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Tini a Tangaroa

Fishery characterisation and standardised CPUE analyses for barracouta (*Thyrsites atun*), in BAR 5, 1989–90 to 2014–15

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EXECUTIVE SUMMARY

Marsh, C.; McGregor, V. (2021). Fishery characterisation and standardised CPUE analyses for barracouta (*Thyrsites atun*), in BAR 5, 1989–90 to 2014–15.

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This report follows the standardised reporting format used in middle depth fishery characterisations for species or stocks for which no robust stock assessment has been developed. It is based on the previous characterisation and CPUE analyses for barracouta, but on Fisheries Management Areas (FMA) 5 and 6 which are the areas containing the barracouta Fishstock BAR 5, with additional information and analyses where appropriate.

Barracouta fisheries have been exploited since the late-1960s, with significant landings developing in 1968, the year after Japanese vessels commenced fishing in New Zealand waters. Fishing in inshore waters by foreign vessels was restricted after the introduction of the Exclusive Economic Zone (EEZ) on 1 April 1978, which limited expansion of foreign vessel barracouta catches. Interim management controls introduced under the Deepwater Policy on 1 October 1983 (EEZ annual total allowable catch (TAC) of 31 000 t) controlled development of the trawl fishery by foreign chartered or larger domestic vessels prior to introduction of the Quota Management System (QMS) on 1 October 1986 (EEZ annual total allowable commercial catch (TACC) of 31 050 t).

Within BAR 5, barracouta are primarily targeted by midwater and bottom trawls around Snares shelf. Fishing takes place over the continental shelf down to about 400 m depth. Catches in BAR 5 have exceeded the TACC six times in the last ten years.

Barracouta in an exploited fishery have been aged to 11 years old, suggesting a maximum age of about 15 years and natural mortality of about 0.3. They mature at about 50–60 cm and age 2–3 years. The main spawning season is in late winter and spring off western coasts of New Zealand and late spring off Southland. There is also evidence of some spawning activity in summer/autumn in a few areas. The main fishing seasons are on spawning grounds in late winter and spring as well as summer/autumn feeding grounds. In Southland, barracouta are also commonly caught in squid targeted trawls.

Standardised annual catch per unit effort (CPUE) indices were developed from 1989–90 to 2014–15 for BAR 5. The models for major target species at the tow level explained 36% of the null deviance. Because the Southland barracouta fishery is a multi-species fishery, with a mix of targeted and bycatch fishing, two CPUE series from subsets of the tow level data were developed, one included barracouta and blue warehou target and the other used squid target. Both of these showed a large one year increase in 2006–07 and a relatively high abundance in the latter part of the series (2007–08 to 2014–15). They differed in the earlier part of the series (pre-1995), when the squid bycatch series declined and the barracouta and blue warehou target index was flat. An observer CPUE analysis was similar to the squid target series, except that the increase in abundance between 2007–08 to 2014–15 was not as extreme.

Most observer collected length frequency data and otoliths are from the Stewart-Snares shelf and are adequate to develop a series of catch-at-age for this fishery. Catch-at-age data are currently available for the Southland trawl fishery from years 1992–93 to 1995–96 and from the commercial fishery from fishing years 2004–05 and 2009–10.

1. Introduction

This report summarises the analyses carried out for the Ministry for Primary Industries under project BAR201501, Objectives 1-2:

1. To update the descriptive analysis of barracouta in BAR 5 with data up to and including the 2014-15 fishing year.

2. To update and complete CPUE indices.

The report is based on the previous characterisation of New Zealand barracouta (Hurst et al., 2012; McGregor, 2020) except where additional information and analyses have been included to meet the specific objectives of this project. Tables 1–5 and Figures 1–6 are given in the report body, with the remaining figures and tables laid in the following Appendices: A, Observer data; B, Summaries of catch and effort data grooming; C, Summaries of catch and effort data; and D, Catch-per-unit-effort analyses.

Hurst et al. (2012) and McGregor (2020) carried out the previous characterisations of New Zealand barracouta fisheries for QMAs BAR 1, 4, 5 and 7, covering years 1989–90 to 2007–08 and 1989–90 to 2010–11 respectively. Specific area analyses were carried out for BAR 5, from 1989–90 to 1997–98, by Harley et al. (1999). Stock structure has been reviewed by Hurst (1988a,b); Hurst & Bagley (1989), and Langley & Bentley (2002). Historically, research trawl surveys designed to estimate barracouta abundance (often in conjunction with other species) have been carried out off Southland by *Shinkai Maru* 1981–86 (Kawahara & Tokusa, 1981; van den Broek et al., 1984; Uozumi et al., 1987; Hatanaka et al., 1989; Hurst et al., 2000), in November 1986 by *Akebono Maru 3* (Hurst & Bagley, 1997*a*) and 1993–96 by *Tangaroa* (Hurst & Bagley, 1997*b*).

2. Fishing Summary

2.1. Commercial fisheries

Barracouta (or snoek) are semipelagic fish found in temperate, continental shelf waters of the Southern Hemisphere. New Zealand has the second largest fishery, the largest being off south and west Africa that peaked at 81 000 t in 1978 (Griffiths, 2002). The fishery is presently managed as four separate fish stocks based on Quota Management Areas (QMAs, Figure 1): eastern (BAR 1), Chatham Island (BAR 4), southern (BAR 5) and western (BAR 7). An administrative stock has been established for the Kermadec area (BAR l0T), but no catch of barracouta has been recorded from that area.

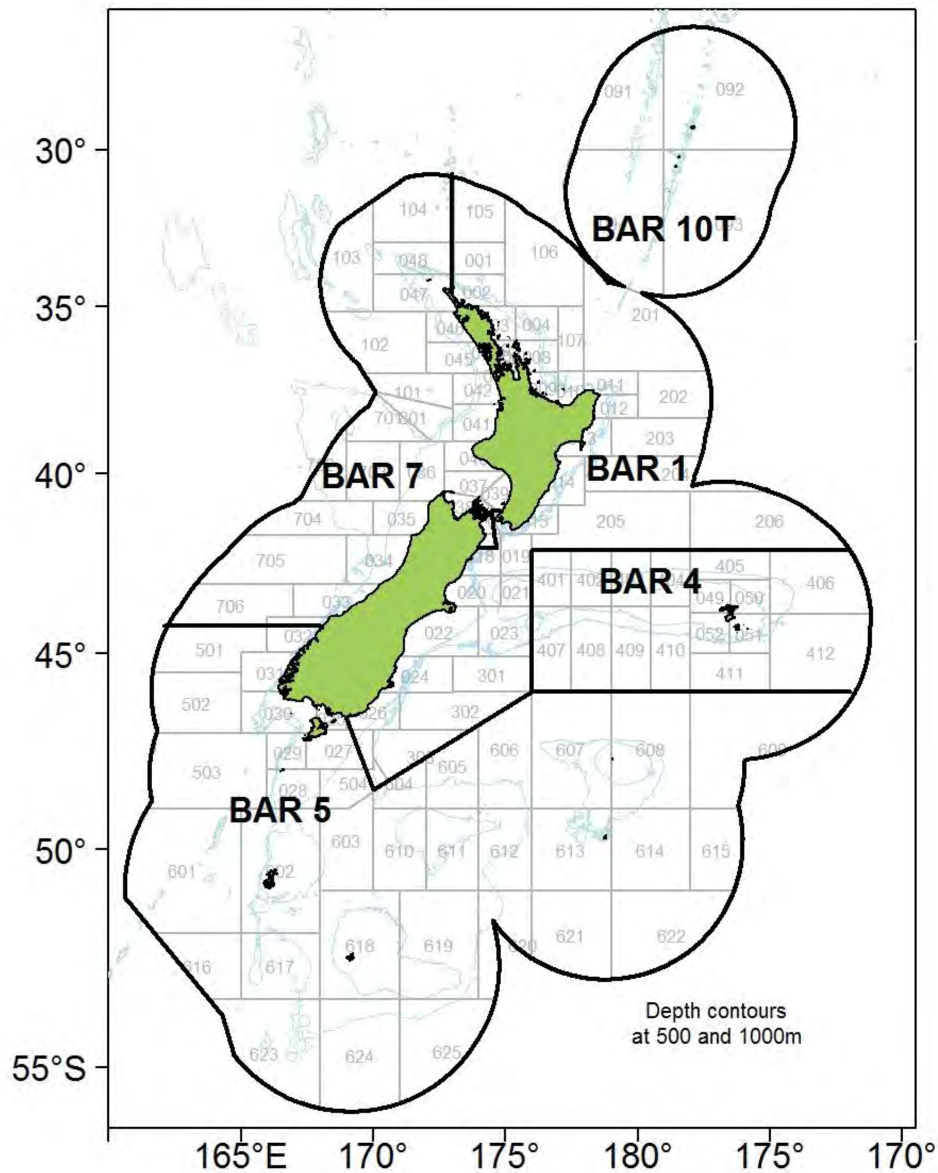

Figure 1: Map showing the administrative fishstock boundaries for BAR 1, 4, 5, 7 and 10T, including statistical areas, and the 500 m and 1000 m depth contours.

Previous characterisations of BAR 5 have been carried out using data from 1936–37 to 1983–84 (Hurst, 1988b), 1989–90 to 1997–98 (Harley et al., 1999), 1989–90 to 2007–08 Hurst et al. (2012), and 1989–90 to 2010–11 (McGregor, 2020). Norris (1988) documented catch limits from 1978–79 to 1986–87. Administrative Fishstock boundaries were based on hypothesised stock structure from commercial and research data up to the mid–1980s (e.g., Hurst (1988b); Hurst & Bagley (1989), see section 3.3). However, for the purposes of this report, fishstock area BAR 5 was subdivided into two main fishery areas (Figure 2), in order to allow for sub-area comparisons. Catch or effort restrictions and other management regulations prior to the introduction of the QMS are summarised below, in section 2.6, and by Hurst (1988b).

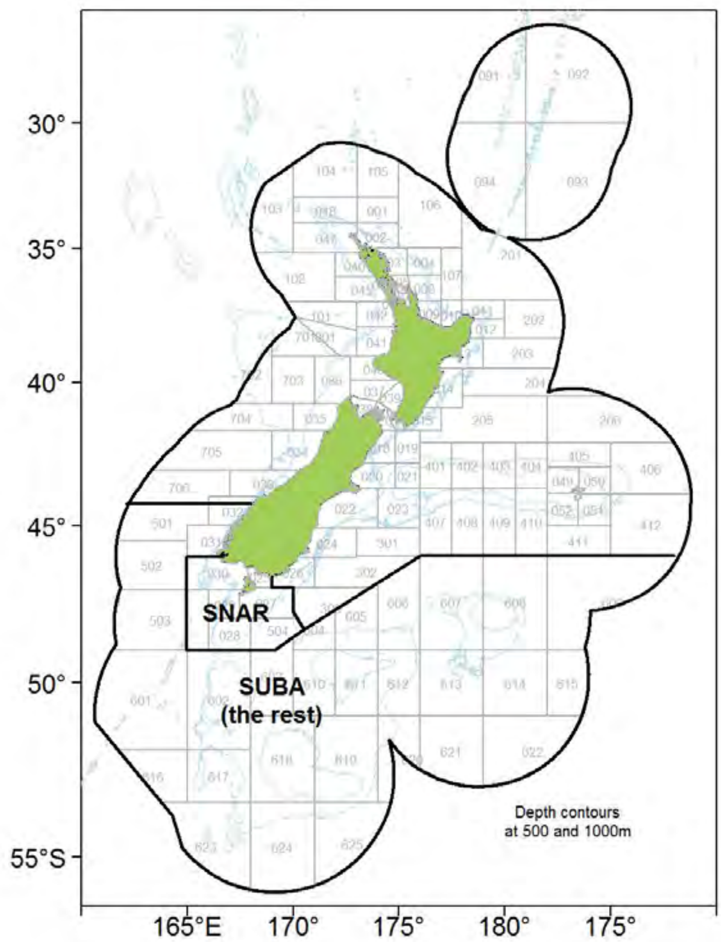

Figure 2: Map showing the areas used in the analysis, SNAR (the Snares) and SUBA (the Sub-Antarctic), including statistical areas, and the 500 m and 1000 m depth contours.

Commercial fishing for barracouta is recorded from 1936–37 but was less than 1000 t until the Japanese commenced fishing in 1967. By 1968 the catch was 11 313 t and peaked at 47 163 t in 1977, the year prior to the introduction of the EEZ. Table 1 provides a summary of the early history of the fishery from 1967 up to the first year of the Quota Management System (QMS), 1986–87. Foreign catch prior to 1978–79 was provided by each nation; note that barracouta were never reported by the U.S.S.R, even though they recorded catch of associated species from known barracouta grounds. The recent catch history from 1989–90 for BAR 5, is shown in Figure 3 and Table 2. For a more detailed description of the early history of the fishery to 1983, including catch by ports of landing and EEZ areas, see Hurst (1988a,b). Note that the definition of fishing years has changed over time (see Table 1). Since October 1983, fishing years have been 1 October 1 to 30 September 30, and, in this report, when fishing years are abbreviated, they are labelled as the most recent year (e.g., 1998–99 becomes 1999).

Table 1: Reported landings (t) by nationality from 1967 to 1987–88 (from Hurst (1988b), Ministry of Fisheries 2009).

Fishing year	New Zealand		Foreign			Total	
	Domestic	Chartered	Japan	Korea	USSR	(FSU)	(QMS)
[1]1967–68	232		2 276	–	[2]–	2 508	
1968–69	569	–	10 744	–	–	11 313	–
1969–70	643	–	13 613	–	–	14 256	–
1970–71	755	–	16 191	–	–	16 946	–
1971–72	1 100	–	14 421	–	–	15 521	–
1972–73	1 428	–	17 118	–	–	18 546	–
1973–74	2 850	–	9 981	–	–	12 831	–
1974–75	3 375	–	18 219	–	–	21 594	–
1975–76	2 503	–	10 560	–	–	13 063	–
1976–77	3 673	–	10 151	–	–	13 824	–
1977–78	4 697	0	34 357	8 109	–	47 163	–
1978–79	5 335	58	4 781	2 481	0	12 655	–
1979–80	7 748	6 679	4 339	3 879	47	22 922	–
1980–81	10 058	4 995	4 227	15	60	19 355	–
1981–82	12 055	11 077	2 813	373	0	26 328	–
1982–83	10 814	7 110	1 746	1 888	31	21 589	–
1983–83	7 763	2 961	803	1 115	0	12 642	–
1983–84	12 390	10 226	1 786	4 355	0	28 757	–
1984–85	7 869	10 425	1 430	5 252	0	24 976	–
1985–86	8 427	7 865	1 371	815	0	18 478	–
1986–87	9 829	13 732	1 575	742	0	25 878	[3]27 660
1987–88	9 335	12 077	896	609	0	22 971	[3]26 607

[1]Fishing years up to 1997 are calendar years, then 1 April–30 March to 1982–3083; 1983–3083 is a six month changeover period; then years are 1 October to 30 September.
[2]not recorded.
[3]The discrepancies between QMS and FSU total landings are due to under–30reporting to the FSU.

Three main management measures have influenced barracouta catches: the introduction of the 200 n. mile EEZ (from 1 April 1978) restricted the amount and location of catch by foreign vessels; the Deepwater Trawl Policy (from 1 October 1983 for barracouta) controlled development of the fishery by foreign chartered or larger domestic vessels (over 43 m length) by setting a total EEZ annual Total Allowable Catch (TAC) of 31 040 t; and lastly, the Quota Management System (QMS) (from 1 October 1986) set an initial Total Allowable Commercial Catch (TACC) of 9 010 t for BAR 5. This was increased slightly to 9 282 t in 1990–91 and later reduced in 1998–99 to a level of 7 470 t where it still sits in the 2014–15 year (Table 2).

In BAR 5 barracouta are primarily caught around the Snares shelf of depths between 50–200m. Catches are usually within or slightly over the quota limits, the largest over-catch being 27% in 2005–06. The last time BAR 5 catch exceeded the TACC by more than 10% was in 2007–08.

Table 2: Reported landings (t) of BAR 5 from 1989–1990 to 2014–15 and TACCs (t) from 1989–1990 to 2014–15.

Year	TACC	Landings
1990	9 281	5 960
1991	9 282	8 817
1992	9 282	6 897
1993	9 282	7 019
1994	9 282	3 410
1995	9 282	2 645
1996	9 282	4 255
1997	9 282	2 839
1998	9 282	6 167
1999	7 470	7 302
2000	7 470	6 205
2001	7 470	6 101
2002	7 470	5 883
2003	7 470	7 843
2004	7 470	6 919
2005	7 470	8 593
2006	7 470	9 479
2007	7 470	6 334
2008	7 470	8 561
2009	7 470	7 659
2010	7 470	6 951
2011	7 470	8 201
2012	7 470	7 071
2013	7 470	7 931
2014	7 470	6 886
2015	7 470	6 779

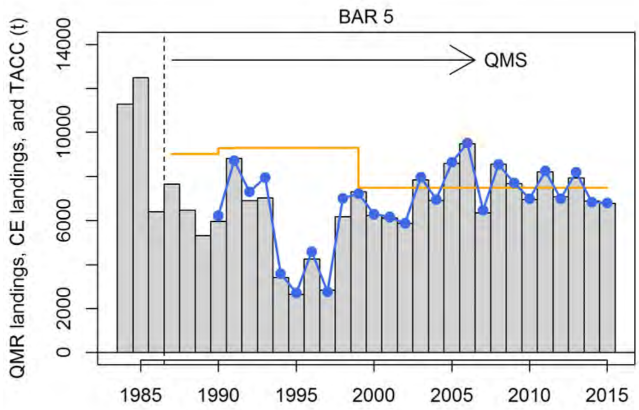

Figure 3: The QMR/MHR landings (grey bars), un-groomed catch effort landings (dotted blue line), and TACC (gold line) for BAR 5 from 1984 to 2015.

2.2. Recreational fisheries

There are two broad approaches to estimating recreational fisheries harvest: the use of onsite or access point methods where fishers are surveyed or counted at the point of fishing or access to their fishing activity; and, offsite methods where some form of post-event interview and/or diary are used to collect data from fishers.

The first estimates of recreational harvest for barracouta were calculated using an offsite approach, the offsite regional telephone and diary survey approach. Estimates for 1996 came from a national telephone and diary survey (Bradford, 1998). Another national telephone and diary survey was carried out in 2000 (Boyd & Reilly, 2002). The harvest estimates provided by these telephone diary surveys (Table 3) are no longer considered reliable.

In response to the cost and scale challenges associated with onsite methods, in particular the difficulties in sampling other than trailer boat fisheries, offsite approaches to estimating recreational fisheries harvest have been revisited. This led to the development and implementation of a national panel survey for the 2011–12 fishing year (Wynne-Jones et al., 2014). The panel survey used face-to-face interviews of a random sample of New Zealand households to recruit a panel of fishers and non-fishers for a full year. The panel members were contacted regularly about their fishing activities and catch information collected in standardised phone interviews. Note that the national panel survey estimate does not include recreational harvest taken under s111 general approvals (i.e., recreational catch taken aboard commercial vessels). Recreational catch estimates from the national panel survey are given in Table 3.

Table 3: Recreational harvest estimates for BAR 5 stocks. The telephone/diary surveys ran from December to November but are denoted by the January calendar year. The national panel survey ran through the October to September fishing year but is denoted by the January calendar year. A mean weight of 2.14 kg was used for the national panel survey.

Year	Survey	Number	CV	Estimated harvest (t)
2000	National	2 000	51%	2–7
2012	Panel Survey	666	-	1.4

2.3. Māori customary fisheries

No quantitative information is available on the current level of customary non-commercial take.

2.4. Illegal and misreported catch

No quantitative information is available on the current level of illegal and misreported catch.

2.5. Other sources of mortality

There may have been considerable amounts of barracouta discarded prior to the introduction of the QMS, either because of restrictions on quota under the deepwater policy, catch restrictions on foreign licensed vessels, low value, or undesirable small size fish. Barracouta may have been under-reported by the U.S.S.R prior to the introduction of the EEZ in 1978 (Table 1) because the fleet size and area of some activities was similar at times to that of the Japanese (e.g., east coast South Island, Fenaughty & Bagley (1981)). Catch under-reporting since the introduction of the QMS is unquantified but may have occurred for reasons of low value, small size or quota limitation. There is also likely to be some mortality associated with escapement from trawl nets.

2.6. Regulations affecting the fishery

Current and historical limits on catch or effort in barracouta fisheries are described in section 2.1. Codend minimum mesh-size regulations that currently apply to the trawl fisheries are 60 mm for Sub-Antarctic (FMA 6) fisheries and FMA 5 south of 48 °S; and 100 mm elsewhere. From 1 October 1977, the cod–end mesh-size change took effect at the boundary between the Snares Islands fishery and Auckland Islands fishery (the old EEZ area F/E boundary), which was at 48° 30'S. The management area boundary was changed on 1 October 1983 to 49 °S (now the FMA5/6 boundary) but the codend mesh size change takes effect at latitude 48 °S to allow for targeting of squid around the Snares Islands (Hurst, 1988b).

Protection of bycatch species in multi-species fisheries (particularly relevant in trawl fisheries such as barracouta) is mainly through the QMS, with quotas in the year 2014–15 set on 628 fishstocks. Catch of protected species such as seabirds and furseals is monitored through the Observer programme and all trawl vessels have been required to deploy seabird mitigation devices to minimise interactions with trawl warps since April 2006 (Ministry of Fisheries 2010). From 1 October 2008, all commercial fishers have been required to state on their catch effort returns whether they have caught any non-fish or protected fish species, and if so, to give details on the Protected Species Catch Return.

3. Biology

3.1. Distribution

Barracouta have been recorded in research bottom trawls in 5–670 m depth (Anderson et al., 1998). They are recorded in midwater trawls and occasionally by tuna longliners (Bagley et al., 2000). The main distribution is around the mainland of New Zealand, shallower areas of the Chatham Rise (Mernoo, Veryan and Reserve banks, Chatham Islands), and occasionally at the Auckland Islands. Tuna longliners have recorded barracouta in deeper waters to the north-east of the North Island and south-east and west of the South Island, although some early records may have been the black barracouta *Nesiarchus nasutus*. Distribution varies seasonally with extensive spawning migrations (Hurst & Bagley, 1989), leading to the definition of 4 key fishery areas described above (Figure 1). Barracouta are targeted or caught as bycatch of associated key target species; arrow squid (*Nototodarus spp.*), jack mackerel (*Trachurus spp.*), and blue warehou (*Seriolella brama*) trawl fisheries: and to a lesser extent, gemfish (*Rexea solandri*), and hoki (*Macruronus novaezelandiae*) trawl fisheries (see section 6 for details by fishery area).

Juvenile barracouta occur in the shallower part of the mature fish depth range. Age 0+ and 1+ fish appear to have an even more restricted coastal range and have not been recorded from the Auckland Island area and only rarely from the eastern Chatham Rise. To some extent this may be a reflection of the deeper sampling by research and commercial sampling in these areas (often over 200 m). A summary of research trawl survey data (Hurst, 1988a) provided catch rate plots for vessels using the same gear. Surveys off Southland found higher catch rates in shallow coastal waters of Southland and Stewart Island compared with offshore.

Biomass trends and length frequencies for key research survey series since 1990 that cover appropriate depth ranges for barracouta and have sampled lengths are shown in Appendix A. These include *Tangaroa* surveys off Southland (Hurst & Bagley, 1997*b*).

The Ministry for Primary Industries observer sampling programme has collected length frequencies and otoliths from commercial fisheries mainly in the SNAR, and SUBA areas (Appendix A, Tables 7 –12 and see section 5.1). Data for these areas have been summarised by year and show that fisheries in the SNAR area catch proportionately more small fish (1+, less than 45 cm) than other fisheries, mainly due to the depths and target species (barracouta, squid and jack mackerels) and codend mesh size (60 mm south of 48° S in the SNAR area).

3.2. Spawning

Sexual maturity is reached at about 50–60 cm fork length (FL) at about 2–3 years of age (Ministry of Fisheries 2010) (Hurst et al., 2000). Mature-size fish occur all around New Zealand, and in shallower waters around the Auckland Island area in tow depths of 30–350 m (Hurst et al., 2000).

Known spawning areas and seasons from research surveys and observer records were summarised by Hurst (1988a,b) and Hurst et al. (2000). Spawning grounds were identified around the Southland region, particularly around Stewart Island. (October/November), and around the Auckland Island (January/February), see Figure 4, although indications of spawning in January at the Auckland Islands are still based on small numbers of fish. There was also some evidence of an extended or secondary summer spawning season off Southland (January/February) from research surveys (Hurst & Bagley, 1994).

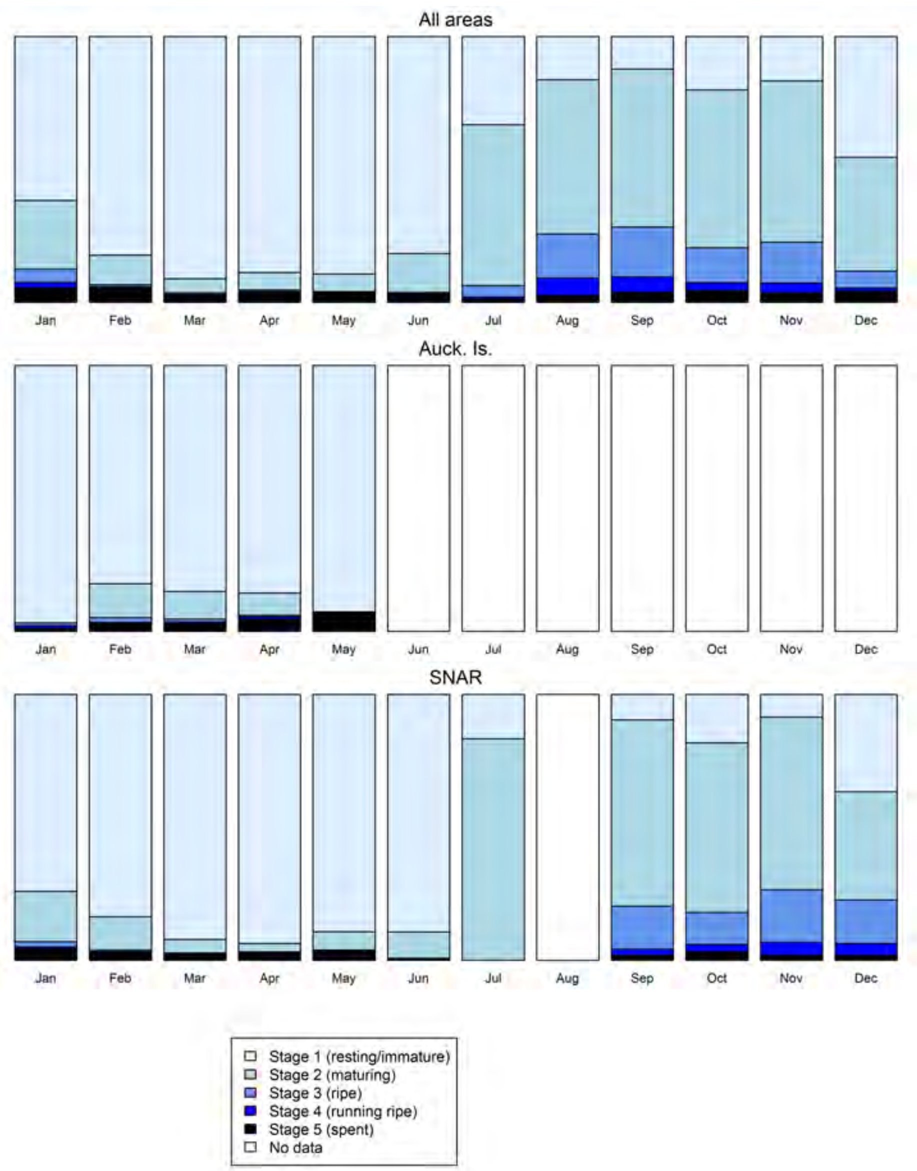

Figure 4: Female gonad stage from observers in Snare's (bottom panel), Auckland Is. (middle panel) and all staged female barracouta from around New Zealand (top panel).

Observer information is updated here, covering the fishing years 1990–2015 (section 5 and Appendix A).

There were a few ripe fish in February, but mostly spent fish from February to May. Indications of spawning activity remain consistent with those noted by Hurst et al. (2012); McGregor (2020).

Tagging results (Hurst & Bagley, 1989) suggest extensive (up to 500 n.mile) northward spawning migrations of barracouta tagged in summer off the east coast of the South Island (mostly Kaikōura) and recaptured in winter/spring off the east coast North Island. No tag returns were received from fish tagged off Stewart Island. Given the lack of information on stock structure and the inconclusive results from tagging off Southland, it is difficult to conclude whether there is migration out of or into Southland.

Surveys off Southland in various seasons by *Shinkai Maru* and *Akebono Maru No. 3* found evidence of spawning. Only 25% of the biomass of mature sized fish were found in the area in spring (October/November), suggesting some fish may move out of the area to spawn (Hurst & Bagley, 1997*a*), although the potential difference in vessel catchability cannot be discounted.

3.3. Stocks and spatial distribution

Stock structure of barracouta was reviewed by Hurst (1988a) and Hurst & Bagley (1989) based on seasonality of commercial fisheries, research surveys up to 1986, and movements of tagged fish. More recent relevant information comes from a summary of all research and commercial observer data on areas of importance for juveniles (described above in section 3.1) and spawning (Hurst et al., 2012).

Langley & Walker (2002) reviewed barracouta stock structure around the South Island based on published literature, research survey biomass trends, commercial and research survey size frequencies from which they inferred relative year class strengths (YCS), and commercial catch and unstandardised catch rates. They found that fish off Southland appear to be less abundant in winter/spring and suggested, on the basis of catch rates and extrapolated year class strengths, that they have stronger affinities with the East Coast South Island (ECSI) than the West Coast South Island (WCSI) stock.

The approach of examining trends in trawl surveys, CPUE and YCS between the main fishery areas (ECSI, Snares (SNAR), WCSI and West Coast North Island (WCNI)) was updated by Hurst et al. (2012). Although they found similarity in patterns of strong and weak year classes between ECSI, WCSI, and the Snares (in 11 of 16 years), it was concluded these similarities may not be indicative of stock structure. It is possible they are caused by strong environmental influences on recruitment which could be quite similar in the three areas.

Hurst et al. (2012) suggested the current management boundaries be retained, although mentioned the west coast stock structure may be more complex than assumed by these management areas. Stock affinities of BAR 5 remain uncertain, with the possibility of overlap with BAR 1 and BAR 7. The updated analyses here do not suggest any change in approach to assessment monitoring is required.

3.4. Climate and recruitment

Dunn et al. (2009) carried out correlations and association tests between YCS and abundance (trawl survey or CPUE) indices for 56 fish species with 20 climate indices. For barracouta, there were significant relationships for some west coast South Island (2+) and Tasman Bay\Golden Bay (0+) YCS indices (from WCSI trawl surveys) with various Kidson weather patterns and Trenberth pressure indices, and with the Southern Oscillation Index (SOI) (0+ only). BAR 1 (Langley & Walker, 2002) and BAR 5 (Harley et al., 1999) CPUE indices also showed significant correlations with Kidson or Trenberth indices. Of these, possibly the Tasman Bay\Golden Bay (0+) YCS with the Zonal Kidson regime showed the most potential because there were several cycles encompassed within the survey time span, but with only 7 data points, a longer time series is required to determine if there is any relationship. Potential climate relationships were not further investigated here or in the previous characterisations by Hurst et al. (2012) or McGregor (2020), except to note that in 11 year classes shared between ECSI, SNAR, and WCSI (section 3.3, Hurst et al. (2012)), four (1989, 1996, 1999, 2003) of the six high YCS came from La Niña or average SOI conditions and four (1991–94) of the five low YCS came from El Niño conditions.

3.5. Ageing

Age determination of otoliths was validated by Harley et al. (1999). They analysed otoliths from a time series of four research trawl surveys off Southland and found that estimated ages from counting probable annual bands in whole otoliths matched well with distinct length frequency modes for 0+ to 3+ fish, and there was a progression of a strong year class (1989). Mean length at age data for barracouta from a 1984 survey around the Chatham Islands have also been published (Hurst & Bagley, 1987), but the technique was unvalidated. Horn et al. (2012) developed catch-at-age for fishing years 2004–05 and 2009–10 for the Southland trawl fishery. The mean age for males and females was 3–4 years and the right hand tail extended to 11 years (Appendix A; Figure 9 and Table 15).

3.6. Growth curves

Von Bertalanffy parameters for each sex are presented for Southland barracouta in Table 4 (Horn, 2002).

3.7. Natural mortality

The best estimate of natural mortality (M) for New Zealand barracouta is considered to be 0.3 (Hurst et al., 2012) which implies a maximum age of 15 years old, based on the formula of Sparre et al. (1989):

$$M = log_e(100)/A_{max}$$

where A_{max} is for the maximum age reached by 1% of the population. Harley et al. (1999) found barracouta females up to 11 years old in the relatively heavily fished Southland population, which suggests a slightly higher maximum age is probable and that M is unlikely to be over 0.4 (Hurst & Bagley, 1987).

3.8. Length-weight relationships

Length-weight relationships reported for barracouta from BAR 5 are given in Table 4.

Table 4: Estimates of biological parameters for fish stock BAR 5.

Estimate	**Value**		**Source**
Natural Mortality			
M	0.3 (likely < 0.46)		Hurst (unpub. data)
$W = a(length)^b$			
a	0.0075	Both sexes	Hurst & Bagley (1992)
b	2.90	Both sexes	
von Bertalanffy growth parameters			
K	0.336	Male	Horn (2002)
t0	-0.35	Male	
L_∞	81.1	Male	
K	0.259	Female	
t0	-0.6	Female	
L_∞	89.3	Female	

3.9. Feeding and trophic status

The following section summarises information on feeding and trophic studies on barracouta from around New Zealand and abroad. Feeding records are available from most of the main areas except off the west coast of the North Island (Stevens et al., 2011). Of 15 542 barracouta (mainly 30–100 cm fork length) sampled, 48% had stomachs containing food. The highest proportion of empty stomachs (79%) was from the North Island area, possibly because most of the sampling was during the spawning season.

Crustaceans were the most important prey overall, occurring in 77% of stomachs with food. The main crustaceans identified were euphausiids (74%), and *Munida gregaria* (4%). Teleosts comprised 18% overall, with hoki the most commonly identified (4%), mainly from the WCSI, and some myctophids (1%) and sprats (0.6%). Cephalopods, particularly squid, were also important (9%). In total, at least eight main invertebrate groups in four phyla and 24 teleost (including two mesopelagic) species were identified.

There were no major differences in diet between smaller (up to 60 cm) and larger fish. However, in northern and western areas (North Island and Challenger), teleosts were more important in the diet (about 50%) than off the east and southern coasts of the South Island and at the Chatham Islands (about 10%). Euphausiids (about 40–60%) and cephalopods (1%) were correspondingly less important in the north and west and more important in the other areas (about 70–90% euphausiid and 6–15% squid). *Munida gregaria* was locally important (up to 9%) off eastern and southern coasts of the South Island.

These findings are consistent with other records (Thomson, 1892; Thomson & Anderton, 1921; Phillips, 1926; Graham, 1939; Mehl, 1969; O'Driscoll, 1998; Russell, 1983; Hurst, 1980) from around New Zealand (i.e., euphausiids and fish were important in all studies; *Munida gregaria*, hoki and sprats are locally important). Studies in south-east Australian waters, found the euphausiid *Nyctiphanes australis* was the main item in the diet for December–July, with teleosts (mainly anchovy, *Engraulis australis*) of secondary importance (Blackburn, 1957), highlighting the significance of euphausiid. They are different to studies from South Africa, where teleosts are more important in the diet than crustaceans (Nepgun, 1979; Griffiths, 2002), and their importance increases with increasing fish size (Griffiths, 2002). Barracouta have been recorded in the diet of New Zealand fur seals, *Arctocephalus forsteri* (Street, 1964; Tate, 1981).

3.10. Catch at age

Barracouta sampling by observers has provided good representation of the Snares barracouta catch, with an average of 156 samples per annum (across a four-month season) since 1993 and over 4000 tows sampled (with about 30–50 fish measured per sample). Representativeness of sampling around the Auckland Islands has been reasonable since 1994, but the number of samples is lower, averaging about 36 samples across a mainly three-month season and this has dropped off in Auckland Islands in the last ten years. Numbers of fish measured annually are mostly less than 500 for the Auckland Islands.

Age sampling in Southland has achieved over 500 otolith pairs per year since 2001 (mostly over 800), with over 1000 otolith pairs since 2011. This could be a valuable resource if aged and used as an input to stock assessment.

Optimisation for future observer sampling will depend on whether both length and otolith sampling are also to be optimised and whether a direct age sampling approach or age-length keys are to be used. If the direct age sampling approach is to be used, 500 otoliths from the key catching season (January–April) would be adequate. Length sampling in the Snares area is adequate and could possibly be optimised to reduce oversampling in some years.

4. Current and Associated Research Programmes

4.1. Fisheries New Zealand

There are no specific ongoing research programmes for barracouta. Ongoing research trawl surveys in two areas routinely record catches and length frequencies of barracouta in appropriate depths but these do not occur in the Southland region.

5. Fishery Independent Observations

5.1. Research surveys

Bottom trawl surveys in areas and depths appropriate to catch barracouta have been conducted since the early 1980s; some of these were designed to estimate barracouta abundance (summarised by Hurst & Bagley (1997*b*)). The most recent surveys relevant to BAR 5 were conducted by *Tangaroa* during 1993–1996 (Table 5). Biomass in barracouta declined during this trawl survey series in conjunction with relatively poor recruitment after the strong 1989 year class. There was good correlation with observer length frequencies for the fishery for larger (>55 cm) fish (Hurst & Bagley, 1997*a*) and between ages frequencies determined for the survey and observer data using the survey otoliths and age-at-length key (Harley et al., 1999). This survey appears to be appropriate for monitoring the barracouta in BAR 5 at the main time that the fishery operates.

Table 5: Biomass indices (t) and coefficients of variation (CV) (Assumptions: areal availability, vertical availability and vulnerability = 1).

Area	Vessel	Trip code	Date	Biomass	% CV
Southland	Tangaroa	TAN9301	Feb-Mar 93	11 587	18
		TAN9402	Feb-Mar 94	6 151	20
		TAN9502	Feb-Mar 95	4 539	17
		TAN9604	Feb-Mar 96	7 693	19

In the summer of 2016 *Tangaroa* sailed down to Snares and Stewart islands. (Roberts et al., 2018) and sampled strata in common with the 1993–96 series. These data are not summarised here because they did not cover the full survey area.

6. Fishery Dependent Observations

6.1. Catch and effort data source

Catch and effort data were requested from the Ministry for Primary Industries catch-effort database "warehou" as extract 10432. The data consist of all fishing and landing events associated with a set of fishing trips that reported a positive landing of barracouta in BAR 5 between 1 October 1989 and 30 September 2015. The fields from the database tables requested are listed in Table 17 (in Appendix B).

The estimated catch associated with the fishing events was reported on the general Catch Effort Landing Returns (CELR) and the more detailed Trawl Catch Effort and Processing Return (TCEPR). The green weight associated with landing events was reported on the bottom part of the CELR forms, or, where fishing was reported on the TCEPR, on the associated Catch Landing Return (CLR). TCEPR forms record tow-by-tow data and summarise the estimated catch for the top five species (by weight) for individual tows. CELR forms summarise daily catches, which are further stratified by statistical area, method of capture, and target species. Trawl vessels less than 28 m in length used either CELR or TCEPR forms; trawl vessels over 28 m used TCEPR forms. From 1 October 2007, the Trawl Catch effort Return (TCER) form replaced the CELR form, and it summarises daily estimated catches up to the top eight species for all vessel sizes. The dominant form type from the requested data was TCEPR (98%). The working group suggested using TCEPR data given such a high a proportion of the information is captured on the TCEPR form type. Using tow-by-tow data allows for the trend in catch rates to be modelled using smaller spatial and temporal scales, and also enables additional factors influencing CPUE to be included (such as tow distance or bottom depth) (Parker & Fu, 2011). Although the analysis presented here uses TCEPR data, data from all form types were restratified for summarising and reporting.

Information on total harvest levels are provided via the QMR/MHR system, but only at the resolution of Quota Management Area. The catch-effort and landing returns report catches at the level of individual fishing events, and the fishers are only required to report the top five species in their catch.

The extracted data were groomed and restratified to derive the datasets required for the characterisation and CPUE analyses using a variation of the Starr (2003) data processing method as implemented by Manning et al. (2004), with refinements by Blackwell et al. (2006), and further modified for this study. The method allows catch-effort and landings data collected using different form types that record data with different spatial and temporal resolutions to be combined. It also overcomes the main limitation of the CELR reporting systems (frequent non-reporting of species that make up only a minor component of the catch). The procedure was developed for monitoring bycatch species in the Adaptive Management Programme, and is comprehensively described by Manning et al. (2004) and Starr (2007).

6.1.1. Summary of catches

All tables and figures relating to characterisation of barracouta fisheries are contained in Appendix B (Tables 17–26, Figures 17–23 and Appendix C (Tables 27–30, Figures 24–36).

The reported QMR/HMR landings, catch-effort landings (un-groomed), and TACC for BAR 5, from 1984 to 2015 are shown in Figure 17. The ungroomed catch-effort landings in the raw dataset are similar to the reported MHR landings throughout the time series. The MHR landings have slightly overrun the TACC in five of the last ten years in BAR 5 (Table 25, Figure 17).

The landings data provide a verified green weight landed for a fish stock on a trip basis. However, landings data include all final landing events where a vessel offloads catch to a Licensed Fish Receiver and interim landing events, where catch is transferred or retained, and may therefore appear subsequently as a final landing event. The procedure of Starr (2007) separates final and interim landings based on the landing destination code, and only landings with destination codes which indicate a final landing are retained (see table 2 of Starr (2007)).

Table 19 summarises the number of landing events for the major destination codes in the dataset. The proportion of landing events recorded under "T" (transferred to another vessel) and "R" (retained on board) destination codes (both defined as interim landing events by Starr (2007)) varies by area. For "T" events, the proportions for BAR 5 was 4.6%, for events. This represented 6.0%, by weight for the whole series (Table 19). For "R" events, the proportions were 6.8% for events and 2.5% for green weight. It was unknown how the catches from "T" trips are recorded, because the transferred catches could be landed by foreign vessels to ports outside New Zealand. Other interim landing events (retained as bait, in holding receptacles, or on board) were dropped (after Starr (2007) & Hurst et al. (2012)). The weight, number of records, and destination of each potential landed state is given in Table 19. Details of the data corrections by imputation and invalid record removal during the grooming process are given in Table 22. The retained landings, interim landings, and total landings dropped during data grooming are shown in Figure 18. The estimated catch and landings removed from the dataset in this process are generally insignificant throughout the time series.

The main processed state for barracouta is "Dressed" (includes "Dressed", and "Headed and gutted") in the offshore fisheries carried out by larger vessels. The conversion factors for barracouta have been static since the full implementation of the QMS (Ministry of Fisheries 2008) for BAR 5. This means no adjustment was needed for the amount of green weight associated with processed weight.

The retained landings were allocated to the effort strata using the relationship between the statistical area for each effort stratum and the statistical areas contained within each fish stock. Difficulties arise with effort strata associated with statistical areas that straddle stock management area boundaries, because the proportion of catches to be allocated to each QMA cannot be determined. Statistical areas were allocated to BAR fishstocks based on the location of the centroid of each area ("centroid" method). Details of the retained landings in unmerged and merged datasets and estimated catches in the groomed and merged datasets, by QMA, are given in Table 25. The recovery rates, defined as the groomed and merged landings as a proportion of the groomed and unmerged landings (after Manning et al. (2004), are plotted in Figure 19.

The reporting rate, defined to be the annual estimated catch as a proportion of the retained landings in the groomed and merged dataset, was also calculated (Figure 21). The TCEPR/CLR reporting rate is close to 90% or above in most years for BAR 5 indicating a fairly consistent match between the recorded statistical areas on the TCEPR and the stocks reported on the CELR on a trip basis.

The proportions of estimated catches and retained landings by form type for each fish stock are shown in Figure 22. For BAR 5 most of estimated catches are recorded on TCEPR (with the landings recorded on the corresponding CLR forms).

Trips recording barracouta catch and using CELR forms generally report no estimated barracouta catch more often than trips using TCEPR forms (as found for silver warehou by Parker & Fu (2011)). The percentage of zero estimated catch (when barracouta is landed) on CELR reported trips generally ranges from about 10 to 50% in BAR 5 (Table 21). On TCEPR recorded trips, the percentage is mostly less than 20% and mostly less than 10% in BAR 5.

There is a clear decreasing trend in the proportion of zero tows for BAR target off Southland (Figure 34).

Though estimated catches tend not to be recorded when catches are small (because vessels only report the top five species caught), overall the estimated catches capture approximately 90% of the harvest reported via the MHR/QMR system for BAR 5 (Table 25). There appears to be a reasonably close match between estimated catch and reported landings at the trip level.

6.1.2. Fishery summary

Barracouta fisheries occur around east of Stewart Island along the 200 m contour of the Stewart-Snares shelf and off the Auckland Islands (Figure 28). Highest catches during 1990–2015 (Figure 31) were in Statistical Areas 025, 027, and 028 in Southland area.

The type of vessels that catch barracouta in the Southland region range between 55 and 105 m in length. Since 1998 the most dominant vessel are the larger vessels around the 105 m length. (Figure 23). These vessels are mostly from foreign nationalities, mainly Ukraine, Korea, and to a lesser extent, Vanuatu and Dominica, all of which have increased their catches over the time period (Figure 23, Table 27). In the last five years there is a noticeable increase in catch from New Zealand owned vessels. A high proportion of catch in the early 1990s was taken by vessels of unrecorded nationality. The main difference to earlier (pre-QMS) participation in the fishery (Table 1) is that Japanese vessels are no longer present and that USSR vessels are now from the Ukraine and reporting significantly more barracouta catch.

6.1.3. Southland region

Barracouta from Southland are caught mainly during the October–May period, predominantly in Statistical Area 028, and to a lesser extent Statistical Areas 025, 027, 029, and 504. They are taken mainly by bottom and mid-bottom trawls with a smaller amount of mid water trawls, targeting barracouta and arrow squid (Figure 30). Target species of secondary importance are jack mackerel, mainly in Statistical Area 028, and blue warehou, mainly in Statistical Areas 025 and 027 (Figure 31). Main months of fishing by key target species are: barracouta October–April; squid January–April; and jack mackerel January–April (Figure 32). The proportion of barracouta catch targeted is highest (over 50%) in areas 025, 027, and 029, but under 25% in the main area, 028, except from 2004–2007 (Figure 33). Proportion targeted is consistently highest in October–December, but also higher during February to April from 2003 to 2007 (Figure 33). Tows reporting the lowest proportion of zero tows with barracouta catch are barracouta (mostly <30% 1990–2000 and <10% from 2001), jack mackerel and blue warehou (< 40% from 1999) (Figure 34). The location of highest barracouta catch within the Southland area from 2006 is consistently to the east of Stewart Island and south of the Snares Islands, with the area to the north of the Snares important in most years (Figure 27). Catches at the Auckland Islands are sporadic and relatively minor, but occur mainly to the north. The combined distribution of tows for the major target species encountering barracouta within the South region shows the overlap between the four main target species, although squid occur more extensively at the Auckland Islands (Figure 35).

6.2. Observer data

All tables and figures relating to observer data collected from barracouta fisheries are contained in Appendix A (Tables 7–16 and Figures 7–16).

Observer catch per tow analysis was also conducted. The high coverage on Foreign Chartered Vessels (FCV) since 2013 means the observer data can provide an independent validation of reported catches for vessels catching barracouta in BAR 5. Tows were requested from the Centralised Observer Database (cod), where barracouta were observed.

6.2.1. Length and age sampling

The Ministry for Primary Industries Observer Programme has collected barracouta length, weight, female gonad stage, and otoliths from various fisheries since 1985 (Appendix A). The use of observer data to help determine distribution of adults and juveniles, spawning fish, and stock structure is described in section 3. Tables 8–14 show the number of length, gonad and otolith samples collected in the Southland area (Appendix A).

The representativeness of observer sampling of barracouta was evaluated by plotting the proportion of landed catch for each year by area and by month and statistical area as circles, and overlaying this with the proportion of the observed catch for those same cells as crosses (Figures 10 and 11). If the proportions are the same, the observer sampling is representative of the catches; if over- or under-sampling has occurred, the crosses are either larger or smaller (respectively) than the circles. The Snares and Auckland islands were combined to make one area (Southland) as for the catch and effort analyses. Sampling was representative of catch distributions for Southland, by statistical area and month (Figures 10 and 11).

Most samples appear to measure about 30–50 fish. For the Snares, the average of 164 samples per year has resulted in an average of 6 400 fish measured per year (Tables 8 and 10) and provides a good time series for monitoring YCSs moving through the fishery (section 3.3, Hurst et al. (2012)). The average number of tows sampled for the Auckland Islands is 22 with the average number of fish measured per year being 362 (Tables 9 and 11).

The best otolith collection for barracouta around New Zealand comes from the Southland area where over 500 otoliths have been collected per year since 2001 (Table 12).

6.2.2. Length and age frequencies

Scaled length frequencies were determined using NIWA ‘catch-at-age’ software (Bull & Dunn, 2002) which scales the length frequency from each catch up to the tow catch, sums over catches in each stratum, scales up to the total stratum catch, and then sums across the strata, to yield overall length frequencies. Numbers of barracouta were estimated from catch weights using the length-weight relationship (Table 4) for trawl surveys in BAR 5. No weight data were collected by observers.

The size of fish caught by commercial vessels varies by area, due to a combination of season, depth of target fishing and cod-end mesh size (Figures 13–16). The smallest fish (down to about 30 cm fork length) are encountered in the Sub-Antarctic, where cod-end mesh of 60 mm is allowed south of 48° S and the fishery operates in areas and depths where smaller fish are present. Modal classes at 1+, 2+, and 3+ were able to be determined.

Maximum sizes of fish caught in Southland occasionally reach up to 90 cm fork length up until about 1999, but the maxima have been nearer 80 cm in the years since, to 2015.

The analysis of modal transition is not updated here following McGregor (2020). As in Hurst et al. (2012), modal transition is not generally clear in the length frequencies. In Southland there is often a dominant mode around 60–70 cm and sometimes a smaller mode around 50 cm.

Horn et al. (2013) developed catch-at-age for fishing years 2004–405 and 2009–410 for Southland. The mean age for males and females was 3–4 years and the right-hand tail extended to 11 years (Figure 9, Table 15).

6.2.3. Female maturity

Observer collected data on female maturity stage has used a 5-stage gonad scale (immature/resting, maturing, ripe, running ripe, spent). Distribution of 0+, 1+, immature, and mature fish from these and survey data combined were summarised by Hurst et al. (2000) and are discussed in section 3.

The number of female barracouta staged from 1990 to 2015, for the Snares and Auckland islands are given in Tables 13 and 14. As for lengths measured, the numbers staged for the Snares are the highest, mostly over 400 per year, up to nearly 8000. Data for the Snares and Auckland Island areas have been combined across all years to establish a pattern of spawning activity by month (Figure 4). The location of ripe (stage 3) and running ripe (stage 4) fish is shown for January–June and July–December (Figures 7 and 8).

7. CPUE

All tables and figures relating to CPUE analyses of the main barracouta fisheries are contained in Appendix D (Tables 31–439 and Figures 38–463).

In the previous analyses McGregor (2020) three models were fitted for the Southland region (Model 1a, Model 1b, and Model 5). Model 1a is a lognormal model fitted to merged data. Model 1b is a delta lognormal model which is fitted to unmerged data, that were restricted to variables in Table 6.
Model 5 is a delta lognormal model fitted to unmerged data that had been restricted to tows that targeted barracouta. Of these models, Model 1b and a slightly varied version of Model 5 (added blue warehou target tows along with barracouta target tows) are presented in this report. The selected model for Southland from McGregor (2020) was a lognormal model fitted to the merged dataset with major target species, major statistical areas, and months October–May selected. For this analysis, trip level or merged data were investigated but the unmerged CPUE analysis (Model 1b) was preferred because most of the catch information is recorded on TCEPR form types. Using tow level data allows for the trend in catch rates to be modelled using smaller spatial and temporal scales, and also enables additional factors influencing CPUE to be included, such as tow distance or bottom depth (Parker & Fu, 2011). The main fishing

Table 6: Variables offered for CPUE standardisation along with description and type of variable.

Variable	Description	type of variable
fish_year	Fishing year	factor
Trip key	Trip unique key	factor
vessel_key	unique vessel identifier	factor
target_species	Species recorded in logbook as targeted	factor
start_stats_area_code	Statistical area the tow started in	factor
fish_month	Fishing month	factor
primary_method	Primary method for the trawl	factor
best_start_time	time of day the trawl started (24hr unit)	factor
start_latitude	starting latitude coordinate	Continuous
start_longitude	starting longitude coordinate	Continuous
effort_depth	recorded trawl depth	Continuous
effort_height	trawl height	Continuous
effort_width	Door width	Continuous
fishing_distance	difference between start lat and long and finish lat and long	Continuous
distance2	derived distance which is fishing duration × effort speed	Continuous
fishing_duration	recorded trawl time	Continuous

method for barracouta was trawl, with bottom, mid-bottom, and mid-water trawl methods being important. Therefore, all trawl data were included. A set of core vessels was identified for each dataset, requiring each core vessel to have at least four consecutive years in the fishery with at least 40 tows per year that could potentially catch barracouta. These tows were defined as all tows from a trip where barracouta were caught. Core vessels under this criterion retained 82% of the estimated barracouta catch. These vessels were identified from the tow level data. Core vessels identified were also used in all subset analyses using the tow level data.

Estimates of relative year effects in each CPUE model were obtained from a stepwise multiple regression method in which the data were modelled using a lognormal generalised linear model following Dunn et al. (2000). A forward stepwise multiple-regression fitting algorithm (Chambers & Hastie, 1991) implemented in the R statistical programming language (R Core Team, 2016) was used to fit all models. The algorithm generates a final regression model iteratively and used the fishing year term as the initial or base model in all cases. The reduction in residual deviance relative to the null deviance, R^2, is calculated for each single term added to the base model. The term that results in the greatest reduction in residual deviance is added to the base model if this would result in an improvement in the residual deviance of more than 1%. The algorithm then repeats this process, updating the model, until no new terms can be added. A stopping rule of 1% change in residual deviance was used because this results in a relatively parsimonious model with moderate explanatory power (Parker & Fu, 2011). Alternative stopping rules or error structures were not investigated. Note that while R^2 values are reported, they do not necessarily assist in helping choose between the various models.

The variables offered to the models are listed in Table 6. The continuous variables were offered as third order polynomials. Year indices were standardised to the mean and were presented in canonical form (Francis, 1999).

The dependent variable was the log-transformed estimated catch per tow. Only positive catches were retained, except for the delta-lognormal model fitted to the unmerged dataset (Model 1b). These used a binomial model with the same variables available for the lognormal part of the model, then multiplied the fitted probability of a non-zero catch by the fitted CPUE for each year. This was important because of the trend in the proportion of zero tows (see section 6.1.1).

The four models presented to the MPI working group were: delta lognormal model using all tow level data (Model 1b), a lognormal observer model, a lognormal model using squid targeted tows in Statistical Area 028, and finally a lognormal model using tows targeting barracouta and blue warehou. Of these, the index thought to be the most representative index of abundance for barracouta, was a squid targeted analysis in Statistical Area 028. This was chosen because it had a very similar trend to the tow level data analysis (model 1b) and the observer index.

Another index that the working group suggested could be used as a sensitivity index for use in a stock assessment model was the tow level, barracouta (BAR) and blue warehou (WAR) targeted index. This analysis contained mutually exclusive data to the squid analysis but displayed similar trends over the past 15 years.

The following sections discuss and present the two preferred CPUE series above. For completeness the tow level model (Model 1b) and observer model are presented in Appendices D and D. More information on changes in markets, market prices, and fishing practices is also required to interpret trends as barracouta are a relatively low value species and there is some evidence of fishers being able to avoid them by changing fishing gear or behaviour.

7.1. Southland CPUE analysis

7.1.1. Squid target tows in Statistical Area 028

Tow level data were restricted to squid (SQU) targeted tows within Statistical Area 028. This region and target species were chosen because most of the barracouta catch in the squid fishery was caught in Statistical Area 028 (see Figure 31). Following this, only core vessel tows were retained (Tables 31–32 and Figure 37). This retained 36% of all estimated barracouta catch for the analysis. A more detailed breakdown of the analysis can be found in Appendix D. The CPUE shows a period of decline from 1990 to 1995 followed by a period of stability then another decreasing trend between 2000 and 2007. From 2007 to 2009 there is a large increase followed by variable decreases and increases (Figure 5).

This large increase between 2007 and 2009 was explored, but no variable available in the dataset could explain the large spike. There was an observed decrease in squid catch around the Stewart-Snares shelf region at the same time (McGregor & Large, 2016), which could be related.

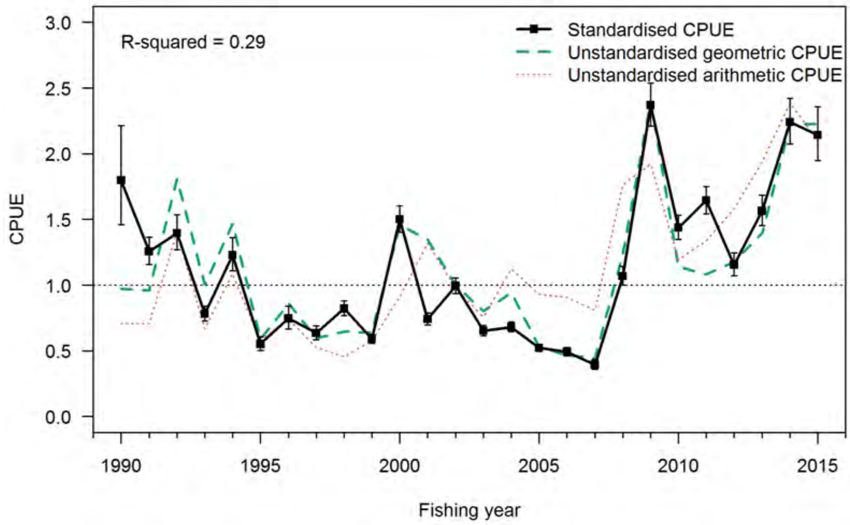

Figure 5: BAR 5 CPUE based on squid target tows in Statistical Area 028, plotted as the canonical index for each year.

7.1.2. Barracouta and blue warehou target tows

Tow level data were restricted to barracouta and blue warehou target tows. Blue warehou was included because in the previous ten years there had been an increased catch of barracouta in warehou targetted tows during the assumed barracouta spawning season (Figures 32 and 4). As most of the barracouta targeted fishing occurs during the spawning season, it was suggested by the working group to use barracouta catch from warehou targeted tows, which occurs around the same time and in the same area (Figure 31). Following this, we only retained tows by vessels that were identified as core vessels from the tow level data considered (Tables 31 and 32 and Figure 37), 30% of the catch was retained. The CPUE shows an increase in the latter part of the series (from 2000) which is rather variable from 2008 (Figure 6). It is fairly flat for 1990–2000, unlike the squid target model which is decreasing over this time (Figure 5).

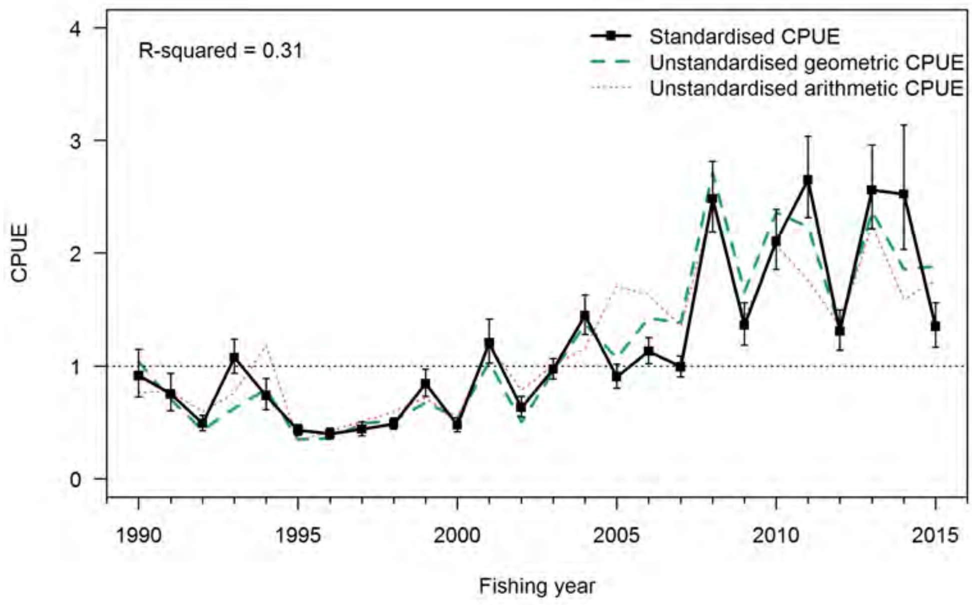

Figure 6: BAR 5 CPUE based on barracouta and warehou target tows, plotted as a canonical index for each year.

8. Summary Recommendations

8.1. Biology

Barracouta have been harvested commercially at significant levels at a national level (average annual catch 23 500 t) for the last 30 years and were the subject of targeted research programmes from the late 1970s to the mid-1990s. Other research surveys of inshore or middle depth species, and MPI observers, have also collected barracouta data and this is ongoing. Data available have provided information on the location of spawning grounds, the timing of main spawning events, size and age at maturity, size and age composition in selected areas and years, the location of juveniles, and diet.

Although seasonal patterns in commercial fisheries and a tagging study in the mid-1980s established some migration patterns and stock relationships, there are key questions about the relationship of BAR 5 with BAR 1 and BAR 7 that remain unresolved. Nevertheless, the current management boundaries are probably appropriate to manage stocks given the current information.

Barracouta are relatively short-lived with maximum observed ages of 12 years for females and 11 years for males recorded in Southland data that have been aged. Monitoring of recruitment variability is required to help understand current relative abundance trends, and prediction of future trends, in the main fisheries. For Southland, otoliths have been aged for the years 1993–1996 (trawl survey) and 2004–05 and 2009–10 (commercial data). Observer data collected since the year 2000 were adequate to develop catch-at-age models (see Table 11).

8.2. Status of the stocks

Estimates of current and reference biomass are not available for any barracouta stocks, so it is not known if current TACCs and recent catches are sustainable, or whether they are at levels which will allow the stocks to move towards a size that will support the maximum sustainable yield.

In BAR 5 catch levels in the last five years have averaged 89% of the TACC. There is no estimate of sustainable yield for this fishery so it is not known if current catch levels or the TACC are sustainable.

The chosen squid target CPUE indices indicate declining catch rates during the mid to late 1990s, followed by lower levels to 2007. This is followed by a large increase in 2008–2009 and a fluctuating trend above average. Patterns of recruitment from observer data are consistent with the low period in the 1990's and the recovery. A stock assessment model is required to appropriately integrate and assess these data. There is no current trawl survey in the area in appropriate depth ranges, but a survey for this species was carried out successfully by *Tangaroa* during 1993–96 and could be used to monitor biomass in future if the survey was reinstated. Potential stock movement between FMA 5 and FMA 7 or FMA 3 is unresolved. An alternative CPUE model of barracouta and blue warehou target tows suggested a lower than average trend to 2007, average catch rates to 2007, followed by a large increase in 2008 followed by a highly variable trend above average. In summary, available information that could inform a stock assessment is.

- Relative selectivity of trawls with 60–100 mm codends (from research and commercial data)
- Catch-at-age data (1993–96 Horn (2002) and from fishing years 2004–05 and 2009–10 Horn et al. (2012))
- An index of abundance or biomass (CPUE series)
- Catch history

8.3. Future data needs and research requirements

Recognising that CPUE may not provide a reliable relative abundance indicator for barracouta in isolation, and with the goal of developing a quantitative stock assessment in the future, the data collection needs for barracouta are as follows:

1. Further investigation of stock relationships, focusing on the possible inter-relationship between BAR 5 with BAR 7 and BAR 1
2. Development of age-based stock assessments for BAR 5 and BAR 7, incorporating commercial CPUE and catch-at-age and inshore trawl survey biomass indices and potentially length frequencies. Alternatively, length-based assessments could be attempted if no catch-at-age data are available.

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10. 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 Technical Report 42. 303 p* .

Bagley, N. W., Anderson, O. F., Hurst, R. & Francis, M. (2000). Atlas of New Zealand fish and squid distributions from midwater trawls, tuna longline sets, and aerial sightings. *NIWA Technical Report 72* .

Blackburn, M. (1957). The relation between the food of the Australian barracouta, *Thyrsites atun* (Euphrasen), and recent fluctuations in the fisheries. *Marine and Freshwater Research* **8**(1), 29:54.

Blackwell, R. G., Manning, M., Gilbert, D. & Baird, S. (2006). *Standardised CPUE Analysis of the Target Rig (Mustelus Lenticulatus) Setnet Fishery in Northern New Zealand (SPO 1 and 8)*. Ministry of Fisheries.

Boyd, R. O. & Reilly, J. L. (2002). 1999/2000 national marine recreational fishing survey: harvest estimates. *Unpublished report held by Ministry for Primary Industries, Wellington* .

Bradford, E. (1998). *Harvest estimates from the 1996 national marine recreational fishing surveys*. Ministry of Fisheries.

Bull, B. & Dunn, A. (2002). Catch-at-age: User manual v1.06.2002/09/12.. *NIWA Internal Report 114* .

Chambers, J. M. & Hastie, T. J. (1991). *Statistical models in S*. CRC Press, Inc.

Dunn, A., Harley, S., Doonan, I. & l, B. (2000). Calculation and interpretation of catch-per-unit-effort (CPUE) indices. *New Zealand Fisheries Assessment Report* p. 1:44.

Dunn, M. R., Hurst, R., Renwick, J., Francis, C., Devine, J. & McKenzie, A. (2009). *Fish abundance and climate trends in New Zealand*. Ministry of Fisheries.

Fenaughty, J. M. & Bagley, N. W. (1981). WJ Scott New Zealand trawl survey: South Island East Coast. *Fisheries Technical Report-New Zealand Ministry of Agriculture and Fisheries, Fisheries Management Division (New Zealand)* .

Francis, R. I. C. C. (1999). The impact of correlations in standardised CPUE indices. *New Zealand Fisheries Assessment Research Document 99/42* .

Graham, D. H. (1939). Food of the fishes of Otago Harbour and adjacent sea. Royal Society of New Zealand.

Griffiths, M. H. (2002). Life history of South African snoek, *Thyrsites atun* (Pisces: Gempylidae): a pelagic predator of the Benguela ecosystem. *Fishery Bulletin* **100**(4), 690–710.

Harley, S. J., Horn, P. L., Hurst, R. J. & Bagley, N. W. (1999). Analysis of commercial catch and effort data and age determination and catch-at-age of barracouta in BAR 5.. *New Zealand Fisheries Assessment Research Document 99/39* .

Hatanaka, H., Uozumi, Y., Fukui, J., Aizawa, M. & Hurst, R. (1989). Japan–New Zealand trawl survey off southern New Zealand, October–November 1983. *N.Z. Fisheries Technical Report* .

Horn, P. (2002). Age estimation of barracouta (*Thyrsites atun*) off southern New Zealand. *Marine & Freshwater Research* **53**, 1169–1178.

Horn, P. L., Hulston, D. & Maolagáin, C. (2013). Commercial catch sampling for species proportion, sex, length, and age of jack mackerels in JMA 7 in the 2011–12 fishing year, with a summary of all available data sets. *New Zealand Fisheries Assessment Research Document 2013/43* .

Horn, P. L., Sutton, C., Hulston, D. & Marriott, P. (2012). Catch-at-age for jack mackerels (*Trachurus spp.*) in the 2009-10 fishing year, and barracouta (*Thyrsites atun*) and silver warehou (*Seriolella puntata*) in the 2004–05 and 2009–10 fishing years.. *Routine age determination of hoki and middle depth species from commercial fisheries and trawl surveys.* .

Hurst, R. (1980). Studies on the life cycle of some New Zealand *Anisakidae* (Nematoda).

Hurst, R. & Bagley, N. (1992). Trawl survey of barracouta and associated finfish near the Chatham Islands, New Zealand December 1985. *New Zealand Fisheries Technical Report* .

Hurst, R. J. (1988a). The barracouta, *Thyrsites atun*, fishery around New Zealand: historical trends to 1984.. *New Zealand Fisheries Assessment Report* .

Hurst, R. J. (1988b). Barracouta. *New Zealand Fisheries Assessment Research Document. 88/8* .

Hurst, R. J. & Bagley, N. W. (1987). *Results of a trawl survey of barracouta and associated finfish near the Chatham Islands, New Zealand, December 1984*. MAFFish.

Hurst, R. J. & Bagley, N. W. (1989). Movements and possible stock relationships of the New Zealand barracouta, *Thrysites atun*, from tag returns. *New Zealand Journal of Marine and Freshwater Research* **23**(1), 105–111.

Hurst, R. J. & Bagley, N. W. (1994). Trawl survey of middle depth and inshore bottom species off Southland, February-March 1993 (TAN9301). *MAF Fisheries* .

Hurst, R. J. & Bagley, N. W. (1997*a*). Trawl survey of shelf and upper slope species off Southern New Zealand, November 1986. *NIWA* .

Hurst, R. J. & Bagley, N. W. (1997*b*). Trends in Southland trawl surveys of inshore and middle depth species, 1993-96. *NIWA Technical Report* .

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

Hurst, R. J., Ballara, S. L. & MacGibbon, D. J. (2012). Fishery characterisation and standardised CPUE analyses for barracouta, *Thyrsites Atun*,(Euphrasen, 1791)(Gempyliade), 1989-90 to 2007-08. *New Zealand Fisheries Assessment Report 2012/12* .

Kawahara, S. & Tokusa, K. (1981). Report on 1981 Japan/New Zealand joint squid survey in areas E and F by Shinkai Maru. Technical report.

Langley, A. D. & Bentley, N. (2002). *An examination of the stock structure of barracouta (Thyrsites atun) around the South Island of New Zealand*. Ministry of Fisheries.

Langley, A. D. & Walker, N. (2002). CPUE analysis of the southeast South Island BAR fishery, 1989-90 to 1999-2000.. *New Zealand Fisheries Assessment Report 2001/44* .

Manning, M. J., 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. **135**.

McGregor, V. (2020). Fishery characterisation and standardised CPUE analyses for barracouta, *Thyrsites atun*, (*Euphrasen*, 1791) (*Gempylidae*), 1989-–90 to 2010-–11. *New Zealand Fisheries Assessment Report 2020/45* p. 272.

McGregor, V. & Large, K. (2016). Stock Assessment of arrow squid (SQU 1T and 6T). *New Zealand Fisheries Assessment Report 2016/28* .

Mehl, J. A. P. (1969). Food of the barracouta (*Teleostei: Genpylidae*) from eastern Cook Strait.. *New Zealand Journal of Marine and Freshwater Research* **3**, 389–394.

Ministry of Fisheries (2010). Report from the Fisheries Assessment Plenary. Stock assessments and yield estimates.. *Ministry of Fisheries Report* .

Nepgun, C. S. D. (1979). The food of the snowk *Thyrsites atun*. *Fishery Bulletin South Africa* **11**, 39–42.

Norris, T. E. (1988). Summary of allocations, acceptances, and species limits for foreign licensed fishing nations.. Technical report.

O'Driscoll, R. L. (1998). Feeding and schooling behaviour of barracouta (*Thyrsites atun*) off Otago, New Zealand. *Marine and freshwater research* **49**(1), 19–24.

Parker, S. & Fu, D. (2011). Fishery characterisation and standardised CPUE analyses for silver warehou (*Seriolella punctata*) in SWA 1 and 4, 1989-90 to 2007-08.. *New Zealand Fisheries Assessment Report* .

Phillips, W. J. (1926). Food of New Zealand fishes.. *in* 'Transactions and Proceedings of the N.Z. Institure'. Vol. 56. p. 525:529.

R Core Team (2016). *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing. Vienna, Austria.
URL: *https://www.R-project.org*

Roberts, J., O'Driscoll, R., Hart, A. & Graham, B. (2018). Survey of New Zealand sea lion prey at the Auckland Islands and Stewart Snares Shelf. *New Zealand Aquatic Environment and Biodiversity Report* **7**(204).

Russell, B. C. (1983). The food and feeding habits of rocky reef fish of north-eastern New Zealand. *New Zealand Journal of Marine and Freshwater Research* **17**(2), 121:145.

Sparre, P., Ursin, E. & Venema, S. C. (1989). *Introduction to tropical fish stock assessment: part 2-Exercises*. Food and Agriculture Organization of the United Nations.

Starr, P. (2003). Procedure for merging MFish landing and effort data. Version 1.0. 13 p. *Unpublished report available from the author:* `paul@starrfish.net` .

Starr, P. (2007). Procedure for merging MFish Landing and Effort data. V2. 0. *Unpublished report held by MFish as document AMPWG* **7**, 04–17.

Stevens, D. W., Hurst, R. J. & Bagley, N. W. (2011). *Feeding habits of New Zealand fishes: a literature review and summary of research trawl database records 1960 to 2000*. Ministry of Fisheries.

Street, R. J. (1964). *Feeding habits of the New Zealand fur seal (Arctocephalus forsteri)*. New Zealand Marine Department.

Tate, M. L. (1981). The autumn-winter diet of the New Zealand fur seal *Arctocephalus forsteri* (Lesson) with special regerence to its cephlapod prey.

Thomson, G. M. (1892). Notes on sea-fishes. *in* 'Transactions and Proceedings of the Royal Society of New Zealand'. pp. 202–215.

Thomson, G. M. & Anderton, T. (1921). *History of the Portobello Marine Fishhatchery and Biological Station*. Wellington, N.Z. Govt.

Uozumi, Y., Baird, G. G., Robertson, D. A. & Yatsu, A. (1987). *Japan-New Zealand trawl survey off southern New Zealand, April 1983*. MAFFish.

van den Broek, W., Tokusa, K. & Kono, H. (1984). A survey of demersal fish stocks in waters south of New Zealand, March-May 1982.. *Occasional Publication-Fisheries Research Division (New Zealand). no. 44.* .

Wynne-Jones, J., Gray, A., Hill, L. & Heinemann, A. (2014). National Panel Survey of Marine Recreational Fishers 2011–12: Harvest Estimates. *New Zealand Fisheries Assessment Report* **67**, 30.

Appendix

A. Observer Summary

Table 7: Number of trawl tows sampled for length from each barracouta area by the observer programme, for fishing years 1989-90 to 2014-15

	Auck. Is.	ChatE	ChatW	ECNI	ECSI	SNAR	WCNI	WCSI	Total
1989-90	-	-	-	-	-	1	-	-	1
1990-91	1	17	-	-	1	22	-	27	68
1991-92	-	-	-	-	1	22	-	1	24
1992-93	8	-	-	-	14	91	-	6	119
1993-94	62	-	-	-	13	93	12	30	210
1994-95	44	1	-	-	7	68	34	12	166
1995-96	44	-	-	-	4	26	-	40	114
1996-97	17	-	-	-	3	17	1	24	62
1997-98	-	-	-	1	2	40	3	3	49
1998-99	6	-	-	1	16	107	1	22	153
1999-00	51	4	6	1	22	132	20	25	261
2000-01	86	10	-	7	69	395	15	80	662
2001-02	37	23	-	-	31	225	35	42	393
2002-03	21	1	-	-	32	241	104	26	425
2003-04	20	-	-	-	8	236	55	18	337
2004-05	52	-	-	9	18	290	53	66	488
2005-06	91	-	-	1	19	227	104	23	465
2006-07	6	22	1	3	17	163	103	66	381
2007-08	8	23	3	4	38	112	93	48	329
2008-09	1	-	-	2	11	131	76	20	241
2009-10	2	28	-	-	43	166	111	18	368
2010-11	9	12	-	-	53	180	13	12	279
2011-12	-	35	-	-	91	221	173	51	571
2012-13	7	27	-	-	207	482	223	58	1 004
2013-14	7	49	-	4	237	325	242	40	904
2014-15	3	101	-	5	132	273	327	95	936
Total	583	353	10	38	1 089	4 286	1 798	853	9 010

Table 8: Number of tows by fishing year and month sampled for barracouta length from Snares region overall by the observer programme, for fishing years 1989-90 to 2014-15.

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1989-90	1	-	-	-	-	-	-	-	-	-	-	-	1
1990-91	-	-	-	-	17	5	-	-	-	-	-	-	22
1991-92	6	15	-	-	-	1	-	-	-	-	-	-	22
1992-93	-	-	-	-	30	39	22	-	-	-	-	-	91
1993-94	-	-	-	-	18	44	31	-	-	-	-	-	93
1994-95	-	-	-	-	39	29	-	-	-	-	-	-	68
1995-96	-	-	-	2	19	2	3	-	-	-	-	-	26
1996-97	-	-	-	-	1	6	9	-	-	-	-	1	17
1997-98	-	-	-	-	30	9	1	-	-	-	-	-	40
1998-99	-	-	4	3	59	33	8	-	-	-	-	-	107
1999-00	-	-	-	7	39	77	8	1	-	-	-	-	132
2000-01	6	-	-	23	163	126	77	-	-	-	-	-	395
2001-02	-	-	-	1	103	87	34	-	-	-	-	-	225
2002-03	5	47	-	49	61	43	32	4	-	-	-	-	241
2003-04	-	-	-	57	118	34	27	-	-	-	-	-	236
2004-05	-	-	6	60	138	58	25	2	1	-	-	-	290
2005-06	-	5	8	45	32	101	32	4	-	-	-	-	227
2006-07	-	6	-	22	32	62	38	3	-	-	-	-	163
2007-08	1	-	5	1	49	26	30	-	-	-	-	-	112
2008-09	4	3	-	7	84	11	14	5	3	-	-	-	131
2009-10	13	21	-	20	55	32	1	17	5	2	-	-	166
2010-11	-	-	4	42	56	51	23	3	1	-	-	-	180
2011-12	12	-	-	15	36	94	48	12	-	-	-	4	221
2012-13	44	10	39	99	83	87	61	59	-	-	-	-	482
2013-14	35	9	2	24	64	153	34	4	-	-	-	-	325
2014-15	8	17	4	75	76	45	29	6	2	-	-	11	273
Total	135	133	72	552	1 402	1 255	587	120	12	2	-	16	4 286

Table 9: Number of tows by fishing year and month sampled for barracouta length from Auckland Is. area overall by the observer programme, for fishing years 1989-90 to 2014-15.

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1989-90	-	-	-	-	-	-	-	-	-	-	-	-	-
1990-91	-	-	-	-	-	1	-	-	-	-	-	-	1
1991-92	-	-	-	-	-	-	-	-	-	-	-	-	-
1992-93	-	-	-	-	-	6	2	-	-	-	-	-	8
1993-94	-	-	-	-	2	53	7	-	-	-	-	-	62
1994-95	-	-	-	-	-	22	22	-	-	-	-	-	44
1995-96	-	-	-	-	2	9	30	3	-	-	-	-	44
1996-97	-	-	-	5	10	2	-	-	-	-	-	-	17
1997-98	-	-	-	-	-	-	-	-	-	-	-	-	-
1998-99	-	-	-	-	-	-	6	-	-	-	-	-	6
1999-00	-	-	-	2	37	12	-	-	-	-	-	-	51
2000-01	-	-	-	-	77	9	-	-	-	-	-	-	86
2001-02	-	-	-	-	8	24	5	-	-	-	-	-	37
2002-03	-	-	-	-	10	2	9	-	-	-	-	-	21
2003-04	-	-	-	-	6	14	-	-	-	-	-	-	20
2004-05	-	-	-	-	5	33	14	-	-	-	-	-	52
2005-06	-	-	-	-	39	39	13	-	-	-	-	-	91
2006-07	-	-	-	-	4	2	-	-	-	-	-	-	6
2007-08	-	-	-	-	-	2	6	-	-	-	-	-	8
2008-09	-	-	-	-	-	1	-	-	-	-	-	-	1
2009-10	-	-	-	-	-	1	1	-	-	-	-	-	2
2010-11	-	-	-	-	-	5	4	-	-	-	-	-	9
2011-12	-	-	-	-	-	-	-	-	-	-	-	-	-
2012-13	-	-	-	1	-	4	1	1	-	-	-	-	7
2013-14	-	-	-	-	7	-	-	-	-	-	-	-	7
2014-15	-	-	-	-	1	2	-	-	-	-	-	-	3
Total	-	-	-	8	208	243	120	4	-	-	-	-	583

Table 10: Number of barracouta measured by fishing year and month sampled from each tow for the Snares region by the observer programme, for fishing years 1989-90 to 2014-15.

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1989-90	102	-	-	-	-	-	-	-	-	-	-	-	102
1990-91	-	-	-	-	1 662	499	-	-	-	-	-	-	2 161
1991-92	529	1 218	-	-	-	150	-	-	-	-	-	-	1 897
1992-93	-	-	-	-	782	1 202	1 276	-	-	-	-	-	3 260
1993-94	-	-	-	-	581	2 742	1 258	-	-	-	-	-	4 581
1994-95	-	-	-	-	617	1 046	-	-	-	-	-	-	1 663
1995-96	-	-	-	97	601	173	268	-	-	-	-	-	1 139
1996-97	-	-	-	-	6	55	858	-	-	-	-	50	969
1997-98	-	-	-	-	991	488	104	-	-	-	-	-	1 583
1998-99	-	-	189	14	1 905	2 081	499	-	-	-	-	-	4 688
1999-00	-	-	-	219	1 609	5 075	806	20	-	-	-	-	7 729
2000-01	613	-	-	1 181	5 386	4 464	3 672	-	-	-	-	-	15 316
2001-02	-	-	-	10	4 568	3 782	894	-	-	-	-	-	9 254
2002-03	539	3 672	-	491	2 141	835	1 335	27	-	-	-	-	9 040
2003-04	-	-	-	863	2 678	1 544	1 636	-	-	-	-	-	6 721
2004-05	-	-	257	877	3 444	1 746	1 450	21	47	-	-	-	7 842
2005-06	-	24	122	864	1 347	5 696	1 716	23	-	-	-	-	9 792
2006-07	-	573	-	206	264	1 717	1 907	147	-	-	-	-	4 814
2007-08	20	-	420	20	982	515	837	-	-	-	-	-	2 794
2008-09	400	135	-	195	2 064	370	855	36	27	-	-	-	4 082
2009-10	1 289	2 005	-	205	1 046	549	20	354	94	60	-	-	5 622
2010-11	-	-	386	1 504	1 642	1 841	1 120	271	10	-	-	-	6 774
2011-12	761	-	-	434	1 425	3 031	1 763	812	-	-	-	367	8 593
2012-13	3 746	829	2 546	3 972	2 473	5 029	2 169	1 595	-	-	-	-	22 359
2013-14	1 774	517	34	1 167	3 115	5 301	1 280	240	-	-	-	-	13 428
2014-15	462	535	140	3 626	1 889	1 715	1 722	205	91	-	-	400	10 785
Total	10 235	9 508	4 094	15 945	43 218	51 646	27 445	3 751	269	60	-	817	166 988

Table 11: Number of barracouta measured by fishing year and month sampled from each tow at the Auckland Is. by the observer programme, for fishing years 1989-90 to 2014-15.

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1989-90	-	-	-	-	-	-	-	-	-	-	-	-	-
1990-91	-	-	-	-	-	42	-	-	-	-	-	-	42
1991-92	-	-	-	-	-	-	-	-	-	-	-	-	-
1992-93	-	-	-	-	-	131	169	-	-	-	-	-	300
1993-94	-	-	-	-	46	740	27	-	-	-	-	-	813
1994-95	-	-	-	-	-	222	179	-	-	-	-	-	401
1995-96	-	-	-	-	13	698	1 296	125	-	-	-	-	2 132
1996-97	-	-	-	57	152	23	-	-	-	-	-	-	232
1997-98	-	-	-	-	-	-	-	-	-	-	-	-	-
1998-99	-	-	-	-	-	-	171	-	-	-	-	-	171
1999-00	-	-	-	40	360	227	-	-	-	-	-	-	627
2000-01	-	-	-	-	1 669	153	-	-	-	-	-	-	1 822
2001-02	-	-	-	-	72	155	64	-	-	-	-	-	291
2002-03	-	-	-	-	130	71	145	-	-	-	-	-	346
2003-04	-	-	-	-	31	91	-	-	-	-	-	-	122
2004-05	-	-	-	-	32	568	294	-	-	-	-	-	894
2005-06	-	-	-	-	164	359	151	-	-	-	-	-	674
2006-07	-	-	-	-	8	11	-	-	-	-	-	-	19
2007-08	-	-	-	-	-	11	95	-	-	-	-	-	106
2008-09	-	-	-	-	-	9	-	-	-	-	-	-	9
2009-10	-	-	-	-	-	5	20	-	-	-	-	-	25
2010-11	-	-	-	-	-	13	80	-	-	-	-	-	93
2011-12	-	-	-	-	-	-	-	-	-	-	-	-	-
2012-13	-	-	-	100	-	70	8	10	-	-	-	-	188
2013-14	-	-	-	-	93	-	-	-	-	-	-	-	93
2014-15	-	-	-	-	20	12	-	-	-	-	-	-	32
Total	-	-	-	197	2 790	3 611	2 699	135	-	-	-	-	9 432

Table 12: Number of barracouta otoliths collected in FMA 5 and 6, by fishing year and source

	Observer	Survey
1991	63	0
1993	368	760
1994	458	518
1995	233	671
1996	102	313
1997	44	0
1998	248	0
1999	558	0
2000	449	0
2001	1542	0
2002	978	0
2003	1199	0
2004	1158	0
2005	1788	0
2006	1104	0
2007	868	0
2008	847	0
2009	596	0
2010	753	0
2011	1006	0
2012	1329	0
2013	2466	0
2014	1612	0
2015	1434	0
2016	1200	0

Table 13: Number of female barracouta gonads staged by fishing year and month sampled from the Snares region by the observer programme.

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1989-90	-	-	-	-	-	-	-	-	-	-	-	-	-
1990-91	-	-	-	-	251	234	-	-	-	-	-	-	485
1991-92	66	260	-	-	-	-	-	-	-	-	-	-	326
1992-93	-	-	-	-	363	659	656	-	-	-	-	-	1 678
1993-94	-	-	-	-	229	1 449	775	-	-	-	-	-	2 453
1994-95	-	-	-	-	343	534	-	-	-	-	-	-	877
1995-96	-	-	-	67	347	104	155	-	-	-	-	-	673
1996-97	-	-	-	-	5	15	438	-	-	-	-	-	458
1997-98	-	-	-	-	555	260	44	-	-	-	-	-	859
1998-99	-	-	93	10	1 238	1 146	252	-	-	-	-	-	2 739
1999-00	-	-	-	141	886	2 827	464	13	-	-	-	-	4 331
2000-01	228	-	-	602	2 925	2 255	1 721	-	-	-	-	-	7 731
2001-02	-	-	-	4	2 480	1 958	434	-	-	-	-	-	4 876
2002-03	240	1 612	-	294	1 161	414	651	17	-	-	-	-	4 389
2003-04	-	-	-	434	1 392	757	826	-	-	-	-	-	3 409
2004-05	-	-	114	494	1 642	850	695	13	34	-	-	-	3 842
2005-06	-	16	62	454	632	2 722	914	12	-	-	-	-	4 812
2006-07	-	129	-	111	170	847	957	62	-	-	-	-	2 276
2007-08	15	-	83	4	489	283	398	-	-	-	-	-	1 272
2008-09	221	72	-	84	1 126	216	491	21	13	-	-	-	2 244
2009-10	631	803	-	153	628	300	12	186	56	36	-	-	2 805
2010-11	-	-	188	665	1 004	1 059	557	148	7	-	-	-	3 628
2011-12	417	-	-	255	812	1 663	970	521	-	-	-	113	4 751
2012-13	1 602	232	910	2 440	1 444	2 670	1 208	887	-	-	-	-	11 393
2013-14	855	184	19	679	1 598	2 877	640	123	-	-	-	-	6 975
2014-15	205	324	86	1 788	1 202	906	991	90	31	-	-	198	5 821
Total	4 480	3 632	1 555	8 679	22 922	27 005	14 249	2 093	141	36	-	311	85 103

Table 14: Number of female barracouta gonads staged by fishing year and month sampled from the Auckland Island region, by the observer programme.

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1989-90	-	-	-	-	-	-	-	-	-	-	-	-	-
1990-91	-	-	-	-	-	14	-	-	-	-	-	-	14
1991-92	-	-	-	-	-	-	-	-	-	-	-	-	-
1992-93	-	-	-	-	-	69	98	-	-	-	-	-	167
1993-94	-	-	-	-	21	445	18	-	-	-	-	-	484
1994-95	-	-	-	-	-	147	132	-	-	-	-	-	279
1995-96	-	-	-	-	10	292	788	93	-	-	-	-	1 183
1996-97	-	-	-	3	10	1	-	-	-	-	-	-	14
1997-98	-	-	-	-	-	-	-	-	-	-	-	-	-
1998-99	-	-	-	-	-	-	101	-	-	-	-	-	101
1999-00	-	-	-	26	237	165	-	-	-	-	-	-	428
2000-01	-	-	-	-	959	86	-	-	-	-	-	-	1 045
2001-02	-	-	-	-	54	80	32	-	-	-	-	-	166
2002-03	-	-	-	-	94	51	97	-	-	-	-	-	242
2003-04	-	-	-	-	22	58	-	-	-	-	-	-	80
2004-05	-	-	-	-	15	334	190	-	-	-	-	-	539
2005-06	-	-	-	-	96	164	93	-	-	-	-	-	353
2006-07	-	-	-	-	3	8	-	-	-	-	-	-	11
2007-08	-	-	-	-	-	6	52	-	-	-	-	-	58
2008-09	-	-	-	-	-	3	-	-	-	-	-	-	3
2009-10	-	-	-	-	-	5	5	-	-	-	-	-	10
2010-11	-	-	-	-	-	7	46	-	-	-	-	-	53
2011-12	-	-	-	-	-	-	-	-	-	-	-	-	-
2012-13	-	-	-	65	-	33	4	3	-	-	-	-	105
2013-14	-	-	-	-	60	-	-	-	-	-	-	-	60
2014-15	-	-	-	-	14	8	-	-	-	-	-	-	22
Total	-	-	-	94	1 595	1 976	1 656	96	-	-	-	-	5 417

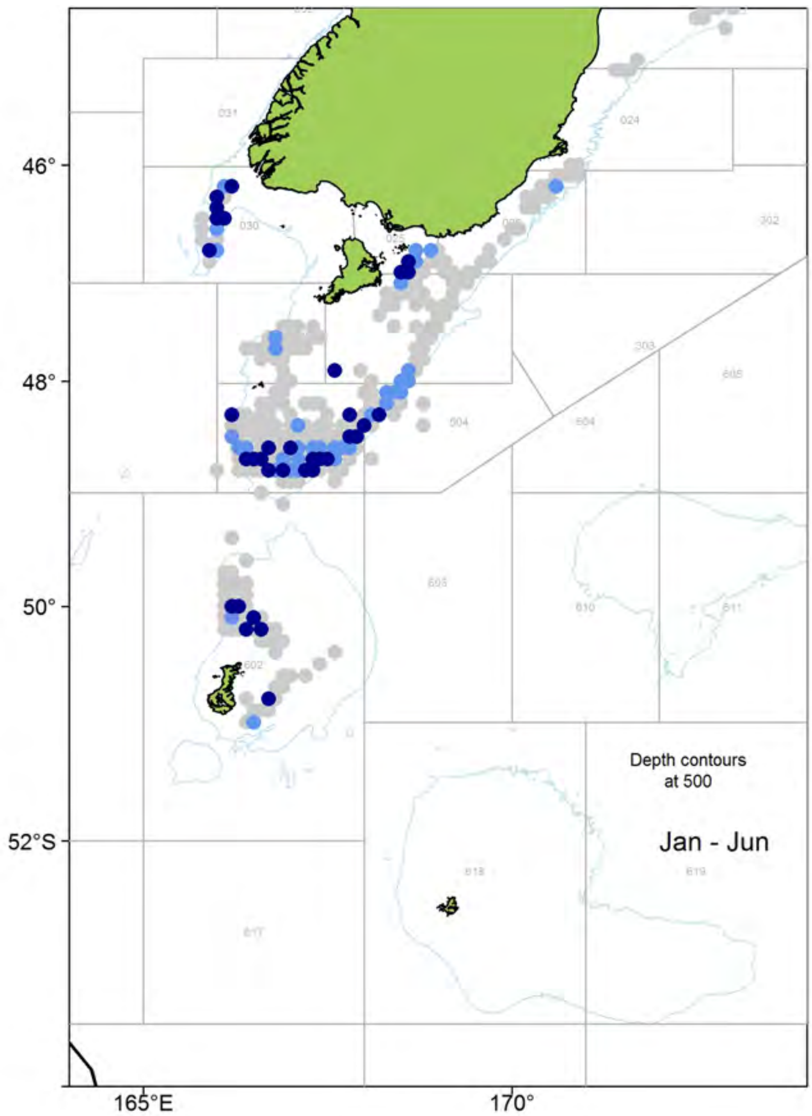


Figure 7: Location of female barracouta gonad stages 5 (running ripe, dark blue dots) and 4 (ripe, light blue dots) taken in commercial catches, January-June, sampled by the Observer Programme.

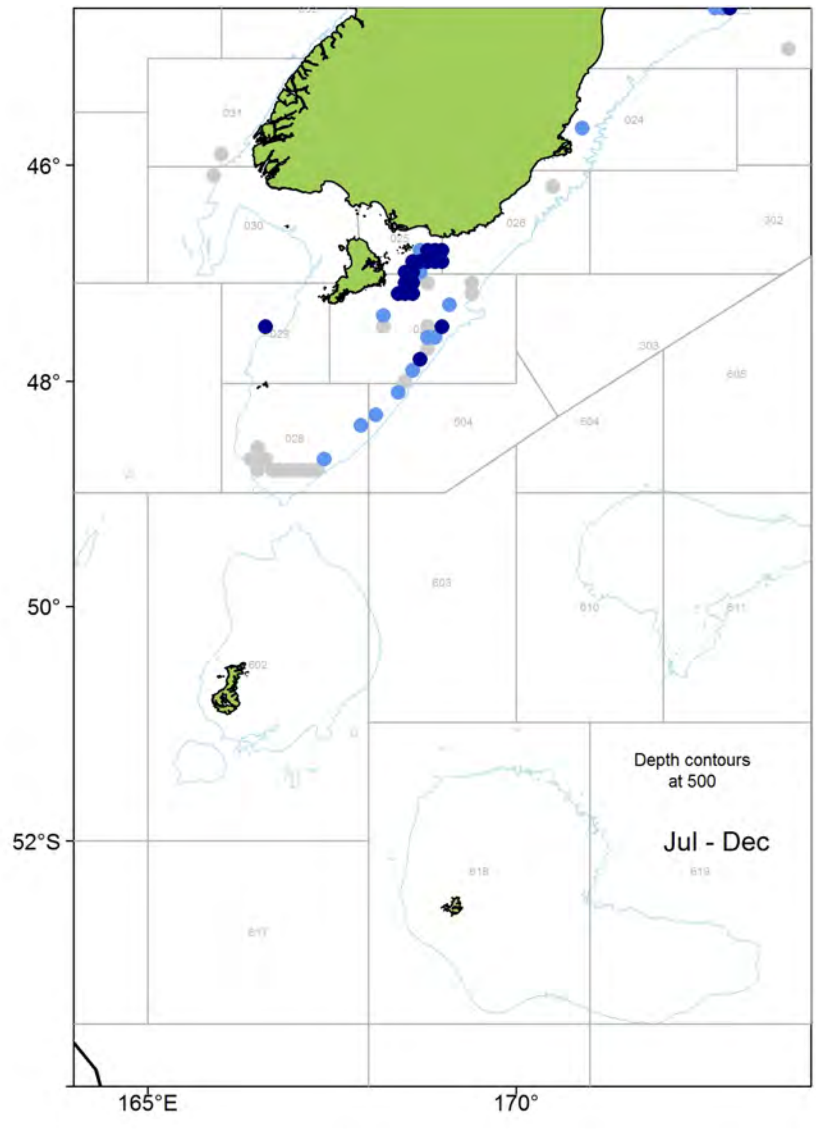


Figure 8: Location of female barracouta gonad stages 5 (running ripe, dark blue dots) and 4 (ripe, light blue dots) taken in commercial catches, July-December, sampled by the Observer Programme.

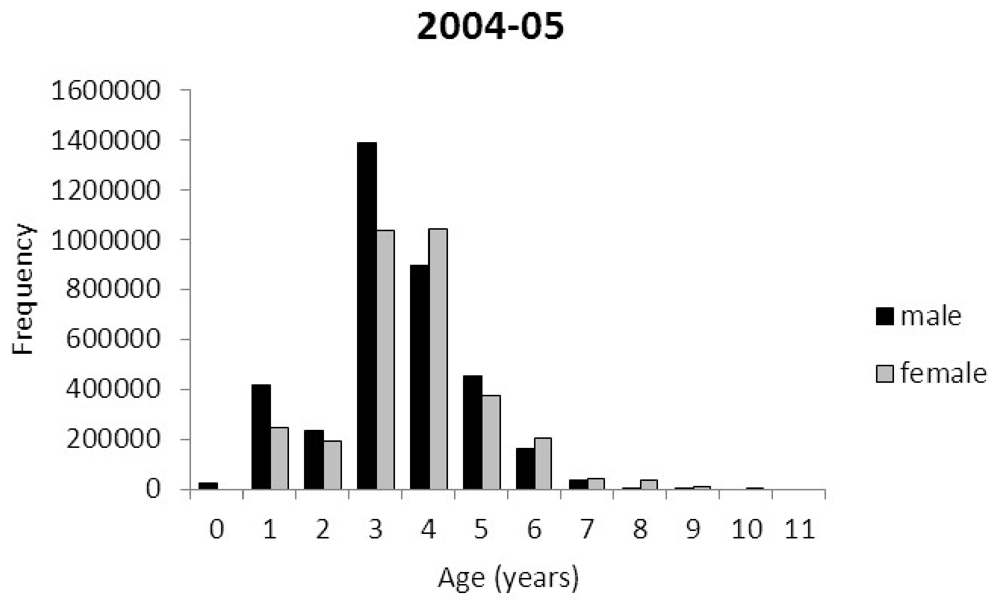
Table 15: Calculated numbers-at-age, separately by sex, with c.v.s, for barracouta caught during commercial trawl operations off Southland during the 2004-05 and 2009-10 fishing years. Summary statistics for the samples are also presented (Horn et al., 2012).

				2004-05					2009-10
Age	Male	c.v.	Female	c.v.	Age	Male	c.v.	Female	c.v.
0	24 811	1.436	0		0	0		0	
1	418 020	0.353	246 634	0.45	1	36 654	0.412	65 744	0.471
2	233 963	0.32	190 694	0.477	2	122 062	0.399	126 462	0.346
3	1 387 787	0.119	1 037 283	0.15	3	890 623	0.116	1 013 362	0.124
4	894 380	0.17	1 038 830	0.13	4	832 033	0.133	977 440	0.124
5	452 901	0.178	371 226	0.211	5	311 623	0.201	293 353	0.19
6	164 424	0.276	205 465	0.261	6	167 061	0.323	81 406	0.438
7	33 663	0.474	42 454	0.391	7	36 588	0.689	60 184	0.301
8	3 589	0.604	32 272	0.603	8	62 133	0.457	23 873	0.49
9	443	1.589	8 270	0.644	9	5 604	0.702	6 848	0.977
10	0		317	1.524	10	0		646	2.283
11	0		0		11	0		590	1.702

	2004-05	2009-10
No. measured males	4 339	2 704
No. measured females	4 349	2 736
No. aged males	166	150
No. aged females	171	179
No. of tows sampled	342	155
Mean weighted c.v. (sexes pooled)	15.9	12.7

Table 16: Observed catch compared to commercial landings and percentage observed for each fishing year.

Fishing year	Observed catch (t)	BAR5 landings	% coverage
1990	698	5 960	12
1991	1 379	8 817	16
1992	1 084	6 897	16
1993	1 643	7 019	23
1994	568	3 410	17
1995	201	2 645	8
1996	495	4 255	12
1997	258	2 839	9
1998	740	6 167	12
1999	1 451	7 302	20
2000	2 455	6 205	40
2001	4 118	6 101	67
2002	2 369	5 883	40
2003	1 650	7 843	21
2004	1 264	6 919	18
2005	1 735	8 593	20
2006	3 833	9 479	40
2007	1 046	6 334	17
2008	2 680	8 561	31
2009	2 293	7 659	30
2010	2 880	6 951	41
2011	2 236	8 201	27
2012	3 528	7 071	50
2013	6 945	7 931	88
2014	5 462	6 886	79
2015	5 836	6 779	86



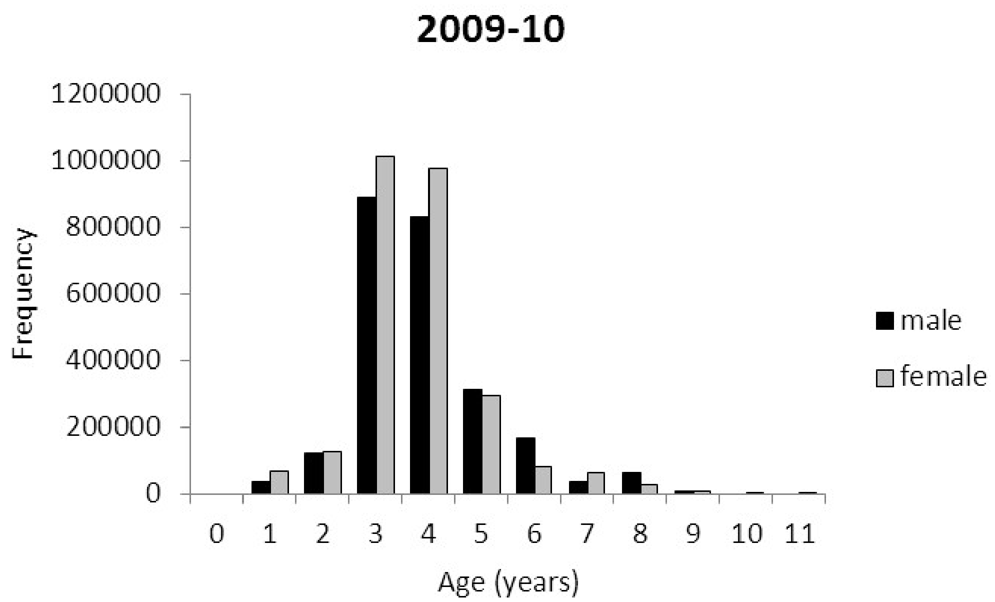


Figure 9: Location of female barracouta gonad stages 5 (running ripe, dark blue dots) and 4 (ripe, light blue dots) taken in commercial catches, July-December, sampled by the Observer Programme.

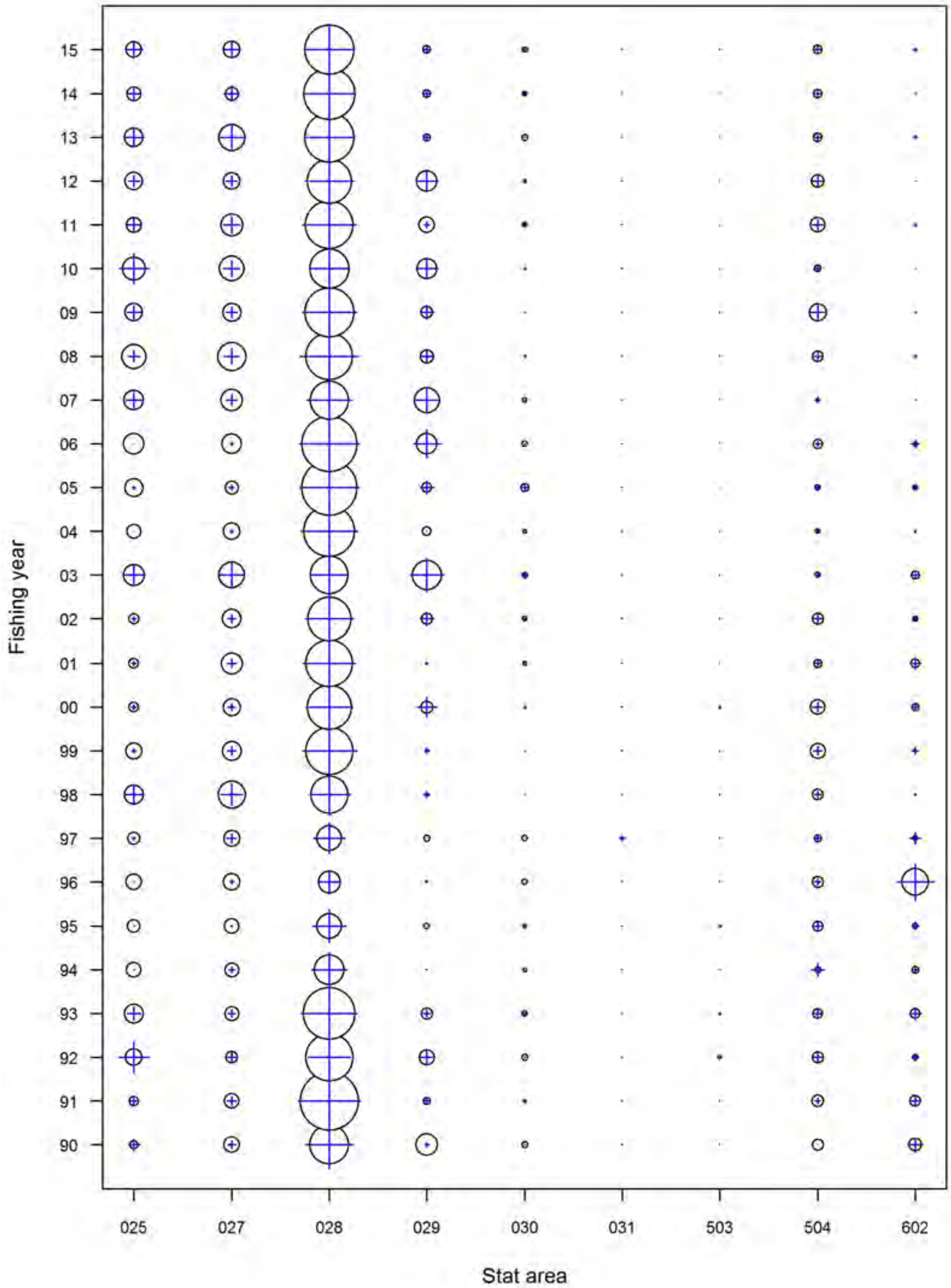


Figure 10: Representativeness of observer sampling of barracouta catch by fishing year and statistical area. Circles show the proportion of target catch by area within a year; crosses show the proportion of observed target catch for the same cells. Representation is demonstrated by how closely the cross matches the circle diameter. The Snares Shelf and Auckland Is. observer data were combined to compare with Southland commercial data.

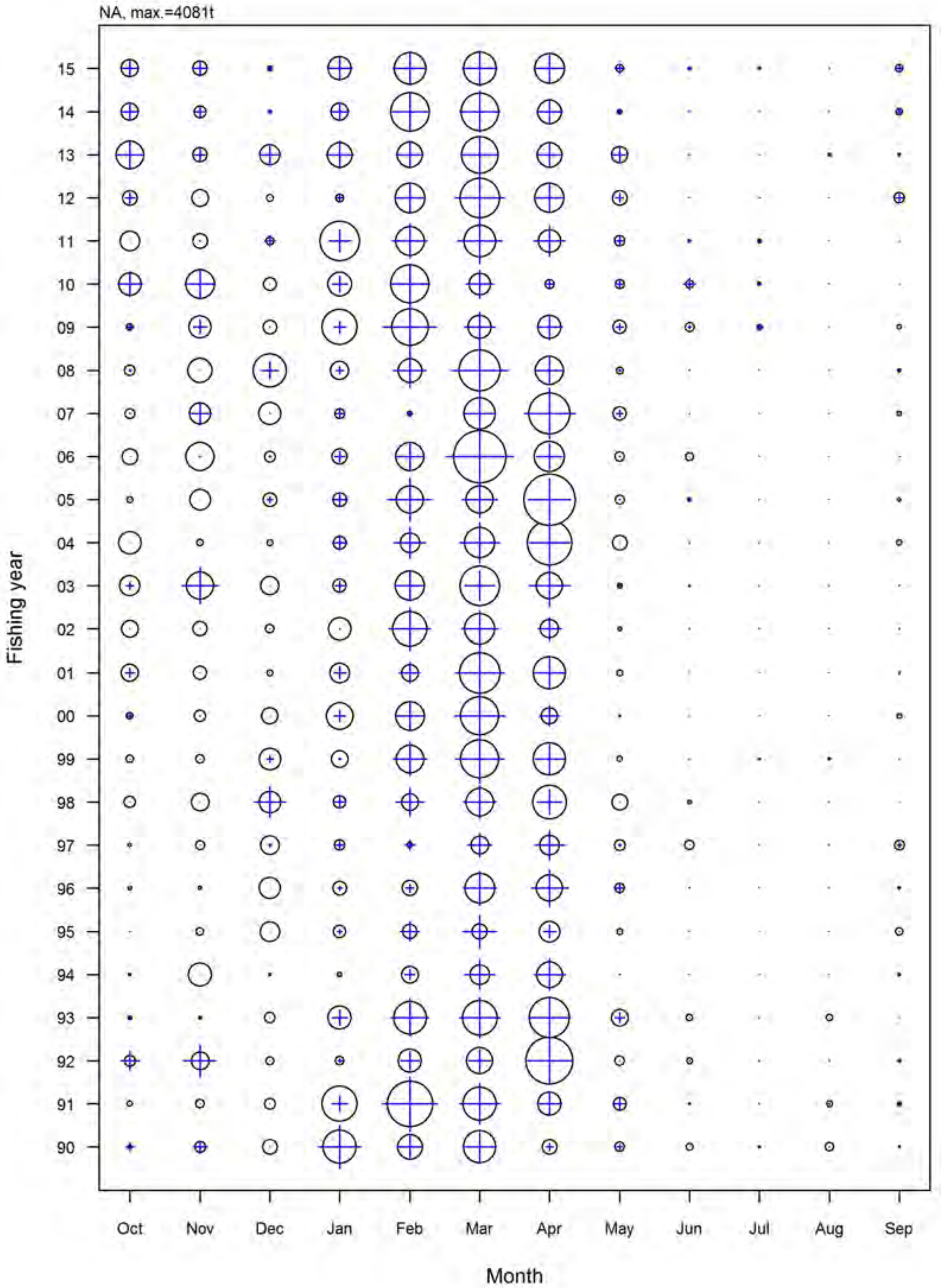


Figure 11: Representativeness of observer sampling of barracouta catch by fishing year and month. Circles show the proportion of target catch by area within a year; crosses show the proportion of observed target catch for the same cells. Representation is demonstrated by how closely the cross matches the circle diameter. The Snares Shelf and Auckland Is. observer data were combined to compare with Southland commercial data

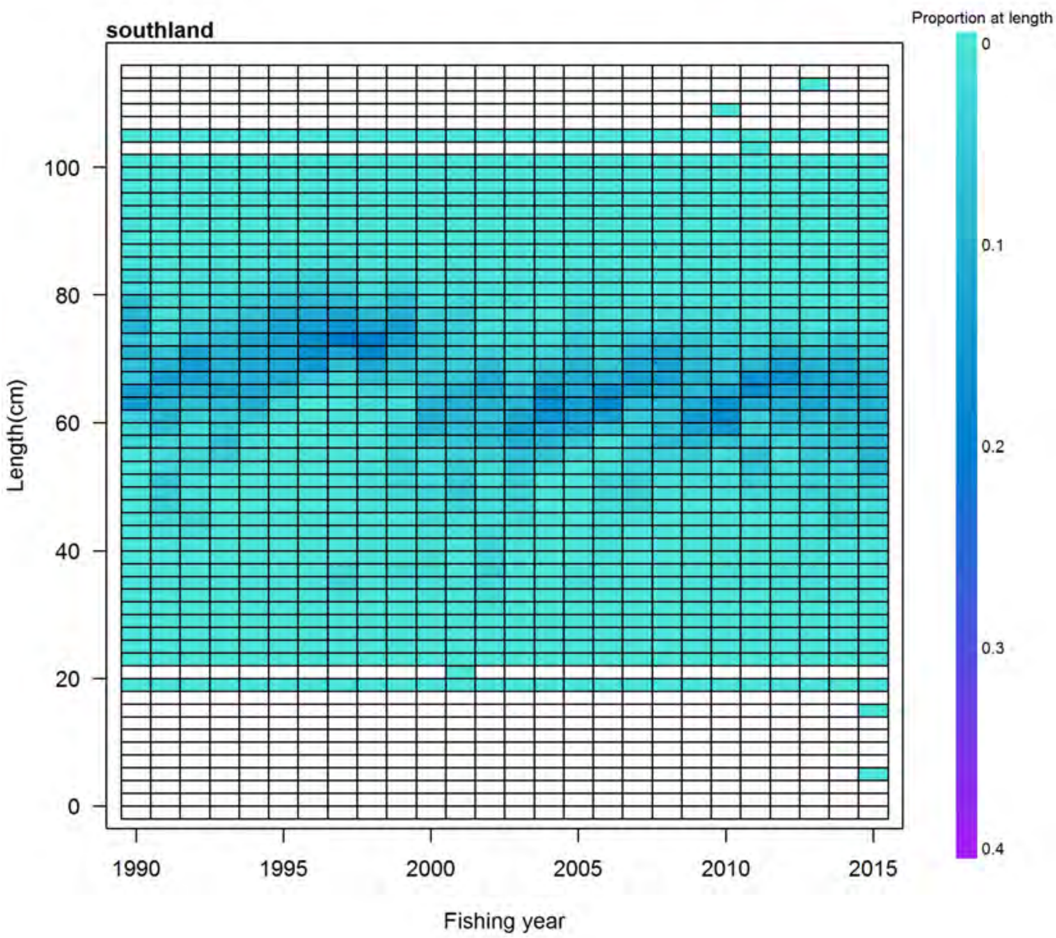


Figure 12: Time series of length frequency of the Southland area by 1cm length bins, fishing years 1990–2015.

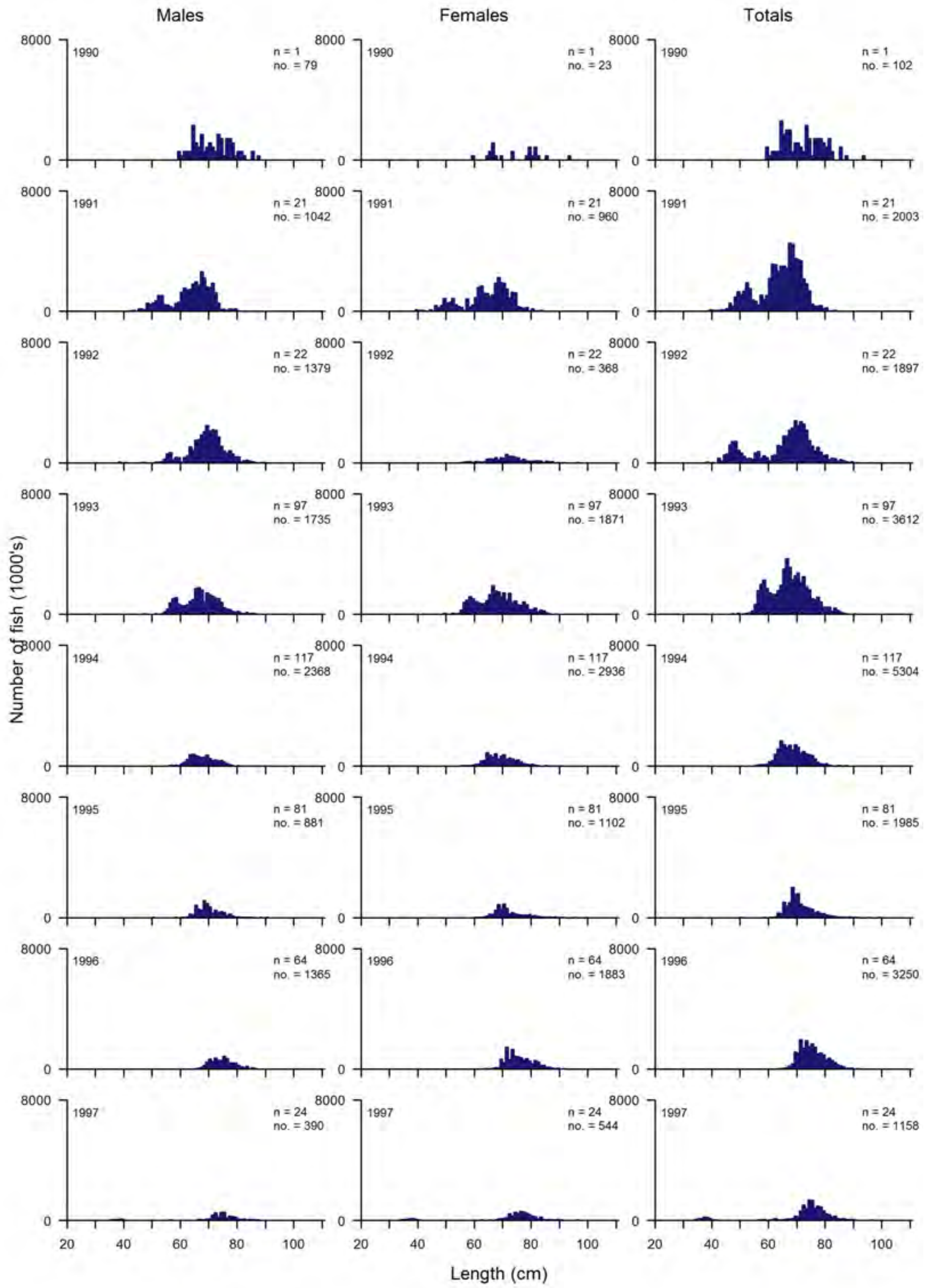


Figure 13: Scaled length frequency of barracouta taken in commercial catches from the Southland trawl fishery by fishing year sampled by the Observer Programme for fishing years 1990–1997. N, number of tows sampled; no., number of fish sampled. Note that the vertical axis changes in some cases to accommodate exceptionally large or small numbers.

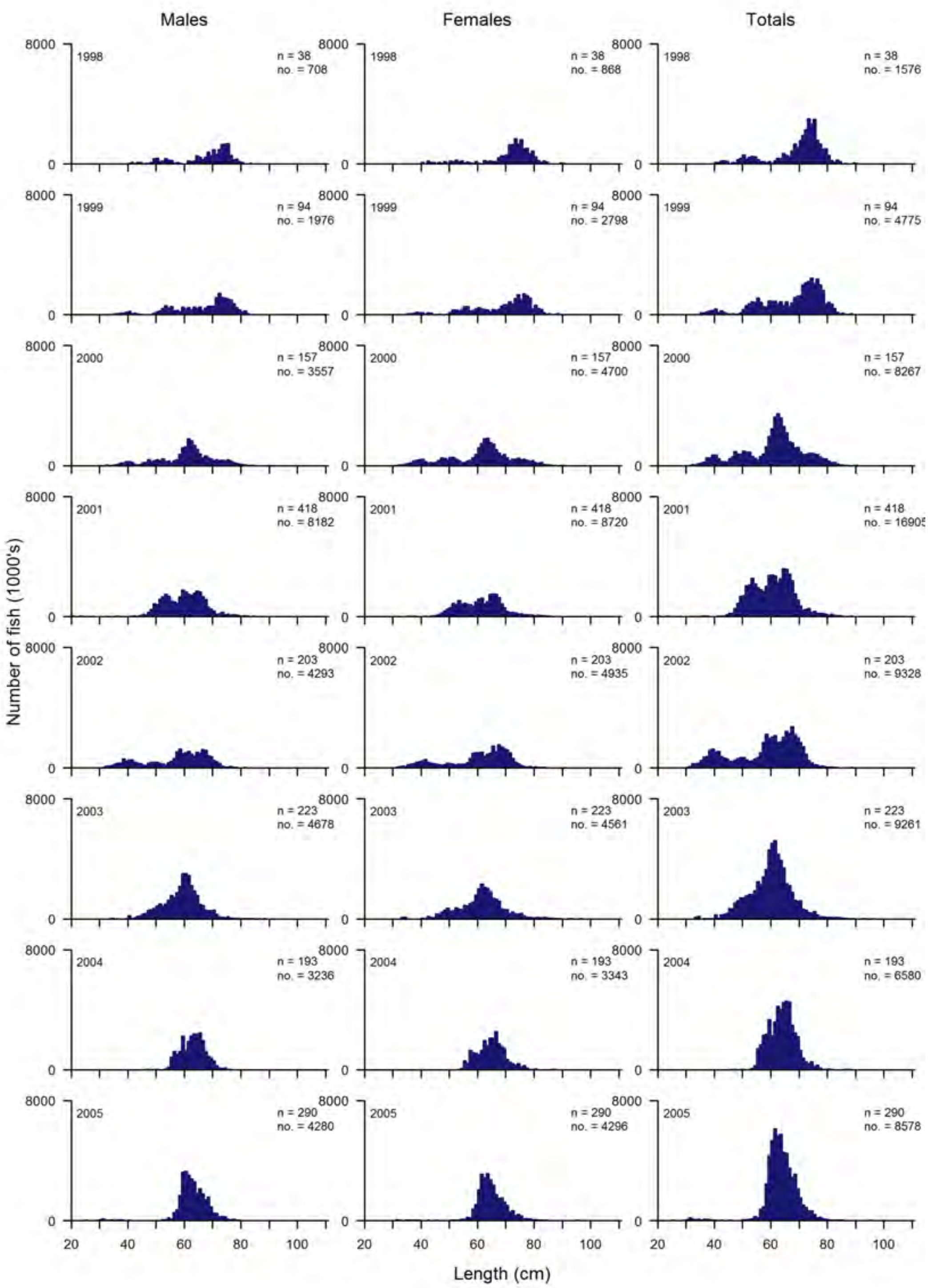


Figure 14: Scaled length frequency of barracouta taken in commercial catches from the Southland trawl fishery by fishing year sampled by the Observer Programme for fishing years 1998–2005. N, number of tows sampled; no., number of fish sampled. Note that the vertical axis changes in some cases to accommodate exceptionally large or small numbers.

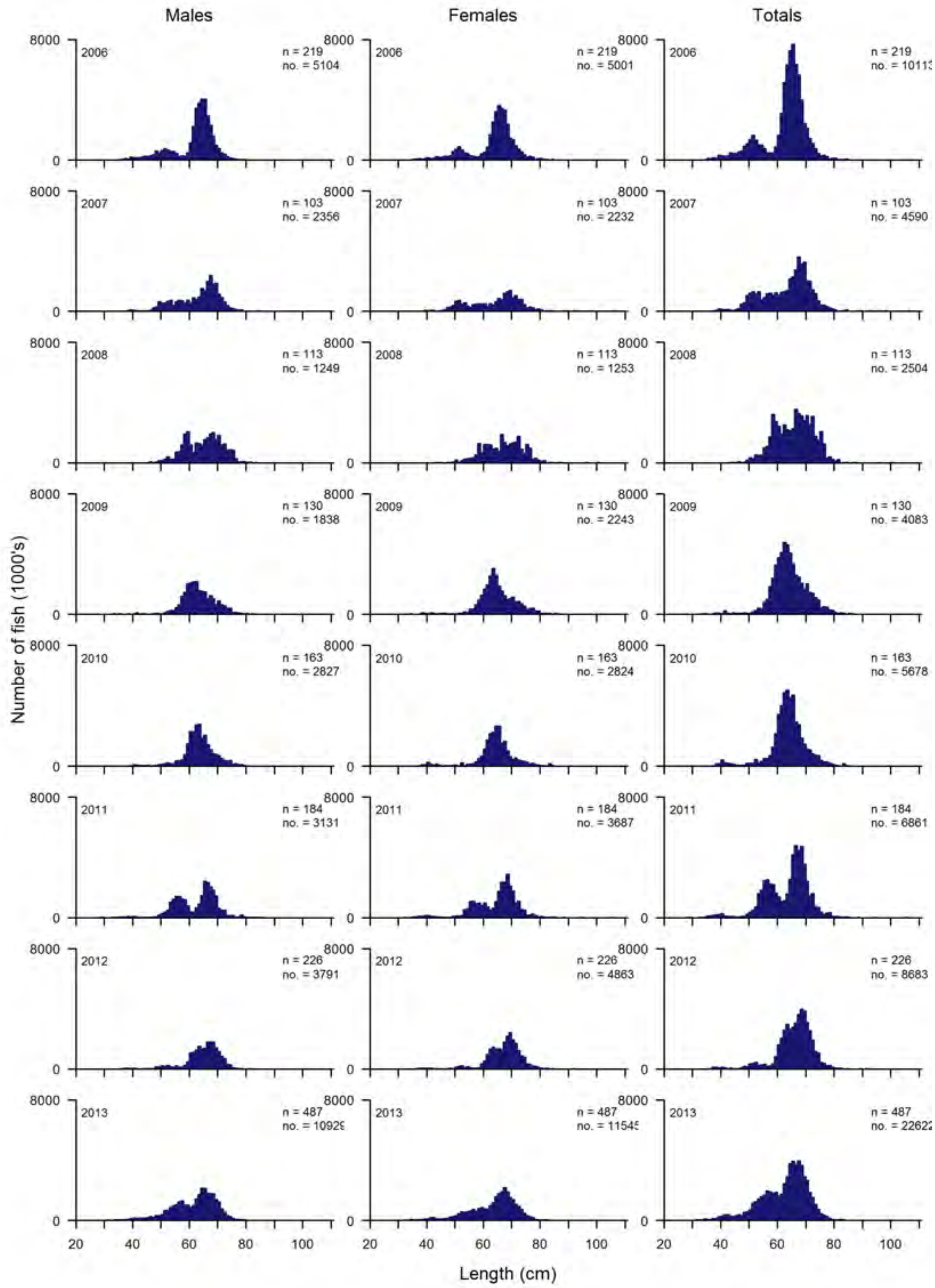


Figure 15: Scaled length frequency of barracouta taken in commercial catches from the Southland trawl fishery by fishing year sampled by the Observer Programme for fishing years 2006–2013. N, number of tows sampled; no., number of fish sampled. Note that the vertical axis changes in some cases to accommodate exceptionally large or small numbers.

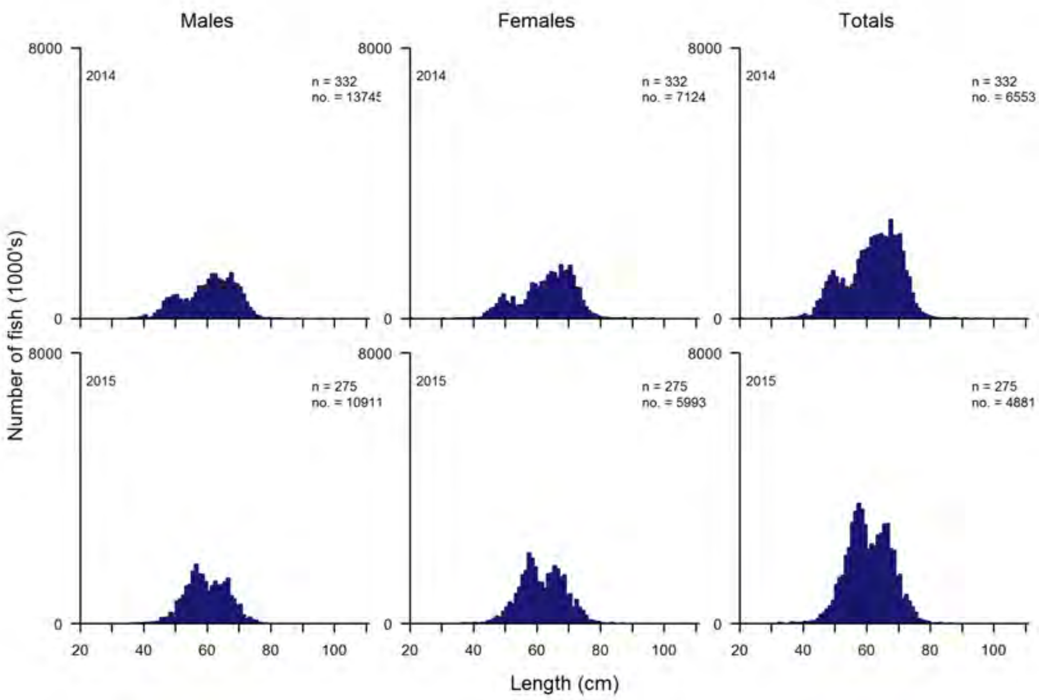


Figure 16: Scaled length frequency of barracouta taken in commercial catches from the Southland trawl fishery by fishing year sampled by the Observer Programme for fishing years 2014–2015. N, number of tows sampled; no., number of fish sampled. Note that the vertical axis changes in some cases to accommodate exceptionally large or small numbers.

B. SUMMARIES OF CATCH AND EFFORT DATA GROOMING

Table 17: List of tables and fields requested in the Ministry for Primary Industries extract 10432.

Fishing_events table		
Event_Key	Effort_seqno	Bottom_depth
Version_seqno	Effort_total_num	Column_a
DCF_key	Effort_width	Column_b
Start_datetime	Effort_speed	Column_c
End_datetime	Total_net_length	Column_d
Primary_method	Total_hook_num	Display_fishyear
Target_species	Set_end_datetime	Start_stats_area_code
Fishing_duration	Haul_start_datetime	Vessel_key
Catch_weight	Start_latitude (full accuracy)	Form_type
Effort_depth	Start_longitude (full accuracy)	Trip
Effort_height	End_latitude (full accuracy)	Literal_yn
Effort_num	End_longitude (full accuracy)	Interp_yn
Effort_num_2	Pair_trawl_yn	Resrch_yn
Landing_events table		
Event_Key	Destination_type	Form_type
Version_seqno	Unit_type	Trip_key
DCF_key	Unit_num	Trip_start_datetime
Landing_datetime	Unit_weight	Trip_end_datetime
Landing_name	Conv_factor	Vessel_key
Species_code	Green_weight	Form_type
Species_name	Green_weight_type	Literal_yn
Fishstock_code (ALL fish stocks)	Processed_weight	Interp_yn
State_code	Processed_weight_type	Resrch_yn
Estimated subcatch table		
Event_Key	Species_code (ALL species for each fishing event)	Literal_yn
Version_seqno		Interp_yn
DCF_key	Catch_weight	Resrch_yn
Process data table		
Event_Key	Unit_type	Processed_weight_type
Version_seqno	Unit_num	Vessel_key
DCF_key	Unit_weight	Form_type
Spec_prod_action_type	Conv_factor	Trip_key
Processed_datatime	Green_weight	Literal_yn
Species_code	Green_weight_type	Interp_yn
State_code	Processed_weight	Resrch_yn
Vessel_history table		
Vessel_key	Gross_tonnes	
Flag_nationality_code	Overall_length_metres	
Built_year	History_start_datetime	
Engine_kilowatts	History_end_datetime	

Table 18: Number of landing events by major destination code and form type for BAR 5 from fishing years 1990–2015. L= landed in NZ; T= transferred to another vessel; R= retained on board.

	CLR			CELR			
	L	**T**	**R**	**L**	**T**	**R**	**Total**
1990	114	61	33	50	-	-	270
1991	152	70	54	69	-	-	373
1992	157	49	66	47	-	-	327
1993	175	58	43	63	-	-	357
1994	124	37	50	53	-	-	279
1995	124	44	38	46	-	-	266
1996	203	80	32	40	-	-	364
1997	201	39	41	36	-	-	334
1998	237	5	31	20	-	-	303
1999	228	-	31	29	-	-	299
2000	228	-	23	38	-	-	297
2001	226	-	9	73	-	-	331
2002	299	-	5	74	-	-	402
2003	262	-	14	49	-	2	351
2004	326	-	18	51	-	2	445
2005	326	-	32	24	-	-	434
2006	321	-	13	27	-	-	409
2007	300	-	20	41	-	-	405
2008	323	-	14	-	-	-	381
2009	298	-	21	-	-	-	373
2010	259	-	9	-	-	-	343
2011	358	-	13	-	-	-	446
2012	368	-	11	-	-	-	438
2013	375	-	14	-	-	-	482
2014	321	-	5	-	-	-	409
2015	340	-	10	-	-	-	431
Total	6 645	443	650	830	-	4	9 549

Table 19: Destination codes, total landing weight, number of landings and if the records were kept or discarded to all BAR catch 1990–2015 for BAR 5.

Destination code	Greenweight (t)	No. records	Description	Action
L	159 335.92	7 479	Landed in New Zealand to a Licensed Fish Receiver	Keep
T	10 544.02	443	Transferred to another vessel	Keep
O	1 114.03	46	Conveyed outside New Zealand	Keep
A	275.57	209	Accidental loss	Keep
D	82.80	36	Discarded	Keep
E	33.04	533	Eaten	Keep
U	0.36	6	Used as bait	Keep
F	0.01	3	Recreational catch	Keep
S	0.01	2	Seized by the Crown	Keep
R	4 343.27	654	Retained on board	Drop
Invalid	294.16	119	Invalid destination type code recorded	Drop
Null	95.62	6	Missing destination type code	Drop
B	15.47	12	Stored as bait	Drop
Q	0.05	1	Holding receptacle on land	Drop

Table 20: The reported TACC, MHR, annual retained landings in the groomed merged and unmerged dataset, and retained landings in the groomed and merged dataset, and estimated catches in the groomed and merged dataset for BAR 5 from 1990 to 2015.

Year	TACC	MHR	Un-merged landings	Merged landings	Catch	% MHR
1990	9281	5960	5189	5185	5333	89
1991	9282	8817	8289	8289	8177	93
1992	9282	6897	6524	6403	6327	92
1993	9282	7019	7391	7390	7236	103
1994	9282	3410	3233	3170	2904	85
1995	9282	2645	2536	2530	2338	88
1996	9282	4255	4151	4147	3950	93
1997	9282	2839	2565	2564	2307	81
1998	9282	6167	6122	5999	5499	89
1999	7470	7302	7032	7001	6292	86
2000	7470	6205	5985	5772	5614	90
2001	7470	6101	6091	6077	5910	97
2002	7470	5883	5876	5864	5364	91
2003	7470	7843	7831	7815	7223	92
2004	7470	6919	6894	6875	6508	94
2005	7470	8593	8245	8175	7689	89
2006	7470	9479	9253	9191	9041	95
2007	7470	6334	6239	6238	6094	96
2008	7470	8561	8341	8294	7840	92
2009	7470	7659	7489	7886	7117	93
2010	7470	6951	6922	6927	6512	94
2011	7470	8201	7918	7917	7163	87
2012	7470	7071	6852	6850	6294	89
2013	7470	7931	8034	8323	7537	95
2014	7470	6886	6795	6862	6441	94
2015	7470	6779	6667	6748	6302	93

Table 21: Total number of trips, number of trips with zero daily processed catch and proportion of trips with zero daily processed catch, for TCEPR and CEL forms for BAR 5 from 1990 to 2015.

	CELR/TCE			TCEPR		
	Total	Zero	Proportion	Total	Zero	Proportion
1990	49	11	0.22	118	4	0.03
1991	67	14	0.21	160	6	0.04
1992	45	9	0.2	144	8	0.06
1993	61	22	0.36	149	8	0.05
1994	52	25	0.48	108	9	0.08
1995	45	14	0.31	128	7	0.05
1996	41	14	0.34	180	3	0.02
1997	35	11	0.31	147	8	0.05
1998	20	8	0.4	155	5	0.03
1999	27	13	0.48	125	3	0.02
2000	38	20	0.53	108	11	0.1
2001	69	35	0.51	108	15	0.14
2002	70	27	0.39	133	8	0.06
2003	49	18	0.37	129	10	0.08
2004	52	17	0.33	155	12	0.08
2005	24	3	0.12	166	8	0.05
2006	27	11	0.41	155	11	0.07
2007	41	14	0.34	123	16	0.13
2008	40	4	0.1	108	2	0.02
2009	46	7	0.15	113	6	0.05
2010	48	8	0.17	109	9	0.08
2011	85	3	0.04	125	3	0.02
2012	-	-	-	127	4	0.03
2013	-	-	-	120	9	0.08
2014	-	-	-	106	13	0.12
2015	-	-	-	101	13	0.13

Table 22: Details of data corrections by imputation and invalid record removal of the landing data during the grooming process for BAR 5.

			Landing
	Records	Trips	Catch
Original extract	14 605	5 252	177 929
Missing keys	14 486	5 251	177 878
Unmatched trip number	14 434	5 219	176 596
Duplicate form number	14 400	5 202	176 470
Invalid start date	14 389	5 199	176 446
Invalid primary method	14 389	5 199	176 446
Invalid target method	14 389	5 199	176 446
Invalid stats area	14 205	5 138	174 631
Restratify effort	14 205	5 138	174 631
Remove BQRT destination types	13 191	5 043	170 268
Remove multiple states	12 244	5 043	170 267
Remove invalid green weight	12 242	5 041	170 267
Remove NA green weight	12 242	5 041	170 267
DQSS	12 242	5 041	170 267
Drop straddle stats area	12 242	5 041	170 267

Table 23: Details of data corrections by imputation and invalid record removal during the grooming process for BAR 5 by fishing year 1990–2004.

Effort Records	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
START	270	373	327	357	279	266	364	334	303	299	297	331	402	351	445
Remove_Missing_Keys	270	373	327	357	279	265	363	334	302	298	297	331	402	351	445
Remove_Unmatched_Trips	256	370	324	353	276	265	363	334	301	298	297	331	402	351	445
Remove_Duplicate_Trip_Form	256	365	321	351	276	265	363	334	301	298	297	331	402	351	445
Remove_Invalid_start_datetime	258	362	324	350	275	264	363	316	317	292	295	337	402	348	447
Remove_Invalid_primary_method	258	362	324	350	275	264	363	316	317	292	295	337	402	348	447
Remove_Invalid_target_method	258	362	324	350	275	264	363	316	317	292	295	337	402	348	447
Remove_Invalid_stats_area	251	359	322	348	272	261	354	315	315	292	295	330	400	348	446
Restratify_effort	251	359	322	348	272	261	354	315	315	292	295	330	400	348	446
Remove_BPQRT_destination_type	216	308	254	301	222	221	322	284	272	264	275	314	395	335	424
Remove_Multiple_state	214	306	254	299	221	219	305	253	244	249	235	290	378	318	397
Remove_Invalid_green_weight	214	306	254	299	221	219	305	253	244	249	235	289	378	318	397
Fix_NA_green_weight	214	306	254	299	221	219	305	253	244	249	235	289	378	318	397
Fix_extreme_green_weight	214	306	254	299	221	219	305	253	244	249	235	289	378	318	397
DQSS	214	306	254	299	221	219	305	253	244	249	235	289	378	318	397
Drop_Straddle_stats_area	214	306	254	299	221	219	305	253	244	249	235	289	378	318	397

Table 24: Details of data corrections by imputation and invalid record removal during the grooming process for BAR 5 by fishing year 2005–2015.

Effort Records	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
START	434	409	405	381	373	343	446	438	482	409	431
Remove_Missing_Keys	433	409	405	381	373	343	446	438	482	409	431
Remove_Unmatched_Trips	433	409	405	381	370	343	444	438	482	407	424
Remove_Duplicate_Trip_Form	433	409	405	381	370	341	439	433	482	407	424
Remove_Invalid_start_datetime	432	409	409	381	365	346	435	434	485	406	421
Remove_Invalid_primary_method	432	409	409	381	365	346	435	434	485	406	421
Remove_Invalid_target_method	432	409	409	381	365	346	435	434	485	406	421
Remove_Invalid_stats_area	422	395	397	369	357	340	426	431	482	404	419
Restratify_effort	422	395	397	369	357	340	426	431	482	404	419
Remove_BPQRT_destination_type	391	382	375	355	342	326	417	419	465	397	411
Remove_Multiple_state	368	360	342	316	298	294	384	358	439	389	392
Remove_Invalid_green_weight	368	360	342	316	298	294	384	358	439	389	392
Fix_NA_green_weight	368	360	342	316	298	294	384	358	439	389	392
Fix_extreme_green_weight	368	360	342	316	298	294	384	358	439	389	392
DQSS	368	360	342	316	298	294	384	358	439	389	392
Drop_Straddle_stats_area	368	360	342	316	298	294	384	358	439	389	392

Table 25: The reported TACC, MHR, annual retained landings in the groomed merged and unmerged dataset, and retained landings in the groomed and merged dataset, and estimated catches in the groomed and merged dataset for BAR 5 from 1990 to 2015.

Year	TACC	MHR	Un-merged landings	Merged landings	Catch	% MHR
1990	9281	5960	5189	5185	5333	89
1991	9282	8817	8289	8289	8177	93
1992	9282	6897	6524	6403	6327	92
1993	9282	7019	7391	7390	7236	103
1994	9282	3410	3233	3170	2904	85
1995	9282	2645	2536	2530	2338	88
1996	9282	4255	4151	4147	3950	93
1997	9282	2839	2565	2564	2307	81
1998	9282	6167	6122	5999	5499	89
1999	7470	7302	7032	7001	6292	86
2000	7470	6205	5985	5772	5614	90
2001	7470	6101	6091	6077	5910	97
2002	7470	5883	5876	5864	5364	91
2003	7470	7843	7831	7815	7223	92
2004	7470	6919	6894	6875	6508	94
2005	7470	8593	8245	8175	7689	89
2006	7470	9479	9253	9191	9041	95
2007	7470	6334	6239	6238	6094	96
2008	7470	8561	8341	8294	7840	92
2009	7470	7659	7489	7886	7117	93
2010	7470	6951	6922	6927	6512	94
2011	7470	8201	7918	7917	7163	87
2012	7470	7071	6852	6850	6294	89
2013	7470	7931	8034	8323	7537	95
2014	7470	6886	6795	6862	6441	94
2015	7470	6779	6667	6748	6302	93

Table 26: Species codes used in the report.

Code	Common name	Scientific name
BAR	Barracouta	*Thyrsites atun*
HAK	Hake	*Merluccius australis*
HOK	Hoki	*Macruronus novaezelandiae*
JDO	John dory	*Zues faber*
JMA	Jack mackerels	*Trachurus declivis, T. novaezelandiae, T. symmetricus murphyi*
KAH	Kahawai	*Arripis trutta, A. xylabion*
LIN	Ling	*Genypterus blacodes*
RCO	Red cod	*Pseudophycis bachus*
SFL	Sand flounder	*Rhombosolea plebeia*
SPE	Sea perch	*Helicolenus percoides*
SQU	Arrow squid	*Nototodarus gouldi, N. sloanni*
SQX	Squid	*Unidentified squid*
SSO	Smooth oreo	*Pseudocyttus maculatus*
STA	Stargazers	*Kathestoma giganteum*
SWA	Silver warehou	*Seriolella punctata*
TAR	Tarakihi	*Nemadactylus macropterus*
TRE	Trevally	*Pseudocaranx dentex*
WAR	Blue warehou	*Seriolella brama*

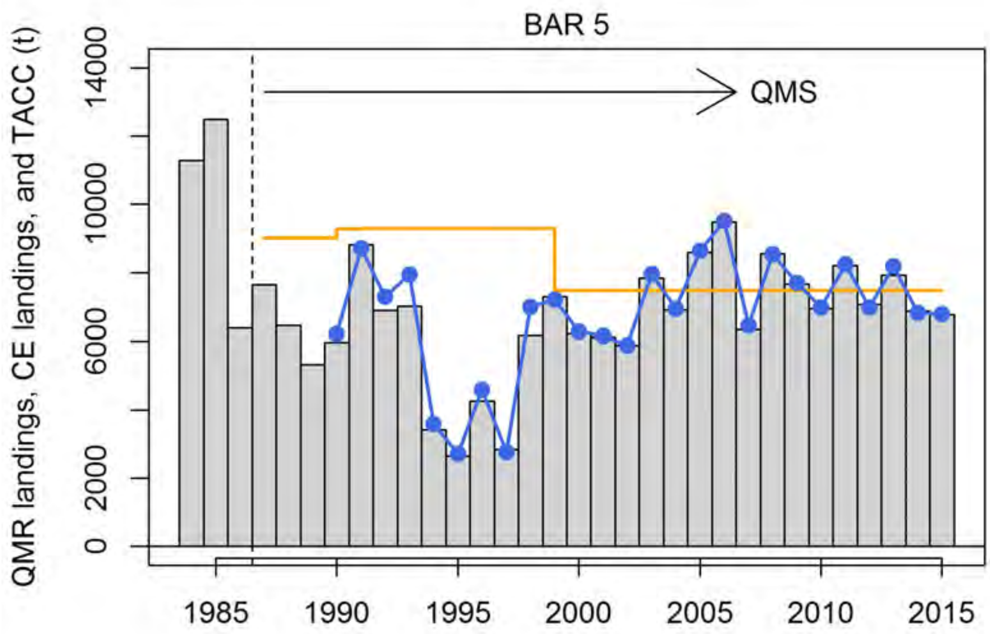


Figure 17: The QMR/MHR landings (grey bars), un-groomed catch effort landings (dotted blue line), and TACC (gold line) for BAR 5 from 1984 to 2015.

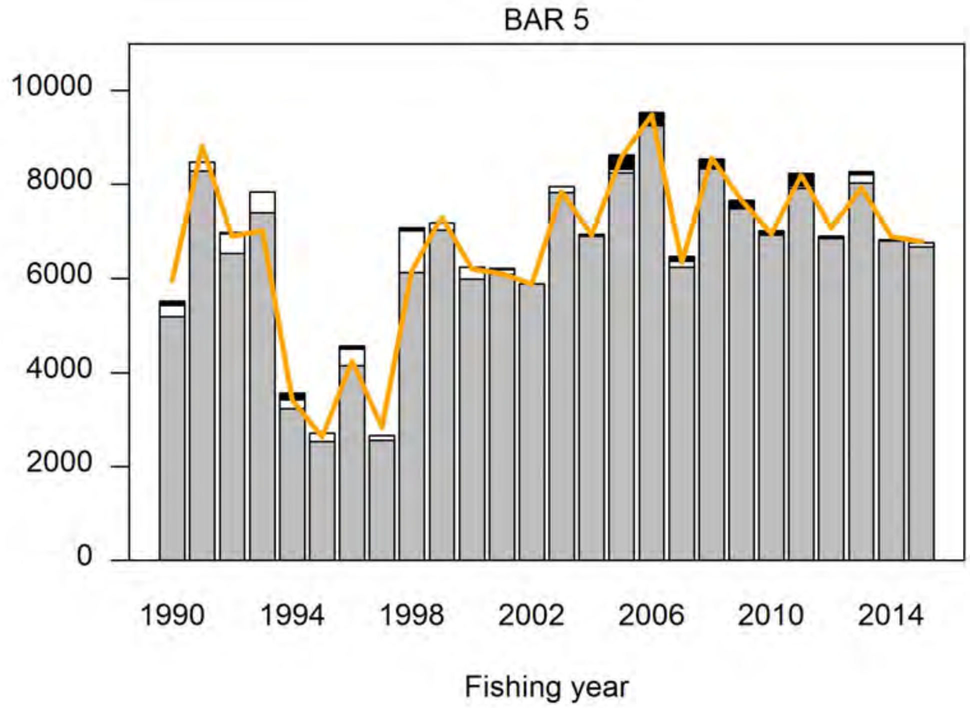


Figure 18: The retained landings (grey bars), interim landings (white bars), and landings dropped during data grooming (black bars), and MHR landings (gold line) for BAR 5 from the 1990 to 2015 fishing year.

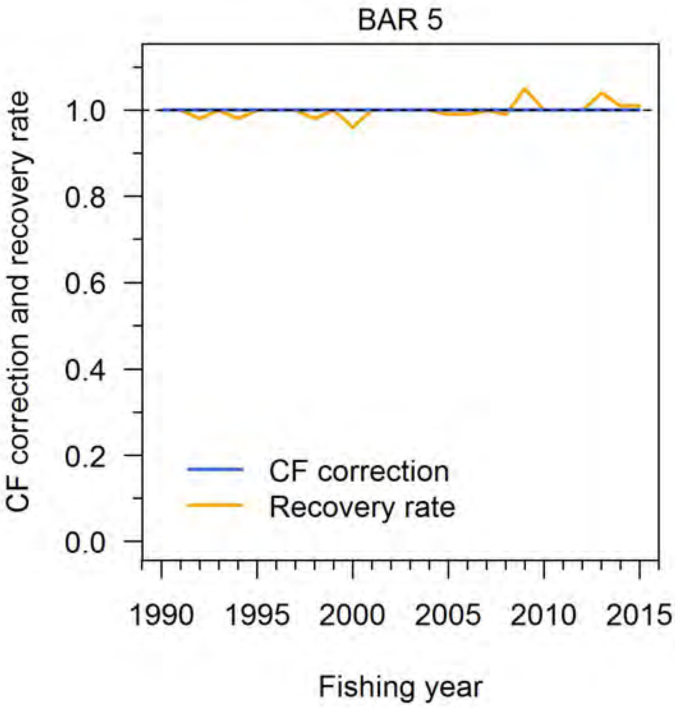


Figure 19: Conversion factor (CF) corrections (by the centroid method), defined as the ratio of annual green weight recalculated using the most recent correction factors for each processed state to the reported green weight, and the recovery rate, defined as the ration of annual landings in the groomed and merged dataset to those in the groomed and unmerged dataset, for BAR 5 from the 1990 to 2015 fishing year.

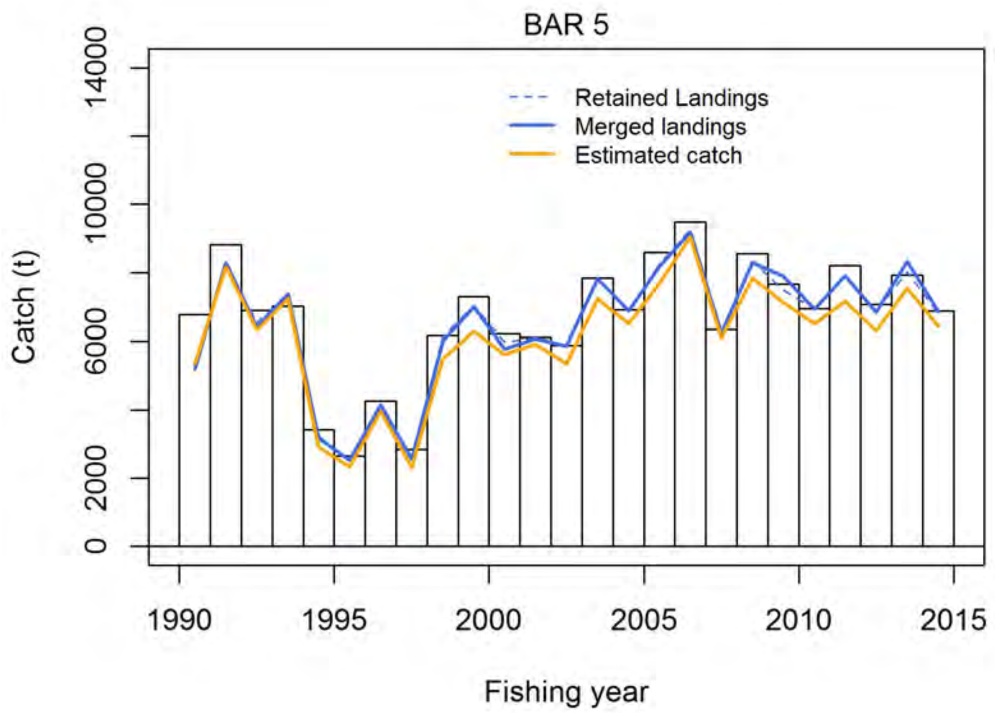


Figure 20: The QMR/MHR landings (white bars), retained landings in the groomed and unmerged dataset (blue dashed line), retained landings in groomed and merged dataset (green solid line), and daily processed catch in the groomed and merged dataset (gold solid line), using the centroid method, for BAR 5 from the 1990 to 2015 fishing year.

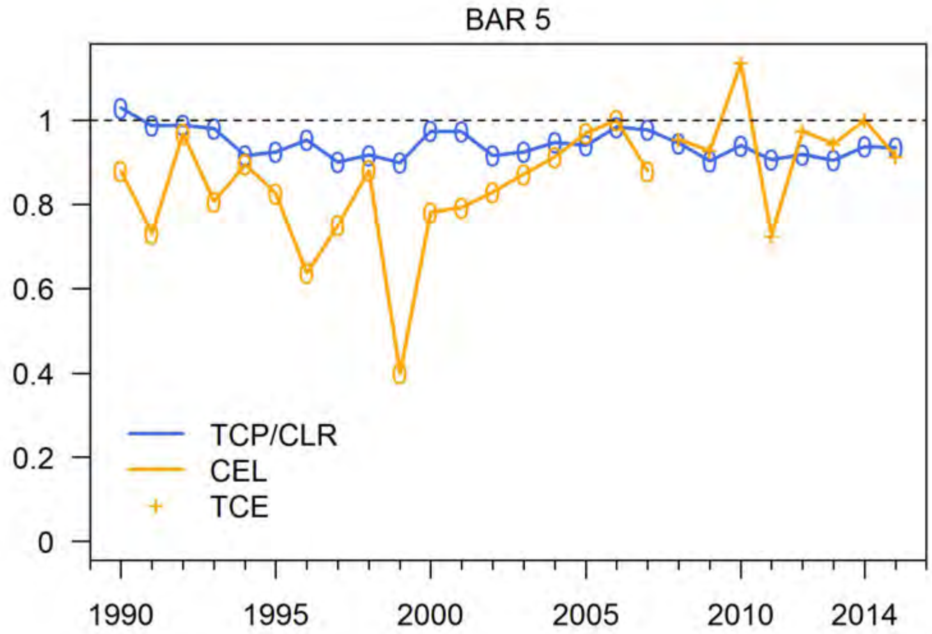


Figure 21: The reporting rate, defined as the ratio of greenweight calculated from annual processed catch as a proportion of retained landings in the groomed and merged dataset, for BAR 5 from the 1990 to 2015 fishing year.

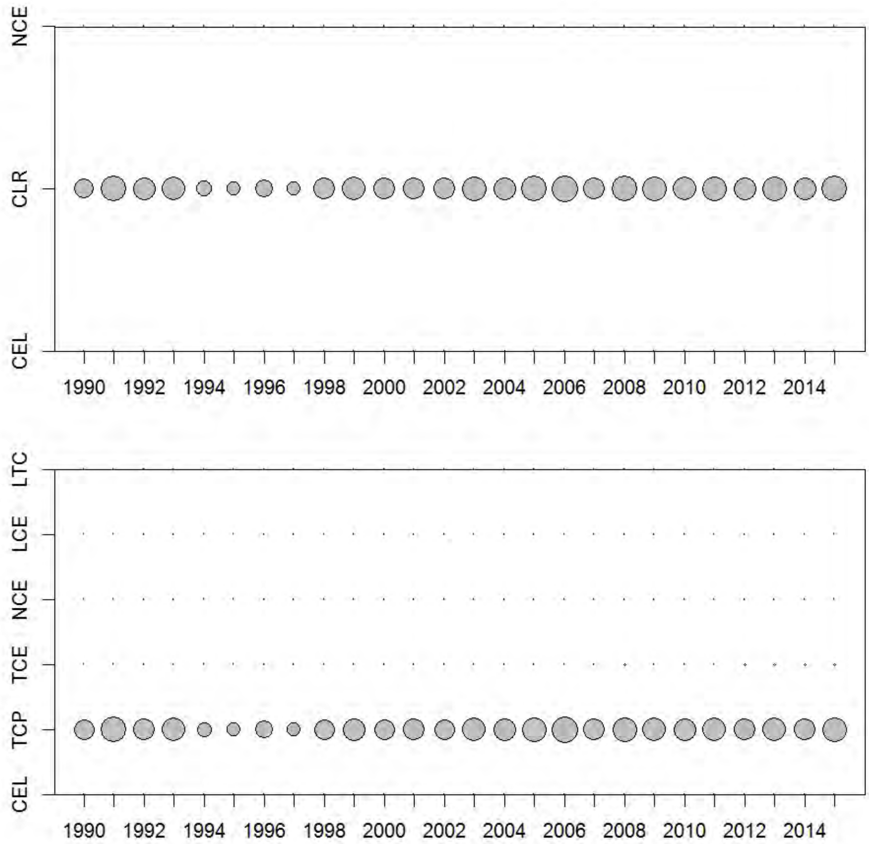


Figure 22: Proportion of landings by form type (top panels) in the groomed and unmerged dataset, and proportion of processed catches by form type (bottom panels) in the groomed and merged dataset, for BAR 5 from the 1990 to 2015 fishing year.

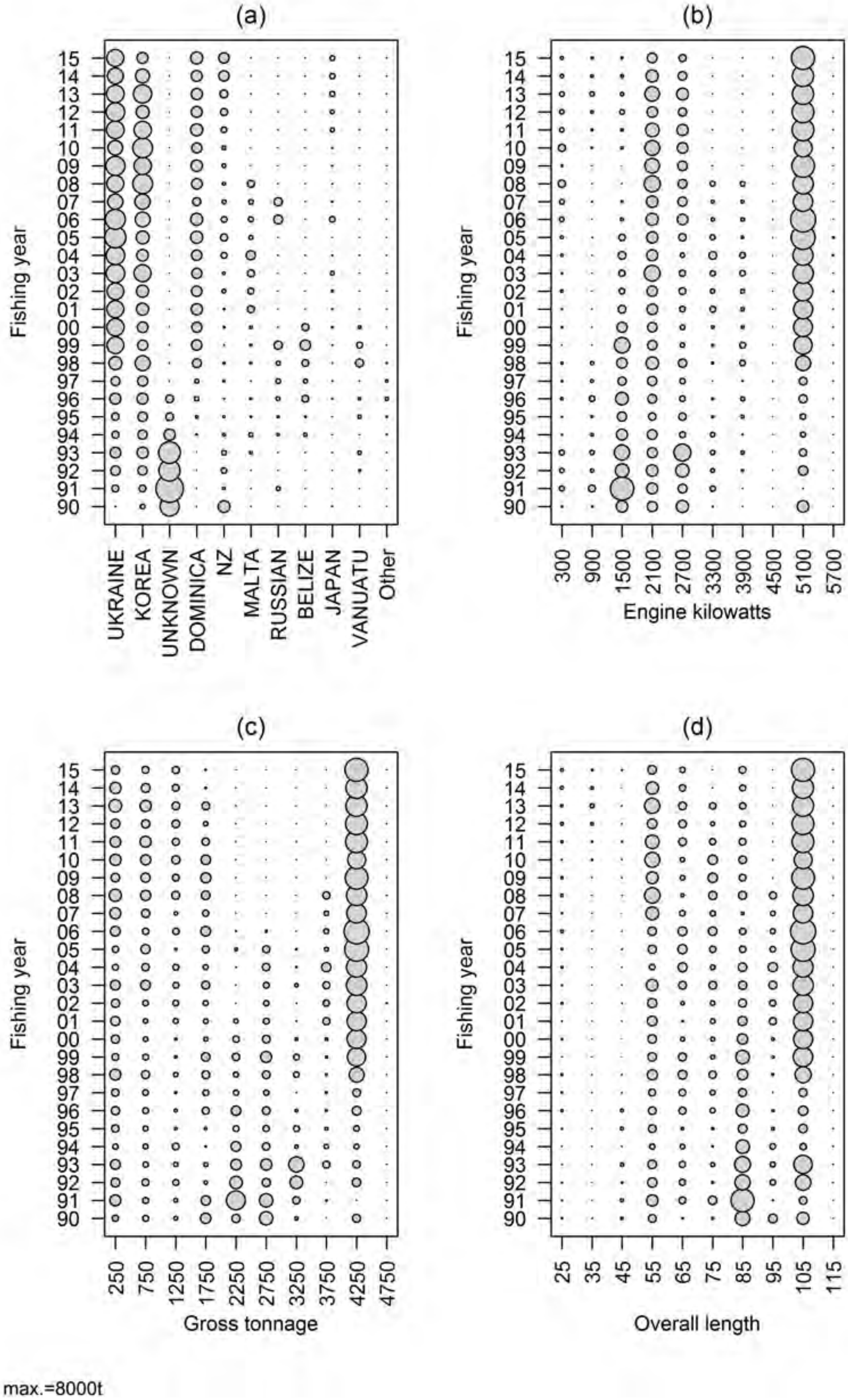


Figure 23: Proportion of landings by vessel characterisation. a) nationality, b) engine size, c) gross weight and d) length of vessel. For Southland from 1990 to 2015.

C. CHARACTERISATION

Table 27: Total barracouta catch (t) for Southland from groomed and merged data for fishing years 1990–2015.

	UKRAINE	KOREA	UNKNOWN	DOMINICA	NZ	MALTA	BELIZE	RUSSIAN	JAPAN	VANUATU	Other	Total
1990	6.49	320.18	3241.72	0.00	1809.45	0.00	0.00	0.00	10.30	0.00	0.00	5 388.14
1991	424.81	555.31	6952.65	0.00	67.56	0.00	0.00	184.75	0.00	0.00	0.00	8 185.08
1992	874.27	825.61	4218.92	0.00	347.79	0.00	0.00	0.00	2.90	61.70	0.00	6 331.19
1993	1 203.06	1 156.61	4 575.59	0.00	224.53	90.12	0.00	0.00	0.00	141.50	0.00	7 391.40
1994	488.85	708.91	1 172.82	29.90	109.87	173.53	129.81	79.08	0.00	0.00	13.56	2 906.32
1995	513.01	875.10	578.08	70.92	71.19	41.84	37.02	50.60	0.00	131.23	24.50	2 393.49
1996	1195.72	1 096.95	756.00	97.35	22.57	61.85	427.58	122.03	8.30	92.35	125.57	4 006.26
1997	749.34	915.94	0.80	186.46	43.06	5.20	192.13	213.65	0.00	0.00	37.04	2 343.61
1998	1 523.09	2 099.45	0.00	604.15	81.53	59.95	490.53	118.29	1.50	571.98	15.00	5 565.46
1999	2 336.93	962.98	0.00	974.52	4.41	39.15	951.44	671.54	3.00	360.75	0.00	6 304.72
2000	2 907.26	1 005.25	0.00	1 005.85	57.62	76.80	472.90	0.00	31.20	90.56	0.00	5 647.44
2001	2 715.38	1 497.34	0.00	1 219.55	81.64	439.72	0.00	0.00	15.45	0.00	0.00	5 969.08
2002	2 659.17	1 182.16	0.00	1 012.97	169.14	322.06	0.00	0.00	48.06	0.00	0.00	5 393.56
2003	3 147.28	2 482.93	0.00	948.65	98.14	428.06	0.00	0.00	151.38	0.00	0.20	7 256.64
2004	3 166.54	1 155.15	0.00	1 041.63	386.94	753.72	0.00	0.00	20.45	0.00	0.00	6 524.43
2005	4 117.11	1 539.55	0.00	1 396.35	475.81	169.93	0.00	0.00	0.45	0.00	0.00	7 699.20
2006	4 105.35	1 985.28	0.00	1 385.77	333.36	275.89	0.00	660.12	311.40	0.00	0.00	9 057.17
2007	2 346.12	2 110.97	0.00	668.00	191.07	226.77	0.00	537.05	30.07	0.00	0.00	6 110.05
2008	2 732.34	3 509.12	0.00	1 023.70	134.47	471.39	0.00	0.00	16.90	0.00	0.00	7 887.92
2009	3 034.43	2 647.77	0.00	1 276.44	153.07	0.00	0.00	0.00	11.75	0.00	0.00	7 123.47
2010	1 930.41	3 429.14	0.00	960.35	189.16	0.00	0.00	0.00	21.80	0.00	0.00	6 530.86
2011	2 719.74	2 631.11	0.00	1 380.22	258.56	0.00	0.00	0.00	194.30	0.00	0.00	7 183.94
2012	3 029.77	1 520.26	0.00	1 124.55	469.89	0.00	0.00	0.00	169.35	0.00	0.00	6 313.82
2013	2 709.50	2 804.96	0.00	1 190.20	566.74	0.00	0.00	0.00	279.14	0.00	0.00	7 550.54
2014	2 427.91	1 607.26	0.00	1 122.70	1 035.10	0.00	0.00	0.00	278.25	0.00	0.00	6 471.23
2015	2 636.96	1 008.89	0.00	1 405.70	1 046.03	0.00	0.00	0.00	213.45	0.00	0.00	6311.03
Total	55 700.84	41 634.18	21 496.58	20 125.94	8 428.69	3 635.97	2 701.40	2 637.11	1819.40	1450.06	215.86	159 846.04

Table 28: Proportion of barracouta catch (total in tonnes) reported each month from the Southland area for fishing years 1990-2015.

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1990	-	0.04	0.10	0.36	0.11	0.27	0.04	0.03	0.02	-	0.03	-	5 185
1991	0.02	0.02	0.13	0.30	0.25	0.22	0.04	0.02	-	-	0.01	-	8 289
1992	0.07	0.06	0.02	0.03	0.27	0.34	0.14	0.05	0.01	-	-	0.01	6 403
1993	-	-	0.05	0.08	0.43	0.24	0.16	0.01	0.01	-	0.01	-	7 390
1994	-	0.30	-	0.01	0.22	0.16	0.30	-	-	-	-	-	3 170
1995	-	0.06	0.25	0.08	0.16	0.28	0.13	0.02	-	-	-	0.01	2 530
1996	0.01	0.01	0.18	0.06	0.15	0.30	0.22	0.05	-	-	-	0.02	4 147
1997	0.02	0.07	0.24	0.08	0.04	0.28	0.16	0.07	0.05	-	-	0.01	2 564
1998	0.04	0.08	0.15	0.05	0.09	0.28	0.23	0.07	-	-	-	-	5 999
1999	0.01	0.02	0.19	0.11	0.14	0.42	0.11	-	-	-	-	-	7 001
2000	0.01	0.08	0.07	0.29	0.26	0.29	0.01	-	-	-	-	-	5 772
2001	0.05	0.04	0.03	0.16	0.10	0.47	0.13	0.01	-	-	-	0.02	6 077
2002	0.12	0.03	0.05	0.20	0.36	0.14	0.08	0.01	-	-	-	-	5 864
2003	0.16	0.12	0.04	0.15	0.15	0.28	0.09	-	-	-	-	-	7 815
2004	0.14	0.01	0.01	0.10	0.06	0.42	0.24	0.01	-	-	-	0.01	6 875
2005	0.01	0.10	0.04	0.12	0.10	0.29	0.32	0.01	-	-	-	-	8 175
2006	0.07	0.11	0.03	0.10	0.31	0.21	0.15	0.01	0.01	-	-	-	9 191
2007	0.03	0.15	0.10	0.02	0.04	0.44	0.18	0.03	-	-	-	-	6 238
2008	0.06	0.08	0.21	0.14	0.15	0.25	0.10	0.01	-	-	-	-	8 294
2009	0.02	0.10	0.08	0.27	0.32	0.04	0.12	0.04	0.01	-	-	-	7 886
2010	0.22	0.13	0.01	0.28	0.24	0.06	0.02	0.02	0.01	-	-	-	6 927
2011	0.08	0.06	0.03	0.37	0.24	0.11	0.08	0.02	-	-	-	-	7 917
2012	0.07	0.06	-	0.03	0.36	0.29	0.13	0.05	-	-	-	-	6 850
2013	0.17	0.05	0.07	0.16	0.23	0.16	0.11	0.03	-	-	-	0.02	8 323
2014	0.07	0.03	-	0.26	0.22	0.34	0.06	0.01	-	-	-	0.01	6 862
2015	0.08	0.05	0.01	0.14	0.29	0.34	0.07	0.01	-	-	-	0.01	6 748
Total	0.07	0.07	0.07	0.16	0.21	0.26	0.13	0.02	-	-	-	0.01	168 492

Table 29: Proportion of barracouta catch (total in tonnes) reported by gear type from the Southland area for fishing years 1990-2015.

	BT	MB	MW	Other	Total
1990	0.67	0.32	0.01	-	5 185
1991	0.33	0.61	0.07	-	8 289
1992	0.36	0.52	0.12	-	6 403
1993	0.25	0.69	0.06	-	7 390
1994	0.46	0.50	0.04	-	3 170
1995	0.43	0.53	0.04	-	2 530
1996	0.34	0.62	0.04	-	4 147
1997	0.28	0.55	0.17	-	2 564
1998	0.38	0.58	0.05	-	5 999
1999	0.13	0.78	0.10	-	7 001
2000	0.19	0.72	0.09	-	5 772
2001	0.19	0.73	0.08	-	6 077
2002	0.20	0.74	0.06	-	5 864
2003	0.24	0.73	0.03	-	7 815
2004	0.13	0.82	0.05	-	6 875
2005	0.25	0.72	0.04	-	8 175
2006	0.23	0.71	0.06	-	9 191
2007	0.39	0.53	0.08	-	6 238
2008	0.40	0.55	0.05	-	8 294
2009	0.25	0.68	0.07	-	7 886
2010	0.24	0.69	0.06	-	6 927
2011	0.27	0.69	0.03	-	7 917
2012	0.25	0.74	0.01	-	6 850
2013	0.37	0.62	0.01	-	8 323
2014	0.30	0.66	0.04	-	6 862
2015	0.16	0.78	0.06	-	6 748
Total	0.28	0.66	0.06	-	168 492

Table 30: Characterisation overview.

	Southland
FMA	5 & 6
Season	October-April
Dominant Statistical Area	028
Trawl type	Mid-bottom, Bottom
Form type	TCEPR
Target species	SQU, BAR
Target BAR as % of total catch	30%
<20% tows with zero BAR catch	BAR (since 1997), WAR (since 2006)
Catch trends	Increasing from 1997 to 2006 then flat

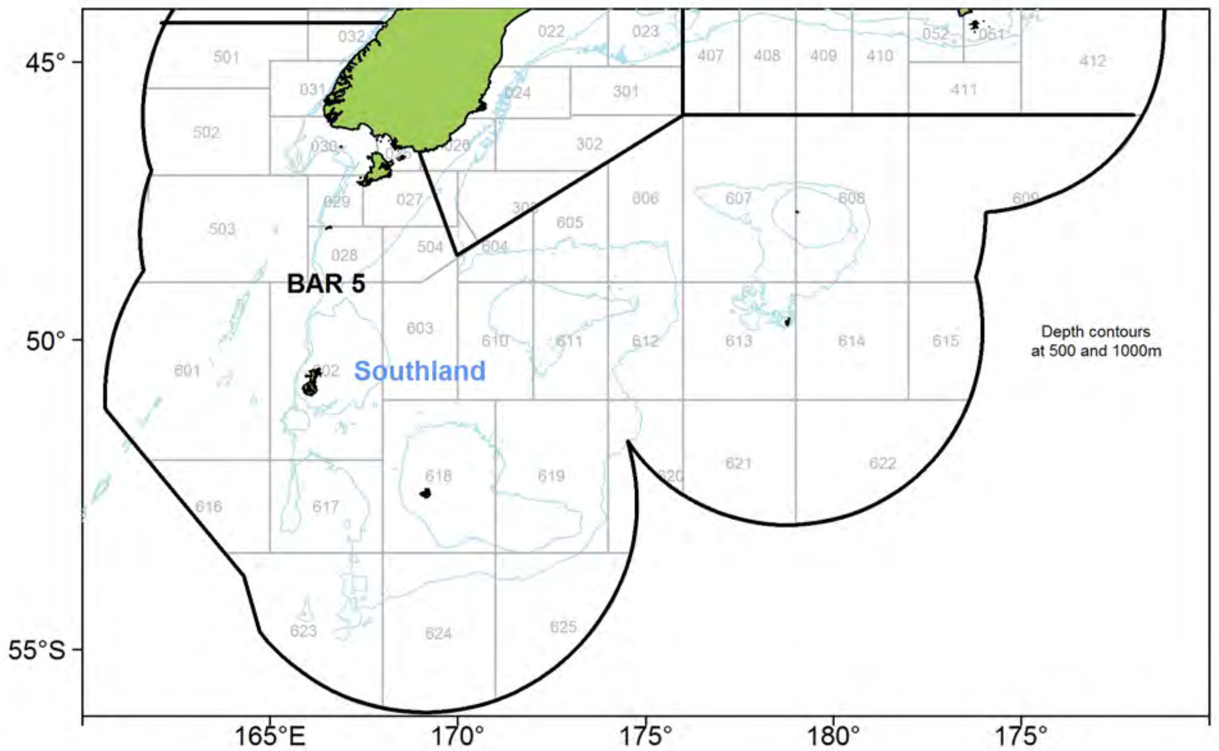


Figure 24: Boundaries used in this analysis and the administrative fish stock boundaries for BAR 5, including statistical areas, and the 500 m and 1000 m depth contours.

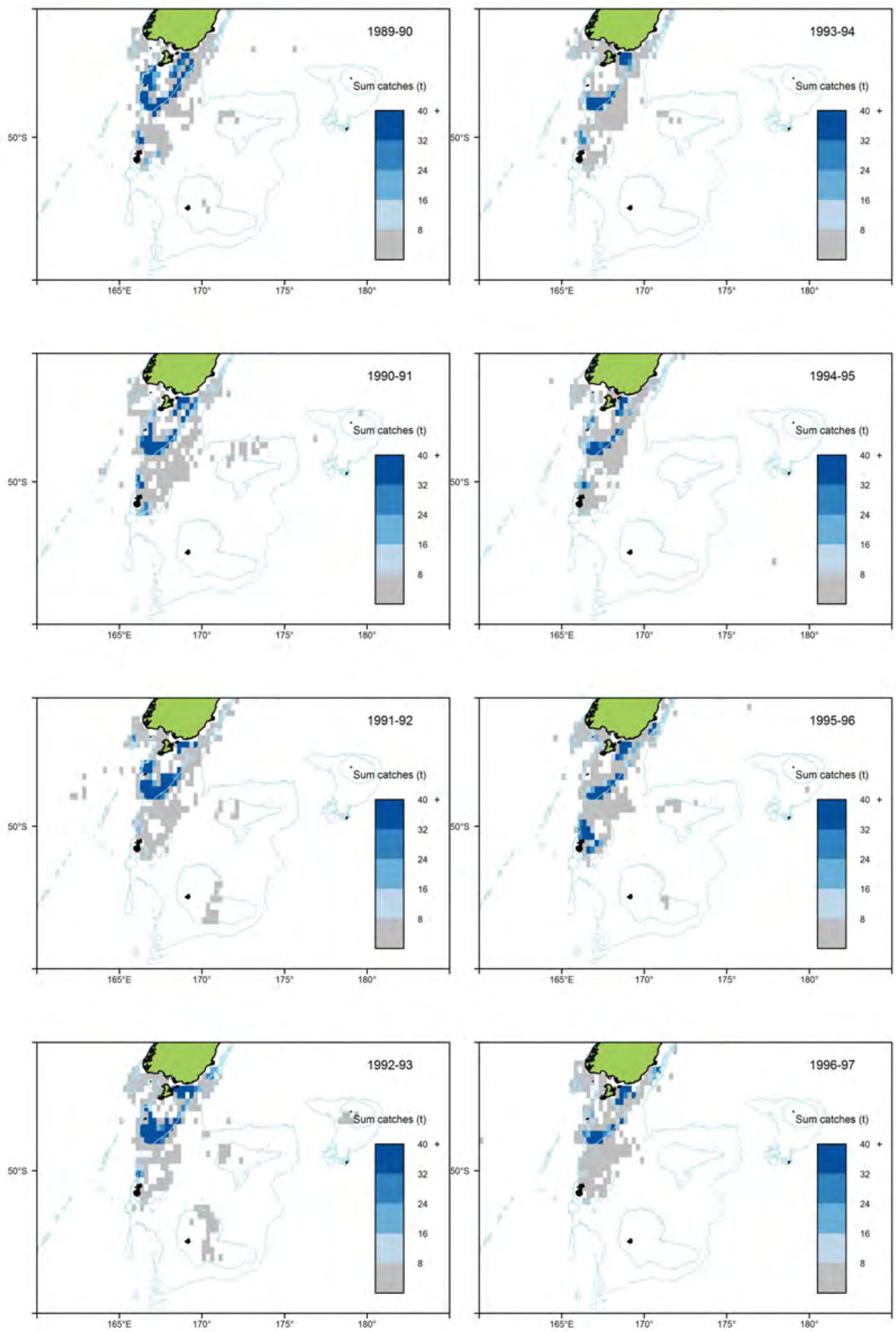


Figure 25: Annual commercial catch (in tonnes) of barracouta from TCEPR records by fishing year 1989-90 to 1996-97.

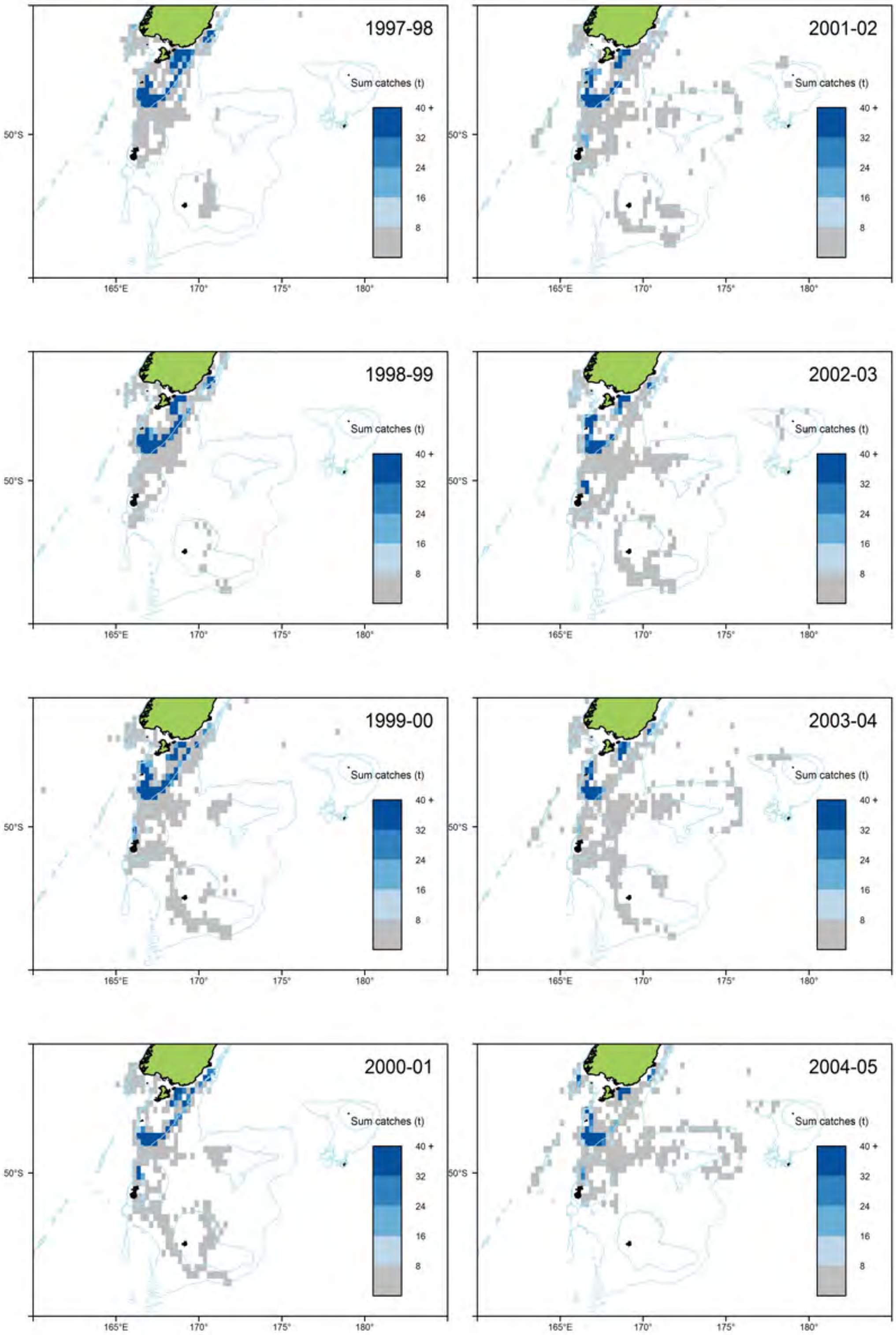


Figure 26: Annual commercial catch (in tonnes) of barracouta from TCEPR records by fishing year 1997-98 to 2004-05.

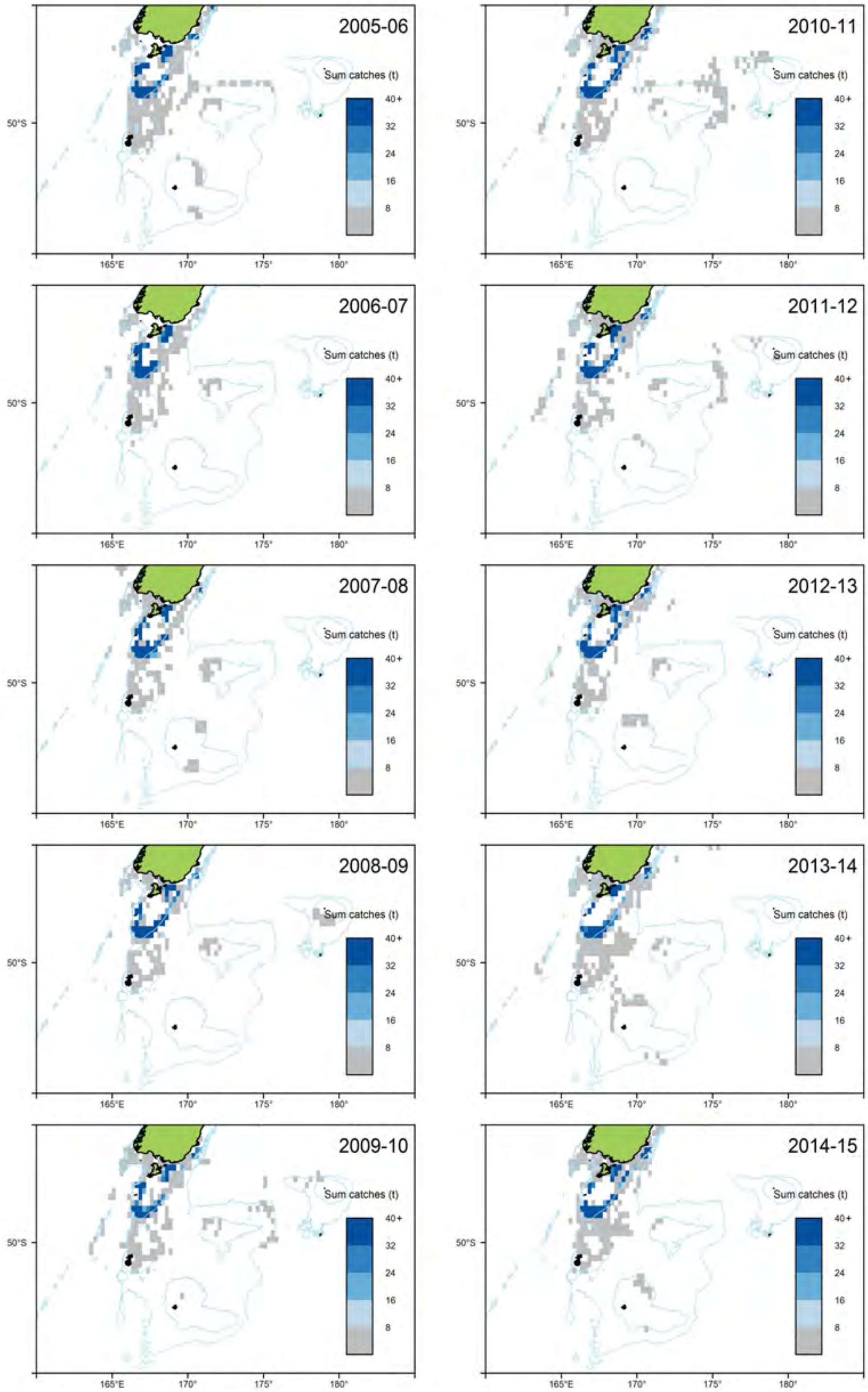
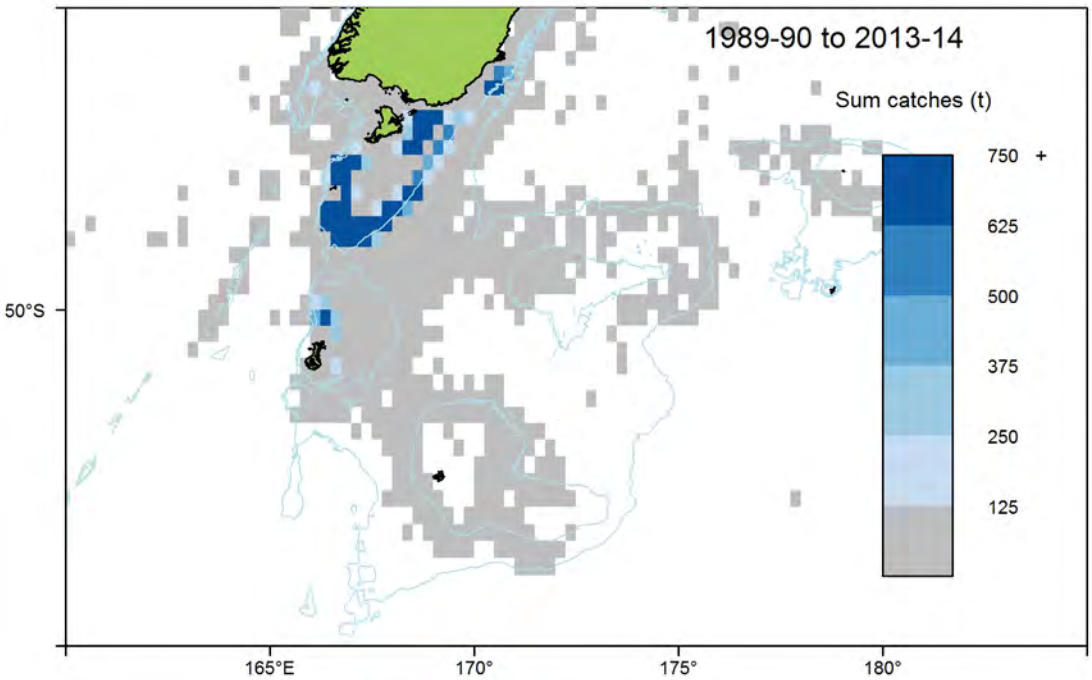


Figure 27: Annual commercial catch (in tonnes) of barracouta from TCEPR records by fishing year 2005-06 to 2014-15.



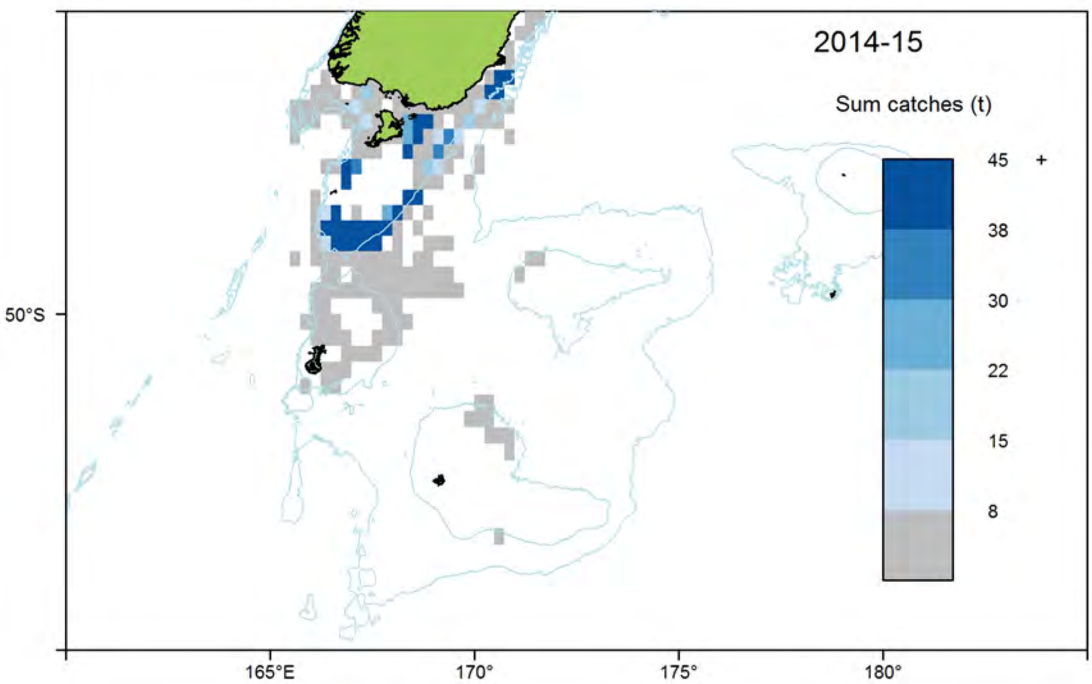


Figure 28: Annual commercial catch (in tonnes) of barracouta from TCEPR records for fishing years 1989-90 to 2013-14 (top) and fishing year 2015 (bottom).

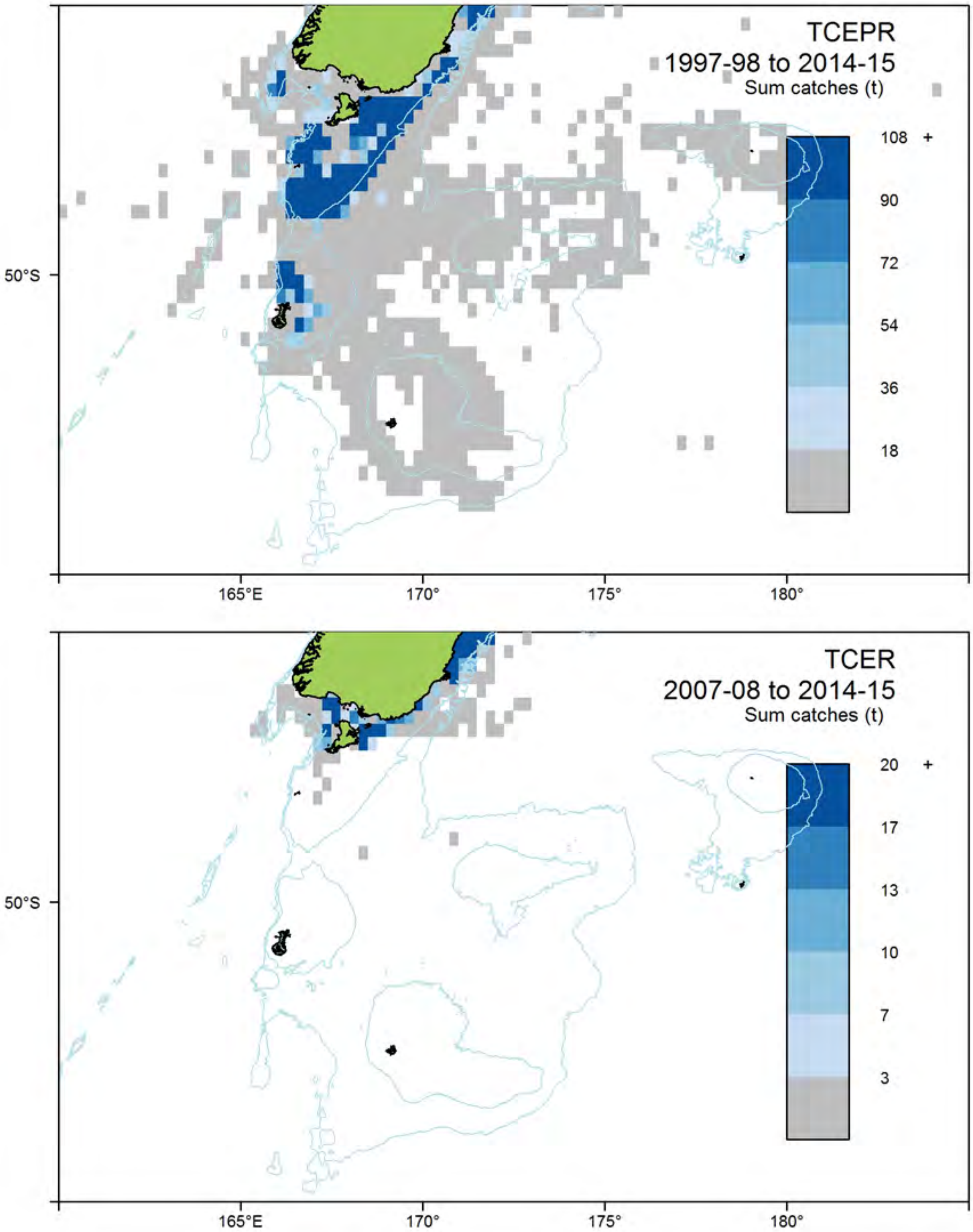


Figure 29: Catch (in tonnes) of all commercial barracouta catches from TCEPR for fishing years 1990-2015 (top) and TCER for fishing years 2008-2015 (bottom).

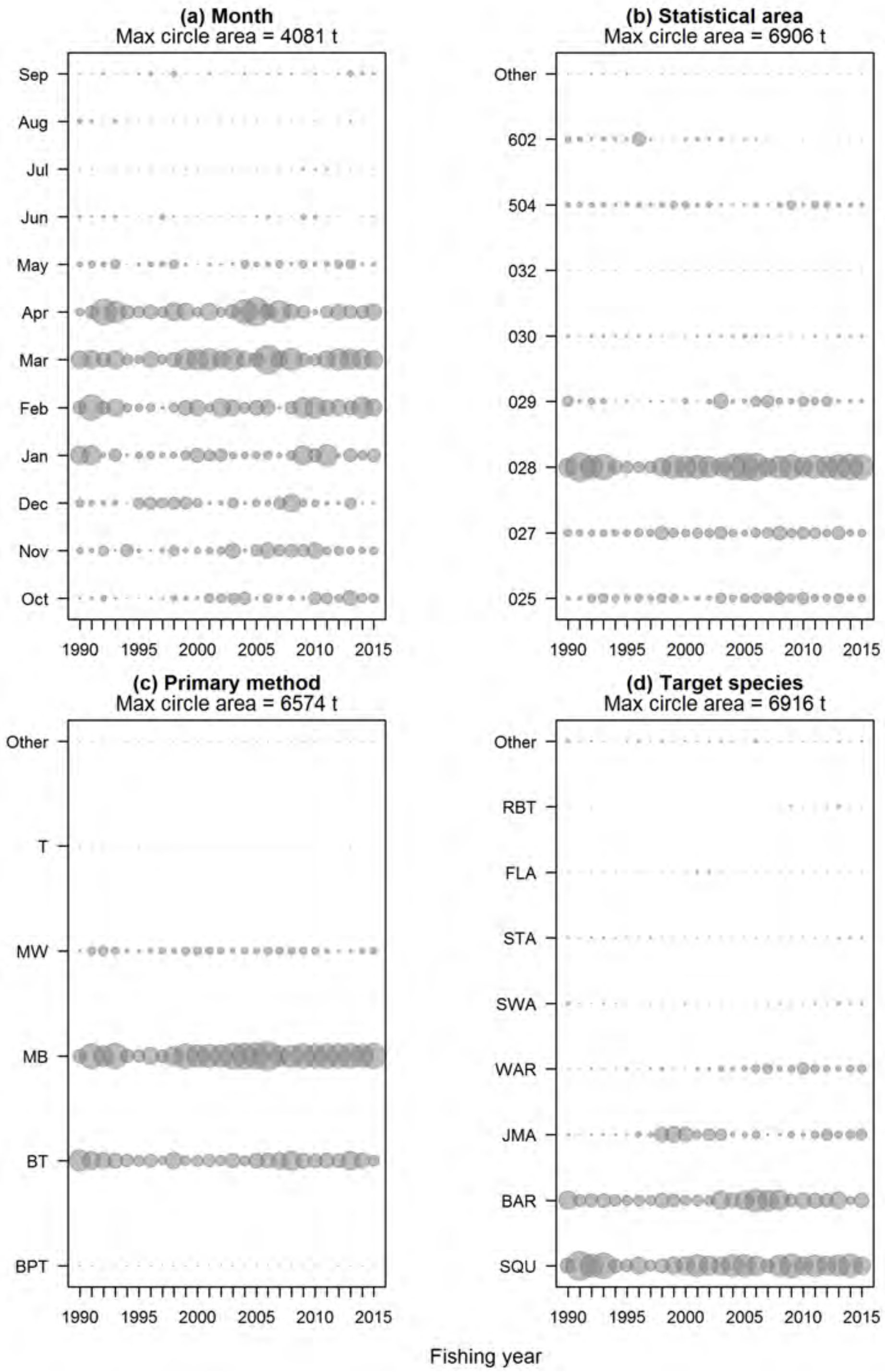


Figure 30: Distribution of barracouta commercial catch in Southland for fishing years 1990–2015 in relation to a) month, b) statistical area, c) fishing method, and d) target species.

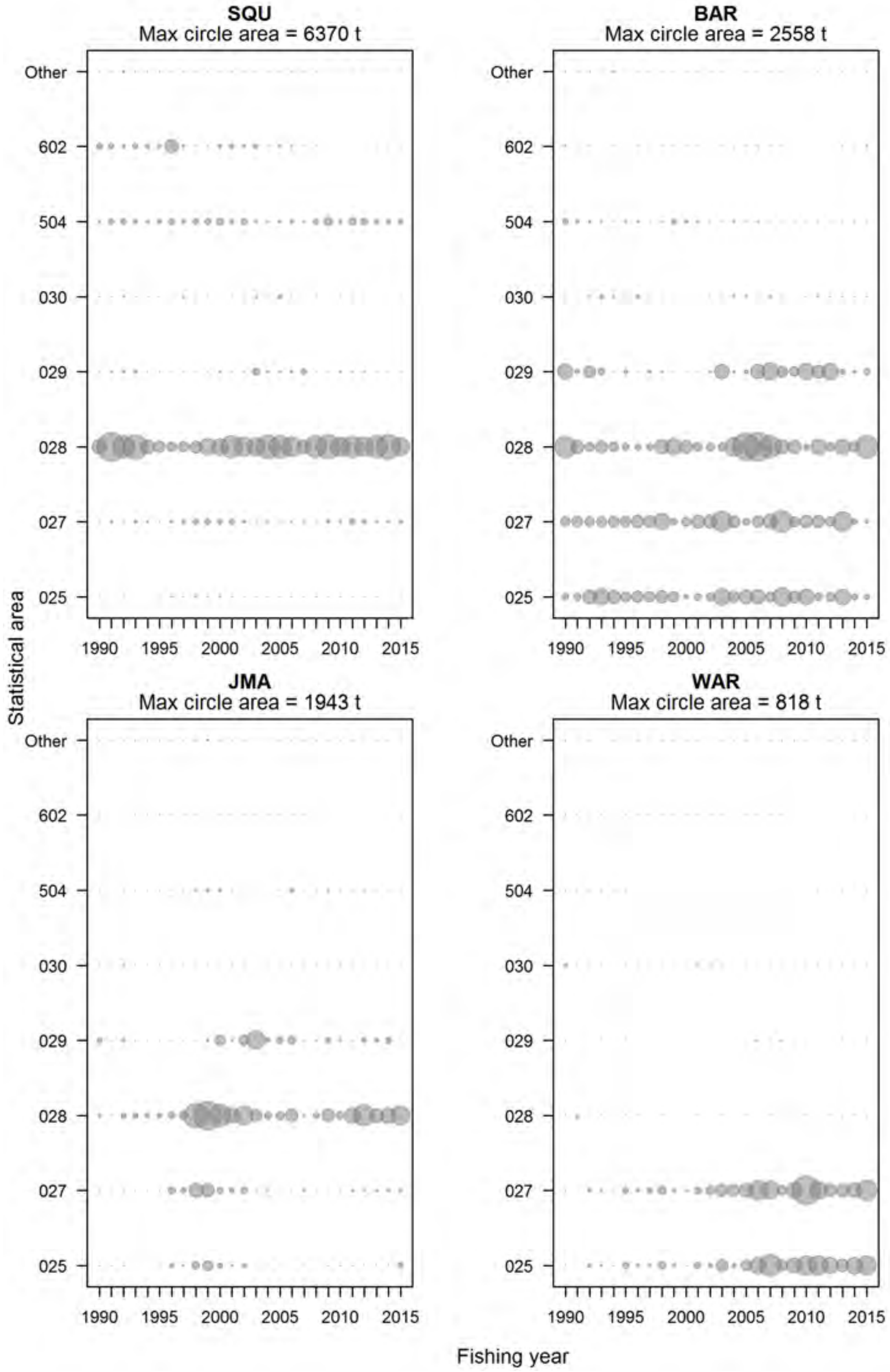


Figure 31: Distribution of barracouta catch in Southland for fishing years 1990–2015 in relation to statistical area for the top four target species.

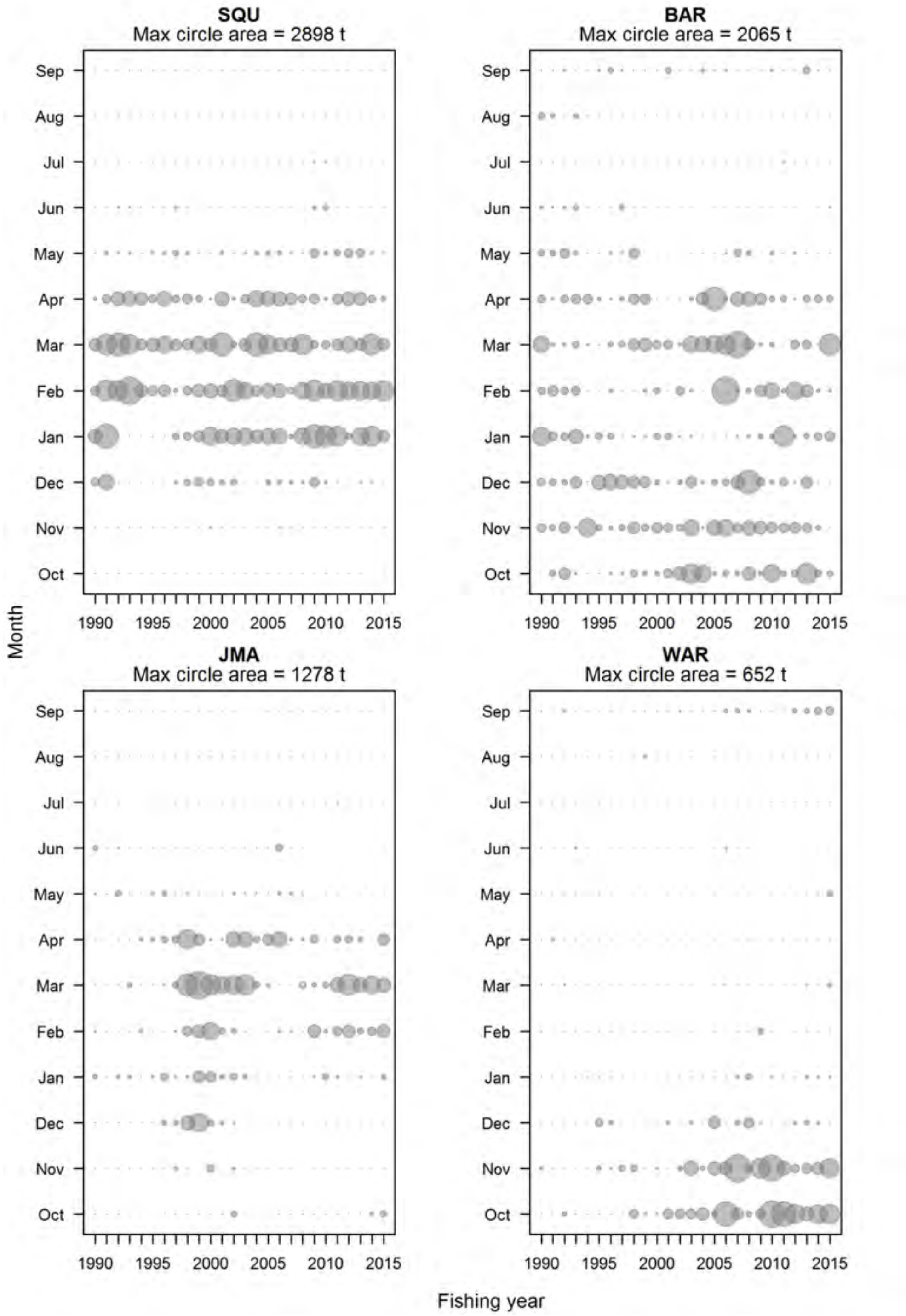
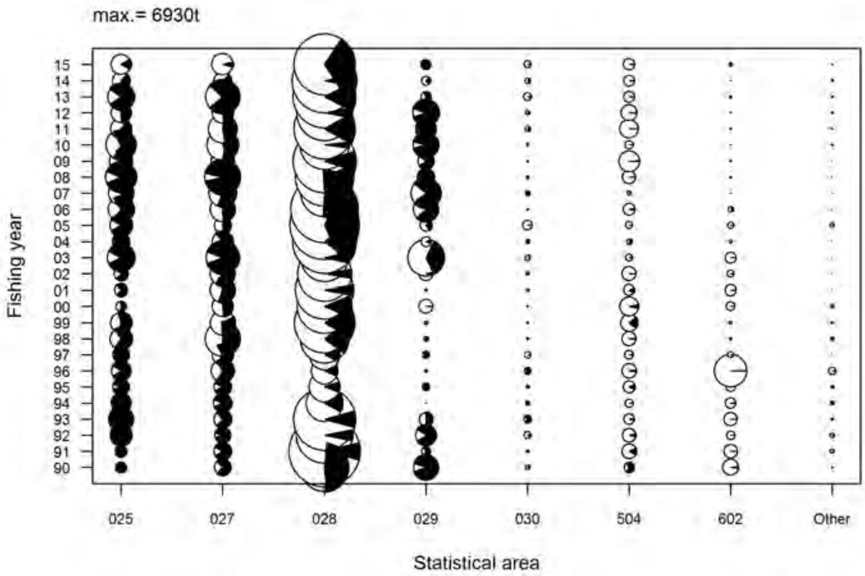
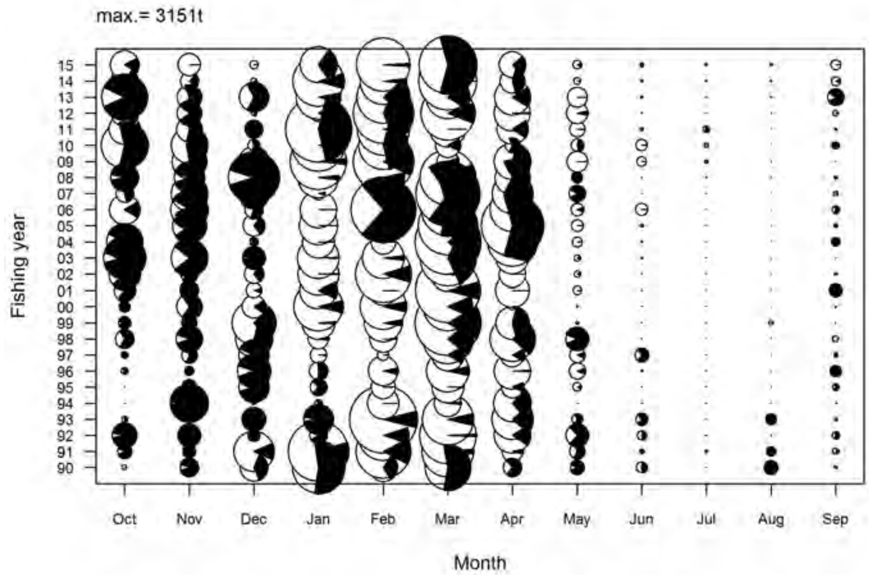


Figure 32: Distribution of barracouta catch in Southland for fishing years 1990–2015 in relation to month for the top four target species.



(a)



(b)

Figure 33: Distribution of BAR catch by fishing year with circle size proportional to the total catch and black portion of the pie indicating proportion of the catch as target BAR by a) statistical area, and b) month for the Southland area.

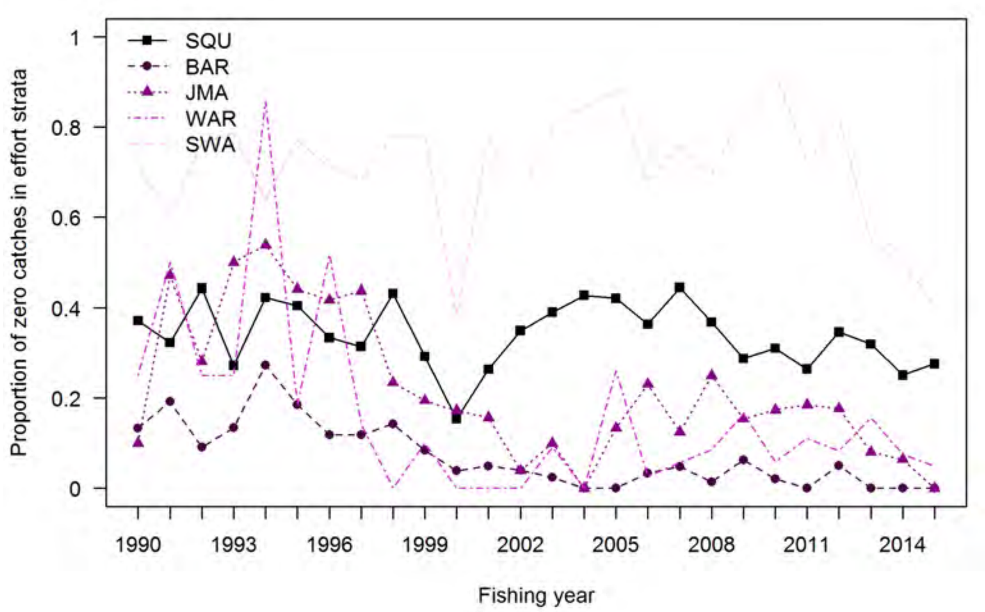


Figure 34: Proportion of TCEPR tows with zero reported BAR catch for major target species for the Southland area.

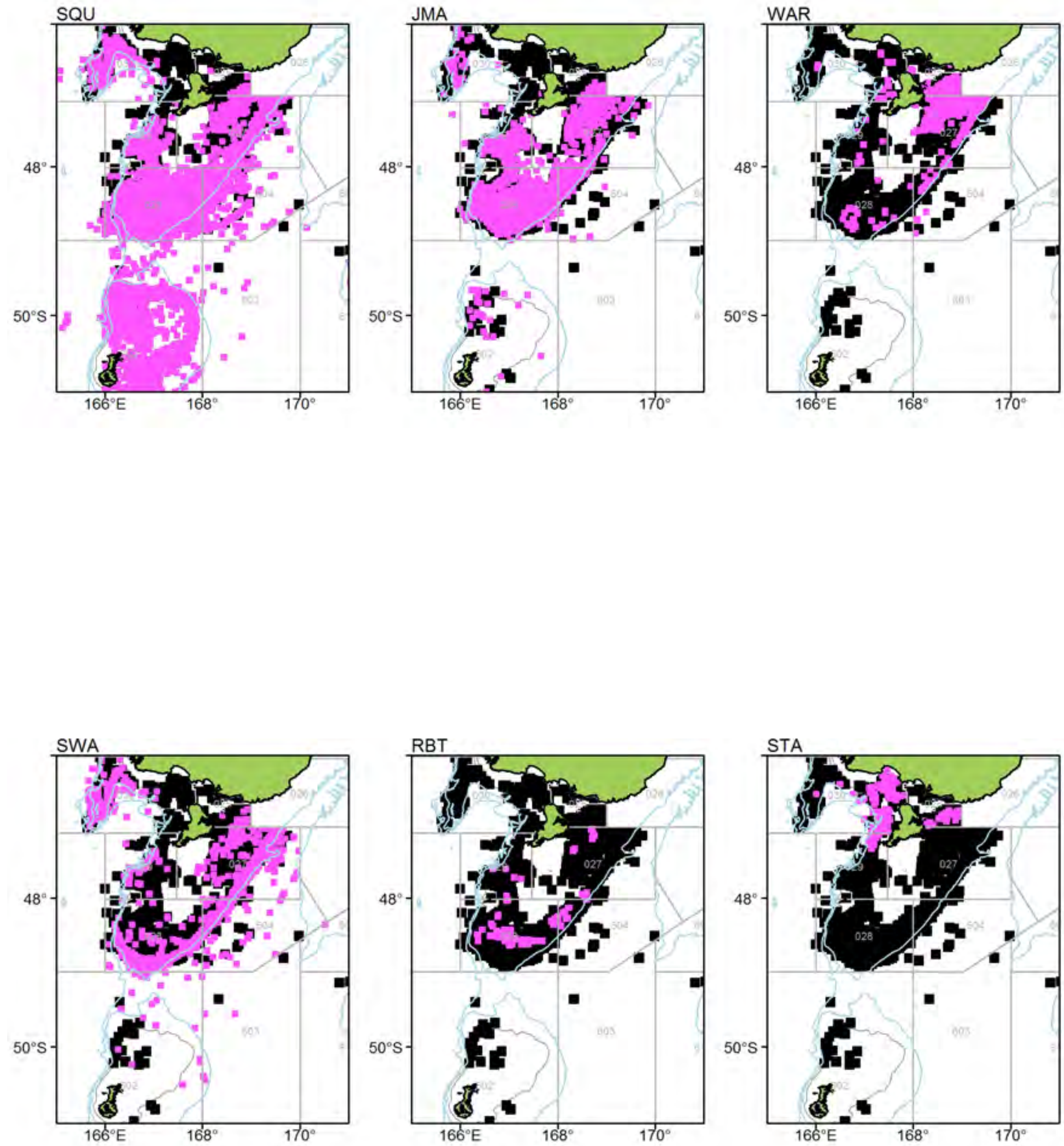


Figure 35: Southland statistical areas and bathymetry showing the distribution of trawls by target species for the main target species (pink cells) compared to the distribution of BAR target effort distribution (black cells) for all fishing years 1990–2015 combined.

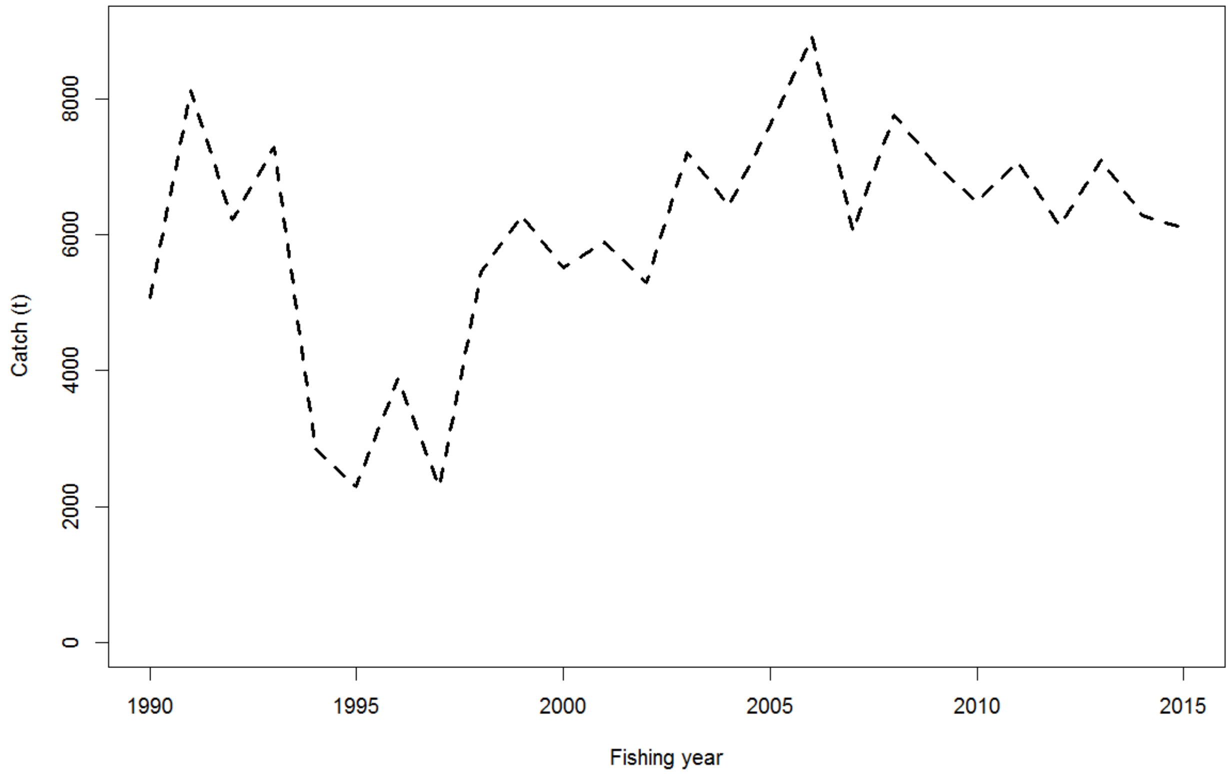


Figure 36: Catch for Southland (1990–2015).

D. Catch-per-unit-effort analyses

Core vessels •

Table 31: CPUE datasets for total non-twin vessels for each year (1990–2015) for CPUE analysis. CPUE is unstandardised catch per non-zero tow.

	No. vessels	No. records	Zeros	Catch (t)	Effort	CPUE
1990	50	6 450	0.70	4 898.60	1 916	2.56
1991	51	10 382	0.54	8 044.10	4 773	1.69
1992	52	6 399	0.69	6 158.50	2 001	3.08
1993	49	7 279	0.46	7 140.70	3 925	1.82
1994	44	6 418	0.82	2 850.80	1 166	2.44
1995	55	8 355	0.78	2 287.10	1 868	1.22
1996	51	7 539	0.58	3 885.60	3 199	1.21
1997	44	7 351	0.73	2 160.40	1 960	1.10
1998	36	7 306	0.63	5 441.50	2 704	2.01
1999	35	6 918	0.51	6 254.90	3 374	1.85
2000	27	4 331	0.42	5 516.60	2 522	2.19
2001	26	4 217	0.52	5 884.10	2 037	2.89
2002	31	5 833	0.60	5 294	2 319	2.28
2003	31	6 331	0.55	7 192.80	2 830	2.54
2004	33	6 455	0.65	6 428.50	2 233	2.88
2005	38	8 593	0.65	7 592	2 977	2.55
2006	38	6 900	0.64	8 805.70	2 505	3.52
2007	28	4 498	0.70	6 042.60	1 347	4.49
2008	25	3 918	0.61	7 754.10	1 518	5.11
2009	24	3 595	0.58	6 847.40	1 494	4.58
2010	23	3 321	0.49	6 354.60	1 697	3.74
2011	25	3 674	0.49	7 038.20	1 889	3.73
2012	23	3 393	0.53	6 126.30	1 601	3.83
2013	23	2 860	0.49	7 092.40	1 468	4.83
2014	17	2 180	0.46	6 285.60	1 177	5.34
2015	18	1 947	0.45	6 070.50	1 075	5.65

Table 32: CPUE datasets for core non-twin vessels for each year (1990–2015) for CPUE analysis. CPUE is unstandardised catch per non-zero tow.

	No. vessels	No. records	Zeros	Catch (t)	Effort	CPUE
1990	11	1 696	0.68	1 477.20	538	2.75
1991	15	2 678	0.54	2 127.50	1 225	1.74
1992	19	2 816	0.66	2 888.60	947	3.05
1993	25	3 477	0.51	3 222.30	1 716	1.88
1994	28	4 565	0.81	2 171.40	846	2.57
1995	37	5 813	0.78	1 725.20	1 264	1.36
1996	32	4 976	0.56	3 098.70	2 175	1.42
1997	29	5 635	0.72	1 895.10	1 556	1.22
1998	31	6 469	0.63	4 817.90	2 399	2.01
1999	32	6 517	0.52	5 648.70	3 131	1.80
2000	26	4 082	0.42	5 239.70	2 368	2.21
2001	25	4 181	0.52	5 872.20	2 017	2.91
2002	27	5 602	0.60	5 260.10	2 248	2.34
2003	27	6 024	0.55	7 017	2 721	2.58
2004	28	6 060	0.66	6 297.60	2 079	3.03
2005	30	7 847	0.65	7 417.60	2 735	2.71
2006	30	6 263	0.64	8 074.10	2 257	3.58
2007	26	4 200	0.70	5 504.10	1 244	4.42
2008	24	3 915	0.61	7 750.40	1 516	5.11
2009	21	3 567	0.59	6 838.10	1 473	4.64
2010	23	3 321	0.49	6 354.60	1 697	3.74
2011	23	3 610	0.48	6 995.10	1 874	3.73
2012	23	3 393	0.53	6 126.30	1 601	3.83
2013	22	2 824	0.49	7 087.60	1 444	4.91
2014	16	2 087	0.46	5 633.60	1 123	5.02
2015	16	1 773	0.45	5 267.20	969	5.44

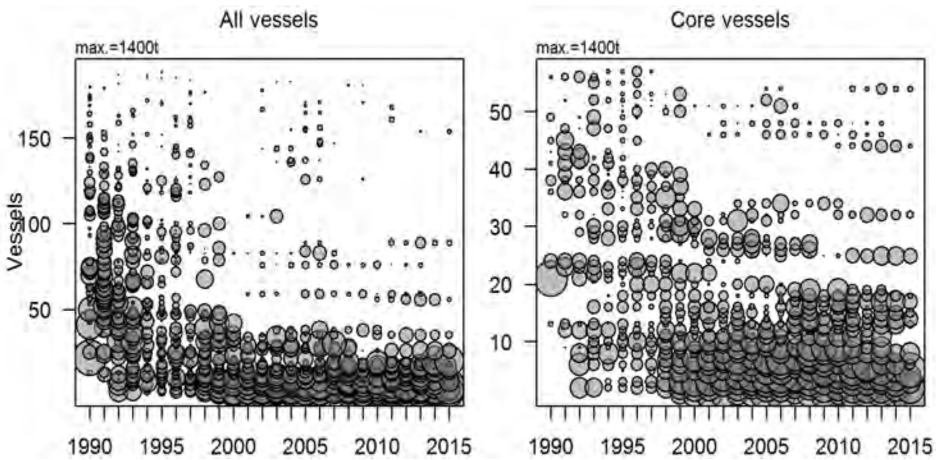


Figure 37: The left panel shows the catch for every vessel (y-axis) operating in the BAR5 fishery over time (x-axis). The right panel shows the core vessels used in the analysis after the core vessel criteria had been applied to all vessels.

Table 33: **Final model after applying forward stepwise model selection using a stopping rule of 1% residual deviance explained.**

Variable	R-squared
fish_year	6.73
vessel_key	24.28
fish_month	26.99
poly(start_longitude, 3)	28.02
poly(effort_depth, 3)	29.06

Table 34: Deviance explained by each covariate by forward stepwise selection.

	1	2	3	4	5
+fish_year	0.07				
+vessel_key	0.24	0.24			
+fish_month	0.10	0.27	0.27		
+poly(start_longitude, 3)	0.08	0.25	0.28	0.28	
+poly(effort_depth, 3)	0.10	0.25	0.28	0.29	0.29
+trip	0.07	0.24	0.27	0.28	0.29
+poly(best_start_time, 3)	0.07	0.25	0.27	0.28	0.29
+primary_method	0.19	0.24	0.27	0.28	0.29
+poly(start_latitude, 3)	0.07	0.24	0.27	0.29	0.29
+poly(effort_height, 3)	0.20	0.24	0.27	0.28	0.29
+poly(effort_width, 3)	0.19	0.24	0.27	0.28	0.29
+poly(fishing_distance, 3)	0.07	0.24	0.27	0.28	0.29
+poly(distance2, 3)	0.07	0.24	0.27	0.28	0.29
+poly(fishing_duration, 3)	0.07	0.24	0.27	0.28	0.29

Squid targeted tows in statistical area 028

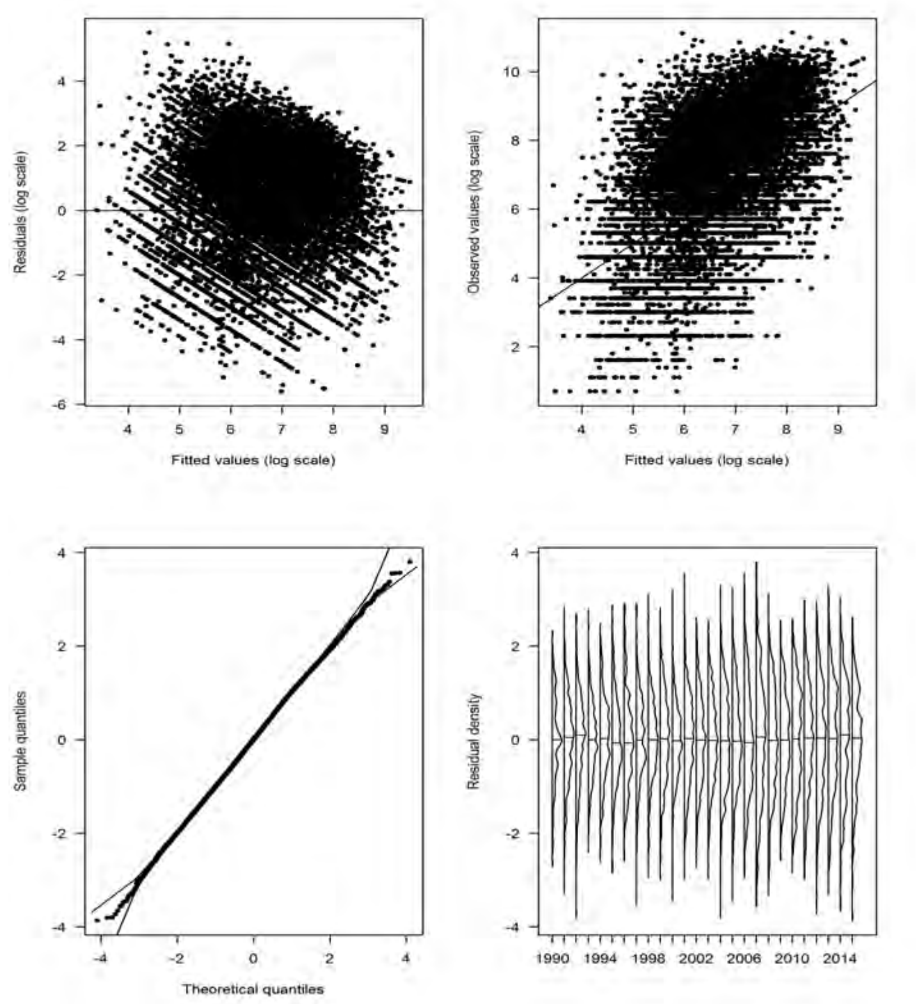


Figure 38: Model diagnostics plots, from the final model.

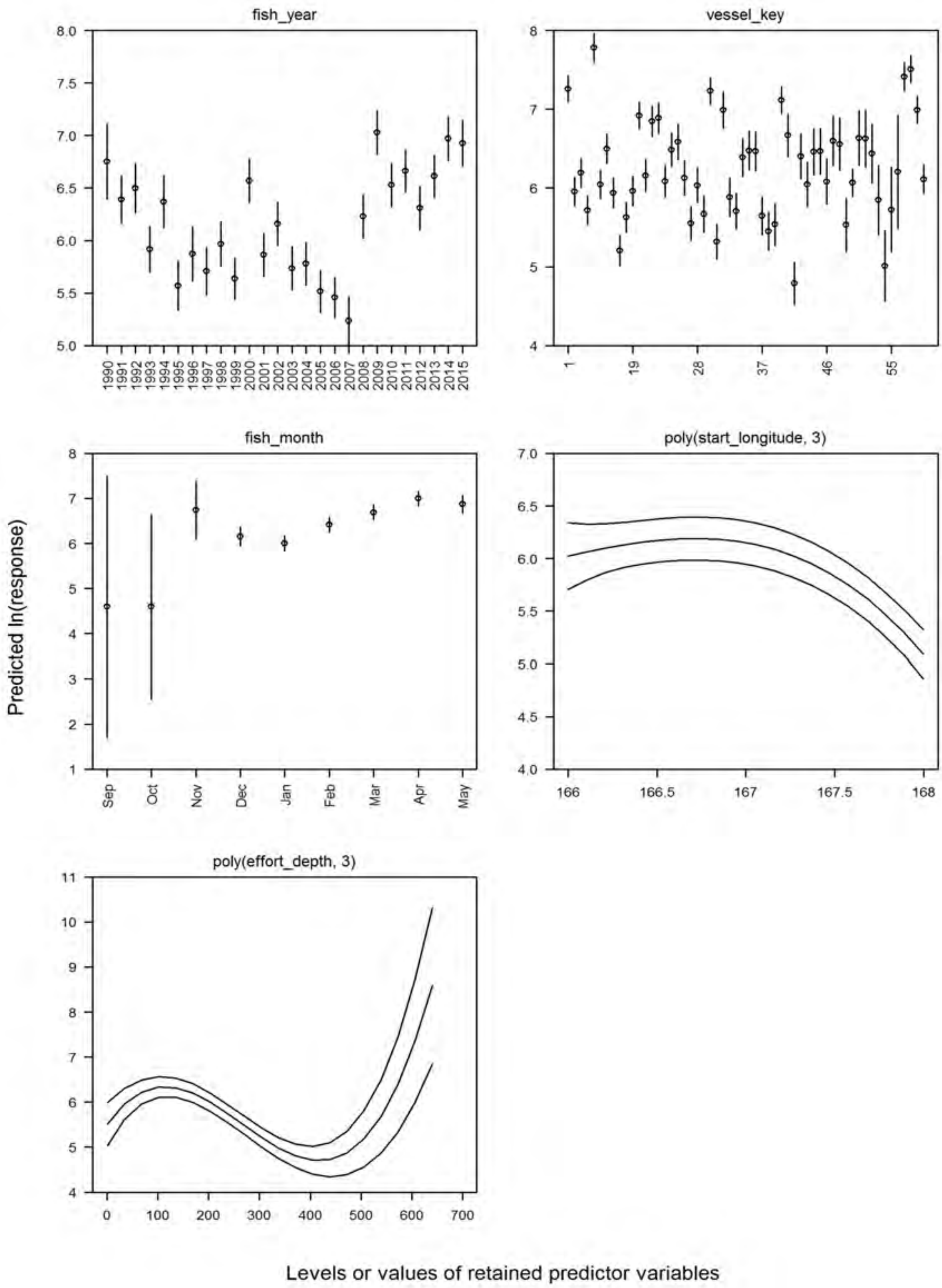


Figure 39: Predicted explanatory effects from the final model.

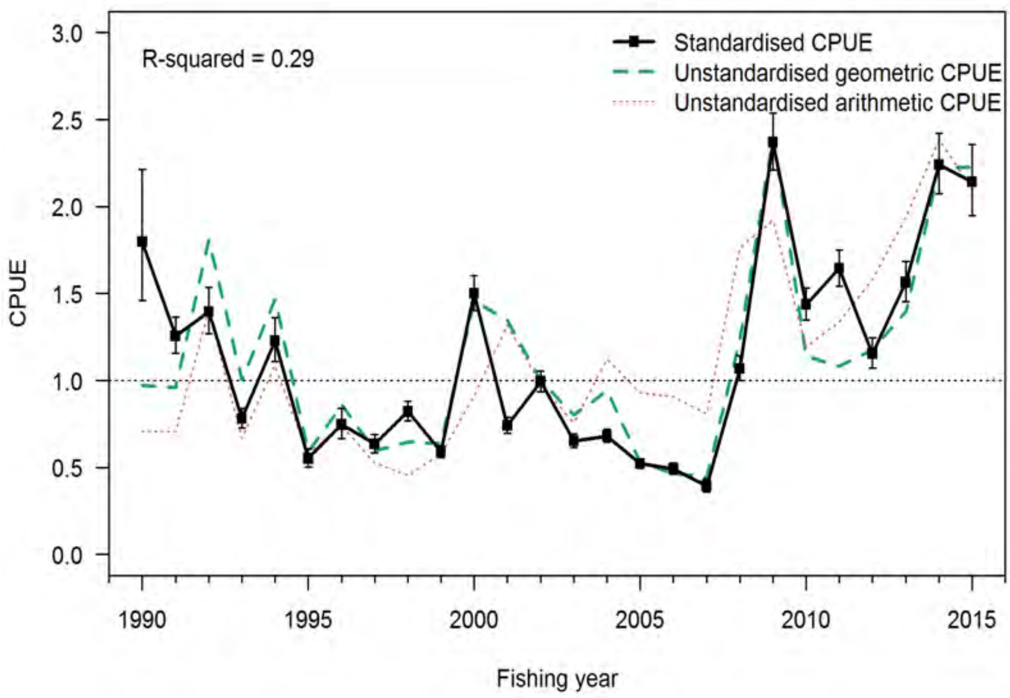
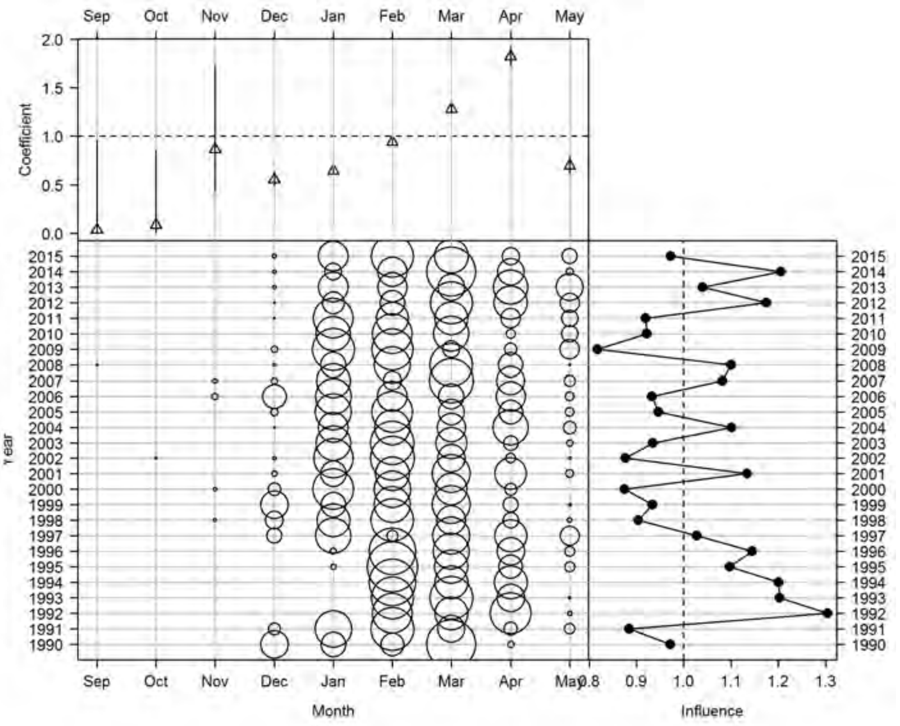
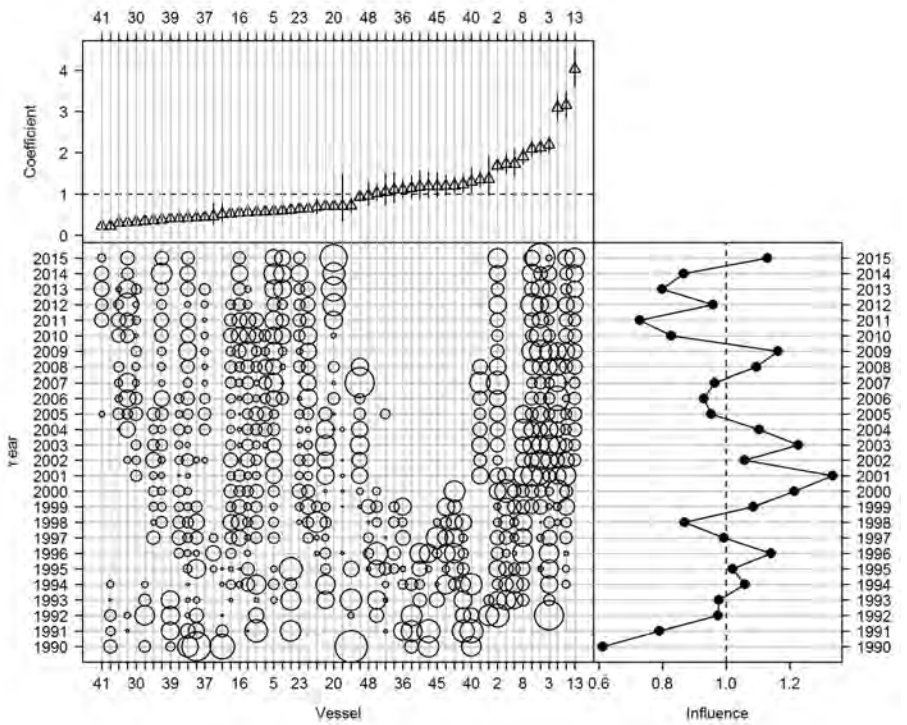


Figure 40: Canonical index for the year effect from the final model.

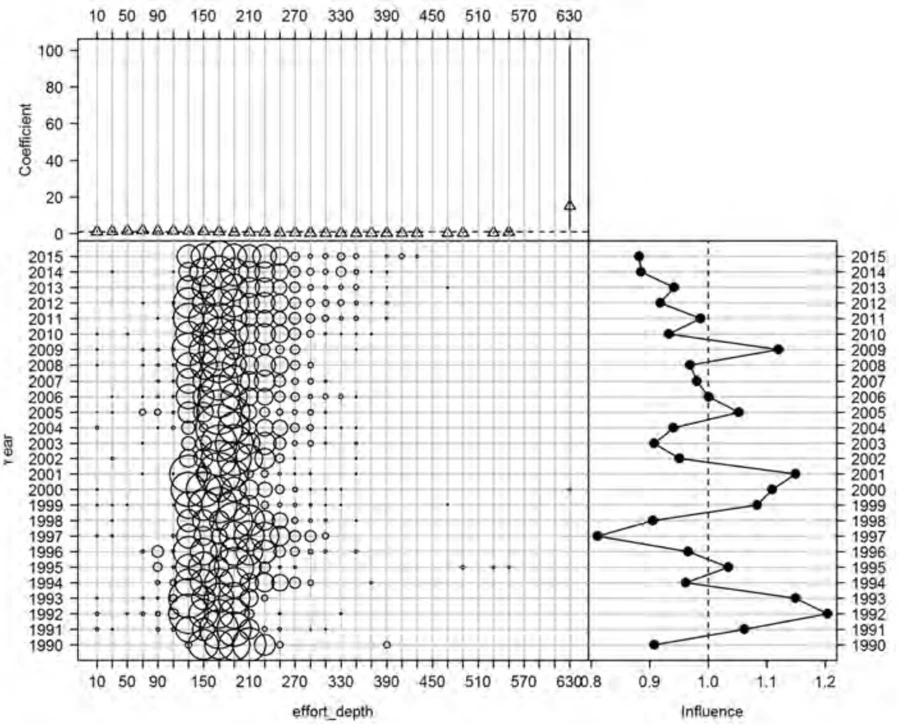


(a)

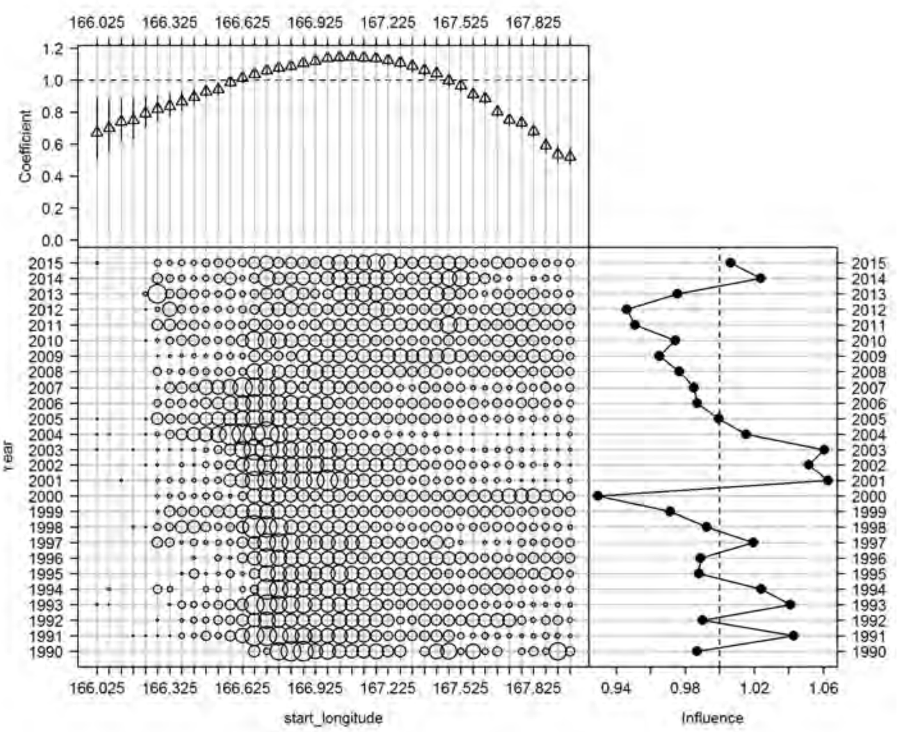


(b)

Figure 41: Influence plots for month (top) and vessel (bottom).

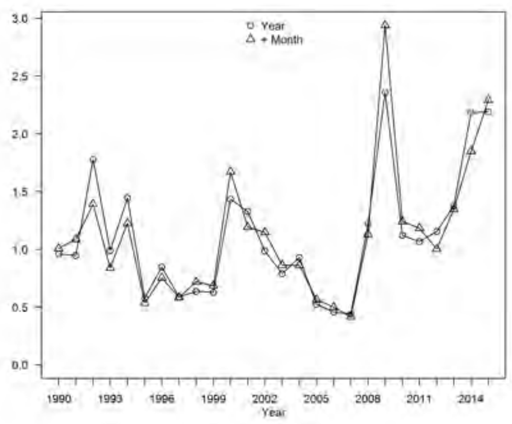


(a)

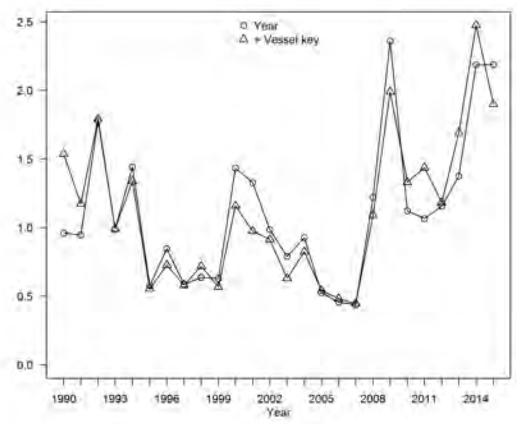


(b)

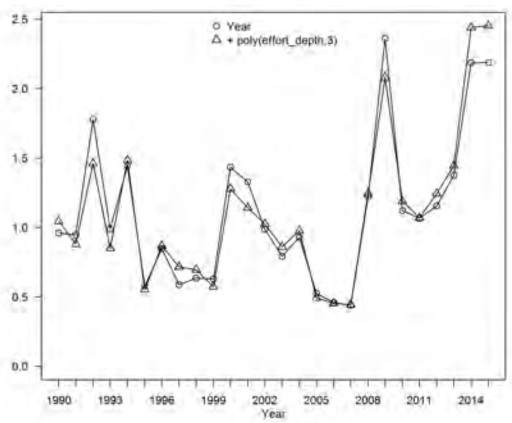
Figure 42: Influence plots for depth (top) and start longitude (bottom).



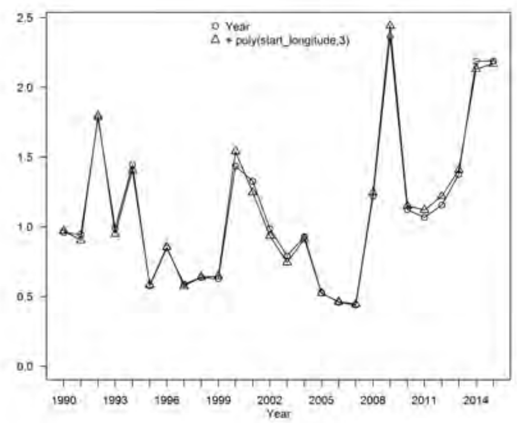
(a)



(b)



(c)



(d)

Figure 43: Covariate influence plots for the final predictors, Panel a) month variable, b) vessel key, c) effort depth, d) longitude.

Table 35: Percentage of deviance explained by each covariate from forward selection.

Variable	R-squared
fish_year	16.17
vessel_key	24.05
fish_month	28.64
poly(best_start_time, 3)	29.87
poly(distance2, 3)	30.89

Table 36: Proportion of deviance explained by each covariate from forward selection.

	1	2	3	4	5
fish_year	0.16				
+vessel_key	0.24	0.24			
+fish_month	0.24	0.29	0.29		
+poly(best_start_time, 3)	0.17	0.25	0.30	0.30	
+poly(distance2, 3)	0.17	0.25	0.30	0.31	0.31
+trip	0.16	0.24	0.29	0.30	0.31
+start_stats_area_code	0.19	0.25	0.30	0.31	0.32
+primary_method	0.20	0.25	0.30	0.31	0.32
+poly(start_latitude, 3)	0.17	0.24	0.29	0.30	0.31
+poly(start_longitude, 3)	0.18	0.24	0.29	0.30	0.31
+poly(effort_depth, 3)	0.16	0.25	0.29	0.30	0.31
+poly(effort_height, 3)	0.20	0.26	0.30	0.31	0.32
+poly(effort_width, 3)	0.20	0.24	0.29	0.30	0.31
+poly(fishing_duration, 3)	0.17	0.25	0.30	0.31	0.31

Tow level BAR + WAR targeted CPUE analysis

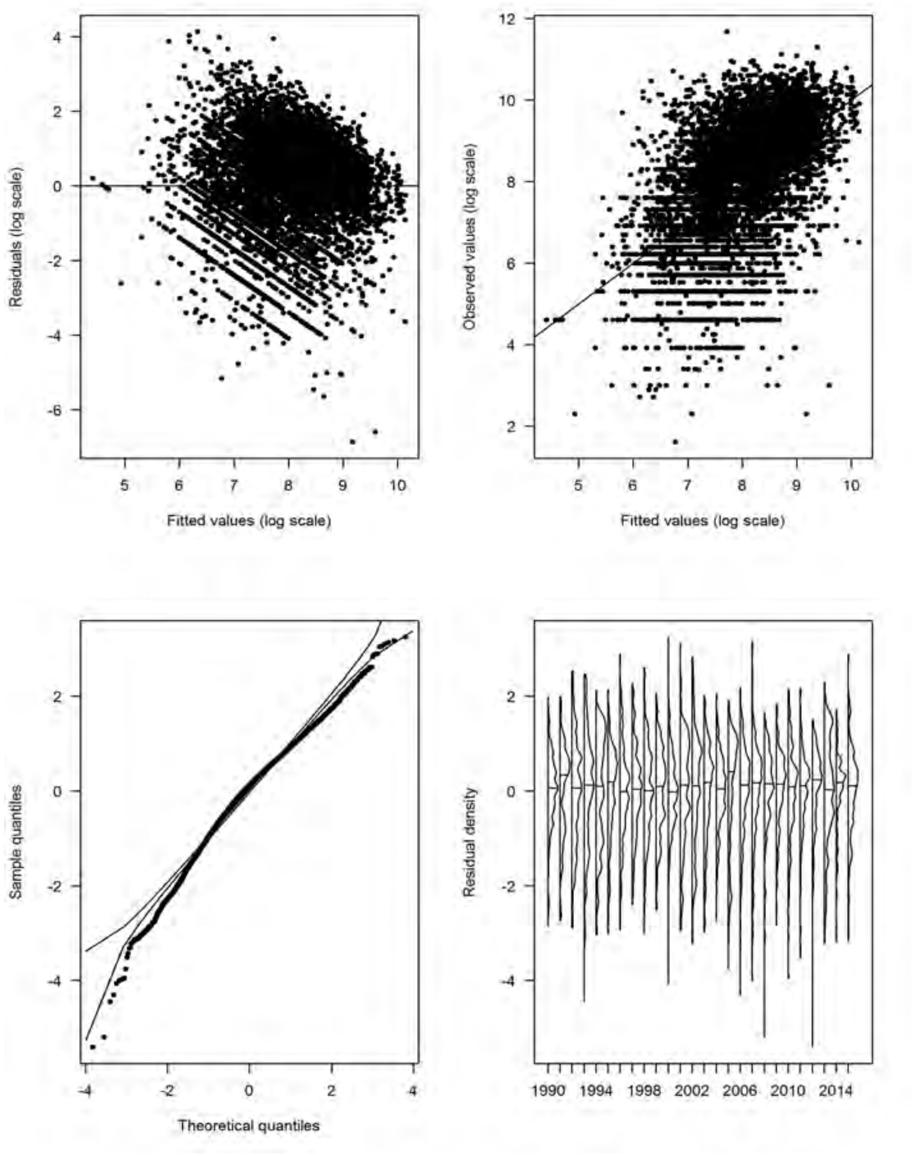


Figure 44: Model diagnostics plots, from the baracouta-warehou target model.

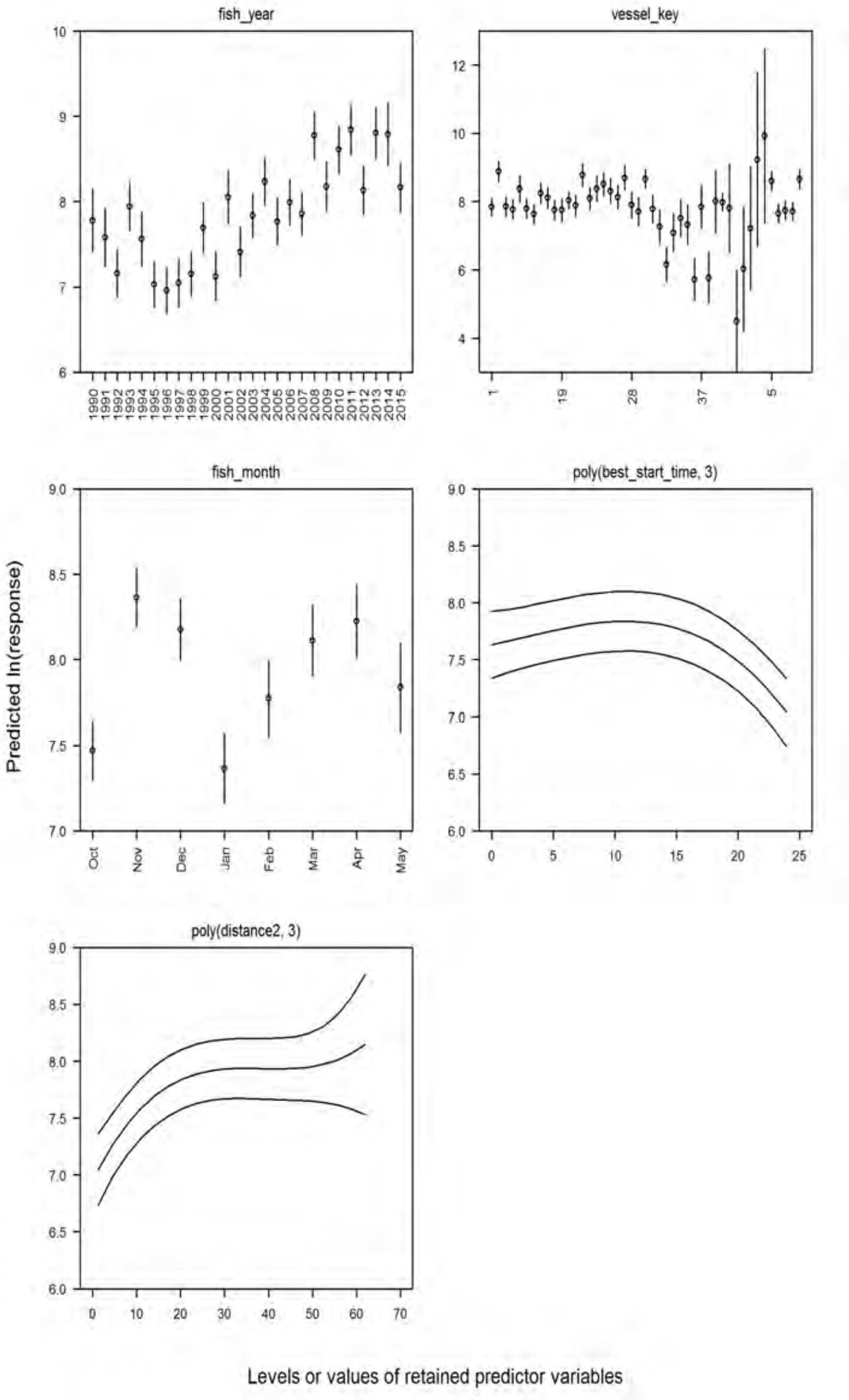


Figure 45: Predicted values for each covariate.

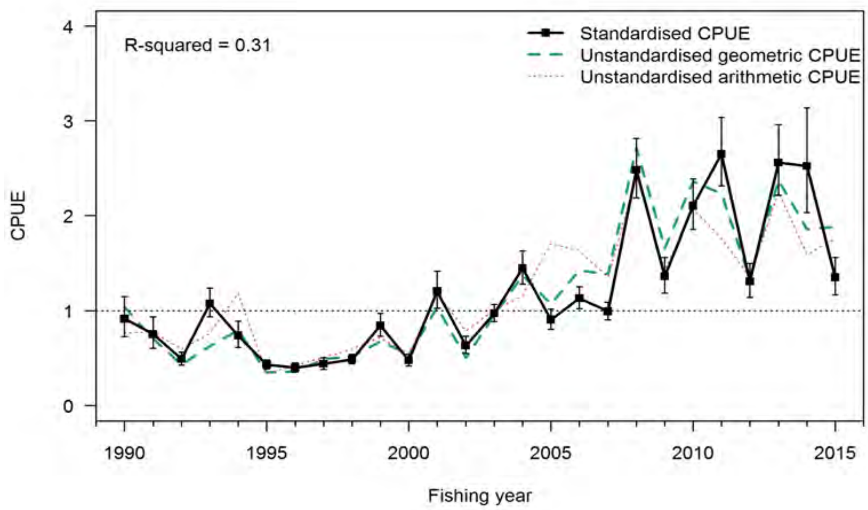
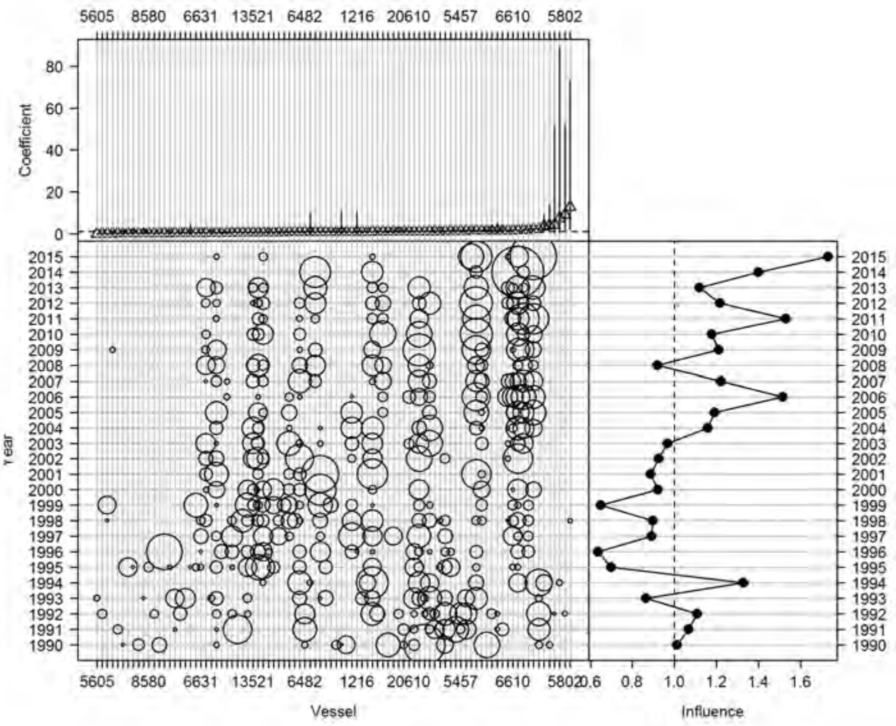
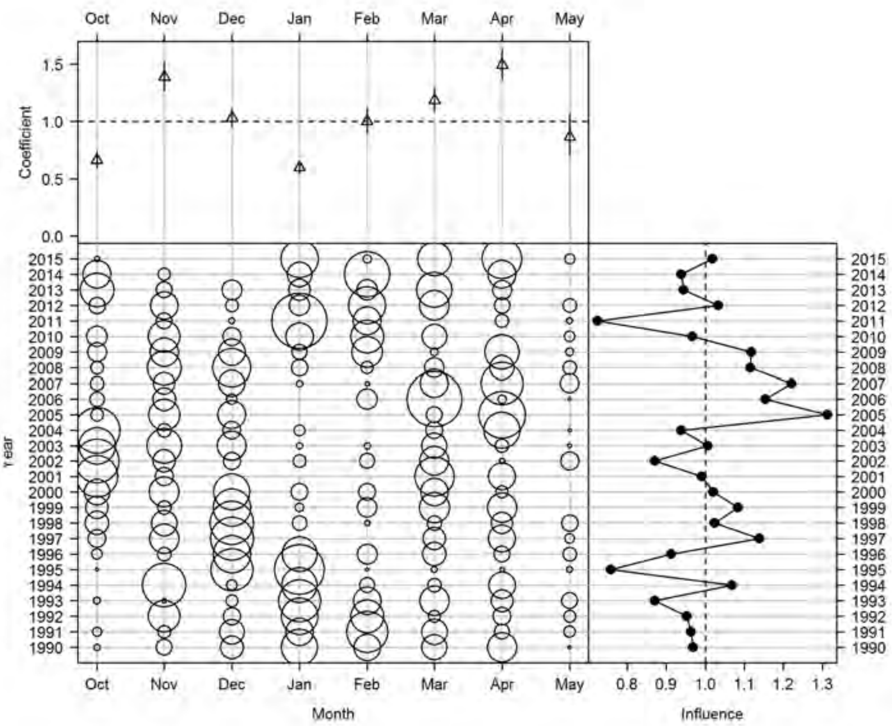


Figure 46: Conical index for the year effect from the baracouta-warehou target model.

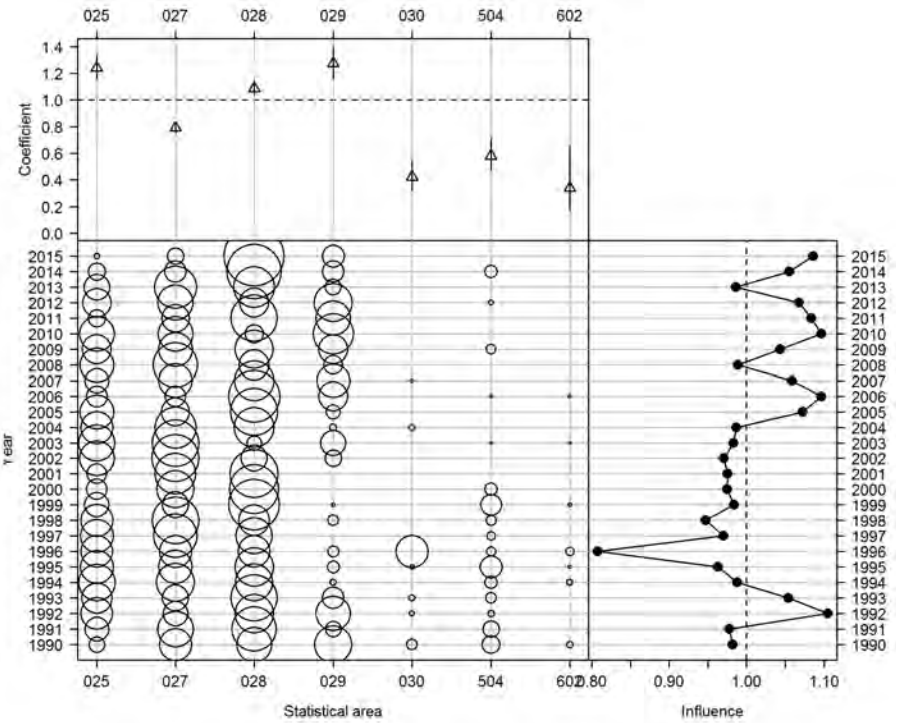


(a)

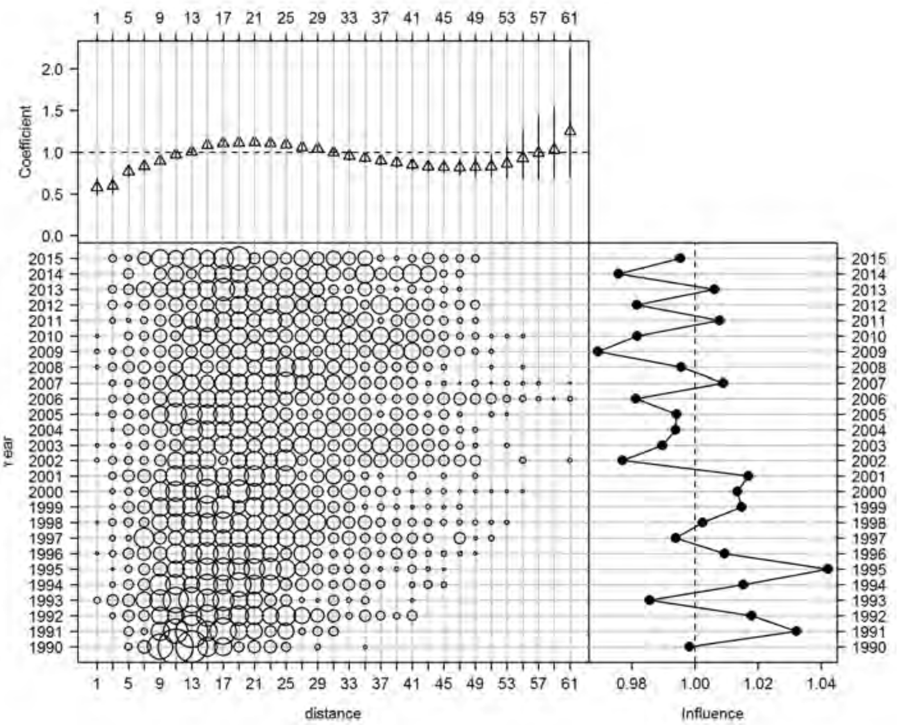


(b)

Figure 47: Influence plots for vessel (top) and month (bottom).

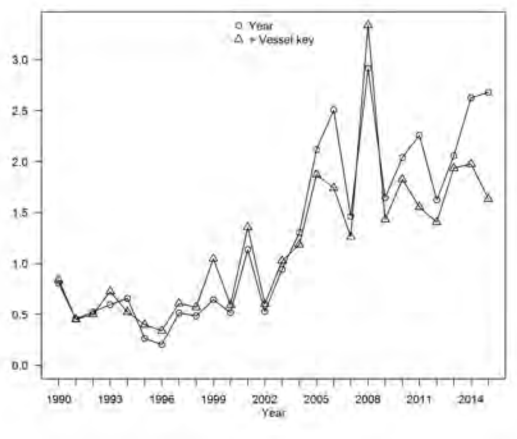


(a)

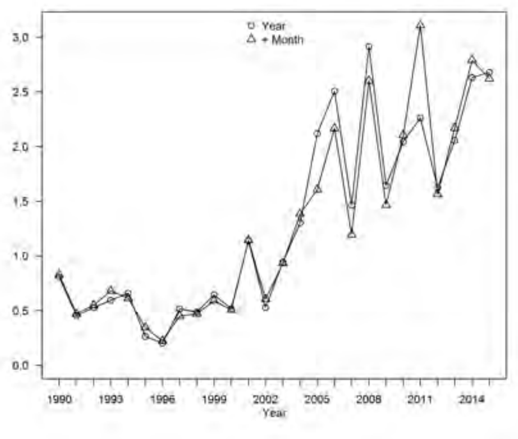


(b)

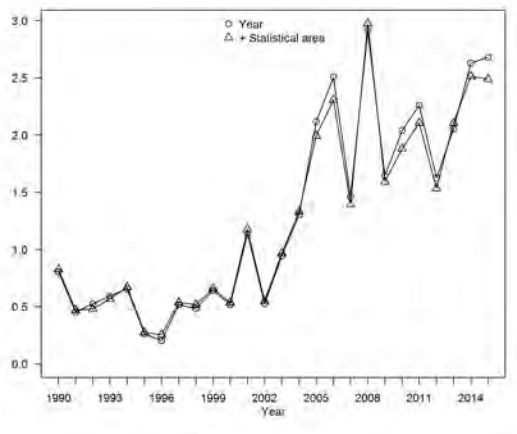
Figure 48: Influence plots for statistical area (top) and distance (bottom).



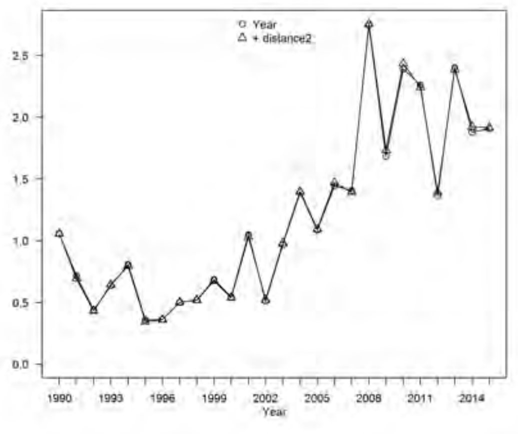
(a)



(b)



(c)



(d)

Figure 49: A plot of each predictor's effect when only fishing year is in the model. Panel a) vessel key, b) month, c) statistical area, d) distance.

Tow level analysis (Model 1b)

Table 37: Proportion of residual deviance explained by each covariate from forward selection.

	1	2	3	4	5
+fish_year	0.04				
+vessel_key	0.19	0.19			
+target_species	0.18	0.31	0.31		
+start_stats_area_code	0.16	0.29	0.34	0.34	
+fish_month	0.09	0.26	0.32	0.36	0.36
+primary_method	0.13	0.22	0.31	0.35	0.37
+trip	0.04	0.19	0.31	0.34	0.37
+poly(best_start_time, 3)	0.05	0.19	0.31	0.34	0.37
+poly(start_latitude, 3)	0.11	0.25	0.33	0.34	0.37
+poly(start_longitude, 3)	0.05	0.20	0.31	0.34	0.37
+poly(effort_depth, 3)	0.12	0.24	0.31	0.34	0.37
+poly(effort_height, 3)	0.13	0.23	0.31	0.35	0.37
+poly(effort_width, 3)	0.13	0.19	0.31	0.34	0.37
+poly(fishing_distance, 3)	0.04	0.19	0.31	0.34	0.36
+poly(distance2, 3)	0.04	0.19	0.31	0.34	0.37
+poly(fishing_duration, 3)	0.04	0.19	0.31	0.34	0.37

Log normal component

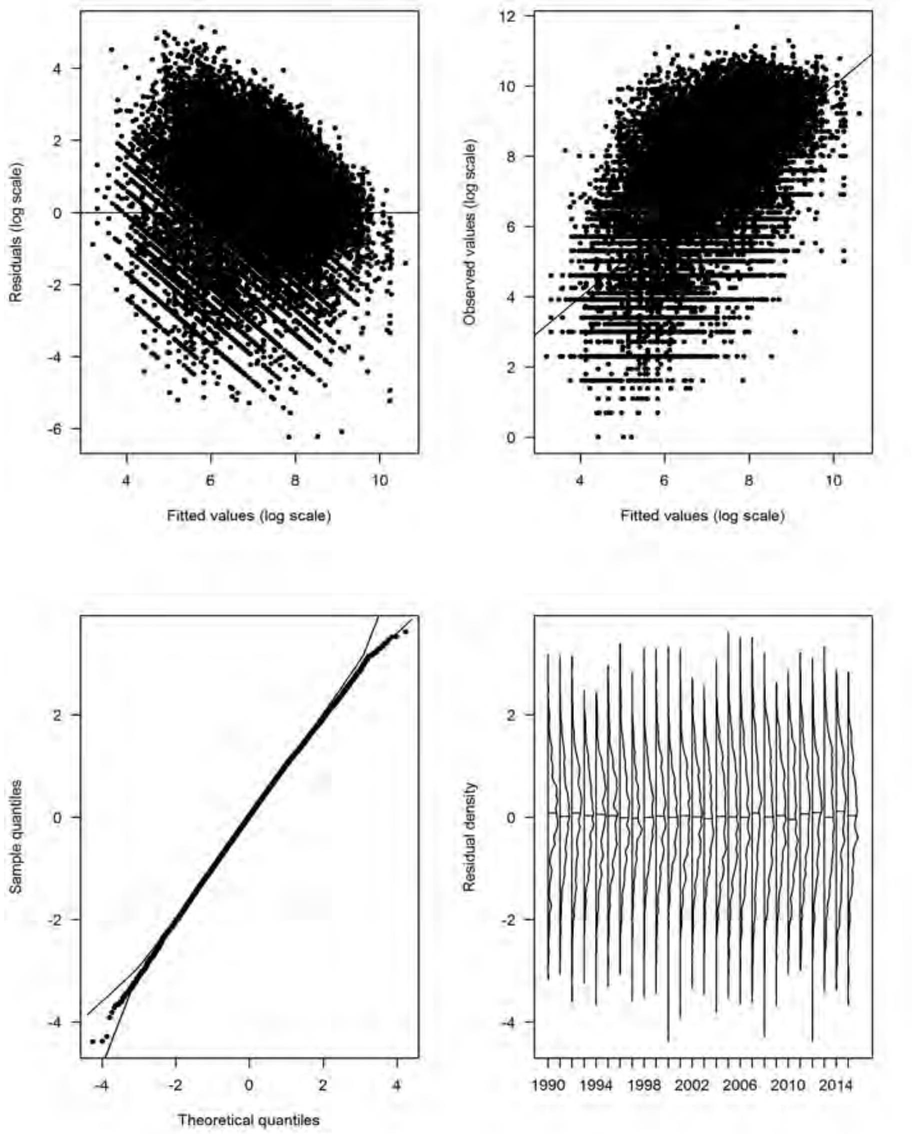


Figure 50: Model diagnostics plots, from the final model.

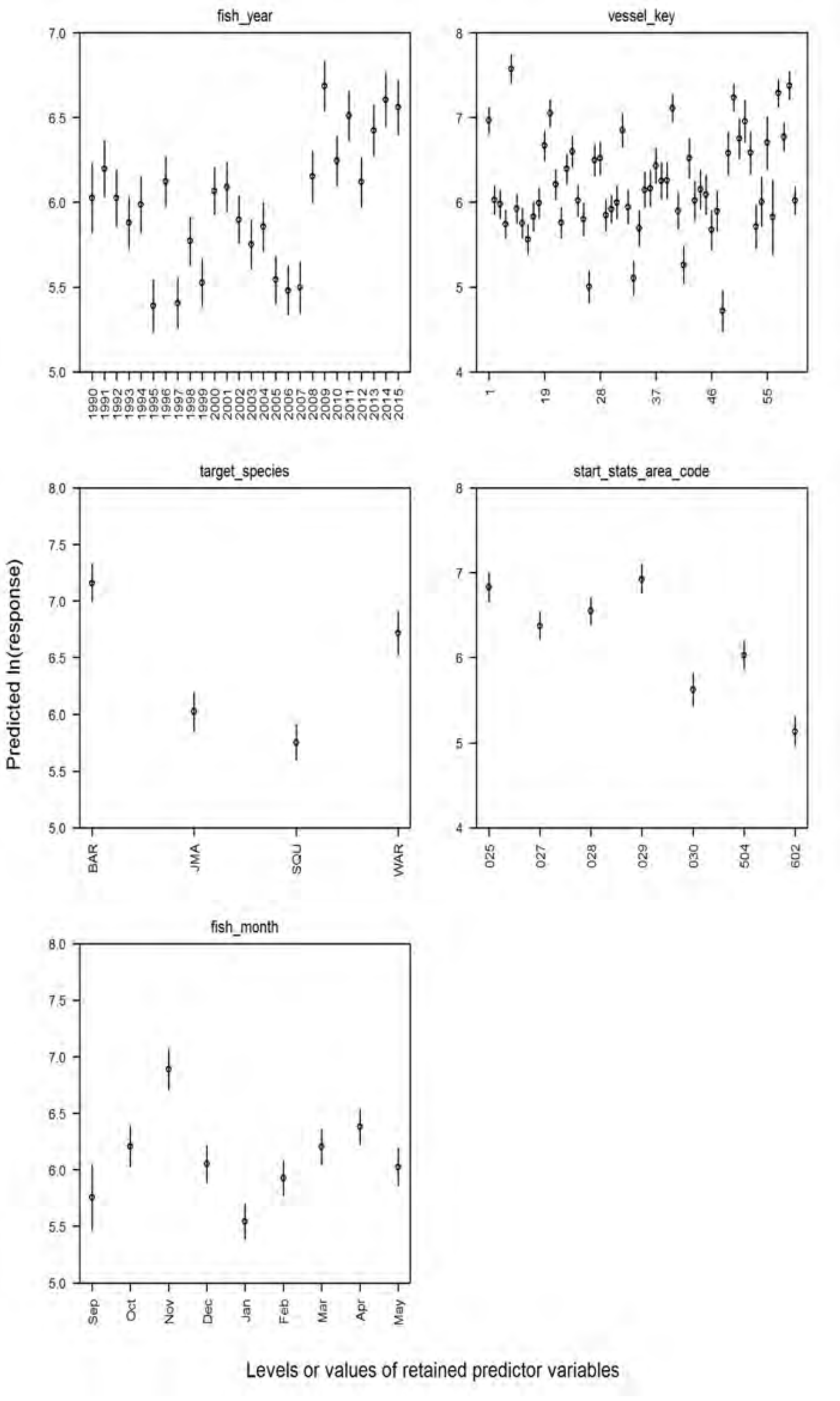


Figure 51: Predicted values for each covariate

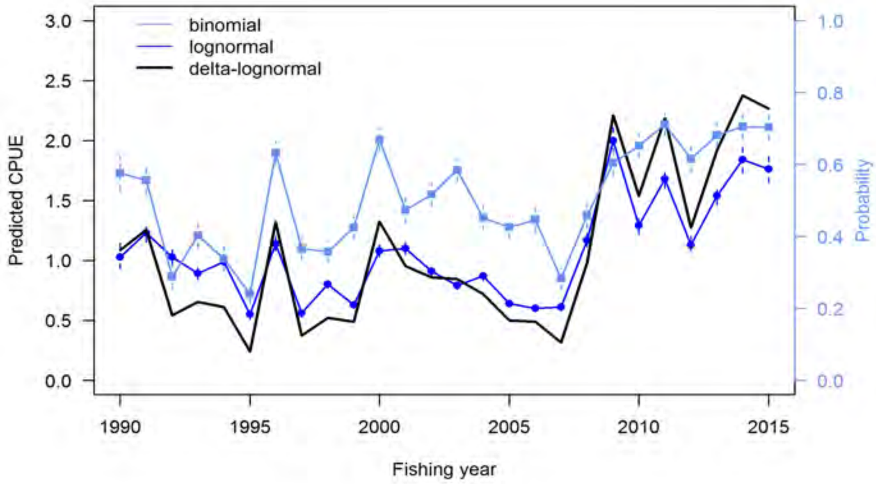
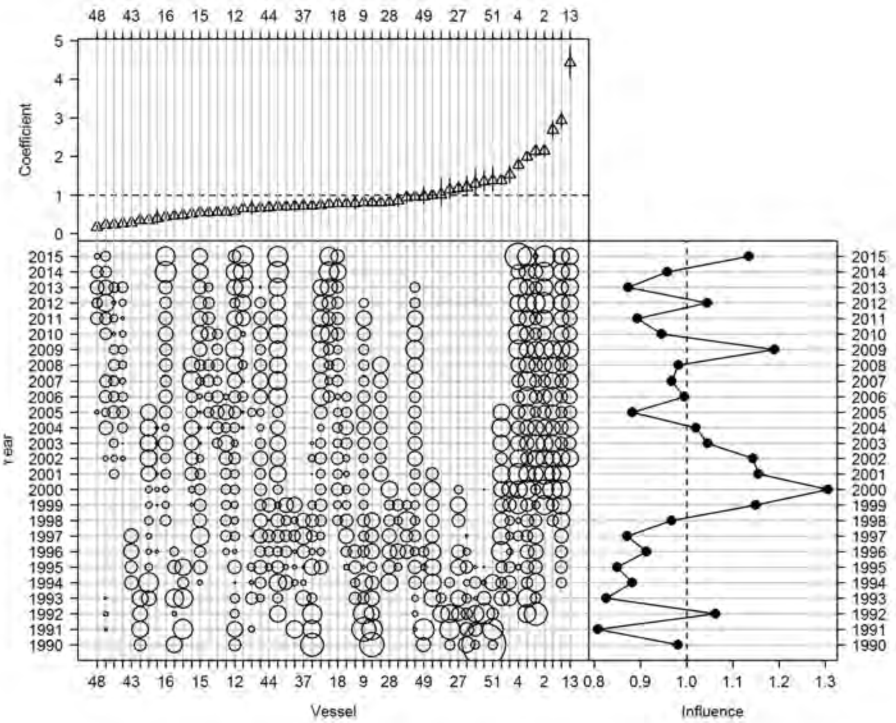
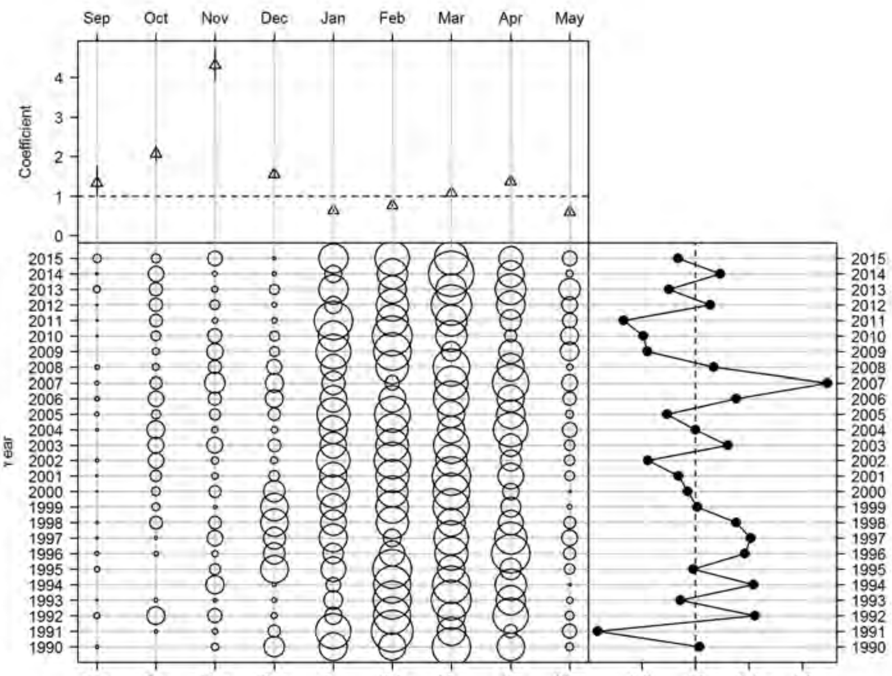


Figure 52: Predicted values for each covariate

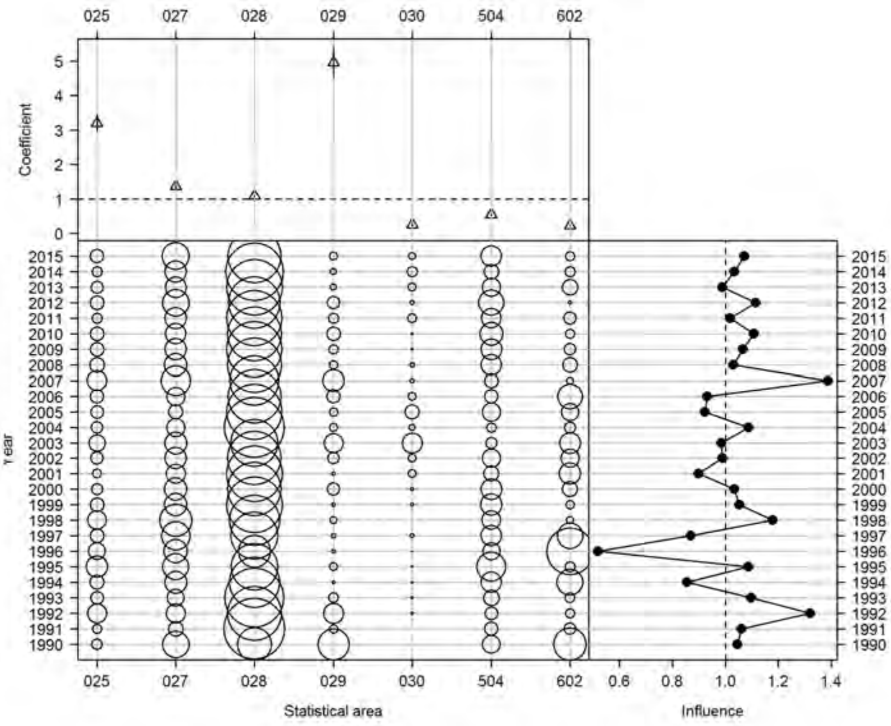


(a)

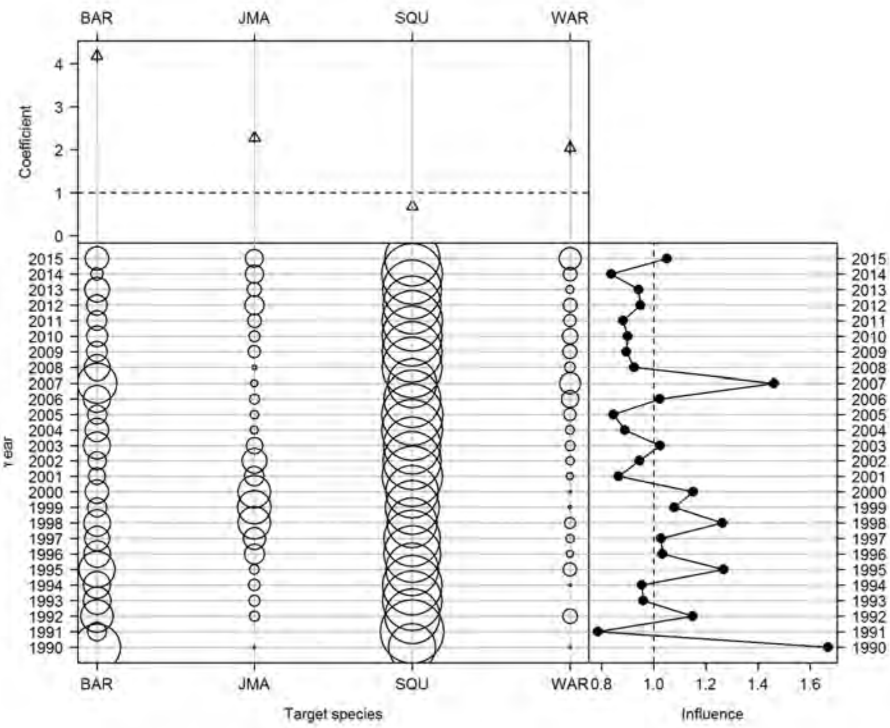


(b)

Figure 53: Influence plots.

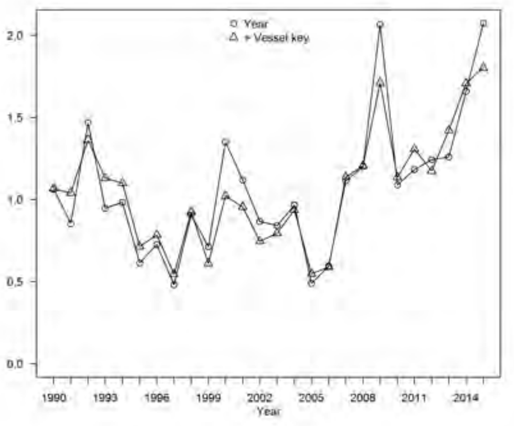


(a)

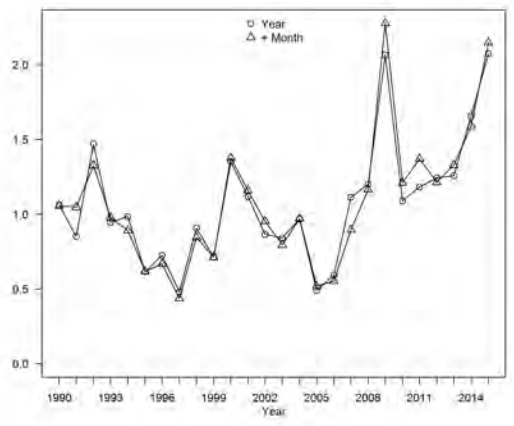


(b)

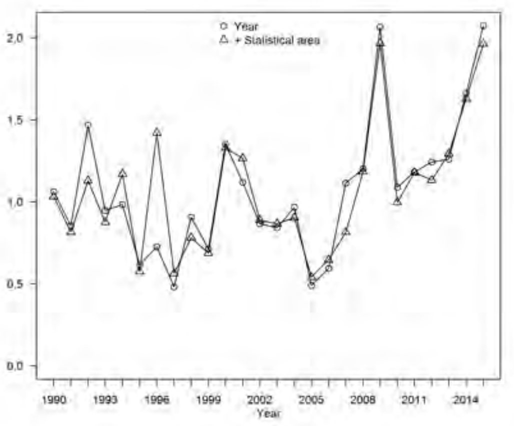
Figure 54: Influence plots.



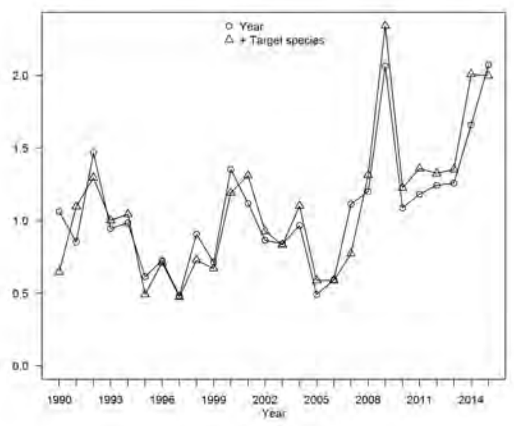
(a)



(b)



(c)



(d)

Figure 55: A plot of each predictor's effect when only fishing year is in the model. Panel a) vessel key, b) month, c) effort depth, d) longitude.

Binomial component All the same variables were offered to the binomial GLM that were offered to the log normal component. The difference being, that the response variable is binary variable where,

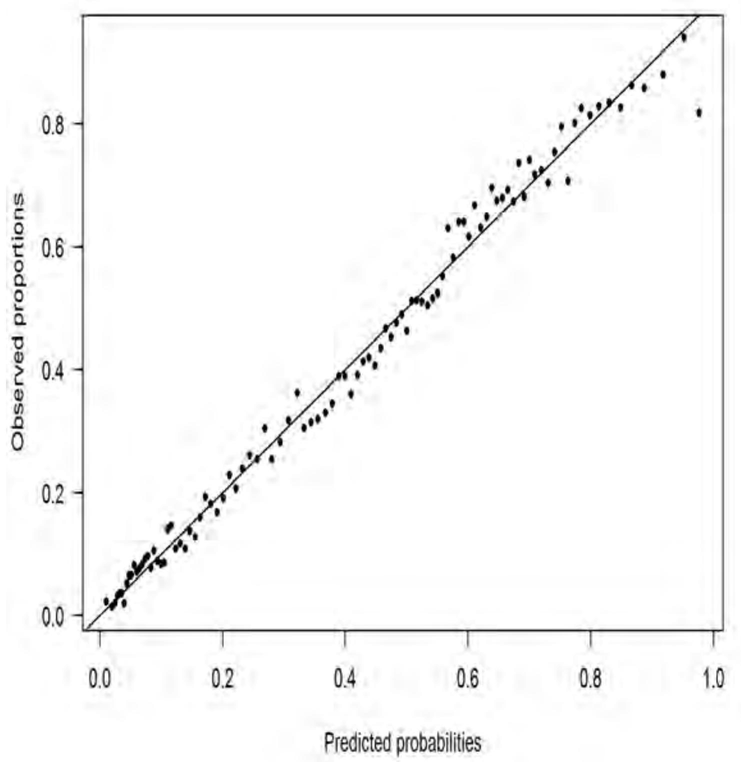


Figure 56: Diagnostic form the final selected model.

Table 38: Variables offered to the observer CPUE standardisation analysis

Variable	Description	type of variable
fish_year	Fishing year	factor
tripno	Trip id	factor
vesselkey	unique vessel identifier	factor
target	Species recorded in logbook as targeted	factor
fmonth	Fishing month	factor
gear	Primary method for the trawl	factor
times	time of day the tow started (24hr unit)	Continuous
latsdec	starting latitude in decimal degrees	Continuous
longsdec	starting longitude in decimal degrees	Continuous
depthbottom	recorded trawl depth bottom	Continuous
duration	recorded trawl time	Continuous

Observer analysis

Table 39: Proportion of residual deviance explained by each covariate from forward selection.

	1	2	3	4	5	6	7
+fish_year	0.06						
+poly(latsdec, 3)	0.25	0.25					
+target	0.21	0.36	0.36				
+vesselkey	0.15	0.34	0.40	0.40			
+poly(longsdec, 3)	0.15	0.31	0.39	0.44	0.44		
+poly(depthbottoms, 3)	0.15	0.32	0.37	0.41	0.45	0.45	
+poly(times, 3)	0.06	0.25	0.37	0.42	0.45	0.47	0.47
+fmonth	0.07	0.27	0.37	0.41	0.44	0.46	0.47
+tripno	0.06	0.25	0.36	0.41	0.44	0.45	0.47
+gear	0.07	0.27	0.37	0.41	0.44	0.46	0.47
+poly(duration, 3)	0.07	0.25	0.36	0.41	0.44	0.46	0.47

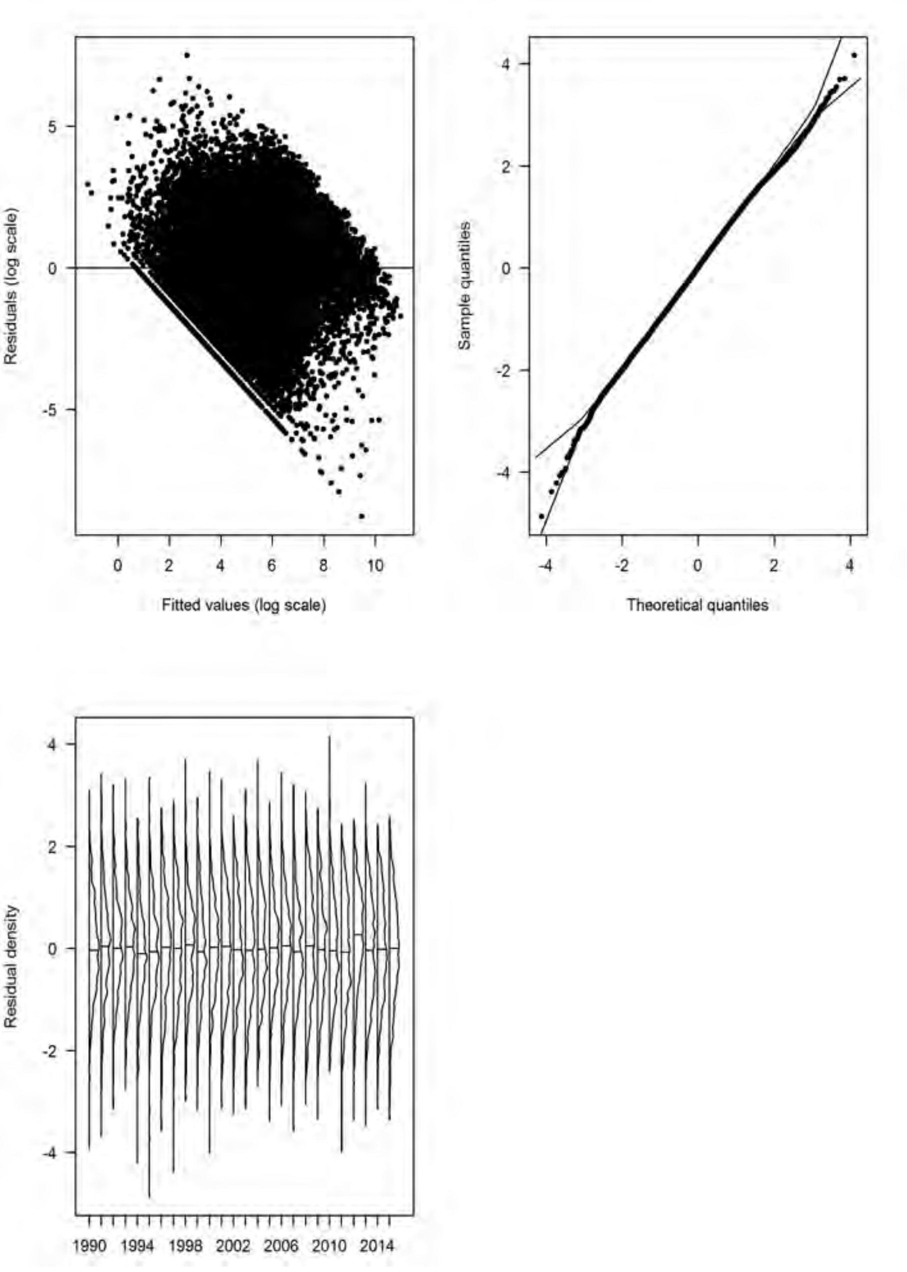


Figure 57: Diagnostic plots from the final model.

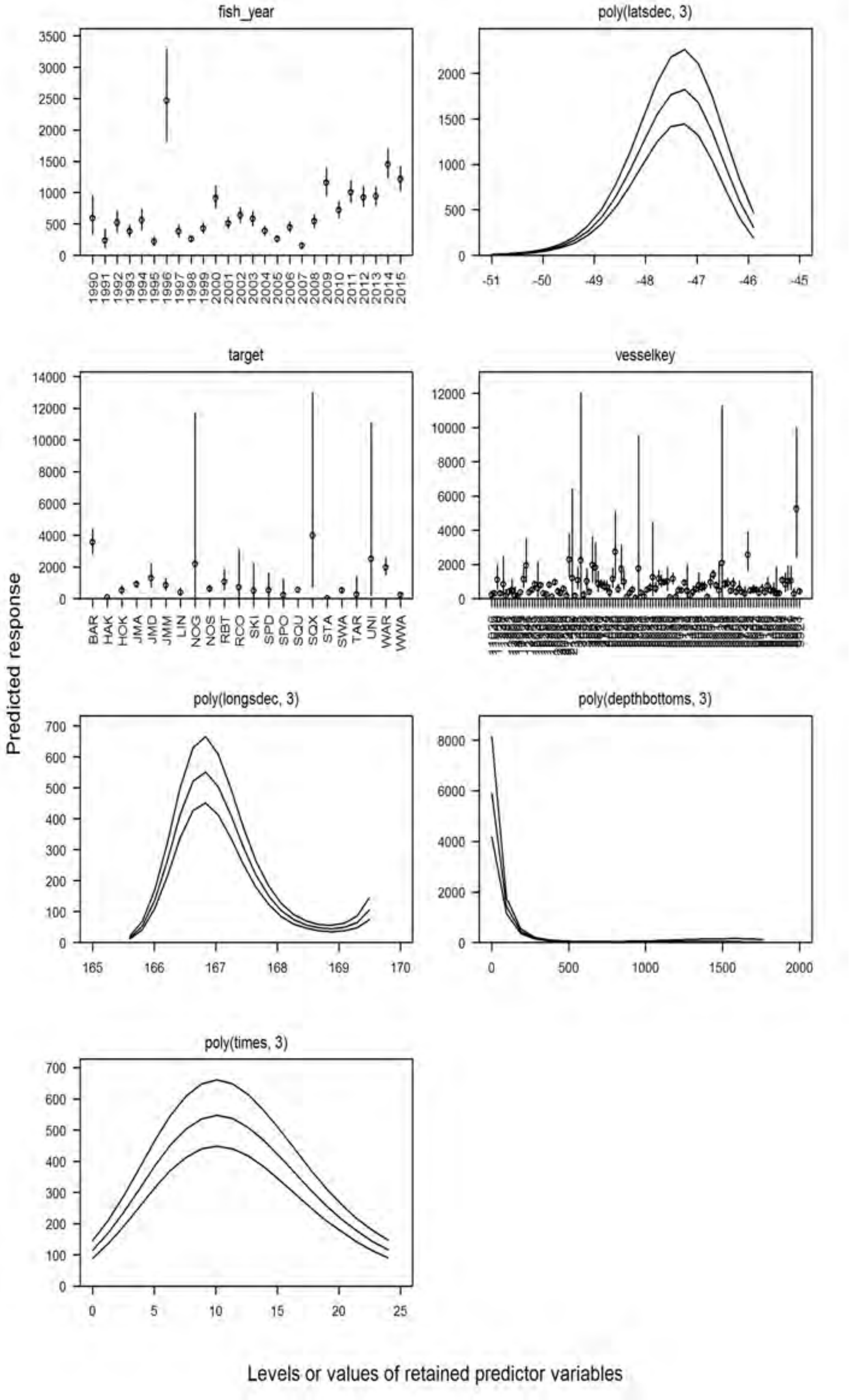


Figure 58: Predicted values for each covariate

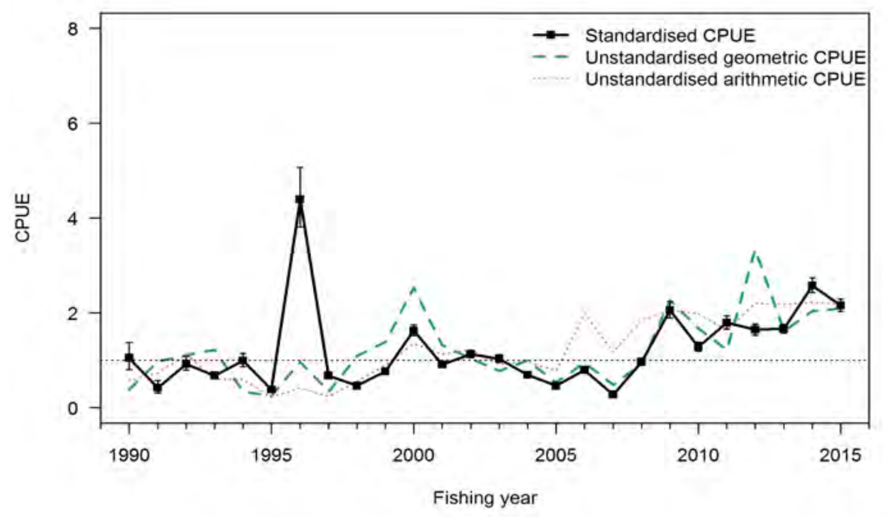
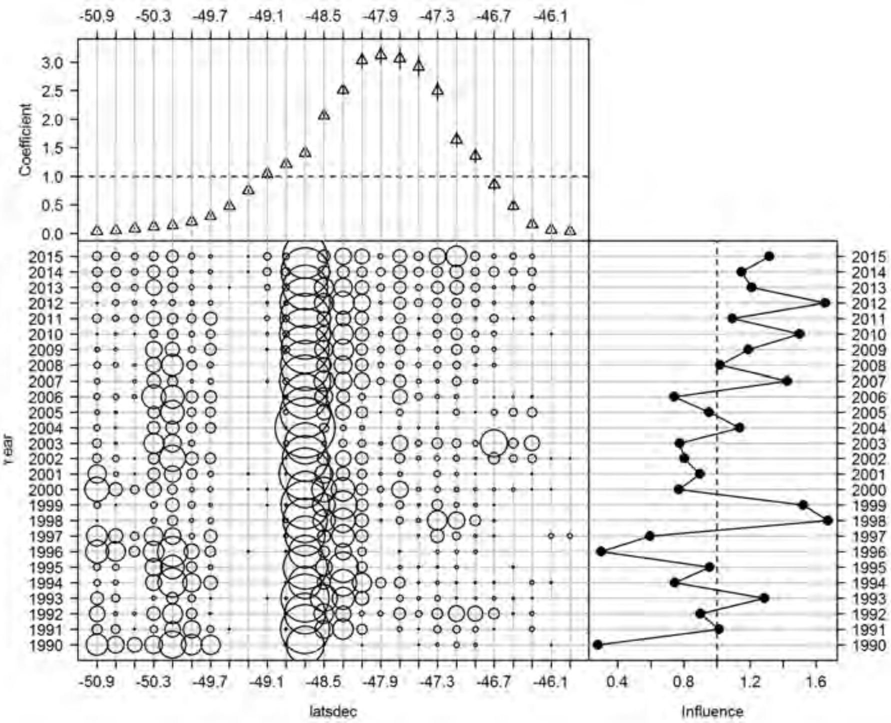
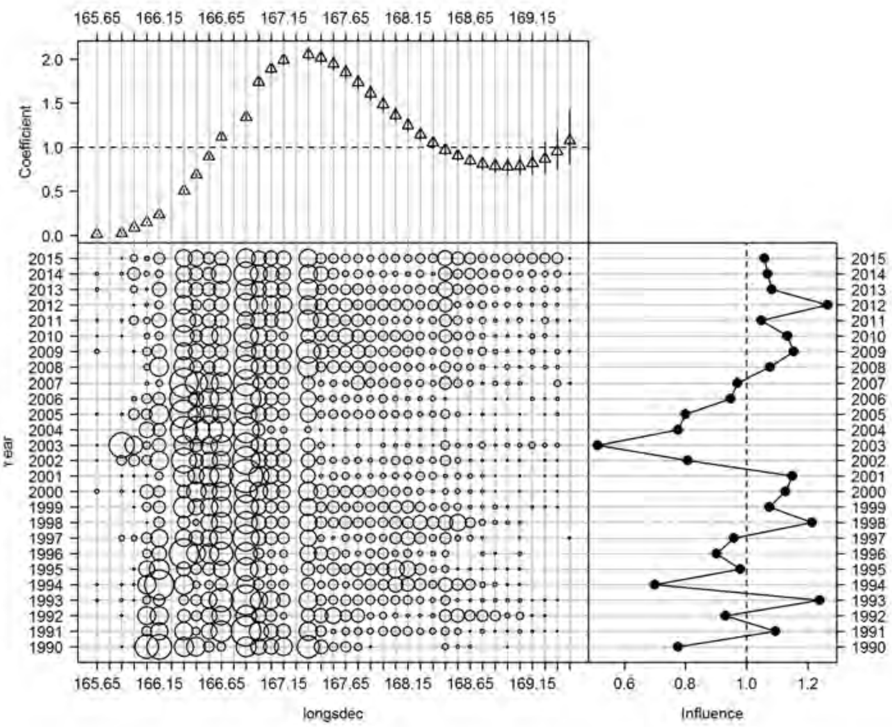


Figure 59: CPUE by year, plotted in the canonical form.

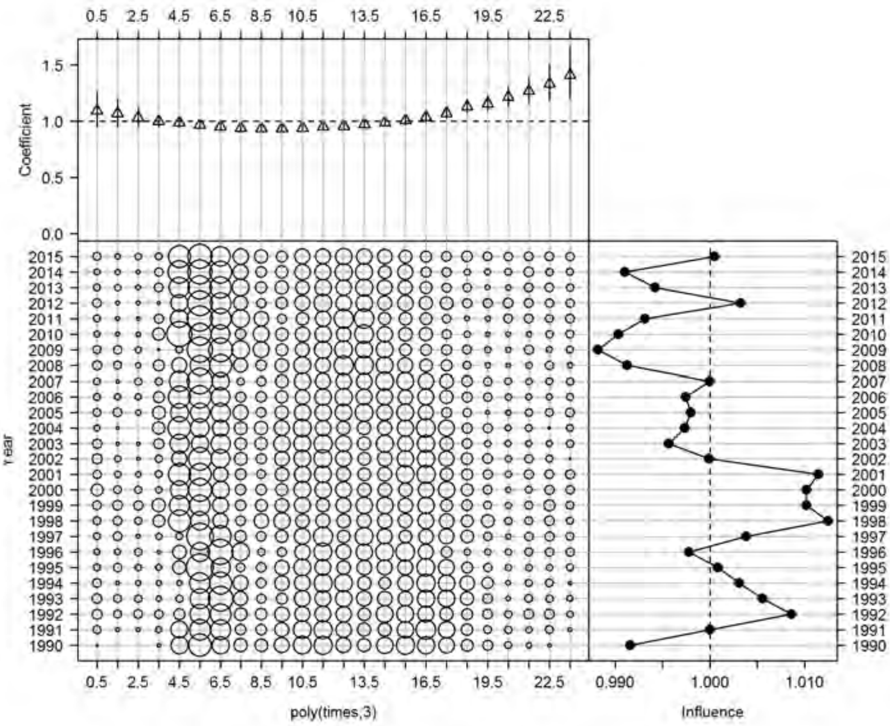


(a)

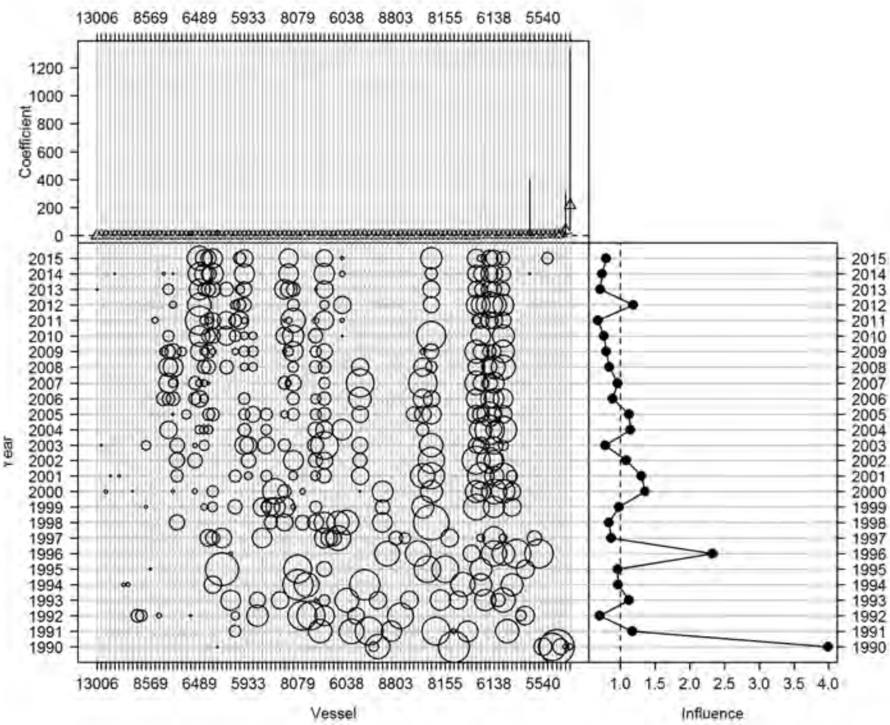


(b)

Figure 60: Influence plots.



(a)



(b)

Figure 61: Influence plots.

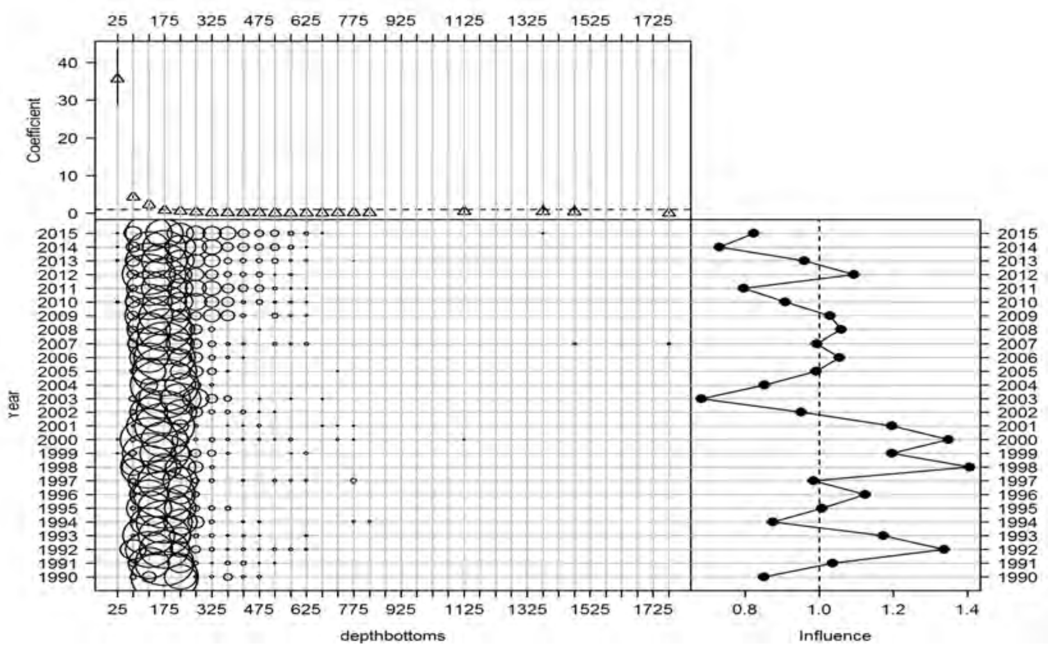
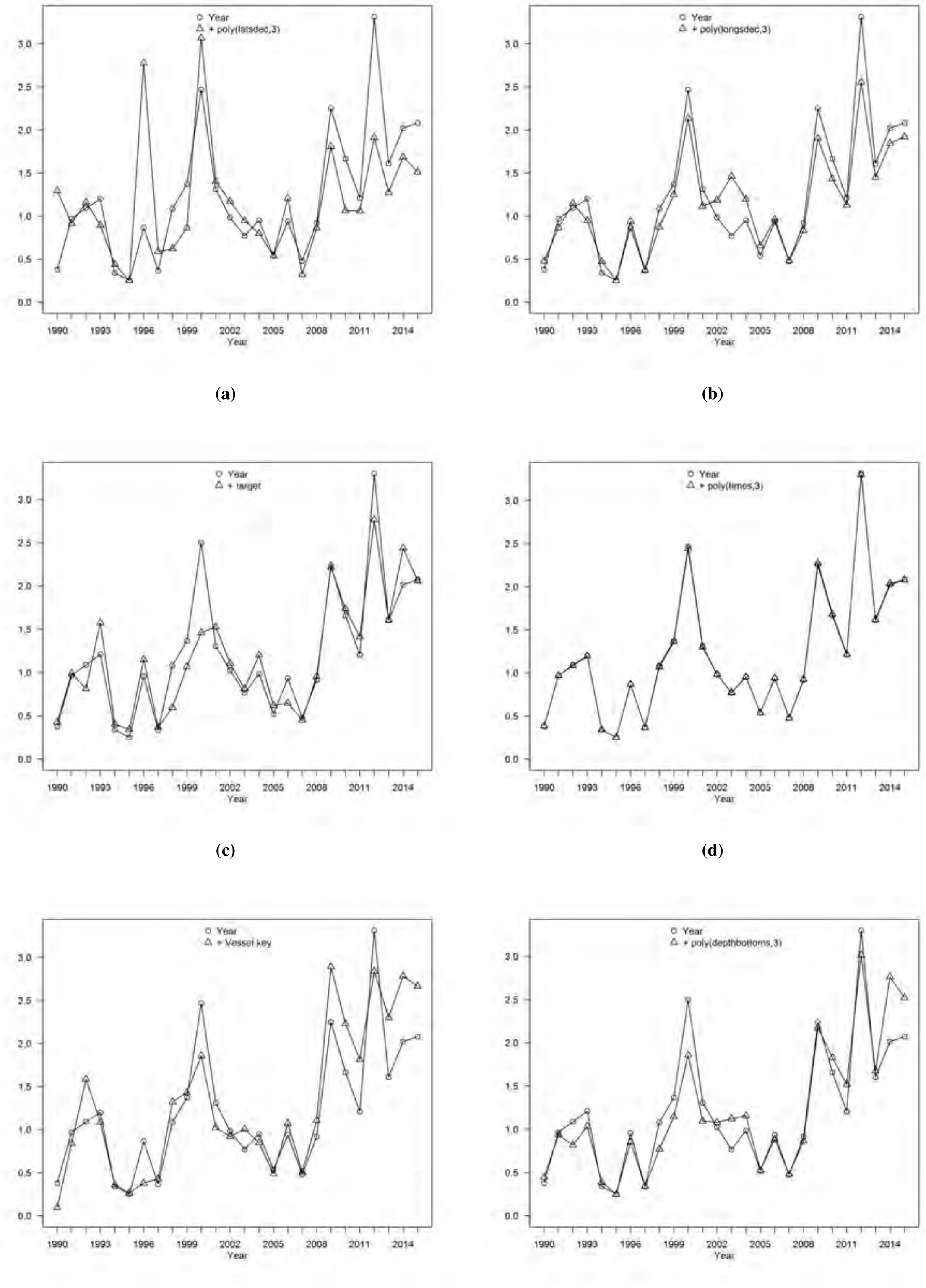


Figure 62: CPUE by year, plotted in the canonical form.



(a) (b)

(c) (d)

(e) (f)

Figure 63: A plot of each predictor's effect when only fishing year is in the model. Panel a) latitude, b) longitude, c) target, d) time of day, e) vessel key, f) bottomdepth.