



Characterisation analyses for blue mackerel (*Scomber australasicus*) in EMA 1, 2, 3, and 7, 1989–90 to 2009–10
New Zealand Fisheries Assessment Report 2013/16

D. Fu

ISSN 1179-5352 (online)
ISBN 978-0-478-40568-2 (online)

March 2013



Requests for further copies should be directed to:

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

Email: brand@mpi.govt.nz

Telephone: 0800 00 83 33

Facsimile: 04-894 0300

This publication is also available on the Ministry for Primary Industries websites at:

<http://www.mpi.govt.nz/news-resources/publications.aspx>

<http://fs.fish.govt.nz> go to Document library/Research reports

© Crown Copyright - Ministry for Primary Industries.

EXECUTIVE SUMMARY

Fu, D. (2013). Characterisation analyses for blue mackerel (*Scomber australasicus*) in EMA 1, 2, 3, and 7, 1989–90 to 2009–10.

New Zealand Fisheries Assessment Report 2013/16. 54 p.

For fish stocks for which there are no robust stock assessments, the Ministry of Fisheries' approach is to assemble fishery and biological information to characterise and evaluate the status of the stock. This strategy will be utilized for selected middle depth fish stocks on a routine basis, and blue mackerel (*Scomber australasicus*) (EMA) was identified as one of the species for this process in 2011.

The commercial catch is caught by a variety of methods in all QMAs, but most is caught north of latitude 43° S. The largest and most consistent catches across fishing years are by purse-seine vessels targeting blue mackerel schools in EMA 1. The target purse-seine catch in EMA 1 is the single largest component of the catch by any method. Catches by midwater trawl vessels targeting jack mackerels in EMA 7 are also important.

The commercial catch in the New Zealand EEZ varies greatly between fishing years. Total annual reported landings increased rapidly from the 1989–90 to the 1992–93 fishing year and have fluctuated between about 6 000 and 15 000 t in every subsequent fishing year. Annual landings peaked at 15 128 t during 1991–92, and exceeded 10 000 t in seven of the last ten years. Inter-annual variation in catches is thought to reflect variable market demand.

The landings for EMA 7 were low before 1995–96 with the average annual catch below 2000 t. The landings have increased since then and the annual catch generally ranged between 2500 t and 5000 t, with a peak in 1997–98 at 8800 t. Landings exceeded the TACC (3350 t) in five of the last seven years. Blue mackerel in EMA7 was mostly taken as bycatch from the midwater trawl fishery, and sometimes as a target species from the purse seine fishery. There was no target catch from the purse seine fishery during the 2009–10 fishing year. Catches were highly seasonal, with the target purse-seine fishery in EMA 7 mainly operating between March and May, and with the midwater trawl bycatch mostly taken in July and August. The midwater trawl fishery operated off the west coast of South Island through most of the 1990s, but since then there has been a shift of effort to the north over time where a fishery has developed in the North Taranaki Bight and further north off the west coast of North Island.

The landings for EMA 1 exceeded 10 000 t during 1991–92 and 1992–93, and since then have fluctuated between about 3000 and 8000 t in most years. The landings during 2008–09 were the lowest over the last twenty years, but the landings during 2009–10 exceeded the TACC (7750 t). Almost all the catch in EMA 1 was taken from the purse seine fishery, mostly as a target species and sometimes as a bycatch. The target purse-seine fishery mainly operated off the northeast coast of the North Island (Statistical Areas 002 and 003) and in the northern area of the Bay of Plenty (Statistical Areas 008 and 009). Catches were highly seasonal, with the target purse-seine fishery mainly operating between July and December.

The commercial catch in EMA 2 and EMA 3 was very small and the TACC was not fully caught. The total annual landings for EMA 2 and EMA 3 have been below 200 t since 2000–01, and were below 15 t for EMA 2 in five of the last six years. Blue mackerel in EMA 2 was mostly taken by inshore purse seine vessels off the east coast of the North Island targeting a mixture of species. Blue mackerel in EMA 3 was mostly taken by midwater trawls targeting jack mackerel near Mernoo Bank.

A standardised catch per unit effort (CPUE) analysis was carried out using the catch effort data from the midwater trawl fishery in EMA 7. The standardisation was based on tows where jack mackerel was targeted and blue mackerel was taken as bycatch. Because there was a dramatic change in the composition of the fleet that occurred during the mid to late 1990s, separate CPUE indices were calculated for an early time series covering 1989–90 to 1997–98 and a late time series covering 1996–97 to 2009–10. Estimates of relative year effects were obtained using a forward stepwise multiple regression method, where the data were fitted using a lognormal model. For the early time series, the CPUE indices showed a generally flat trend; for the late time series, the CPUE indices showed a steep declining trend through to the early 2000s, and then remained relatively flat with a slight increase over the last three years.

1. INTRODUCTION

Many of New Zealand's middle depth fisheries are not routinely monitored or assessed despite their moderate size and value. The Ministry of Fisheries has developed an assessment strategy to assemble fishery and biological information to assess the status of fish stocks for which no robust stock assessment has been developed. Project DEE201007 developed under the 10-Year Research Programme for Deepwater Fisheries requires characterisations of 18 species on a three year rotating schedule. The suite of species to be covered in the first year of this project includes blue mackerel (*Scomber australasicus*), alfonsino (*Beryx splendens*), frostfish (*Lepidopus caudatus*), white warehou (*Seriola lalandi*), pale ghost shark (*Hydrolagus bemisi*), and sea perch (*Helicolenus percoides*). These species have been chosen for full characterisation in 2011 based on the information needs required to manage these fisheries in the short-term. This report fulfils objective 1 of the Ministry of Fisheries' project DEEP201007: "To review the status of deepwater and middle depth Fishstocks not routinely assessed" and it summarises the analyses carried out for characterising blue mackerel fisheries in EMA 1, EMA 2, EMA 3, and EMA 7 up to 2009–10.

1.1 Recent research

Most recent research has focused on stock monitoring, principally commercial catch-sampling in both EMA 1 and 7 during 1997–98 (Morrison et al. 2001a), 2002–03 (Manning et al. 2006), 2003–04 (Manning et al. 2007a), 2004–05 (Manning et al. 2007b), 2005–06 (Devine et al. 2009), 2006–07 and 2007–08 (M.H. Smith & P. Taylor, unpublished results from research project EMA2007/01). Age validation has recently been carried out using radioisotope dating methods and may provide support for the age estimates produced in the catch-sampling series (M. Manning, unpublished results from research project EMA2005/02). The age validation study also investigated optimal market sampling designs and some causes of imprecision in the age estimates produced and has led to improved protocols for preparing and interpreting blue mackerel otoliths (Manning & Marriott 2006). Associated biological relationships for New Zealand blue mackerel such as length-at-age, weight-at-length, and length- and age-at-maturity have also been quantified (Manning et al. 2006, Manning et al. 2007a, Manning et al. 2007b).

Relative abundance indices derived from aerial sightings data produced by pilots supporting purse-seine fishing operations have been developed (Taylor, P.R. submitted-a), although most of the data is concentrated in EMA 1 off the northeast coast of the North Island. Recent research has shown that producing indices of relative abundance of EMA from the aerial sighting data is uncertain over small areas. Bradford & Taylor (1995) produced several indices, including a presence/absence or binomial index, annual medians of the number of schools, and total tonnage sighted. They found some conflict between the indices and little change throughout the time series apart from a peak in the late 1980s. Annual means of total tonnage and number of schools were used as indices by Taylor (1999, unpublished results), but an independent examination of the aerial sightings data by Sampson (2000) has found that they are not a reliable measure of relative abundance because they are not standardised by the amount of flying time. The feasibility of fishery-independent aerial surveys for blue mackerel and other small pelagic species in the New Zealand EEZ has also been investigated (Taylor submitted-b), but no fishery-independent survey using aerial overflights or other methods has yet been carried out.

The catch per unit effort (CPUE) of the northern purse-seine fishery was examined by Morrison et al. (2001b). This data source held little or no information that would be useful in a stock assessment. Some of the basic assumptions required for the application of CPUE analyses were also violated, due to the fishery targeting surface schools, and variability in fishing effort due to market forces, and the availability of other target purse-seine species, independent of blue mackerel abundance. Fu & Taylor (2007) developed standardised CPUE indices based on commercial catch-per-unit-effort associated with the midwater trawl fishery for blue and jack mackerels (*Trachurus* spp.) in EMA 7. The standardised indices were updated in 2010 using fishery data up to 2008-09 (Fu & Taylor 2011).

Concerns over inter-annual variation in the indices led the Middle Depths Fisheries Assessment Working Group to conclude that the extent to which these indices provide information on the true level of stock abundance was uncertain.

2. REVIEW OF THE FISHERIES

2.1 Commercial fishery

The commercial catch is caught by a variety of methods in all QMAs, but most is caught north of latitude 43° S (Morrison et al. 2001a). The largest and most consistent catches across fishing years are by purse-seine vessels targeting blue mackerel schools in EMA 1–3 and 7 (Figure 1). In EMA 7, catches are mainly by midwater trawl vessels targeting jack mackerels. Most of the purse-seine catch comes from the Bay of Plenty and east Northland, and the target purse-seine catch in EMA 1 is the single largest component of the catch by any method in any QMA (Morrison et al. 2001a).

Total annual reported landings increased rapidly over the 1989–90 to 1992–93 fishing years and fluctuated between about 6000 and 15 000 t in every fishing year since then (Table 1). Reported landings peaked at 15 128 t during 1991–92, of which about 70% was caught by purse-seine vessels (Morrison et al. 2001a), and averaged 10 965 t between 2002–03 and 2006–07. Reported landings declined to 8973 t in 2007–08, and further to 6740 t in 2008–09, but increased to 11 815 t in 2009–10.

There was considerable temporal variation in the catch within and between fishing years. Within a given fishing year, catches were usually highly seasonal, with the target purse-seine fishery in EMA 1 typically operating between July and December before the summer skipjack tuna (*Katsuwonus pelamis*) season (Taylor 2008). There was somewhat less seasonality in the EMA 7 trawl fishery, but in some years a peak in catch appeared during the winter months (June to September) before the end of the fishing year.

Manning et al. (2007b) and Taylor (2008) suggested that inter-annual variations in catch may reflect variable market demand and fishing effort rather than changes in stock abundance. In the purse-seine fishery, blue mackerel has become the second most preferred species because of decreased TACCs on kahawai. Skipjack tuna is the preferred species and blue mackerel are seldom targeted once the skipjack season has begun in late-spring, early summer. Thus, the early arrival of skipjack can result in reduced volumes of blue mackerel being landed.

Management of company quota is complicated by the relative timing of the fishing season and the fishing year and this, along with the timing of the main market, may influence whether the blue mackerel TACC can all be taken in a particular year. The fishing season usually begins in about July–August and finishes in about November. The main market for purse-seine blue mackerel takes up to 80% of the catch and requires premium fish to be available from early spring. To meet the demands of this market and to minimise the costs of storing fish from the previous season, fishing companies must carry over some proportion of their quota for a given year until fish become available the following season. If availability is delayed until after October 1, only 10% of the total quota can then be carried over into the new fishing year.

Because blue mackerel was taken principally as bycatch in the jack mackerel target fishery reported on Trawl Catch Effort Processing Returns (TCEPR) in JMA 7, factors influencing the targeting of jack mackerel also affect blue mackerel landings. Other bycatch species taken in this fishery included barracouta (*Thyrsites atun*), red gurnard (*Chelidonichthys kumu*), John dory (*Zeus faber*), kingfish (*Seriola lalandi*), and snapper (*Pagrus auratus*), and, although non-availability of ACE is unlikely to be constraining in the first three of these, the same is not true of kingfish and snapper. Fishing company spokespersons have stated that known hotspots of snapper are avoided. Other factors in this fishery include strategies to avoid the catch of marine mammals, and a voluntary code of practice

requires that gear is not deployed between 2 a.m. and 4 a.m. It is unknown whether this affects total landing volumes.

2.2 Recreational fishery

Recreational catch in the northern region (EMA 1) was estimated at 114 000 fish by a diary survey in 1993–94, 47 000 fish in a national recreational survey in 1996, 84 000 fish (c.v. 42%) in the 2000 survey, and 58 000 fish (c.v. 27%) in the 2001 survey (Ministry of Fisheries Science Group 2010). Estimates from other areas are very low (between 500 and 3000 fish) and are likely to be insignificant in the context of the commercial catch. Some confusion exists between blue and jack mackerels in the recreational data.

2.3 Customary non-commercial fishery

Quantitative information on the current level of customary non-commercial catch is not available.

2.4 Illegal and misreported catch

There is no known illegal catch of blue mackerel.

3. BIOLOGY AND DISTRIBUTION

3.1 Stock structure

Using parasite markers and meristic characters, and based on their differences between areas, Smith et al (2005) showed that blue mackerel in the New Zealand EEZ are subdivided into at least three stocks: in EMA 1, EMA 2, and EMA 7.

Blue mackerel are widespread in North Island and northern South Island waters. Bagley et al. (2000) presented summary distributions of blue mackerel from various datasets, and found that catches were from North and South Taranaki Bights, northern West Coast South Island southwards to the Hokitika Trench, and around Mernoo Bank. Taylor (2002) found that blue mackerel were distributed over most of the range covered by aerial sightings supporting purse-seine vessels, from the Three Kings Islands around the entire coastline of the North Island, and from the Kahurangi Shoals, outer Golden and Tasman Bays to Kaikoura. The highest densities were seen on the east coast from North Cape to Hawke Bay, and in the area including the South Taranaki Bight to Kahurangi and the outer Golden and Tasman Bays.

Using recorded commercial and research catches, Taylor (2002) found that the geographical distribution and habitat of blue mackerel vary with life history stage. Hurst et al. (2000a) summarised life history stages from the research trawl and found that juvenile and immature blue mackerel were northerly in their distribution around the North Island and into Golden and Tasman Bay, whereas adults were recorded around both the North and South Islands to Stewart Island and across the Chatham Rise to almost the Chatham Islands (Figure 2).

3.2 Spawning

Smith et al. (2005) reported that two spawning centres have been noted for blue mackerel. Crossland (1981, 1982) used egg and larval surveys to identify spawning in the Hauraki Gulf and east Northland. Hurst et al. (2000a) produced spatial distribution maps of fish in "ripe and running ripe" and "spent" condition using gonad staging data and showed spawning blue mackerel from a few tows off Tasman Bay and Taranaki in EMA 7.

Gonad staging data of blue mackerel collected from the research trawl and observer databases provide information on the presence and timing of spawning. These data provided some evidence that spawning of blue mackerel took place in EMA 7 over the summer period (Figure 3). However, Taylor (2002) cautioned that the reliability of the gonad staging data is unknown and there may be some difficulty in distinguishing between immature and resting gonads and early stage maturing.

3.3 Age and growth

Morrison et al. (2001a) estimated von Bertalanffy growth curves using otoliths collected from the Tauranga purse-seine fishery, and from archived otoliths from the west coast of the North Island, the Hauraki Gulf, and the Bay of Plenty (see Table 4, Morrison et al. 2001a). Manning et al. (2006) estimated von Bertalanffy growth curves from the age and length data collected from the EMA 1 purse fishery and reported that the estimates were consistent with those of Morrison et al. (2001a). Both studies found no apparent difference in growth rate between sexes. Differences in growth between EMA 1 and EMA 7 fish were assumed to be less than differences in growth of fish in New Zealand versus Australian waters (Devine et al. 2009).

3.4 Natural mortality

Morrison et al. (2001a) estimated instantaneous natural mortality (M) for both male and female fish using the method of Hoenig (1983). Based on age estimates from otoliths collected during the mid-1980s when fishing pressure was presumably light, natural mortality estimates of 0.22 for males and 0.20 for females were derived.

3.5 Length-weight relationships

The length-weight relationship for blue mackerel was estimated from a linear regression of log-transformed length and weight data from EMA 1 fishery (Manning et al. 2007b). This relationship supersedes an earlier relationship derived from Australian data (Manning et al. 2006).

4. DESCRIPTIVE ANALYSIS OF CATCH

4.1 Catch and effort data sources

Catch and effort data were requested from the Ministry of Fisheries catch-effort database "warehouse" as extract 8208 (see Appendix A for a list of data fields requested). The dataset consists of all fishing and landing events associated with a set of fishing trips that reported a positive landing of blue mackerel in any of the QMAs between 1 October 1989 and 30 September 2010. The fishing year extends from October 1 through to September 30 of the next calendar year. In the rest of this report, fishing year is labelled as the most recent year (*i.e.*, the 1998–1999 fishing year is referred to as 1999). Catches from EMA 7 were reported to FMAs (Fishery Management Area) 7, 8, and 9 before blue mackerel was introduced into the Quota Management System (QMS) in October 2002.

The estimated catches associated with the fishing events were reported on the Ministry of Fisheries Catch Effort Landing Returns (CELR), Trawl Catch Effort Returns (TCER), Trawl Catch Effort and Processing Return (TCEPR), and Net Catch Effort Returns (NCER). The green weight associated with landing events was reported on the bottom part of the CELRs, and the back of NCERs, or where fishing was reported on the two other forms it was recorded on the associated Catch Landing Return (CLR). TCEPR and TCER forms record tow-by-tow data and summarise the estimated catch for the top five species and eight species respectively (by weight) for individual tows, together with latitude and longitude of the tow. CELR forms summarise daily fishing effort and catch, which are further stratified by statistical area, method of capture, target species and estimates of the top five species. NCER forms record set-by-set data and summarise the estimated catch for the top eight species (by weight) for individual sets, together with latitude and longitude. Before 1 October 2007, Trawl vessels less than 28 m in length can use either CELR or TCEPR forms whereas trawl vessels over 28 m must use TCEPR forms. From 1 October 2007 TCER forms were used by vessels over 6 m and less than 28 m (if less than 6 m the CELR is still used). NCER forms were introduced on 1 October 2006 for set net vessels over 6 m (if less than 6 m the CELR is still used).

Information on total harvest levels was provided via the Quota Monthly Return (QMR) or the Monthly Harvest Return (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. This has led to concerns that bycatch species may not be well reported at the fishing event level (e.g. Phillips, 2001). For example, the Adaptive Management Program (AMP) review on SWA 1 (SeaFIC 2007) found that up to 40% of trips that landed catch from SWA 1 reported no estimated catch on TCEPR/CELR forms; but the landings were small (less than 1 t).

The daily processed part of the TCEPR contains information regarding the catch (of all quota species) that was caught and processed that day, and these data are generally believed to provide a more accurate account of low and zero catch observations (Phillips 2001). However, it has been suggested (SeaFIC 2007) that processed catch data can suffer from similar problems as the estimated catch data: trips that have no estimated catch, also tend to have no processed catch recorded. In addition, daily processed catch data suffer from the inability to assign processed catch to a specific day or amount of effort because the catch is not always processed on the day it is caught and thus can be split among days. The daily processed catch is not examined in this study.

The extracted data were groomed and restratified to derive the datasets required for the characterisation and CPUE analyses using a variation of Starr's (2007) data processing method as implemented by Manning et al. (2004), with refinements by Blackwell et al. (2005), and Manning (2007) and further modified by Parker & Fu (2011). 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 and TCEPR reporting systems (frequent non-reporting of species that make up only a minor component of the catch). The procedure has been developed for monitoring bycatch species in the AMP, and is comprehensively described by Manning et al. (2004) and Starr (2007). The major steps are as follows.

- Step1: The fishing effort and landings data are first groomed separately. Outlier values in key variables that fail a range check are corrected using median imputation. This involves replacing missing or outlier values with a median value calculated over some subset of the data. Where grooming fails to find a replacement, all fishing and landing events associated with the trip are excluded.
- Step 2: The fishing effort within each valid trip is then restratified by statistical area, method, and target species.
- Step 3: The greenweight landings for each fish stock for each trip are then allocated to the effort strata. The greenweight landings are mapped to the effort strata using the relationship

between the statistical area for each effort stratum and the statistical areas contained within each fish stock.

- Step 4: The greenweight landings are then allocated to the effort strata using the total estimated catch in each effort stratum as a proportion of the total estimated catch for the trip. If estimated catches are not recorded for the trip although a landing was recorded for the trip, then the total fishing effort in each effort stratum as a proportion of the total fishing effort for the trip is used to allocate the greenweight landings.
- Step 5: The original intent of the merging process was to allow trip level landings data to be mapped to CELR effort strata. However, many species are captured in fisheries reporting using a combination of form types, and some may use TCEPR forms almost exclusively. The grooming and merging process also allows an evaluation of the amount of catch and effort that is not captured using TCEPR forms at the fishing event level. If significant, the best characterisation dataset is likely the merged trip-level data. But if the amount of lost catch and effort is predictable, minor, and stable over time and area, the estimated catch at the level of the fishing event provides a much more detailed dataset for characterisation and CPUE analysis.

Processed product weights in New Zealand fisheries are converted to greenweight catches using species and product-form-specific conversion factors (multiplicative constants). Product form conversion factors for many New Zealand species have changed several times since the full implementation of the QMS. This means that different amounts of greenweight catch are associated with the same amount of processed catch for particular product forms throughout the database. We standardise these changes relative to the latest conversion factor defined for each product state and apply the catch-consistency checking algorithm designed by Blackwell et al. (2005). This algorithm systematically compares the different catch weights recorded for a particular fishing trip against one another and returns the single most consistent catch type for each trip and explicitly and rigorously accounts for conversion factor changes.

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 (SeaFIC 2007). Starr's procedure separates final and interim landings based on the landing destination code, and only landings with destination codes that indicate a final landing are retained (see Table 2 in Starr (2007)).

4.2 Summary of catches

The reported QMR/MHR landings, the catch-effort landings (un-groomed), and the TACC for EMA 7, EMA 1, EMA 2, and EMA 3 from 1983–84 to 2009–are shown in Figure 4. In general, the catch-effort landings in the raw dataset conform closely with the reported MHR landings.

The annual landings for EMA 7 before 1995–96 were mostly below 2000 t and increased since then ranging generally between 2500 t and 5000 t. The landings peaked in 1998–99 at about 8800 t. The TACC for EMA 7 was initially set at 3350 t in 2002–03 and has remained unchanged. The landings overran the TACC in 2002–03, 2004–05, 2005–06, and 2008–09.

The landings for EMA 1 peaked at 10 926 t in 1991–92 and again at 10 684 t in 1992–93, and since then have fluctuated between 3000 and 8000 t in most years. The landings in 2008–09 were the lowest over the last twenty years, but the landings in 2009–10 exceeded the TACC (7750 t).

The annual commercial catch in EMA 2 and EMA 3 was very small and under the TACC. The total annual reported landings for EMA 2 and EMA 3 have been below 200 t since 2000–01, and the catch in EMA 2 was less than 15 t in five of the last six years.

A summary of data by landed state is given in Table 2. A substantial number of landing events was recorded under “T” (transferred to another vessel) and “R” (retained on board) destination codes (both are defined as interim landing events by Starr (2007)). For EMA 7, the “T” events accounted for about 5% of the total reported landings and most of them appeared in the early part of the series through to the late 1990s. It was unknown how the catches from those trips were recorded, because the transferred catches could be landed by foreign vessels to ports outside New Zealand. Those interim events accounted for more than half of the annual landings in some of the early years and excluding them from the dataset would lead to (1) retained landings falling short of the MHR by more than 50%, (2) a large number of trips with estimated catch, but no reported landings, and (3) annual estimated catch exceeding retained landings by up to 40% in some years. It is therefore prudent to retain the “T” landing events in the analysis, but to exclude other interim landing events as defined by Starr (2007).

The reported landings present in the raw dataset and retained landings and estimated catches in the groomed and merged dataset are summarised in Table 3 and plotted in Figure 4. The grooming procedure has excluded trips with invalid codes in fishing method, target species, statistical area, and trip date that cannot be fixed using the median imputation method, but the removed catch as a result of this was generally insignificant. For EMA 7, the retained landings were short of the reported MHR in the early 1990s, but match closely for the later part of the time series. For EMA 1, the retained landings during the 1993 fishing year was about 3000 t less than the reported landings. A closer examination showed that about 1360 t of the catches were taken from trips that fished in Statistical Areas 037, 040–042, and 045–047 (outside EMA 1), and about 2140 t were from trips that had used both the CLR and CELR forms (the catch appeared to have been equally split between the two forms). For EMA 2, 120 t of landings in 2003 were reported under destination code ‘R’ (retained on board).

The estimated catches appeared to track the retained landings reasonably well over time (see Figure 4) and they have captured the majority of the harvest reported via the MHR/QMR system over recent years for all stocks. Some of the differences could be explained by the large numbers of trips that reported non-zero landings but zero estimated catch, and the proportions of such trips were usually above 50% in most years (Table 4). However, landings from those trips were generally very small (less than 1 t, although there were exceptions), and accounted for an insignificant proportion of the total catch. For EMA 7, the ratio of estimated catch to landings was generally above 80% for the TCEPR forms, but appeared to be more variable for the CELR forms (Figure 5). During the 1997 fishing year, the landings reported on the CELR forms were about 310 t, but the associated estimated catch was only about 3 t; between 2001 and 2003, many CELR records appeared to have recorded the catch in wrong units (i.e. 100 t was recorded as 100 rather than 100 000 kg). For EMA 1, where the majority of the vessels used CELR forms, the ratio of estimated catch to the retained landings was generally about 90% (Figure 5). For EMA 2, 7 t of estimated catches were recorded during the 2007 fishing year and the reported landings was about 130 t. At the trip level, there appears to be a reasonably close match between estimated catch and the reported landings (Figure 6).

The landings are summarised by processed state in Figure 7. For EMA 7 and EMA 3, the bulk of catches were processed to the “Dressed” state (DRE). A small proportion of catches were landed green in recent years, but that proportion was higher in early years, and some catches were processed to “Head and Gutted” state (HGU) before 2002–03. The conversion factor for the “DRE” state was decreased from 1.80 to 1.50 from 1 October 1996. This means that different amounts of greenweight catch are associated with the same amount of processed catch for particular product forms throughout the database. Therefore the greenweights were standardised using the most recent conversion factor for each processed state. This assumed that the changes in conversion factors reflect improving estimates of the actual conversion when processing blue mackerel, rather than real changes in processing methodology across the fleet. The adjustment has slightly decreased the greenweight in the early years. For EMA 1 and 2, almost all the catches were landed as ‘green’.

The landings are summarised by form type in Figure 8. For EMA 7 and EMA 3, the bulk of catches were recorded on the CLR forms, and a small proportion was from the CELR forms. For EMA 1 and 2 almost all the catches were recorded on the CELR forms.

4.3 Descriptive analyses

The characterisation analysis was based on the groomed, restratified, and merged dataset. The spatial and temporal trends in catch and effort in the fisheries were summarised to provide a description of how the fishery operates. In particular the distribution of blue mackerel catches was described by fishing year for fishing method and target species. The spatial and temporal distribution of catch was described by statistical area and month for each fishery and for each QMA.

4.3.1 EMA 7

The majority of the blue mackerel catch was taken by midwater trawl (MW) and purse-seine methods (PS) in EMA 7 (Figure 9). MW accounted for about 78% of the total catch between 1989–90 and 2009–10, and PS accounted for about 18%. Before 1998–99, some catches were taken by the bottom trawl (BT) method, which accounted for up to 18% of the annual catch from 1989–90 to 1992–93. A minor portion of catch was taken by bottom pair trawl, set-net, and Danish seine. The high and low catches by MW generally do not coincide with those by PS except for 1998–99 when catch peaked in both fisheries. In 2009–10 virtually all the catches were taken by midwater trawl. All the catches taken by midwater trawlers were recorded on the TCEPR forms, and those by purse-seine were recorded on the CELR forms.

Blue mackerel catches in EMA 7 were widely distributed. MW catches of blue mackerel were taken from the North and South Taranaki Bights, and from the northern West Coast South Island southward to the Hokitika Trench, with most effort targeting jack mackerel (Figure 10). Target fishing of blue mackerel by midwater trawl was confined to smaller areas in the North Taranaki Bight and off the northern West Coast South Island. The PS fishery operated mostly in the South Taranaki Bight and in the outer waters of Golden Bay and Tasman Bay.

Purse-seine fishery

The purse-seine fishery in EMA 7 is largely a target fishery and target fishing has accounted for over 90% of the annual purse-seine catch since 1997–98. Before 1997–98, a large proportion of the catch was taken when the effort was directed at jack mackerel and kahawai, but those catches varied considerably between years (Figure 11). Blue mackerel was also caught occasionally when skipjack (SKJ) was the target species, as occurred in 2006–07 when skipjack target accounted for about 10% of the blue mackerel catch by PS (see Figure 11). The purse-seine fishery for blue mackerel did not operate during 2009–10.

The spatial distribution of purse-seine catches appear patchy (Figure 12). Fishing was concentrated in areas between Tasman Bay and Golden Bay and the South Taranaki Bight (Statistical Areas 037–041), and occurred as far north as near the top of North Island (Statistical Area 047). The fishery also operated off the north-eastern coast of the South Island from Cloudy Bay to Kaikoura during the early 1990s (Statistical Areas 017 and 018), but this fishery ceased to operate by the end of 1990s. The exceptionally high catch in 1998–99 was mostly taken in Statistical Area 037. Catches were relatively consistent between February and May and were sporadic in other months, with almost no catch in more recent years (see Figure 12).

The catch rates of blue mackerel by the purse-seine method generally ranged between 0 and 100 t per set, but catches over 100 t from a single set were not uncommon. Before 1997, most effort was directed at jack mackerel and kahawai, and catch rates of blue mackerel were low (Figure 13). Between 1998–99 and 2002–03 more effort was directed at blue mackerel. Since 2004–05 total effort in the fishery has decreased considerably although the target catch rates appear to have increased.

Midwater trawl fishery

There was no midwater trawl catch of blue mackerel in 1989–90, but it has since become the largest fishery for blue mackerel in EMA 7. Blue mackerel catch from midwater trawling was taken mostly as bycatch when effort was directed at jack mackerel (Figure 14). The target catch of blue mackerel was usually small and also variable. There was no target catch from 1992–93 to 1993–94, and again from 1999–2000 to 2001–02. However, since 2002–03, there has been an increase in the target catch, which has accounted for 5–30% of the annual catches from midwater trawling (see Figure 14). Other target species in the fishery included hoki, barracouta, frostoffish, and redbait (*Emmelichthys nitidus*). Before 1996–97, hoki target tows accounted for up to 30% of annual catches of blue mackerel by midwater trawl.

Fishing effort in the fishery has shifted from the south to the north over time (Figure 15–left). This appears to be the result of a northward movement of midwater trawl jack mackerel targeted effort in JMA 7 (McKenzie 2008). Before 1999–2000, the catches were stable in Statistical Areas 034–037 off the west coast of South Island. Then the fishery developed off the west coast of North Island in Statistical Areas 040–042 and 045, and far offshore in Statistical Area 801. The catches in Statistical Area 041 (north Taranaki Bight) have been consistently high in the last 10 years. About 70% and 75% of catch was taken from Statistical Area 041 alone in 2008–09 and 2009–10.

Catches of blue mackerel from the midwater trawl fishery exhibited a clear seasonal pattern, with catches mostly in the winter period with peaks in July and August (see Figure 15–right). Over the last five years catches between October and January have increased.

Blue mackerel and jack mackerels can be considered separate elements of a single mixed-species midwater trawl fishery in EMA 7/JMA 7. Effort that targeted jack mackerel and caught blue mackerel can potentially be used to monitor the encounter rates of blue mackerel in the fishery. Following Fu & Taylor (2011), the proportion of zero catches of blue mackerel from the midwater trawl jack mackerel target fishery was examined using two approaches: one was based on the tow-level data where tows that target jack mackerel but caught no blue mackerel were considered zeros, and the other was based on the stratified and merged data where effort strata (a unique combination of trip, target species, statistical area, and month) with no allocated green weight landings of blue mackerel were considered zeros. The proportion of zeros defined using the two approaches have shown an overall flat trend (Figure 16). The proportion of zeros defined at the tow level was generally over 60% since 2001–02 and was much higher than that defined at the trip-stratum level, which was generally below 40%. The difference is because the latter accounted for trips that recorded no estimated catch but reported a positive landing.

The catch rates of blue mackerel from midwater trawl jack mackerel target tows were examined for subareas within EMA 7. The catch rates are variable and the trends are difficult to interpret (Figure 17). In areas off the west coast of South Island (Statistical Areas 034, 035, and 036), there was generally an increasing trend in catch rates through the late 1990s, followed by a declining trend from 2000 to 2004. The catch rates appear lower in Statistical Area 036, where it appears most annual effort has been in last 10 years. In South Taranaki Bight (Statistical Area 037 and 040), there was an overall decreasing trend in catch rates through the time series, with the effort increasing through the early 2000s. In North Taranaki Bight and areas off the west coast of North Island, there was little fishing before 2000. In Statistical Area 041, where most fishing effort was concentrated, the catch rate

was exceptionally high in 2001–02, but dropped dramatically in the following year, and since then has remained relatively flat.

Distributions of selected effort variables for tows targeted at jack mackerel are shown in Figure 18. Most effort variables were variable in the early years, but they have become more stable in recent years, reflecting the consistency of the Ukrainian fleet targeting JMA in those years. The average tow duration has increased over the last 10 years. The depth of the tow is generally below 200 m, and appears to have decreased since the late 1990s.

Target catches of blue mackerel by midwater trawl were sporadic before early 2000s with no target catch in some years. Between 2004–05 and 2008–09, 30 to 40 tows each year consistently targeted blue mackerel and the average catch rates were about 15 to 25 t per tow (Figure 19). The mean catch rate increased to about 40 t per tow in 2009–10, but the effort appeared about the same as the previous year. Target fishing occurred in smaller areas in the North Taranaki Bight and off the northern west coast South Island.

4.3.2 EMA 1

Purse-seine was the dominant fishing method in EMA 1, accounting for nearly all the blue mackerel catches (Figure 20). During 1990–91 about 180 t of blue mackerel was caught by Danish seine and between 1991–92 and 1997–98 about 10–20 t was caught by set net each year, but these were less than 1% of the total catch. All the purse-seine catches were recorded on the CELR forms. The PS fishery mainly operated in the inshore areas with catches mostly taken off the northeast coast of the North Island and in the northern area of the Bay of Plenty (Figure 21).

Purse-seine fishery

The purse-seine fishery in EMA 1 is largely a target fishery and over 90% of the annual catches were taken as a target species (Figure 22). About 5–10% of catches were taken by effort directed at jack mackerel, and other target species in the fishery included skipjack or kahawai, but catches of blue mackerel from these target species were minor.

Statistical Areas 002, 003, 008, and 009 accounted about 25%, 40%, 10%, and 25% of the total catch respectively, but the catch exhibited large inter-annual variability over the last two decades (Figure 23–left). Catches dropped considerably in Statistical Area 002 over the last few years, and about 370 t of blue mackerel were taken between 2007–08 and 2009–10, whereas about 7500 t were caught over the previous three years. Catch in Statistical Area 008 also decreased from about 1200 t in 2008–09 to about 140 t in 2009–10. Within a fishing year, catches were usually highly seasonal and the target purse-seine fishery typically operated between September and December before the summer skipjack season (Figure 23–right).

Most effort off the northeast coast of the North Island targeted blue mackerel, whereas most sets in the Bay of Plenty targeted jack mackerel (Figure 24). In both areas, the mean catch rates for sets targeting blue mackerel fluctuated over time but were generally over 25 t per set. The catch rates of blue mackerel for effort targeting jack mackerel were usually less than 2 t per set.

4.3.3 EMA 2

The commercial catch in EMA 2 was very small. Annual catches were below 200 t since 1994–95 and less than 15 t in five of the last six years. Catch was mostly taken using purse-seine nets (Figure 25) by inshore vessels off the east coast of the North Island from East Cape to Cape Palliser (Figure 26).

In the early years, most catches were taken by effort targeted at kahawai. But since the mid-1990s, catches were taken from a mixture of target species including kahawai, blue mackerel, and jack mackerel (Figure 27). Although catches were widely distributed along the coast northward to East Cape, most catches were concentrated in Statistical Areas 013 and 014 (Figure 28–left). The temporal distributions were very patchy with most catches taken in October and November, and almost no catches in June and July (see Figure 28–right). Both effort and catch rates have exhibited large inter-annual variability; fewer than 30 sets were made in most years since 2004 (Figure 29).

4.3.4 EMA 3

Blue mackerel in EMA 3 were caught by a number of fishing methods including purse-seine, bottom trawl, and midwater trawl (Figure 30). The purse-seine catch was part of the fishery that operated off the north-eastern coast of the South Island in EMA 7. The purse-seine catches dominated in the early 1990s, but the fishery had ceased by the late 1990s. Catch in recent years was mostly taken by midwater trawl near Mernoo Bank (Figure 31).

Most catches were taken from jack mackerel targeted tows (Figure 32) and were taken throughout the fishing year (Figure 33). Fishing effort decreased from 1994 to 1999 and there was no recorded effort in 2000, 2001, 2004, and 2005 (Figure 34). Effort in the fishery varied considerably over the last five years. Catch rates of blue mackerel from the jack mackerel targeted tows exhibited large inter-annual variability and was generally less than 0.5 t per tow.

5. STANDARDISED ANALYSIS

Taylor (2002) suggested that catch and effort data from purse-seine fishery was unlikely to provide a reliable set of abundance indices for blue mackerel, because the distribution of the catch and effort was patchy in time and space, and also because the effective effort cannot be easily measured when the species school at the surface and are bulk-caught in purse-seine nets with assistance of spotter planes. Fu & Taylor (2007) developed standardised CPUE indices for the midwater trawl fishery in EMA 7, based on the bycatch of blue mackerel from jack mackerel targeted effort. The standardised indices were updated to 2008–09 by Fu & Taylor (2011), and are further updated in this report to the 2009–10 fishing year.

Estimates of relative year effects were obtained from a stepwise multiple regression method in which the data were modelled using a lognormal generalised linear model. A forward stepwise multiple-regression fitting algorithm (Chambers & Hastie 1991) 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 , was 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 resulted in a relatively parsimonious model with moderate explanatory power.

Following Fu & Taylor (2011), the CPUE dataset comprised tows that targeted jack mackerel with blue mackerel caught as bycatch. Tows that targeted blue mackerel were not considered because they constituted a small amount of catch and effort (about 30 tows each year for the last six years) and they were confined to a few areas in the fishery and were directed at large sub-surface schools of blue mackerel. The CPUE dataset was split into two time series, one extending from 1989–90 to 1997–98 and the other extending from 1996–97 to 2009–10. Separate CPUE indices were derived to account for the dramatic change in the composition of the fleet that occurred during the mid- to late 1990s (a shift from a bottom-trawl fishery executed by vessels about 3000 gross tonnes to a midwater trawl fishery executed by vessels about 4000 gross tonnes).

The standardisation analysis was restricted to data associated with large (more than 28 m in overall length) trawl vessels completing the TCEPR forms. Fu & Taylor (2011) fitted standardisation models using estimated catch from the tow by tow data, and also investigated an alternative model based on the allocated green weight landings of the stratified data. Standardised CPUE indices from the two models showed very similar trends. However utilising tow by tow data allowed for the changes in catch rates to be modelled using smaller spatial and temporal scales, and also enabled additional factors influencing CPUE to be included (such as tow distance or bottom depth). In this analysis, standardisation analysis was carried out for the TCEPR tow by tow data using the estimated catch.

Previous CPUE analysis (Fu & Taylor 2011) investigated incorporating zero catches (a zero is a tow with no estimated catch of blue mackerel) in the standardisation by fitting the binomial-lognormal model to the data and found that the indices for the proportions of zeros had a flat trend, and that the combined indices were very close to the indices for the positive catches. In this analysis, only the positive catches were used and zeros were excluded.

The dependent variable was the log-transformed estimated catch per hour. The use of catch per tow in the standardisations was investigated in a previous CPUE analysis (Fu & Taylor 2011); however, variable *fishing duration* was not selected into the final model and the resulting CPUE showed less of a decline. Given that the tow duration in this fishery has decreased over time (see Figure 18), the use of catch per hour as a measure of CPUE allows for the effect of fishing duration to be incorporated in the standardisations. Explanatory variables offered to the initial model were *fish_year*, *vessel_key*, *start_stats_area_code*, *month*, with additional variables *start_latitude*, *start_longitude*, *effort_depth*, *effort_width*, and *effort_height* included as 3rd order polynomials. Year indices were standardised to the mean and were presented in canonical form (Francis 1999).

5.1 The split of the vessel fleet

Vessel effects were incorporated into the CPUE standardisations to allow for possible differences in fishing power between vessels. Vessels not involved in the fishery for consecutive years, or that had only participated for 1–3 years, were excluded because they provided little information for the standardisations, and could result in model over-fitting (Francis 2001). The standardisation was undertaken for “core” vessels that had reported positive catches of blue mackerel in the fishery for at least four consecutive years. There were 16 vessels that were included in the final dataset, and they made up about 25% of the fleet and accounted for over 80% of total catch of blue mackerel in EMA 7. A summary of the catch and effort by all vessels and by core vessels is given in Table 5. The distribution of catches by the core vessels is shown in Figure 35. There was an apparent temporal change in the fleet composition: most of the vessels that fished in the early 1990s appeared to have dropped out of the fishery by 1997–98, and since then the fishery has been dominated by seven vessels (vessels 1–7 in Figure 35, note that vessel codes given here do not correspond to any real vessel code). Those seven vessels are Ukraine vessels over 100 m in length and over 4000 t in tonnage. The early vessels are much smaller in size and power.

Based on the temporal change of fleet compositions, separate CPUE standardisations were carried out: for the early time series from 1989–90 to 1997–98 involving vessels 8–15, and for a late time series from 1996–1997 to 2009–10 involving vessels 1–7 (Figure 35). The split in the data series also coincided with the spatial shift of effort in the fishery, where the early vessels mainly fished off the west coast of the South Island (Statistical Areas 034–037) and the late vessels gradually fished towards the north (Statistical Areas 040–042, 045, and 801). Only the standardised indices for the late series were updated; standardised indices for the early series from the previous analysis are re-presented.

5.2 Standardised CPUE indices

Standardised CPUE indices for the model fitted to the CPUE series 1996–97 to 2009–10 are shown in Figure 36 and summarised in Table 6. The standardised index fluctuated in the first three years, then declined steeply to 2003–04, and since then has remained relatively flat. The index in 2009–10 is about 30% of the level in 1997–98.

Variables *vessel*, *fishing day*, *start latitude*, and *effort height* (headline height) were selected into the final model, and together they explained 27% of variability in the data. Predicted catch rates by selected variables appeared to be reasonable (Figure 37). Diagnostic plots of residuals against fitted values and residuals against quantiles of the standard normal distribution suggested no apparent departures from model assumption of homoscedasticity and normality of errors in log-space (Figure 38).

Influence plots (Bentley et al. 2012) by selected variables show changes of fishing behaviour by core vessels around 2000 (Figures B1–B4 in Appendix B): before 2000, the core vessels used higher headline heights, fished in more southern areas, and caught blue mackerel almost exclusive during winter seasons; after 2000, those core vessels used a wide range of headline heights, fished mostly in the northern areas, and caught blue mackerel around the year.

Potential differences in CPUE trends among sub-areas were investigated. This was carried out in two steps. In the first step, the model was refitted with variable *start latitude* being replaced by *statistical area* and mean annual catch rates were predicted for each statistical area with other variables assuming median values (the catch rates have the same trend but are different in scale among sub-areas). In the second step, a *year * statistical area* interaction term was offered to the model and the predicted catch rates for each statistical area showed comparable trends to those from the model without the interaction term (Figure 39), except for some evidently high catch rates in some areas and in some years (e.g. Statistical Area 036 in 1996–97). This suggested that the changes in relative abundance were likely to be similar between statistical areas within EMA 7.

6. FISHERY DEPENDENT OBSERVATIONS

6.1 Commercial catch length data

Commercial catches of blue mackerel were sampled from a number of sources. Length and age data of blue mackerel were collected during limited sampling of purse-seine catch in EMA 1 during 1997–98 (Morrison et al 2001a) and 2002–03 (Manning et al. 2006). A new sampling programme was developed under the Ministry of Fisheries research project EMA200401 with the aim to representatively sample the target purse-seine catch in EMA 1 and the target purse-seine catch and catches by midwater trawl vessels targeting jack mackerel in EMA 7 since 2003–04.

Landings by purse-seine vessels targeting blue mackerel in EMA 1 and EMA 7 were sampled in fish processing factories in Tauranga using a stratified scheme in 2003–04 (Manning et al. 2007a), 2004–05 (Manning et al. 2007b), and 2005–06 (Devine et al. 2009). There was no formal spatial or temporal allocation of sampling effort. Samples were systematically collected from the vessel-hold strata for each landing, where about 100 fish were randomly sampled from each hold at a rate of up to three samples per hold per day. Most samples were from EMA 1, and for EMA 7, the sample size was generally small, with only 2–3 landings sampled each year (Table 7). The spatial and temporal distribution of the catch and sampling effort suggested that sampling data collected from EMA 1 may be representative of the fishery, and data collected from EMA 7 may be not representative — at least for some years (Devine et al. 2009). In 2003–04 no target purse-seine vessels operated in EMA 7. Samples were taken from inshore trawlers as bycatch of fishing effort directed at other preferred species (Manning et al. 2007b).

Blue mackerel catches by midwater-trawl vessels targeting jack mackerel in EMA 7 have been sampled at sea by the Ministry of Fisheries Observer Programme since 1987. The sampling scheme was described in full by Sutton (2002). Typically, about 100 fish were randomly sampled by length from the catch every two to three days during each fishing trip for length measurements. Samples were collected more frequently when larger catches of blue mackerel were made. However, observers were assigned to vessels opportunistically with no formal spatial or temporal allocation of sampling effort. The sample size was small in the early years, with generally less than 500 fish sampled each year. The sampling effort has significantly increased since 2003–04 under the new sampling programme, with more tows sampled and over 2000 fish measured each year (

Table 8). The MW-JMA fishery in EMA 7 appeared to be sampled adequately with respect to area, month, and target species, and the data collected are thought to be representative of fishery in EMA 7 since 2003–04.

Scaled length frequencies were estimated for each of the fisheries using NIWA’s catch-at-age software (Bull & Dunn 2002). For the purse-seine fishery, the catch samples were scaled up to each landed catch, summed over all landings. For the midwater trawl fishery, the length frequency of fish from each tow were scaled up to the tow catch weight, summed over all tows, scaled up to the total catch in each trip, and then summed across the all trips, to yield overall length frequencies.

Length distributions of blue mackerel sampled from in EMA 7 generally ranged from 40 cm to 55 cm and were strongly unimodal, with the mode roughly centred around 48 cm in most years (Figures 40 and Figure 41–left). The purse-seine target fishery in EMA 7 did not sample any fish outside the 30–55 cm size range, and the fish caught during 2004–05 and 2005–06 were smaller than those during 2003–04 (samples in 2003–04 were from non-target catch). The trawl bycatch fishery in EMA 7 caught few fish in the 30–40 cm size range, but caught slightly more large fish before 2003–04. Length distributions of blue mackerel sampled in EMA 1 ranged from 30 cm to 55 cm, with the mode roughly centred around 45 cm in most years (see Figure 41–right). There appears to be no sign of mode progression present over time in the length distribution in any of the fisheries.

Otoliths were collected from sampled landings, as well as by observers for observed fishing trips between 2002–03 and 2005–06 in EMA 7 and EMA 1. Scaled age distributions for the EMA 7 purse seine fishery and the midwater trawl fishery and the EMA 1 purse seine fishery were estimated by applying the age-length key to the scaled length frequency for 2002–03, 2003–04, 2004–05, and 2005–06 fishing years (see Figure 11 of Manning et al. 2006, Figure 9 of Manning et al. 2007a, Figure 8 of Manning et al. 2007b, and Figure 10 of Devine 2009). The age distribution generally ranged between 2 and 25 years with slightly more young fish caught in the purse-seine fisheries. Catch from the midwater trawl fishery had a slightly broader range.

Number of blue mackerel gonad development stages collected by the Observer Programme in EMA 7 are summarised in Table 9. There were few data available from either source before 2000. After 2003, more data became available from the observer programme (generally over 1000 fish were sampled each year). These data show that ripe or running ripe males and female mostly occur between November and January (Figure 42).

7. FISHERY INDEPENDENT OBSERVATIONS

7.1 Research surveys

Bottom trawl surveys have been conducted since the early 1990s using either the *Tangaroa* (Chatham Rise survey or Sub-Antarctic Survey) or the *Kaharoa* (ECSI, ECNI, WCSI, WCNI). Some of those surveys encounter blue mackerel, but these surveys are not optimised to estimate biomass for this species. The length data collected from those research trawl voyages throughout New Zealand waters are summarised in Table 10. Length data of blue mackerel sampled in some of the early exploratory

surveys conducted in the 1970s by other vessels (*Ikatere* and *James Cook*) were summarised by Taylor (2002).

Unscaled length frequencies of blue mackerel sampled from trawl surveys in EMA 7 and EMA 1 are shown in Figure 43 (only surveys with more than 50 fish sampled are shown). In most years the length data were too few to provide useful length distributions, and most fish caught during the surveys were juvenile fish less than 20 cm. The length distributions from the 1989–90 survey in EMA 7 (more than 300 fish were sampled) showed four possible modes, centred at about 12, 20, 30, and 45 cm. This suggested that some size classes may be more vulnerable to the gear, but the small sample sizes prevent any reliable interpretation.

8. DISCUSSIONS

The commercial catch is caught by a variety of methods in all QMAs. The largest and most consistent catches across fishing years are by purse-seine vessels targeting blue mackerel schools in EMA 1. Catches by midwater trawl vessels targeting jack mackerels in EMA 7 are also important. Catches in EMA 2 and 3 have been very small.

There appears to be some changes in the fisheries in recent years: there was almost no catch from EMA 2 in five of the last six years; the purse seine fishery in EMA 7 did not operate during 2009–10, the fishing year in which the target catch in the midwater trawl fishery doubled; the purse seine catch in EMA 1 increased considerably in 2009–10, but was taken from smaller areas than previous years. Unstandardised catch rates from the purse-seine target fishery in EMA 1 and from the midwater trawl bycatch fishery in EMA7 were generally stable over recent years, though they have exhibited large inter-annual variability.

The commercial catch of blue mackerel in the New Zealand EEZ varies greatly between fishing years. Inter-annual variation in catches is thought to reflect variable market demand rather than changes in stock abundance (Morrison et al. 2001a). For example, blue mackerel has become a more valuable alternative to jack mackerel as a replacement for kahawai during the skipjack tuna off-season in EMA 1. Taylor (2002) suggested that irregular fluctuations in catch from bottom trawl, midwater trawl, and purse-seine fishing may have indicated a lack of concurrence in availability of fish to main gear types rather than providing evidence of years of high or low abundance. There are other factors which influence catch and thus reduce the validity of using catch as an indicator of abundance. The low abundance of skipjack tuna in 1998–99 was considered to be the key factor that resulted in high catches of blue mackerel in both the purse-seine and midwater trawl fisheries.

Catch seasonality showed inversely correlated patterns for the purse-seine and midwater trawl methods in EMA 7: purse-seine catches were taken in most months except between June and August; midwater trawl catches were low for most of the year with a large peak in July and August. Taylor (2002) examined patterns in aerial sighting data and found that a large proportion of blue mackerel in EMA 7 is absent from surface schools during winter, but is present in subsurface schools mixed with jack mackerel; though these data were too patchy to provide a definitive seasonal pattern. He argued that blue mackerel change their behaviour in June–August and thus become more vulnerable to the midwater fleet, or that the fleet switch their strategy to take advantage of the change in fish behaviour.

Taylor (2002) suggested that CPUE indices are likely to be unreliable indicators of changes in abundance for blue mackerel because the fish are highly mobile, both vertically within the water column and geographically between areas, and have the tendency to school by size. For the purse-seine fleet, there is a tendency for fishers to target blue mackerel by size and a tendency for the catch rates to remain high when abundance is low. For the midwater trawl fleet where blue mackerel is taken as bycatch in the jack mackerel target fishery, the preference for blue mackerel catch is driven by market conditions and also differs by fishing company depending on the amount of blue mackerel quota each company owns (Devine et al. 2009). However, fishers have suggested that the sounder-

mark for jack mackerel schools has the same appearance as a mark for mixed schools of jack mackerel and blue mackerel (Taylor 2002), which suggests that the blue mackerel catch is largely beyond the control of vessel operators and will fluctuate according to both the abundance and fishing effort present in the fishery.

The standardised CPUE indices have suggested a large decline of abundance from the late 1990s through to the early 2000s. However, there has been little evidence in the commercial catch sampling data to support this decline of abundance in that there has been no great change in the length distribution. However it has been noted that there appear to have been more large fish in the catch before 2003, although the sample size was generally too small in the early years to make any firm conclusion.

Length frequency distributions from observer and research trawl data presented here show differences in size ranges: length frequency distributions showed wider length ranges for the research trawl data (about 9–50 cm) with a predominance of small fish, and length frequency distributions from observer data were tighter and more structured, with narrower ranges (30–55 cm). Taylor (2002) suggested that the distribution of small fish is more coastal, resulting in them not being vulnerable to the TCEPR fleet fishing outside 12 miles.

In EMA 1, almost all the catches are taken as a target species. In EMA 7, most catches are captured on TCEPR forms and the fisheries encountering blue mackerel have several dominant vessels. Observer sampling in EMA 7 and market shed sampling in EMA 1 have provided consistent length frequency and age distributions. The biology is reasonably well understood, but a few directed studies of reproductive development would enable robust maturity ogives to be determined. For future possible stock assessment one limiting factor is that no biomass estimates are available from existing fishery independent surveys, because none are optimised for this species.

9. ACKNOWLEDGMENTS

This work was supported by a contract from the Ministry of Primary Industries (DEEP201007). I thank Suze Baird and Andy McKenzie for reviewing this report.

10. REFERENCES

- Bagley, N.W.; Anderson, O.F.; Hurst, R.J.; Francis, M.P.; Clark, M.R.; Paul, P.J. (2000). Atlas of New Zealand fish and squid distributions from midwater trawls, tuna longline sets, and aerial sightings. *NIWA Technical Report 2000/72*. 167 p.
- Bentley, N.; Kendrick, T.H.; Starr, P.J.; Breen, P.A. (2012). Influence plots and metrics: tools for better understanding fisheries catch-per-unit-effort standardizations. *ICES Journal of Marine Science* 69(1): 84–88.
- Blackwell, R.G.; Manning, M.J.; Gilbert, D.J. (2005). Standardised CPUE analysis of the target rig (*Mustelus lenticulatus*) set net fishery in northern New Zealand (SPO 1 and SPO 8). Final Research Report for Ministry of Fisheries Project SPO2004-01, Objective 1. 37 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)
- Bradford, E.; Taylor, P.R. (1995). Trends in pelagic fish abundance from aerial sightings data. New Zealand Fisheries Assessment Research Document 95/8. 60 p. (Unpublished report held in NIWA library, Wellington.)
- Bull, B.; Dunn, A. (2002). Catch-at-age: User manual v1.06.2002/09/12. NIWA Internal Report 2002/114. 23 p.
- Chambers, J.M.; Hastie, T.J. (1991). Statistical models in S. Wadsworth & Brooks-Cole, Pacific Grove, CA. 608 p.
- Crossland, J. (1981). Fish eggs and larvae of the Hauraki Gulf, New Zealand. *Fisheries Research Bulletin* 23. 61 p.
- Crossland, J. (1982). Distribution and abundance of fish eggs and larvae from the spring and summer plankton of North East New Zealand, 1976–78. *Fisheries Research Division Bulletin* 24. 59 p.
- Devine, J.A.; Manning, M.J.; Taylor, P.R. (2009). The length and age composition of the commercial catch of blue mackerel (*Scomber australasicus*) in EMA 1 & 7 during the 2005–06 fishing year. *New Zealand Fisheries Assessment Report 2009/48*. 33 p.
- Francis, R.I.C.C. (1999). The impact of correlations in standardised CPUE indices. New Zealand Fisheries Assessment Research Document 99/42. 30 p. (Unpublished report held in NIWA library, Wellington.)
- Francis, R.I.C.C. (2001). Orange roughy CPUE on the South and East Chatham Rise. *New Zealand Fisheries Assessment Report 2001/26*. 30 p.
- Fu, D.; Taylor, P.R. (2007). Standardised CPUE analyses for blue mackerel (*Scomber australasicus*) in EMA 7, 1989–90 to 2004–05. *New Zealand Fisheries Assessment Report 2007/33*. 33 p.
- Fu, D.; Taylor, P.R. (2011). Characterisation and standardised CPUE analyses for blue mackerel (*Scomber australasicus*) in EMA 7, 1989–90 to 2008–09. *New Zealand Fisheries Assessment Report 2011/56*. 64p.
- Hoenig, J.M. (1983). Empirical use of longevity data to estimate mortality rates. *Fisheries Bulletin*. 81: 898–903.

- Hurst, R.J.; Bagley, N.W.; Anderson, O.F.; Francis, M.P.; Griggs, L.H.; Clark, M.R.; Paul, L.J.; Taylor, P.R. (2000a). Atlas of juvenile and adult fish and squid distributions from bottom and midwater trawls and tuna longlines in New Zealand waters. *NIWA Technical Report 84*. 162 p.
- Hurst, R.J.; Stevenson, M.L.; Bagley, N.W.; Griggs, L.H.; Morrison, M.A.; Francis, M.P. (2000b). Areas of importance for spawning, pupping or egg-laying, and juveniles of New Zealand coastal fish. Final Research Report for Ministry of Fisheries Research Project ENV1999103 Objective 1. 282 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)
- McKenzie, A. (2008). Standardised CPUE analyses for *Trachurus declivis* and *Trachurus novaezealandiae* in the JMA 7 jack mackerel fishery to 2004–05. *New Zealand Fisheries Assessment Report 2008/46*. 36 p.
- Manning, M.J. (2007). Relative abundance of giant stargazer (*Kathetostoma giganteum*) in STA 5 based on commercial catch-per-unit-effort data. *New Zealand Fisheries Assessment Report 2007/14*. 42 p.
- Manning, M.J.; Devine, J.A.; Marriott, P.M.; Taylor, P.R. (2007b). The length and age composition of the commercial catch of blue mackerel (*Scomber australasicus*) in EMA 1 & 7 during the 2004–05 fishing year. *New Zealand Fisheries Assessment Report 2007/35*. 36 p.
- 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. *New Zealand Fisheries Assessment Report 2004/61*. 135 p.
- Manning, M.J.; Marriott, P.M. (2006). Investigating blue mackerel age estimation error: progress achieved to 31 March 2006. Research Progress Report submitted to the Ministry of Fisheries for research project EMA2005-02 Specific Objectives 1–3. 26 p. (Unpublished report held by the Ministry for Primary Industries, Wellington.)
- Manning, M.J.; Marriott, P.M.; Taylor, P.R. (2006). The length and age composition of the commercial catch of blue mackerel (*Scomber australasicus*) in EMA 1 during the 2002–03 fishing year, including a comparison with data collected during the 1997–98 fishing year, and some remarks on estimating blue mackerel ages from otoliths. *New Zealand Fisheries Assessment Report 2006/42*. 42 p.
- Manning, M.J.; Marriott, P.M.; Taylor, P.R. (2007a). The length and age composition of the commercial catch of blue mackerel (*Scomber australasicus*) in EMA 1 and 7 during the 2003–04 fishing year. *New Zealand Fisheries Assessment Report 2007/13*. 41 p.
- Ministry of Fisheries Science Group (2010). Report from the Fisheries Assessment Plenary, May 2010: stock assessments and yield estimates. Ministry of Fisheries, Wellington, New Zealand. (Unpublished document held by Ministry for Primary Industries, Wellington.)
- Morrison, M.A.; Stevenson, M.L.; Hanchet, S.M. (2001a). Review of west coast North Island trawl survey time series, 1986–96. *NIWA Technical Report 97*. 56 p.
- Morrison, M.A.; Taylor, P.R.; Marriott, P.M.; Sutton, C.P. (2001b). An assessment of information on blue mackerel (*Scomber australasicus*) stocks. *New Zealand Fisheries Assessment Report 2001/44*. 26 p.
- Parker, S.; Fu, D. (2011). Fishery characterisation and standardised CPUE analyses for silver warehou (*Seriotelella punctata*) in SWA 3 and 4, 1989–90 to 2007–08. *New Zealand Fisheries Assessment Report 2011/1*. 141 p.

- Phillips, N.L. (2001). Analysis of silver warehou (*Seriotelella punctata*) catch-per-unit-effort (CPUE) data. *New Zealand Fisheries Assessment Report 2001/73*. 48 p.
- Sampson, D.B. (2000). Review of MFish contracted aerial sightings research. (Unpublished report available from the Ministry for Primary Industries, Wellington).
- Seafood Industry Council (SeaFIC) (2007). Silver warehou: SWA 1 Adaptive Management Programme Full-term Review Report. AMPWG-2007/22. Unpublished report held by the Ministry for Primary Industries, Wellington.
- Smith, P.J.; Diggles, B.; Kim, S. (2005). Stock structure of blue mackerel, *Scomber australasicus*. *New Zealand Fisheries Assessment Report 2005/43*. 38 p.
- Starr, P.J. (2007). Procedure for merging Mfish landing and effort data, V2.0. Document AMPWG/07/04. (Unpublished report held by Ministry for Primary Industries, Wellington).
- Sutton, C.P., editor. (2002). Biological data collection manual for Ministry of Fisheries observers. Unpublished technical manual held by Ministry for Primary Industries, Wellington.
- Taylor, P.R. (1999). Time series of relative abundance indices from aerial sightings data for some important pelagic schooling species. *New Zealand Fisheries Assessment Research Document 99/53*. 35 p. (Unpublished report held in NIWA library, Wellington.)
- Taylor, P.R. (2002). A summary of information on blue mackerel (*Scomber australasicus*), characterisation of its fishery in QMAs 7, 8, and 9, and recommendations on appropriate methods to monitor the status of this stock. *New Zealand Fisheries Assessment Report 2002/50*. 68 p.
- Taylor, P.R. (2008). Factors affecting affecting fish size and landed volumes in the purse-seine and TCEPR charter-boat fisheries in 2004–05 and 2005–06. *New Zealand Fisheries Assessment Report 32*. 16 p.
- Taylor, P.R. (submitted-a). Refining the aerial sightings data, their collection, and the method using them to estimate relative abundance of coastal pelagic fish species. Manuscript submitted to the Ministry of Fisheries for publication as a New Zealand Fisheries Assessment Report. (Unpublished report held by Ministry for Primary Industries). 45 p.
- Taylor, P.R. (submitted-b). A summary of survey methods for small inshore pelagic finfish species. Manuscript submitted to the Ministry of Fisheries for publication as a New Zealand Fisheries Assessment Report. (Unpublished report held by Ministry for Primary Industries). 66 p.

Table 1 : Reported landings (t) of blue mackerel by QMA and where area was unspecified (Unsp.), from 1983–84 to 2009–10.

QMA	EMA 1	EMA 2	EMA 3	EMA 7	EMA 10#	Unsp	Total
1983–84*	480	259	44	245	0	1	1 029
1984–85*	565	222	18	865	0	73	1 743
1985–86*	618	30	190	408	0	51	1 297
1986–87†	1 431	7	424	489	0	49	2 400
1987–88†	2 641	168	864	1 896	0	58	5 627
1988–89†	1 580	<1	1 141	1 021	0	469	4 211
1989–90†	2 158	76	518	1 492	0	<1	4 245
1990–91†	5 783	94	478	3 004	0	0	9 359
1991–92†	10 926	530	65	3 607	0	0	15 128
1992–93†	10 684	309	133	1 880	0	0	13 006
1993–94†	4 178	218	223	1 402	5	0	6 026
1994–95†	6 734	94	154	1 804	10	149	8 945
1995–96†	4 170	119	173	1 218	0	1	5 681
1996–97†	6 754	78	340	2 537	0	<1	9 710
1997–98†	4 595	122	78	2 310	0	<1	7 106
1998–99†	4 505	186	62	8 756	0	4	13 513
1999–00†	3 602	73	3	3 169	0	0	6 847
2000–01†	9 738	113	6	3 278	0	<1	13 136
2001–02‡	6 368	177	49	5 101	0	0	11 695
2002–03‡	7 609	115	88	3 563	0	0	11 375
2003–04‡	6 523	149	1	2 701	0	0	9 374
2004–05‡	7 920	8	<1	4 817	0	0	12 746
2005–06‡	6 713	13	133	3 784	0	0	10 643
2006–07‡	7 815	133	42	2 698	0	0	10 688
2007–08‡	5 926	6	122	2 929	0	0	8 983
2008–09‡	3 147	2	88	3 503	0	0	6 740
2009–10‡	8 538	3	14	3 260	0	0	11 815

* FSU data.

† CELR data.

Landings reported from QMA 10 are probably attributable to Statistical Area 010 in the Bay of Plenty (i.e., QMA 1).

‡ QMS data.

Table 2: Total landing weight (t) and number of records by destination type for EMA 7, EMA 1, EMA 2, and EMA 3.

Code	Description	Action	EMA7		EMA 1		EMA 2		EMA 3	
			Landings	Records	Landings	Records	Landings	Records	Landings	Records
A	Accidental loss	keep	3	8	19	27	0	0	0	1
C	Disposed to the Crown	keep	0	1	0	1	0	0	0	0
D	Discarded	keep	31	43	1	16	0	1	0	4
E	Eaten	keep	32	543	0	8	0	0	5	165
F	Recreational catch	keep	0	5	2	34	0	9	0	0
H	Loss from holding pot	keep	0	0	0	1	0	0	0	0
L	Landed to a Licensed Fish Receiver	keep	61458	5262	134537	8453	2345	1198	2738	1141
O	Conveyed outside New Zealand	keep	128	29	0	1	0	0	9	2
S	Seized by the Crown	keep	0	2	0	2	0	0	0	2
U	Used as bait	keep	2	37	3	160	1	2	0	6
W	Sold at wharf	keep	0	1	2	206	0	8	0	1
NULL		keep	0	0	0	0	0	0	0	0
B	Stored as bait	drop	23	277	8	200	1	51	5	37
P	Holding receptacle in the water	drop	0	0	0	2	0	0	0	0
Q	Holding receptacle on land	drop	1	23	12	264	0	31	1	41
R	Retained on board	drop	2215	314	246	66	165	12	332	33
T	Transferred to another vessel	drop	3811	257	1206	30	122	2	8	18
Invalid	Invalid destination code recorded	drop	0	0	0	0	0	0	0	0

Table 3: Reported Monthly Harvest Return (MHR), raw landings, groomed landings in the merged dataset, and groomed estimated catches in merged dataset by fishing year for EMA 7, EMA 1, EMA 2, and EMA 3.

Fishing year	MHR	Raw landing	Merged landing	EMA 7	MHR	Raw landing	Merged landing	EMA 1
				merged estimated catch				merged estimated catch
1990	1 492	1 536	1 255	1 469	2 158	2 158	2 153	2 110
1991	3 004	3 005	2 219	2 095	5 783	5 793	5 687	5 104
1992	3 607	3 607	3 296	2 954	10 926	11 216	11 198	10 485
1993	1 880	1 880	1 326	1 003	10 684	10 685	7 630	6 240
1994	1 402	1 402	1 229	1 010	4 178	4 178	4 067	4 441
1995	1 804	1 680	1 658	1 380	6 734	6 912	6 221	5 175
1996	1 218	1 480	1 022	653	4 170	4 183	3 470	3 295
1997	2 537	2 657	2 308	1 921	6 754	6 757	6 743	6 514
1998	2 310	2 425	2 305	2 090	4 595	4 595	4 575	4 619
1999	8 756	8 839	8 637	7 452	4 505	4 506	4 505	4 138
2000	3 169	3 171	3 168	2 922	3 602	3 602	3 601	3 197
2001	3 278	3 281	3 277	2 636	9 738	9 738	9 738	9 486
2002	5 101	5 098	5 087	4 338	6 368	6 689	6 664	6 298
2003	3 563	3 578	3 260	2 514	7 609	7 754	7 748	7 574
2004	2 701	2 747	2 565	2 330	6 523	6 572	6 564	6 173
2005	4 817	4 947	4 946	4 698	7 920	7 909	7 899	6 742
2006	3 784	3 888	3 662	3 367	6 713	6 590	6 586	5 711
2007	2 698	2 616	2 714	2 520	7 815	8 027	8 025	9 053
2008	2 929	2 972	2 787	2 528	5 926	6200	6154	5183
2009	3 503	3 578	3 221	2 941	3 147	3 364	3 310	2 895
2010	3 260	3 318	3 249	2 928	8 538	9 007	8 859	8 297

Fishing year	MHR	Raw landing	Merged landings	EMA 2	MHR	Raw landing	Merged landing	EMA 3
				merged estimated catch				merged estimated catch
1990	76	76	76	45	518	518	453	425
1991	94	94	93	96	478	479	428	478
1992	530	530	285	302	65	65	65	41
1993	309	309	260	211	133	133	102	91
1994	218	218	218	204	223	222	216	160
1995	94	94	94	94	154	154	137	122
1996	119	160	119	166	173	299	125	203
1997	78	79	75	51	340	500	334	243
1998	122	122	105	118	78	77	36	16
1999	186	186	172	34	62	62	28	21
2000	73	74	74	46	3	4	3	2
2001	113	113	113	63	6	4	4	2
2002	177	160	160	96	49	48	48	39
2003	115	115	115	81	88	88	88	83
2004	149	109	109	80	1	3	1	0
2005	8	9	9	3	1	0	1	0
2006	13	13	13	0	133	133	133	112
2007	133	133	133	7	42	42	19	15
2008	6	34	4	1	122	126	95	83
2009	2	2	2	3	88	98	97	84
2010	3	3	2	1	14	43	37	35

Table 4: Total number of trips, trips with zero estimated catch in number and proportion by fishing year for EMA 7, EMA 1, EMA 2, and EMA3.

Fishing year	EMA 7			EMA 1			EMA 2			EMA 3		
	Total	Zero	Proportion	Total	Zero	Proportion	Total	Zero	Proportion	Total	Zero	Proportion
1990	155	62	0.40	127	68	0.54	17	5	0.29	144	85	0.59
1991	185	89	0.48	346	170	0.49	38	9	0.24	96	54	0.56
1992	241	126	0.52	491	220	0.45	30	14	0.47	34	26	0.76
1993	408	134	0.33	553	203	0.37	33	12	0.36	83	48	0.58
1994	389	152	0.39	464	227	0.49	43	33	0.77	52	29	0.56
1995	330	132	0.40	443	218	0.49	45	25	0.56	48	28	0.58
1996	176	93	0.53	418	220	0.53	66	43	0.65	85	55	0.65
1997	162	83	0.51	520	278	0.53	66	52	0.79	43	25	0.58
1998	158	59	0.37	586	339	0.58	33	24	0.73	28	7	0.25
1999	220	115	0.52	301	205	0.68	61	39	0.64	19	8	0.42
2000	197	129	0.65	335	223	0.67	32	23	0.72	28	21	0.75
2001	186	123	0.66	342	158	0.46	56	40	0.71	33	24	0.73
2002	169	112	0.66	390	238	0.61	52	38	0.73	29	24	0.83
2003	200	121	0.61	398	199	0.50	67	48	0.72	47	26	0.55
2004	134	88	0.66	327	157	0.48	54	40	0.74	10	8	0.80
2005	157	94	0.60	306	152	0.50	47	37	0.79	12	8	0.67
2006	124	74	0.60	361	198	0.55	42	38	0.90	67	43	0.64
2007	145	73	0.50	352	166	0.47	48	33	0.69	64	29	0.45
2008	177	96	0.54	287	140	0.49	75	42	0.56	66	22	0.33
2009	201	100	0.50	274	128	0.47	108	59	0.55	49	21	0.43
2010	198	97	0.49	371	163	0.44	99	56	0.57	46	27	0.59

Table 5: summary of CPUE datasets, for all vessels and for core vessels (CPUE is catch per tow).

Year	All vessels					Core vessels				
	Total tows	Proportion zeros	Catch (t)	Non-zero tows	CPUE	Total tows	Proportion zeros	Catch (t)	Non-zero tows	CPUE
1990	108	0.37	51	68	0.75	108	0.37	51	68	0.75
1991	333	0.36	460	212	2.17	224	0.28	256	161	1.59
1992	1 045	0.51	2 397	509	4.71	403	0.55	416	180	2.31
1993	445	0.67	436	147	2.97	269	0.68	238	87	2.74
1994	717	0.71	496	210	2.36	558	0.72	408	159	2.57
1995	1 379	0.64	1 009	496	2.03	978	0.61	768	380	2.02
1996	376	0.67	265	125	2.12	310	0.64	228	112	2.04
1997	927	0.61	1 702	366	4.65	567	0.57	1 202	242	4.97
1998	985	0.54	1 753	452	3.88	678	0.5	1 652	338	4.89
1999	1 039	0.4	3 787	620	6.11	848	0.41	2 969	499	5.95
2000	933	0.44	2 456	520	4.72	908	0.44	2 437	509	4.79
2001	1 459	0.64	2 427	520	4.67	1 448	0.64	2 427	517	4.69
2002	2 009	0.66	3 978	682	5.83	1 921	0.65	3 977	678	5.87
2003	2 516	0.81	1 869	475	3.93	2 482	0.81	1 868	469	3.98
2004	2 224	0.67	2 068	729	2.84	2 224	0.67	2 068	729	2.84
2005	2 446	0.59	3 282	1 007	3.26	2 438	0.59	3 282	1 006	3.26
2006	2 177	0.76	2 416	527	4.58	2 177	0.76	2 416	527	4.58
2007	2 415	0.65	1 855	835	2.22	2 305	0.66	1 720	787	2.18
2008	2 338	0.66	1 948	799	2.44	2 336	0.66	1 948	798	2.44
2009	1 884	0.69	2 049	576	3.56	1 873	0.69	2 049	576	3.56
2010	2 277	0.69	2 010	698	2.88	2 230	0.69	2 005	684	2.93

Table 6: Standardised CPUE indices for the early series from 1989–90 to 1997–98 (see Table B2 from Fu & Taylor 2011) and for the late series from 1996–97 to 2009–10. Only the late series were updated in this report.

Fishing year	Indices	c.v.	Indices	c.v.
1990	0.67	0.20		
1991	0.87	0.10		
1992	1.24	0.11		
1993	1.01	0.13		
1994	0.99	0.09		
1995	1.05	0.07		
1996	0.87	0.11		
1997	1.34	0.08	3.19	0.09
1998	1.13	0.08	2.09	0.07
1999			2.78	0.05
2000			1.91	0.05
2001			1.32	0.04
2002			1.28	0.04
2003			0.82	0.05
2004			0.52	0.04
2005			0.55	0.04
2006			0.66	0.04
2007			0.48	0.04
2008			0.54	0.04
2009			0.66	0.04
2010			0.61	0.04

Table 7: Number of landings, and fish measured for length for blue mackerel collected from market sampling program in EMA 7, EMA 1, and EMA 2 since 1996–97 fishing year.

EMA 7				
Fishing year	Landings	Males	Females	Total
2004	3	30	26	56
2005	2	200	224	424
2006	2	313	281	594
EMA 1				
Fishing year	Landings	Males	Females	Total
1997	1	1 260	852	2 112
1998	9	18 663	19 543	38 206
2002	7	15 113	14 761	29 874
2003	44	80 182	79 638	159 821
2004	27	20 677	21 008	41 685
2005	33	21 981	28 263	50 244
2006	34	15 251	16 927	32 178
2007	33	27 723	29 560	60 828
2008	1	0	0	956
EMA 2				
Fishing year	Landings	Males	Females	Total
2007	1	756	736	1 492

Table 8: Number of trips, tows, and fish measured for length for blue mackerel collected from observer sampling program in EMA 7 and EMA 3 since 1986–87 fishing year.

EMA 7					
Fishing year	Trips	Tows	Males	Females	Total
1987	2	2	16	17	34
1989	1	3	63	79	197
1994	1	1	10	14	24
1995	1	5	33	102	135
1997	1	1	20	21	41
1998	2	7	218	209	427
2000	1	1	56	41	97
2002	4	27	197	181	378
2003	4	57	268	289	557
2004	3	38	938	1 060	1 998
2005	6	34	448	439	3 288
2006	7	69	1 637	1 590	3 462
2007	14	138	2 691	2 367	5 071
2008	15	162	3 092	3 869	6 971
2009	12	136	3 738	4 015	7 757
2010	9	124	3 340	3 673	7 034
2011	6	65	2 425	2 832	5 279
EMA 3					
Fishing year	Trips	Tows	Males	Females	Total
1993	1	2	100	84	184
2001	1	1	2	0	2
2002	1	8	40	51	91
2003	1	1	2	3	5
2006	1	1	7	13	20
2007	2	5	52	29	81
2008	2	4	36	21	57
2010	2	4	36	44	80

Table 9: Number of blue mackerel gonad stages collected by the Observer Programme in EMA 7.

Fishing year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Female													
1995			64	38									102
1998				80	20					46			146
2000										41			41
2002	78									41	10	52	181
2003	195	7					19				10	58	289
2004	12		796	13							118	121	1 060
2005		358	43				1			44			446
2006		118	779						101	599	22		1 619
2007	348	26	455	372			9		276	566	251	73	2 376
2008	424	217	2 058	28					373	434	311	27	3 872
2009	712	375	1 495	295					940	88	110		4 015
2010	1 674												1 674
Male													
2006		37	564						153	0	0		754
2007	80	26	476	224			0		264	629	80	163	1 942
2008	525	120	1 146	0					400	404	205	14	2 814
2009	816	82	1 295	231					1 081	0	0		3 505
2010	1 927												

Table 10: Sources of fish length data and key information of blue mackerel collected from research trawl surveys in EMA 7, EMA 1, EMA 2, and EMA 7 since 1981–82.

EMA 7

Fishing year	Trip code	Vessel	Min length (cm)	Max length (cm)	No of fish measured	Female	Male
1981–82	kah8205	Kaharoa	16	30	6	0	0
1982–83	jco8306	James Cook	46	51	5	3	2
	kah8216	Kaharoa	17	18	2	0	0
1983–84	jco8415	James Cook	47	51	6	0	6
1984–85	jco8420	James Cook	53	53	1	1	0
1986–87	kah8612	Kaharoa	15	27	68	0	0
1987–88	kah8715	Kaharoa	20	20	2	0	0
1989–90	cor9001	Cordella	15	53	313	100	189
1991–92	kah9111	Kaharoa	48	51	2	0	0
	kah9204	Kaharoa	46	49	2	1	0
1994–95	kah9410	Kaharoa	13	22	73	0	13
	kah9504	Kaharoa	46	51	12	3	8
	kah9507	Kaharoa	18	18	1	0	0
1995–96	kah9608	Kaharoa	10	21	325	0	0
1996–97	kah9615	Kaharoa	12	26	39	0	0
	kah9701	Kaharoa	47	50	5	3	2
1999–00	kah0004	Kaharoa	48	50	5	2	3
	kah9915	Kaharoa	15	48	183	3	2
2002–03	kah0304	Kaharoa	47	49	3	0	1
2004–05	kah0503	Kaharoa	49	49	3	0	2
2006–07	kah0704	Kaharoa	49	49	1	0	1
2010–11	kah1104	Kaharoa	15	22	8	0	0

EMA 1

1981–82	kah8203	Kaharoa	9	43	55	0	0
1982–83	kah8303	Kaharoa	8	15	233	0	0
1983–84	kah8413	Kaharoa	13	22	22	0	0
1984–85	kah8421	Kaharoa	23	23	1	0	0
1984–85	kah8506	Kaharoa	11	43	101	0	0
1985–86	kah8517	Kaharoa	19	46	15	0	0
1985–86	kah8609	Kaharoa	8	23	384	0	0
1986–87	kah8613	Kaharoa	16	24	28	0	0
1986–87	kah8711	Kaharoa	7	26	74	0	0
1987–88	kah8716	Kaharoa	15	42	109	0	0
1988–89	kah8810	Kaharoa	17	47	50	0	0
1989–90	kah8917	Kaharoa	17	28	99	0	0
1989–90	kah9004	Kaharoa	15	15	1	0	0
1990–91	kah9016	Kaharoa	17	35	27	0	0
1991–92	kah9202	Kaharoa	6	11	73	0	0
1992–93	kah9212	Kaharoa	14	35	95	0	1
1992–93	kah9302	Kaharoa	9	75	153	0	2
1993–94	kah9311	Kaharoa	12	36	568	0	1
1994–95	kah9411	Kaharoa	19	44	25	0	0
1995–96	kah9601	Kaharoa	9	10	2	0	0
1997–98	kah9720	Kaharoa	14	28	97	0	0
1998–99	kah9902	Kaharoa	11	42	17	0	0

2000–01	kah0012	Kaharoa	10	30	75	0	0
2008–09	kah0907	Kaharoa	16	27	46	4	5

EMA 2

1981–82	kah8211	Kaharoa	51	53	2	0	0
1982–83	kah8313	Kaharoa	51	51	1	0	0
1984–85	jco8420	James Cook	53	53	1	1	0
1993–94	kah9402	Kaharoa	5	47	131	0	2
1994–95	kah9502	Kaharoa	32	53	2	1	0
1995–96	kah9602	Kaharoa	10	47	11	0	0
2000–01	tan0111	Tangaroa	52	53	2	0	0
2001–02	kah0209	Kaharoa	49	49	1	0	0
2004–05	kah0506	Kaharoa	54	54	1	0	0
2005–06	kah0611	Kaharoa	45	53	2	1	1

EMA 3

1990–91	kah9105	Kaharoa	51	51	2	2	0
1991–92	kah9205	Kaharoa	52	56	3	1	2
1991–92	tan9106	Tangaroa	43	43	1	0	1
1992–93	kah9306	Kaharoa	51	53	4	2	2
1992–93	tan9301	Tangaroa	46	46	1	0	1
1993–94	kah9406	Kaharoa	51	51	1	1	0
1993–94	tan9401	Tangaroa	41	41	1	1	0
1993–94	tan9402	Tangaroa	44	44	1	1	0
1994–95	tan9502	Tangaroa	45	45	1	0	0
1995–96	kah9606	Kaharoa	49	52	2	1	1
1995–96	tan9601	Tangaroa	48	48	1	0	1
1996–97	tan9701	Tangaroa	48	48	1	0	1
1997–98	tan9801	Tangaroa	47	48	2	1	1
2001–02	tan0201	Tangaroa	49	49	1	1	0
2002–03	tan0301	Tangaroa	39	50	12	4	8
2004–05	tan0501	Tangaroa	42	48	5	5	0
2005–06	tan0601	Tangaroa	35	37	3	1	2
2006–07	kah0705	Kaharoa	53	53	1	1	0
2007–08	kah0806	Kaharoa	53	53	1	0	1
2007–08	tan0801	Tangaroa	40	51	3	2	1
2008–09	kah0905	Kaharoa	52	52	1	1	0
2009–10	tan1001	Tangaroa	43	47	11	4	7

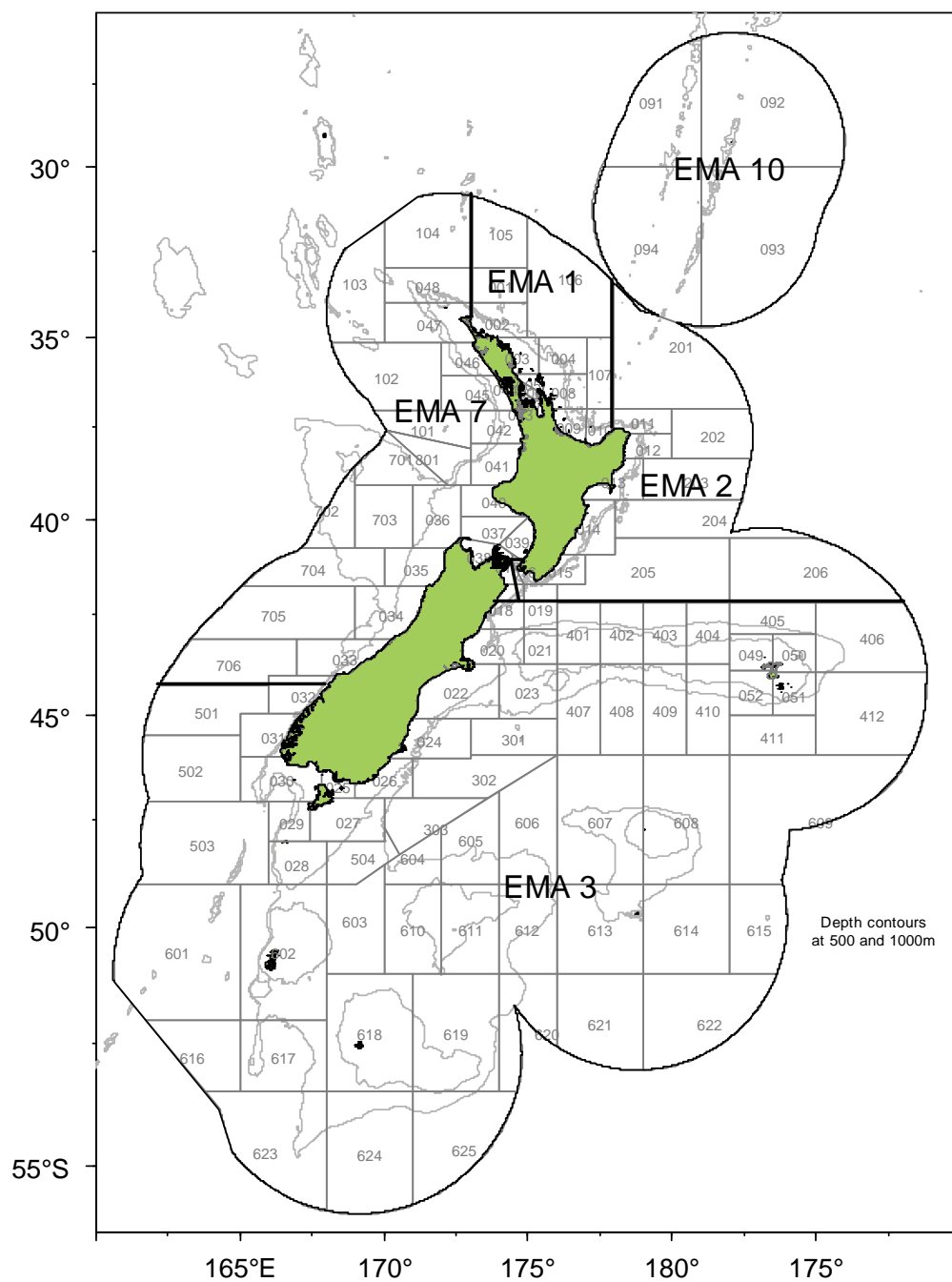


Figure 1: Map showing the administrative fishstock boundaries for EMA 1, EMA 2, EMA 3, EMA 7 and EMA 10, including statistical areas, and the 500 m and 1000 m depth contours.

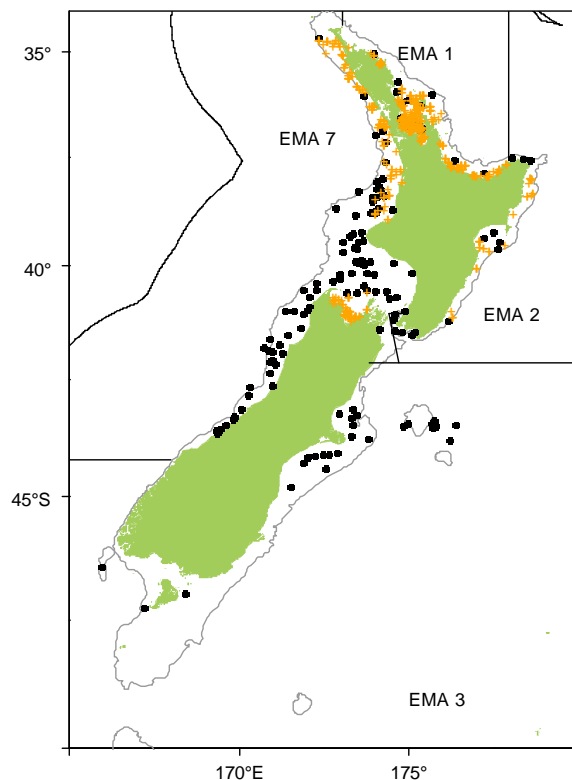


Figure 2: Distribution of blue mackerel from all research fishing in the *trawl* database to 2010. Black circles represent fish greater than equal 30 cm in length; Orange crosses represent fish less than 30 cm in length.

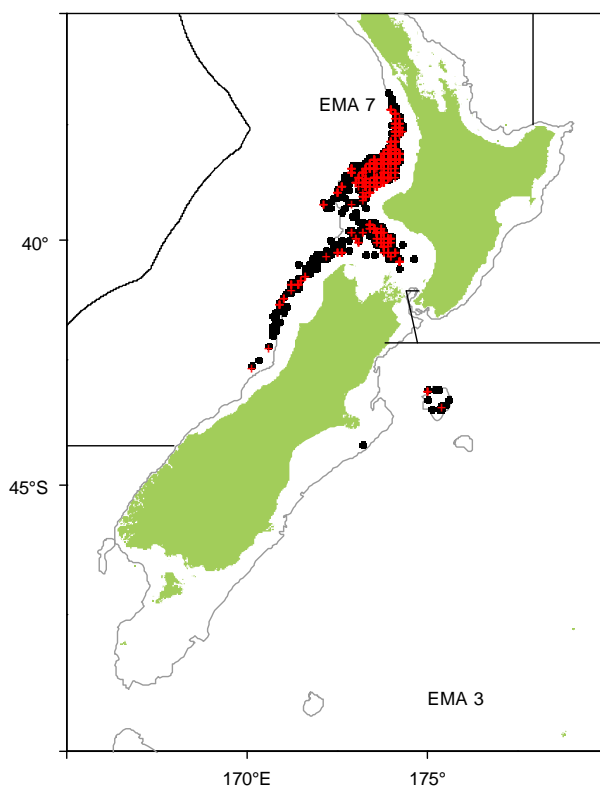


Figure 3: Distribution of blue mackerel from observer database to 2010 (Black circles); Red crosses represent locations where gonad stages of 'ripe', 'running ripe', or 'spent' were recorded.

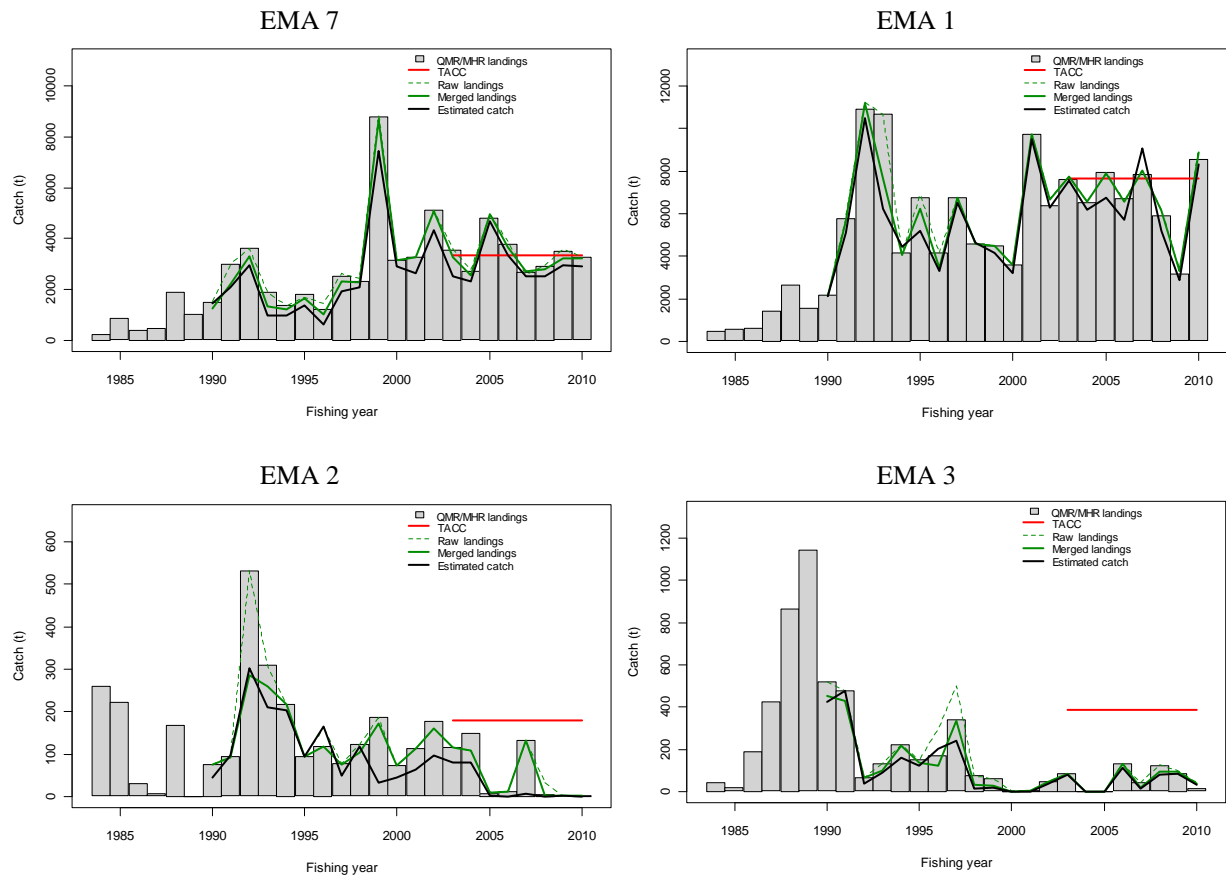


Figure 4: QMR/MHR landings, raw landings, groomed and merged landings, groomed and merged estimated catch, and TACC by fishing year for EMA 7, EMA 1, EMA 2, and EMA 3.

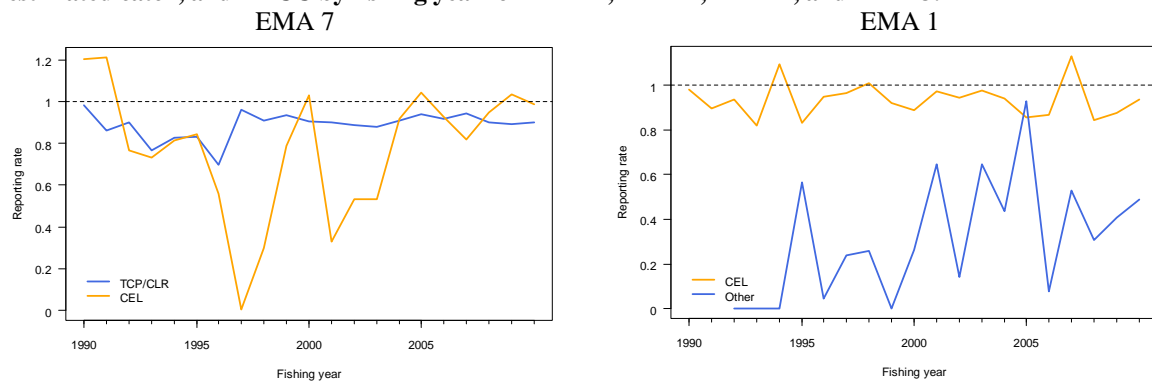


Figure 5: The ratio of estimated catch to retained landings in the groomed and merged dataset by fishing year, for EMA 7 and EMA 1. The ratio was calculated for subsets of form types separately.

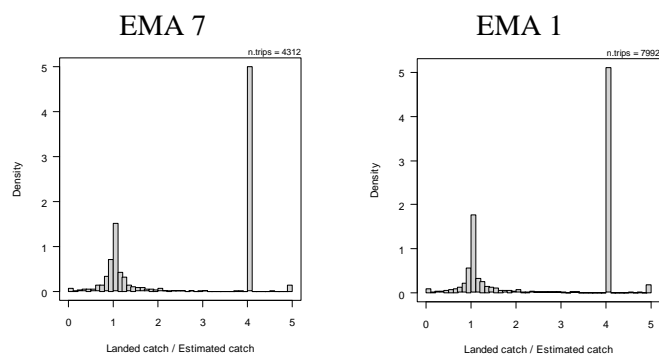


Figure 6: Distribution of the ratio of the landed catch to estimated catch for the groomed and merged data for EMA 7 and EMA 1. Where estimated catch is zero, the ratio is arbitrarily placed at 4 on the x axis.

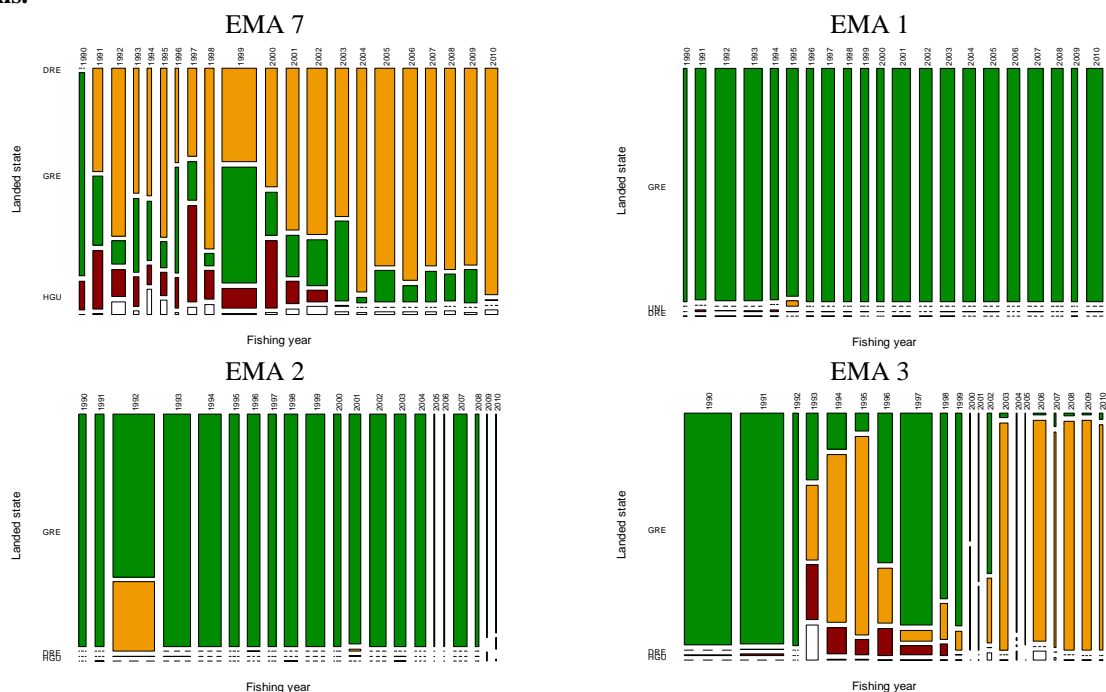


Figure 7: The proportion of landings by processed state and fishing year for EMA 7, EMA 1, EMA 2, and EMA 3. “DRE”, “dressed”; “GRE”, “Whole or Green”; “HGU”, “Headed and Gutted”.

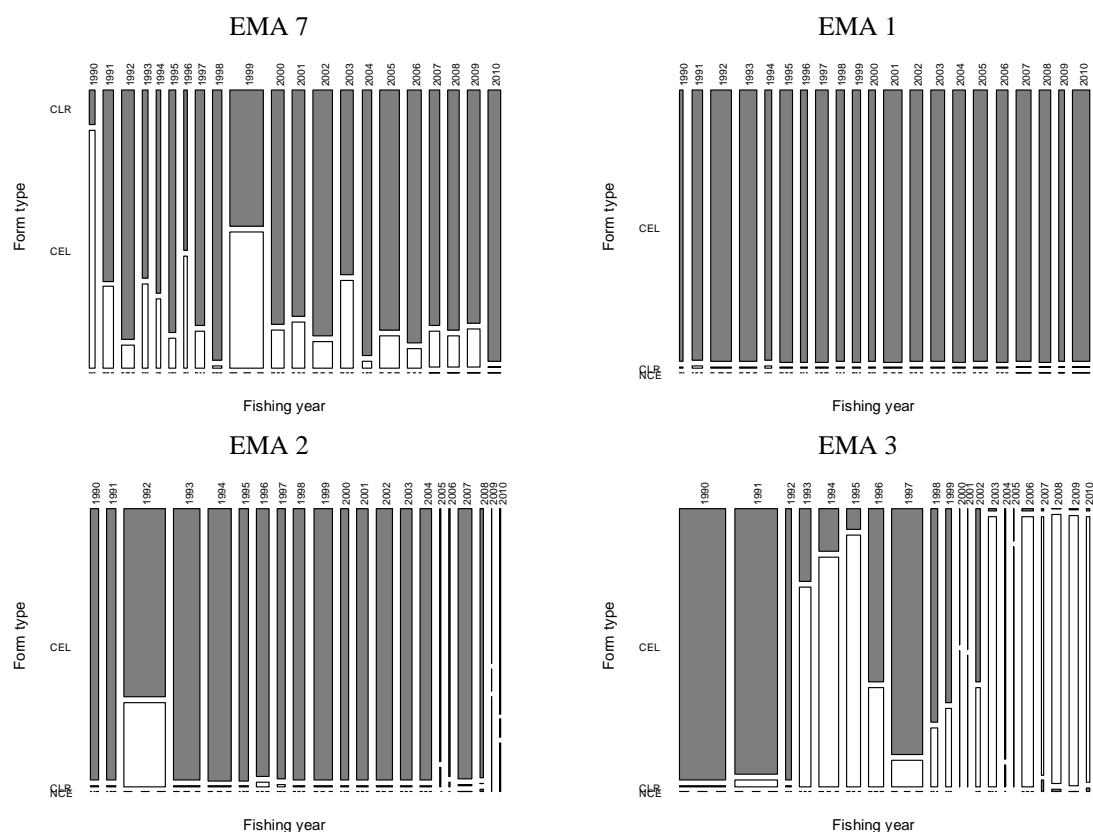


Figure 8: Proportion of landings by form type and fishing year in the groomed and merged dataset, for EMA 7, EMA 1, EMA 2, and EMA 3. The width of the bar is proportional to the annual catch.

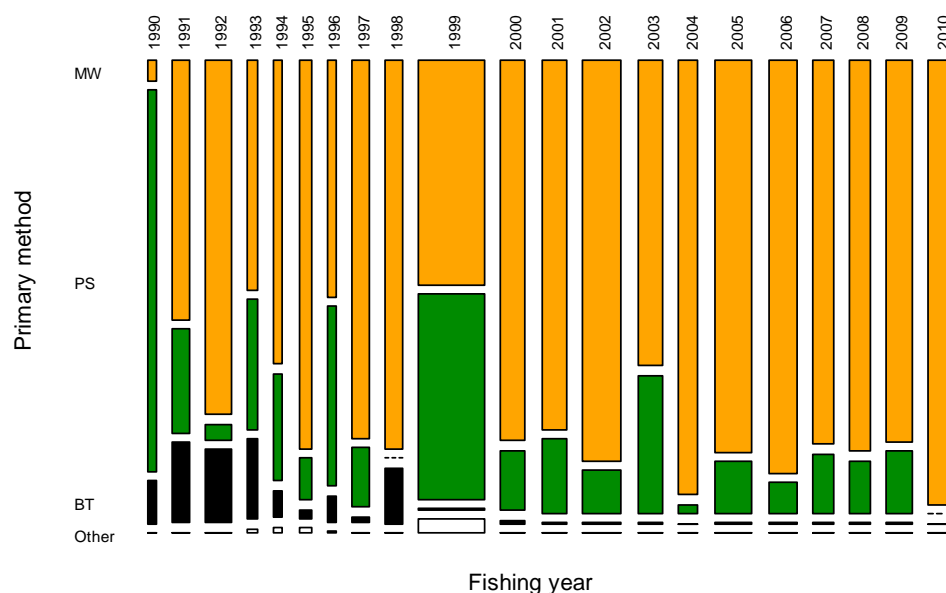


Figure 9: Distribution of blue mackerel catch in EMA 7 by major fishing methods, 1989–90 to 2009–10 fishing year. MW is midwater trawl; PS is purse-seine; BT is bottom trawl. The width of the bar is proportional to the annual catches.

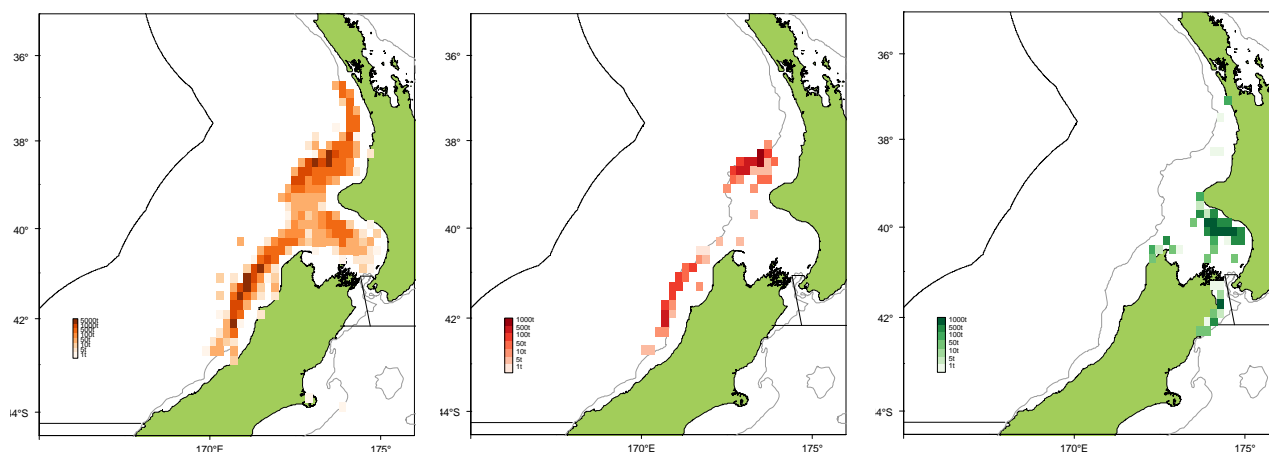


Figure 10: Distribution of blue mackerel catch by 0.2 degree grid for midwater trawl JMA target tows (left), midwater trawl EMA target tows (middle), and purse seine fishery in EMA 7, 1989–90 to 2009–10.

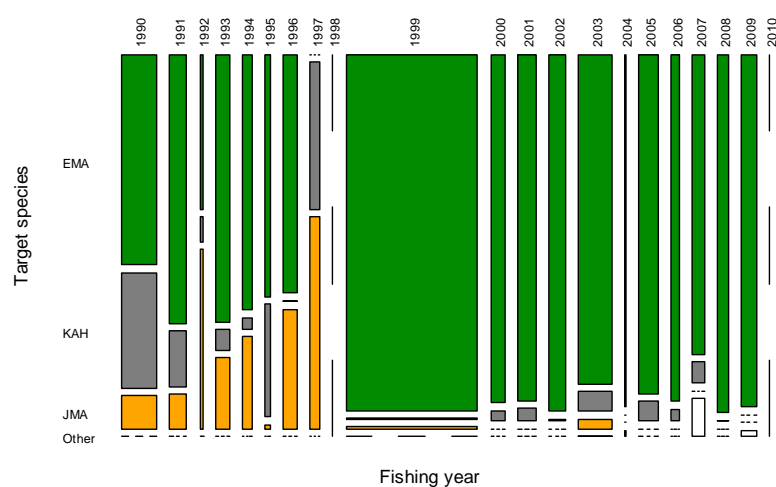


Figure 11: Distribution of blue mackerel catch by target species for the purse-seine fishery in EMA 7, 1989–90 to 2009–10 fishing year. EMA is blue mackerel; KAH is kahawai; JMA is jack mackerel.

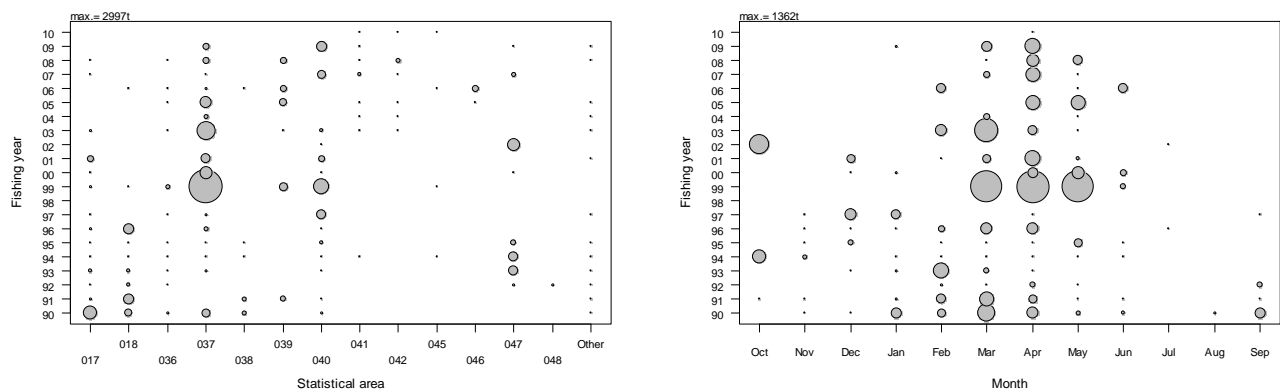


Figure 12: Distribution of blue mackerel catch by statistical area (left) and by month (right) for the purse-seine fishery in EMA 7, 1989–90 to 2009–10 fishing year.

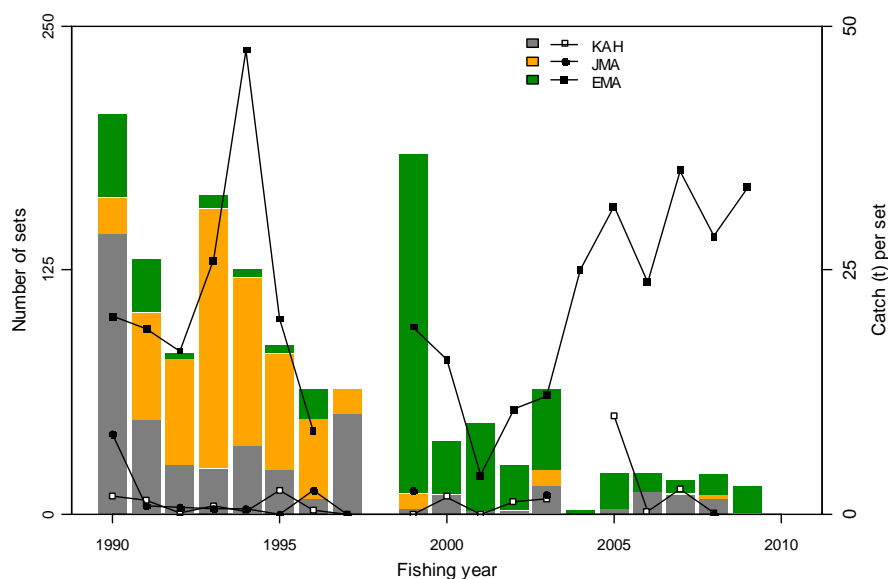


Figure 13: Number of sets (bars) and catch per set (lines) by target species for the purse-seine fishery in EMA 7 1989–90 to 2009–10. KAH is kahawai; JMA is jack mackerel; EMA is blue mackerel.

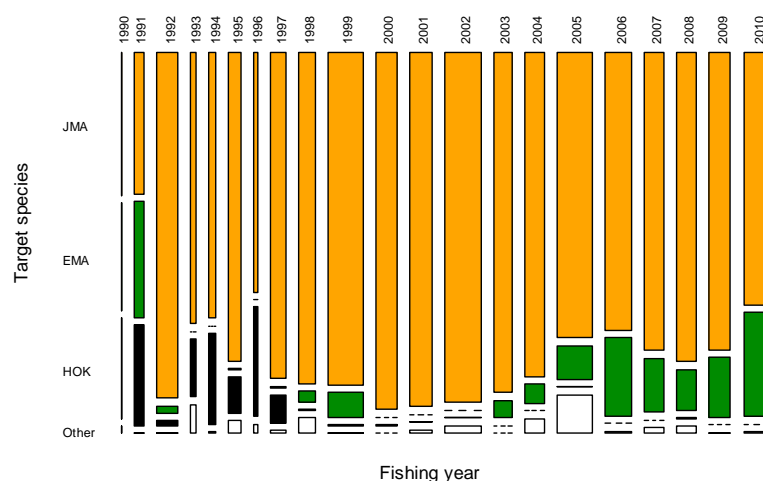


Figure 14: Distribution of blue mackerel catch by target species for the midwater fishery in EMA 7, 1989–90 to 2009–10 fishing year. JMA is jack mackerel; EMA is blue mackerel; HOK is hoki.

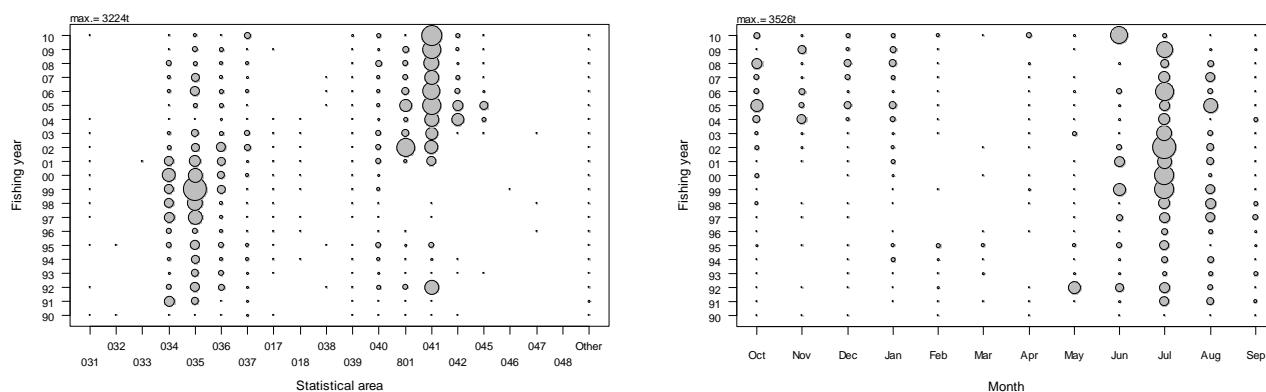


Figure 15: Distribution of blue mackerel catch by statistical area (left) and by month (right) for the midwater trawl fishery in EMA 7, 1989–90 to 2009–10 fishing year.

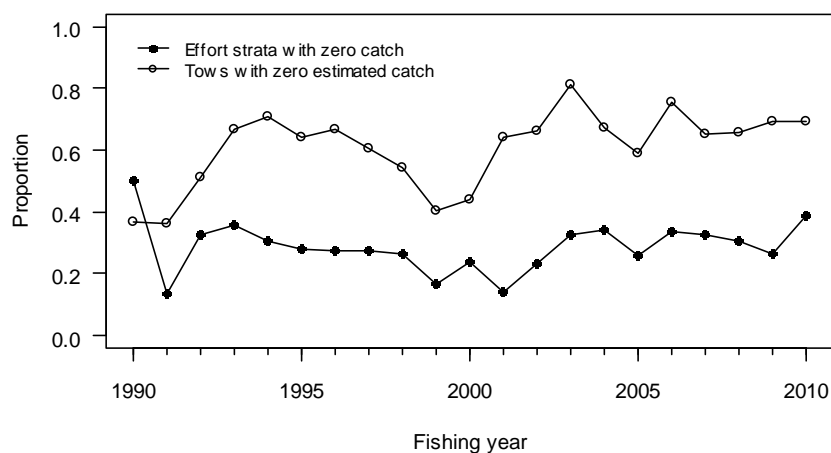


Figure 16: Proportion of zero catches of blue mackerel for the midwater trawl jack mackerel target fishery in EMA 7, 1989–90 to 2009–10 fishing year. The proportion was calculated with respect to the effort strata using the merged data, and with respect to the tows using the tow-level unmerged data.

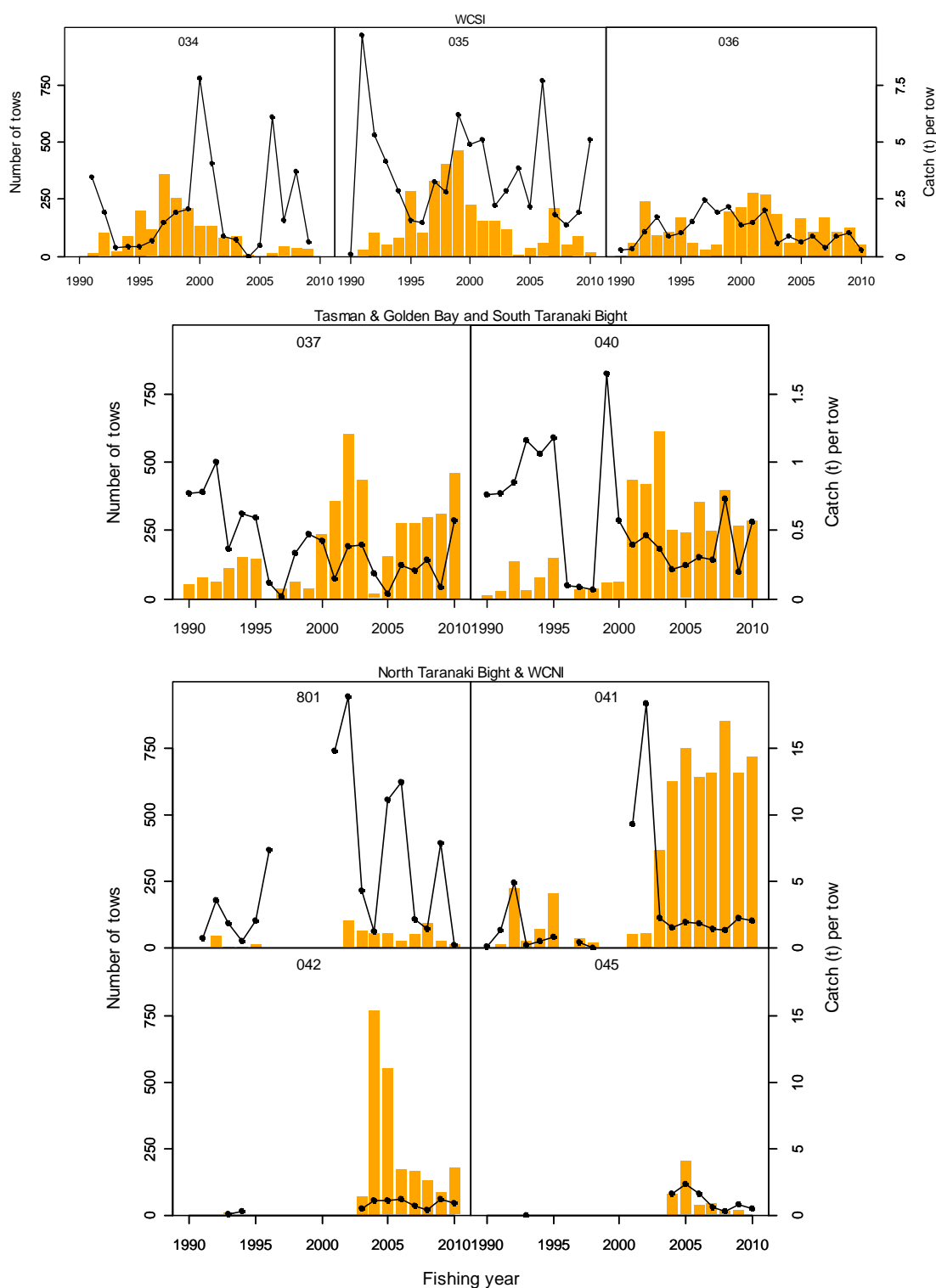


Figure 17: Number of tows (bars) and catch (t) per tow (lines) of blue mackerel by statistical area and region, for midwater trawl JMA targeted tows in EMA 7, 1989–90 to 2009–10 fishing years, based on the non-zero effort strata of the merged datasets.

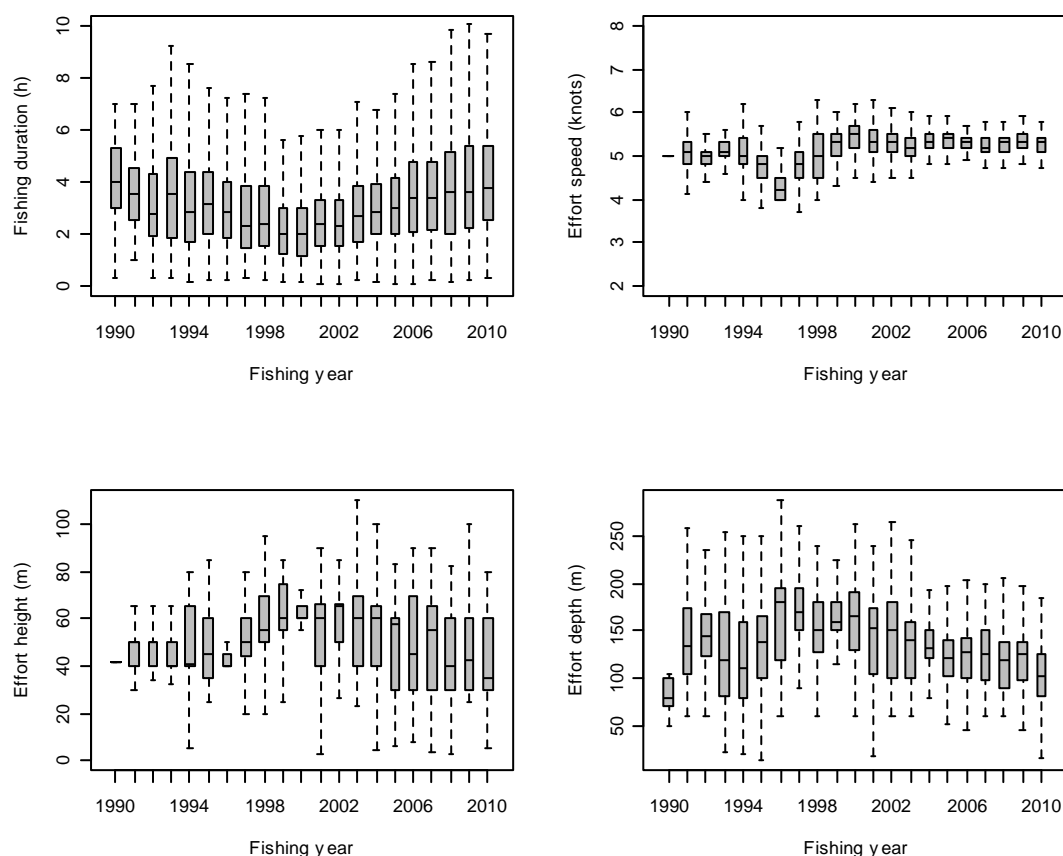


Figure 18: Distribution of selected tow variables including fishing duration (hours), effort speed (knots), effort height (m), and effort depth (m) for midwater trawl JMA target tows which caught blue mackerel in EMA 7, 1989–90 to 2009–10 fishing years.

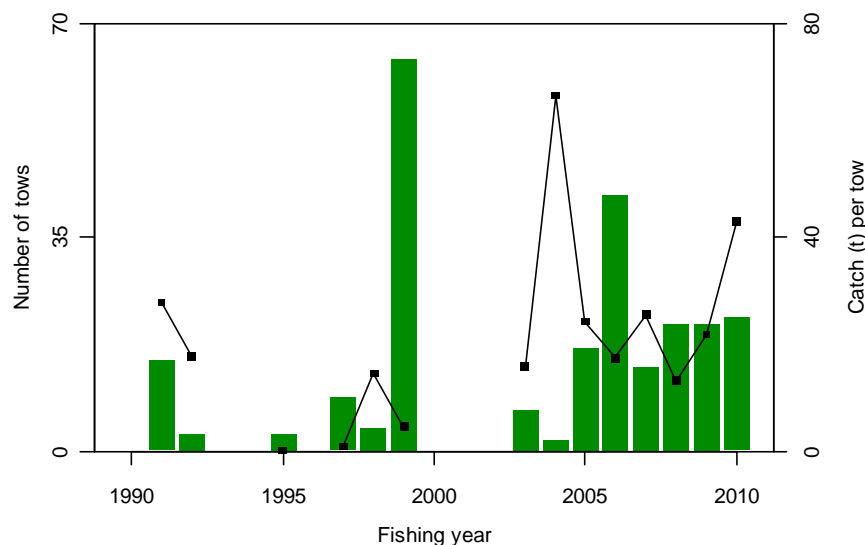


Figure 19: Number of tows (bars) and catch per tow (lines) of blue mackerel for midwater trawl blue mackerel targeted tows in EMA 7, 1989–90 to 2009–10 fishing years, based on the non-zero effort strata of the merged datasets.

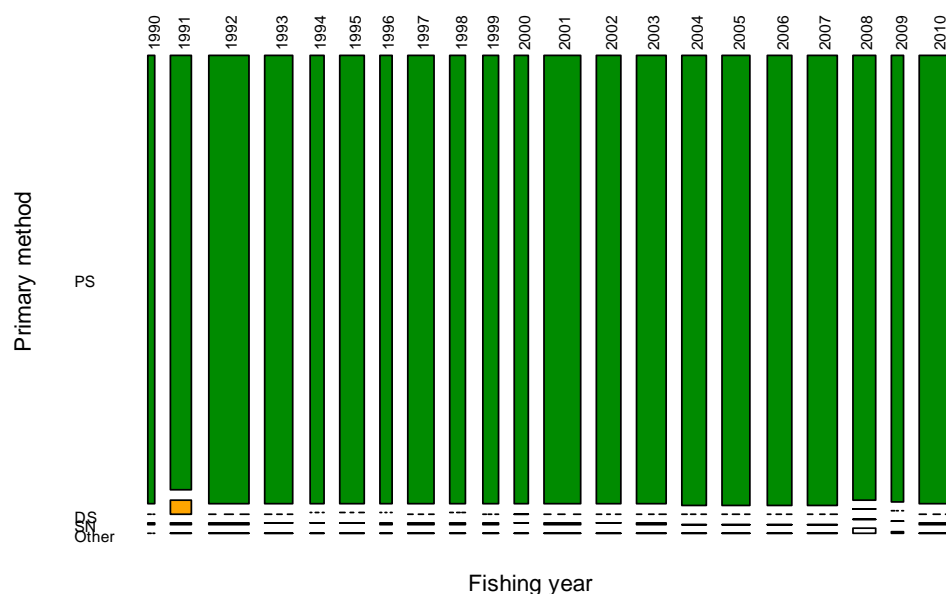


Figure 20: Distribution of blue mackerel catch in EMA 1 by major fishing methods, 1989–90 to 2009–10 fishing year. PS is purse-seine; DS is Danish seine; SN is set net. The width of the bar is proportional to the annual catches.

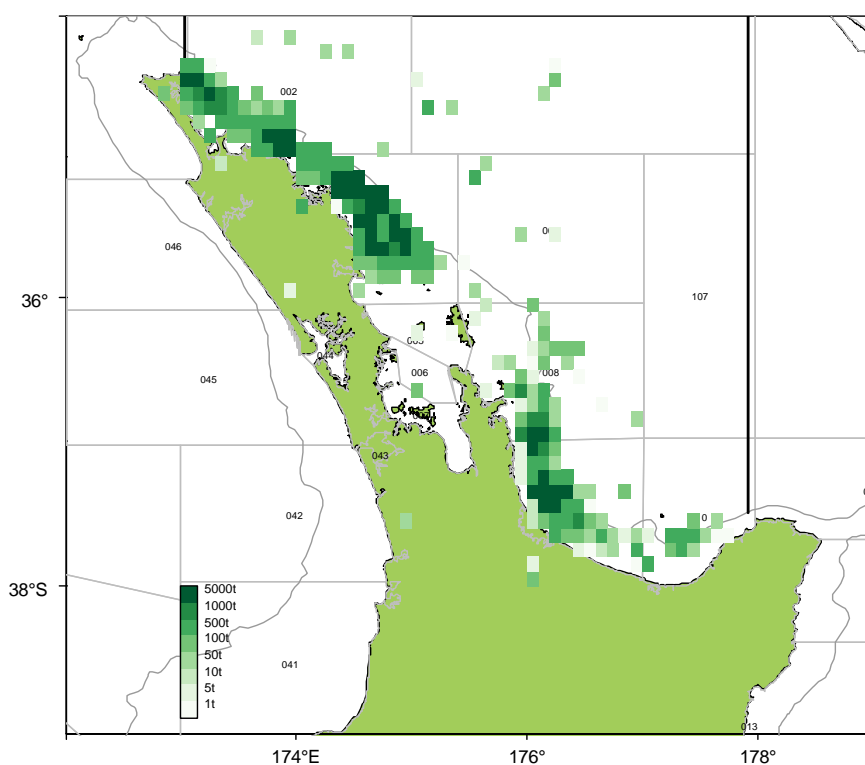


Figure 21: Distribution of blue mackerel catch by 0.2 degree grid for the purse seine fishery in EMA 1, 1989–90 to 2009–10.

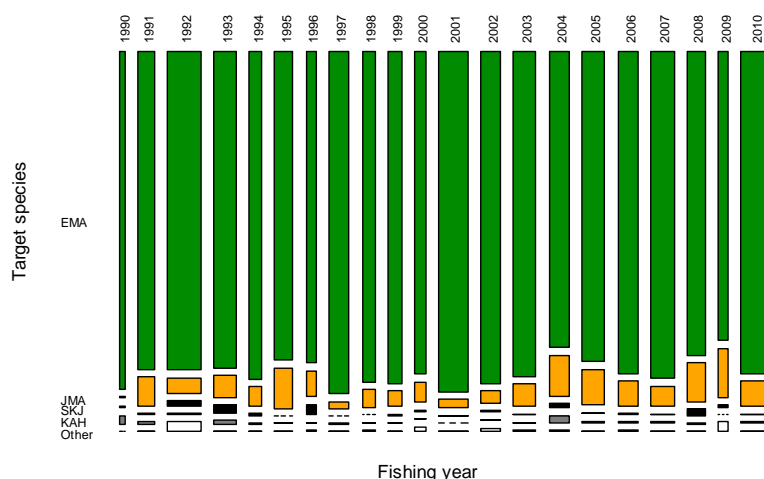


Figure 22: Distribution of blue mackerel catch by target species for the purse-seine fishery in EMA 7, 1989–90 to 2009–10 fishing year. EMA is blue mackerel; JMA is jack mackerel; SKJ is skip jack; KAH is kahawai.

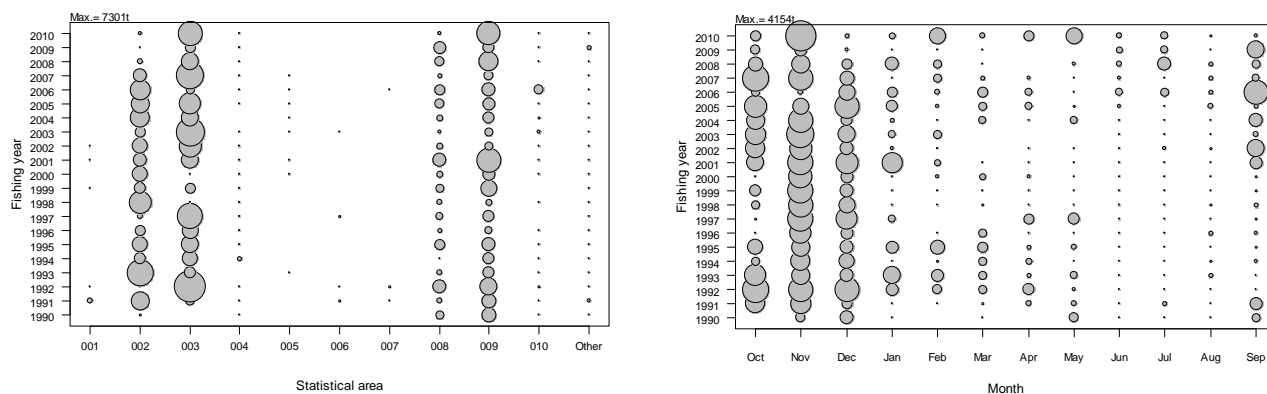


Figure 23: Distribution of blue mackerel catch by statistical area (left) and by month (right) for the purse-seine fishery in EMA 1, 1989–90 to 2009–10 fishing year.

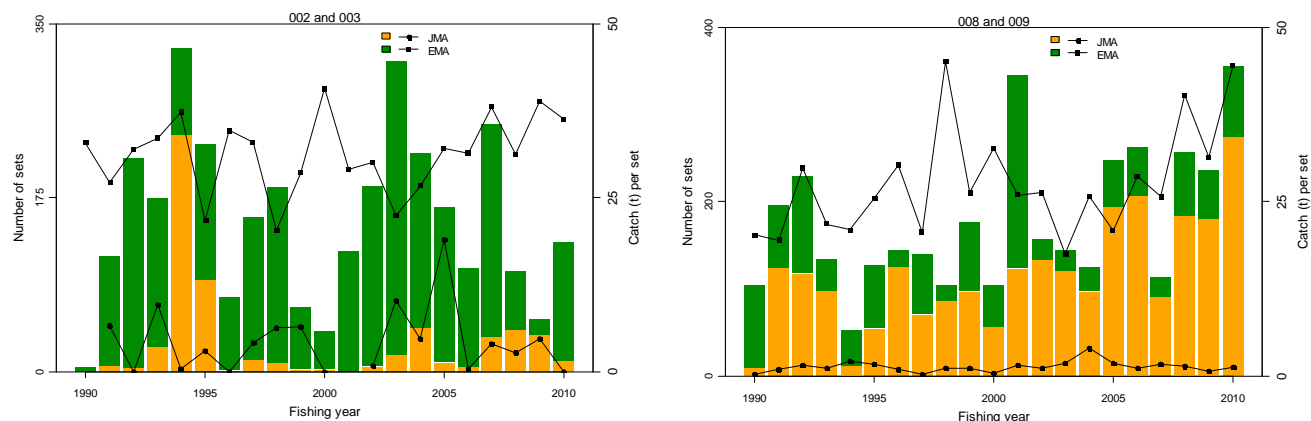


Figure 24: Number of sets (bars) and catch per set (lines) by target species for the purse-seine fishery in EMA 1 1989–90 to 2009–10. Left panel is for catch and effort from Statistical Areas 002 and 003; right panel is for Statistical Areas 008 and 009.

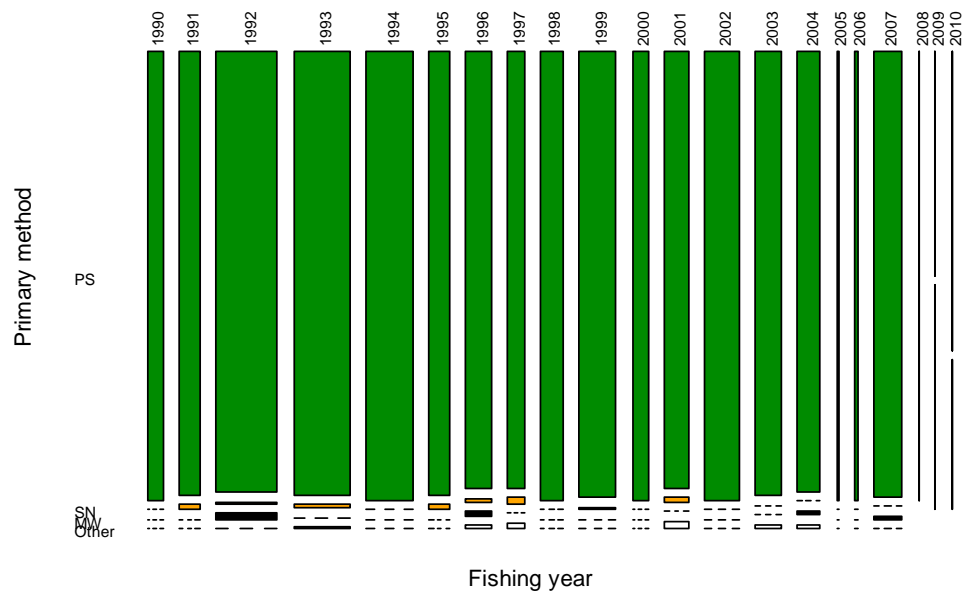


Figure 25: Distribution of blue mackerel catch in EMA 2 by major fishing methods, 1989–90 to 2009–10 fishing year. PS is purse-seine; DS is Danish seine; SN is set net; MW, midwater trawl. The width of the bar is proportional to the annual catches.

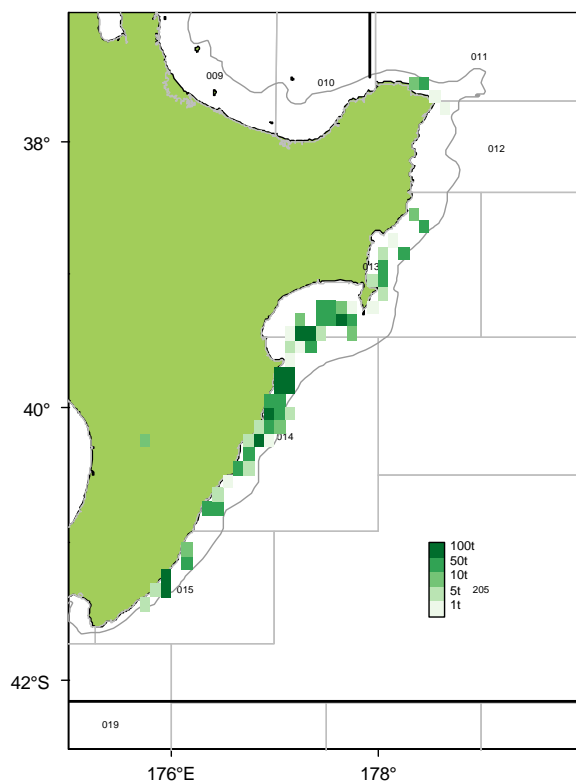


Figure 26: Distribution of blue mackerel catch by 0.2 degree grid for the purse seine fishery in EMA 2, 1989–90 to 2009–10.

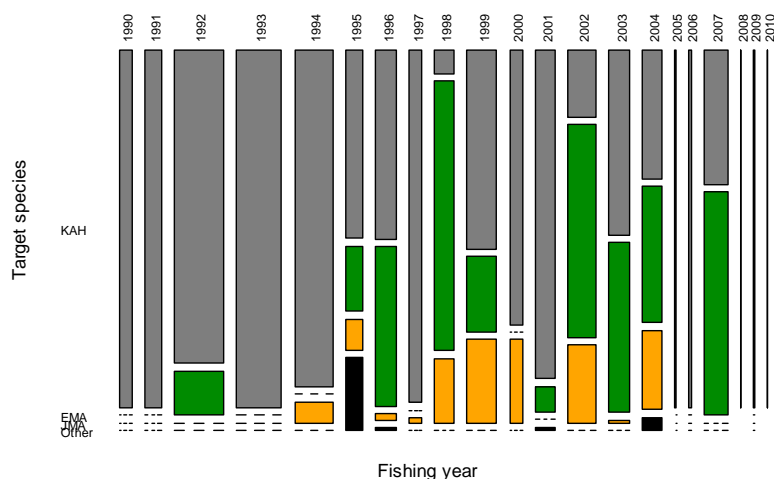


Figure 27: Distribution of blue mackerel catch by target species for the purse-seine fishery in EMA 2, 1989–90 to 2009–10 fishing year. EMA is blue mackerel; JMA is jack mackerel; KAH is kahawai.

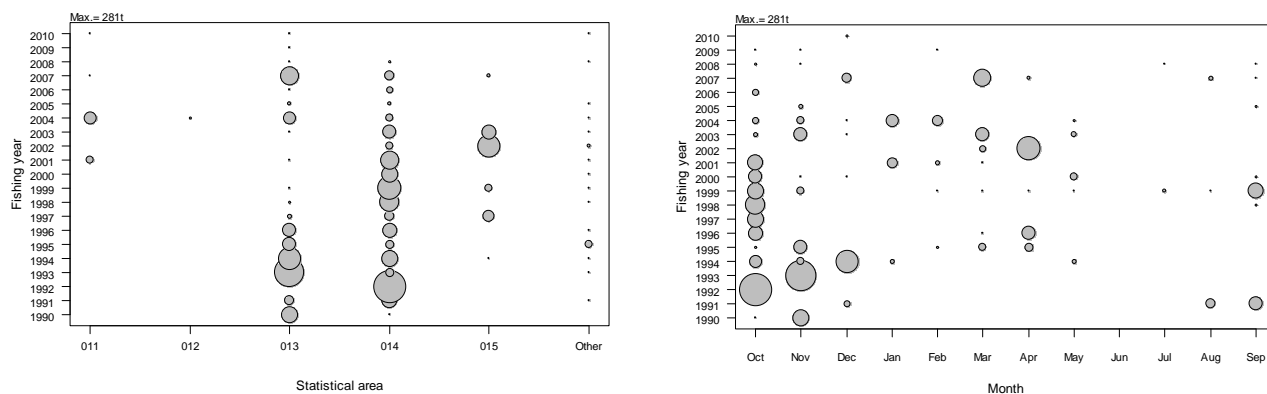


Figure 28: Distribution of blue mackerel catch by statistical area (left) and by month (right) for the purse-seine fishery in EMA 1, 1989–90 to 2009–10 fishing year.

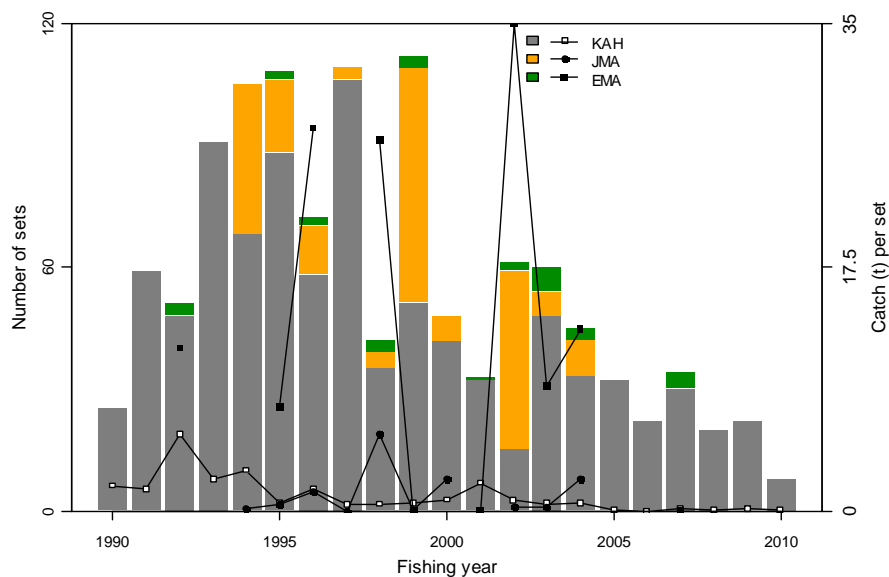


Figure 29: Number of sets (bars) and catch per set (lines) by target species for the purse-seine fishery in EMA 2 1989–90 to 2009–10.

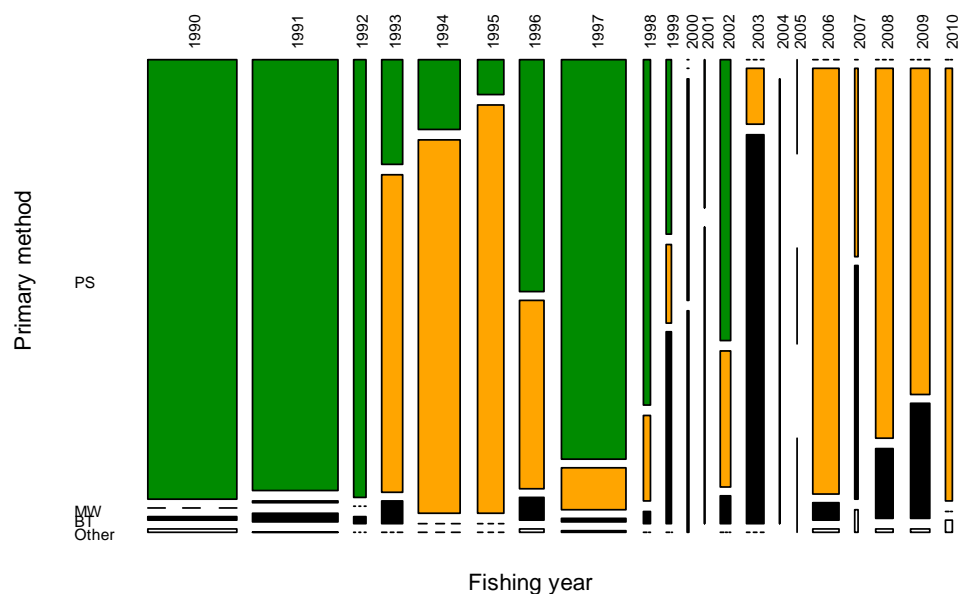


Figure 30: Distribution of blue mackerel catch in EMA 3 by major fishing methods, 1989–90 to 2009–10 fishing year. PS is purse-seine; MW is midwater trawl; BT is bottom trawl. The width of the bar is proportional to the annual catches.

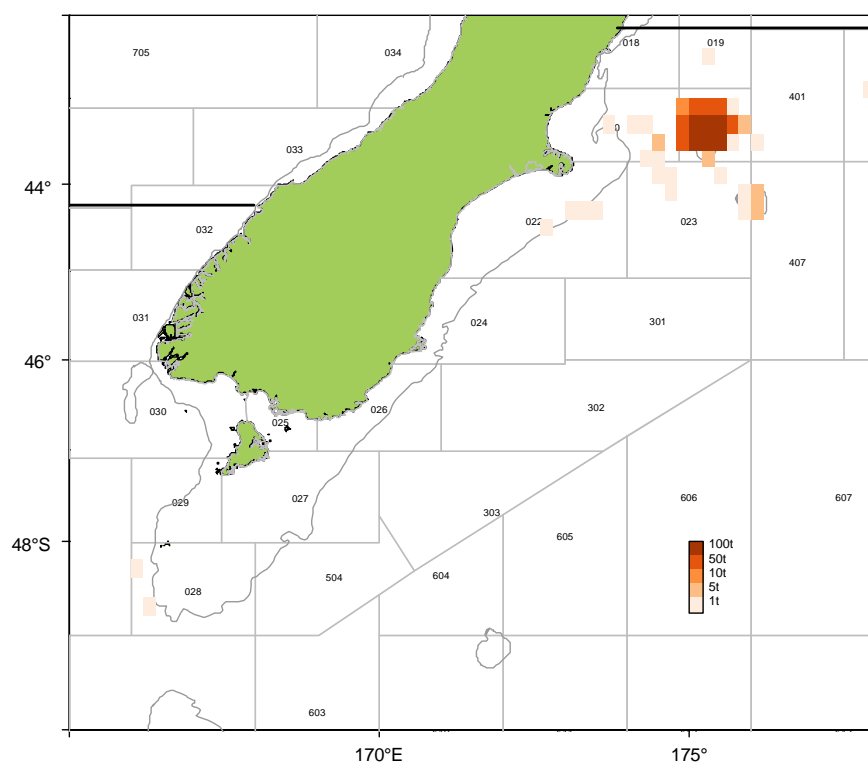


Figure 31: Distribution of blue mackerel catch by 0.2 degree grid for midwater trawl jack mackerel targeted tows EMA 3, 1989–90 to 2009–10.

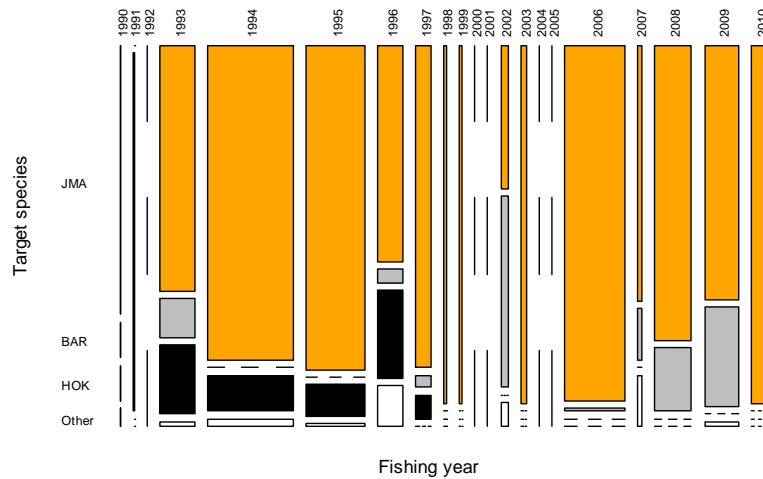


Figure 32: Distribution of blue mackerel catch by target species for the midwater trawl fishery in EMA 3, 1989–90 to 2009–10 fishing year. JMA is jack mackerel; BAR is barracouta.

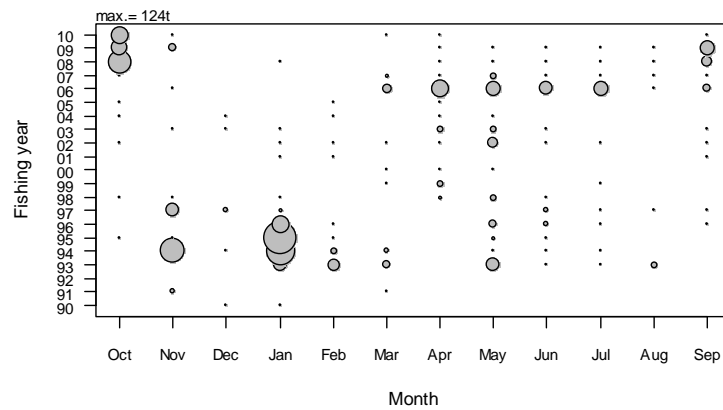


Figure 33: Distribution of blue mackerel catch by month for the midwater trawl fishery in EMA 3, 1989–90 to 2009–10 fishing year.

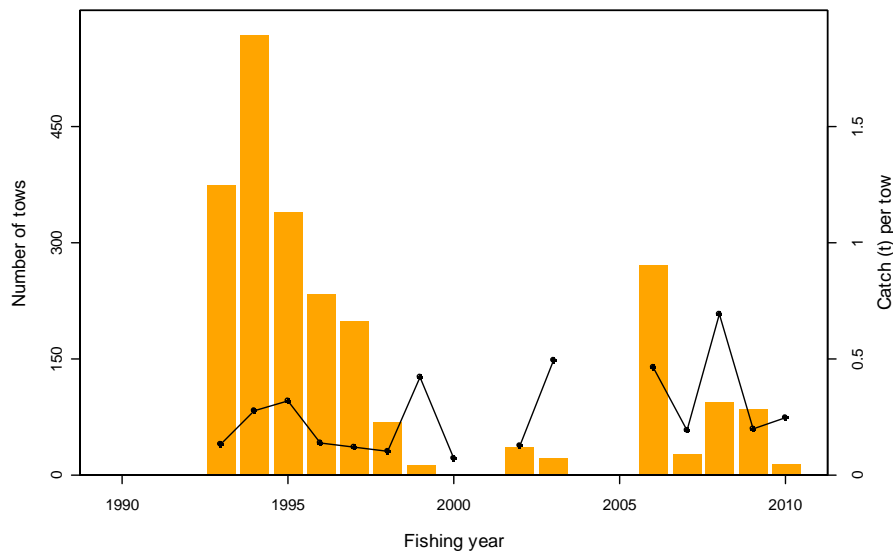


Figure 34: Number of tows (bars) and catch per tow (lines) of blue mackerel for midwater trawl jack mackerel targeted tows in EMA 3, 1989–90 to 2009–10 fishing years, based on the non-zero effort strata of the merged datasets.

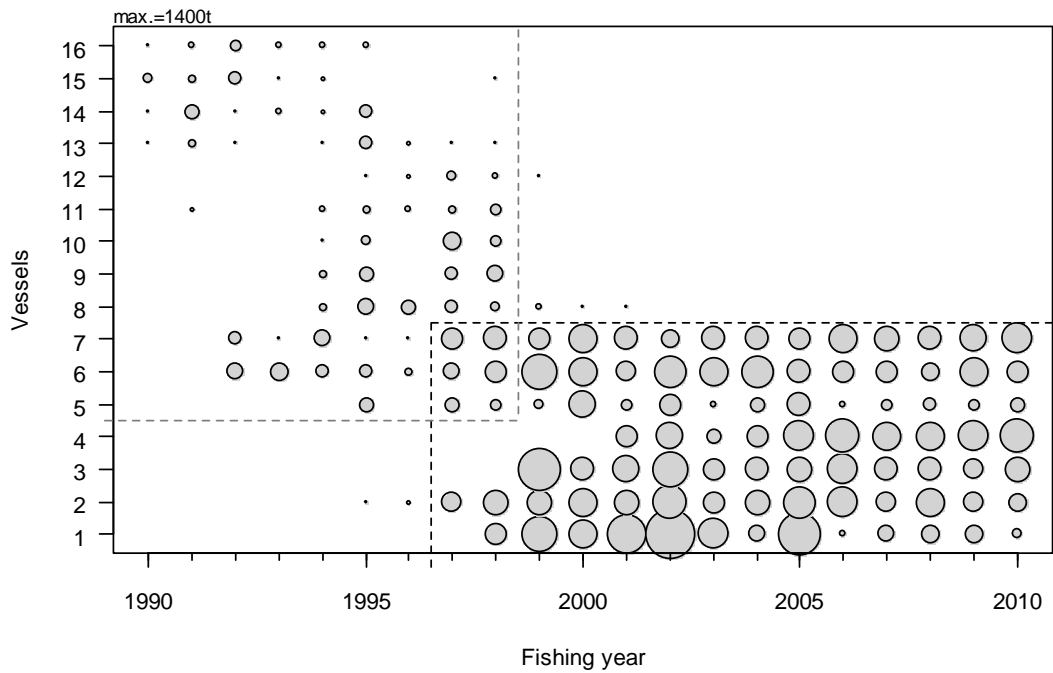


Figure 35: Relative catch of blue mackerel for core fishers included in the catch per unit effort analyses of the merged data. The area of the circle is proportional to the catch. The core vessel datasets are split into an early series comprising vessels 5–15 for fishing years 1989–90 to 1997–98, and a late series comprising vessels 1–7 for fishing years 1996–97 to 2009–10. Vessel numbers are arbitrary numbers.

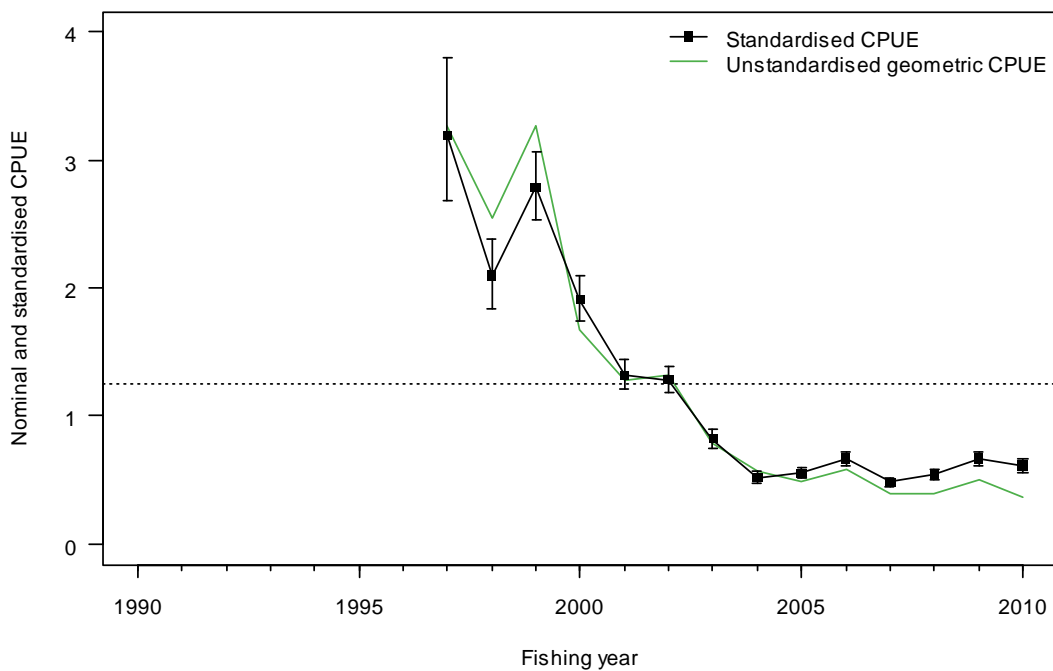


Figure 36: Standardised CPUE indices from 1996–97 to 2009–10 based on tow by tow data from the midwater trawl jack mackerel target fishery. Vertical bars indicate the 95% confidence interval of the standardised indices.

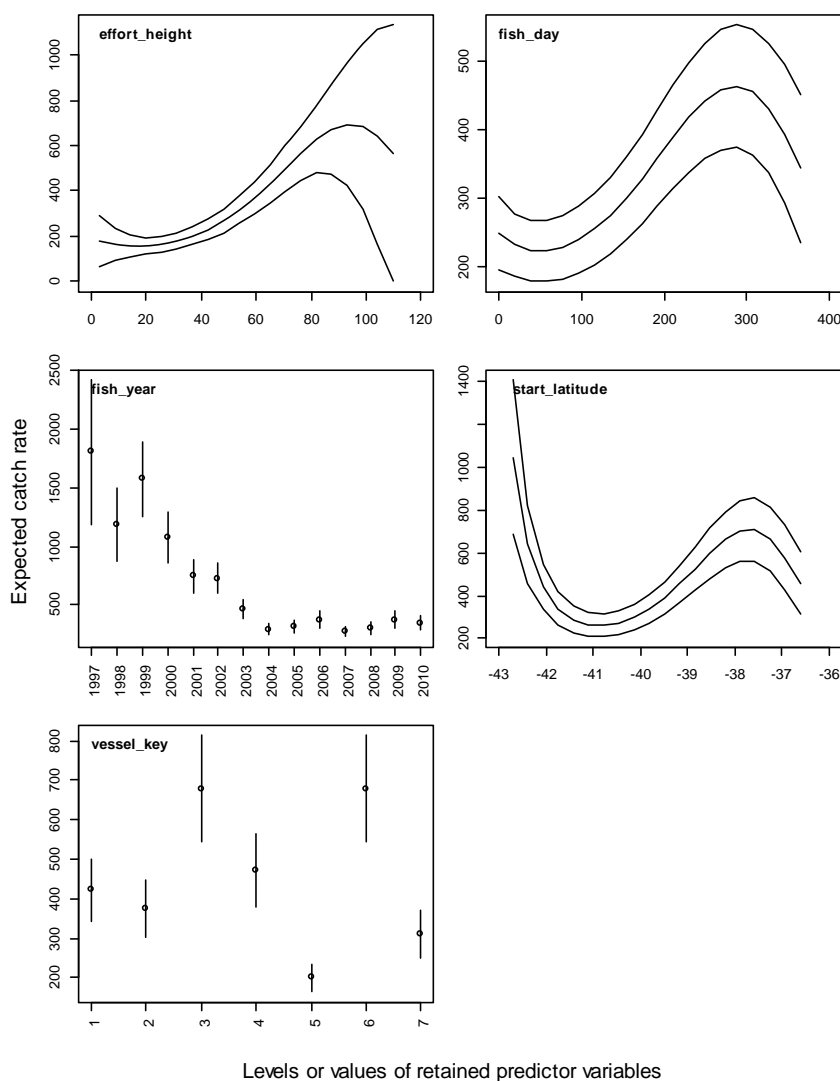


Figure 37: Predicted CPUE for variables *effort height*, *day of fishing*, *fishing year*, *start latitude*, and *vessel key* for the lognormal model fitted to the CPUE series 1996–97 to 2009–10. Bounds show the expected values plus or minus two standard deviations.

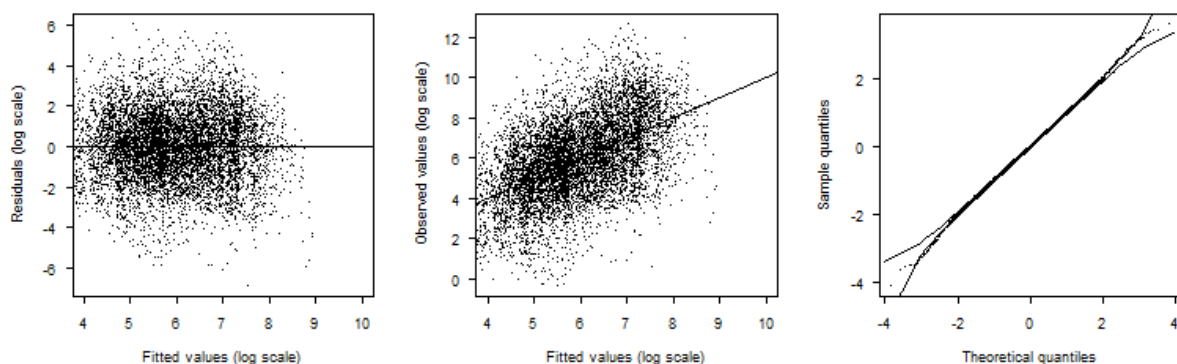


Figure 38: Residual diagnostic plots for the lognormal model fitted to the CPUE series 1996–97 to 2009–10.

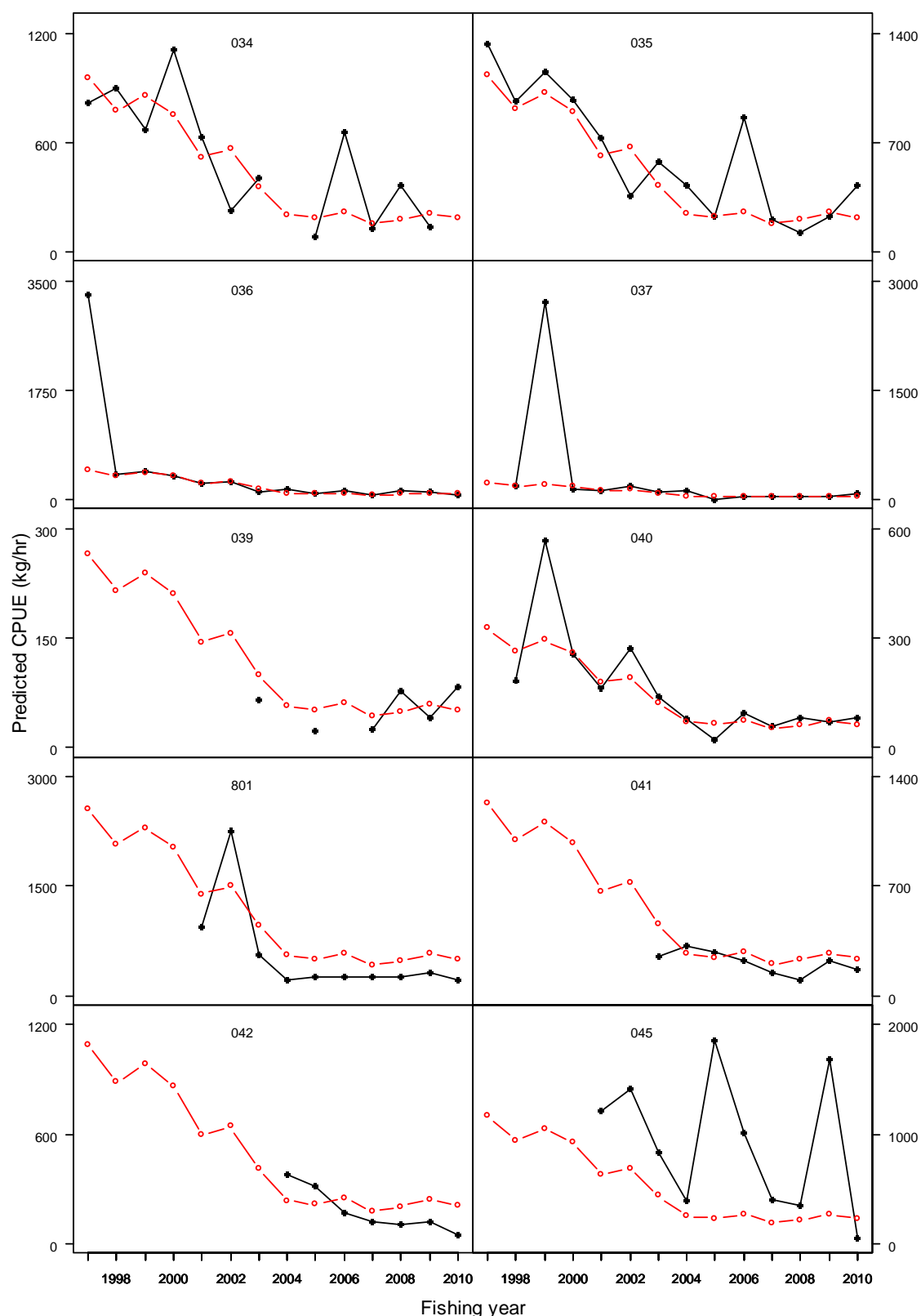


Figure 39: Predicted catch rates (red lines and open circles) for each statistical area from a variation of the standardised CPUE model fitted to tow by tow data from the midwater trawl jack mackerel fishery in which statistical area was offered as an explanatory variable, overlaid with predicted catch rates from the model fitted to the same data but with a year * statistical area interaction.

EMA7

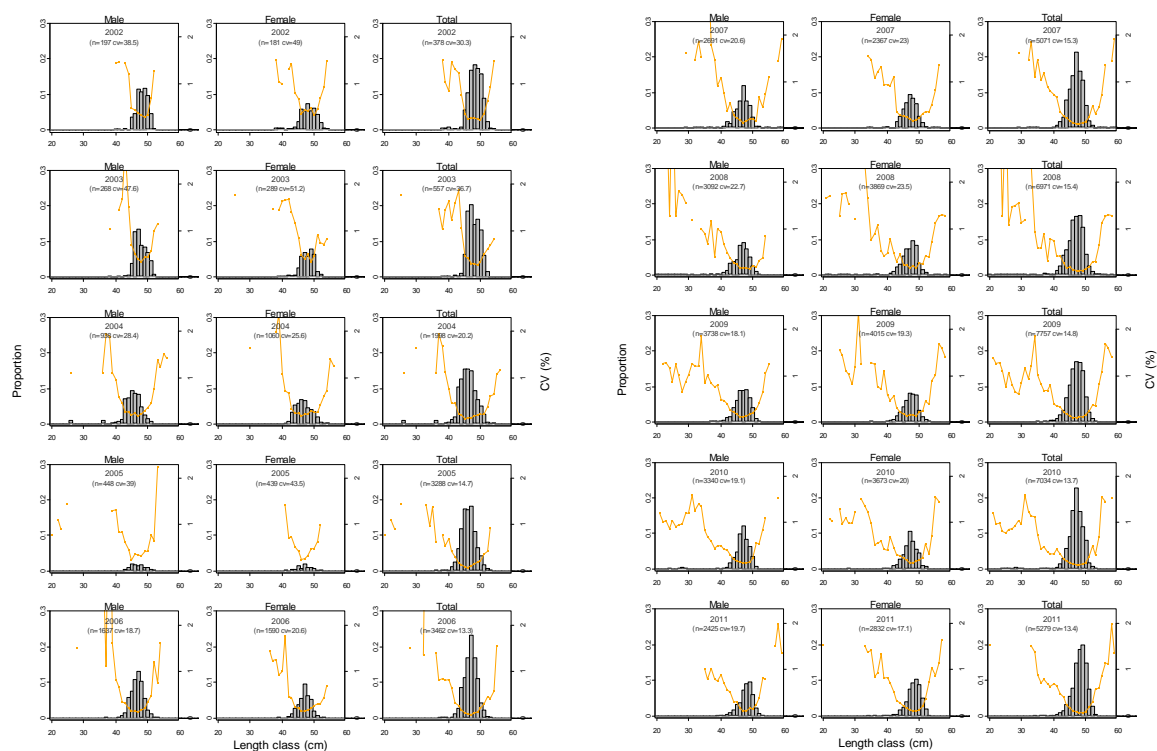
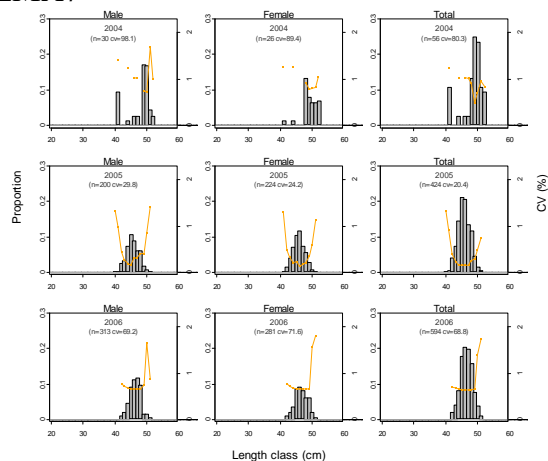


Figure 40: Scaled length frequencies of blue mackerel from observer sampling program in EMA 7 2002–2012.

EMA7



EMA 1

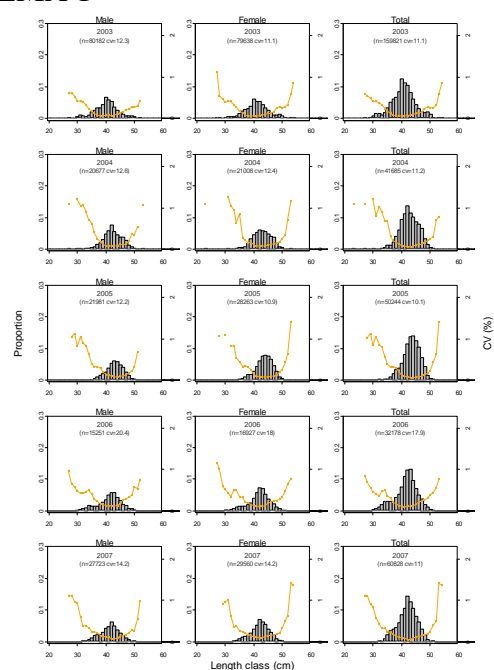


Figure 41: Scaled length frequencies of blue mackerel from market sampling in EMA 7 2004–2006 and EMA 1 2003–2007.

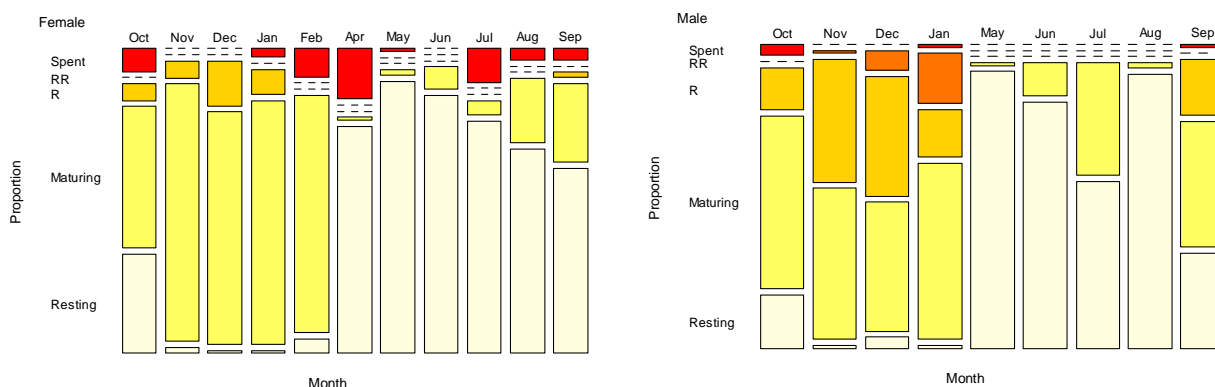
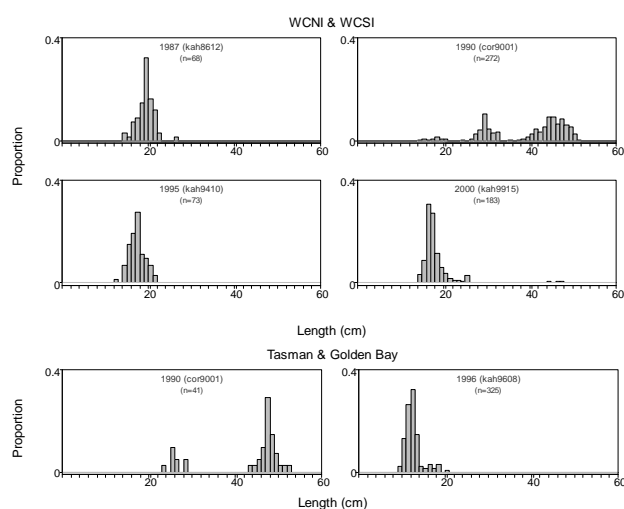


Figure 42: Monthly proportions of female and male blue mackerel gonad developmental stages collected by the Observer Programme in EMA 7, 1994–95 to 2009–10 fishing years combined. Reproductive stages are coloured Resting: pale yellow, Maturing: yellow, Ripe: gold, Running ripe: orange, and Spent: red.

EMA 7



EMA 1

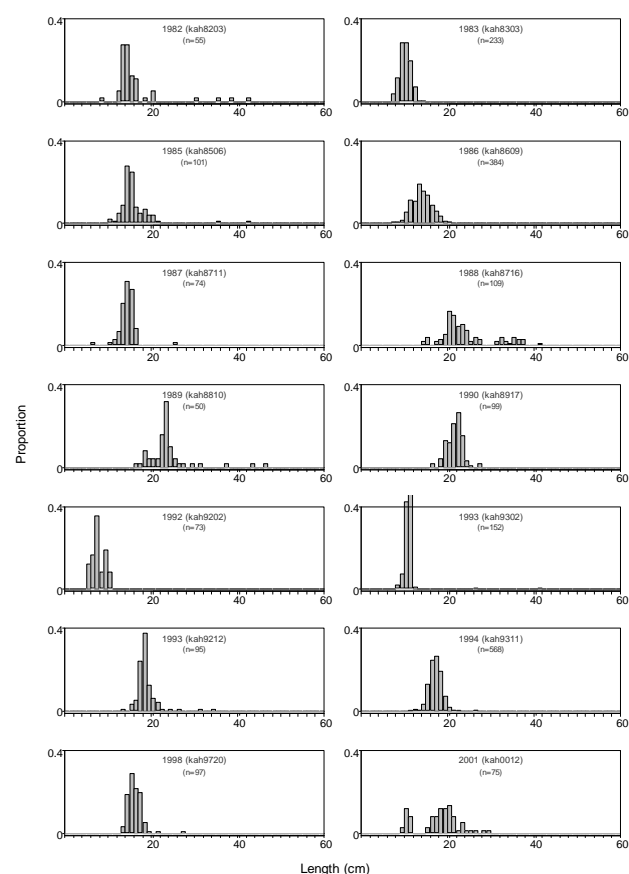


Figure 43: Unscaled length frequencies of blue mackerel from research trawls in EMA 7 and EMA 1 since the 1981–82 fishing year. For EMA 7, length frequencies are shown for Tasman and Golden Bay and the West coast of the North and South Islands separately. Years where sample size was less than 50 were excluded.

APPENDIX A: CATCH EFFORT DATA EXTRACTS

Table A1. List of tables and fields requested in the Ministry of Fisheries extract 7378.

Fishing_events table

Event_Key	Effort_total_num	Pair_trawl_yn
Version_seqno	Effort_width	Bottom_depth
DCF_key	Effort_speed	Column_a
Start_datetime	Total_net_length	Column_b
End_datetime	Total_hook_num	Column_c
Primary_method	Set_end_datetime	Column_d
Target_species	Haul_start_datetime	Display_fishyear
Fishing_duration	Start_latitude (full accuracy)	Start_stats_area_code
Catch_weight	Start_longitude (full accuracy)	Vessel_key
Effort_depth	End_latitude (full accuracy)	Form_type
Effort_height	End_longitude (full accuracy)	Trip
Effort_num		Literal_yn
Effort_num_2		Interp_yn
Effort_seqno		Resrch_yn

Landing_events table

Event_Key	Destination_type	Trip_key
Version_seqno	Unit_type	Trip_start_datetime
DCF_key	Unit_num	Trip_end_datetime
Landing_datetime	Unit_weight	Vessel_key
Landing_name	Conv_factor	Form_type
Species_code	Green_weight	Literal_yn
Species_name	Green_weight_type	Interp_yn
Fishstock_code (ALL fish stocks)	Processed_weight	Resrch_yn
State_code	Processed_weight_type	
	Form_type	

Estimated subcatch table

Event_Key	Species_code (ALL species for each fishing event)	Literal_yn
Version_seqno	Catch_weight	Interp_yn
DCF_key		Resrch_yn

Vessel_history table

Vessel_key
Flag_nationality_code
Built_year
Engine_kilowatts
Gross_tonnes
Overall_length_meter

APPENDIX B: STANDARDISED CPUE ANALYSIS INFLUENCE PLOTS

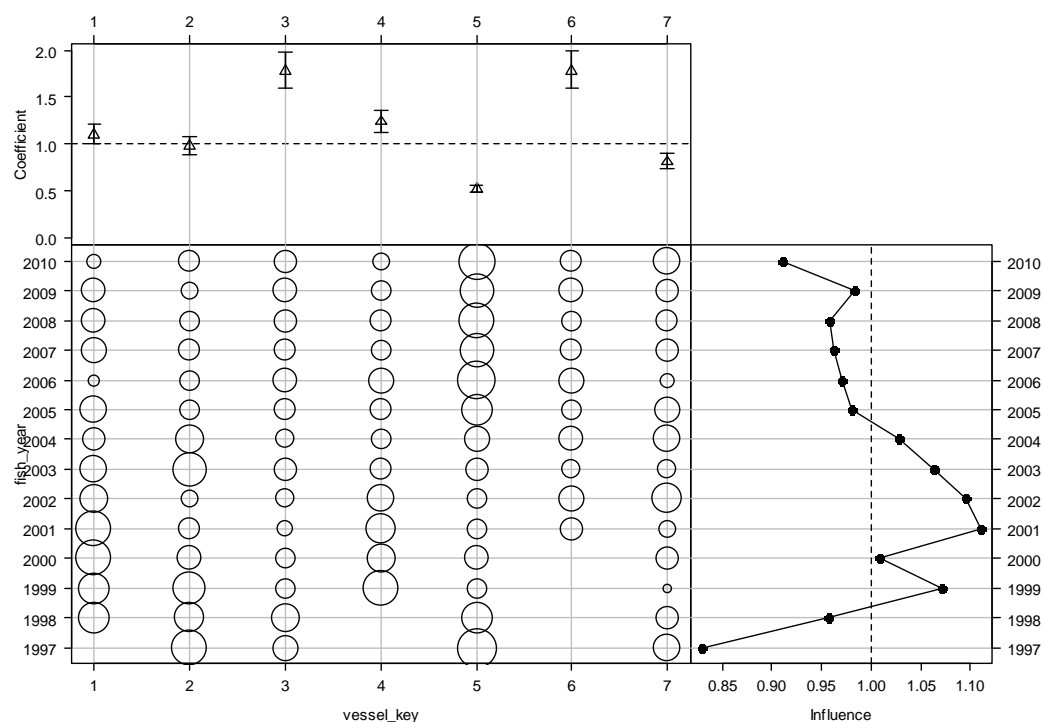


Figure B1: Effect and influence of vessel key in the standardised CPUE model fitted to the CPUE series 1996–97 to 2009–10. See section 5.2 for details.

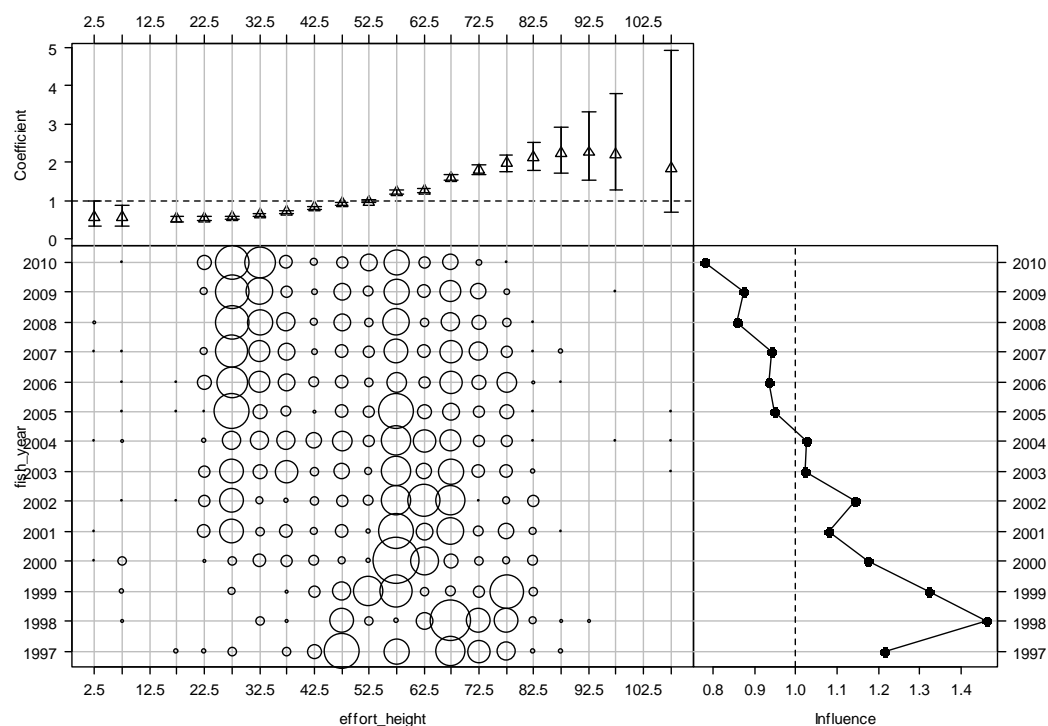


Figure B2: Effect and influence of effort height in the standardised CPUE model fitted to the CPUE series 1996–97 to 2009–10. See section 5.2 for details.

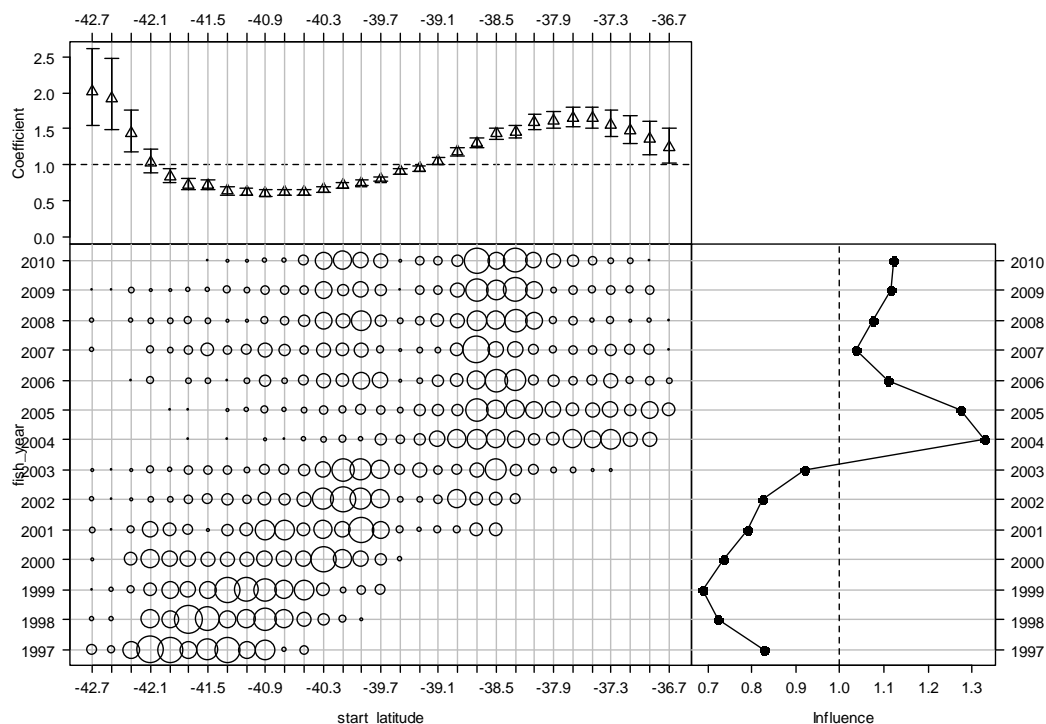


Figure B3: Effect and influence of start latitude in the standardised CPUE model fitted to the CPUE series 1996–97 to 2009–10. See section 5.2 for details.

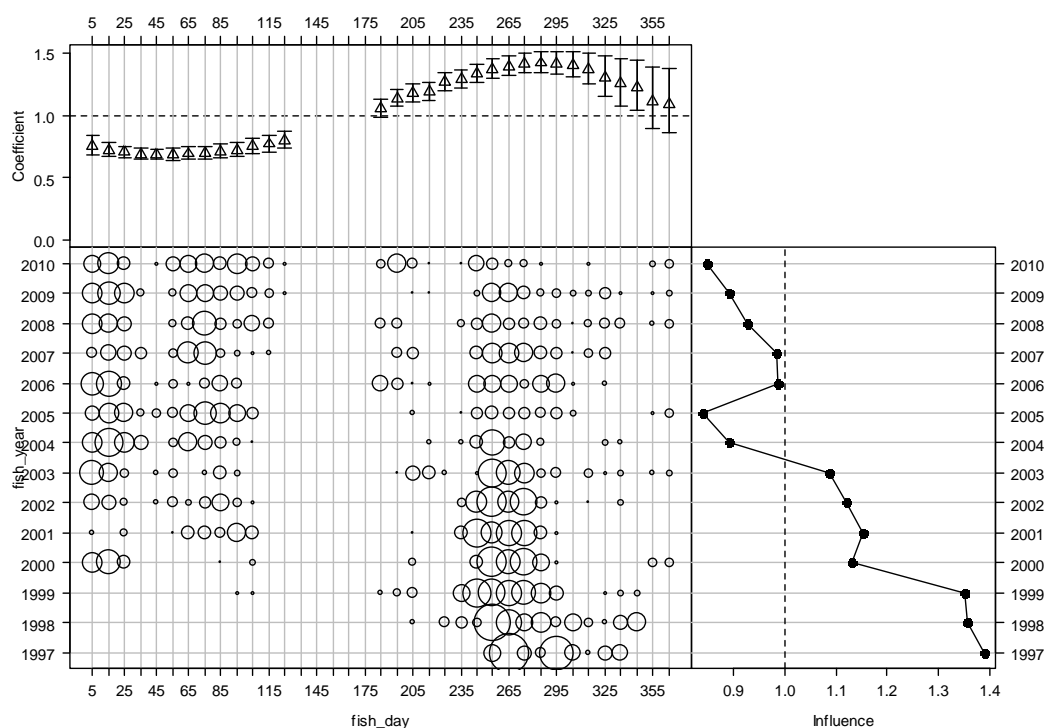


Figure B4: Effect and influence of fishing day in the standardised CPUE model fitted to the CPUE series 1996–97 to 2009–10. See section 5.2 for details.