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Spatial-temporal standardisation of commercial longline and trawl survey of ling on the Chatham Rise (LIN 3&4) up to 2020–21

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EXECUTIVE SUMMARY

Mormede, S.[1]; Dunn, A.[2]; Webber, D.N.[3] (2023). Spatial-temporal standardisation of commercial longline and trawl survey catches of ling on the Chatham Rise (LIN 3&4) up to 2020–21.

***New Zealand Fisheries Assessment Report 2023/13*. 10 p.**

Ling (*Genypterus blacodes*) are an important commercial species caught mainly by bottom trawls and bottom longlines and more recently by potting. They are found throughout the middle depths of New Zealand waters. Ling are managed as eight administrative Quota Management Areas with five of those reporting about 95% of the landings. There are at least five major biological stocks: the Chatham Rise, the Sub-Antarctic (including the Stewart-Snares shelf and Puysegur Bank), the Bounty Plateau, the west coast of the South Island, and Cook Strait.

This report summarises spatial-temporal standardisation analyses of both the longline standardised catch per unit effort (CPUE) and the trawl survey biomass indices for ling on the Chatham Rise to investigate if the differences in the two indices can be explained by spatial-temporal differences.

Trawl survey biomass indices and CPUE of commercial longline fisheries are the two main indices of abundance which can be used to inform the assessment of ling stocks, such as in the Sub-Antarctic and the Chatham Rise. In the case of Chatham Rise ling (LIN 3&4), these two indices had different trends during the 1990s with the survey index being flat and the standardised longline CPUE showing a sharp decline. The survey biomass index was used in the base case assessment model, and a sensitivity model was carried out with the longline CPUE index. These two models had different initial biomass and current stock status estimates.

Accounting for fine-scale spatial and temporal structure of the fisheries and the underlying ling population in the longline CPUE resulted in only a small change in the CPUE trend compared with the CPUE trend used in the stock assessment. This small change resulted in a small change in the equivalent stock assessment but was not sufficient to reconcile the standardised longline CPUE and trawl survey biomass trends.

Accounting for fine-scale spatial and temporal structure of the fisheries and the underlying ling population in the survey catch standardisation resulted in an almost identical trend for the core area which is used for stock assessment purposes. This is not surprising given that surveys are designed to capture spatial differences through stratification and that this survey was designed to capture the biomass of hoki (*Macruronus novaezelandiae*), hake (*Merluccius australis*), and ling. However, the standardised biomass trend resulting from the fine-scale spatial and temporal standardisation of the entire survey data (including deeper strata) resulted in a small difference in terms of trends, in particular in the first point and last four points of the series. This might be due to a number of factors including changes over time of the survey area and extrapolation assumptions made in the spatial-temporal standardisation of those strata with low ling densities.

Although this work was not able to reconcile the longline CPUE and survey biomass trends for ling on the Chatham Rise, it confirmed that the standardisation of both the longline CPUE and the survey data were sensitive to the addition of spatial-temporal parameters, in turn resulting in slightly different stock initial biomass and current stock status. It further confirmed that changes in survey design and, in particular, the areal coverage should be considered carefully when changes are proposed.

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1. INTRODUCTION

Ling (*Genypterus blacodes*) are an important commercially caught species and are targeted by both bottom trawls and demersal longlines. Adult ling are found throughout the middle depths of the New Zealand Exclusive Economic Zone (EEZ) typically in depths 100–800 m (Hurst et al. 2000). Ling are caught mainly by deepwater trawlers, often as bycatch in hoki (*Macruronus novaezelandiae*) target fisheries and by target demersal longliners. Small quantities of ling are also caught by inshore trawl, setnets, and increasingly in LIN 3&4 potting (Mormede et al. 2022).

Trawl survey biomass indices and standardised catch per unit effort (CPUE) of commercial longline fisheries are the two main indices of abundance which can be used to inform the assessment of the ling stocks, such as in the Sub-Antarctic (LIN 5&6, e.g., Fisheries New Zealand 2021, Mormede et al. 2021). The assessment of ling on the Chatham Rise (LIN 3&4) was last carried out in 2022 (Fisheries New Zealand 2022; Mormede et al. 2023); results were similar to the previous stock assessment reported by Holmes (2019). The main index of abundance provided to the model was the Chatham Rise summer trawl survey. The commercial longline standardised CPUE series was used in a sensitivity model but the trend was in conflict with the survey biomass series. The CPUE had a strong decline in the 1990s, when the survey biomass series showed no trend.

Although the trawl survey biomass index had no trend and was in conflict with the age composition data (including the survey age data), the survey was considered to be robust and a consistent index of abundance. Hence, it was preferred as the index of abundance for the base case assessment model. The base case and the sensitivity models provided different estimates of initial biomass and current status, and the choice of which model should be the base case had an effect on potential advice on the status of stocks.

The Chatham Rise trawl survey was designed and optimised for hoki, hake (*Merluccius australis*), and ling (Stevens et al. 2021). It is a stratified random survey that aims to produce estimates of ling biomass with very low uncertainty (and had an estimated CV < 10% in most years). Most ling are found in the core strata (200–800 m) with little biomass found in the deeper strata (800–1200 m). The strata and allocation of stations within strata for the survey has changed slightly over time, including a higher number of stations during the initial years of the survey and the addition of deeper strata from 2010 and then additional deeper strata from 2016.

The biomass trend for ling over the period of the survey has been variable but generally flat. Estimates of biomass for each survey are calculated using a stratified random sampling methodology, effectively scaling up the mean areal catch per stratum to the overall survey area (Stevens et al. 2021).

The standardised longline CPUE series was derived using generalised linear models (GLM) and was detailed by Mormede et al. (2022). The dependent variable was the catch per set and a lognormal distribution was assumed. The final model included year, vessel, number of hooks, and month as explanatory variables. The resulting index was similar to that obtained in the previous standardisation and showed a strong decline in the 1990s followed by a variable but flat trend since. One of the effects of the standardisation was to accentuate the initial decline compared with raw catch rates, driven by the number of hooks and to a lesser extent the vessel. Different standardisation models were attempted by proposing different potential explanatory variables to the model, but all resulted in similar standardised trends in the indices. The raw longline CPUE, standardised longline CPUE, previously standardised longline CPUE, and trawl survey biomass index are shown in Figure 1.

We carry out a spatial-temporal standardisation of both the trawl survey biomass and the longline CPUE to ascertain if the differences in the indices might be due to spatial-temporal processes not captured in the standardisations used for the stock assessment. This report is in support of Specific Objective 2 of Project LIN2021-01 and Specific Objective 2 was "To carry out a stock assessment of the Chatham Rise ling stock including estimates of current biomass, the status of the stock in relation to management reference points, and future projections of stock status as required to support management."

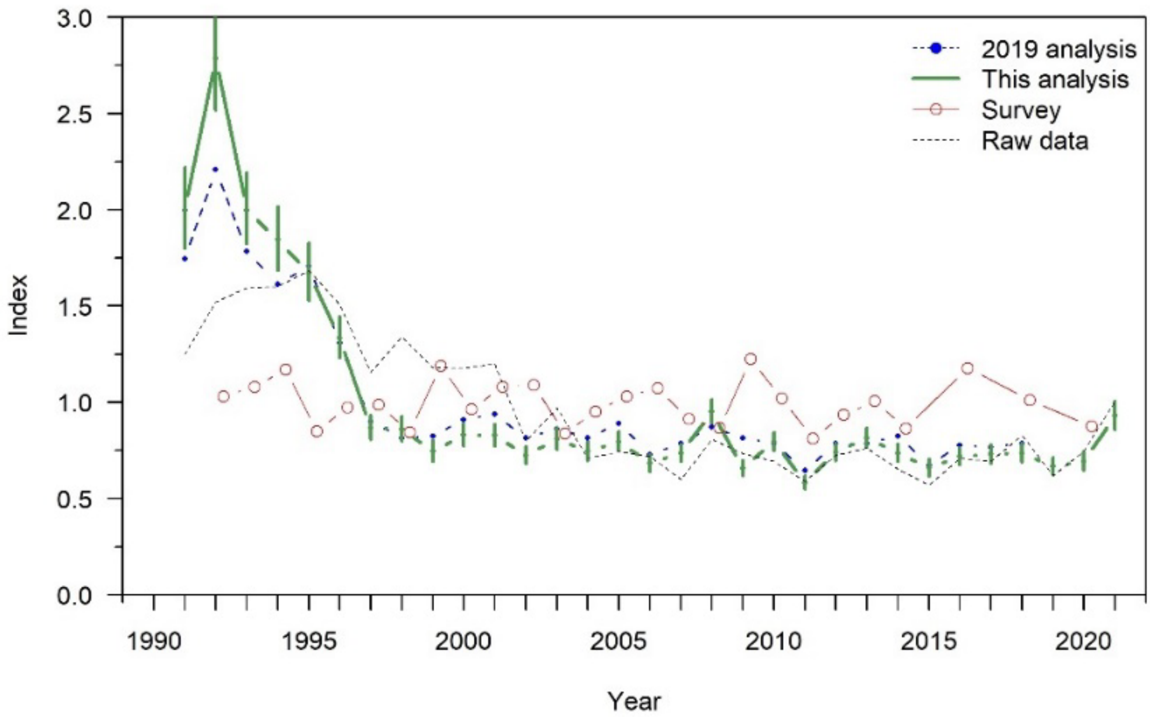

Figure 1: Year index for the standardised longline CPUE for Chatham Rise ling (LIN 3&4). Also plotted the 2019 index (Dutilloy 2019), the Chatham Rise trawl survey biomass series (Fisheries New Zealand 2021) and the raw catch rates. Year is calendar year. (This is figure D.2 of Mormede et al. 2022)

2. METHODS

2.1 Resource survey data

Resource survey data (i.e., data from the RV *Tangaroa* Chatham Rise standardised trawl survey) were extracted by Fisheries New Zealand for the period from October 1989 to September 2021 (REPLOG 14055) on 8th December 2021.

The same summer surveys of the Chatham Rise used for the biomass indices that were calculated for the stock assessment were used for this analysis (Fisheries New Zealand 2022). All valid tows were used, as well as the surface area covered by each station were used (e.g., Stevens et al. 2021). Standardisations were carried out using either all strata or the core strata only (i.e., depths 200–800 m), noting that the assessment model uses the series with core strata only as there are very few ling caught in the deeper strata.

2.2 Fisheries data

The data extract and processing are detailed by Mormede et al. (2022). Data were extracted by Fisheries New Zealand for the period from October 1989 to September 2021 (REPLOG 14055) on 8th December 2021. Catch and effort data included all data from trips where hoki, hake, or ling were reported as either caught, processed, or landed. Catch and effort data were corrected for errors using simple checking and imputation algorithms.

The CPUE data selection for the spatial-temporal standardisation followed that used in the stock characterisation (Mormede et al. 2022), although the event-by-event longline data were used rather than aggregated to a daily and statistical area level so as to retain the geolocated attributes of the data. The dependent variable used for the standardisation was the catch per fishing event (in kilograms).

As for non-spatial CPUE standardisations (Mormede et al. 2022), analyses were carried out on the 'core' fleet for each of the indices, aiming to keep at least 80% of the ling catch in each instance and cover the duration of the fishery with overlap between fishing vessels over the entire time series (Figure 2). The same explanatory variables were offered to the model as in the non-spatial standardisation and added in order of the most AIC explained until less than 1% of additional residual deviance was explained (Mormede et al. 2022).

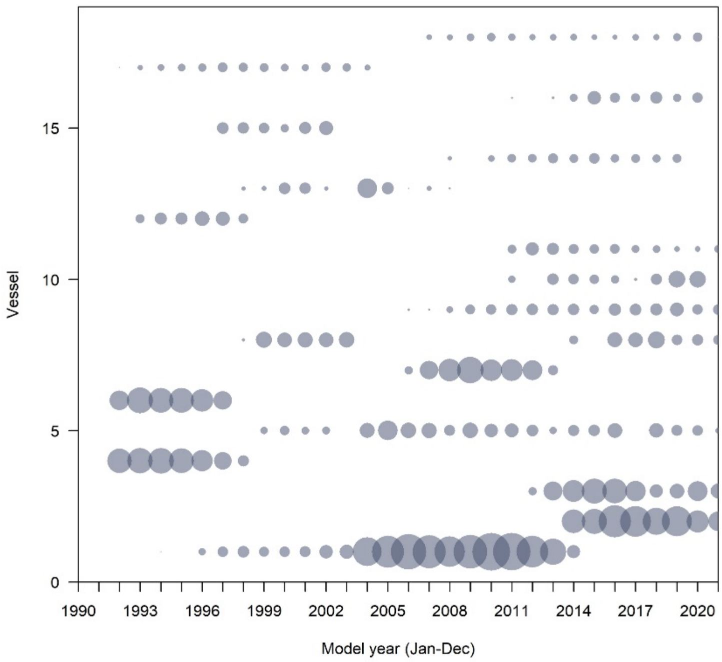

Figure 2: Core vessel selection for the bottom longline event-by-event spatial-temporal CPUE model for Chatham Rise ling (LIN 3&4): annual catch per vessel over time.

2.3 Spatial-temporal standardisation

Methods such as vector autoregressive spatial-temporal models (VAST, Thorson & Barnett 2017) apply a smoother to catch data (expressed in catch per area) in both time and space. Maunder et al. (2020) showed that spatial-temporal models were useful to derive indices of abundance and composition data when sampling intensity varies across the spatial domain—better accounting for variability in sampling over space and time that otherwise would violate the assumptions of time-invariant catchability and selectivity in stock assessment models. Similar results to that of Maunder et al. (2020) were reported elsewhere; for example, in comparisons of generalised additive model and VAST performance (Grüss et al. 2019, Mormede et al. 2020). The utility of VAST has also been tested using simulations (e.g., Brodie et al. 2020).

VAST was used in this study to fully account for the spatial and spatial-temporal relationship in the data. Model development and selection followed recommendations by Thorson and others (Thorson 2019, Thorson et al. 2021):

- The model distribution chosen was the delta-gamma distribution. The first component of a delta model (here a binomial distribution) estimates the probability of encountering a species at a given location and time, and the second component (here a gamma distribution) of the model estimates positive catch rates on condition that the species is encountered. The predicted biomass accounts for both the probability of presence and the catch rate given the species is encountered.

- The method used was the default '*mesh*' as there is no significant land barrier to account in the area studied.
- Overdispersion was turned off for both encounter probability and for positive catch rates (VAST parameter *OverdispersionConfig = c(0, 0)*).
- The number of knots used was 100. This was the maximum number of knots where the model still converged and provided marginal improvement in precision compared with 50 or 200 knots. Each knot represents the centre of each mesh cell used to split the space occupied by the fishery, whereby in this instance space was divided into 100 individual spatial areas with distinct underlying annual biomass.
- Bias correction was implemented for the probability of presence and abundance indices, whereby these derived quantities are corrected for retransformation bias (Thorson 2019).
- Spatial and temporal variation were assumed and estimated as random effects. Spatial-temporal effects were initially estimated but very close to zero for the model of survey data and therefore removed in the final models (VAST parameter *FieldConfig = 0* for *L_epsilon1_z* and *L_epsilon2_z*). This indicated that the model could not find changes in spatial distribution over time. This was subsequently applied to all models, including fisheries models, with a single spatial distribution estimated, assumed constant over all years.

During model selection, potential explanatory variables were added to the models in a stepwise manner. The model structure selected was a combination of lower AIC, highest deviance explained, and no convergence or dispersion issues. A model was deemed to have no obvious convergence issues if no parameters hit a bound, the gradient of the marginal log-likelihood was less than 0.0001 for all fixed effects, and the Hessian matrix of second derivative of the negative log-likelihood was positive definite. Partial effect plots were also investigated to check for a significant effect.

3. RESULTS

3.1 Standardised trawl survey index

The spatial-temporal standardisation using VAST takes into consideration surface area fished derived from the distance between trawl doors and tow length. The explanatory variables offered to the spatial-temporal standardisation of the survey index were headline height and time of the day the tow was started. All other potential explanatory variables such as speed were already standardised through survey design and did not vary sufficiently to warrant offering to the model. The model with most deviance explained and lowest AIC was the most complex model (Table 1). The addition of explanatory variables increased the CV of the index but not the index itself, and the partial effects were not significant (not shown).

Two further model runs were carried out: using all stations of the survey or only using the stations within the core strata (200 m to 800 m depth). The model run with only the core strata presented a very similar trend in relative biomass to that calculated using traditional random stratified survey methods, with both trends well within each other's credible intervals (Figure 3). In contrast, the biomass trend of the model run that included data from all strata deviated from that calculated using traditional random stratified survey methods, particularly in the first and last four data points of the series (Figure 3).

Table 1: Model selection for the spatial-temporal standardisation of the survey index. Explanatory variables listed are additional to the spatial and temporal explanatory variables included in the VAST model.

Additional explanatory variables	AIC	Deviance explained	Model converges
	27 279	0.56	yes
+ headline height	27 241	0.60	yes
+ time start	27 252	0.60	yes
+ headline height + time start	27 217	0.63	yes

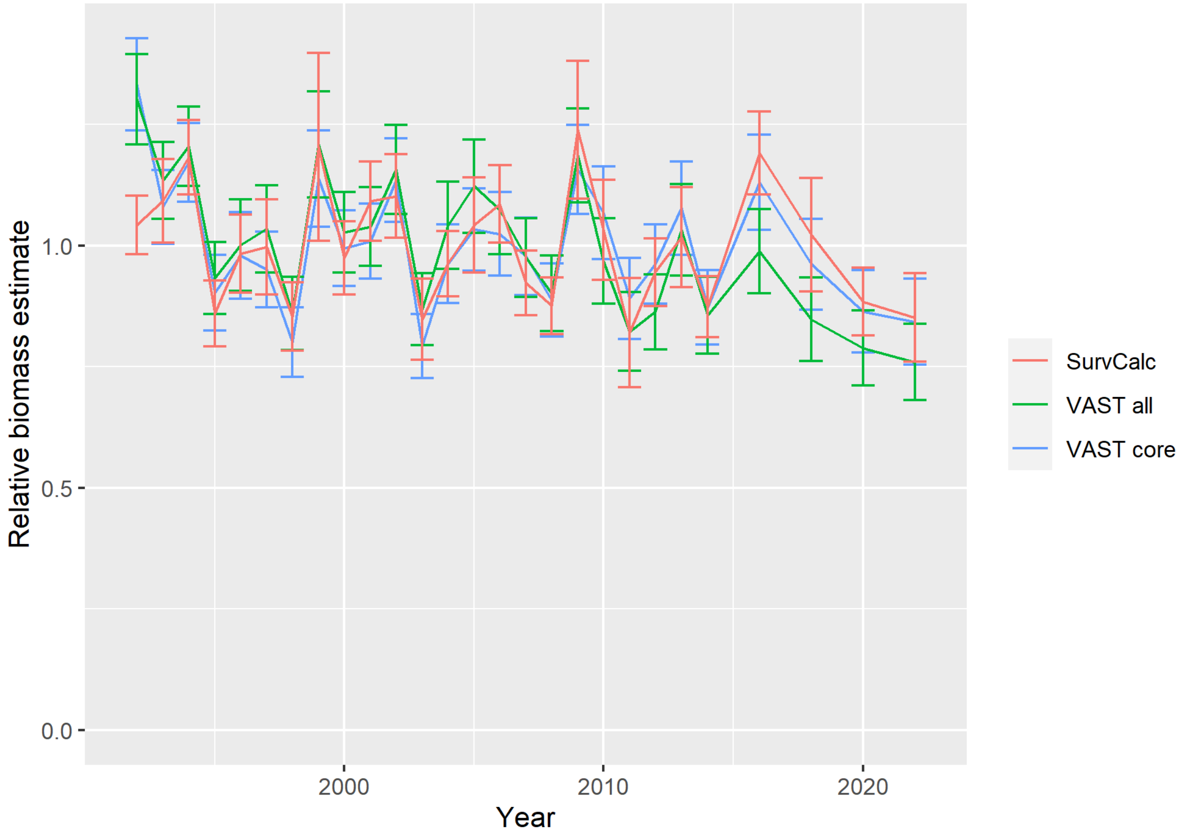

Figure 3: Comparison of the survey biomass indices: calculated empirically with the random stratified method using the NIWA SurvCalc software (Stevens et al. 2021), standardised spatially and temporally using VAST with all stations (VAST all) and the stations of the core strata (VAST core). 95% credible intervals are also shown.

3.2 Standardised longline CPUE index

The model setup for standardising longline catches was the same as that used for standardising the survey catches. In particular, no spatial-temporal variation was allowed in the model as this was not found in the survey analysis and would therefore likely be a proxy for other explanatory variables such as vessel effect in the commercial data.

Explanatory variables were added to the model in a stepwise manner, in order of highest incremental AIC until less than 1% additional deviance was explained (Table 2). The final model had six explanatory variables including: year, fine-scale spatial structure, hooks, month, longline type, and form type. Vessel identification was offered as either a fixed or random effect but did not improve the model, and neither did the variable ‘observed’, representing if a trip carried an observer onboard or not. The non-spatial CPUE standardisation used year, vessel identification, hooks, and month as explanatory variables.

The spatially-explicit standardised longline CPUE developed using VAST presented a steeper decline than the non-spatially explicit standardised longline CPUE developed using a GLM (Mormede et al. 2022) as well as wider credible intervals (Figure 4).

Table 2: Model selection for the spatial-temporal standardisation of the commercial longline CPUE. Covariates listed are additional to the spatial and temporal explanatory variables included in the VAST model. The models below the line did not increase the deviance explained by 1% or more.

Explanatory variables	AIC	Deviance explained	Model converges
Null model	78 912	0.68	yes
hooks	74 794	0.67	yes
hooks + month	71 641	0.70	yes
hooks + month + longline type	67 236	0.69	yes
hooks + month + longline type + form type	67 198	0.83	yes
hooks + month + longline type + form type + vessel experience	66 911	0.83	yes
hooks + month + longline type + form type + vessel experience + observed	66 852	0.83	yes

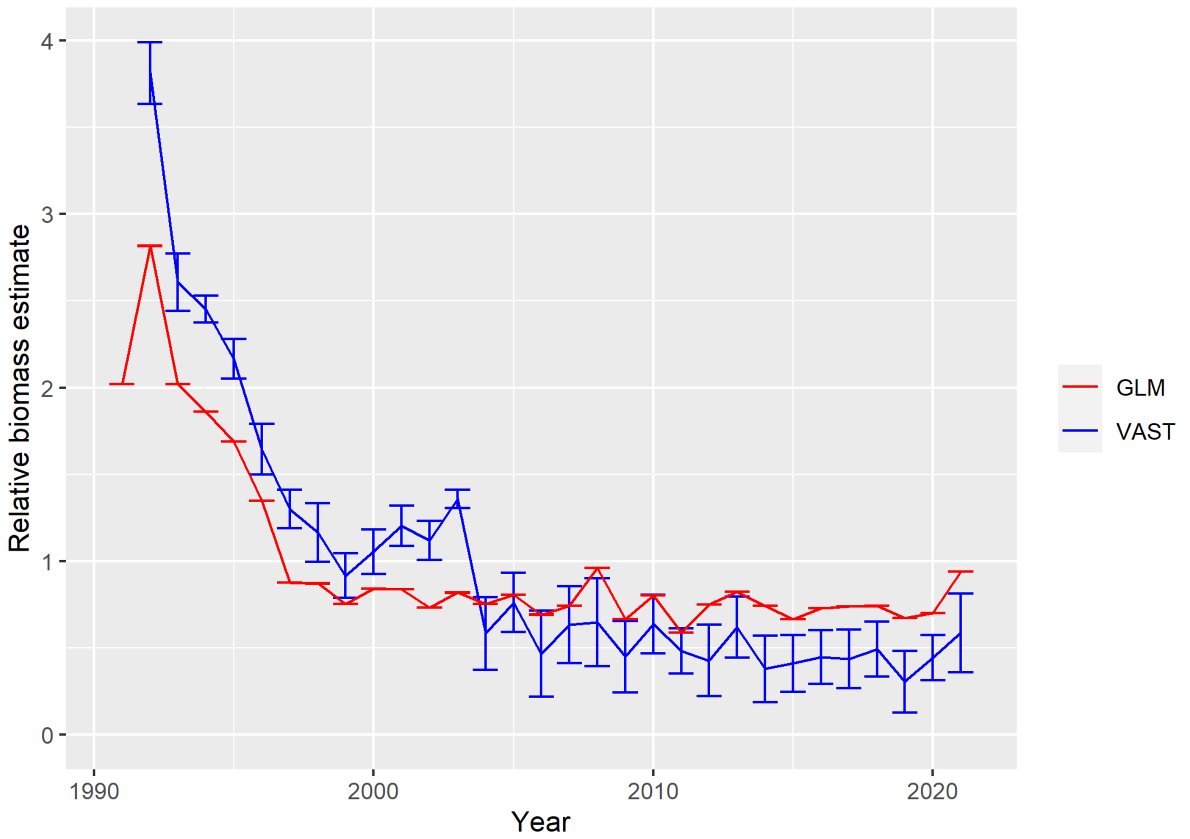

Figure 4: Comparison of the non-spatial standardised longline CPUE (GLM) and spatially explicit standardised longline CPUE (VAST) with 95% credible intervals.

3.3 Effect on the stock assessment model

The two spatially explicit standardised series were used in the 2022 stock assessment models (Mormede et al. 2023) to assess their potential effect on the stock assessment outcomes. The 2022 base case (model R2.0) included survey biomass but no CPUE observations and was updated with the spatially explicit survey biomass standardisation (model R2.1). The 2022 CPUE sensitivity run included the CPUE observations but not the survey biomass and was updated with the spatially explicit CPUE standardisation (model R3.1). In both instances the initial biomass and status dropped compared with the non-spatially explicit equivalent model (Table 3).

Table 3: Model runs maximum posterior density estimates. R2.0 and R3.0 were reproduced from Mormede et al. (2023).

Model	Description	B_0	B_{2022}/B_0	M	M_{diff}
R2.0	Base case – survey	108 224	0.54	0.153	-0.014
R3.0	Sensitivity - CPUE	91 960	0.33	0.136	-0.010
R2.1	Base with new survey	100 489	0.46	0.151	-0.014
R3.1	Sensitivity with new CPUE	87 016	0.22	0.131	-0.010

4. DISCUSSION

The spatially explicit standardisation of the survey biomass produced almost identical results to the random stratified survey biomass estimates when including data from the core strata only; however, it was different in the first and last four points of the series when including data from all strata in the survey. The cause of deviation in the last four points of the series was not explored but may be due to the addition of further deepwater strata in 2016, although the biomass of ling in those strata was very minimal. The addition of some deepwater strata in 2010 did not have the same effect though, with no deviation in the two series between 2010 and 2015. The Chatham Rise trawl survey is adequate for ling, with a CV lower than 10% in most years, yet this suggests any potential changes to the survey strata should be evaluated before introducing change. Although the deviation between the two resulting series was limited, the effect on the stock assessment of ling stock on the Chatham Rise was to reduce the initial biomass by about 8% and the current status of the stock from 54 to 46% B_0 when compared with its equivalent model run.

The spatially explicit standardisation of the longline CPUE produced an even more pronounced decline in the series than seen in the non-spatially explicit standardisation. This decline was deemed to not represent biomass changes but rather changes in the way the fishery operates (Fisheries New Zealand 2022) yet does not seem to be explainable through spatially discrete changes in the fisheries. The effect on the assessment of the ling stock on the Chatham Rise was to reduce the initial biomass by about 5% and the current status of the stock from 33 to 22% B_0 when compared with its equivalent model run.

Although the trends in the indices were generally similar between the spatial and non-spatial standardisations, the effect on the model outcome was significant. The spatial-temporal standardisation of both indices was not sufficient to explain the difference in trend in those two indices in the 1990s: flat for the survey and steeply declining for the longline CPUE. Therefore, the differences in the indices are unlikely to be due to spatial-temporal changes in the longline fishery, which were not previously captured in standardisations but expected to be standardised here.

The longline fishery data were standardised with a spatially-explicit distribution assumed to not vary between years based on the evidence from the trawl survey spatial-temporal standardisation. Future work could include testing if there might be a seasonal variation of the spatial distribution of ling.

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6. REFERENCES

Brodie, S.J.; Thorson, J.T.; Carroll, G.; Hazen, E.L.; Bograd, S.; Haltuch, M.A.; Holsman, K.K.; Kotwicki, S.; Samhouri, J.F.; Willis-Norton, E.; Selden, R.L. (2020). Trade-offs in covariate selection for species distribution models: a methodological comparison. *Ecography 43*: 11–24. https://doi.org/10.1111/ecog.04707

Dutilloy, A. (2019). A descriptive analysis of all ling (*Genypterus blacodes*) fisheries, and CPUE for ling longline fisheries for LIN 3&4 from 1990 to 2018. *New Zealand Fisheries Assessment Report 2019/53*. 77 p.

Fisheries New Zealand (2021). Fisheries Assessment Plenary, May 2021: stock assessments and stock status. Compiled by the Fisheries Science Team. Fisheries New Zealand. 1782 p.

Fisheries New Zealand (2022). Fisheries Assessment Plenary, May 2022: stock assessments and stock status. Compiled by the Fisheries Science Team. Fisheries New Zealand. 1886 p.

Grüss, A.; Walter, J.F.; Babcock, E.A.; Forrestal, F.C.; Thorson, J.T.; Lauretta, M.V.; Schirripa, M.J. (2019). Evaluation of the impacts of different treatments of spatio-temporal variation in catch-per-unit-effort standardization models. *Fisheries Research 213*: 75–93. https://doi.org/10.1016/j.fishres.2019.01.008

Holmes, S.J. (2019). Stock assessment of ling (*Genypterus blacodes*) on the Chatham Rise (LIN 3&4) for the 2018-19 fishing year. *New Zealand Fisheries Assessment Report 2019/70*. 49 p.

Hurst, R.J.; Bagley, N.W.; Anderson, O.F.; Francis, M.P.; Griggs, L.H.; Clark, M.R.; Paul, L.J.; Taylor, P.R. (2000). Atlas of juvenile and adult fish and squid distributions from bottom and midwater trawls and tuna longlines in New Zealand waters. *NIWA Technical Report 84*. 162 p.

Maunder, M.N.; Thorson, J.T.; Xu, H.; Oliveros-Ramos, R.; Hoyle, S.D.; Tremblay-Boyer, L.; Lee, H.H.; Kai, M.; Chang, S.-K.; Kitakado, T.; Albertsen, C.M.; Minte-Vera, C.V.; Lennert-Cody, C.E.; Aires-da-Silva, A.M.; Piner, K.R. (2020). The need for spatio-temporal modeling to determine catch-per-unit effort based indices of abundance and associated composition data for inclusion in stock assessment models. *Fisheries Research 229*: 105594. https://doi.org/10.1016/j.fishres.2020.105594

Mormede, S.; Dunn, A.; Webber, D.N. (2021). Stock assessment of ling (*Genypterus blacodes*) in the Sub-Antarctic (LIN5&6) for the 2020–21 fishing year. *New Zealand Fisheries Assessment Report 2021/61*. 40 p.

Mormede, S.; Dunn, A.; Webber, D.N. (2022). Descriptive analysis of ling (*Genypterus blacodes*) on the Chatham Rise (LIN 3&4) up to 2020–21 and inputs for the 2022 stock assessment. *New Zealand Fisheries Assessment Report 2022/64*. 85 p.

Mormede, S.; Dunn, A.; Webber, D.N. (2023). Stock assessment of ling (*Genypterus blacodes*) on the Chatham Rise (LIN 3&4) for the 2021–22 fishing year. *New Zealand Fisheries Assessment Report 2023/14*. 39 p.

Mormede, S.; Parker, S.J.; Pinkerton, M.H. (2020). Comparing spatial distribution modelling of fisheries data with single-area or spatially-explicit integrated population models, a case study of toothfish in the Ross Sea region. *Fisheries Research 221*: 105381. https://doi.org/10.1016/j.fishres.2019.105381

Stevens, D.W.; O'Driscoll, R.L.; Ballara, S.L.; Schimel, A.C.G. (2021). Trawl survey of hoki and middle depth species on the Chatham Rise, January 2020 (TAN2001). *New Zealand Fisheries Assessment Report 2021/33*. 126 p.

Thorson, J.T. (2019). Guidance for decisions using the Vector Autoregressive Spatio-Temporal (VAST) package in stock, ecosystem, habitat and climate assessments. *Fisheries Research 210*: 143–161. https://doi.org/10.1016/j.fishres.2018.10.013

Thorson, J.T.; Barnett, L.A.K. (2017). Comparing estimates of abundance trends and distribution shifts using single- and multispecies models of fishes and biogenic habitat. *ICES Journal of Marine Science 74*: 1311–1321.

Thorson, J.T.; Cunningham, C.J.; Jorgensen, E.; Havron, A.; Hulson, P.-J.F.; Monnahan, C.C.; von Szalay, P. (2021). The surprising sensitivity of index scale to delta-model assumptions: Recommendations for model-based index standardization. *Fisheries Research 233*: 105745. https://doi.org/10.1016/j.fishres.2020.105745