Fisheries New Zealand

Tini a Tangaroa

Chatham Rise hake (*Merluccius australis*) 1989–90 to 2018–19: Descriptive analysis of the commercial catch effort data and standardised catch and effort analysis (CPUE)

New Zealand Fisheries Assessment Report 2020/...

V. L. McGregor

ISSN XXXX-XXXX(print)
ISBN XXXX-XXXX(online)

XX 2020

New Zealand Government

Requests for further copies should be directed to:

Publications Logistics Officer
Ministry for Primary Industries
PO Box 2526
WELLINGTON 6140

Email: brand@mpi.govt.nz
Telephone: 0800 00 83 33
Facsimile: 04-894 0300

This publication is also available on the Ministry for Primary Industries websites at:
http://www.mpi.govt.nz/news-and-resources/publications and
http://fs.fish.govt.nz (go to Document library/Research reports)

Field Code Changed

Field Code Changed

This report was produced using a LaTeX template developed by NIWA Ltd., which is available from the authors on request.

Contents

Field Code Changed
Field Code Changed
Field Code Changed
Field Code Changed
Field Code Changed
Field Code Changed
Field Code Changed
Field Code Changed
Field Code Changed
Field Code Changed
Field Code Changed
Field Code Changed
Field Code Changed
Field Code Changed
Field Code Changed
Field Code Changed

Field Code Changed

EXECUTIVESUMMARY

V. L. McGregor

Chatham Rise hake (*Merluccius australis*) 1989–90 to 2018–19: Descriptive analysis of the commercial catch effort data and standardised catch and effort analysis (CPUE) New Zealand Fisheries Assessment Report 2020/...

This report provides a descriptive analysis of the catch and effort data for hake on the Chatham Rise (HAK 4 and part of HAK 1) from 1989–1990 to 2018–2019 and standardised CPUE analyses for the Chatham Rise hake fishery for the same years. The method for reallocation of catches from the Chatham Rise to the west coast South Island was explored with respect to the current data. Updated catch history required for stock assessment is presented, including the method for obtaining it.

Catches in HAK 1 and HAK 4 have been well below TACC since 2005 and 1999 respectively. Chatham Rise catches were mostly from bottom trawl events that targeted hoki or hake. The spawning fishery was identified as statistical areas 018, 020 and 404 based on very high catches in these areas within spawning months September–February. These statistical areas were omitted from CPUE analyses to avoid hyper-stability dynamics.

Standardised CPUE indices were produced by fitting GLMs to merged daily processed data from the Chatham Rise fishery. Three final CPUE indices are presented: western Chatham Rise, eastern Chatham Rise, and whole-of Chatham Rise. These indices were very similar from 1995–2019 and all presented a general decline followed by an increase from around 2012. The earlier part of the western series had an increasing trend, whereas this was decreasing for the other two series. The eastern and whole-of Chatham Rise indices matched the *Tangaroa* trawl survey abundance index fairly well.

0.1. Web summary

A descriptive analysis of the catch and effort data for hake on the Chatham Rise (HAK 4 and part of HAK 1) and standardised CPUE analyses for the Chatham Rise hake fishery from 1989–1990 to

2018–2019 are presented. CPUE indices for eastern Chatham Rise and whole-of Chatham Rise showed decreasing trends until around 2012 after which there was an increasing trend. The western index gave an initial increasing trend.

1. Introduction

Hake are widely distributed through the middle depths of the New Zealand Exclusive Economic Zone
(EEZ) mostly south of latitude 40°S (Anderson et al., 1998). Adults are mainly distributed in depths from 250 to 800 m although some have been found as deep as 1200 m, while juveniles (age 0+) are found in shallower inshore regions under 250 m (Hurst et al., 2000). Hake have been taken almost exclusively by trawl, and predominantly by large demersal trawlers often as bycatch in fisheries targeting other species such as hoki and southern blue whiting, although target fisheries have also existed (Ballara, 2013, 2015, Devine, 2009).

Hake within the New Zealand Economic Exclusion Zone (EEZ) are managed as three separate Fishstocks: the Challenger Plateau and west coast of the South Island (HAK 7), the eastern Chatham Rise (HAK 4), and the remainder of the EEZ (HAK 1), which includes waters around the North Island, east coast of the South Island and Sub-Antarctic, but excludes the Kermadec area (Figure 1), (Fisheries New Zealand, 2020). The Chatham Rise fishery is considered to be all of HAK 4 and part of HAK 1 (Figure 1), (Ballara, 2018).

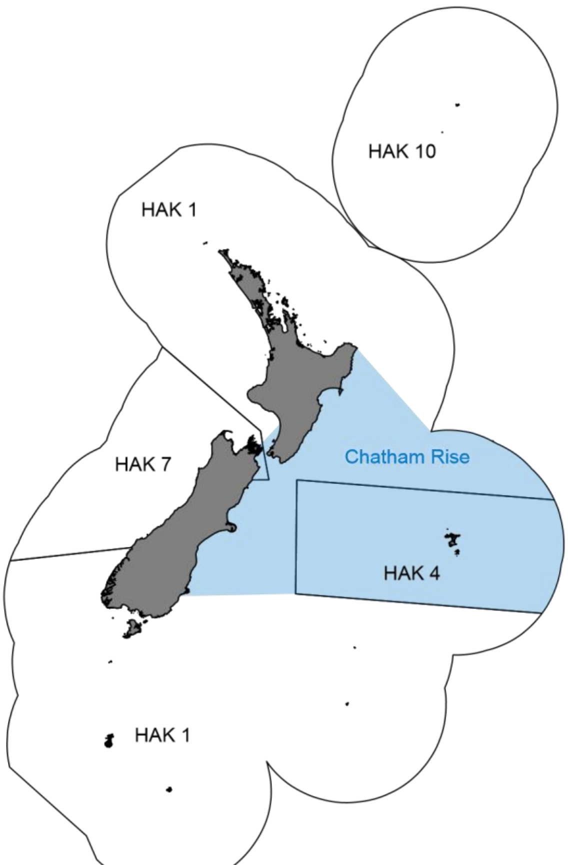


Figure 1: Quota Management Areas (QMAs) HAK 1, 4, 7 and 10, and the Chatham Rise biological stock boundary as defined in Ballara (2018) and used for the catch and effort analyses in this report.

In 2018–19, the TACCs for the QMAs were 2272 t in HAK 7, 1800 t in HAK 4, 3701 t in HAK 1 and a nominal 10 t in HAK 10 (Fisheries New Zealand, 2020). The TACC for HAK 4 was increased from 1000 t to 3500 t in the 1992 fishing year (fishing year defined as 1 October–30 S~~t~~eptember and labeled as the later year), after which time the catches increased until they came up against the TACC from 1990–1998. Catches in HAK 4 then declined, falling well below the TACC which was then lowered in 2005 to its current level of 1800 t. The TACC for HAK 1 underwent several small~~ish~~ increases from its level of 2610 t in 1990 through to its current level of 3701 t which was set in 2002. Catches in HAK 1 have been declining since 2009 and now sit at around a quarter of the TACC. Catches in HAK 7 were well below the TACC from 2008–2019, when the TACC was lowered to 2272 t (Fisheries New Zealand, 2020).

Dunn (2003) found that area misreporting between the WCSI and the Chatham Rise fisheries occurred from 1994–95 to 2000–01. He estimated that between 16 and 23% (700–1000 t annually) of WCSI landings were misreported as deriving from Chatham Rise, predominantly in June, July, and
September. Levels of misreporting before 1994–95 and after 2000–01, and between WCSI and the Sub-Antarctic, were estimated as negligible, and there has been no evidence of significant misreporting since (Ballara, 2013).

Fishing year for hake in New Zealand is defined as 1 October –31 September, except for the Chatham Rise fishery, for which it is defined 1 September –30 August due to the timing of spawning. Spawning occurs on the Chatham Rise September–January, and sometimes extending out to February. Spawning locations include statistical area 404 (north-west of the Chatham Islands) and Mernoo Bank (Colman 1998, Devine 2009, Figure 2).

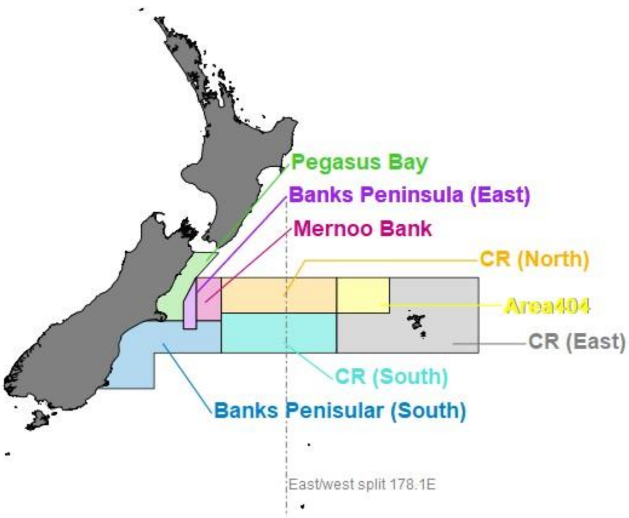


Figure 2: Chatham Rise fishery areas defined for previous Chatham Rise hake characterisations (Ballara, 2018).

The most recent hake Chatham Rise CPUE was developed using merged daily processed data from HAK 4 (Ballara, 2018), and hence did not include the western Chatham Rise. Earlier CPUE analyses for Chatham Rise hake have considered both the western and eastern Chatham Rise fisheries (e.g. Ballara 2013).

A review of the *Tangaroa* trawl survey series defined hake as 'very well estimated' in the core survey area (O'Driscoll et al., 2011). The relative abundance index and proportions-at-age from this trawl survey series are both used to inform the stock assessment (Horn, 2017, Horn and Francis, 2010). In comparing CPUE indices to the trawl survey abundance indices, Ballara (2013) found a good match for the eastern Chatham Rise fishery, but not the western Chatham Rise fishery.

Earlier reports that have included descriptive analyses of catch and effort for hake on the Chatham Rise are listed in Table 1.

Table 1: Recent previous Chatham Rise hake reports that included catch and effort descriptive analyses.

Report title	Reference
Descriptive analysis of the fishery for hake (*Merluccius australis*) in HAK 1, 4 and 7 from 1989–90 to 2014–15, and a catch-per-unit-effort (CPUE) analysis for Chatham Rise and WCSI hake	Ballara (2018)
Descriptive analysis of the fishery for hake (*Merluccius australis*) in HAK 1, 4 and 7 from 1989–90 to 2012–13, and a catch-per-unit-effort (CPUE) analysis for Sub-Antarctic hake	Ballara (2015)
Descriptive analysis of the fishery for hake (*Merluccius australis*) in HAK 1, 4 and 7 from 1989–90 to 2010–11, and a catch-per-unit-effort (CPUE) analysis for Chatham Rise and WCSI hake	Ballara (2013)
Descriptive analysis of the fishery for hake (*Merluccius australis*) in HAK 1, 4 and 7 from 1989–90 to 2009–10, and a catch-per-unit-effort (CPUE) analysis for Sub-Antarctic hake	Ballara (2012)
Catch-per-unit-effort (CPUE) analysis and descriptive analysis of the fishery for hake (*Merluccius australis*) in HAK 1, 4 and 7 from 1989–90 to 2008–09	Ballara and Horn (2011)
Catch-per-unit-effort (CPUE) analysis of hake (*Merluccius australis*) for HAK 1 and HAK 4 from 1989–90 to 2007–08	Devine (2010)
Descriptive analysis of the commercial catch and effort data for New Zealand hake (*Merluccius australis*) for the 1989–90 to 2005–06 fishing years	Devine (2009)
Catch and effort (CPUE) analysis of hake (*Merluccius australis*) for the Chatham Rise from 1989–90 to 2004–05	Dunn and Phillip (2006)

This document reports on Specific Objectives 1 and 2 from Project HAK2019-01: Stock assessment of hake in HAK4.

- Objective 1: To carry out a descriptive analysis of the commercial catch and effort data for hake on the Chatham Rise in preparation for the quantitative stock assessment.
- Objective 2: To complete a standardised catch and effort analyses from the Chatham Rise hake fisheries.

There are two additional components in this report not previously included in similar analyses for hake in New Zealand (Table 1)

1. The method for identifying and rescaling catches due to mis-reporting of fishstock ((Dunn, 2003)) was revisited. This method has been routinely applied to commercial catch and effort data for hake descriptive analyses since the work of Dunn (2003), but not reported on, and with no apparent checks on the appropriateness of the method when applied to more recent data.
2. The method for updating the catch history was clarified. The updated catch history has previously been reported as part of the stock assessment report (e.g. Horn (2017)), with little detail on the method applied to obtain the catches. In these reports, only catches for the additional year(s) were reported, with no comparison of the new catch history for overlapping years from previous assessments.

2. Data and grooming

Catch-effort, daily processed, and landed data were extracted from the FNZ Enterprise Data Warehouse (EDW) (extract 12649B) and consisted of all fishing and landing events associated with a set of fishing trips that reported a positive catch or landing of hoki, hake, or ling during fishing years 1989–90 to 2018–19. The extract included all fishing recorded on forms listed in Table 2, and included high seas versions of these forms. Catch and effort data for hake from the FNZ observer sampling programme (administered by NIWA in the *cod* database) were also extracted.

Table 2: Form types from FNZ Enterprise Data Warehouse (EDW) included in data extract 12649B.

Form code	Form description
ERS-trawl	Electronic Reporting System
TCEPR	Trawl Catch, Effort and Processing Returns
TCER	Trawl Catch Effort returns
CELR	Catch, Effort and Landing Returns
LCER	Lining Catch Effort Return
LTCER	Lining Trip Catch Effort Return
NCELR	Netting Catch Effort Landing Return

TCEPR and TCER forms record tow-by-tow data with the estimated catch (by weight) of the top five species (TCEPRs) or the top eight species (TCERs) in each individual tow. The new ERS-trawl form reports the top five QMS species and top three non-QMS species and consequently should produce data closely comparable to that from the TCEPR and TCER paper forms for deepwater vessels. CELR forms record estimated daily catches for the top five species, which are further stratified by statistical area, method of capture, and target species. Greenweight data associated with landing events are reported on the bottom part of the CELR forms, or on CLR forms for fishing reported on TCEPRs and TCERs. Information on total harvest levels are provided via the Quota Management Report/Monthly Harvest Return (QMR/MHR) system, but only at the resolution of Quota Management Area (Ballara and O'Driscoll, 2019).

The extracted data were groomed and restratified to derive the datasets required for these analyses using a variation of the data processing method developed by Starr (2007) as implemented by Manning et al. (2004), with refinements by Blackwell et al. (2006) and Manning (2007), and further modifications for this study following Ballara and O'Driscoll (2019).

Data from the whole EEZ were groomed for the purpose of defining the catch history and for applying the reallocation method of Dunn (2003). The Chatham Rise data were then selected based on the boundary shown in Figure 1 for the purpose of the descriptive analysis of the catch and effort data and CPUE.

2.1. Reallocation of misreported catches

The reallocation of misreported catches from the Chatham Rise fishery to the WCSI (west coast South Island) fishery followed the method presented in Dunn (2003). The method identifies fishing trips that may have mis-reported catch from WCSI as catch from the Chatham Rise, then compares catch rates from the potentially mis-reported catches to those that have not mis-reported to detemine which ones to reallocate. The comparison of catch rates is done by fitting a mixed-effects generalised linear model (Equation 1) to data from fishing trips that did not misreport. The resulting model is then used to predict catch rates for the events that may have mis-reported. If the observed catches fall outside a defined confidence interval, the difference between the observed catch and the predicted catch is reallocated from being a Chatham Rise catch to be being a WCSI catch. The method only applies to catches recorded on TCEPR forms. Once the reallocation has been applied at the fishing event level, the adjustments are then applied to the landings by QMA (quota management area).

log(catch) year + poly(net depth, 3) + poly(vessel length, 3) + target + method/(poly(gear width, 3)+ poly(headline height,3)) + statistical area/month

(1)

where catch is tonnes/tow year, target, method,
statistical area were categorical year was defined as
fishing year, i.e. October–September
Note: / indicates a nested term

The current analysis produced slight differences in the updated reallocation from the Chatham Rise to WCSI at the QMA level, which were expected due to evolving grooming algorithms applied prior to applying the reallocation method, as well as some assumptions around the reallocation method that were not apparent from the documentation presented in Dunn (2003). Initially, for the purpose of comparison, the current analysis adopted the fishing year definition used in Dunn (2003) of 1 October–30 September. I compared the reallocation at the QMA level using cut-off=0.90 (Figure 3). The only version presented in Dunn (2003) at the QMA level was that with cut-off=0.90, although this was not the final proposed version from the report. The cut-off value determines the confidence interval applied to residuals for trips that may have mis-reported, with 0.9 reallocating catch rates outside the 90% confidence interval, assuming residuals to be normally distribution with μ= 0 and σ= 1. Note, while the reallocation method has been re-applied for every hake stock assessment carried out since Dunn (2003), there is no mention of the resulting values ever being compared with those presented in Dunn (2003).

At the Chatham Rise fishery level, there remained small differences between the resulting catch histories presented in Dunn (2003) and those updated here. The final proposed version of reallocation in Dunn (2003) used p=0.99. The closest match using the updated analysis appears to be using a cut-off of p=0.975 on the current data (Figure 4).

3. Catch history

The catch history for Chatham Rise hake was updated, and in doing so, I compared the entire series with the catch history presented for previous Chatham Rise stock assessments (Horn, 2013, 2017), and found slight differences. The previous catch histories match each other exactly for overlapping years

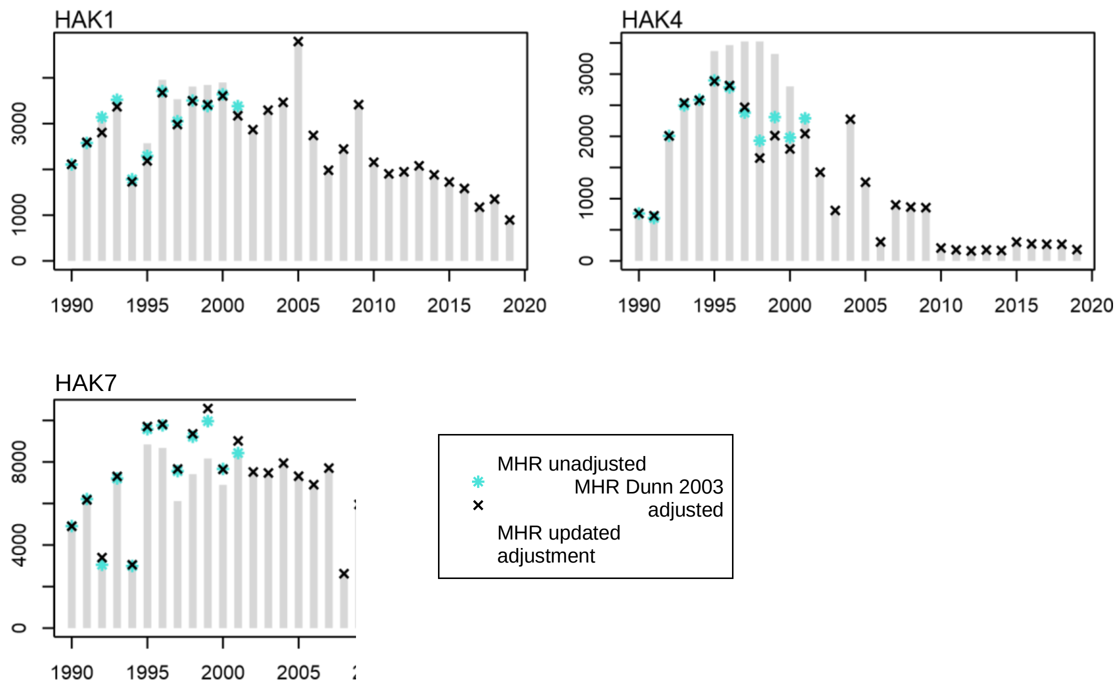


Figure 3: Comparison of reallocation method at QMA level using p=0.90. Grey bars = MHR unadjusted landings; blue asterisks = MHR adjusted for reallocation (Dunn, 2003); black crosses = MHR adjusted for reallocation (current analysis).

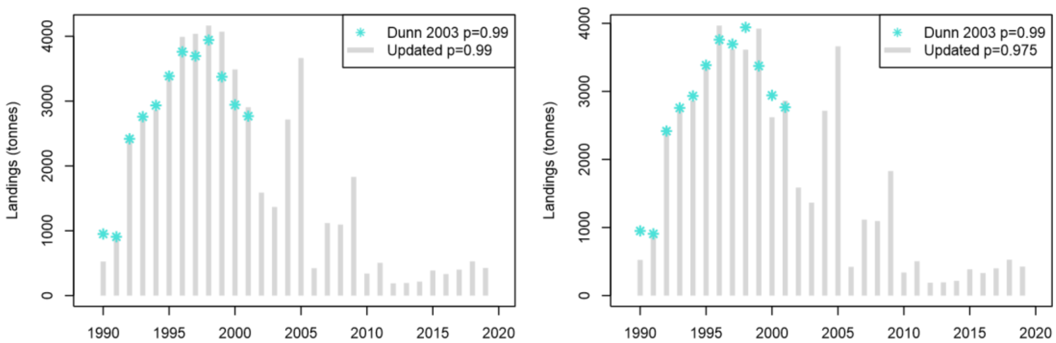


Figure 4: Comparison of catch history by fishing year October–September for the Chatham Rise area (Figure 1) using p=0.99 (left, grey bars) and p=0.75 (right, grey bars). Dunn 2003 p=0.99 (blues asterisks) was the final adjusted catch history presented in Dunn 2003.

as only the additional years were updated. In addition to differences resulting from the reallocation method, there were also differences due to the spatial definition of the 'Chatham Rise fishery' and the split between eastern and western Chatham Rise stocks.

The Chatham Rise fishery has been defined as in Figure 1 and this matches that used in Dunn (2003). The previous stock assessments (Horn, 2013, 2017) defined the Chatham Rise fishery as a subset of the entire Chatham Rise stock, and with an eastern-western split at 178.1^o longitude (Figure 5). The Chatham Rise catch history presented in Dunn (2003) can be assumed to have used the Chatham Rise fishery as in Figure 1, but it is not clear which definition of the Chatham Rise fishery was used for the catch history presented in Horn (2017) and used in the stock assessment. Further, previous CPUE analyses (e.g. Ballara (2018)) have split the eastern Chatham Rise to match the HAK 4 boundary (which can be seen in Figure 1), suggesting the eastern/western split has not always been assumed to be at 178.1^o longitude.

In the absence of a documented area definition for the catch history, a process of~~I found through~~ trial and error revealed a combination of area definition and eastern/western split that produced a catch history that matched those presented for stock assessments previously to the best extent possible.

1. The entire Chatham Rise fishery (in Figure 1) was used to apportion the MHR landings (with reallocation applied) to the Chatham Rise hake fishery. This step produced total Chatham Rise landings that are very similar to the previously defined landings (Figure 6, top left).

2. The east-west split was produced by selecting data from within the boundary in Figure 5 with a longitude split at 178.1^o.

3. The catch from step 1 was split between the eastern and western fisheries using the proportions of east and west catches from step 2. This assigned all of the Chatham Rise fishery landings of step 1 to either the eastern or western Chatham Rise fishery.

It appears a different eastern-western split may have been used for 2009–2016 fishing years, given that ~~as while~~ the totals for the Chatham Rise catch history of Horn (2017) matched those for these years but~~,~~ the ratio did not (Figure 6 top left and bottom right).

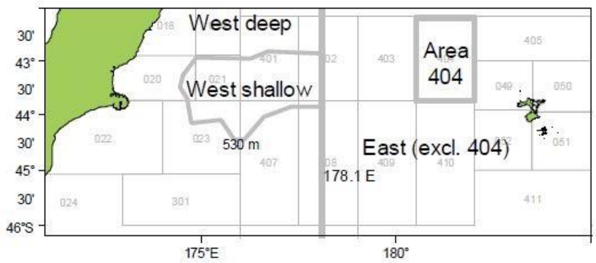


Figure 5: Chatham Rise fishery boundary from Horn (2017).

The resulting updated catch history provided to the stock assessment model (Table 3) used the previously reported catch history (Horn, 2013) for fishing years 1990–2008, and the updated catch history for fishing years 2009–2019. The catch history for fishing years 2009–2016 was updated rather than using the previously reported catches of Horn (2017) because of the difference in ratio between eastern and western Chatham Rise stocks for these fishing years which suggested a different eastern/western split compared to the rest of the catch history series.

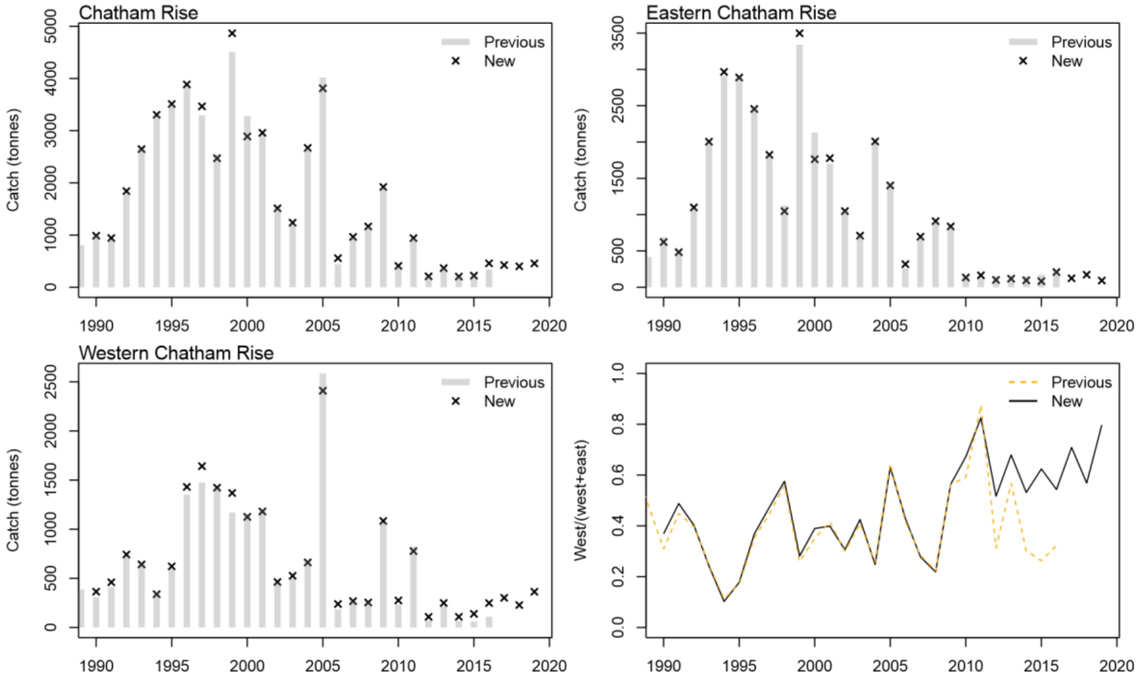


Figure 6: Previous landings from Horn (2017) (grey bars) and new catch history with reallocation p=0.975 (black crosses) for the Chatham Rise fishery (top left), eastern Chatham Rise fishery (top right) and western Chatham Rise fishery (bottom left). Ratio of western
Chatham Rise landings to total Chatham Rise landings from the previous stock assessment (Horn, 2017) (orange dashed line) and the new catch history (black solid line) (bottom right)
.

Table 3: Updated Chatham Rise hake catch history (tonnes) for fishing years 1990–2019, with catches in fishing years 2009–2019 updated, and catches in fishing years 1990–2008 taken from the previous stock assessments (Horn, 2013, 2017). Fishing year defined as September–August.

Fishing year	Western	Eastern	Total
1990	309	689	998
1991	409	503	912
1992	718	1087	1805
1993	656	1996	2652
1994	368	2912	3280
1995	597	2903	3500
1996	1353	2483	3836
1997	1475	1820	3295
1998	1424	1124	2548
1999	1169	3339	4508
2000	1155	2130	3285
2001	1208	1700	2908
2002	454	1058	1512
2003	497	718	1215
2004	687	1983	2670
2005	2585	1434	4019
2006	184	255	439
2007	270	683	953
2008	259	901	1160
2009	1084	838	1922
2010	275	134	409
2011	777	165	942
2012	108	101	209
2013	249	117	366
2014	109	96	205
2015	139	83	222
2016	249	209	458
2017	302	124	426
2018	228	173	401
2019	364	93	457

4. Descriptive analysis

4.1. Catches by QMA

Estimated catches, reported landings, and TACC by stock from fishing years 1990–2019 are shown in Table 4, where fishing year is 1 October–30 September. Catches have been below TACC since fishing year 2007 in HAK 7, 1999 in HAK 4, and 2005 in HAK 1, and have remained well below TACC in subsequent years.

Table 4: Estimated hake catches, reported landings from QMR records, and TACC (all in tonnes, and rounded to the nearest tonne) for fishing years 1990–2019, where fishing year runs from 1 October–30 September and is labeled by the later calendar year. Estimated catches were scaled to QMR or MHR catch totals and adjusted for misreporting.

	Estimated catch			Reported catch			TACC		
Year	HAK1	HAK4	HAK7	HAK1	HAK4	HAK7	HAK1	HAK4	HAK7
1990	2 114	763	4 912	2 115	763	4 903	2 610	1 000	3 310

1991	2 594	718	6 151	2 603	743	6 148	2 610	1 000	3 310
1992	2 798	2 013	3 392	3 156	2 013	3 027	3 500	3 500	6 770
1993	3 387	2 546	7 371	3 525	2 546	7 154	3 501	3 500	6 835
1994	1 768	2 587	2 979	1 803	2 587	2 974	3 501	3 500	6 835
1995	2 401	3 014	10 325	2 572	3 369	8 841	3 632	3 500	6 835
1996	3 740	3 090	9 490	3 956	3 466	8 678	3 632	3 500	6 835
1997	3 170	3 049	6 774	3 534	3 524	6 118	3 632	3 500	6 835
1998	3 737	3 307	7 821	3 809	3 523	7 416	3 632	3 500	6 835
1999	3 681	3 031	8 897	3 845	3 324	8 165	3 632	3 500	6 835
2000	3 831	2 792	6 954	3 899	2 803	6 898	3 632	3 500	6 835
2001	3 391	2 297	8 420	3 429	2 321	8 360	3 632	3 500	6 835
2002	2 870	1 424	7 519	2 870	1 424	7 519	3 701	3 500	6 835
2003	3 310	811	7 452	3 336	811	7 433	3 701	3 500	6 835
2004	3 466	2 275	7 945	3 466	2 275	7 945	3 701	3 500	6 835
2005	4 795	1 264	7 317	4 795	1 264	7 317	3 701	1 800	6 835
2006	2 743	305	6 906	2 743	305	6 906	3 701	1 800	7 700
2007	2 025	900	7 668	2 025	900	7 668	3 701	1 800	7 700
2008	2 445	865	2 620	2 445	865	2 620	3 701	1 800	7 700
2009	3 415	856	5 954	3 415	856	5 954	3 701	1 800	7 700
2010	2 156	208	2 352	2 156	208	2 352	3 701	1 800	7 700
2011	1 904	179	3 754	1 904	179	3 754	3 701	1 800	7 700
2012	1 948	161	4 459	1 948	161	4 459	3 701	1 800	7 700
2013	2 079	177	5 434	2 079	177	5 434	3 701	1 800	7 700
2014	1 883	168	3 642	1 883	168	3 642	3 701	1 800	7 700
2015	1 725	304	6 219	1 725	304	6 219	3 701	1 800	7 700
2016	1 584	274	2 864	1 584	274	2 864	3 701	1 800	7 700
2017	1 175	268	4 701	1 175	268	4 701	3 701	1 800	7 700
2018	1 350	267	3 086	1 350	267	3 086	3 701	1 800	5 064
2019	896	183	1 563	896	183	1 563	3 701	1 800	2 272

4.2. Chatham Rise fishery

Catches from the Chatham Rise fishery were primarily recorded on TCEPR forms, which since 2018 have been replaced by ERS forms (Figure 7). When catches have been high, they have generally occurred during the months September–January (Figure 8), which corresponds with the hake spawning season. In some years, such as 2007–2009, this period has extended out to February. Catches were mostly caught using bottom trawl (BT) (Figure 9), and when targeting hoki or hake, with a small amount from ling target (Figure 10). The spatial distribution of effort by target shows that when hake have been caught on the eastern Chatham Rise, such as near the Chatham Islands or the known spawning ground of statistical area 404, the target has tended to be hake or ling. Hoki target has tended to be further west on the Chatham Rise (Figure 11). Catches by statistical area in five-year blocks showed more of the catches were from the western Chatham Rise from 2010 onwards than prior, and in particular the spawning ground statistical area 404 has had lower catches from 2010 onwards (Figure 12).

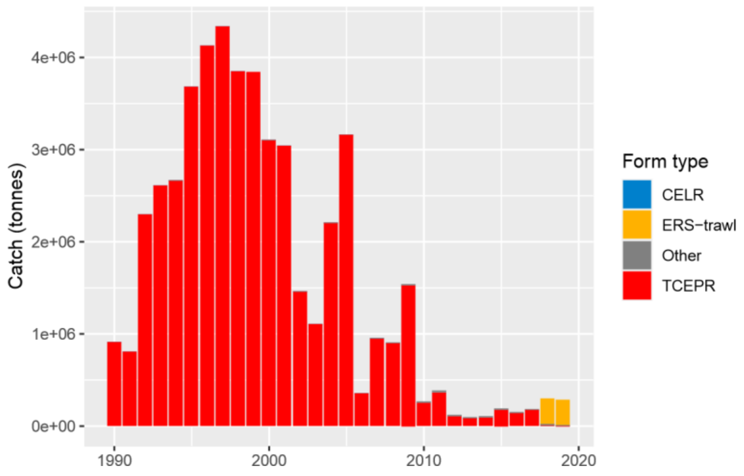


Figure 7: Catches from Chatham Rise by form type. Form types are defined in Table 2.

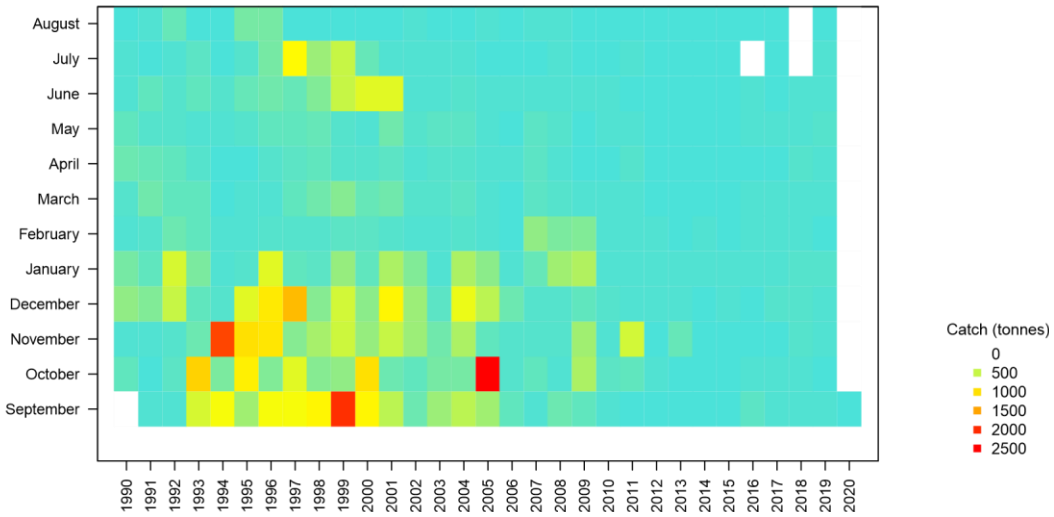


Figure 8: Catches from Chatham Rise by month.

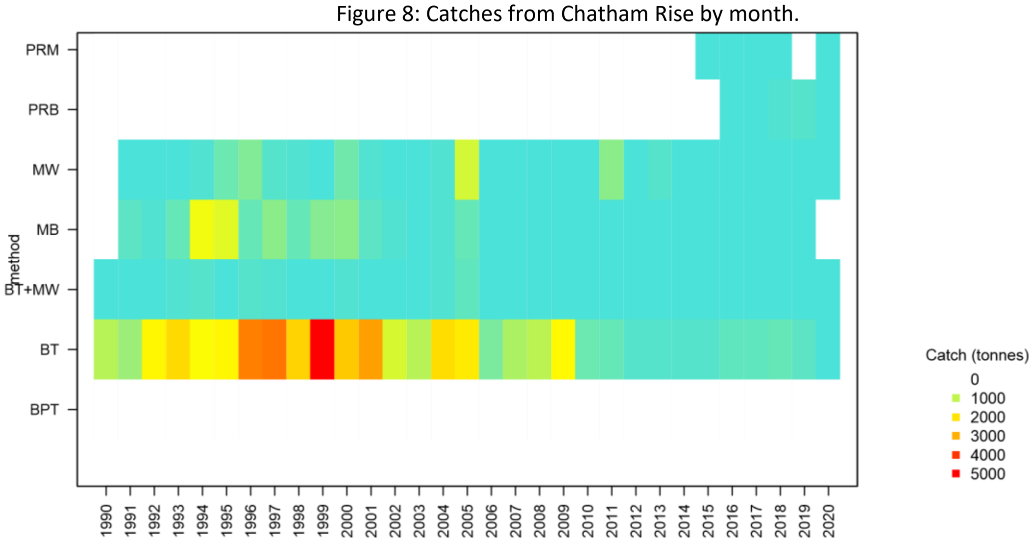


Figure 9: Catches from Chatham Rise by fishing method. BPT=bottom trawl - pair; BT=bottom trawl; MW=midwater; MB=mid-bottom trawl; PRB=precision bottom trawl; PRM=precision midwater trawl.

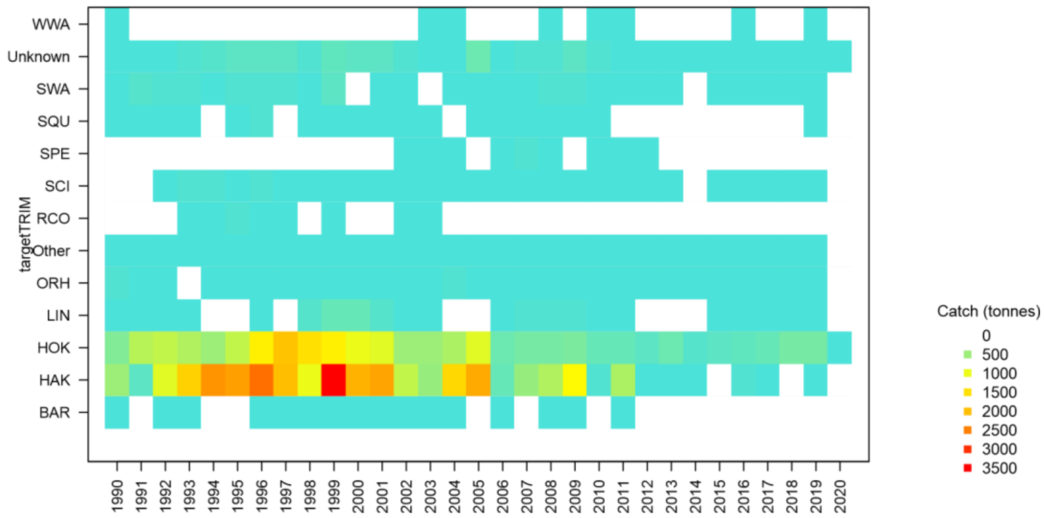


Figure 10: Catches from Chatham Rise by target species.

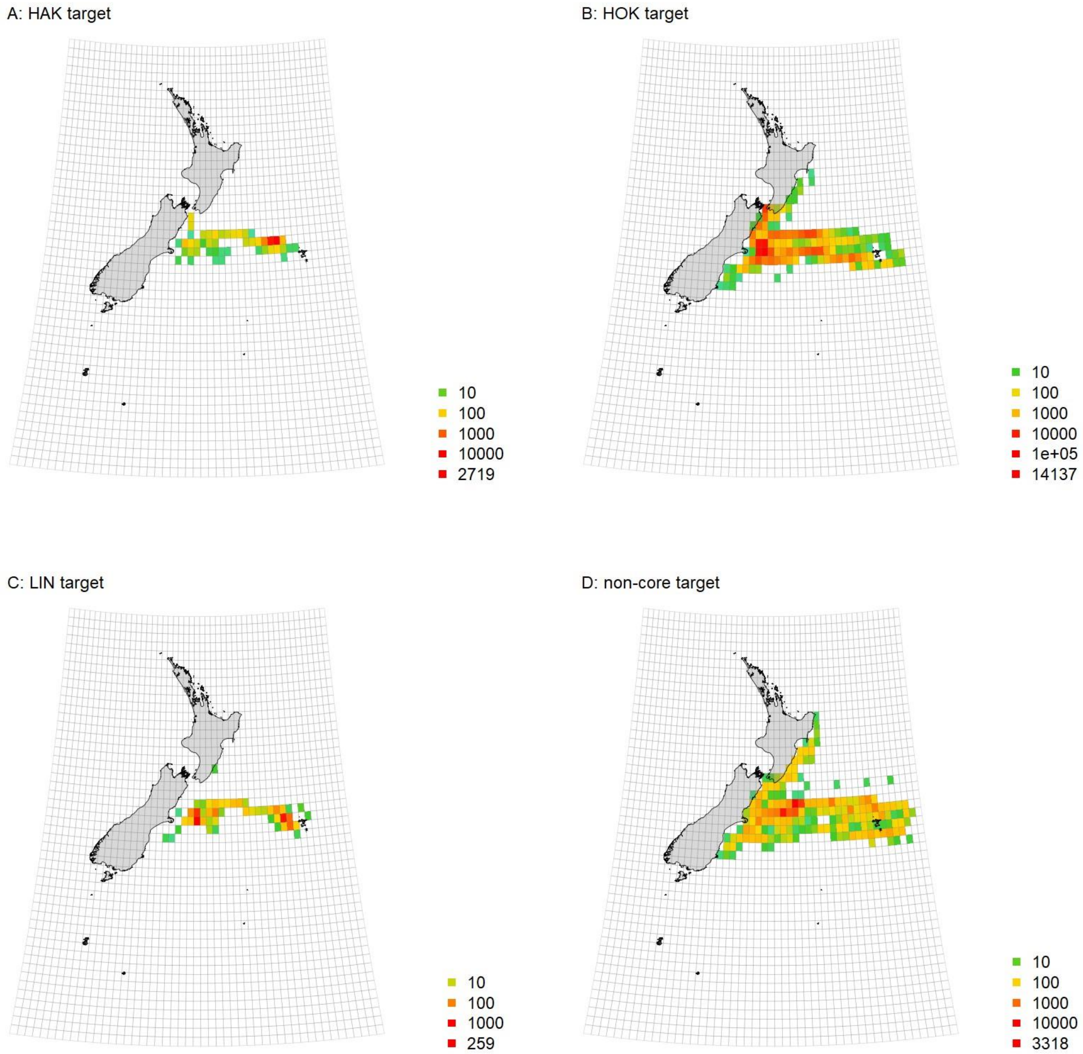


Figure 11: Effort (number of tows) from Chatham Rise fishing years 1990–2019 merged daily processed data where hake were the predominant target species (top left), hoki were the predominant target species (top right), ling were the predominant target species (bottom left) or the target species was not predominantly hake, hoki or ling (bottom right).

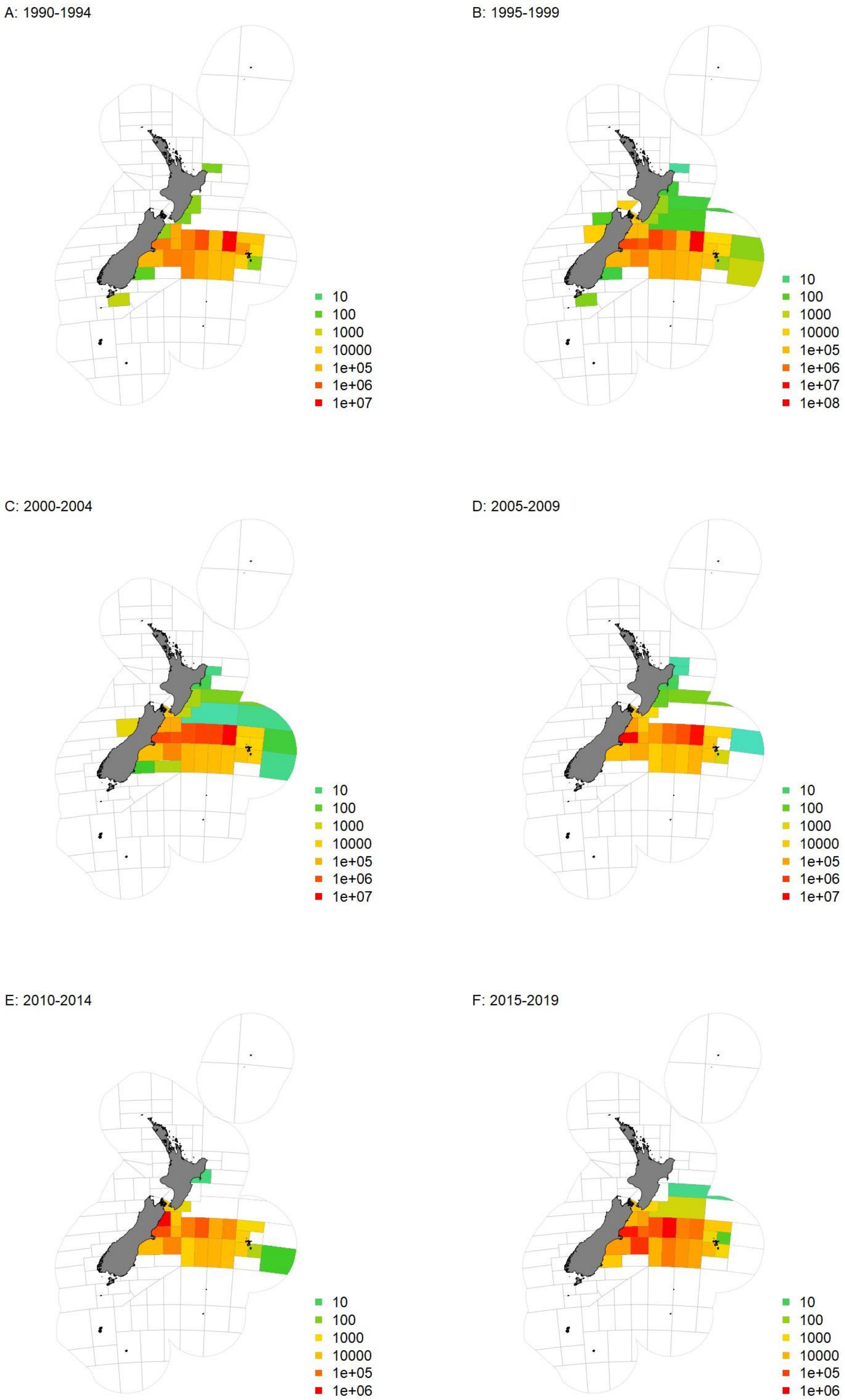

A: 1990-1994
10
100
1000
10000
1e+05
1e+06
1e+07
B: 1995-1999
10
100
1000
10000
1e+05
1e+06
1e+07
1e+08
C: 2000-2004
10
100
1000
10000
1e+05
1e+06
1e+07
D: 2005-2009
10
100
1000
10000
1e+05
1e+06
1e+07
E: 2010-2014
10
100
1000
10000
1e+05
1e+06
F: 2015-2019
10
100
1000
10000
1e+05
1e+06

Figure 12: Catches (kg) from merged daily processed data by statistical area for fishing years (A) 1990–1994; (B) 1995–1999; (C) 2000–2004; (D) 2005–2009; (E) 2010–2014; (F) 2015–2019.

4.3. Identifying the spawning fishery

Catches on spawning fisheries can retain higher catch rates that may not reflect abundance of the stock
(Erisman et al., 2011), and hence should be omitted from CPUE analysis. ~~I explored~~ R~~r~~atios of catches from spawning months (considered here to be September–February) to catches from non-spawning months by statistical area were explored to highlight spawning grounds within the fishery based on high catches. Statistical areas 018, 020 and 404 stood out as having much higher catches during spawning months than ~~in these areas~~ during non-spawning months, or from the other statistical areas during any months (Figure 13). Statistical area 018 had large spikes in catches in 2011 and 2013, statistical area 020 had large spikes in catches in 2005 and 2009, and catches were consistently high in statistical area 404 up until 2010. Hence, catches from statistical areas 018, 020 and 404 were removed from the dataset for the non-spawning fishery for which CPUE models were developed.

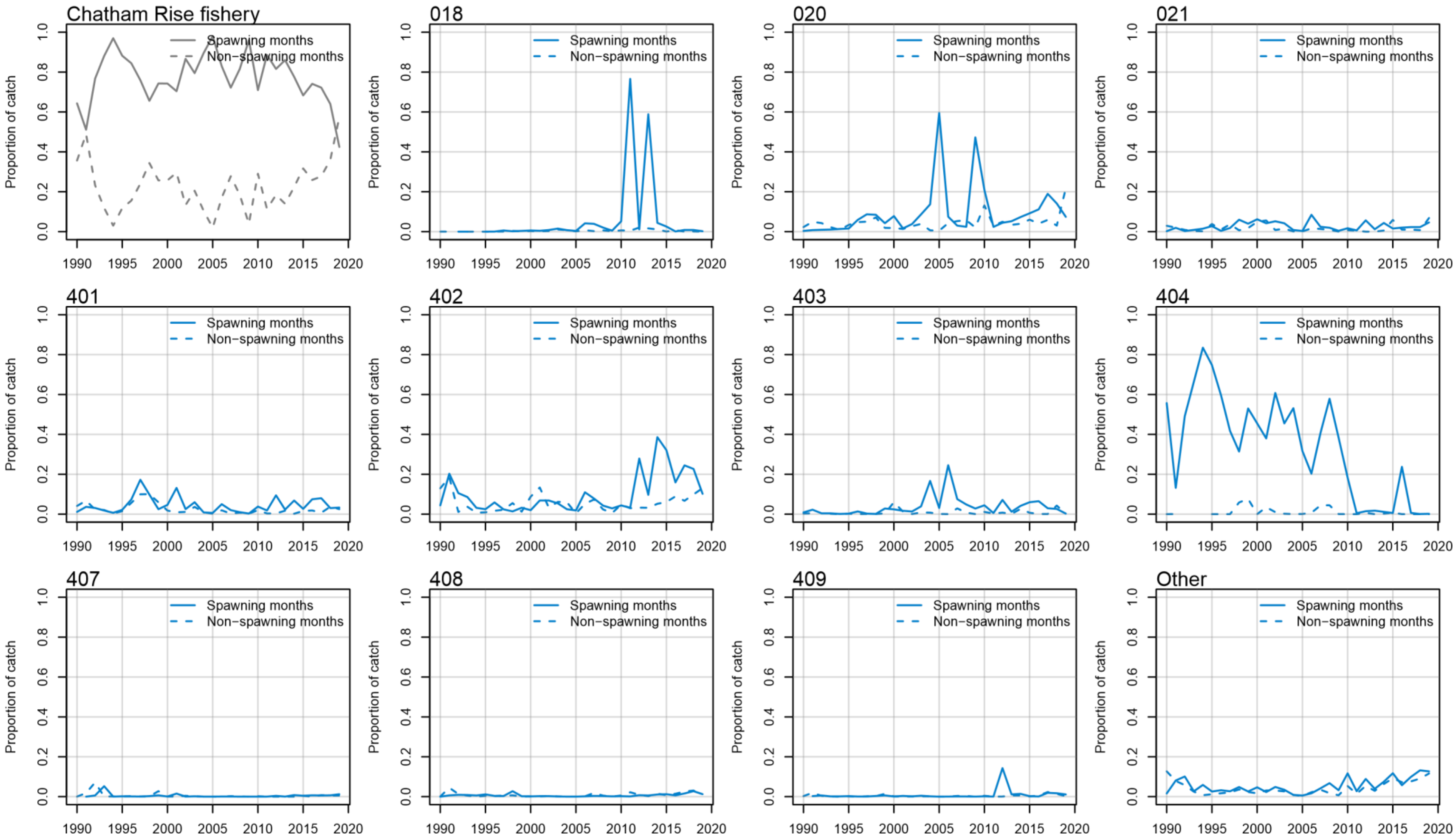


Figure 13: Proportion of Chatham Rise catch taken during spawning months and nonspawning months, by fishing year (top left, grey lines), and for each statistical area, by

fishing year (blue lines). Fishing year defined as 1 September–31 August; spawning months defined as September–February (solid lines) and non-spawning months March–August (dashed lines).

5. CPUE

CPUE models were fitted to daily processed catch and effort data from the non-spawning fishery using GLMs (generalised linear models) with both lognormal and delta-lognormal models explored. Fishing year was forced as a categorical explanatory variable. Additional explanatory variables were selected using a step-wise selection process, with each iteration selecting the variable that explained the largest amount of deviance (r^2), until a lower threshold of 1% in the additional explained deviance was reached. The CPUE analyses were implemented in the R statistical programming language (R Core Team, 2020).

Explanatory variables offered to CPUE models are in Table 5. There were six variables that were offered to the CPUE model in the previous analyses (Ballara, 2018) that were not offered here: *distance* as correlated with duration~~, and~~ was replaced because recording of duration was considered more reliable; *vessel.experience* was not thought to be reliable so was replaced by fishing fleet, or alternatively vessel.key. ~~as vessel.experience was not thought to be reliable~~; *longitude* and *latitude* ~~as they~~ are confounded~~,~~ so statistical area or sub area were preferred; *date* and *fishing.day* were replaced as season or *fishing.month* were thought to provide a sufficiently fine temporal scale for these data. Interaction terms were explored, in particular spatial:temporal interactions such as month and subarea.

Formatt

Commen
Vidette.

Fishing fleets were defined using the classifications of Ballara and O'Driscoll (2019) and are as follows:

- BATM: All Ukranian/Russian crewed vessels (regardless of ownership) are referred to as BATMs, which is the specific class of large factory trawler with a meal plant on board.
- FOV: All Korean/Japanese vessels are combined under the term FOV which is defined as all foreign owned vessels excluding BATMs. These vessels do not have a meal plant on board.
- Domestic: All NZ owned vessels except BATMs and FOVs. The domestic fleet includes vessels that vary in length, presence of meal plants, and on board processing (fillet producing vessels vs ice boats etc.). The domestic category was then further subdivided according to whether meal plants were on board or not.

Table 5: CPUE explanatory variables offered to the models. Continuous variables were offered as 3rd order polynomials.

Variable	Type	Description	Comments
Year	Factor	Fishing year, Sep-Aug	
Vessel.key	Factor	Vessel identifier	
Statarea	Factor	Statistical area	
Subarea	Factor	The 8 subareas shown in Figure 2	Alt. to statarea
Method	Factor	BT, MW, MB	Mostly BT, and alt fitting to only BT explored
Duration	Continuous	Sum of tow durations from given vessel.day	
Bottom.depth	Continuous	Median of bottom depth from given vessel.day	
Effort.depth	Continuous	Median of fishing depth from given vessel.day	

Speed	Continuous	Median tow speed from given vessel.day	
Wingspread	Continuous	Median gear windspread from given vessel.day	
Target.species	Factor	Most common target species from given vessel.day	
Fmonth	Factor	Most common fishing month from given vessel.day	
Season	Factor	Season: non-spawning Mar-Aug; spawning Sep-Feb	
Fleet[1]	Factor	BATM, FOV, DOM[2]	Alt to vessel.key. Only applicable from 2008 fishing year onwards
Twin.trawl	Factor		Only applicable from 2008 fishing year onwards

CPUE models were explored using three spatial subsets of the data: whole-of Chatham Rise used data from the Chatham Rise area defined in Figure 1; eastern and western Chatham Rise split this area at longitude 178.1^{o}E as shown in Figure 2.

For each model fitted, a core data set was defined to consistently represent the fishery definition being explored. Selection of core vessels were based on a minimum number of years in the fishery, with a minimum number of fishing days within each of these years. The minimum thresholds were set for each model based on retaining approximately 80% of the catch for that fishery over the entire time series, and with consideration also given to the percentage of catch retained within each fishing year.

A number of CPUE models were explored, including combinations offering fishing fleet rather than vessel.key, subarea rather than statarea, forcing month:subarea (or month:statarea) interactions, including or excluding spawning areas, and including eastern and/or western Chatham Rise. The models presented in detail are those put forward by the Fisheries Deepwater Working Group to be taken forward to the stock assessment. These final CPUE models all used vessel.key rather than fishing fleet, and the data were restricted to only bottom trawl (BT) events that targeted hoki or hake, and were all based on the non-spawning fishery. For these final CPUE models, spawning areas were assumed to be statistical areas 018, 020, and 404, and data from these areas were dropped for non-spawning CPUE.

5.1. Chatham Rise non-spawning CPUE

The Chatham Rise non-spawning CPUE core vessel selection used criteria of at least 3 fishing years for which at least 10 fishing days were recorded, which kept just under 80% of the catch over all years, and over 80% in most years 1990–2019 (Figure 14).

[1] Ballara pers comm.

[2] Further subdivided into domestic vessels with or without meal plant

Variables selected for this CPUE model were vessel.key, statarea and target, and 53.30% of the null deviance was explained (Table 6). Vessel.key pulled down the index in 1990, and up in the last three years (Figure 15).

The vessels with the highest coefficients featured most in this fishery from around 2004 to 2015, and there was also a large amount of effort from vessels with fairly high coefficients in the 1990s that for the most part then dropped out of the fishery (Figure 16). Effort decreased in statistical area 019, which had a high coefficient, and in recent years increased in statistical area 407 which had a low coefficient (Fgure 28). Target species effort was largely hoki, although hake target featured from 2000–2010.

The diagnostics for this model were sound, suggesting the assumptions of normality of errors were reasonable (Figure 17).

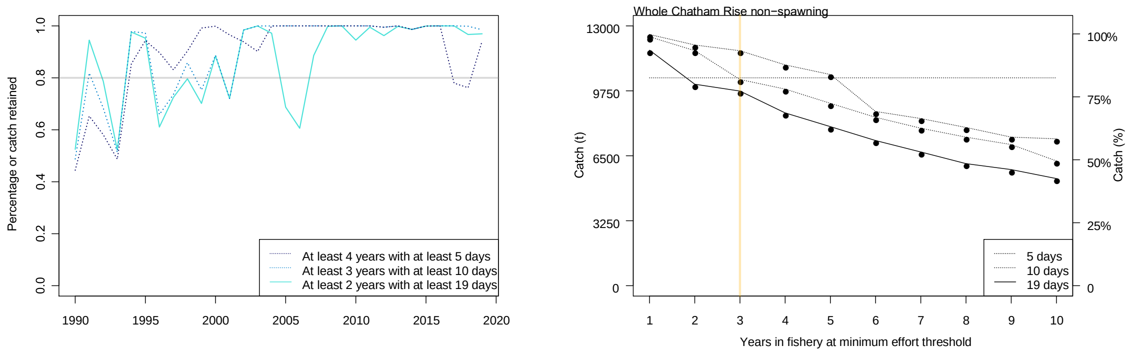


Figure 14: Exploration of core vessel selection criteria for whole-of Chatham Rise nonspawning fishery. Horizontal lines represent target level of catch to be retained by core vessels.

Table 6: Explanatory variables for whole Chatham Rise non-spawning CPUE model, (lognormal model).

Variable	*r*2
fishing year	4.11
vessel.key	36.59
statarea	50.65
target	53.30

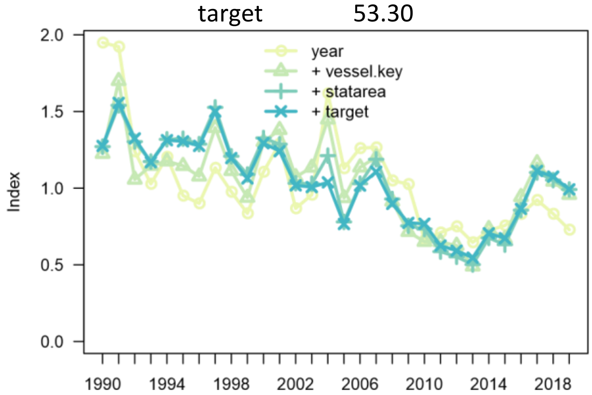


Figure 15: Fitted CPUE model of Chatham Rise, non-spawning fishery, showing the year effects of adding each explanatory variable.

The binomial component of the delta-lognormal model selected variables statarea, vessel.key, duration and bottom.depth, and explained 28.22% of the null deviance (Table 7). The resulting index was fairly flat, and hence the delta-lognormal model produced a very similar index to the lognormal model (Figure 18). The diagnostics for the binomial model were sound (Figure 19).

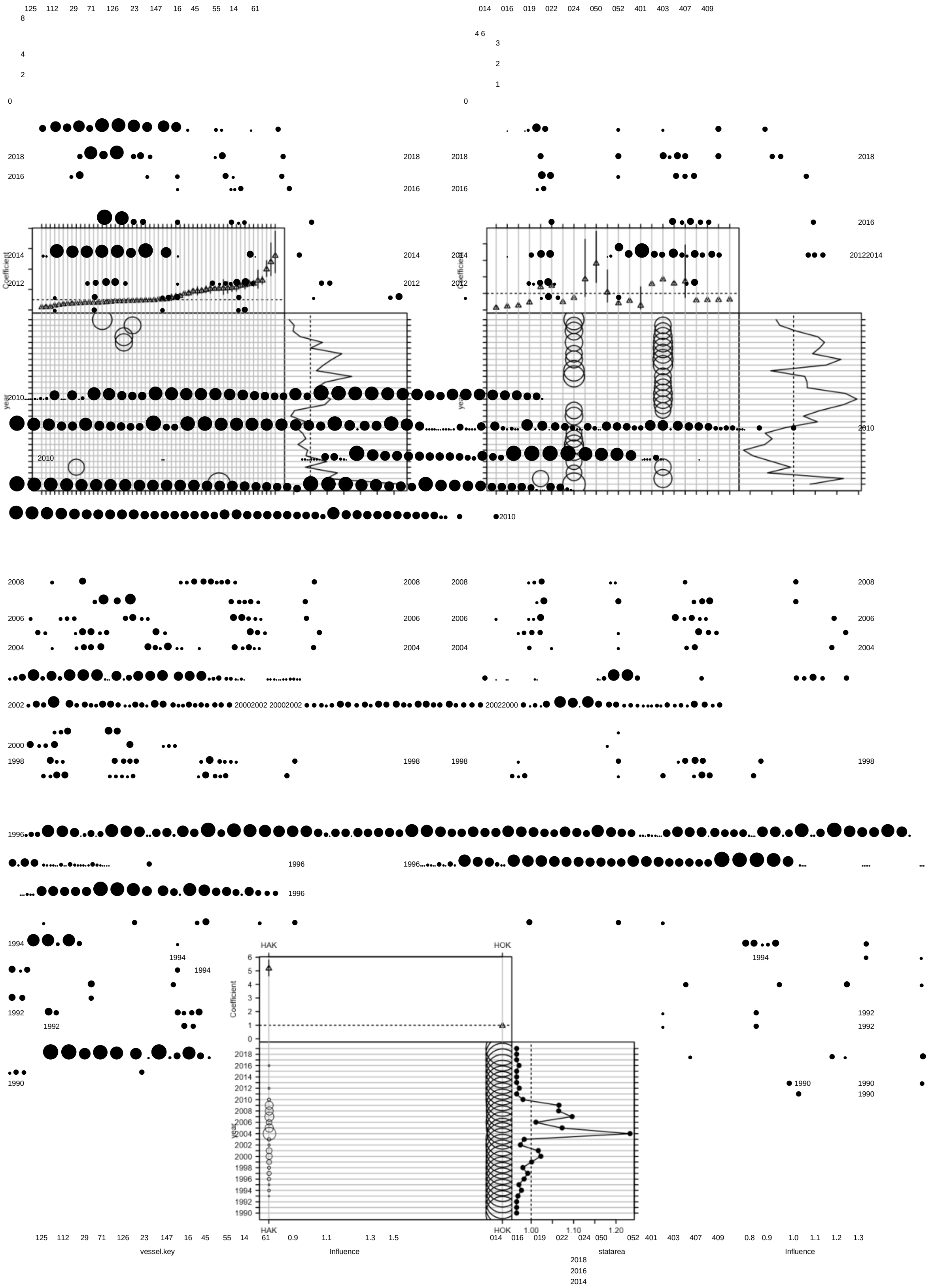


Figure 16: Influence plots for CPUE model of Chatham Rise, non-spawning fishery, for each explanatory variable.

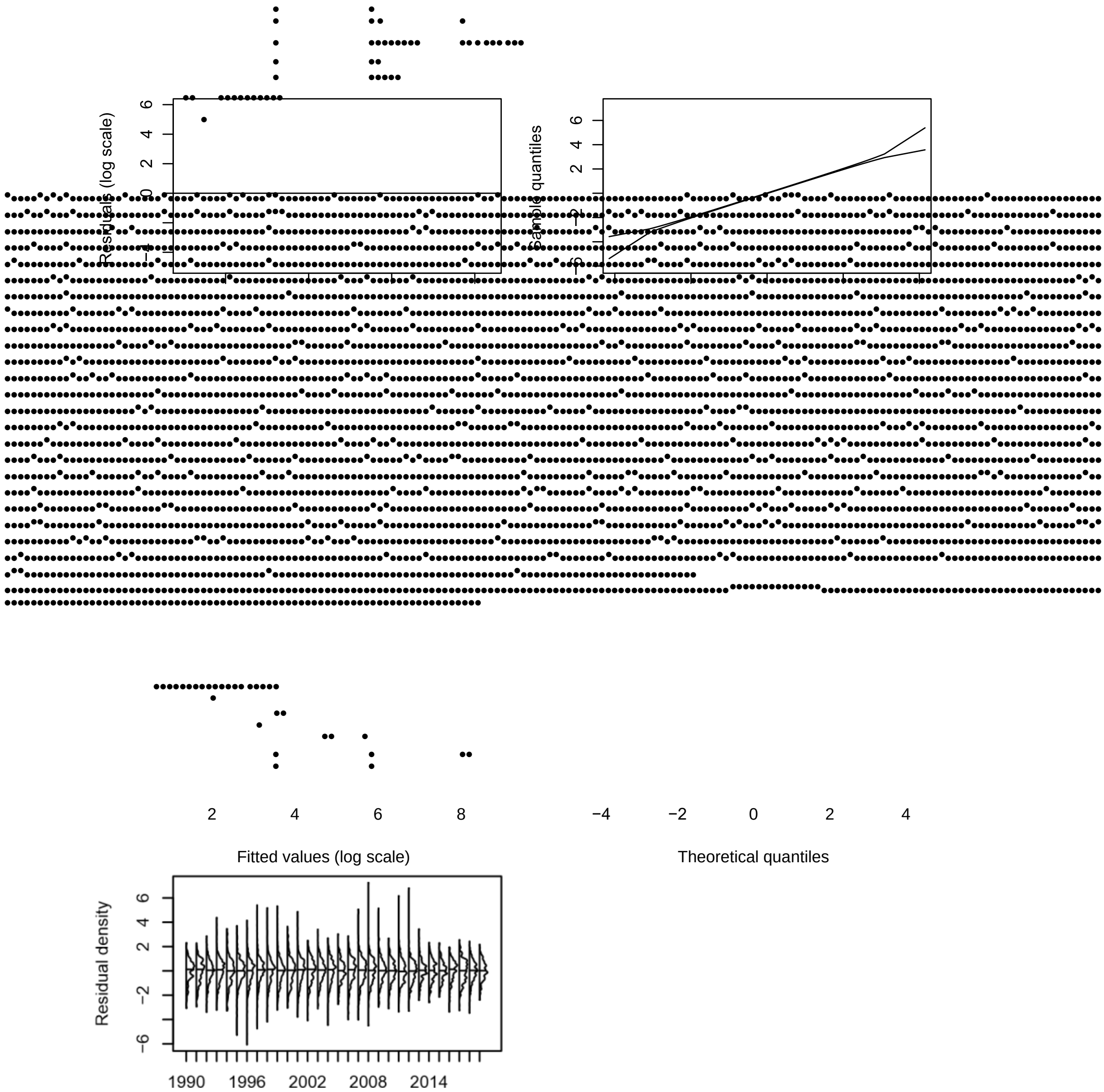


Figure 17: Diagnostics for Chatham Rise non-spawning CPUE model.

Table 7: Explanatory variables for CRern Chatham Rise non-spawning CPUE model, (binomial component of delta-lognormal model).

Variable r^2 fishing year
4.03 statarea 18.24
vessel.key 22.67
poly(duration, 3) 25.73
poly(depth.bottom, 3) 28.22

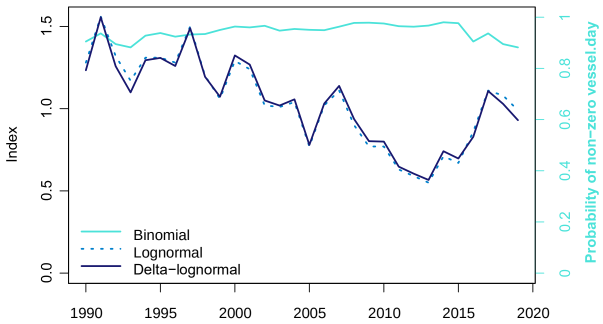


Figure 18: Chatham Rise non-spawning delta-lognormal CPUE (dark blue line), binomial index (light blue line) and lognormal model index (dark blue dashed line).

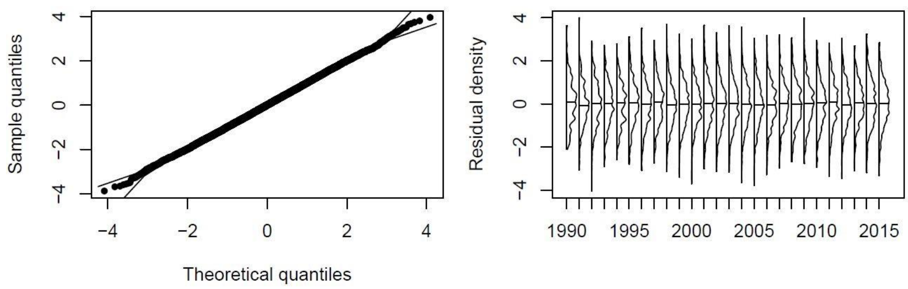


Figure 19: Diagnostics for Chatham Rise non-spawning binomial model.

5.2. Eastern non-spawning CPUE

The eastern Chatham Rise non-spawning CPUE core vessel selection used criteria of at least 3 fishing years for which at least 8 fishing days were recorded, which kept 80% of the catch over all years, and also in most years 1990–2019 (Figure 20).

Variables selected for this CPUE model were vessel.key, statarea and target, and 58.89% of the null deviance was explained (Table 8). Both vessel.key and statarea pulled down the index in 1990, but the rest of the series remained very similar to the unstandardised index (Figure 21).

The vessels with the highest coefficients generally only featured in this fishery from fishing year 2000 onwards, and most of these vessels did not feature in the most recent few years (Figure 22). Effort by statistical area was more consistent over time. Target species effort was largely hoki, although hake target featured from 2000–2010, which reduced the standardised CPUE slightly in these years, most notably in 2004 (Figures 22 and 21).

The diagnostics for this model were sound, suggesting the assumptions of normality of errors were reasonable (Figure 23).

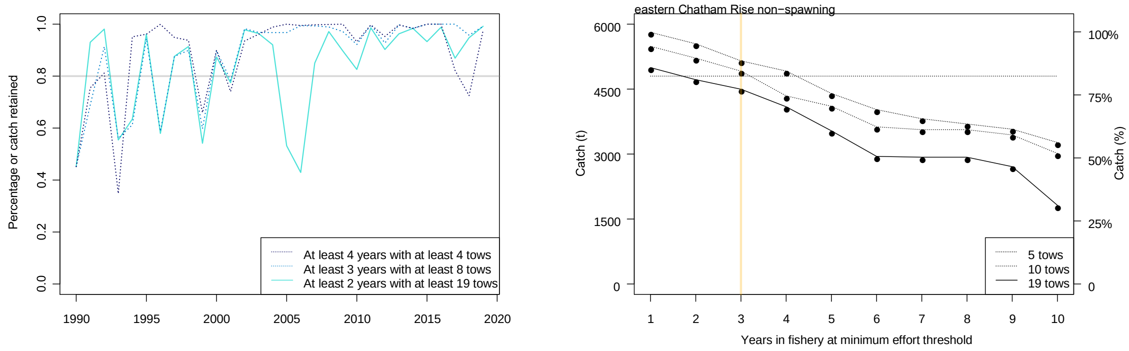


Figure 20: Exploration of core vessel selection criteria for eastern Chatham Rise nonspawning fishery. Horizontal lines represent target level of catch to be retained by core vessels.

Table 8: Explanatory variables for eastern Chatham Rise non-spawning CPUE model, (lognormal model).

Variable	r^2
fishing year	8.9
vessel.key	41.86
statarea	55.90
target	58.89

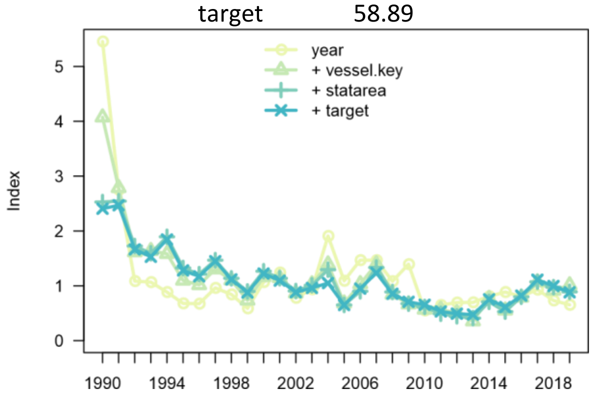


Figure 21: Fitted CPUE model of eastern Chatham Rise, non-spawning fishery, showing the year effects of adding each explanatory variable.

The binomial component of the delta-lognormal model selected variables statarea, duration, vessel.key and bottom.depth, and explained 28.79% of the null deviance (Table 9). The resulting index was fairly flat, and hence the delta-lognormal model produced a very similar index to the lognormal model (Figure 24). The diagnostics for the binomial model were sound (Figure 25).

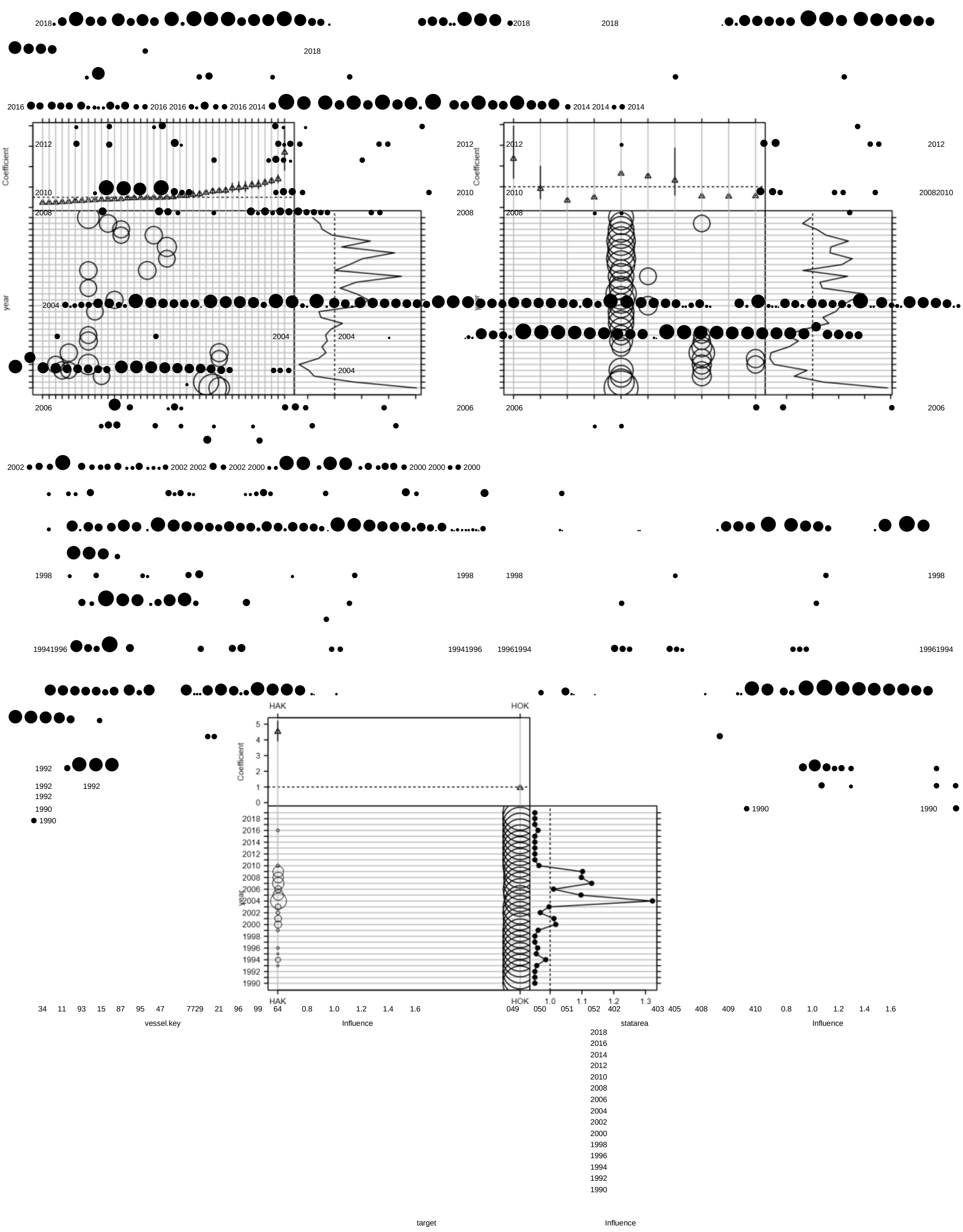


Figure 22: Influence plots for CPUE model of eastern Chatham Rise, non-spawning fishery, for each explanatory variable.

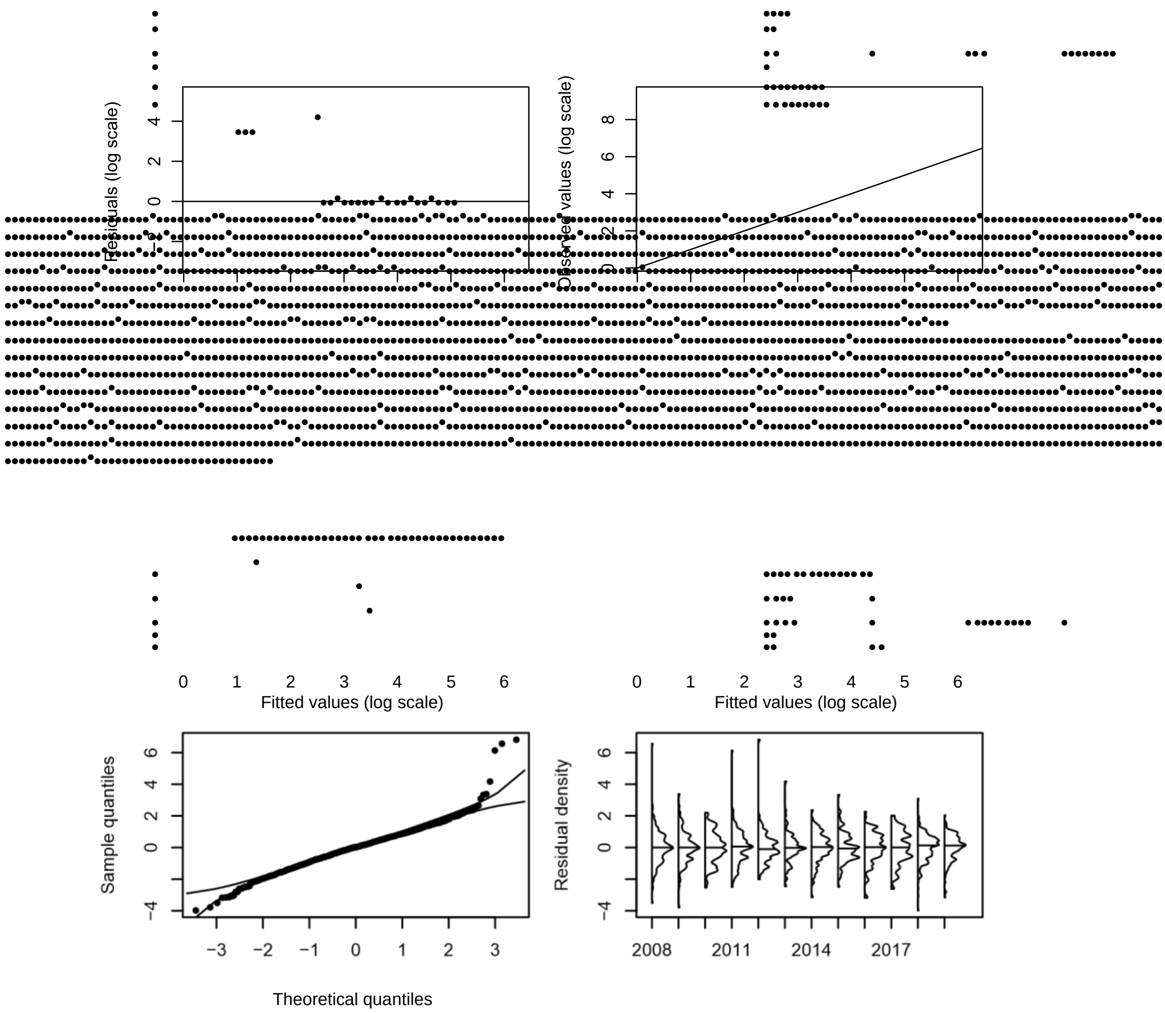


Figure 23: Diagnostics for eastern Chatham Rise non-spawning CPUE model.

Table 9: Explanatory variables for eastern Chatham Rise non-spawning CPUE model, (binomial component of delta-lognormal model).

Variable	r^2
fishing year	6.89
statarea	16.23
poly(duration, 3)	22.04
vessel.key	26.67
poly(depth.bottom, 3)	28.79

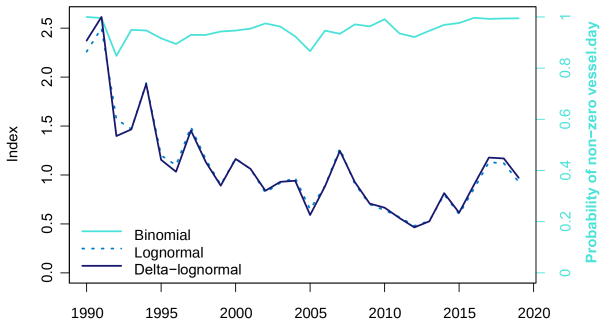


Figure 24: Eastern Chatham Rise non-spawning delta-lognormal CPUE (dark blue line), binomial index (light blue line) and lognormal model index (dark blue dashed line).

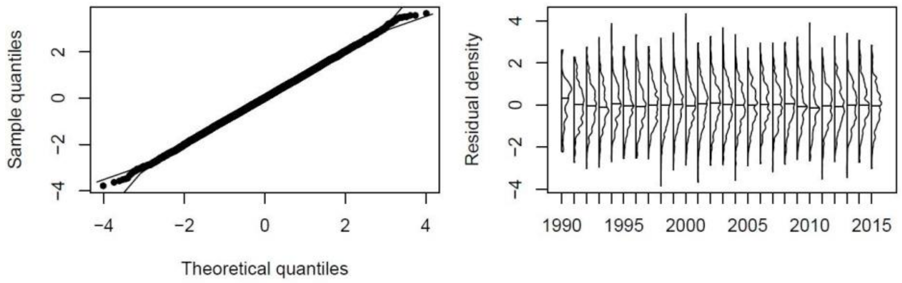


Figure 25: Diagnostics for eastern Chatham Rise non-spawning binomial model.

5.3. Western non-spawning CPUE

The western Chatham Rise non-spawning CPUE core vessel selection used the criteria of at least 3 fishing years for which at least 5 fishing days were recorded, which kept approximately 75% of the catch over all years, and also in most years 1990–2019 (Figure 26).

Variables selected for this CPUE model were vessel.key, statarea, target and depth.bottom, ~~and~~which explained 47.83% of the null deviance ~~was explained~~ (Table 10). Vessel.key pulled down the index in the first few years and up at the end of the series, and statarea pulled the index down around the middle of the series (early–mid 2000s) (Figure 27).

There were some fairly large concentrations of effort from vessels with high coefficients in the early 1990s (Figure 28), which resulted in bringing the standardised CPUE down for these years.

Effort decreased in statistical area 019, which had a high coefficient, and in recent years increased in statistical area 407 which had a low coefficient (Figure 28). The decrease in the standardised index in the mid-2000s from statarea seems to be from high effort in both 021 and 401, both of which had high coefficients (Figures 28 and 27). Target species effort was largely hoki, although hake target featured from 2000–2010. Bottom depth had negative coefficients for depths outside of approximately 500–700 m, and the effort has concentrated within this depth range in the recent part of the time series.

The diagnostics for this model were sound, suggesting the assumptions of normality of errors were reasonable (Figure 29).

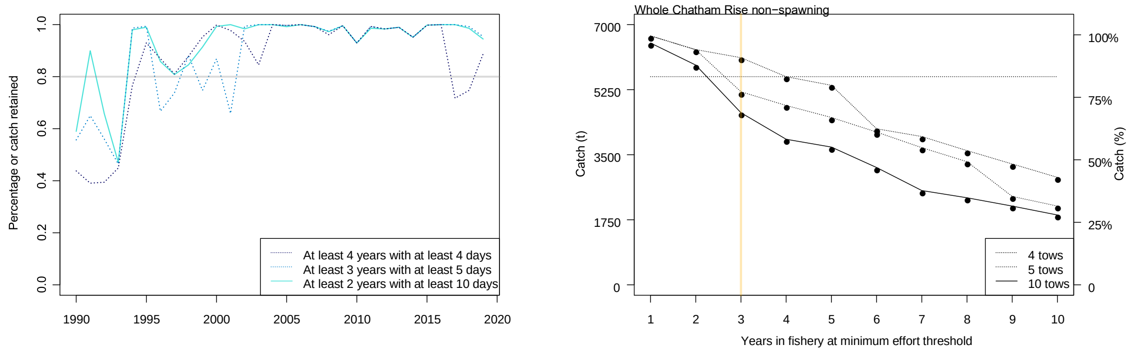


Figure 26: Exploration of core vessel selection criteria for eastern Chatham Rise nonspawning fishery. Horizontal lines represent target level of catch to be retained by core vessels.

Table 10: Explanatory variables for western Chatham Rise non-spawning CPUE model, (lognormal model).

Variable r^2 fishing year
5.78 vessel.key 32.17 statarea
43.18 target 46.73
poly(depth.bottom, 3) 47.83

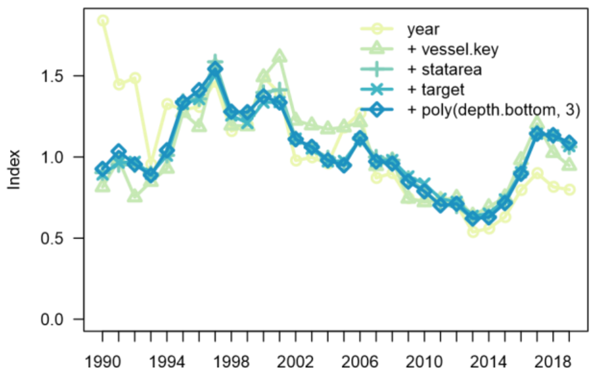
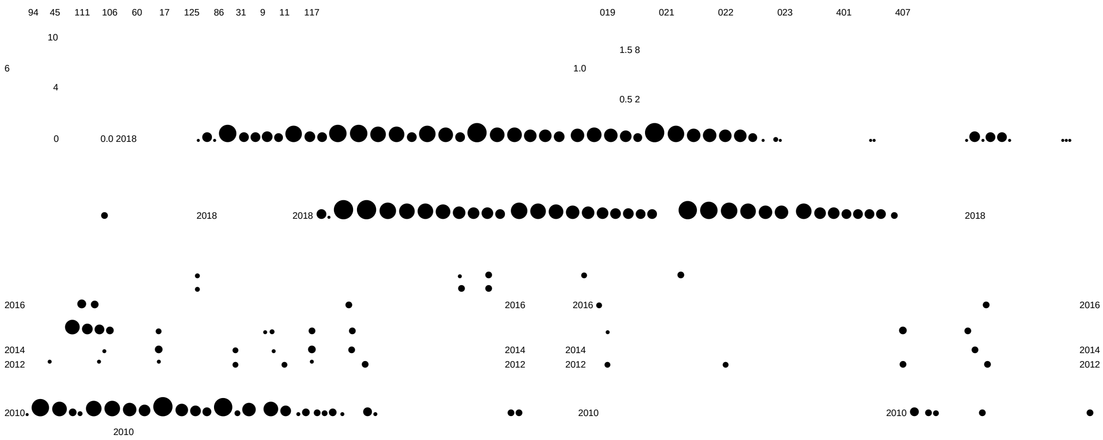


Figure 27: Fitted CPUE model of western Chatham Rise, non-spawning fishery, showing the year effects of adding each explanatory variable.



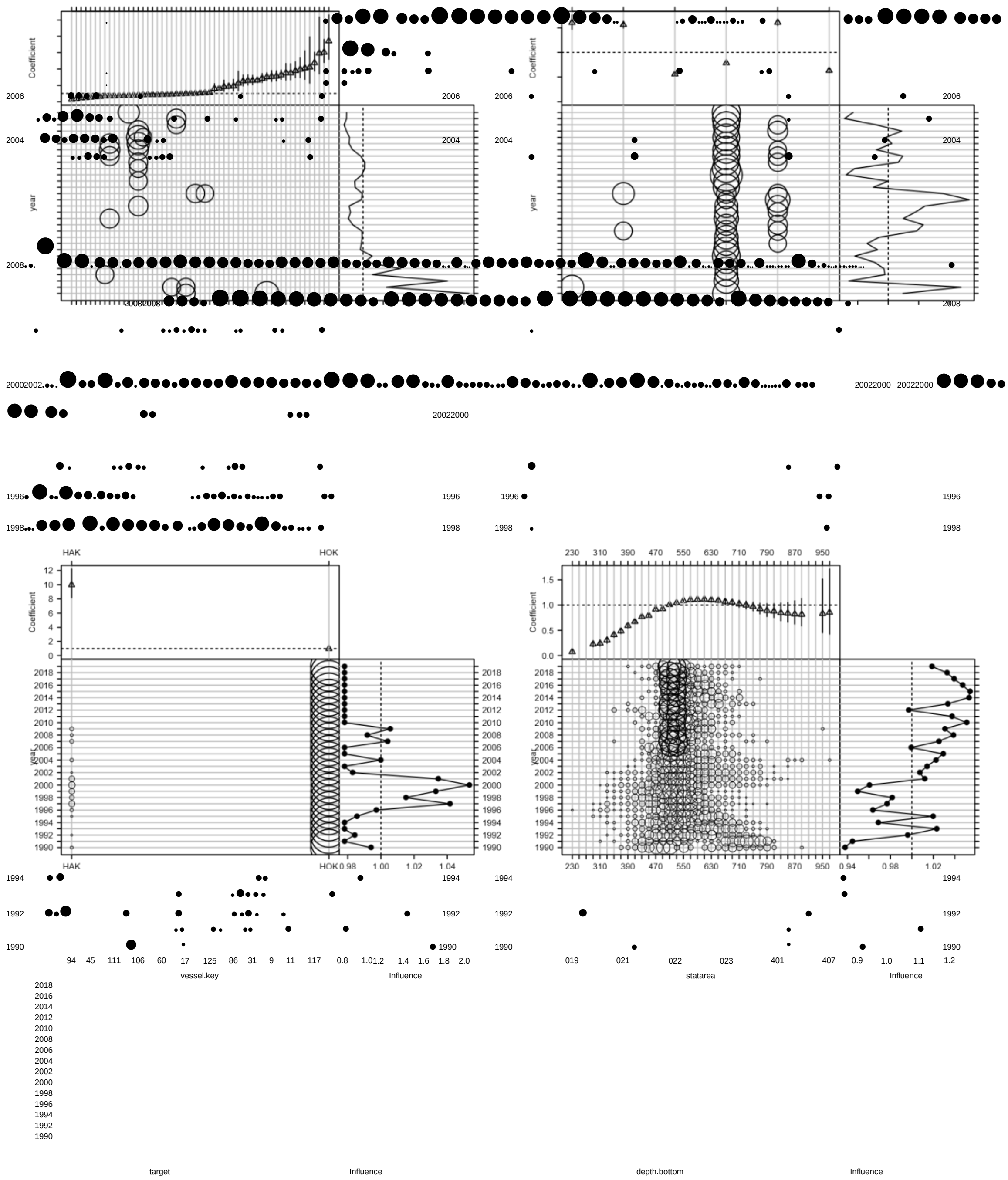
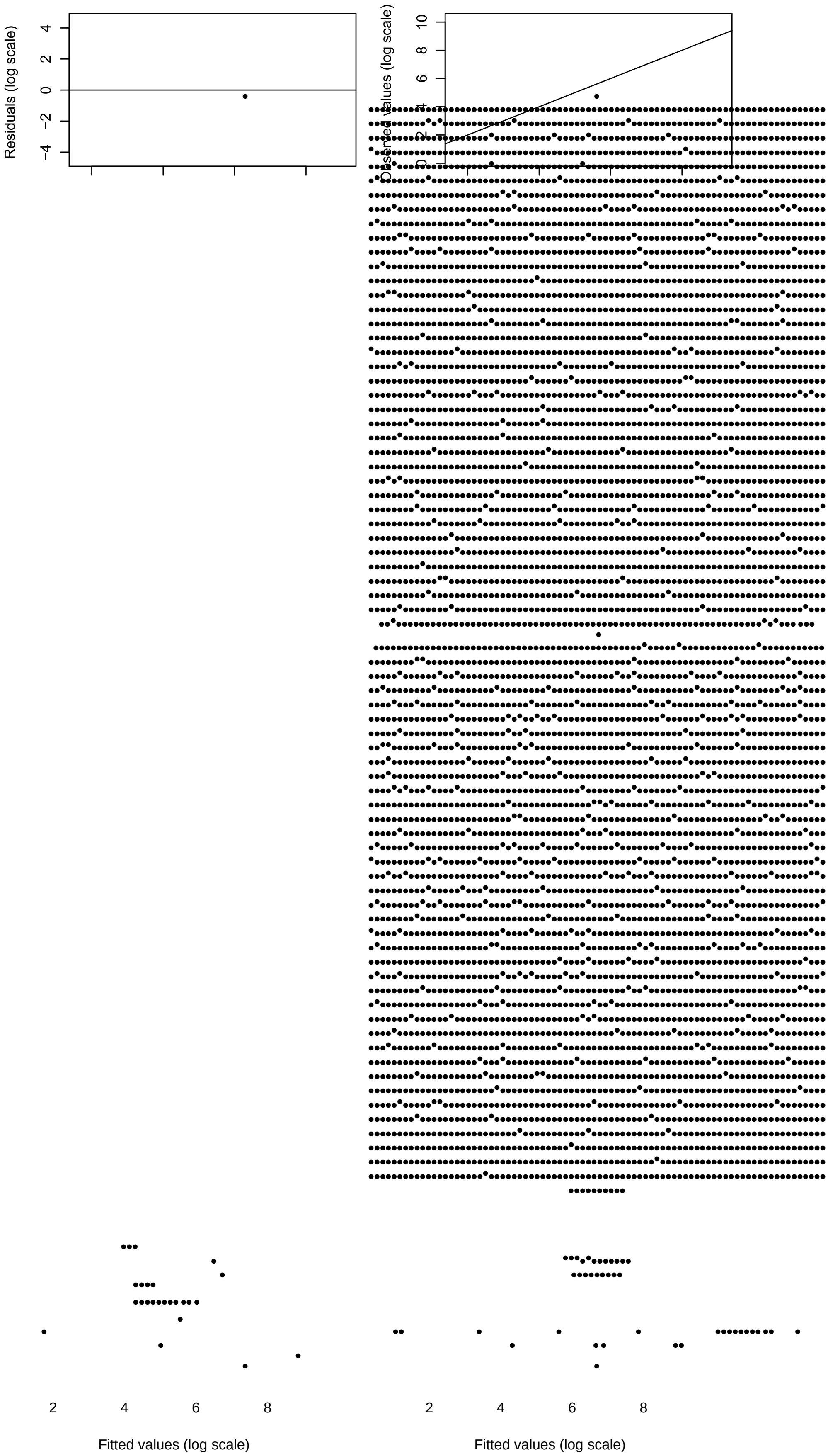


Figure 28: Influence plots for CPUE model of western Chatham Rise, non-spawning fishery, for each explanatory variable.


Residuals (log scale)
4
2
0
−2
−4
Observed values (log scale)
10
8
6
2
4
6
8
Fitted values (log scale)
2
4
6
8
Fitted values (log scale)

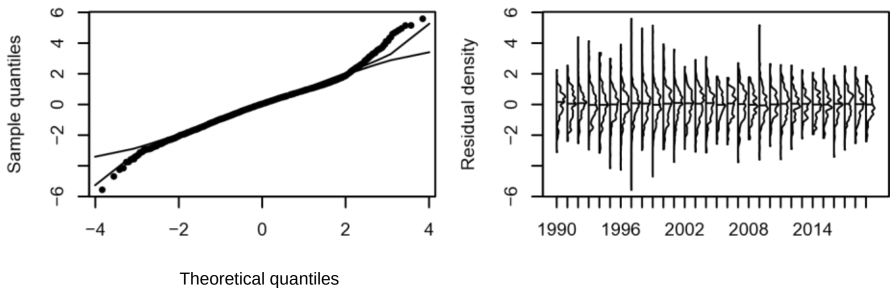


Figure 29: Diagnostics for western Chatham Rise non-spawning CPUE model.

The binomial component of the delta-lognormal model selected variables statarea, vessel.key, duration and bottom.depth, and explained 32.93% of the null deviance (Table 11). The resulting index was fairly flat, and hence the delta-lognormal model produced a very similar index to the lognormal model (Figure 30). The diagnostics for the binomial model were sound (Figure 31).

Table 11: Explanatory variables for western Chatham Rise non-spawning CPUE model, (binomial component of delta-lognormal model).

Variable r^2 fishing year
4.52 statarea 24.18
vessel.key 27.95
poly(duration, 3) 30.70
poly(depth.bottom, 3) 32.93

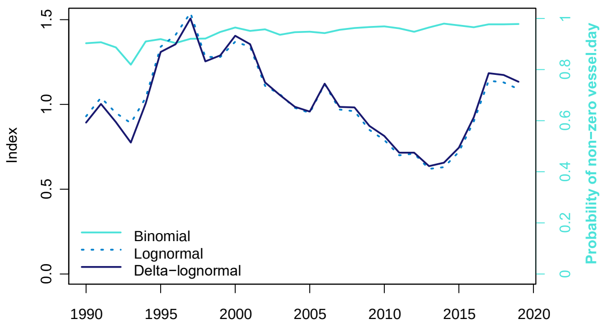


Figure 30: Western Chatham Rise non-spawning delta-lognormal CPUE (dark blue line), binomial index (light blue line) and lognormal model index (dark blue dashed line).

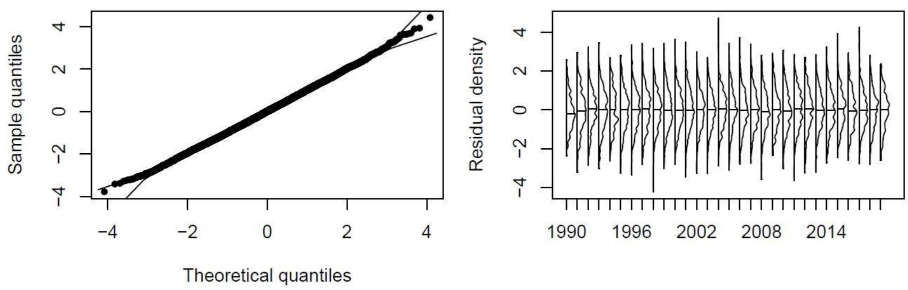


Figure 31: Diagnostics for western Chatham Rise non-spawning binomial model.

5.4. Comparison of final CPUE indices

The CPUE indices were very similar from 1995 onwards (Figure 32). Before 1995 the eastern Chatham Rise CPUE and the previous CPUE which modeled data from HAK 4 (i.e. also the eastern Chatham Rise) declined from a high initial value~~s~~ whereas the western Chatham Rise CPUE index began a lot lower. The trawl survey core biomass estimates matched the early decline of the eastern Chatham Rise CPUE.

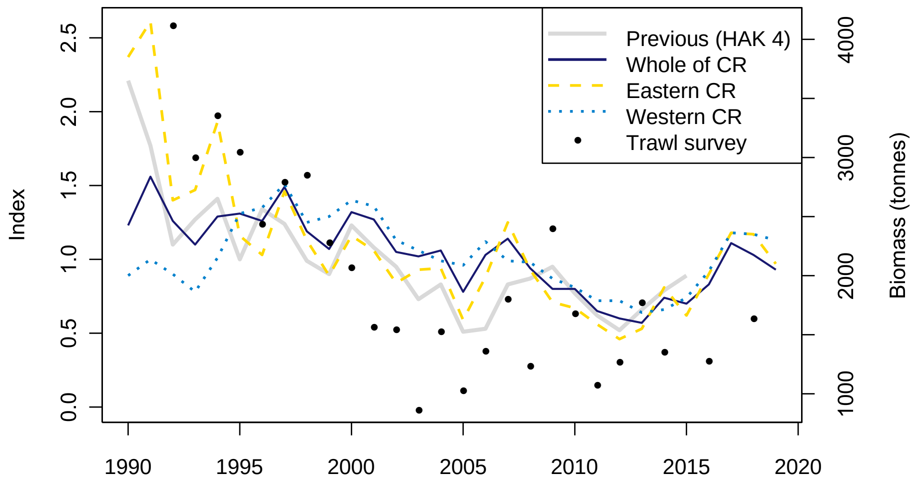


Figure 32: Comparison of final CPUE models, the previous Chatham Rise hake CPUE (Ballara, 2018), and the trawl survey core biomass estimates.

6. Discussion

Hake on the Chatham Rise were still taken mostly by bottom trawling, as stated in previous analyses
(Ballara, 2018). They were predominantly caught when targeting hoki in the recent years, where as other target such as hake, ling and southern blue whiting featured a little more in earlier analyses (e.g. Ballara (2015), Devine (2009)).

Spatial plots of catches showed that in the most recent 10 years, catches have been more from the western Chatham Rise fishery rather than the eastern Chatham Rise fishery that had previously dominated the fishery. In particular, statistical area 404, the known spawning ground for hake, has seen much lower catches (and effort) in these more recent years. Because the effort has also been reduced in statistical area 404, it is difficult to determine whether the fishery is not focusing on this area because the fish are not there, or for other reasons relating to fishery behavior.

Identifying spawning aggregations can be important when standardising CPUE to avoid presenting an index with hyper-stability (Erisman et al., 2011). Statistical area 404 has stood out as a spawning fishery, and CPUE analyses have explored treating this area separately (e.g. Devine (2010)).

The most recent CPUE analysis for the Chatham Rise hake fishery noted the effect of statistical area
404 on the CPUE, but included it in the standardised index based on the rationale that the resulting index matched the trawl survey index fairly well (Ballara, 2018). Statistical areas 018 and 020 that were identified here as likely spawning grounds based on high peaks in catches during spawning months in some years, have also received mention in relation to spawning in Ballara (2018), but not in relation to the CPUE standardisation. The eastern Chatham Rise CPUE index was used as a sensitivity for the stock assessment (Holmes, in press).

The dynamics of the eastern and western Chatham Rise hake fishery seem rather different to each other, in particular with respect to the earlier part of the CPUE index, and this could be of importance when assessing this stock. The spatial dynamics of this fishery are likely confounded with the multi-species fishery dynamics. As hake have often been caught as a by-catch to the hoki fishery, the dynamics of the hake fishery are likely to be affected by the dynamics of the hoki fishery, and as such, it is difficult to assess these fisheries appropriately in isolation.

7. Acknowledgments

I thank the many NIWA staff and ~~Ministry for Primary Industries~~Fisheries New Zealand observers who were involved in the collection of data at sea, and members of the Deepwater Fishery Assessment Working Group for providing useful comments and suggestions on the development of these analyses. Steven Holmes (NIWA) provided a valuable review of this document. This work was completed under Objectives 1 and 2 of Ministry for Primary Industries project HAK2019-01.

8. References

Anderson, O. F., Bagley, N., Hurst, R., Francis, M., Clark, M., McMillan, P., 1998. Atlas of New Zealand fish and squid distributions from research bottom trawls. NIWA.

Ballara, S. L., 2012. Descriptive Analysis of the Fishery for hake (*Merluccius Australis*) in HAK 1, 4 and 7 from 1989-90 to 2009-10, and a Catch-per-unit-effort (CPUE) Analysis for Sub-Antarctic Hake. Vol. 02. Ministry for Primary Industries.

Ballara, S. L., 2013. Descriptive Analysis of the Fishery for hake (*Merluccius Australis*) in HAK 1, 4 and 7 from 1989-90 to 2010-11, and a Catch-per-unit-effort (CPUE) Analysis for Sub-Antarctic Hake. Vol. 12. Ministry for Primary Industries.

Ballara, S. L., 2015. Descriptive Analysis of the Fishery for hake (*Merluccius Australis*) in HAK 1, 4 and 7 from 1989-90 to 2012-13, and a Catch-per-unit-effort (CPUE) Analysis for Sub-Antarctic Hake. Vol. 12. Ministry for Primary Industries.

Ballara, S. L., 2018. Descriptive Analysis of the Fishery for hake (*Merluccius Australis*) in HAK 1, 4 and 7 from 1989-90 to 2014-15, and a Catch-per-unit-effort (CPUE) Analysis for Sub-Antarctic Hake. Vol. 55. Ministry for Primary Industries.

Ballara, S. L., Horn, P., 2011. Descriptive Analysis of the Fishery for hake (*Merluccius Australis*) in HAK 1, 4 and 7 from 1989-90 to 2008-09, and a Catch-per-unit-effort (CPUE) Analysis for Sub-Antarctic Hake. Vol. 66. Ministry for Primary Industries.

Ballara, S. L., O'Driscoll, R. L., 2019. Catches, size, and age structure of the 2017–18 hoki fishery, and a summary of input data used for the 2019 stock assessment. New Zealand Fisheries Assessment Report 48, 140.

Blackwell, R., Manning, M., Gilbert, D., 2006. Standardised CPUE analysis of the target rig (Mustelus lenticulatus) set net fishery in northern New Zealand (SPO 1 and SPO 8). New Zealand Fisheries Assessment Report 32, 56.

Colman, J., 1998. Spawning areas and size and age at maturity of hake (Merluccius australis) in the New Zealand Exclusive Economic Zone. Ministry of Fisheries.

Devine, J., 2009. Descriptive Analysis of the Fishery for hake (*Merluccius Australis*) in HAK 1, 4 and 7 from 1989-90 to 2005-06, and a Catch-per-unit-effort (CPUE) Analysis for Sub-Antarctic Hake. Vol. 21. Ministry for Primary Industries.

Devine, J., 2010. Descriptive Analysis of the Fishery for hake (*Merluccius Australis*) in HAK 1 and 4 from 1989-90 to 2007-08, and a Catch-per-unit-effort (CPUE) Analysis for Sub-Antarctic Hake. Vol. 15. Ministry for Primary Industries.

Dunn, A., 2003. Revised estimates of landings of hake (*Merluccius australis*) for the west coast South Island, Chatham Rise, and Sub-Antarctic stocks in the fishing years 1989-90 to 2000-01. New Zealand Fisheries Assessment Report 39, 36.

Dunn, A., Phillip, N., 2006. Catch and effort (CPUE) analysis of hake (*Merluccius Australis*) for the Chatham Rise from 1989–90 to 2004–05. Vol. project HAK2003-01. Unpublished report held by the Ministry for Primary Industries, Wellington.

Erisman, B. E., Allen, L. G., Claisse, J. T., Pondella, D. J., Miller, E. F., Murray, J. H., 2011. The illusion of plenty: hyperstability masks collapses in two recreational fisheries that target fish spawning aggregations. Canadian Journal of Fisheries and Aquatic Sciences 68 (10), 1705–1716.

Fisheries New Zealand, 2020. Fisheries Assessment Plenary, May 2020: stock assessments and stock status. Compiled by the Fisheries Science and Information Group, Fisheries New Zealand, Wellington, New Zealand, 1746 p.

Holmes, S., in press. Stock assessment of hake (*Merluccius australis*) on the Chatham Rise (HAK 4) and off the west coast of South Island (HAK 7) for the 2019–20 fishing year. New Zealand Fisheries Assessment Report.

Horn, P., 2013. Stock assessment of hake (*Merluccius australis*) on the Chatham Rise (HAK 4) and off the west coast of South Island (HAK 7) for the 2012–13 fishing year. New Zealand Fisheries Assessment Report 31, 62.

Horn, P., 2017. Stock assessment of hake (*Merluccius australis*) on the Chatham Rise (HAK 4) and off the west coast of South Island (HAK 7) for the 2016–17 fishing year. New Zealand Fisheries Assessment Report 47, 70.

Horn, P., Francis, R., 2010. Stock assessment of hake (*Merluccius australis*) on the Chatham Rise for the 2009–10 fishing year. New Zealand Fisheries Assessment Report 14, 65.

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.

Manning, M., 2007. Relative abundance of giant stargazer (*Kathetostoma giganteum*) in STA 5 based on commercial catch-per-unit-effort data. New Zealand Fisheries Assessment Report 14, 42.

Manning, M., Hanchet, S. M., Stevenson, M. L., 2004. A description and analysis of New Zealand's spiny dogfish (*Squalus acanthias*) fisheries and recommendations on appropriate methods to monitor the status of the stocks. Ministry of Fisheries.

O'Driscoll, R., MacGibbon, D., Fu, D., Lyon, W., Stevens, D., 2011. A review of hoki and middledepth trawl surveys of the Chatham Rise, January 1992–2010. New Zealand Fisheries Assessment Report 47, 814.

R Core Team, 2020. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria.
URL https://www.R-project.org/

Starr, P., 2007. Procedure for merging mfish landing and effort data, v2.0. Document AMPWG/07/04. (Unpublished report held by Ministry for Primary Industries, Wellington).

Field Co

Appendix

Table 12: Final CPUE indices for Chatham Rise hake.

	Whole of Chatham Rise						Eastern of Chatham Rise						Western of Chatham Rise					
year	index	lower.CI	upper.CI	se	cv	DeltaLogNormal	index	lower.CI	upper.CI	se	cv	DeltaLogNormal	index	lower.CI	upper.CI	se	cv	DeltaLogNormal
1990	1.28	1.07	1.53	0.09	0.09	1.23	2.26	1.37	3.75	0.25	0.26	2.37	0.93	0.75	1.15	0.11	0.11	0.89
1991	1.56	1.37	1.76	0.06	0.06	1.56	2.5	1.99	3.14	0.11	0.11	2.61	1.04	0.87	1.24	0.09	0.09	1
1992	1.32	1.2	1.47	0.05	0.05	1.26	1.57	1.3	1.9	0.1	0.1	1.4	0.95	0.83	1.1	0.07	0.07	0.9
1993	1.17	1.05	1.31	0.06	0.06	1.1	1.47	1.19	1.81	0.1	0.1	1.47	0.89	0.77	1.03	0.07	0.07	0.78
1994	1.31	1.15	1.5	0.07	0.07	1.29	1.94	1.51	2.5	0.13	0.13	1.93	1.04	0.88	1.24	0.09	0.09	1.01
1995	1.31	1.19	1.43	0.05	0.05	1.31	1.2	1.03	1.39	0.07	0.08	1.16	1.34	1.17	1.52	0.07	0.07	1.31
1996	1.28	1.16	1.4	0.05	0.05	1.26	1.1	0.9	1.35	0.1	0.1	1.03	1.41	1.25	1.59	0.06	0.06	1.35
1997	1.5	1.39	1.62	0.04	0.04	1.49	1.49	1.27	1.74	0.08	0.08	1.46	1.54	1.4	1.7	0.05	0.05	1.51
1998	1.2	1.12	1.28	0.03	0.03	1.19	1.16	1.01	1.33	0.07	0.07	1.13	1.28	1.17	1.4	0.04	0.04	1.25
1999	1.06	0.99	1.14	0.03	0.03	1.07	0.9	0.8	1.01	0.06	0.06	0.89	1.28	1.16	1.4	0.05	0.05	1.29
2000	1.29	1.2	1.39	0.04	0.04	1.32	1.17	1.03	1.34	0.07	0.07	1.16	1.37	1.24	1.52	0.05	0.05	1.4
2001	1.24	1.16	1.33	0.03	0.03	1.27	1.06	0.93	1.2	0.06	0.06	1.06	1.34	1.22	1.46	0.04	0.04	1.36
2002	1.02	0.94	1.1	0.04	0.04	1.05	0.82	0.7	0.96	0.08	0.08	0.84	1.11	1	1.23	0.05	0.05	1.13
2003	1.01	0.93	1.09	0.04	0.04	1.02	0.92	0.79	1.07	0.08	0.08	0.93	1.06	0.96	1.18	0.05	0.05	1.06
2004	1.04	0.95	1.13	0.04	0.04	1.06	0.97	0.84	1.11	0.07	0.07	0.94	0.98	0.85	1.13	0.07	0.07	0.99
2005	0.77	0.69	0.86	0.06	0.06	0.78	0.65	0.54	0.79	0.09	0.09	0.59	0.95	0.8	1.12	0.08	0.08	0.96
2006	1.02	0.9	1.15	0.06	0.06	1.03	0.89	0.71	1.13	0.12	0.12	0.88	1.12	0.95	1.31	0.08	0.08	1.12
2007	1.11	1	1.23	0.05	0.05	1.14	1.27	1.09	1.48	0.08	0.08	1.25	0.97	0.83	1.14	0.08	0.08	0.99
2008	0.9	0.81	0.99	0.05	0.05	0.94	0.91	0.78	1.07	0.08	0.08	0.93	0.96	0.82	1.12	0.08	0.08	0.98
2009	0.77	0.69	0.87	0.06	0.06	0.8	0.7	0.57	0.87	0.11	0.11	0.71	0.85	0.73	0.99	0.08	0.08	0.87
2010	0.77	0.69	0.86	0.06	0.06	0.8	0.64	0.51	0.8	0.11	0.11	0.67	0.79	0.68	0.91	0.07	0.07	0.81
2011	0.63	0.57	0.69	0.05	0.05	0.65	0.57	0.49	0.67	0.08	0.08	0.56	0.7	0.61	0.81	0.07	0.07	0.72
2012	0.59	0.52	0.67	0.06	0.06	0.6	0.48	0.39	0.6	0.11	0.11	0.46	0.71	0.6	0.85	0.09	0.09	0.72
2013	0.55	0.48	0.62	0.06	0.07	0.57	0.53	0.42	0.67	0.12	0.12	0.53	0.62	0.51	0.75	0.09	0.09	0.64
2014	0.71	0.62	0.81	0.07	0.07	0.74	0.8	0.65	0.97	0.1	0.1	0.81	0.63	0.51	0.77	0.1	0.1	0.66
2015	0.67	0.6	0.76	0.06	0.06	0.7	0.6	0.48	0.73	0.11	0.11	0.62	0.72	0.61	0.85	0.08	0.08	0.74
2016	0.86	0.77	0.97	0.06	0.06	0.83	0.86	0.7	1.06	0.11	0.11	0.9	0.9	0.76	1.06	0.09	0.09	0.92
2017	1.11	0.99	1.25	0.06	0.06	1.11	1.13	0.92	1.4	0.11	0.11	1.18	1.14	0.98	1.34	0.08	0.08	1.18
2018	1.08	0.98	1.18	0.05	0.05	1.03	1.12	0.97	1.3	0.07	0.07	1.17	1.13	0.98	1.31	0.07	0.07	1.17
2019	0.99	0.89	1.1	0.05	0.05	0.93	0.93	0.77	1.12	0.09	0.1	0.97	1.09	0.95	1.25	0.07	0.07	1.13