Bottom trawling by the vessel FV Chips in relation to the Napier Port Offshore Disposal Area

Prepared for Napier Port

July 2022

Climate, Freshwater & Ocean Science

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NIWA CLIENT REPORT No: 2022199AK
Report date: July 2022
NIWA Project: NPP22101

Revision	Description	Date
Version 1.0	First release	21 July 2022

Quality Assurance Statement		
[signature]	Reviewed by:	Jeremy McKenzie
[signature]	Formatting checked by:	Emma Hope-Ede
[signature]	Approved for release by:	Richard O'Driscoll

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Executive summary

The greater Hawke Bay region supports a bottom trawl fishery, primarily catching red gurnard *Chelidonichthys kumu* and various flatfish species. There were 11 core vessels undertaking bottom trawling in the Hawke Bay area between 2007-08 and 2019-20. Concerns have been raised regarding the consented dumping of dredge spoil, since 11 June 2020, in a new Offshore Disposal Area (ODA) and the potential effect on the bottom trawl fishery. This report presents an analysis of the bottom trawl fishing activity by the vessel FV Chips in relation to the ODA for the period 01 Oct 2015 to 30 Sep 2021. Confidential high-resolution data is presented for the vessel FV Chips with permission from the vessel owner, Allstar Fishing Ltd. This study found trends in the indices of relative abundance for red gurnard and flatfish. However, there was nothing to suggest that these trends could be attributed to the disposal of dredge spoil in the ODA, despite the vessel still fishing in the vicinity of the ODA. Due to the recent nature of the initial dredge disposal, very little post-dredge data is available. The detection of any potential negative effects of a long-term nature will require continued monitoring.

1 Introduction

The greater Hawke Bay region supports a bottom trawl fishery, primarily catching red gurnard *Chelidonichthys kumu* and various flatfish species, including English sole *Peltorhamphus novaezeelandiae*, lemon sole *Pelotretis flavilatus*, sand flounder *Rhombosolea plebeia*, yellow belly flounder *Rhombosolea leporine*, and others. A previous analysis of commercial logbook data identified 11 core vessels undertaking bottom trawling in the Hawke Bay area between 2007-08 and 2019-20 (Braw Research 2021).

Port of Napier Ltd has obtained various consents related to dredging and the dumping of dredge spoil in Hawke Bay. One such consent relates to the dumping of dredge spoil in the new Offshore Disposal Area (ODA). The ODA is situated approximately three nautical miles east of Napier Port and covers an area of 3.42 km^2. Disposal of dredge spoil in the ODA commenced on the 11 June 2020.

The ODA is not closed to fishing; however, since the dumping of spoil commenced, bottom trawlers have avoided the area due to the risk of getting their gear stuck in the spoil (Paul Rose, Port of Napier Ltd, *pers. comm.* 2022). An earlier investigation, prior to the disposal of spoil in the ODA, reported that red gurnard catches in that area were typical of the wider fishery, whereas flatfish catches were relatively high in that area (Chambers & Middleton 2019).

Besides the loss of fishing ground, there was concern that the dredge spoil would smother the surrounding seafloor and thus adversely affect the benthic invertebrate species preyed on by the target species (red gurnard and flatfish), and therefore the fishery itself. A benthic baseline survey of the ODA and surrounding area was completed in April 2019, prior to the initial spoil disposal, by Cawthron Institute, with repeat surveys taking place in October 2020 and October 2021 (Sneddon 2022). It was found that benthic composition around the ODA had been altered slightly but it could not be concluded that this was due to the dumping of spoil. Macrofaunal communities had also not changed substantially.

An assessment of catches, following the establishment of the ODA, found no evidence that spoil disposal had affected catch rates of red gurnard or flatfish (Braw Research 2021).

Conditions associated with the consents held by Port of Napier Ltd require environmental monitoring. The overall objective of this report was to determine whether the dumping of dredge spoil at the ODA has affected the nearby commercial bottom trawl fishery. This report presents an analysis of bottom trawl catch in the Hawke Bay region by a single commercial vessel, FV Chips. The vessel is owned and operated by Allstar Fishing Ltd, who provided permission to analyse and present confidential tow-level data in this report.

2 Methods

2.1 Study area

The ODA covers an area of 3.42 km^2 within the FMA 2 quota management area. The ODA straddles the border between statistical fishing areas 013 and 014 (Table 1, Figure 2-1).

Table 1: Geographic coordinates for the Napier Port Offshore Disposal Area in Hawke Bay.

Point description	Geographic coordinate
North-west corner	39° 28.174′ S; 176° 58.290′ E
North-east corner	39° 28.174′ S; 176° 59.570′ E
South-east corner	39° 29.174′ S; 176° 59.579′ E
South-west corner	39° 29.177′ S; 176° 58.291′ E

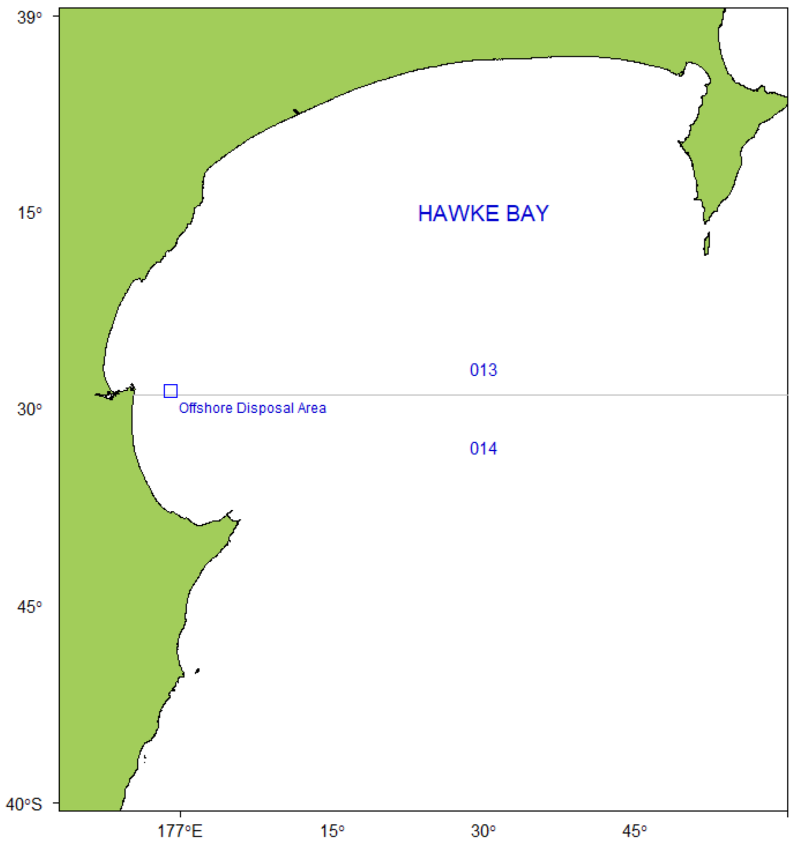

Figure 2-1: Study area showing the Napier Port Offshore Disposal Area in Hawke Bay, including statistical areas 013 and 014.

2.2 Data extract description

Statutory catch and effort data were requested from the Enterprise Data Warehouse, which is managed by Fisheries New Zealand (FNZ), a business unit of the Ministry for Primary Industries. All requested data referred to only one vessel, FV Chips, which is owned by Allstar Fishing Ltd.

Two separate data extract requests were submitted to FNZ for commercial logbook data, with one extract focussed on red gurnard *Chelidonichthys kumu* (species code GUR) and the other focussed on various flatfish species. The requests were for full-accuracy positions with permission having been granted by Allstar Fishing Ltd.

For the red gurnard request, all available effort, estimated catch and landing records were requested for those trips by vessel FV Chips where landings were reported for GUR2. The date range on this request was “all up to 2021-09-30” being the end of the 2020-21 fishing year.

Flatfish refer to a range of species in the families Achiropsettidae, Bothidae, Pleuronectidae and Rhombosoleidae (order Pleuronectiformes). These species should be landed under the FLA species code, but this is not always the case. Consequently, for the flatfish data request, all available effort, estimated catch and landing records were requested for those trips by vessel FV Chips where landings were reported for FLA2, BFL2, BLF2, BRI2, ESO2, FLO2, GFL2, LSO2, SFI2, SFL2, SOL2, TUR2, WIT2, YBF2, BOT2, GBL2, MAN2, SLS2, SDF2. Note that some of the codes, such as BLF represent frequently used misspellings of correct species codes (i.e., BFL – black flounder). The date range on this request was similarly “all up to 2021-09-30”.

Geospatial position reporting (GPR) was introduced by FNZ in 2019 and refers to high-resolution tracking data collected for commercial fishing vessels. All available GPR data for the vessel FV Chips was requested from FNZ with permission having been granted by Allstar Fishing Ltd.

In addition to statutory catch and effort data, the vessel FV Chips also collected length frequency data during experimental tows. Experimental tows were conducted near the ODA from May 2019 to January 2022 on a near-monthly basis (Figure 2-2). On each day, two experimental tows were conducted for a total of four per month. These data were supplied by Port of Napier Ltd for analysis in this report. Experimental tows were considered normal fishing activity for statutory reporting. Thus, the usual catch and effort data were collected during experimental tows and submitted to FNZ. The extract requests described above therefore include catch and effort data collected during experimental tows. Overall, 38 experimental tows were identifiable in the catch and effort data extracts received from FNZ.

In late 2014, a significant change was made to the fishing gear used by FV Chips. The codend of the trawl net was replaced with a steel cage. However, the original mesh codend was used again for experimental tows conducted in Jul, Aug, Sep, Oct, and Nov of 2019.

The length frequency data were received from Port of Napier Ltd on 11 May 2022 and FNZ supplied the GPR data on the 24 May 2022 and the statutory catch and effort on 25 May 2022.

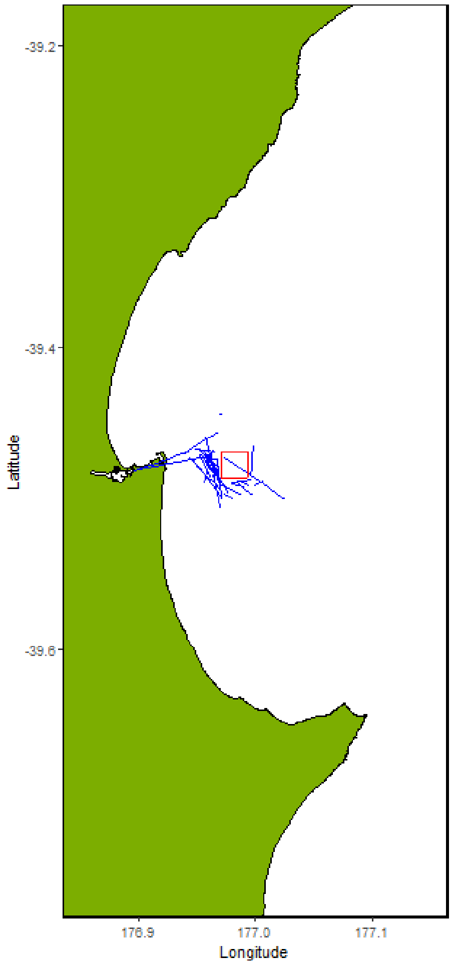

Figure 2-2: Experimental tows (n=38) conducted by the vessel FV Chips from 14 May 2019 to 21 Sep 2021. These tows were included in the length frequency analysis but were removed from the geospatial position reporting, fishery characterisation and CPUE analyses. Red square indicates the Offshore Disposal Area. Line segments indicate the shortest distance between start and end position of the tows but may not accurately reflect the true vessel path.

2.3 Data analysis

2.3.1 Data grooming

Data extracts received from FNZ were groomed following established protocols. The red gurnard dataset was groomed separately to the flatfish dataset. Estimates of red gurnard/flatfish catch per fishing event were linked to their associated effort variables by fishing event (such as fishing location, fishing method, target species, tow speed). Individual fishing events were then linked to landed catch weights for each trip, to prorate the landed weight for each species across events, given event-based catch weight estimates. The link between the event-based estimated effort and trip-based landed catch weight tables was a common trip number field (*trip_key*).

Several events were then removed from the red gurnard and the flatfish datasets. Firstly, all events prior to the 2015-16 fishing year were removed due to the significant change made to the codend. Exploratory analysis indicated a substantial change in catchability linked to the change in codend.

Similarly, all experimental tows were removed prior to analysis, and used only for the length frequency analysis described below. All events with a position occurring on land were removed as well as those with an "unrealistic" tow duration or bottom depth.

The several flatfish species were treated as a species complex and assigned the code FLA during the grooming process.

Groomed data were used in all further catch and effort analyses.

2.3.2 High precision vessel tracking

GPR data was used to investigate the spatial distribution of fishing activity by the vessel FV Chips before and after the initial dredge spoil disposal on the 11 June 2020.

2.3.3 Fishery characterisation

The groomed datasets were used to produce fishery characterisation plots of annual catch by month, target species, and statistical area.

2.3.4 CPUE standardisation

Catch-per-unit-effort (CPUE) is often used to represent an index of fish abundance. However, other factors, such as target species and bottom depth, may also influence CPUE irrespective of fish abundance. Nominal CPUE was therefore standardised, separately for red gurnard and for flatfish, using generalised linear models to account for such influential factors (Campbell 2004; Maunder & Punt 2004; McCullagh & Nelder 1989).

An appreciable number of zero catch events were present in the gurnard-targeted tows but less so in the flatfish-targeted tows (Figure 2-3). It was considered appropriate to include the red gurnard zero catch events in the analysis of CPUE, but this required a two-step modelling approach. Firstly, those fishing events having red gurnard in the catch were modelled using a lognormal distribution. Secondly, using all fishing events in the red gurnard data (including zero catch events), the probability of capture was modelled using a binomial distribution. The resulting indices were then multiplied to derive a combined index of relative abundance, described as a delta-lognormal or hurdle model (Stefánsson 1996, Maunder & Punt 2004, Fletcher 2005). The two-step approach was not applied in the flatfish analysis because there were so few zero catch events. Final model selection, in all cases, used a forward stepwise approach testing for a change in the r^2 value of <0.01.

2.3.5 Length frequency

Length frequency data were collected during experimental tows. The analysis of these data was limited to the most recent complete fishing year from 29 Oct 2020 to 21 Sep 2021. The gear used for experimental tows was a four-inch diamond net with a 54-foot ground line, one-metre end line height, seven-metre wingspan, and a steel cage codend with opening dimensions of 100 mm x 50 mm.

All analyses were performed using R v4.0.2 (R Core Team 2020).

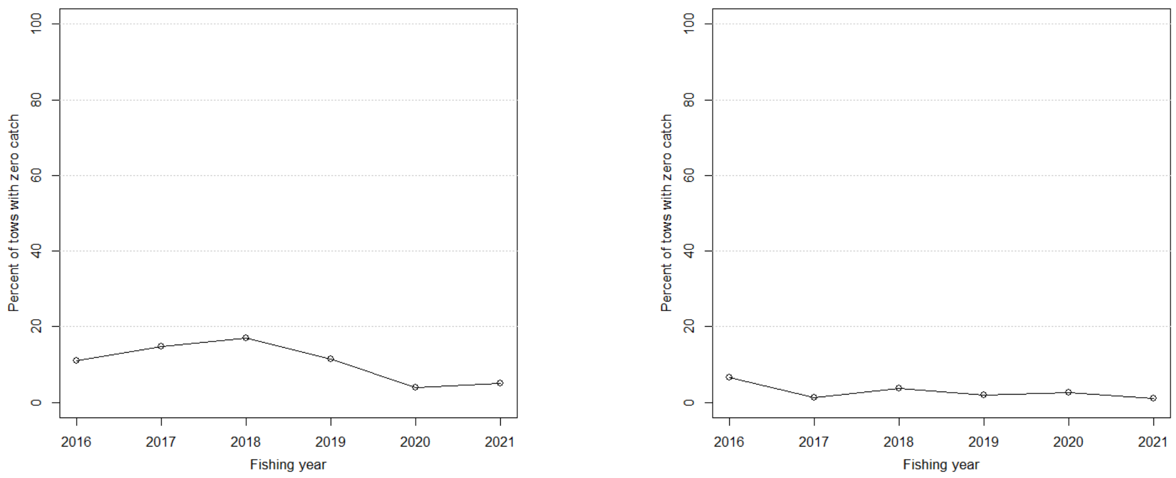

Figure 2-3: Percentage of tows with no catch of red gurnard (left) and no catch of flatfish (right). Data shown is for bottom trawling trips by the vessel FV Chips during the fishing years 2015-16 to 2020-21 in the Hawke Bay region where red gurnard was caught on at least one tow (left) and where flatfish species were caught on at least one tow (right). Experimental tows excluded.

3 Results

3.1 High-resolution vessel tracking

Geospatial position reporting (GPR) data for the vessel FV Chips, consisted of 83 tows before and 128 tows after the initial dredge spoil disposal on the 11 June 2020 (Figure 3-1). The vessel showed a clear change in tactic, avoiding the ODA, but still spending a lot of time in the vicinity of the ODA.

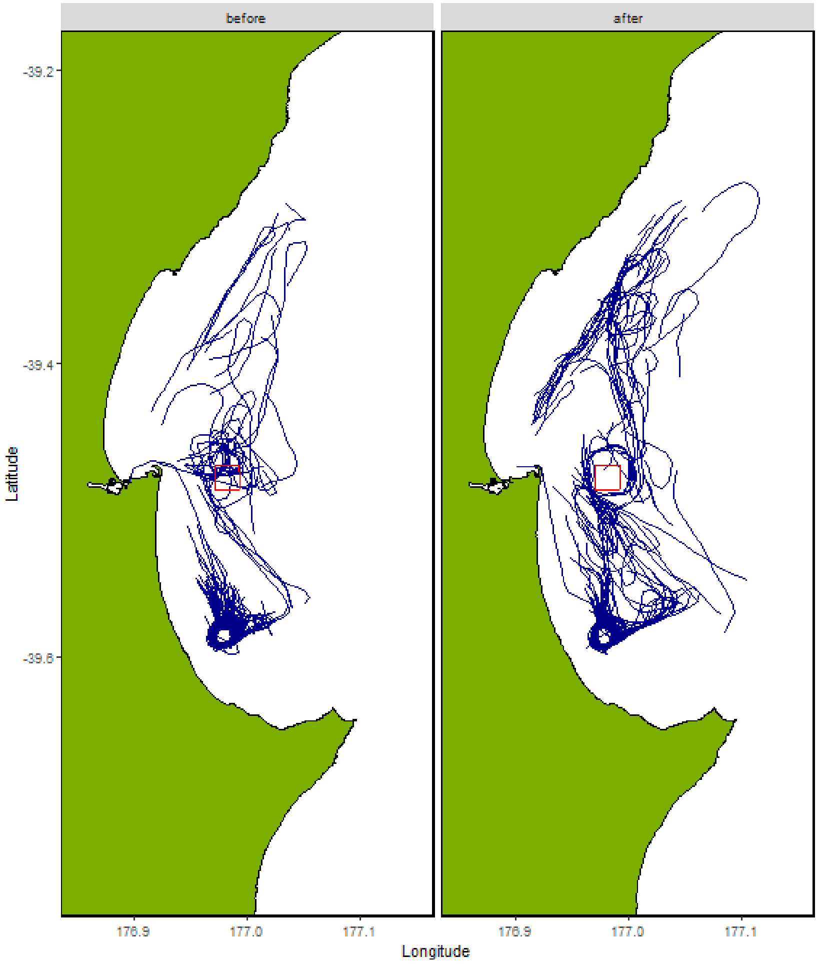

Figure 3-1: Vessel tracks derived from geospatial position reporting for the vessel FV Chips. Before (left) and after (right) the initial dredge spoil disposal on the 11 June 2020. Overall date range is from 09 July 2019 to 21 September 2021. Experimental tows excluded. Red square indicates the Offshore Disposal Area.

3.2 Red gurnard

3.2.1 Fishery characterisation

The fishing activity by FV Chips in the Hawke Bay region, during the fishing years 2015-16 to 2020-21, was spread over a large area in relation to the ODA (Figure 3-2). The red gurnard catch volume by FV Chips varied across the overall fishing area as did the CPUE. Historically, expected catch rates within the ODA were moderate compared to the high catch-rate areas north of Napier and south of Cape Kidnappers.

Over the fishing years 2015-16 to 2020-21, a general reduction was evident in the red gurnard catch reported by FV Chips (Figure 3-3). Higher red gurnard catches were reported for the summer months in statistical area 13 and when targeting red gurnard as opposed to targeting flatfish. The vessel also started fishing in shallower water from 2016-17 onwards (Figure 3-4).

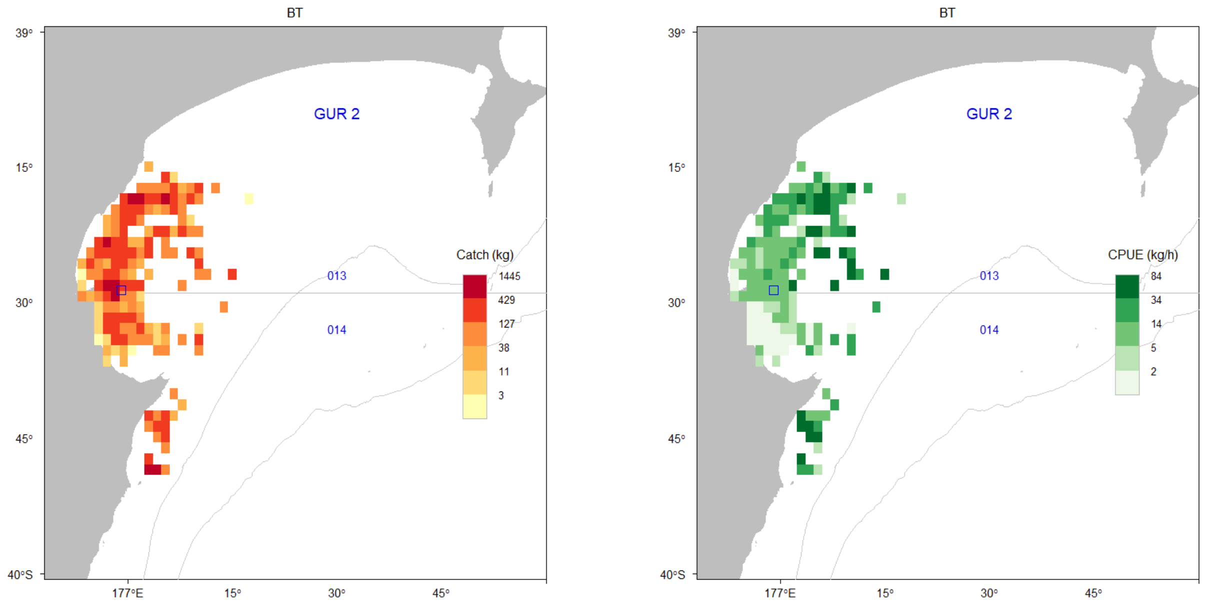

Figure 3-2: Distribution of red gurnard catch in kg (left) and unstandardised catch-per-unit-effort (CPUE) in kg/hour (right). Data shown is for bottom trawling trips by the vessel FV Chips during the fishing years 2015-16 to 2020-21 in the Hawke Bay region where red gurnard was caught on at least one tow. Experimental tows excluded. Blue square indicates the Napier Port Offshore Dumping Area. Statistical areas 013 and 014 included. CPUE is expressed as the geometric mean.

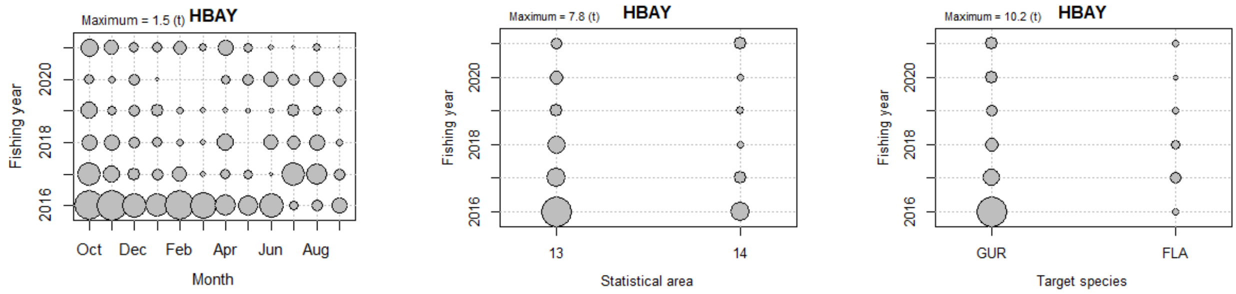

Figure 3-3: Distribution of red gurnard catches (tons) by fishing year and month (left), statistical area (middle) and target species (right). Data shown is for bottom trawling trips by the vessel FV Chips during the fishing years 2015-16 to 2020-21 in the Hawke Bay region where red gurnard was caught on at least one tow. Experimental tows excluded.

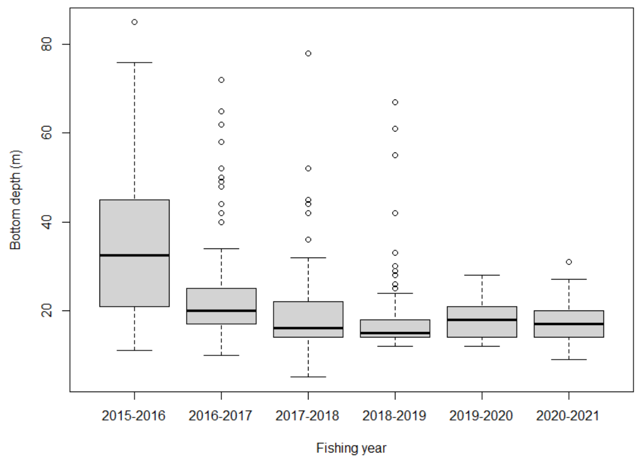

Figure 3-4: Distribution of bottom depths (m). Data shown is for bottom trawling by the vessel FV Chips during the fishing years 2015-16 to 2020-21 in the Hawke Bay region where red gurnard was caught on at least one tow. Experimental tows excluded.

3.2.2 CPUE analysis

The predictor variables selected for the red gurnard model were evaluated prior to inclusion in the model (Figure 3-5). Exploratory plots, selected for the red gurnard model, showed satisfactorily low correlation between the continuous predictor variables. The variables duration, depth, and speed were thus retained for the model. However, due to the consistency in the height of the trawl gear over time, this variable was deemed to have little explanatory power and was thus not offered to the model. There was little evidence of heterogeneity of variance in the categorical predictor variables and all were retained for inclusion in the model. The variables offered to both the lognormal and binomial models for red gurnard are listed in Table 2. The response variable, catch and the effort predictor variables, duration, and speed, were log-transformed and fitted as cubic splines.

The forward stepwise selection produced a final lognormal model of red gurnard catch (non-zero catch events), which included all selected predictor variables except *speed* and explained 53% of the deviance (Table 3). All predictors were statistically significant at the 95% threshold. In the binomial model, the forward stepwise selection produced a final model of red gurnard catch probability (all events), which included all selected predictors and explained 34.2 % of the deviance (Table 4). Only the variables *ns(log_duration)* and *stat* were not statistically significant at the 95% threshold. The variable *effort_depth* had the largest effect on expected catch in both the lognormal and binomial models (Figure B-1, Figure B-2, Figure B-3, Figure B-4, Figure B-5, Figure B-6).

Model diagnostics for the red gurnard models indicated satisfactory fits (Figure B-7, Figure B-8, Figure B-9). There was no indication of an interaction between *fish_year* and *target* (Figure B-10) or between *fish_year* and *stat* (Figure B-11).

The lognormal index showed an increase over time in red gurnard CPUE, and this increase was slightly more pronounced when combining with the binomial model (Figure 3-6). This was contrary to the unstandardised arithmetic CPUE, which showed a downward trajectory over the same period.

The disparity in CPUE indices was most pronounced in 2016 when the depth fished by FV Chips was substantially greater than in subsequent years. This indicated that the model had to apply a greater correction factor to the high nominal CPUE in that year.

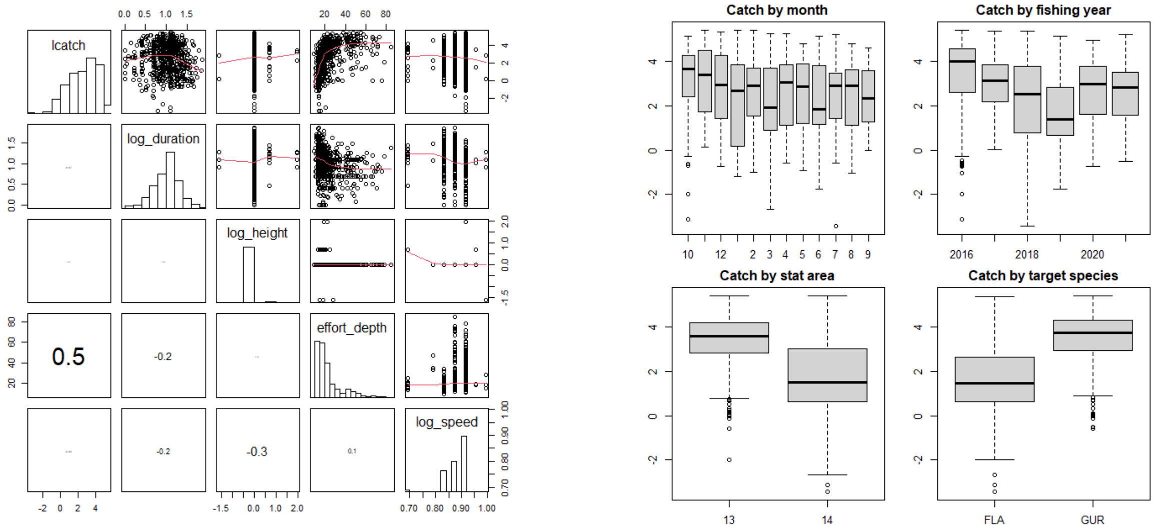

Figure 3-5: Evaluation of the predictor variables selected for the red gurnard models. Correlation (Pearson values) between continuous variables (left); variance in logged catch by categorical variables (right). Data shown is for bottom trawling trips by the vessel FV Chips during the fishing years 2015-16 to 2020-21 in the Hawke Bay region where red gurnard was caught on at least one tow. Experimental tows excluded.

Table 2: Variables offered to the binomial and lognormal models for red gurnard and to the lognormal model for flatfish.

Variable name	Description	Type
fish_year	Fishing year from 1 Oct - 30 Sep	Categorical
stat	Statistical area	Categorical
month	Calendar month	Categorical
target	Target species	Categorical
effort_depth	Bottom depth (metres) fitted as a cubic spline	Continuous
duration	Log duration of tow event (hours) fitted as a cubic spline	Continuous
speed	Log estimated average trawl speed of tow (knots) fitted as a cubic spline	Continuous

Table 3: Final lognormal model for red gurnard catch (non-zero catch events) following forward stepwise selection of predictor variables. Df = degrees of freedom.

Predictor	Step	Df	Residual Deviance	Total deviance explained (%)	Additional deviance explained (%)	r^2	aic	Pr(>Chi)
Null model			1927.00				2736.0	
fish_year	1		1687.02	12.5%	12.5%	0.12461	2651.5	<0.001
ns(effort_depth)	3	-3	1109.92	42.4%	29.9%	0.42407	2358.9	<0.001
stat	5	-1	1026.43	46.7%	4.3%	0.46739	2305.2	<0.001
month	2	-11	963.43	50.0%	3.3%	0.50008	2282.0	<0.001
target	6	-1	929.18	51.8%	1.8%	0.51785	2258.2	<0.001
ns(log_duration)	4	-4	905.79	53.0%	1.2%	0.52999	2248.1	0.001

Table 4: Final binomial model for red gurnard catch probability (all events) following forward stepwise selection of predictors. Df = degrees of freedom.

Predictor	Step	Df	Residual Deviance	Total deviance explained (%)	Additional deviance explained (%)	r^2	aic	Pr(>Chi)
Null model			567.82				569.80	
fish_year	1		552.32	2.7%	2.7%	0.02730	564.32	0.008
ns(effort_depth)	3	-3	443.24	21.9%	19.2%	0.21939	461.24	<0.001
month	2	-11	418.08	26.4%	4.4%	0.26371	458.08	0.009
target	7	-1	401.86	29.2%	2.9%	0.29228	443.86	<0.001
ns(log_speed)	5	-3	389.60	31.4%	2.2%	0.31387	437.60	0.007
ns(log_duration)	4	-4	380.30	33.0%	1.6%	0.33024	436.30	0.054
stat	6	-1	373.65	34.2%	1.2%	0.34196	431.65	0.098

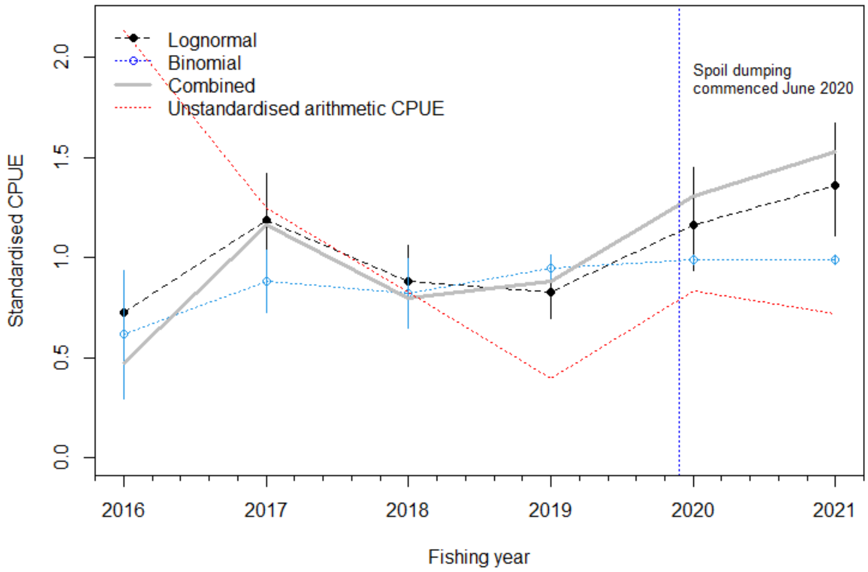

Figure 3-6: Standardised red gurnard catch-per-unit-effort (CPUE) indices in kg/hour for the lognormal, binomial and combined models. Unstandardised arithmetic CPUE included. Data shown is for bottom trawling trips by the vessel FV Chips during the fishing years 2015-16 to 2020-21 in the Hawke Bay region where red gurnard was caught on at least one tow. Experimental tows excluded.

3.2.3 Red gurnard length frequency

Red gurnard caught by FV Chips during experimental tows from 29 Oct 2020 to 21 Sep 2021 were nearly all greater than 30 cm total length (TL) (Figure A-1). The modes of the length frequency distributions were mostly around 35-40 cm TL, similar to those presented by Braw Research (2021) for tows using the steel cage. In August 2021, there was a bimodal distribution with several small red gurnard around 23-29 cm TL, resembling some of the distributions presented by Braw Research (2021) for experimental tows using the four-inch mesh codend.

3.3 Flatfish

3.3.1 Fishery characterisation

The fishing activity by FV Chips in the Hawke Bay region, during the fishing years 2015-16 to 2020-21, was spread over a large area in relation to the ODA (Figure 3-7). The flatfish catch volume by FV Chips varied across the overall fishing area as did the CPUE. Historically, expected catch rates within the ODA were relatively moderate compared to the large high catch-rate area south of Napier.

Over the fishing years 2015-16 to 2020-21, no clear overall pattern was evident in the flatfish catch reported by FV Chips (Figure 3-8). However, higher flatfish catches were generally reported for the summer months in statistical area 14 and when targeting flatfish as opposed to targeting red gurnard. The vessel also started fishing in shallower water from 2016-17 onwards (Figure 3-9).

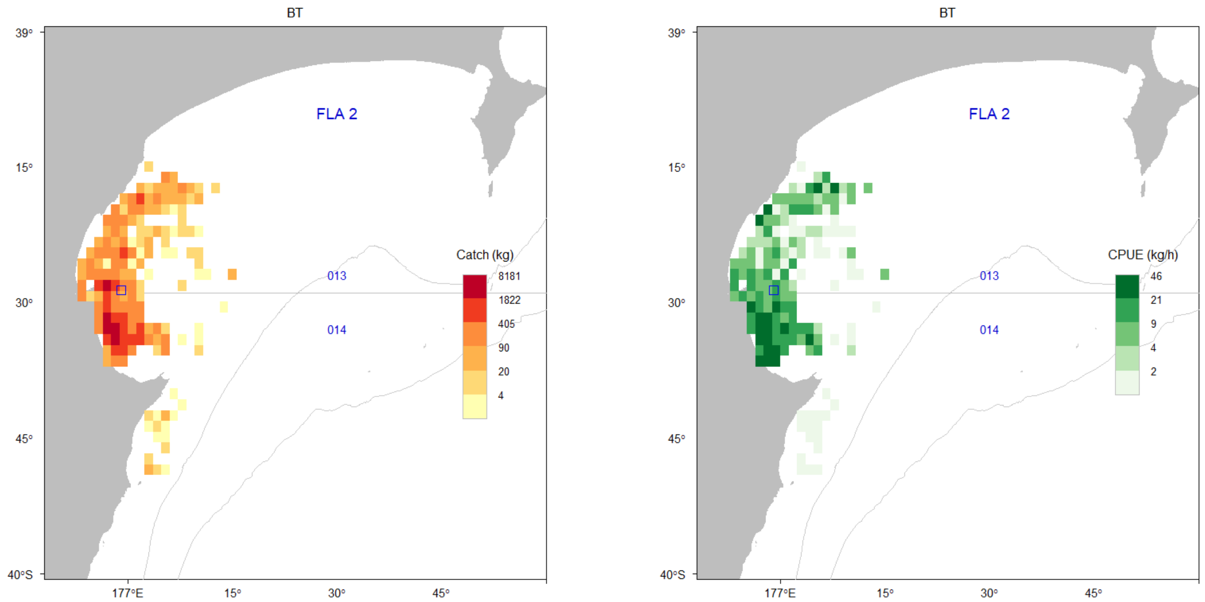

Figure 3-7: Distribution of flatfish catch in kg (left) and unstandardised catch-per-unit-effort (CPUE) in kg/hour (right). Data shown is for bottom trawling trips by the vessel FV Chips during the fishing years 2015-16 to 2020-21 in the Hawke Bay region where flatfish species were caught on at least one tow. Experimental tows excluded. Blue square indicates the Napier Port Offshore Dumping Area. Statistical areas 013 and 014 included. CPUE is expressed as the geometric mean.

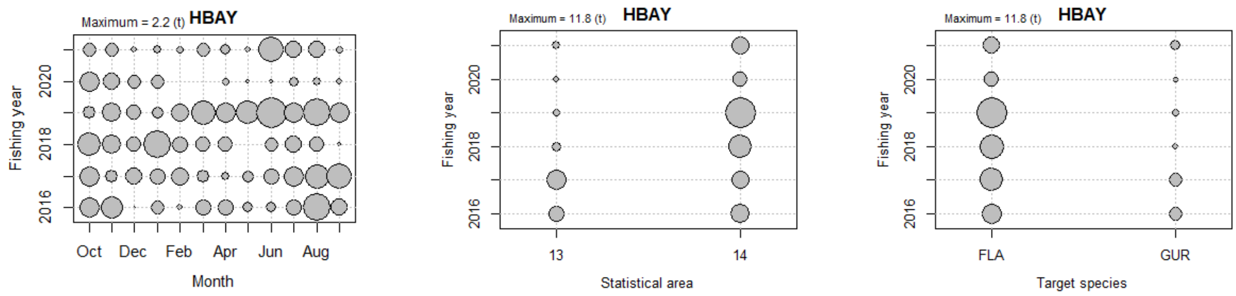

Figure 3-8: Distribution of flatfish catches (tons) by fishing year and month (left), statistical area (middle) and target species (right). Data shown is for bottom trawling trips by the vessel FV Chips during the fishing years 2015-16 to 2020-21 in the Hawke Bay region where flatfish species were caught on at least one tow. Experimental tows excluded.

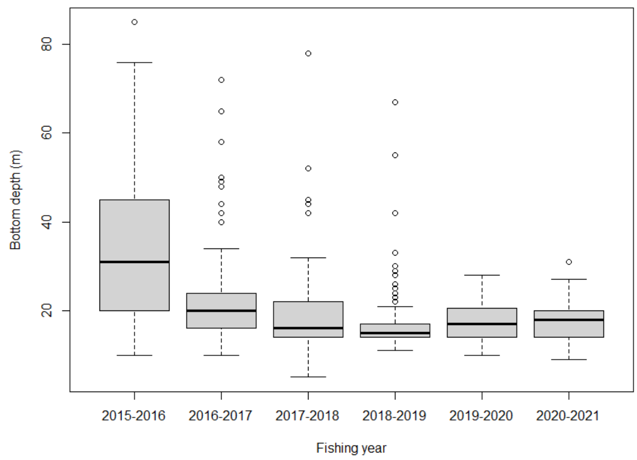

Figure 3-9: Distribution of bottom depths (m). Data shown is for bottom trawling by the vessel FV Chips during the fishing years 2015-16 to 2020-21 in the Hawke Bay region where flatfish species were caught on at least one tow. Experimental tows excluded.

3.3.2 CPUE analysis

The predictor variables selected for the flatfish model were evaluated prior to inclusion in the model (Figure 3-10). Exploratory plots, selected for the flatfish model, showed satisfactorily low correlation between the continuous predictor variables. The variables *duration*, *depth*, and *speed* were thus retained for the model. However, due to the consistency in the headline *height* of the trawl gear over time, this variable was deemed to have little explanatory power and was thus not offered to the model. There was little evidence of heterogeneity of variance in the categorical predictor variables and all were retained for inclusion in the model. The variables offered to the lognormal model for flatfish are listed in Table 2. The response variable, *catch* and the effort predictor variables, *duration* and *speed*, were log-transformed and fitted as cubic splines.

The forward stepwise selection produced a final lognormal model of flatfish catch (non-zero catch events), which included all selected predictor variables except *speed* and *stat* and explained 51.7% of the deviance (Table 5). All predictors were statistically significant at the 95 % threshold. The variable *effort_depth* had the largest effect on expected catch in the lognormal model (Figure C-1, Figure C-2, Figure C-3, Figure C-4, Figure C-5).

Model diagnostics for the flatfish models indicated satisfactory fits (Figure C-6, Figure C-7, Figure C-8). There was no indication of an interaction between *fish_year* and *target* (Figure C-9) or between *fish_year* and *stat* (Figure C-10).

The lognormal index showed a decrease over time in flatfish CPUE (Figure 3-11). This was largely aligned with the unstandardised arithmetic CPUE, which showed a general downward trajectory over the same period. However, both indices show a slight increase in the 2020-21 fishing year.

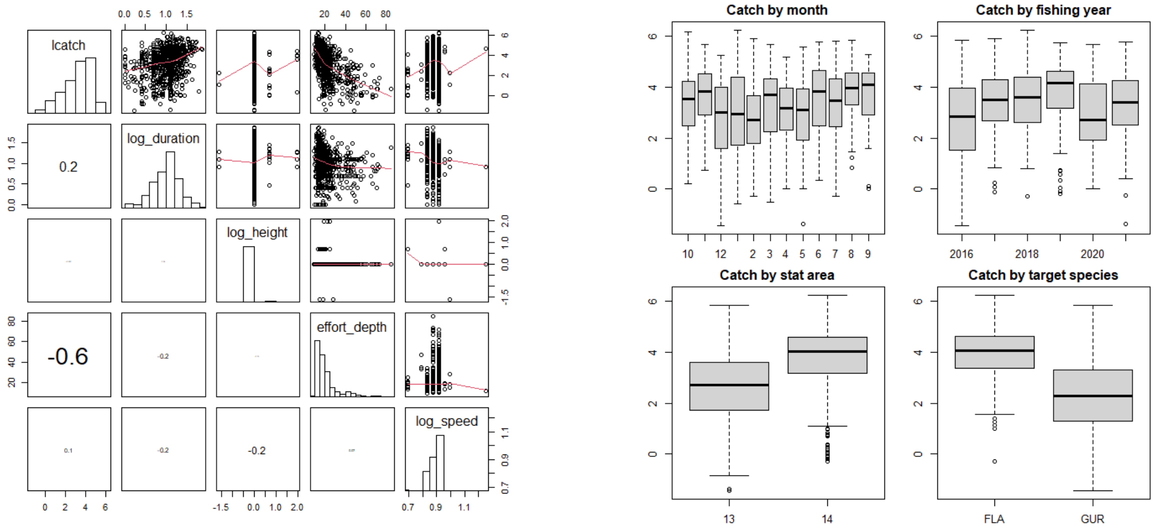

Figure 3-10: Evaluation of the predictor variables selected for the flatfish model. Correlation (Pearson values) between continuous variables (left); variance in logged catch by categorical variables (right). Data shown is for bottom trawling trips by the vessel FV Chips during the fishing years 2015-16 to 2020-21 in the Hawke Bay region where flatfish species were caught on at least one tow. Experimental tows excluded.

Table 5: Final lognormal model for flatfish CPUE (non-zero catch events) following forward stepwise selection of predictor variables. DF = degrees of freedom.

Predictor	Step	Df	Residual Deviance	Total deviance explained (%)	Additional deviance explained (%)	r^2	aic	Pr(>Chi)
Null model			1683.00				2946.0	
fish_year	1		1551.94	7.8%	7.8%	0.07765	2888.9	<0.001
ns(effort_depth, df = 3)	3	-3	1029.24	38.8%	31.1%	0.38830	2554.0	<0.001
target	5	-1	941.11	44.1%	5.2%	0.44068	2481.7	<0.001
month	2	-11	872.77	48.1%	4.1%	0.48130	2441.1	<0.001
ns(log_duration, df = 4)	4	-4	813.11	51.7%	3.5%	0.51675	2390.4	<0.001

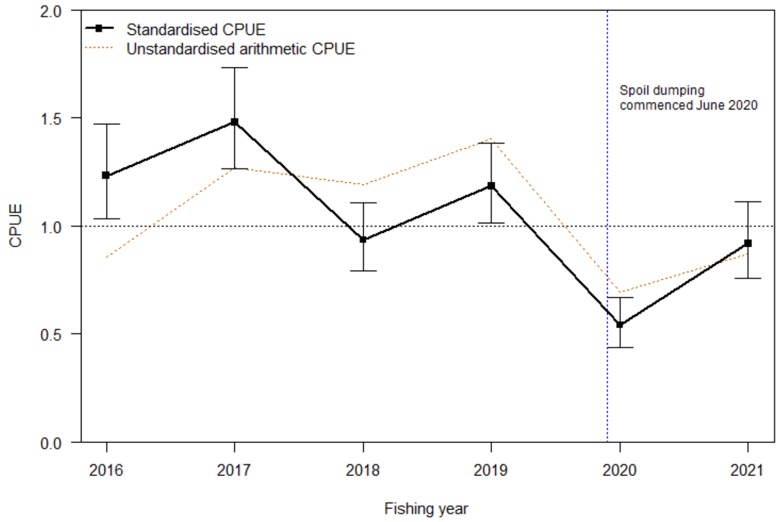

Figure 3-11: Standardised flatfish catch-per-unit-effort (CPUE) indices in kg/hour for the lognormal model. Data shown is for bottom trawling trips by the vessel FV Chips during the fishing years 2015-16 to 2020-21 in the Hawke Bay region where flatfish species were caught on at least one tow. Experimental tows excluded.

3.3.3 Flatfish length frequency

Flatfish caught by FV Chips during experimental tows (steel cage) from 29 Oct 2020 to 21 Sep 2021 were dominated by English sole and showed that almost all fish caught were greater than 20 cm total length (TL). English sole showed a broad distribution in lengths, with many around 25-35 cm TL (Figure A-2). The few lemon sole that were measured were mostly between 25-30 cm TL (Figure A-3). The few sand flounder that were measured showed a broad distribution in lengths with many between 25-35 cm TL (Figure A-4). Similarly, very few yellow belly flounder were measured with a broad distribution in lengths of between 30-40 cm TL (Figure A-5). There were insufficient black flounder or brill measured during experimental tows to produce meaningful length frequency plots.

4 Discussion

This study was able to detect trends in the recent catch rate of the vessel FV Chips for red gurnard and flatfish, but there was nothing to suggest that these trends could be attributed to the dredge spoil disposal, which had commenced on 11 June 2020. Standardised indices of relative abundance showed an increase for red gurnard, beginning before the initial dredge spoil disposal. The indices for flatfish showed an initial decrease leading up to the initial disposal, but then an increase in the following year.

Some notable disparities existed between the unstandardised nominal CPUE and the standardised CPUE. This is largely associated with the vessel changing tactic, first fishing in relatively deeper water during 2015-16 and then fishing shallower in all subsequent years. For both red gurnard and flatfish, the models showed that fishing depth had the greatest effect on expected catches. Consequently, the trend in the unstandardised nominal CPUE is not a reliable index of abundance.

Length frequency plots collected by FV Chips during experimental tows from 29 Oct 2020 to 21 Sep 2021 also showed no concerning patterns.

The study by Braw Research (2021) used a slightly different approach for modelling CPUE. In that study, the proximity of tows to the ODA was quantified and included as a predictor in the model. However, that study found no evidence to suggest that proximity to the disposal site had any effect on catches. Consequently, that approach was not used in the current study.

It is presumed that any negative effect of the disposal plume would be greatest in the ODA and immediate surrounds but would decrease with increasing distance from the disposal site. The high-resolution vessel tracking analysis showed that FV Chips had displaced effort from the ODA following the initial dredge disposal. However, the vessel still appears to be spending much time in the vicinity of the ODA, rather than further afield. This would therefore be expected to highlight any negative effect of the disposal plume. However, this was not apparent in the results.

Previous surveys of the benthos and analyses of the commercial fishery have similarly found no evidence to suggest that the disposal of dredge spoil has to date had any appreciable negative effect (Braw Research 2021, Sneddon 2022). However, this does not discount any long-term negative effects of the dredge disposal on the environment. Very little time has elapsed since the initial dredge disposal and consequently there is very little post-dredge data available. The detection of any potential negative effects of a long-term nature will require continued monitoring.

5 Acknowledgements

Thank you to Fisheries New Zealand for extracting and providing commercial logbook and Geospatial Position Reporting data for use in this report. Karl Warr of Allstar Fishing Ltd provided permission to access high resolution data on his fishing operations. Paul Rose at Port of Napier Ltd provided the length frequency data. Thanks to Jeremy McKenzie at NIWA for assistance with the analysis and providing feedback on the report and to Richard Bian for assisting with R code.

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Stefánsson, G. (1996) Analysis of groundfish survey abundance data: combining the GLM and delta approaches. *ICES Journal of Marine Science*, 53: 577–588.

Appendix A Length frequency plots

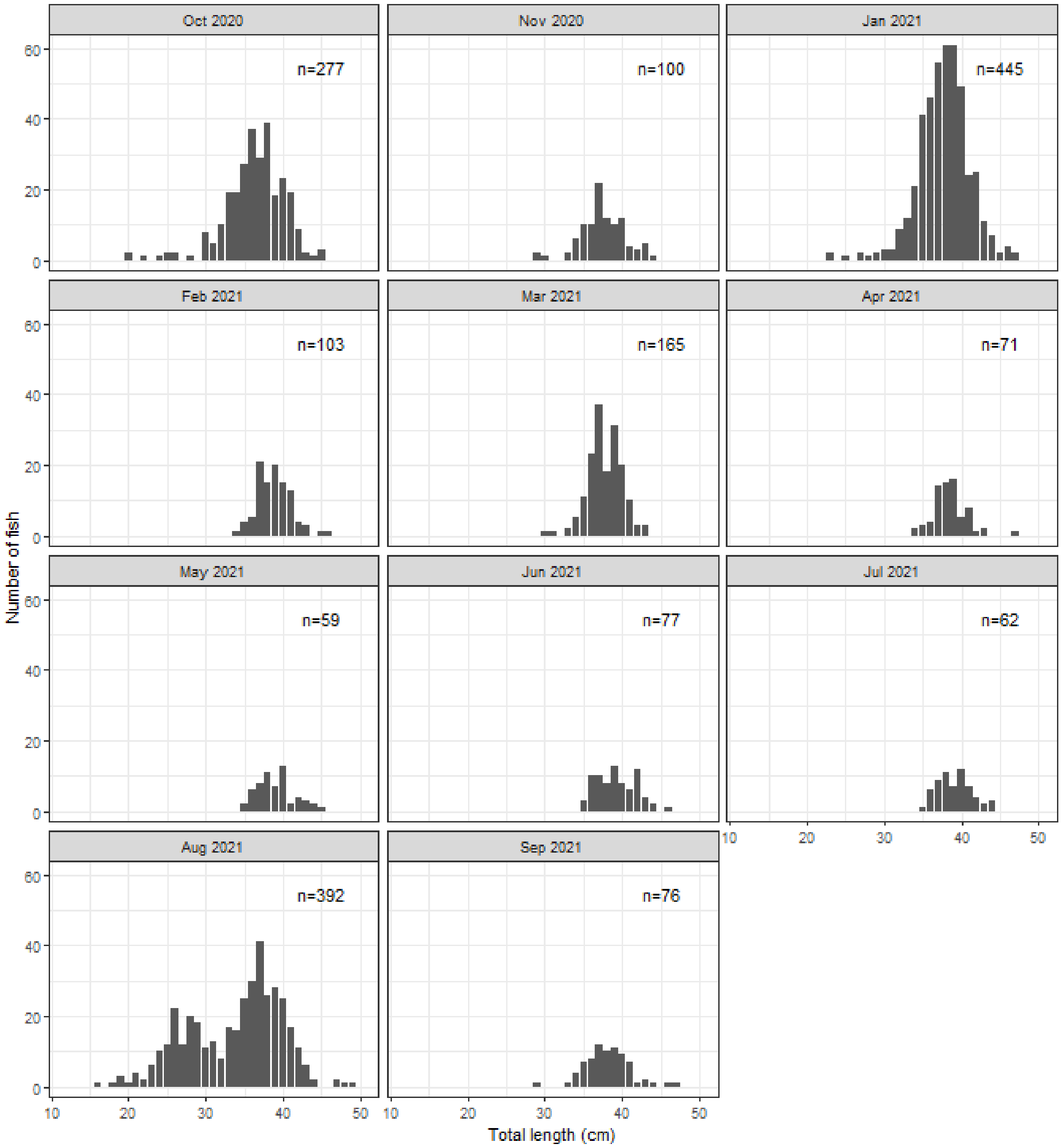

Figure A-1: Length frequency of red gurnard. Collected during experimental tows near the Offshore Disposal Area by vessel FV Chips from 29 Oct 2020 to 21 Sep 2021. All data shown are for tows using a steel cage codend. No data collected in December 2020.

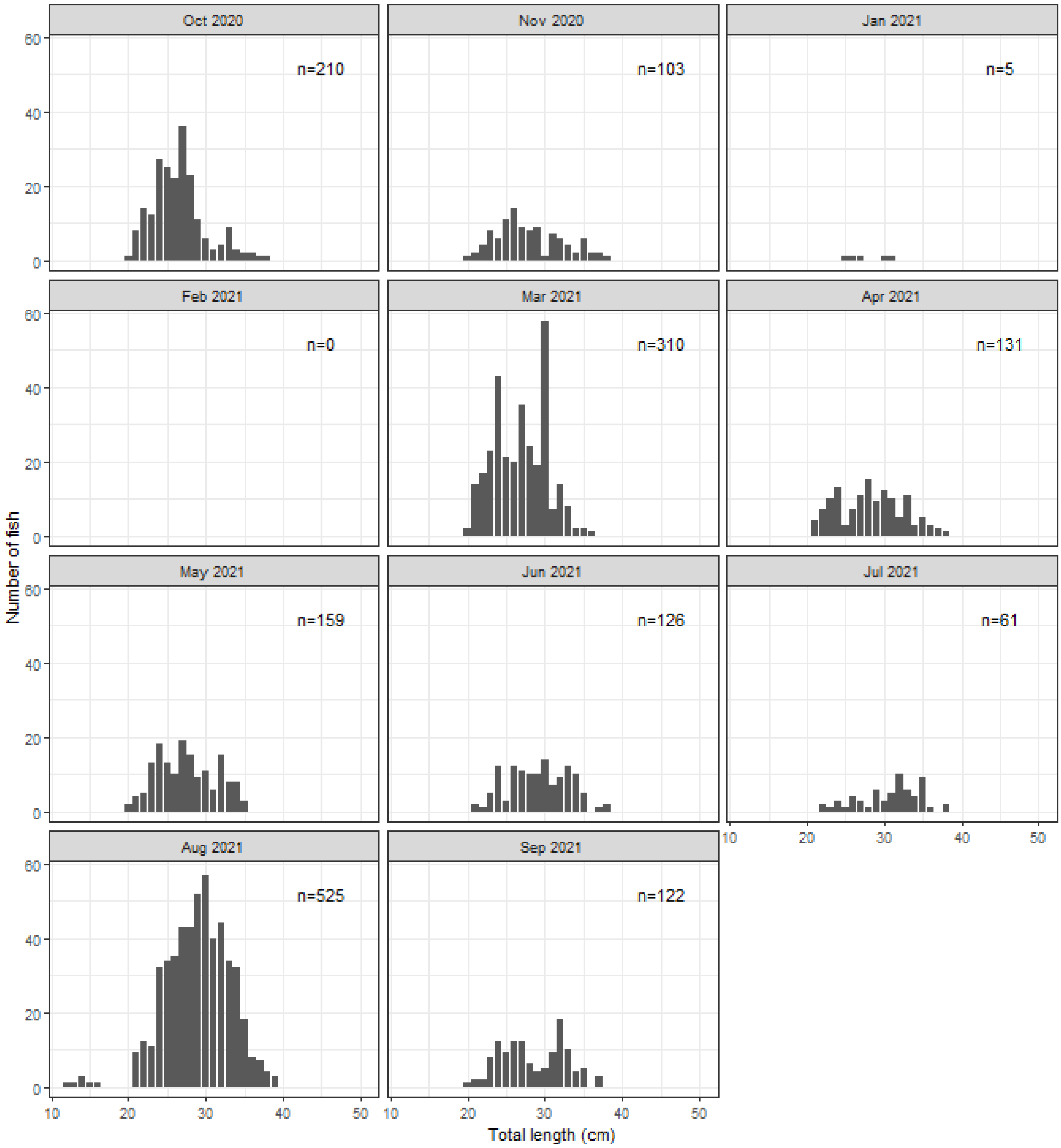

Figure A-2: Length frequency of English sole. Collected during experimental tows near the Offshore Disposal Area by vessel FV Chips from 29 Oct 2020 to 21 Sep 2021. All data shown are for tows using a steel cage codend. No data collected in December 2020.

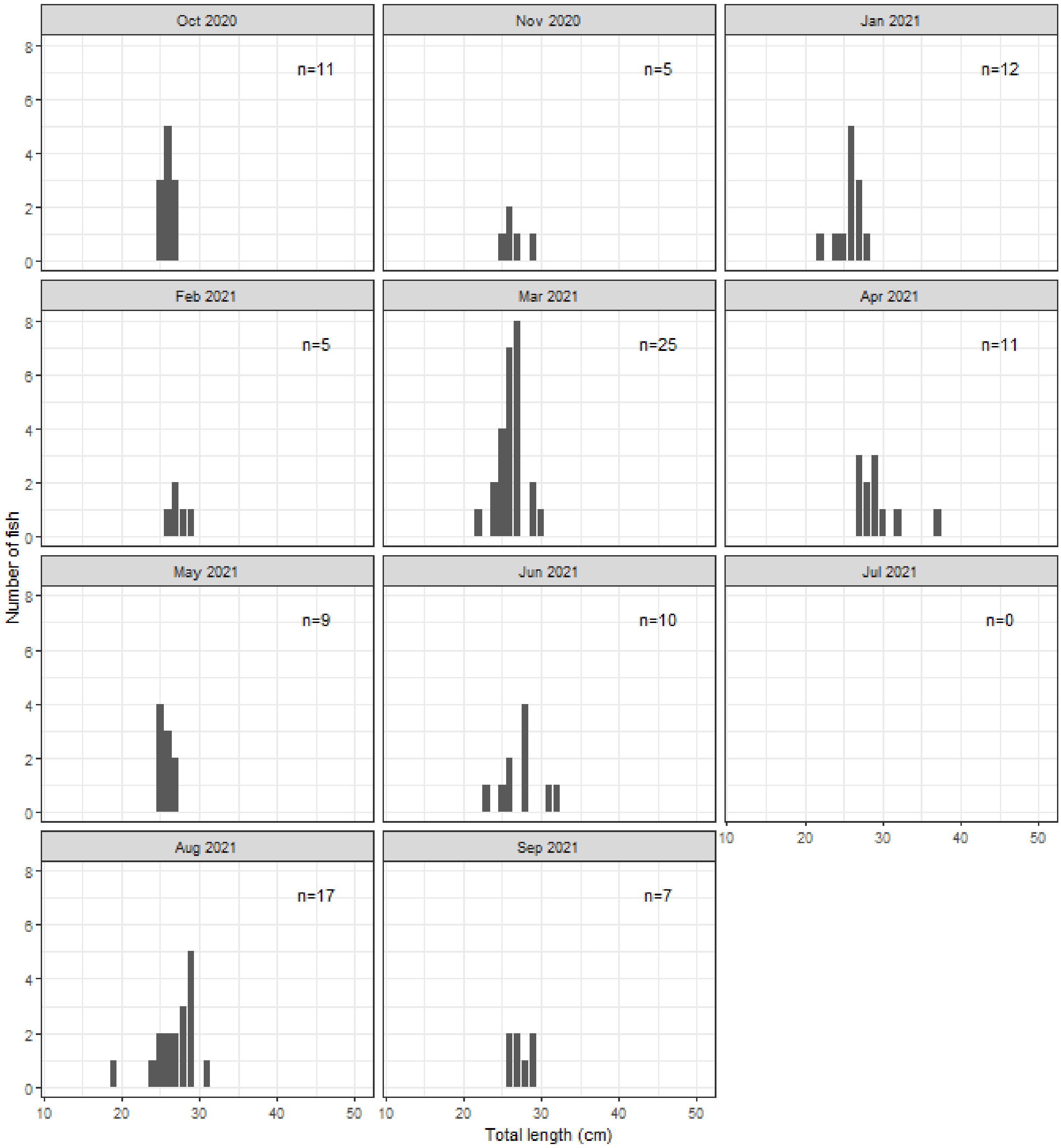

Figure A-3: Length frequency of lemon sole. Collected during experimental tows near the Offshore Disposal Area by vessel FV Chips from 29 Oct 2020 to 21 Sep 2021. All data shown are for tows using a steel cage codend. No data collected in December 2020.

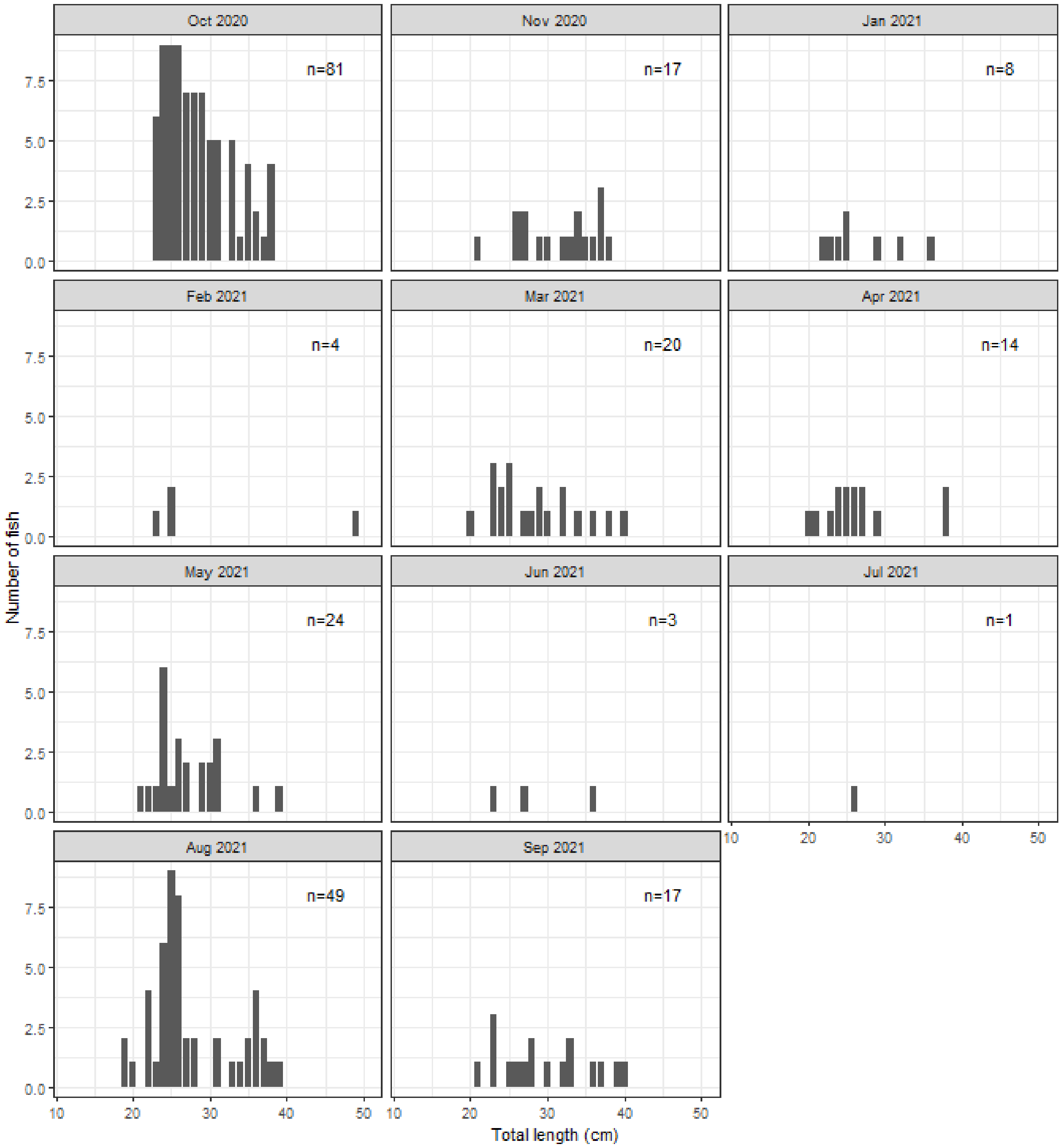

Figure A-4: Length frequency of sand flounder. Collected during experimental tows near the Offshore Disposal Area by vessel FV Chips from 29 Oct 2020 to 21 Sep 2021. All data shown are for tows using a steel cage codend. No data collected in December 2020.

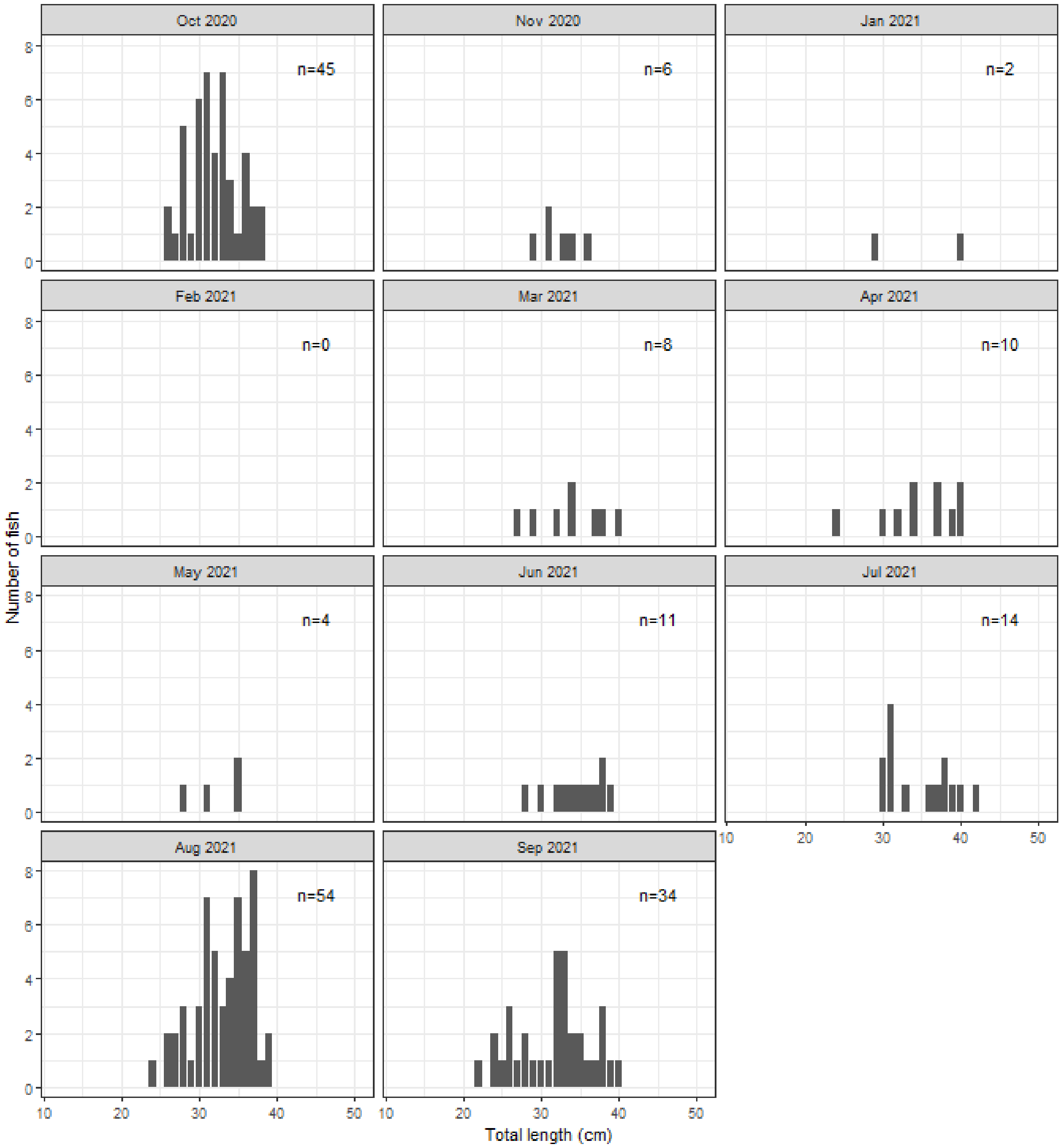

Figure A-5: Length frequency of yellow belly flounder. Collected during experimental tows near the Offshore Disposal Area by vessel FV Chips from 29 Oct 2020 to 21 Sep 2021. All data shown are for tows using a steel cage codend. No data collected in December 2020.

Appendix B Evaluation of input data and model diagnostics for red gurnard

Influence of predictor variables

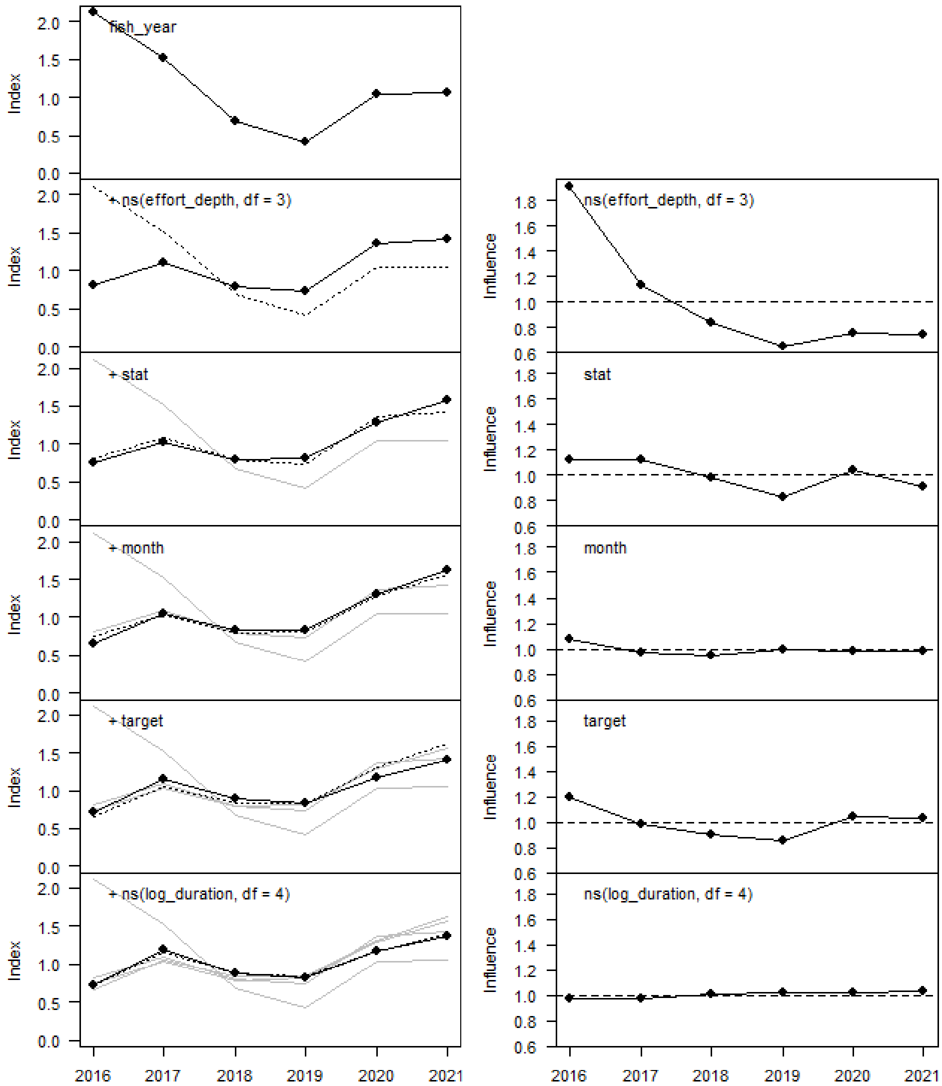

Figure B-1: Step and influence of each predictor on the year effect in the lognormal red gurnard model.

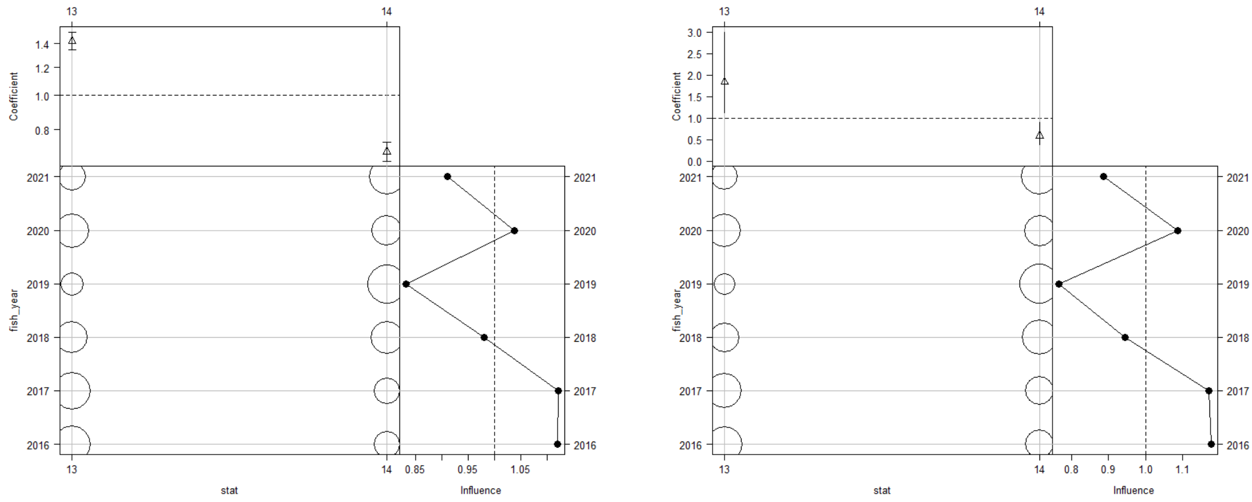

Figure B-2: Statistical area influence plot for the lognormal (left) and binomial (right) models for red gurnard. Top panel: the coefficient estimates for statistical area; bottom left panel: the number of records, with bubble size proportional to the number of records; right panel: the influence of the predictor on the year effect.

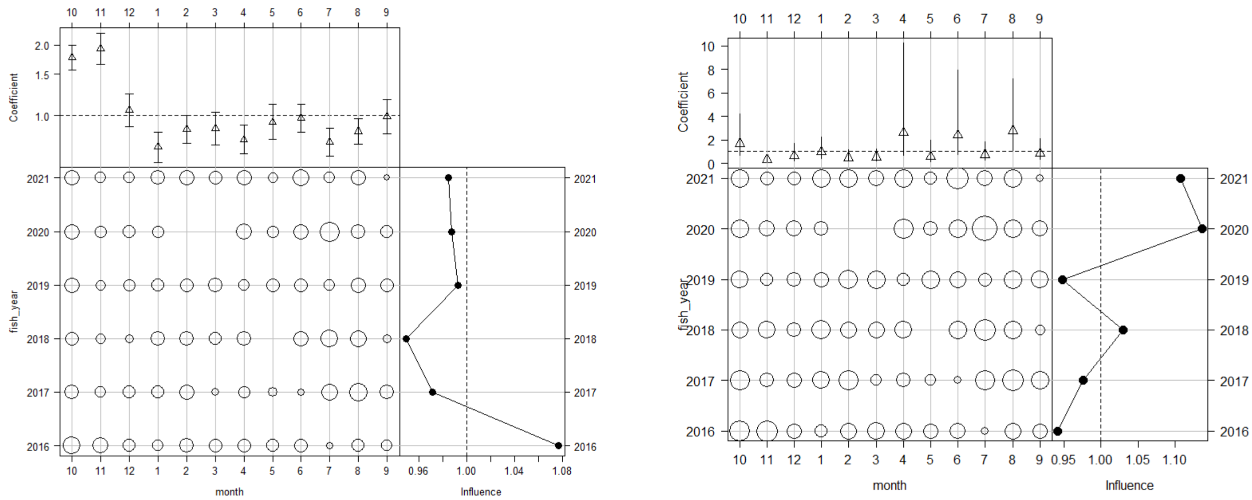

Figure B-3: Month influence plot for lognormal (left) and binomial (right) models for red gurnard. Top panel: the coefficient estimates for month; bottom left panel: the number of records, with bubble size proportional to the number of records; right panel: the influence of the predictor on the year effect.

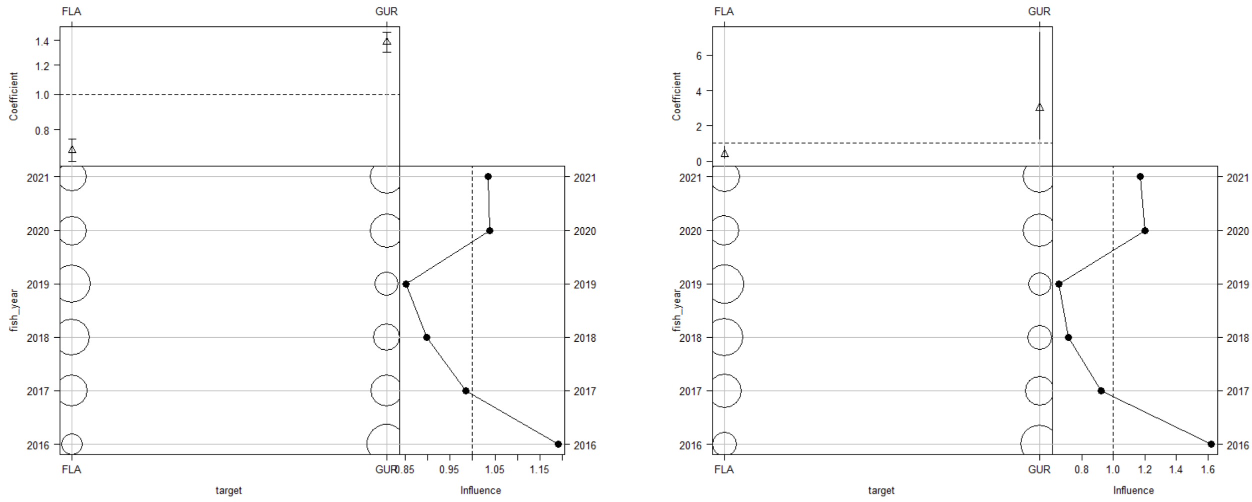

Figure B-4: Target species influence plot for the lognormal (left) and binomial (right) models for red gurnard. Top panel: the coefficient estimates for target species; bottom left panel: the number of records, with bubble size proportional to the number of records; right panel: the influence of the predictor on the year effect.

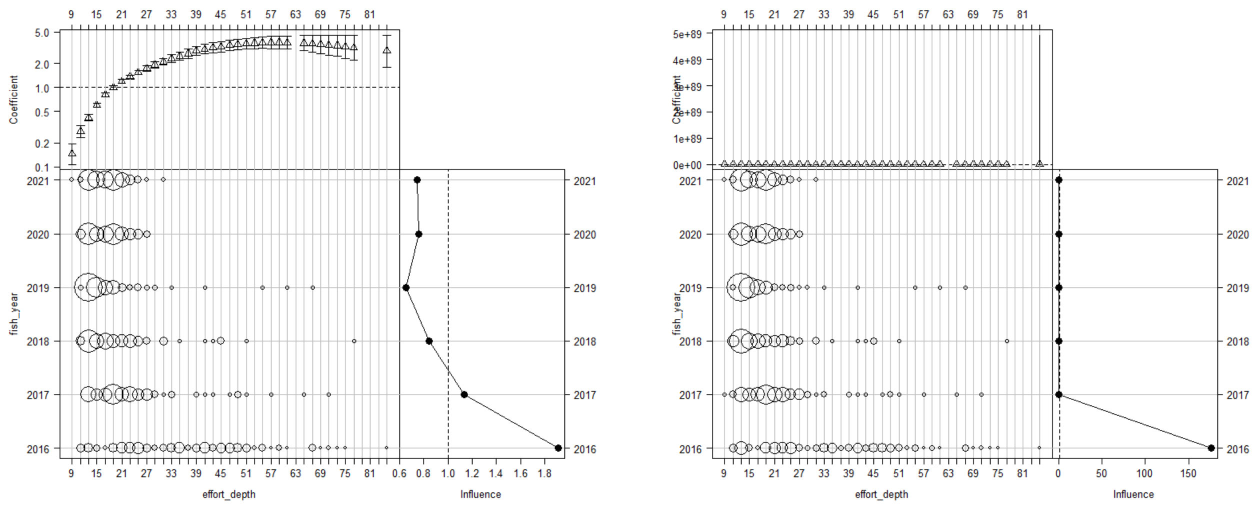

Figure B-5: Bottom depth influence plot for the lognormal (left) and binomial (right) models for red gurnard. Top panel: the coefficient estimates for bottom depth; bottom left panel: the number of records, with bubble size proportional to the number of records; right panel: the influence of the predictor on the year effect.

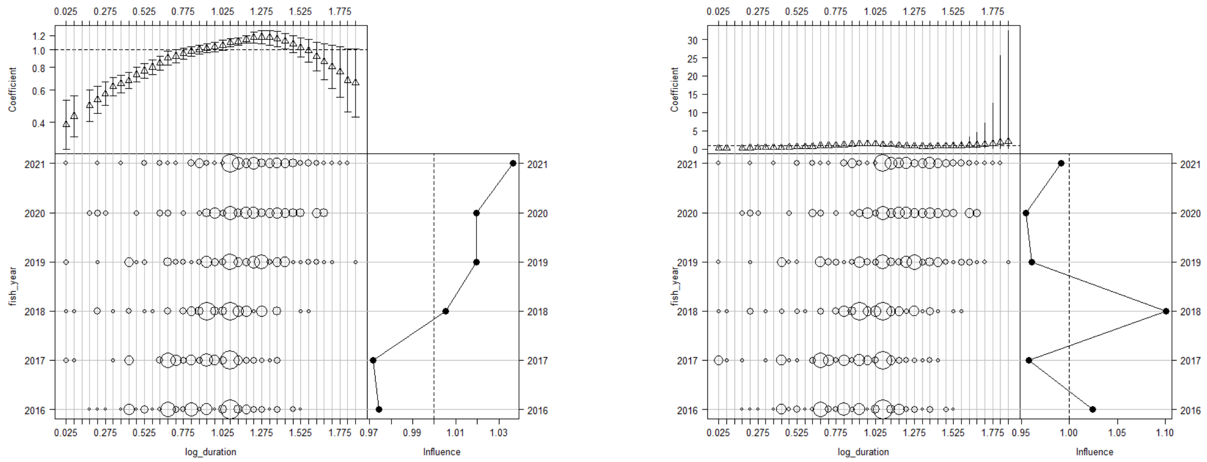

Figure B-6: Log duration influence plot for the lognormal (left) and binomial (right) models for red gurnard. Top panel: the coefficient estimates for log duration; bottom left panel: the number of records, with bubble size proportional to the number of records; right panel: the influence of the predictor on the year effect.

Model fit

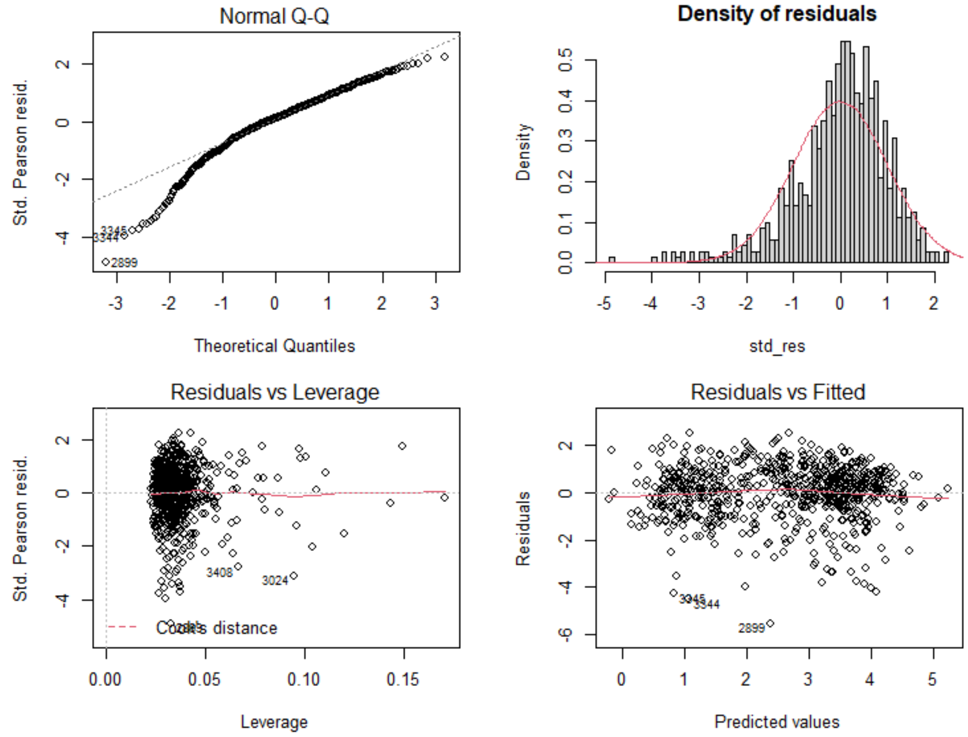

Figure B-7: Diagnostic plots for the overall fit of the lognormal model for red gurnard CPUE. Upper left panel: q-q plot of standardised residuals; upper right panel: histogram of standardised residuals compared to lognormal distribution (red line); lower left panel: residuals versus leverage plot; lower right panel: standardised residuals plotted against the predicted model catch.

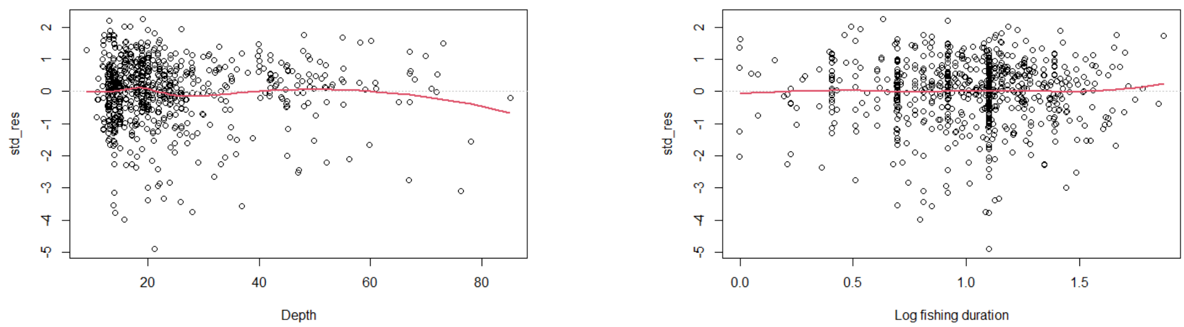

Figure B-8: Residuals in the continuous predictor variables, depth (left) and log duration (right), in the final lognormal model of red gurnard CPUE.

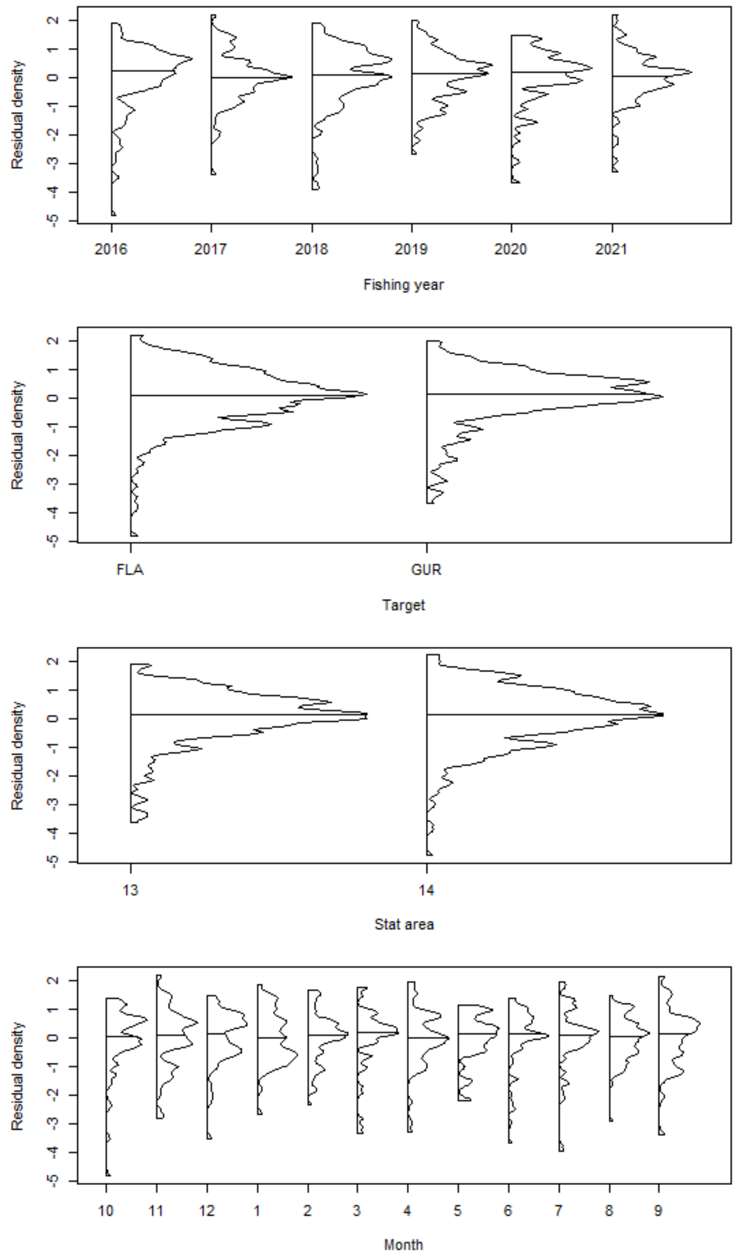

Figure B-9: Residuals in the categorical predictor variables, fishing year, target species, statistical area and month in the final lognormal model of red gurnard CPUE.

Tests for evidence of interaction between categorical predictors

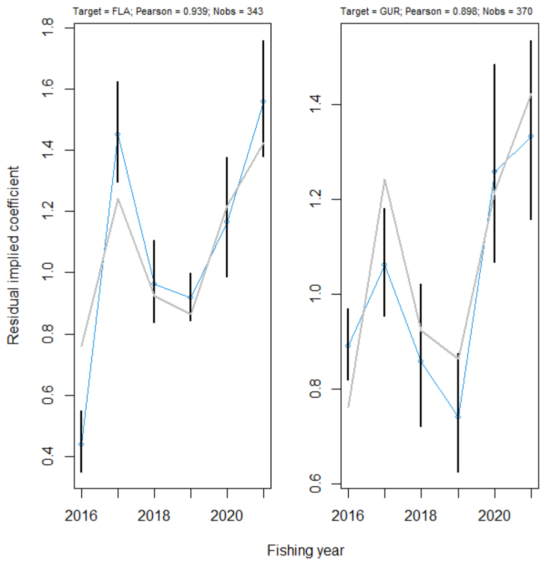

Figure B-10: Residual implied coefficients for fishing year – target species interaction (not offered) for the red gurnard CPUE index. Implied coefficients (points) are calculated as the normalised fishing year coefficient (grey line) plus the mean of the standardised residuals in each fishing year and target species. These values approximate the coefficients obtained when an interaction term is fitted. Error bars indicate one standard error of the standardised residuals. Pearson's rho is reported for the correlation between the year index and the overall model index.

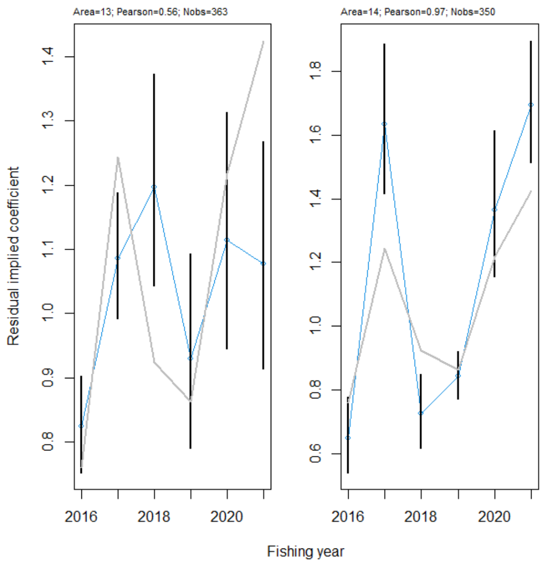

Figure B-11: Residual implied coefficients for fishing year – statistical area interaction (not offered) for the red gurnard CPUE index. Implied coefficients (points) are calculated as the normalised fishing year coefficient (grey line) plus the mean of the standardised residuals in each fishing year and area. These values approximate the coefficients obtained when an interaction term is fitted. Error bars indicate one standard error of the standardised residuals. Pearson's rho is reported for the correlation between the year index and the overall model index.

Appendix C Evaluation of input data and model diagnostics for flatfish

Influence of predictor variables

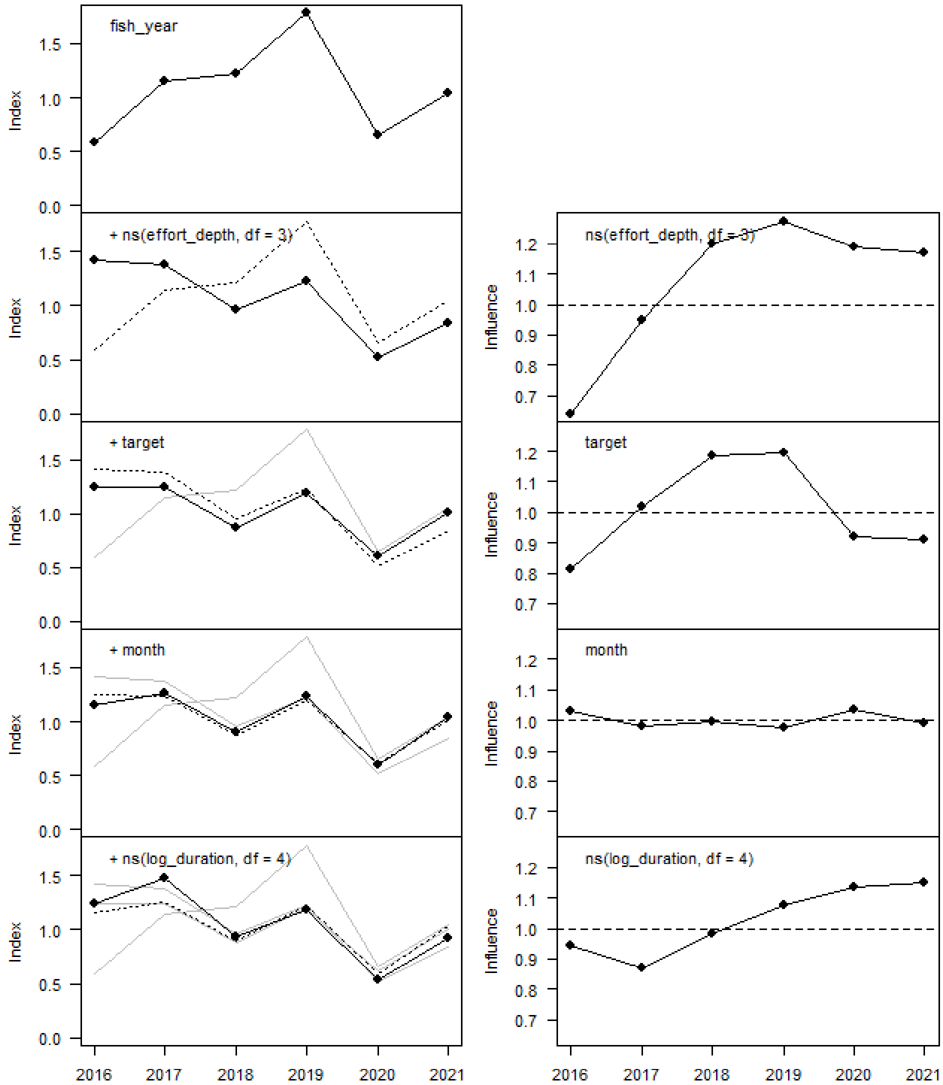

Figure C-1: Step and influence of each predictor on the year effect in the lognormal flatfish model.

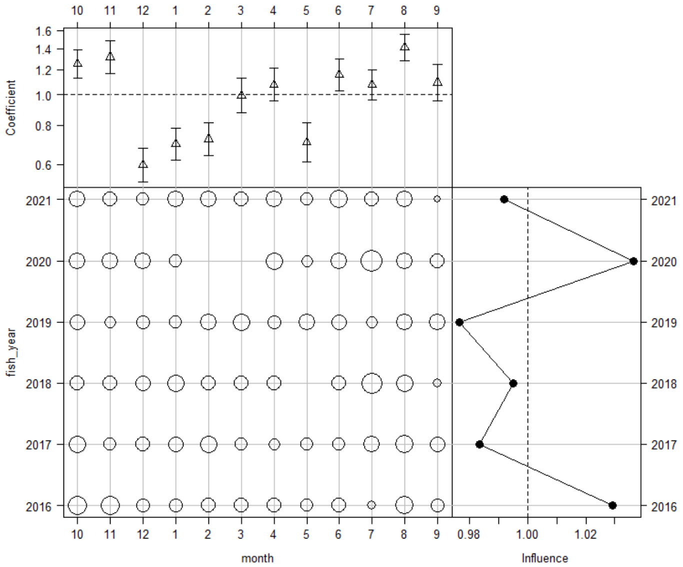

Figure C-2: Month influence plot for lognormal model for flatfish. Top panel: the coefficient estimates for month; bottom left panel: the number of records, with bubble size proportional to the number of records; right panel: the influence of the predictor on the year effect.

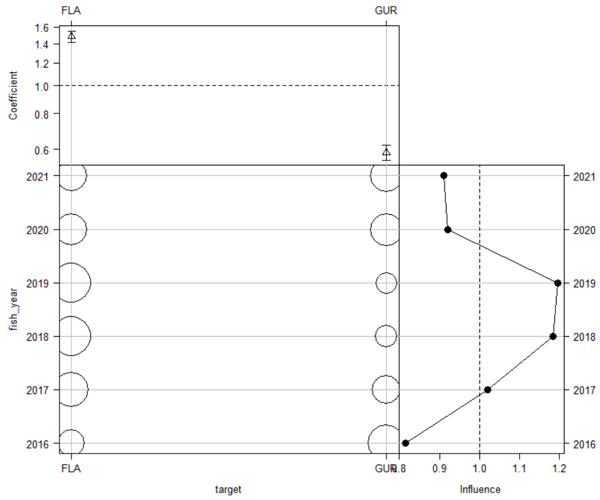

Figure C-3: Target species influence plot for the lognormal model for flatfish. Top panel: the coefficient estimates for target species; bottom left panel: the number of records, with bubble size proportional to the number of records; right panel: the influence of the predictor on the year effect.

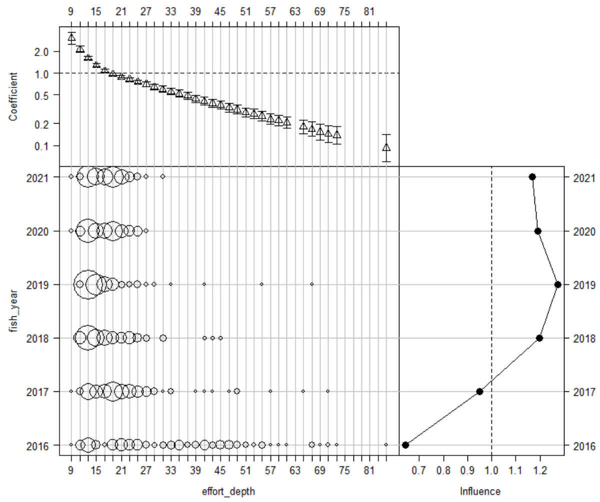

Figure C-4: Bottom depth influence plot for the lognormal model for flatfish. Top panel: the coefficient estimates for bottom depth; bottom left panel: the number of records, with bubble size proportional to the number of records; right panel: the influence of the predictor on the year effect.

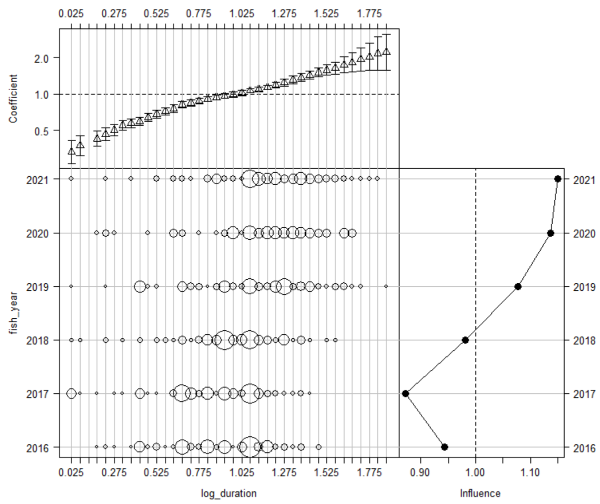

Figure C-5: Log duration influence plot for the lognormal model for flatfish. Top panel: the coefficient estimates for log duration; bottom left panel: the number of records, with bubble size proportional to the number of records; right panel: the influence of the predictor on the year effect.

Model fit

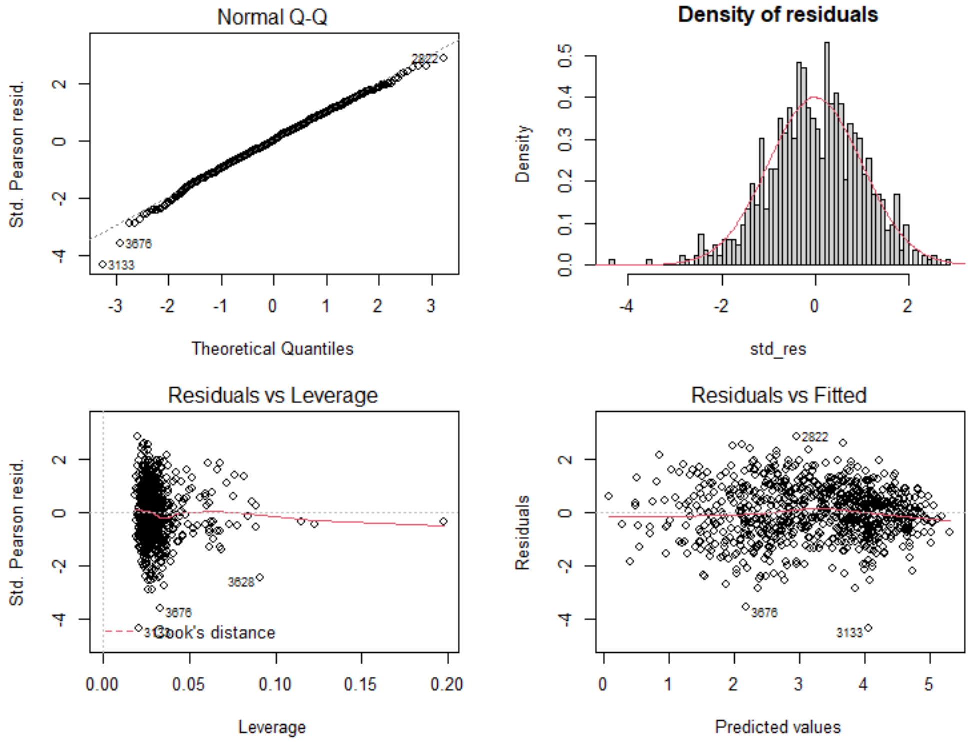

Figure C-6: Diagnostic plots for the overall fit of the lognormal model for flatfish CPUE. Upper left panel: q-q plot of standardised residuals; upper right panel: histogram of standardised residuals compared to lognormal distribution (red line); lower left panel: residuals versus leverage plot; lower right panel: standardised residuals plotted against the predicted model catch.

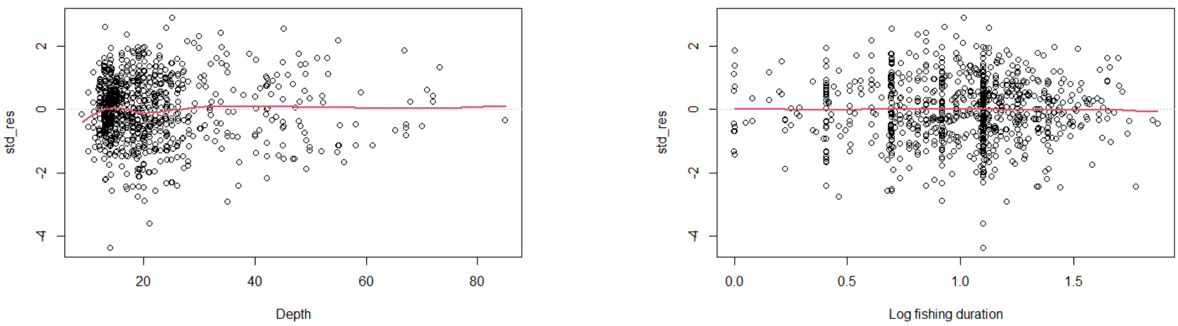

Figure C-7: Residuals in the continuous predictor variables, depth (left) and log duration (right), in the final lognormal model of flatfish CPUE.

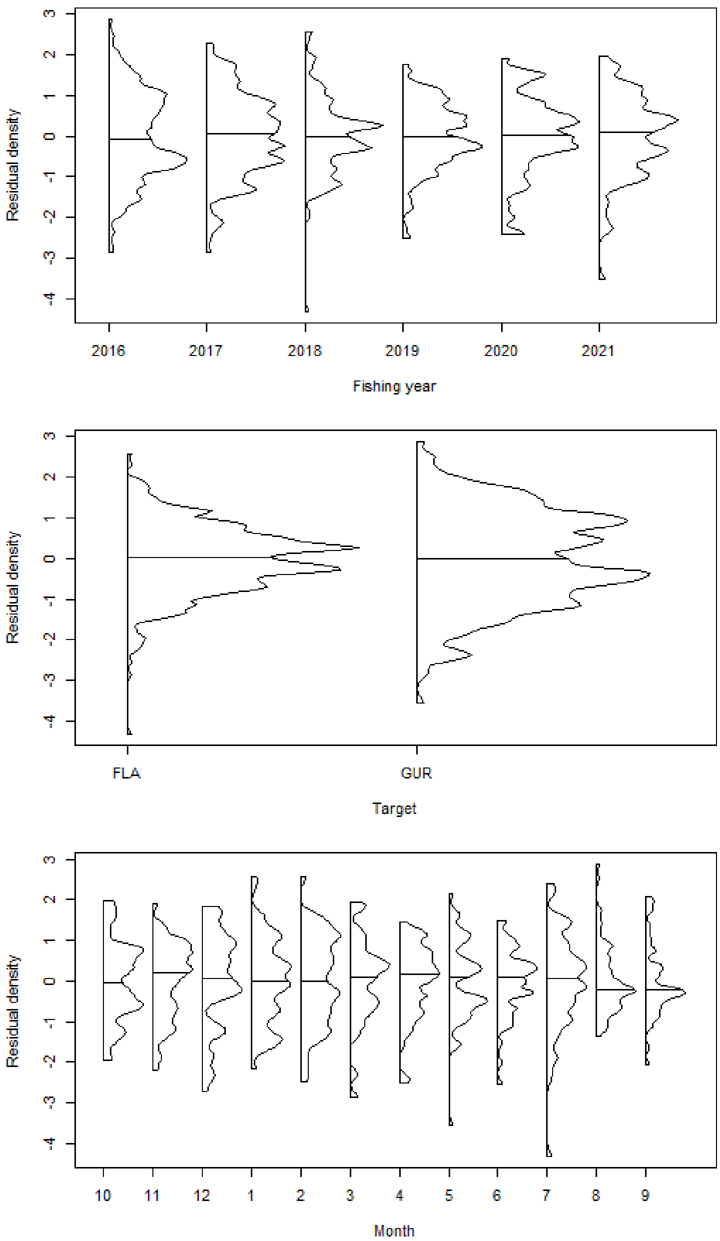

Figure C-8: Residuals in the categorical predictor variables, fishing year, target species and month in the final lognormal model of flatfish CPUE.

Tests for evidence of interaction between categorical predictors

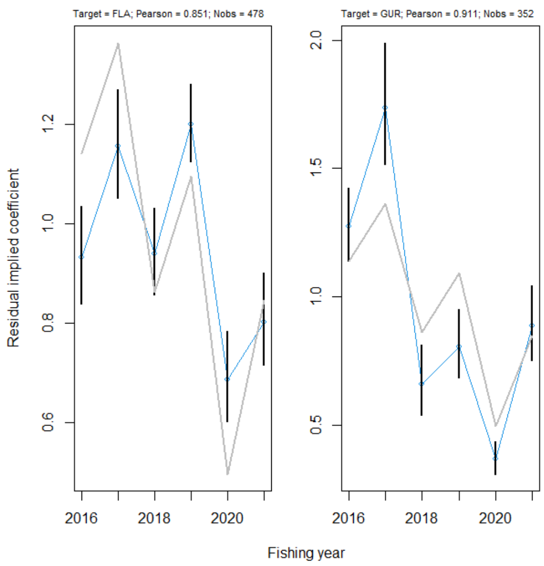

Figure C-9: Residual implied coefficients for fishing year – target species interaction (not offered) for the flatfish CPUE index. Implied coefficients (points) are calculated as the normalised fishing year coefficient (grey line) plus the mean of the standardised residuals in each fishing year and target species. These values approximate the coefficients obtained when an interaction term is fitted. Error bars indicate one standard error of the standardised residuals. Pearson's rho is reported for the correlation between the year index and the overall model index.

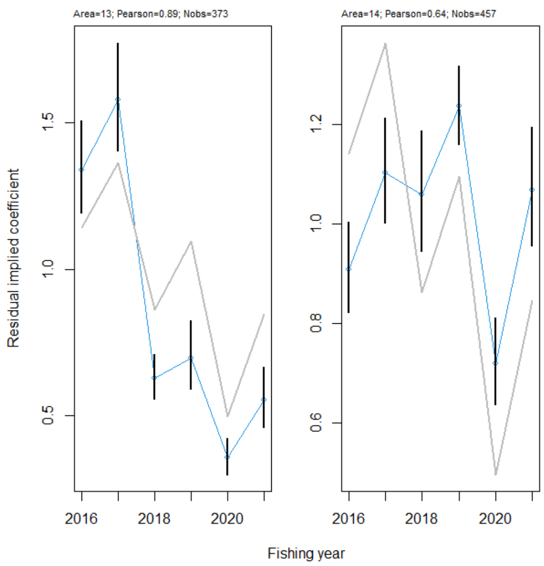

Figure C-10: Residual implied coefficients for fishing year – statistical area interaction (not offered) for the flatfish CPUE index. Implied coefficients (points) are calculated as the normalised fishing year coefficient (grey line) plus the mean of the standardised residuals in each fishing year and area. These values approximate the coefficients obtained when an interaction term is fitted. Error bars indicate one standard error of the standardised residuals. Pearson's rho is reported for the correlation between the year index and the overall model index.