars show the median and 90% credibility intervals per cell. The blue ribbon shows the estimated marginal relationship.

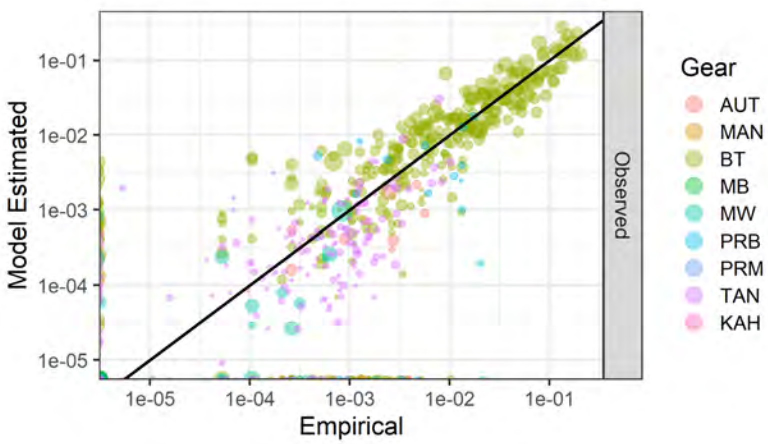


Figure S238: Fit of model to empirical observer catches. Total catches are summed per grid cell and gear type for Baxter's lantern dogfish. Model estimates are the median of the posterior predicted distribution. The size of the point is representative of the number of observed events. Catches are shown in tonnes on a log10 scale.

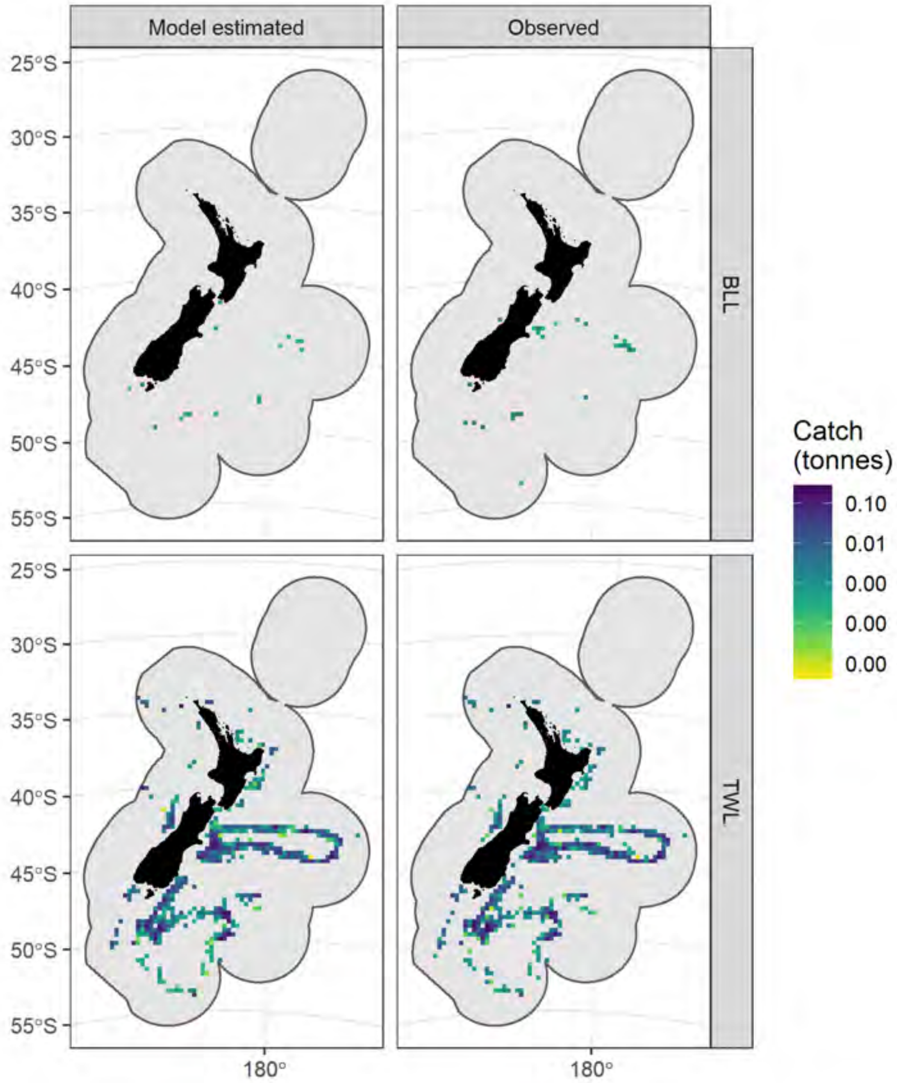


Figure S239: Spatial fit of model to empirical observer catches by grid cell and method for Baxter's lantern dogfish. Average annual catches were calculated as the sum across gear types per cell and method. Posterior median values are shown, with catches in tonnes on a log10 scale.

Table S68: Total predicted bycatch (tonnes) per method for Baxter's lantern dogfish. Posterior median values are given, with the 95% equal-tailed credibility intervals in brackets.

Fishing year	BLL	TWL	Total
2000/01	4 (2 - 9)	302 (275 - 364)	307 (279 - 370)
2001/02	5 (3 - 10)	291 (262 - 346)	295 (266 - 351)
2002/03	2 (1 - 4)	289 (264 - 344)	291 (266 - 346)
2003/04	3 (2 - 6)	276 (248 - 347)	279 (251 - 350)
2004/05	2 (1 - 4)	253 (225 - 308)	255 (228 - 310)
2005/06	2 (1 - 4)	215 (195 - 249)	217 (197 - 251)
2006/07	2 (1 - 5)	221 (202 - 249)	224 (204 - 252)
2007/08	4 (2 - 8)	218 (199 - 248)	222 (203 - 253)
2008/09	2 (1 - 5)	223 (202 - 250)	225 (204 - 253)
2009/10	2 (1 - 6)	242 (220 - 272)	244 (222 - 275)
2010/11	4 (2 - 16)	193 (175 - 215)	198 (178 - 223)
2011/12	4 (2 - 16)	169 (152 - 192)	174 (156 - 200)
2012/13	2 (1 - 8)	164 (148 - 191)	167 (150 - 194)
2013/14	4 (2 - 8)	204 (181 - 237)	208 (185 - 243)
2014/15	3 (1 - 9)	213 (192 - 244)	216 (194 - 249)
2015/16	4 (2 - 9)	197 (178 - 223)	202 (181 - 229)
2016/17	4 (2 - 11)	206 (185 - 237)	211 (189 - 243)
2017/18	3 (1 - 9)	262 (235 - 300)	266 (238 - 307)
2018/19	4 (2 - 9)	220 (191 - 271)	224 (197 - 277)

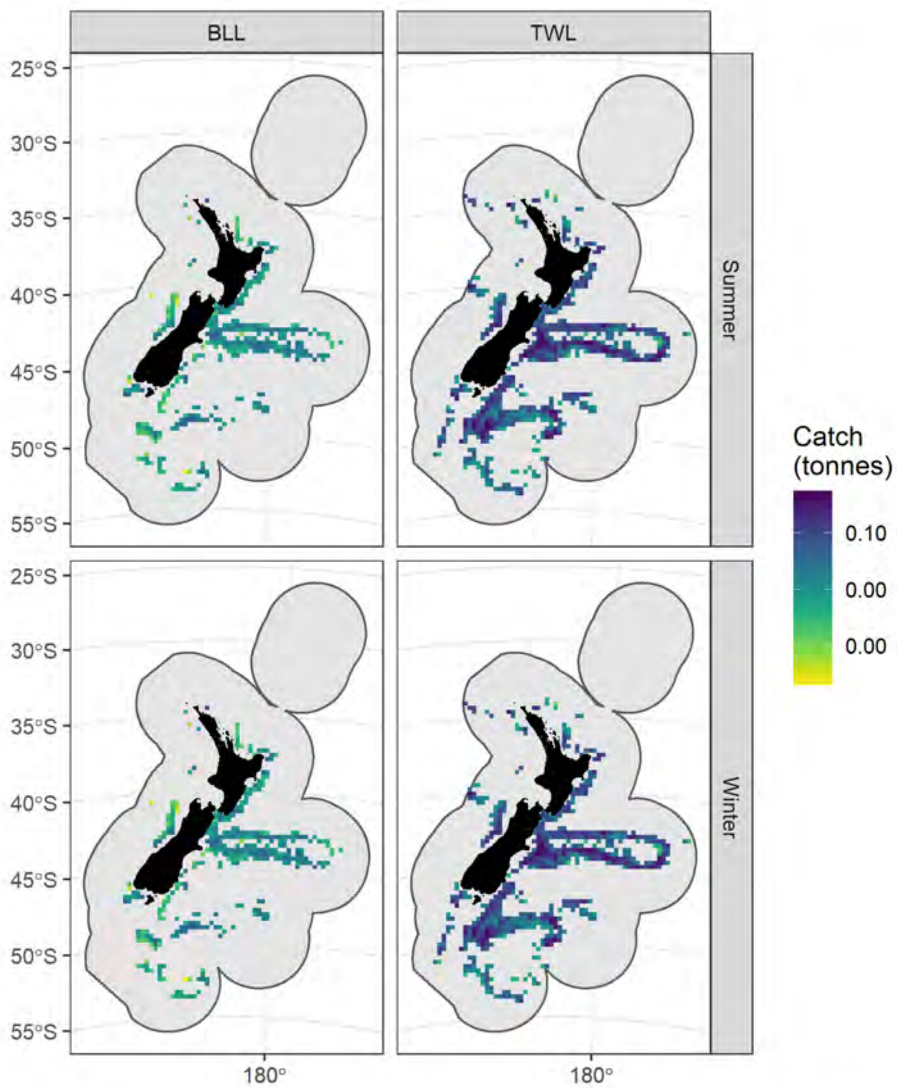


Figure S240: Posterior prediction of the total catches by grid cell, method and season for Baxter's lantern dogfish. Average annual catches per season were calculated as the sum across gear types per cell and method. Posterior median values are shown, with catches in tonnes on a log10 scale.

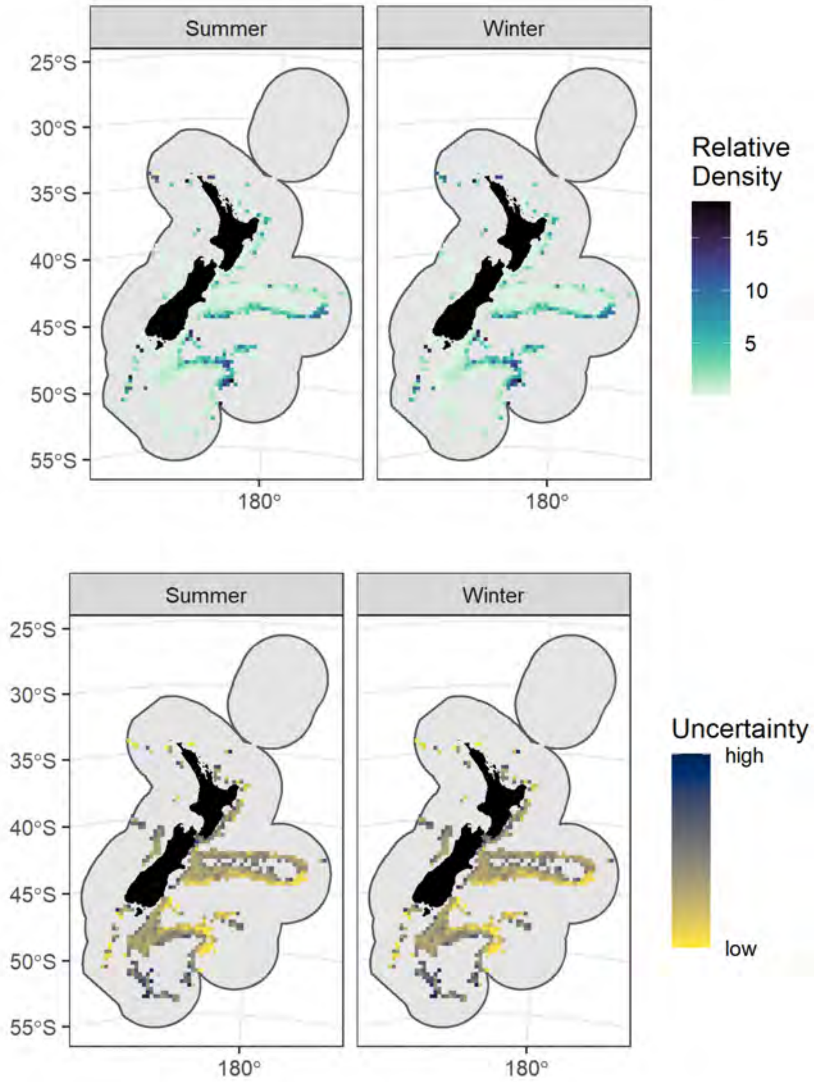


Figure S241: Posterior prediction of the relative density per grid cell and season for Baxter's lantern dogfish. Posterior median values are shown on a natural scale in tonnes per square kilometre. Uncertainty is measured using the difference between the upper and lower 95% equal-tailed posterior density interval.

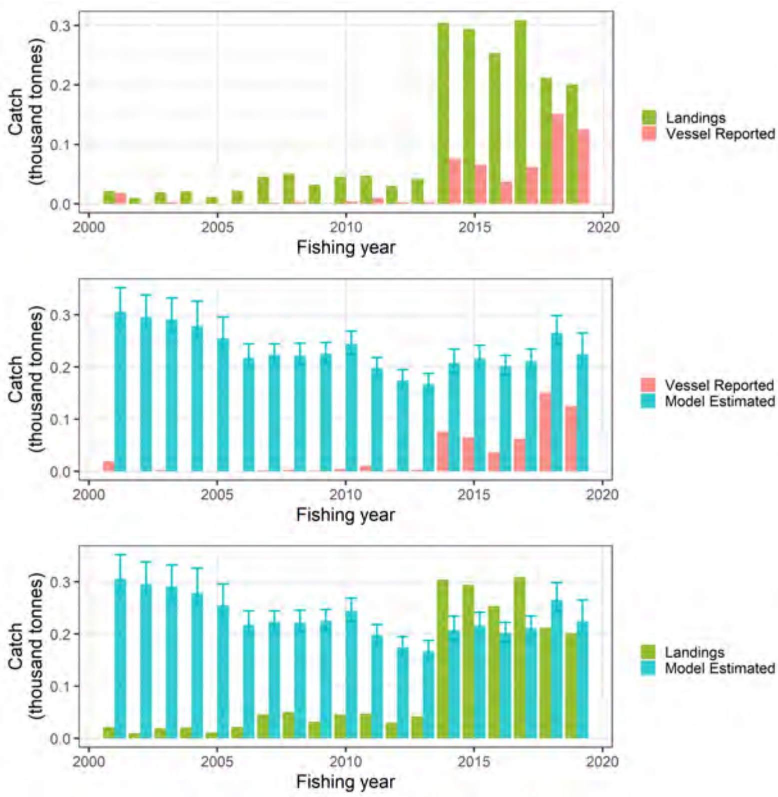


Figure S242: Relationships between landings, vessel reported catches and model estimated catches for Baxter's lantern dogfish.

S2.23 Hydrocorals (Stylasteridae)

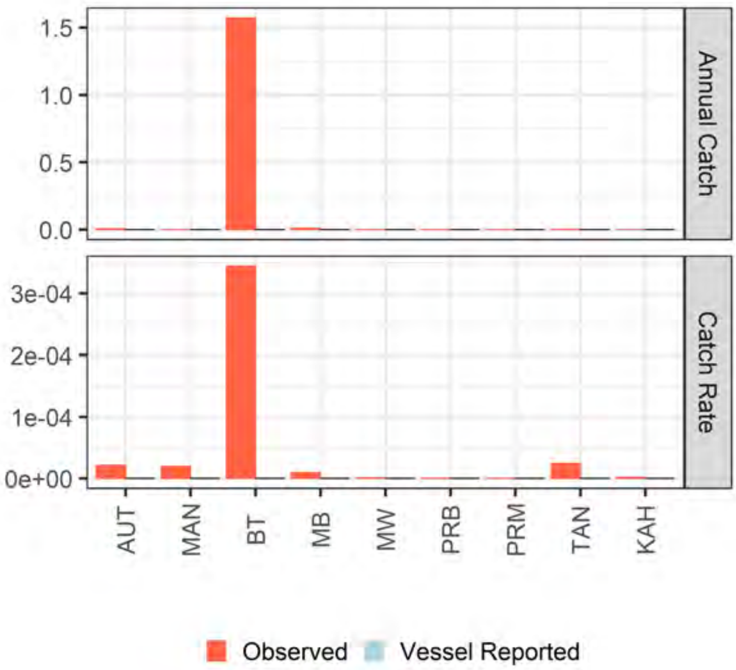


Figure S243: Empirical catch and catch rate data per gear type for hydrocorals. Annual catch is given in tonnes as an average across years. The catch rate is an average calculated as the sum of the observed catch in kilograms (i.e., $\sum X_i$) over the sum of the effort count (number of fishing events). Effort was calculated as a count to allow comparability between methods. There are no vessel reported catches for TAN and KAH surveys.

Table S69: Summary data for hydrocorals across 465 grid cells, removing 172 608 commercial events that were outside the selected cells. The total landings associated with retained commercial effort equal 1 tonnes. Catch is in units of tonnes, effort in the number of fishing events. "Obs." is observed; "Com." is commercial.

Method	Gear	Obs. catch	Obs. effort	Com. catch	Com. effort
BLL	AUT	0	6 424	0	38 868
BLL	MAN	0	503	0	11 797
TWL	BT	30	86 688	0	404 242
TWL	MB	0	22 957	0	71 872
TWL	MW	0	17 379	0	36 304
TWL	PRB	0	771	0	2 796
TWL	PRM	0	37	0	269
TWL	TAN	0	3 243		
TWL	KAH	0	367		
Total		30	138 369	0	566 148

Table S70: Model selection summary statistics for hydrocorals. Model 5 was selected for prediction of the catches.

Model	$\mathbb{L}[X]$	MPE	L^2	WAIC	$\hat{R}(\alpha)$	$\hat{R}(\gamma)$	$\hat{R}(\pi)$	DRE
1	-0.003	0.000	0.007	1304.853	1.001	1.020	1.024	2.397
2	-0.003	0.000	0.007	1304.853	1.001	1.020	1.024	2.397
3	-0.004	0.000	0.005	1300.894	1.009	1.013	1.000	1.965
4	-0.004	0.000	0.004	1304.332	0.999	1.004	1.007	1.949
5	-0.004	0.000	0.004	1306.829	1.008	1.002	1.000	1.952
6	-0.004	0.013	0.365	1301.349	1.001	0.999	1.000	1.927

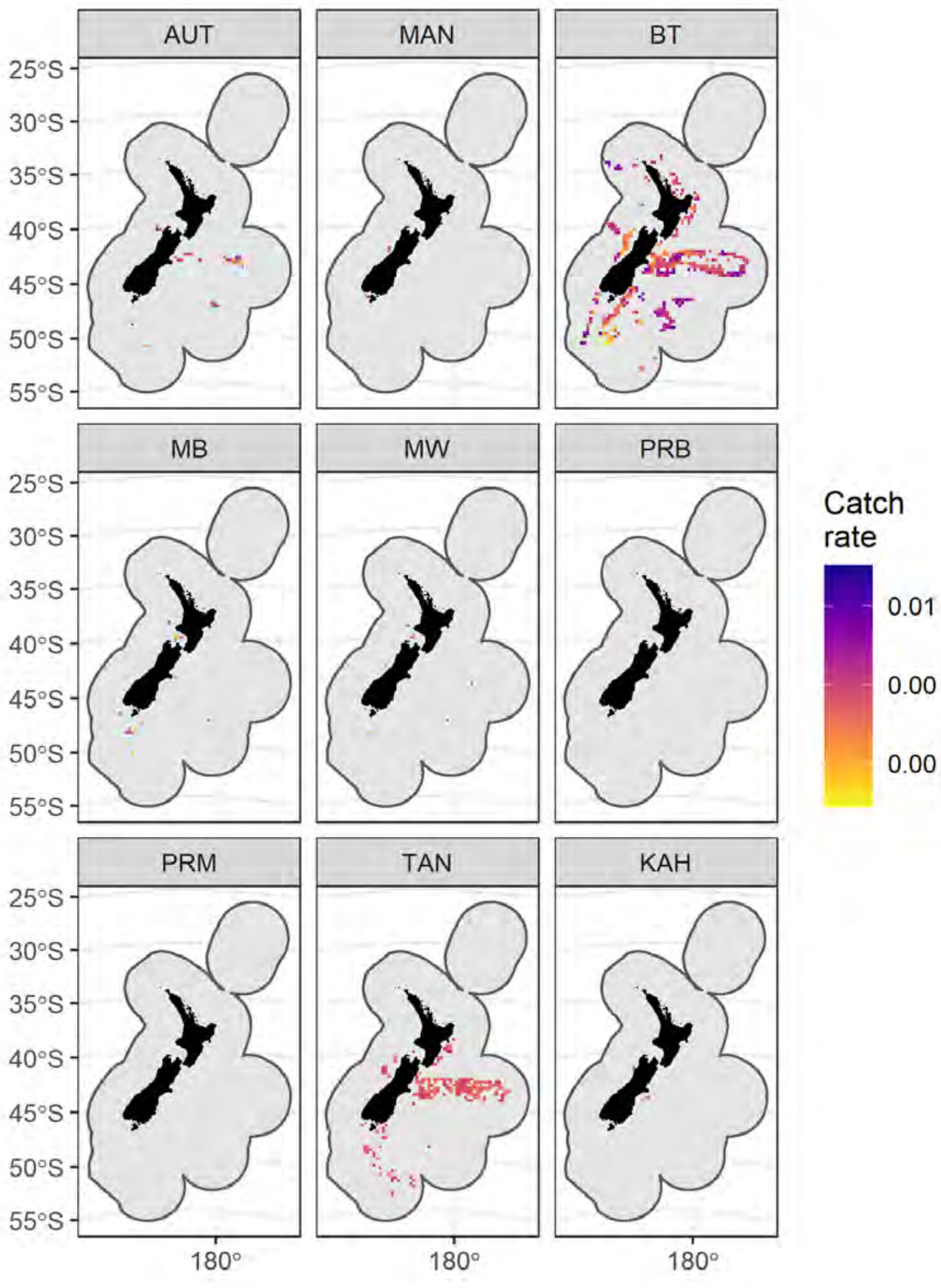


Figure S244: Observer catch rate data for hydrocorals on a log10-scale. The catch rate is an average calculated as the sum of the observed catch $\sum X_i$ over the number of observed fishing events per grid cell and gear type. Effort was calculated as a count to allow comparability between methods.

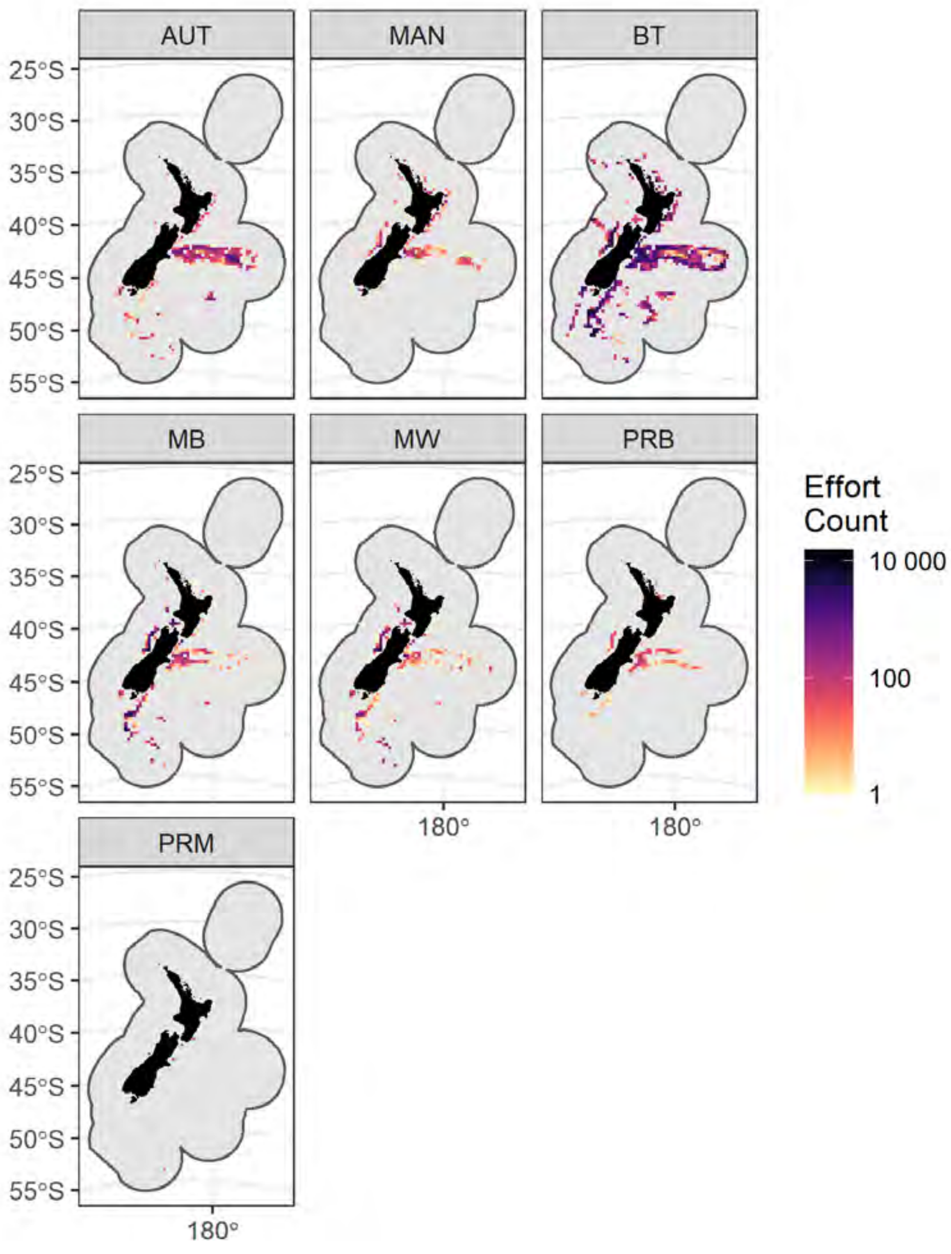


Figure S245: Commercial fishing effort (number of events) for hydrocorals summed across all years and presented on a log10-scale per grid cell and gear type. Effort was calculated as a count to allow comparability between methods.

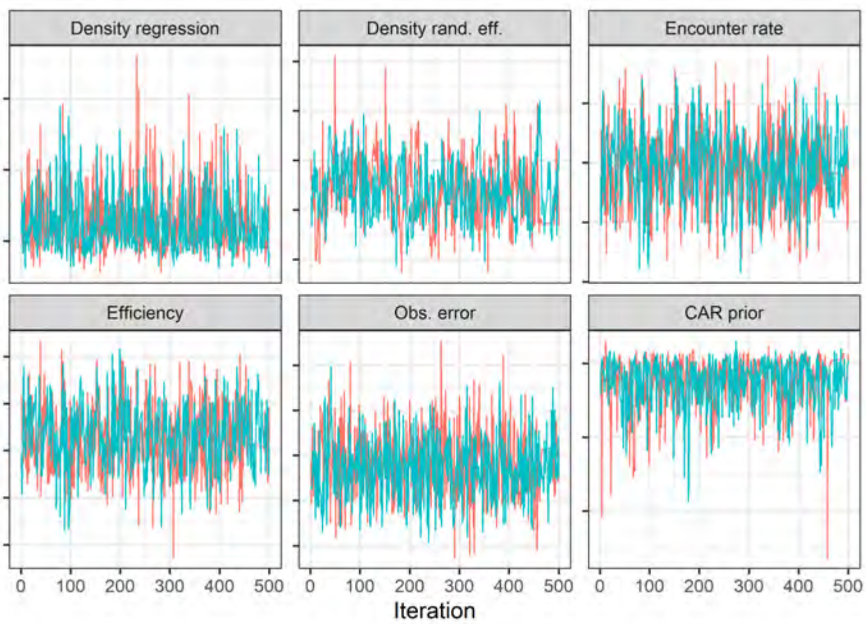


Figure S246: Posterior density sample traces for hydrocorals, for the regression coefficients $||\boldsymbol{\alpha}||$, random effects $||\boldsymbol{\phi}||$, encounter rate $||\boldsymbol{\gamma}||$, efficiency $||\boldsymbol{\pi}||$, observation error $||\boldsymbol{\sigma}||$ and conditional autoregressive prior parameters $||\tau,\rho||$. Colours represent independent sample chains.

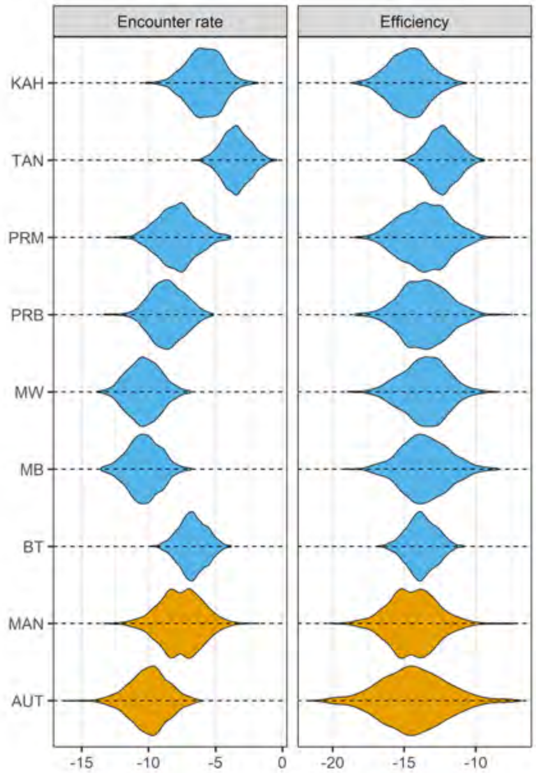


Figure S247: Violin plots of the posterior density for the encounter rate (γ_j) and the efficiency (π_j) per gear type for hydrocorals. Catchability terms for bottom longline gear types (see Table S2) are presented in a different colour as they are not comparable to the trawl gear types because they are dependent on different measures of effort (i.e., thousand hooks and distance, respectively).

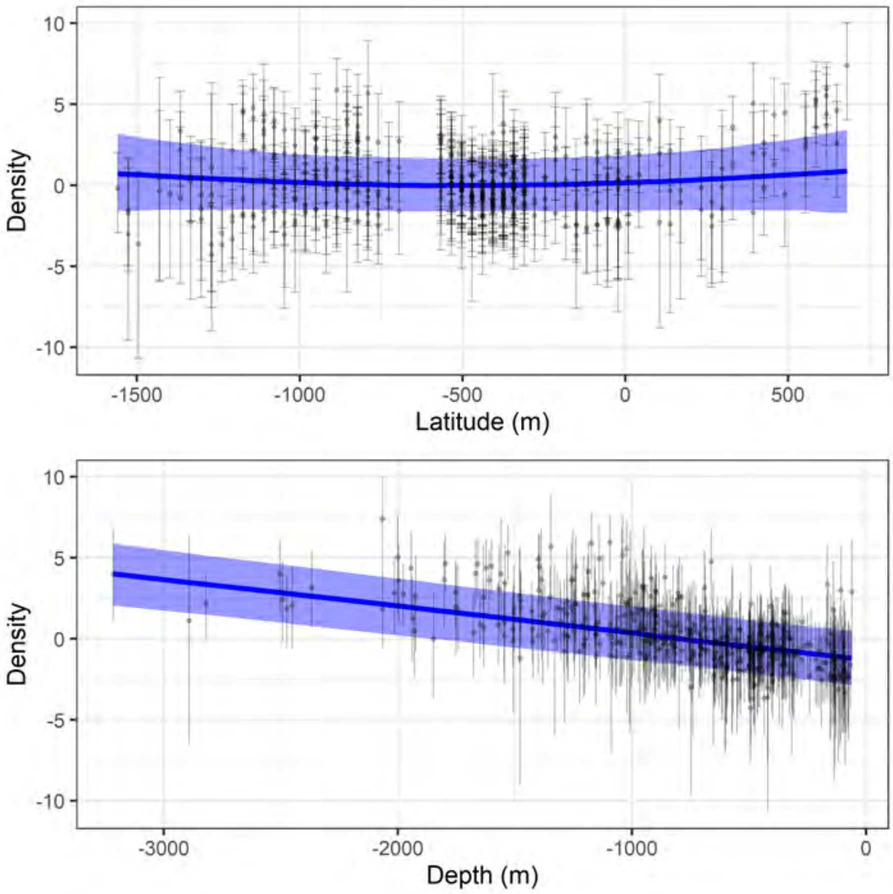


Figure S248: Estimated relationship between biomass density per grid cell and environmental covariates for hydrocorals. Points and error bars show the median and 90% credibility intervals per cell. The blue ribbon shows the estimated marginal relationship.

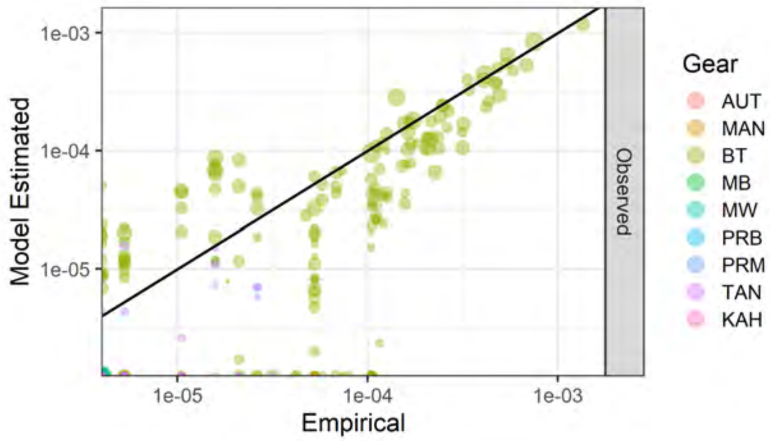


Figure S249: Fit of model to empirical observer catches. Total catches are summed per grid cell and gear type for hydrocorals. Model estimates are the median of the posterior predicted distribution. The size of the point is representative of the number of observed events. Catches are shown in tonnes on a log10 scale.

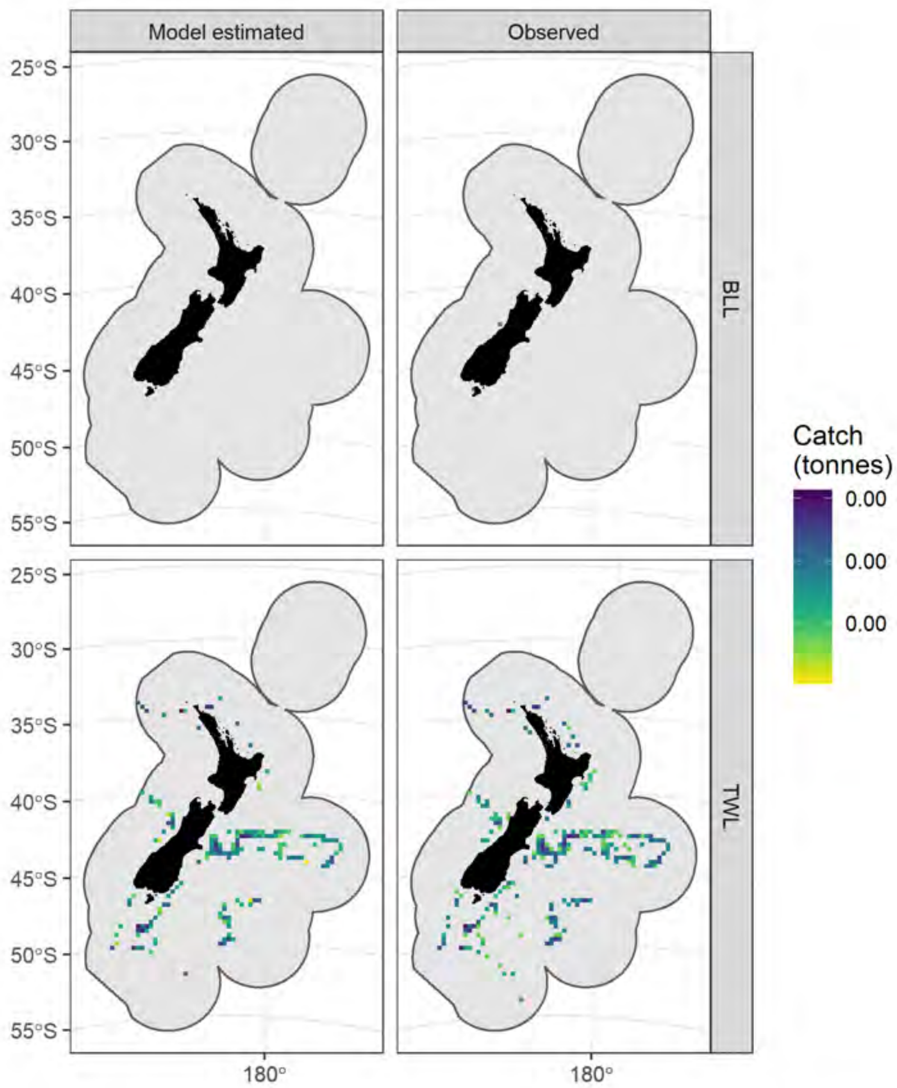


Figure S250: Spatial fit of model to empirical observer catches by grid cell and method for hydrocorals. Average annual catches were calculated as the sum across gear types per cell and method. Posterior median values are shown, with catches in tonnes on a log10 scale.

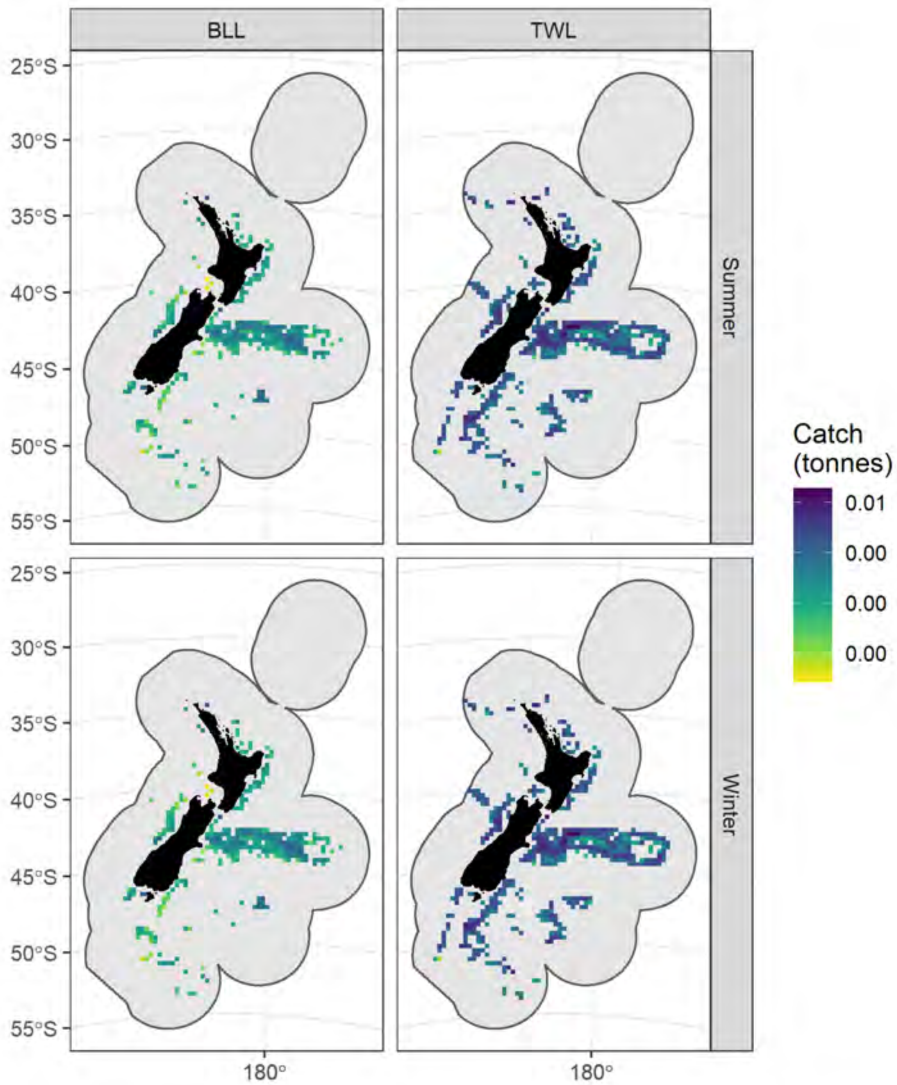


Figure S251: Posterior prediction of the total catches by grid cell, method and season for hydrocorals. Average annual catches per season were calculated as the sum across gear types per cell and method. Posterior median values are shown, with catches in tonnes on a log10 scale.

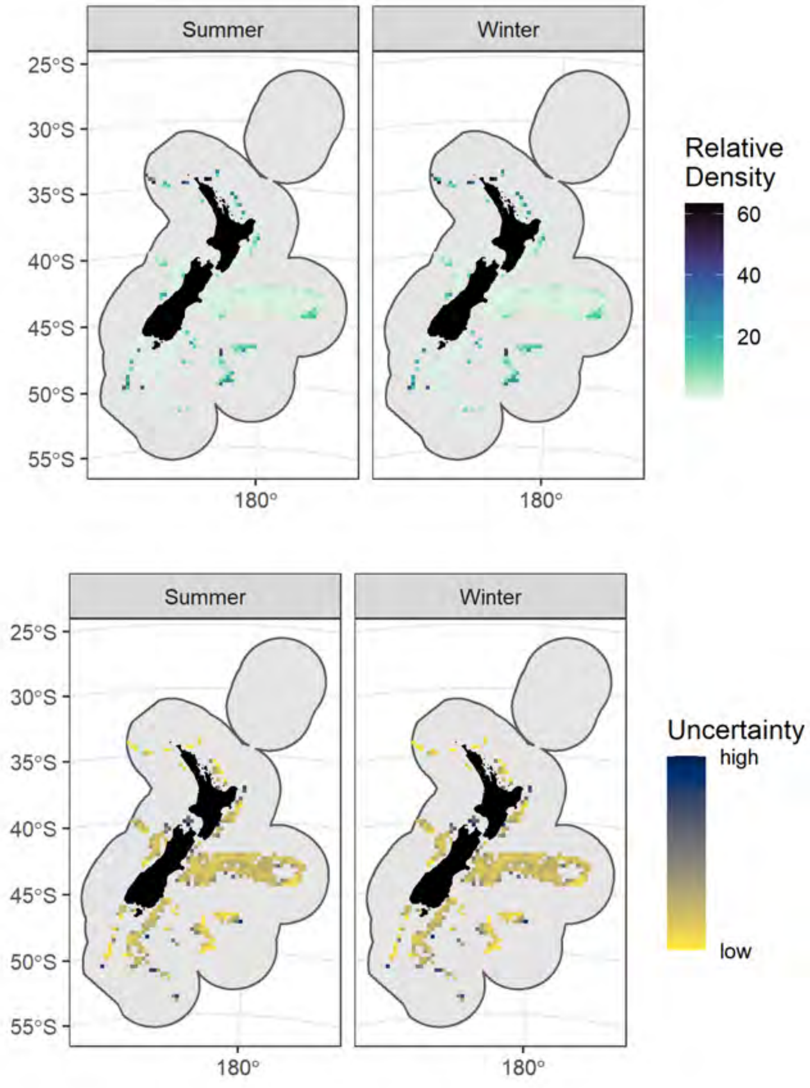


Figure S252: Posterior prediction of the relative density per grid cell and season for hydrocorals. Posterior median values are shown on a natural scale in tonnes per square kilometre. Uncertainty is measured using the difference between the upper and lower 95% equal-tailed posterior density interval.

Table S71: Total predicted bycatch (tonnes) per method for hydrocorals. Posterior median values are given, with the 95% equal-tailed credibility intervals in brackets.

Fishing year	BLL	TWL	Total
2000/01	0 (0 - 1)	1 (1 - 4)	1 (1 - 4)
2001/02	0 (0 - 1)	1 (1 - 3)	1 (1 - 4)
2002/03	0 (0 - 1)	1 (1 - 4)	1 (1 - 5)
2003/04	0 (0 - 1)	1 (1 - 4)	1 (1 - 4)
2004/05	0 (0 - 1)	1 (1 - 4)	1 (1 - 4)
2005/06	0 (0 - 1)	1 (1 - 3)	1 (1 - 3)
2006/07	0 (0 - 1)	1 (1 - 2)	1 (1 - 3)
2007/08	0 (0 - 1)	1 (1 - 3)	1 (1 - 3)
2008/09	0 (0 - 1)	1 (1 - 3)	1 (1 - 3)
2009/10	0 (0 - 1)	1 (1 - 2)	1 (1 - 3)
2010/11	0 (0 - 1)	1 (1 - 2)	1 (1 - 3)
2011/12	0 (0 - 1)	1 (1 - 2)	1 (1 - 3)
2012/13	0 (0 - 0)	1 (1 - 4)	1 (1 - 4)
2013/14	0 (0 - 1)	1 (1 - 2)	1 (1 - 3)
2014/15	0 (0 - 1)	1 (1 - 3)	1 (1 - 3)
2015/16	0 (0 - 1)	1 (1 - 2)	1 (1 - 3)
2016/17	0 (0 - 1)	1 (1 - 2)	1 (1 - 3)
2017/18	0 (0 - 1)	1 (1 - 4)	1 (1 - 4)
2018/19	0 (0 - 1)	1 (1 - 2)	1 (1 - 3)

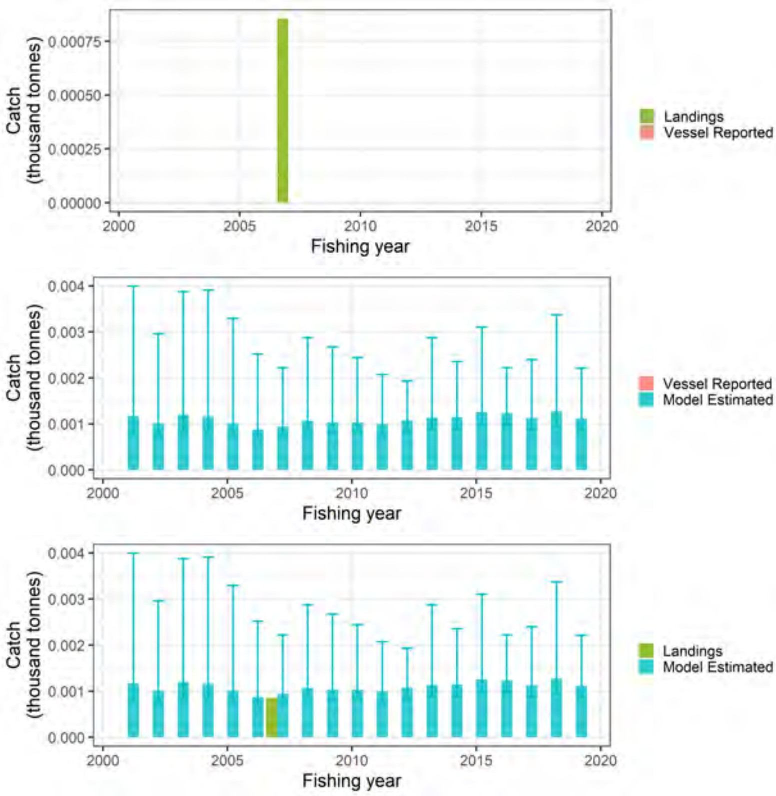


Figure S253: Relationships between landings, vessel reported catches and model estimated catches for hydrocorals.

S3. ACKNOWLEDGEMENTS

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