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Fishery characterisation for blue mackerel, *Scomber australasicus*, in EMA 7, 1989–90 to 2017–18

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This report focuses on a characterisation of blue mackerel, *Scomber australasicus* (Cuvier, 1832), in EMA 7 for fishing years 1989–90 to 2017–18 (1990 to 2018) and updates the most recent characterisation of blue mackerel fisheries which was carried out with data from 1990 to 2014. The purpose of this characterisation is to inform an updated CPUE and development of a full, quantitative stock assessment model for EMA 7 to be presented in a separate report.

Reliable records of blue mackerel catches are available annually since the 1990 fishing year. Blue mackerel entered the Quota Management System (QMS) on 1 October 2002, with a Total Allowable Commercial Catch (TACC) of 3350 t in EMA 7. The commercial catch is caught by a variety of methods in all Quota Management Areas, and most is caught north of latitude 43° S. In EMA 7 most catch is taken by midwater trawls targeting jack mackerel.

The annual landings for EMA 7 before 1996 were mostly less than 2000 t but then increased to be generally between 2500 t and 5000 t, and peaked in 1999 at about 8800 t. The landings exceeded the TACC in 2003, 2005, 2006, and 2009. Catches then steadily declined from 2010 to their lowest point since entering the QMS in 2017, until 2018 when catches increased significantly to just below the TACC. Blue mackerel in EMA 7 is mostly taken as bycatch in the midwater target jack mackerel trawl fishery although some direct targeting occurs at times. The midwater trawl fishery operated off the west coast of South Island through most of the 1990s, but since then a fishery has developed in the North Taranaki Bight and further north off the west coast of North Island. Blue mackerel has also been taken in a target fishery by purse seine vessels at times but in much smaller quantities than by midwater trawl. In recent years the purse seine catch has been negligible.

Blue mackerel are encountered in various trawl surveys, but none are optimised to estimate biomass for this species and too few fish are caught to provide useful length distributions or abundance estimates. Observer sampling in EMA 7 has provided consistent length frequency and age distributions, but market sampling may not be representative of the fishery. An increase in the catch of small fish has been observed on the west coast since 2010. The development of appropriate monitoring schemes for blue mackerel for EMA 7 is recommended.

Past studies of blue mackerel have recommended that a full quantitative stock assessment be carried out for EMA 7 when more age data and an updated CPUE index are available. This will be attempted as part of this project and will be presented in a separate report.

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1. INTRODUCTION

Blue mackerel (*Scomber australasicus*) in EMA 7 is mostly taken as bycatch of midwater trawl fisheries targeting jack mackerel (*Trachurus* species) although there is some direct targeting as well. Targeted catches by purse seine have been decreasing and the overall purse seine catch (both as a target and bycatch fishery) has been decreasing since around 2003–04. The midwater trawl fishery has operated off the west coast throughout the 1990s, but during this time there has been a shift from the west coast of the South Island to the west coast of the North Island, particularly off the North and South Taranaki bights. Landings from EMA 7 were mostly less than 2000 tonnes before 1997 after which landings increased, peaking at nearly 8800 t in 1999. The Total Allowable Commercial Catch (TACC) was exceeded in 2003, 2005, 2006, and 2009 but otherwise has been less than the TACC. Landings in EMA 7 then decreased steadily from 2010 and were at their lowest since entering the QMS in 2017, before increasing dramatically in 2018 to just below the TACC.

Little is known about the current status of blue mackerel stocks and there is no information available with respect to management reference points (Ministry for Primary Industries 2018). No current or past trawl surveys provide acceptable indices of abundance because survey blue mackerel catches are uncommon and trawl surveys conducted to date likely do not cover the blue mackerel geographic range sufficiently. Blue mackerel fishery characterisations and Catch Per Unit Effort (CPUE) analyses have been carried out by Fu & Taylor (2011) for EMA 7, and twice for all blue mackerel stocks under the rotation of the Ministry for Primary Industries (MPI) Ten-Year Plan, first by Fu (2013) and then updated by Ballara (2016). The standardised CPUE analyses for EMA 7 appeared to provide acceptable indices of abundance and these were accepted by the deepwater working group in 2016.

Past catch-at-age data are available from the commercial trawl fishery for fishing years 2004 (Manning et al. 2007a), 2005 (Manning et al. 2007b), and 2006 (Devine et al. 2009). The MPI Deepwater Fishery Assessment Working Group recommended that a stock assessment be run for blue mackerel in EMA 7 once further ageing had been completed, with the suggestion that samples from the observer programme from 2007 and 2014 be aged. Ageing from 2014 has now been completed (Horn & Ó Maolagáin 2018), providing four years of catch-at-age data for the assessment.

The first objective of this project is to update the characterisation of the EMA 7 fishery to see if there are any significant changes that might impact the currently accepted CPUE model which is likely to be an important input to any stock assessment model, particularly in the absence of any adequate fishery-independent data such as trawl surveys. Due to the shift in fishing effort from south to north over time, two CPUE indices were developed for this time series (Fu & Taylor 2011). The first was an early time series from 1990 to 1998 that focused on the west coast of the South Island fishery. The second time series was from 1997 to 2014 with a focus on the fishery after it had shifted to the west coast of the North Island. This also accounts for a shift in the characteristics of the fleet from vessels of around 3000 gross tonnes using bottom trawls and midwater trawls to a fleet of vessels of around 4000 gross tonnes using midwater trawls almost exclusively (Ballara 2016). The early index by Fu & Taylor (2011) showed a generally flat trend. The later index developed by Fu (2013) showed a declining trend from 2000 to 2009 of more than 50% which appeared to have flattened out thereafter when updated to 2014 by Ballara (2016).

The second objective of this project is to update the CPUE index and conduct a full quantitative stock assessment of blue mackerel in EMA 7 using commercial catches, catch-at-age data, and the updated CPUE index as well as any other available biological information as inputs. The work under this objective will form most of the new information available for management advice for EMA 7 and will be presented in a separate Fisheries Assessment Report.

2. FISHERY SUMMARY

2.1 Commercial fishery in EMA 7

EMA 7 (Figure 1) has the second largest catch of the two main blue mackerel Quota Management Areas (QMAs) in the New Zealand Exclusive Economic Zone (EEZ), with EMA 1 being the largest. Blue mackerel are taken by a variety of methods in EMA 7 including bottom longline, bottom pair trawl, beach-seine, bottom trawl, midwater trawl, purse seine, and Danish seine (Fu 2013). However, for many of these methods the catch is very low. The majority is caught by midwater trawling and midwater trawling on the bottom (within five metres of the seabed). These two methods combined accounted for around 80% of the total catch of blue mackerel in EMA 7 for the study period.

Purse seine catches are relatively minor in comparison to midwater trawl methods and have been declining since around 2000, especially since 2010. Purse seine fishing accounted for 17% of the catch for the study period but catches have been declining and in some years the purse seine fishery has not operated at all. Bottom trawling was relatively important in the early 1990s but has been almost non-existent since 1998 and overall accounted for only around 2% of the total catch in EMA 7. Blue mackerel are mainly taken as bycatch of the target jack mackerel fishery but there is some active targeting in some years as well. Historical estimated and recent reported blue mackerel landings for all EMA stocks are given in Table 1, and Figure 2 shows the landings and overall TACC value for all stocks.

(a) **(b)**

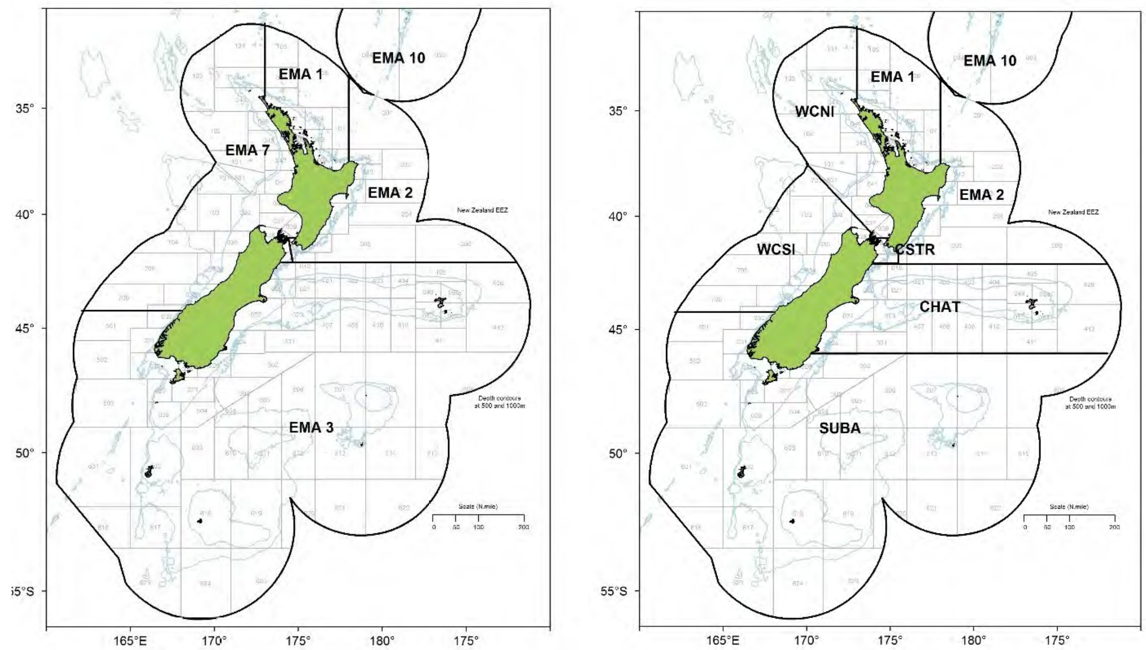

Figure 1: Map showing (a) administrative stock boundaries for all EMA stocks including statistical areas and the 500 and 1000 m contours and (b) areas used by Ballara (2016), including statistical areas, and the 500 m and 1000 m depth contours. CHAT, east coast South Island and the Chatham Rise; CSTR, Cook Strait; WCSI, west coast South Island; WCNI, west coast North Island; and SUBA, Sub-Antarctic. This study uses the split of EMA 7 into WCSI and WCNI as shown above.

Table 1: Reported landings (t) of blue mackerel by QMA, and where area was unspecified (Unsp.), from 1983–84 to 2018–19: Catch Effort Landing Return (CELR) data from 1986–87 to 2000–01; Market Harvest Return (MHR) data from 2001–02 to 2017–18. Source: Fisheries New Zealand (2019).

Fishing year	EMA 1	EMA 2	EMA 3	EMA 7	EMA 10#	Unsp	Total
1983–84*	480	259	44	245	0	1	1 028
1984–85*	565	222	18	865	0	73	1 743
1985–86*	618	30	190	408	0	51	1 296
1986–87	1 431	7	424	489	0	49	2 399
1987–88	2 641	168	864	1 896	0	58	5 625
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	9 358
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	6 025
1994–95	6 734	94	154	1 804	10	149	8 944
1995–96	4 170	119	173	1 218	0	1	5 680
1996–97	6 754	78	340	2 537	0	< 1	9 708
1997–98	4 595	122	78	2 310	0	< 1	7 104
1998–99	4 505	186	62	8 756	0	4	13 519
1999–00	3 602	73	3	3 169	0	0	6 847
2000–01	9 738	113	6	3 278	0	< 1	13 134
2001–02	6 368	177	49	5 101	0	0	11 694
2002–03	7 609	115	88	3 563	0	0	11 375
2003–04	6 523	149	1	2 701	0	0	9 373
2004–05	7 920	9	< 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	8 982
2008–09	3 147	2	88	3 503	0	0	6 740
2009–10	8 539	3	14	3 260	0	0	11 816
2010–11	6 630	2	9	1 996	0	0	8 638
2011–12	8 080	2	28	2 707	0	0	10 817
2012–13	7 213	3	100	2 401	0	0	9 716
2013–14	6 860	4	29	1 200	0	0	8 092
2014–15	8 134	16	87	892	0	0	9 129
2015–16	7 226	18	27	761	0	0	8 033
2016–17	7 551	83	126	625	0	0	8 385
2017–18	7 988	112	46	3 254	0	0	11 400

* FSU data, # Landings reported from EMA 10 are probably attributable to Statistical Area 010 in the Bay of Plenty (i.e., EMA 1).

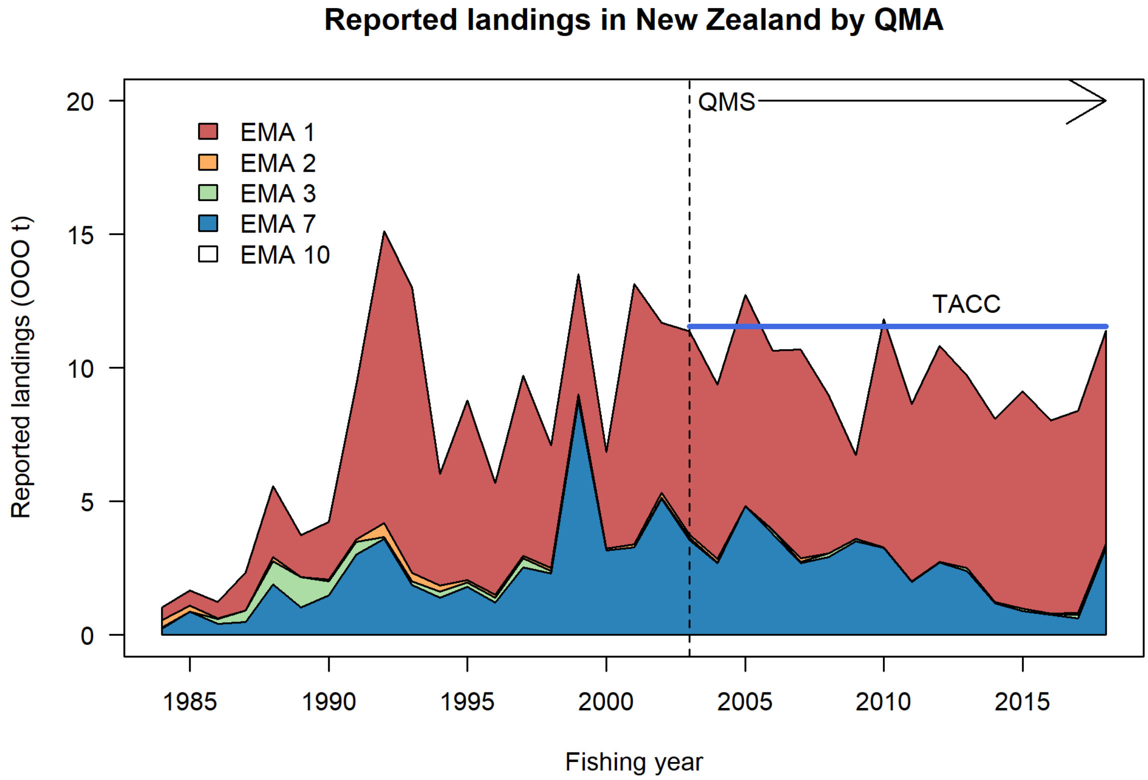

Figure 2: Total reported landings by QMA, and the total TACC, for 1983–84 (1984) to 2017–18 (2018).

Landings from EMA 7 exceeded the TACC in 2003, 2005, 2006, and 2009 (Figure C1 in Appendix C). The catch in EMA 7 is mostly a non-target catch from the jack mackerel (JMA 7) mid-water trawl fishery, therefore, factors influencing the targeting of jack mackerel also affect blue mackerel landings. Other bycatch species taken in the JMA 7 fishery include barracouta (*Thyrsites atun*), hoki (*Macruronus novaezelandiae)*, kahawai (*Arripis trutta*), red gurnard (*Chelidonichthys kumu*), John dory (*Zeus faber*), kingfish (*Seriola lalandi*), and snapper (*Pagrus auratus*). Although non-availability of annual catch entitlement is unlikely to be constraining in the first five of these, the same is not true for kingfish and snapper (Fu 2013). 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 requiring 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

Blue mackerel does not rate highly as a recreational target species although it is popular as bait (Ministry for Primary Industries 2015). There is some uncertainty in all recreational harvest estimates for blue mackerel and there is some confusion between blue and jack mackerels in the recreational data. The harvest estimates from the diary surveys should be used only with the following qualifications: a) they may be very inaccurate; b) the 1996 and earlier surveys contain a methodological error; and, c) the 2000 and 2001 estimates are implausibly high for many important fisheries. Estimates of the recreational catch of blue mackerel reported by Boyd et al. (2004) were very low (between 500 and 3000 fish annually). Estimates by Wynne-Jones et al. (2014, 2019) were higher, with 11 194 fish totalling 11.6 tonnes and 4375 fish totalling 4.5 tonnes caught in 2012 and 2018, respectively, in EMA 7. Although this is higher than the estimates obtained by Boyd et al. it is still likely to be insignificant in comparison to the commercial catch.

2.3 Māori customary fisheries

There is no quantitative information available on Māori customary harvest of blue mackerel.

2.4 Illegal and misreported catch

There is no known illegal catch of blue mackerel.

2.5 Other sources of mortality

There is no information on other sources of mortality.

2.6 Regulations affecting the fishery

Current and historical limits on catch for blue mackerel are described in Section 2.1. Minimum codend mesh-size regulations that currently apply to the trawl fisheries specify 60 mm for Sub-Antarctic (FMA 6) fisheries and FMA 5 south of 48° S; and 100 mm elsewhere. Previously, the codend mesh-size change took effect at the boundary between the Snares Islands and Auckland Islands fisheries (the old EEZ area F/E boundary), at 48° 30' S. However, since 1 October 1983, the codend mesh size change takes effect at latitude 48° S to allow for targeting of squid around the Snares Islands (Hurst 1988).

Protection of bycatch species in multi-species fisheries is mainly through the QMS with quotas currently set for 98 species divided into 642 separate fish stocks. Catches of protected species such as corals, seabirds, and marine mammals are monitored through the government observer programme and since April 2006 all trawl vessels over 28 m have been required to deploy seabird mitigation devices to minimise interactions with trawl warps (Ministry of Fisheries Science Group 2011).

3. BIOLOGY AND DISTRIBUTION

3.1 Distribution and stock structure

Blue mackerel are widespread in northern South Island and North Island waters. Bagley et al. (2000) presented summary distributions of blue mackerel from various datasets and found that catches were made 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 Bay and Tasman Bay to Kaikoura. The highest densities were seen off 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.

The distribution at the surface is seasonal and differs from its known geographical range. During summer, surface schools are found off Northland, Bay of Plenty, South Taranaki Bight, and Kaikoura, but they disappear during winter, when only occasional individuals are found off Northland and the Bay of Plenty (Taylor 2002). This winter disappearance may coincide with the peak in bycatch of blue mackerel in the winter jack mackerel midwater trawl fishery in EMA 7 (Fu 2013). This suggests an increased proportion of the population in deeper water at this time of the year, similar to an observed behavioural characteristic of the related Atlantic mackerel (*Scomber scombrus*) (Sette 1950). Summaries from aerial sightings data show that blue mackerel can be found in mixed schools with jack mackerel, kahawai, skipjack tuna (*Katsuwonus pelamis*), and trevally (*Pseudocaranx dentex*), and that its appearance in mixed schools varies seasonally (Taylor 2002).

Sampling of eggs, larvae, and spawning blue mackerel indicate at least three spawning areas for this species: Northland-Hauraki Gulf; Western Bay of Plenty; and South Taranaki Bight (Crossland 1981, 1982). Nothing is known of migratory patterns or the fidelity of fish to a particular spawning area. Examination of mitochondrial DNA has not identified geographical structuring between New Zealand and Australian fish (Smith et al. 2005). Meristic characters show significant regional differentiation within New Zealand waters, as do some parasite markers. Based on these differences between areas, Smith et al. (2005) considered that blue mackerel in EMA 1, EMA 2, and EMA 7 could be subdivided into at least three biological stocks.

Recorded commercial and research catches show that the geographical distribution and habitat of blue mackerel vary with life history stage (Taylor 2002). Life history stages summarised from research trawls found that juvenile and immature blue mackerel are northerly in their distribution around the North Island and into Golden Bay and Tasman Bay, whereas adults are recorded around both the North Island and South Island to Stewart Island and across the Chatham Rise almost to the Chatham Islands (Hurst et al. 2000). Sporadic catches of small numbers of yearling blue mackerel have been made by bottom trawl in shallow waters (Hurst et al. 2000).

3.2 Spawning

Blue mackerel are serial spawners, releasing eggs in batches over several months (Jones 1983). New Zealand data on sexual maturity are not available, but maturity for both sexes of blue mackerel taken in the Great Australian Bight between January 1979 and December 1980 was estimated, based on gonad condition, to be about 28 cm fork length (FL), which translates to an age of about 2 years (Taylor 2002). Eggs are pelagic and development rate depends on temperature. In plankton surveys, blue mackerel eggs have been found from North Cape to East Cape, with highest concentrations from Northland, the Hauraki Gulf, and the Western Bay of Plenty (Crossland 1981). Eggs have been described throughout the Hauraki Gulf from November to the end of January, at surface temperatures in the range 15–23 °C (Crossland 1981).

Egg and larval surveys have identified spawning locations for blue mackerel in the Hauraki Gulf and east Northland in EMA 1 (Crossland 1981, 1982). Hurst et al. (2000) produced spatial distribution maps of fish in 'ripe', 'running ripe', and 'spent' condition using gonad stage data from research and commercial fishery observer databases and showed that spawning occurred off Tasman Bay and Taranaki in EMA 7 and in the Bay of Plenty in EMA 1.

Gonad stage data from the research trawl and observer databases suggest that spawning takes place in EMA 7 in June and from October to January (Ballara 2016). However, the reliability of the gonad stage data is unknown and there may be some difficulty in distinguishing between immature and resting gonads and early stage maturing (Taylor 2002). These data sources are also sparse, particularly from trawl surveys where few blue mackerel are caught.

3.3 Age and growth

No new information on ageing or growth is available since the previous characterisation (Fu 2013). A comprehensive description of the methods to prepare and interpret blue mackerel otoliths for ageing is available (Marriott & Manning 2011).

Von Bertalanffy growth curves for male, female, and all fish have been estimated using otoliths collected from the Tauranga purse seine fishery combined with archived otoliths from the west coast of the North Island (WCNI), the Hauraki Gulf, and the Bay of Plenty (see table 4 of Morrison et al. 2001a).

Growth curves based on age and length data collected from the EMA 1 purse seine fishery in Bay of Plenty (Manning et al. 2006) were consistent with those of Morrison et al. (2001a). Neither study found differences in growth rate between sexes.

The Bay of Plenty results have a broad distribution, with a maximum age of 24 years, and a mode in the data around 8 to 10 years (Manning et al. 2006). Growth parameters estimated in the Bay of Plenty study are given in Table 2 below. Following a quantitative test of competing growth models in the Bay of Plenty study, no evidence was found of statistically significant differences in growth between the sexes in Bay of Plenty blue mackerel (Manning et al. 2006).

Table 2: Von Bertalanffy growth parameters for Bay of Plenty (EMA 1) blue mackerel (from Manning et al. 2006).

	Males	Females	Both sexes
$L\infty$	52.49	53.1	52.79
K	0.15	0.15	0.15
t_0	-3.29	-3.18	-3.19
Age range (y)	1.8–21.9	1.8–21.9	1.8–21.9
N	240	269	509

Age and growth studies suggest a difference between the age structures of catches taken in the Bay of Plenty (EMA 1) and New South Wales (Australia) (Rohde 1987). For fish from the New South Wales study, a peak was found at 1 year that accounted for more than 55% of the fish sampled, with a maximum age of 7 years. Australian studies may underestimate the ages of larger, older blue mackerel in their catch because the Australian ageing method was based on reading otoliths whole in oil, whereas the New Zealand method was based on reading otolith thin-sections. Results from the New South Wales study suggest that blue mackerel 25–40 cm FL may be 3–7 years old. Using the New Zealand method, fish in this length range could be as old as 16 years. Australian scientists, reading whole otoliths, may be missing opaque zones near the margin, which are visible in sectioned otoliths, and although the Australian study validated the timing of the first opaque zone in blue mackerel otoliths, the results do not cover the complete life history defined using either the Australian or New Zealand method (Marriott et al. 2010).

A feasibility study on validating the New Zealand growth zone counting method used to estimate blue mackerel ages using lead-radium dating was performed (Marriott et al. 2010). Initial radiometric results showed that analysis of otolith cores was impractical given the difficulties associated with extraction in a cost-effective manner. An alternative method using pooled whole otoliths relied on assumptions of otolith mass growth through time, resulting in less precise age determinations. However, the method did indicate that blue mackerel in New Zealand are a relatively long lived small pelagic species living to at least 17 to 49 years, with the real age most likely nearer the lower value (Marriott et al. 2010). Although this range of age estimates is less than desirable for the validation of the growth zone counting method for this species, the findings are consistent with the New Zealand method where traditional otolith ageing studies from commercial catches have blue mackerel living to at least 24 years.

A standard and validated age estimation method for blue mackerel has yet to be developed and is therefore an important future research requirement for New Zealand blue mackerel.

3.4 Natural mortality

No new information on natural mortality is available since the previous characterisation (Ballara 2016). 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

No new information on length weight parameters is available since the previous characterisation (Ballara 2016). The length-weight relationship for blue mackerel was estimated from a linear regression of log-transformed length and weight data from the EMA 1 fishery and is given in table 2 of Manning et al. (2007b). The values are:

- *Males: weight* $= 3.374 \times 10^{-6}(length^{3.4047})$
- *Females: weight* $= 3.2305 \times 10^{-6}(length^{3.4145})$
- *Unsexed: weight* $= 3.3489 \times 10^{-6}(length^{3.4058})$

3.6 Feeding and trophic status

In New Zealand, the diet of blue mackerel has been described as zooplankton, which consists mainly of copepods, but also includes larval crustaceans and molluscs, fish eggs, and fish larvae (Ministry for Primary Industries 2015). Feeding involves both filtering of the water and active pursuit of prey, with blue mackerel feeding on much smaller animals than other fish such as kahawai.

4. CURRENT AND ASSOCIATED RESEARCH PROGRAMMES

4.1 Ministry for Primary Industries/Fisheries New Zealand

Blue mackerel was one of 18 species included on a list to be regularly characterised under rotation as part of the Ministry for Primary Industries 'Deepwater 10-year Plan', now discontinued. This species was last characterised under the 10-year plan by Ballara (2016). The Deepwater Working Group decided as a result of the work by Ballara that a stock assessment should be carried out after further ageing work was completed, for fishing years 2008 to 2015. The age data from 2014 are now available and, combined with previous ageing of fish sampled in 2004, 2005, and 2006, provide four years of ageing data to include as inputs for a full quantitative stock assessment.

Work being carried out under MPI research project JMA2017-01 attempting to develop new methods for standardising CPUE for the mixed jack mackerel fishery in JMA 7 may provide useful and novel information relevant to the blue mackerel fishery in EMA 7.

Research bottom trawl surveys have been conducted since the early 1990s using either the *Tangaroa* (Chatham Rise survey or Sub-Antarctic Survey) or the *Kaharoa* (east coast South Island, west coast South Island). There have also been recently reinstated bottom trawl surveys by *Kaharoa* of the west coast North Island, Hauraki Gulf, and Bay of Plenty. Some of these surveys encounter blue mackerel, but these surveys are not optimised to estimate biomass for this species. Few blue mackerel are caught, and the size range is limited. The sparsity of data from trawl surveys means they are of little use in assessing abundance of blue mackerel and are not considered further in this study.

5. FISHERY DEPENDENT OBSERVATIONS

5.1 Commercial catch length data from observer sampling

Commercial catches of blue mackerel have been sampled by at-sea observers and onshore market samplers. A 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 but also target purse seine catch and catches by midwater trawl vessels targeting jack mackerel in EMA 7 from 2004 onwards. Catches of blue mackerel have been observed at sea since the most recent characterisation of blue mackerel (Ballara 2016) but no further market sampling data have been collected. There is therefore no *new* information on the latter presented here, but previous work is summarised.

Landings by purse seine vessels targeting blue mackerel in EMA 7 were intended to be sampled in fish processing factories in Tauranga using a stratified scheme in 2004 (Manning et al. 2007a), 2005 (Manning et al. 2007b), and 2006 (Devine et al. 2009), although there was no formal spatial or temporal allocation of sampling effort. Only eight trips by purse seine vessels reported landing blue mackerel from EMA 7 in 2004, and, of 173 sets from these trips, only two reported blue mackerel as the target species (Manning 2007a). As a result, no blue mackerel from EMA 7 were sampled from the target purse seine fishery in 2004. Samples were also intended to be taken from small inshore trawlers operating in EMA 7, but small and sporadic catches meant that plans to sample these vessels were abandoned for the remainder of the project. All samples from 2004 were from larger deepwater trawlers, but still mostly from onshore factories rather than at sea.

Samples were systematically collected from the vessel-hold strata for each landing, where between 56 and 424 fish were randomly sampled from each hold at a rate of up to three samples per hold per day. For EMA 7 the sample size was generally small, with only three landings sampled in 2004, and two samples in each of 2005 and 2006 (Table B1 in Appendix B). The spatial and temporal distribution of the catch and sampling effort suggested that sampling data collected from EMA 7 may not be representative—at least for some years (Devine et al. 2009).

Blue mackerel midwater trawl catches have been observed most often in the WCSI and WCNI areas of EMA 7 (as defined by Ballara 2016, see Figure 1) compared with all other areas both in terms of the number of tows observed and the volume of the catches (Tables A1a–b in Appendix A). EMA 7 observer length frequency sampling has been largely representative of midwater trawl catches from WCSI and WCNI for most months, statistical areas, depths, and vessel lengths (Figures A1a–b).

Blue mackerel catches by midwater trawl vessels targeting jack mackerel in EMA 7 have been sampled at sea by the Ministry for Primary Industry Observer Programme since 1987. The sampling scheme was described in full by Sutton (2002). Typically, about 100 fish were randomly sampled 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. By month, fish were most often sampled during June and October to January for WCNI and June to October for the WCSI, with many fewer samples taken from WCSI (Tables A2a–b). The sample size was small in the early years with generally fewer than 200 fish sampled each year but then significantly increased from 2004 with over 2000 fish measured each year for WCNI and more than 300 fish for WCSI (Tables A3a–b). Few otoliths were taken by observers from EMA 7 before 2002 after which sampling increased to more than 200 pairs every year since (Table A4). More than 1000 pairs have been taken in several years.

Length and age frequency distributions

Scaled length frequency distributions were estimated for each of the fisheries using NIWA's catch-at-age software (Bull & Dunn 2002). Market sample catches from the purse seine fishery were scaled up to each landed catch and summed over all landings. For the midwater trawl fishery, the length frequencies 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 all trips to yield overall length frequency distributions. Years referred to here are fishing years, not calendar years.

Length distributions of blue mackerel sampled from EMA 7 come entirely from the trawl fishery. Only two purse seine sets from one trip have measured fish in EMA 7, so no length frequency analyses of purse seine caught fish from the observer programme have been attempted. Blue mackerel from WCNI generally ranged from 40 to 55 cm and were mostly unimodal, with the mode roughly centred around 48 cm in most years to 2013 (Figure A2a). In 2014, this mode is still present but two small modes appear to be present centred on around 28 and 37 cm, but in much smaller numbers than the mode centred on 48 cm. The 2015 length frequency is bimodal with modes centred on about 40 and 50 cm. The 2017 data appear to show a broad length distribution not seen in any other year, with a particular high proportion of fish under 30 cm but still with the characteristic mode centred around 48–50 cm seen in virtually all other years. The large number of small fish under 30 cm in 2017 has possibly moved into the mode centred on 38 cm in 2018, but no cohorts can be tracked through time for any other years.

Observer length distributions of blue mackerel sampled from EMA 7 from WCSI were similar to those from WCNI from 2002 to 2009, with a generally single mode centred around 48–50 cm, although there appeared to be fewer smaller fish compared with WCNI (Table A2b). However, there is a distinct second mode in 2010 centred around 35 cm and modes centred roughly around this length feature in a number of years from 2014 to 2017. It is not obvious why this mode is apparent in some years and not others and does not appear to be related to different vessels, depth, statistical area, target species, or month. As seen for WCNI, no cohorts appear to track through for WCSI.

Only three years of data are available for blue mackerel from the purse seine market sampling programme. For 2004 the distribution is patchy, but it appears that there is again a mode centred around 48 cm, similar to the length distribution from the observer programme (Figure B1). This mode is seen more clearly in 2005 and 2006, when substantially more fish were measured compared with 2004. What is distinct from the market sampling length frequency distribution is the total absence of any fish under 40 cm.

Otoliths were also collected from the market sampling programme and by observers on observed fishing trips between 2002 and 2018 in EMA 7 (Tables B2 and A4). An age-length key was calculated by NIWA's catch-at-age software from each of the length at age datasets from collected in 2003, 2004, 2005, and 2006 under project EMA200401. Scaled age distributions for EMA 7 were estimated by applying the age-length keys calculated to the scaled length frequencies for 2003, 2004, 2005, and 2006 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 et al. 2009). The age distribution generally ranged between 2 and 25 years with slightly more young fish caught in the purse seine fisheries relative to the trawl fisheries. The age distribution of the catch from the midwater trawl fishery had a slightly broader range (Fu 2013).

Female maturity

The female maturity data are summarised here using the observer five stage reproductive scale: 1, immature or resting; 2, maturing;3, ripe; 4, running ripe; and 5, spent. The relative proportions of the reproductive stage data are shown in Figure A3 by area, and the numbers of fish sampled are given in Table A5 by area and fishing year. Locations of gonad stage observations are given in Figure A4. There were few data available before 2003 for WCNI after which most years have more than 1000 fish sampled. For WCSI there were few data before 2007 after which most years have several hundred fish sampled for gonad stage per year. At any time of year, most fish are either immature/resting or maturing. Ripe and running ripe fish are most common in spring and summer from September to February for WCNI. For WCSI, ripe and running ripe fish are most common in winter and autumn from June to October. Spent fish were reported throughout most of the year (Figures A3–A4).

6. DESCRIPTIVE ANALYSIS OF CATCHES

6.1 Catch and effort data sources

Catch-effort, daily processed, and landed catch data were requested from the Fisheries New Zealand catch-effort database 'Enterprise Data Warehouse' as extract 12560. The data consist of all fishing and landing events associated with a set of fishing trips that reported a positive catch or landing of blue mackerel in all EMA fish stock areas (see Figure 1) between 1 October 1989 and 30 September 2018. Data are analysed by fishing year where fishing year is the most recent year (e.g., 1 October 1989 to 30 September 1990 is referred to as the 1990 fishing year). The requested fields from the database tables are listed in Table C1 of Appendix C.

The estimated catches associated with individual fishing events were reported on the Fisheries New Zealand Catch Effort Landing Returns (CELR), Trawl Catch Effort Returns (TCER), Trawl Catch Effort and Processing Return (TCEPR), Netting Catch Effort Returns (NCER). The electronic reporting system (ERS) was introduced in the 2018 fishing year and is intended to supersede other form types. The 2018 fishing year is the last year of the study period for this project and comprises a combination of ERS and the form types it is intended to supersede because some vessels were yet to adopt ERS. Because ERS reports at the level of individual fishing event, for grooming processes they are treated in the same manner as TCEPR and TCER forms which also report at the level of individual fishing event.

Estimated catch was recorded for individual fishing events and the number of species recorded varies with fishing method and the type of data capture system used. This may only be the top five or eight species by weight caught during the event or top five quota species and top three non-quota species. CELR forms record estimated daily catches for the top five species, which are further stratified by statistical area, method of capture, and target species.

Greenweight data associated with landing events are reported on the bottom part of the CELR forms, or on CLR forms for fishing reported on TCEPRs and TCERs. Before 1 October 2007, trawl vessels less than 28 m in length could use either CELR or TCEPR forms whereas trawl vessels over 28 m used only 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 is provided via the Quota Management Report/Monthly Harvest Return (QMR/MHR) system but only at the resolution of Quota Management Area. The data were groomed and re-stratified to derive the datasets required for the characterisation and CPUE analyses. The method allowed catch-effort and landings data collected using different form types that record data with different spatial and temporal resolutions to be combined. It also overcame 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 was developed for monitoring bycatch species in the Adaptive Management Programme using a variation of the method developed by Starr (2007) as implemented by Manning et al. (2007), with refinements by Blackwell et al. (2005) and Manning (2007), and further modifications for this study. The major steps were as follows.

Step 1: The fishing effort, estimated catch, and landings datasets were groomed separately. Outlier values in key variables that failed a range check were corrected using median imputation. This involved replacing missing or outlier values with a median value calculated over some subset of the data. Where grooming failed to find a replacement, all fishing and landing events associated with the trip were excluded.

Step 2: The fishing effort within each valid trip was then restratified by statistical area, method, and target species.

Step 3: The greenweight landings for each fish stock for each trip were then allocated to the effort data. The greenweight landings were 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 and trip ID.

Step 4: The greenweight landings were 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 were not recorded for the trip, but 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 was 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 have used TCEPR forms almost exclusively. The grooming and merging process also allowed an evaluation of the amount of catch and effort not captured using TCEPR, TCER, and ERS forms (as of 2018) at the fishing event level. If substantial, the best characterisation dataset is likely to be 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 will provide a much more detailed dataset for characterisation and CPUE analysis.

Processed product and landed 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 in the database. These changes were standardised relative to the latest conversion factor defined for each product state and applied the catch-consistency checking algorithm designed by Blackwell et al. (2005). This algorithm systematically compared the different catch weights recorded for a particular fishing trip against one another and returned the single most consistent catch type for each trip and explicitly and rigorously accounted for conversion factor changes.

The landings data provide a verified greenweight 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, as well as interim landing events, where catch is transferred or retained, and may therefore appear subsequently as a final landing event (SeaFIC 2007). This analysis used the procedure of Starr (2007), which 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 of Starr (2007)).

6.2 Summary of catches

All tables and figures relating to characterisation of blue mackerel fisheries are contained in Appendix C (Tables C1–9, Figures C1–20). Table C1 summarises the data requested from Fisheries New Zealand for this characterisation, and Table C9 contains a list of species codes used.

The reported QMR/MHR landings, ungroomed catch-effort landings, merged landings, estimated catch, and TACCs (set since 2003) for EMA 7 for the 1990–2018 fishing years are shown in Figure C1. MHR for all EMA stocks are presented in Table 1. In general, the catch-effort landings in the raw dataset conform closely with the reported MHR landings. The annual landings for EMA 7 before 1996 were mostly below 2000 t but increased since then, ranging generally between 2500 t and 5000 t. The peak landing, in 1999, was at about 8800 t. The TACC for EMA 7 was set at 3350 t in 2003 and has remained unchanged. The landings overran the TACC in 2003, 2005, 2006, and 2009 and have been less than the TACC since 2010. Catches were low from 2014 to 2017 and increased sharply in 2018 to just below the TACC of 3350 t.

The weight, number of records, and description of each potential destination type is given in Table C2, and Table C3 summarises the number of landing events for the major destination codes for each stock by fishing year and form type. Most landing events are recorded as “L” (Landed), but substantial numbers were 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 nearly 5% of the total reported landings and most of them appeared in the early part of the series through to the late 1990s. The final destination of the “T” events is unknown because the transferred catches could be landed by foreign vessels to ports outside New Zealand. These 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 retained landings falling short of the MHR by more than 50%. Also, there are many trips with estimated catch but no reported landings, and annual estimated catch exceeds retained landings by up to 40% in some years. It is therefore prudent to retain the “T” landing events (Fu 2013), but other interim landing events (retained as bait, in holding receptacles, or on board) were dropped (after Starr 2007). Destination code “A” may have in the past at least partially accounted for observer authorised discards (Ballara 2016).

The grooming process excluded a small number of trips with invalid codes in the fishing method, target species, statistical area, and trip date fields which could not be fixed using the median imputation method. The estimated catch and landings removed from the dataset in this process were generally insignificant over the time series. The reported QMR/MHR landings (the ratio of the annual estimated catch to the retained landings in the groomed and merged dataset) do not match well with the retained landings for a number of fishing years, particularly in the 1990s (Table C4, Figure C2). The estimated catches appeared to track the retained landings reasonably well over time and they have captured the majority of the harvest reported via the MHR/QMR system over recent years for EMA 7 except in the last few years where estimated catch has been less than 75% and as low as 41% of the QMR/MHR landings (Table C4).

The estimated catches and retained landings by form type for EMA 7 are shown in Figure C3. The bulk of landings were recorded on the CLR forms, and a small proportion was from the CELR forms. In 2018 when ERS forms were introduced, most of the landings were reported on this form but catches reported on CLR forms are still significant. For EMA 7, the ratio of estimated catch to landings was generally above 80% for the TCEPR forms until 2010 at which point the ratio appears to decline, with an increase in 2018 (Figure C2). For the CELR forms the ratio of estimated catch to landings has been variable through time (Figure C2).

The retained landings adjusted for the changes in conversion factors were allocated to the effort strata based on the statistical areas within each fish stock. For this study, the "centroid method" was used in which the midpoint of each statistical area is used to allocate it to the larger fish stock area. For example, Statistical Area 032 straddles EMA 7 and EMA 3 but the centre of the statistical area is in EMA 3 and is therefore not considered part of EMA 7 for this study. This resulted in a closer relationship between QMR/MHR landings, merged landings, and estimated catch for EMA 7.

The main processed state for retained landings of blue mackerel in EMA 7 was "DRE" (includes "dressed", "headed and gutted", and "trunked") with smaller amounts landed green or made into fishmeal (Figure C4). 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 which assumes that the changes in conversion factors reflect improving estimates of the actual conversion factor 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 "OAD" ("observer authorised discard") code introduced on 1 October 2013 with a conversion factor of 1 did not appear in the data.

The percentage of TCEPR forms recording a zero estimated catch in the tow-by-tow data ranged from 24 to 74% in EMA 7 (Table C5). On CELR/TCER recorded trips, the percentage is higher with 29 to 93% of trips reporting to estimated catch of blue mackerel. Some of the differences between the estimated and MHR/QMR catches 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 C5). 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.

6.3 Fishery summary

6.3.1 New Zealand blue mackerel fisheries overview

The spatial distribution of the total blue mackerel commercial catch for all EMA stocks is shown in Figure C5 by statistical area. The highest catches are from EMA 1 and EMA 7 (Table C6, Figures C5a–c and Z6a–c), with most of the trawl catch from EMA 7, and the purse seine fishery mainly from EMA 1 and EMA 7 (Figures C5b–c and Z6b–c).

Across all stocks, blue mackerel are caught throughout the year with peaks in June-July and October to December (Figure C6a). Blue mackerel are caught primarily by purse seine fishing, midwater trawling, and midwater trawling within five metres of the seabed. Midwater trawling within five metres of the seabed is distinguished from other midwater trawling because it is considered to essentially be bottom trawling. This has potential implications both in terms of benthic impact and on CPUE. A variety of other fishing methods also report catching blue mackerel but the catch is negligible. Blue mackerel are mainly taken as a target fishery but also as bycatch of the jack mackerel fishery (Figure C6a). Blue mackerel is mainly taken from June to October by midwater trawl and midwater trawl on-the-bottom in EMA 7 as bycatch of the jack mackerel fishery (Figure C6b). Blue mackerel catches vary without trend from year to year between midwater trawl and midwater trawl on-the-bottom. Most of the EMA 1 purse seine catch is caught in the Bay of Plenty and off East Northland between September and December from target fishing of blue mackerel (Figure C6c).

Most of the New Zealand blue mackerel catch was caught by New Zealand vessels under 1200 kW in power, under 500 gross tonnes in weight, and under 40 metres in length (Table C7, Figure C7). A large proportion of the remainder was taken by Ukrainian and Dominican-flagged vessels, these tended to be larger vessels, i.e., vessels over 4000 kW in power, over 4000 gross tonnes, and over 90 metres in length.

6.3.2 EMA 7

The total EMA 7 catch over the 1990–2018 study period was 80 000 t, 29% of the total New Zealand EEZ blue mackerel catch (Table C6). Most of the EMA 7 catch was taken by midwater trawl and purse seine (Table C8c, Figures C8a–c), with midwater trawls accounting for 80% of the total catch between 1990 and 2018, and purse seine accounting for 17% (Table C8c). Annual EMA 7 purse seine catches have been highly variable; prior to 2000 this method accounted for almost half the TACC in some years. After 2000 the importance of purse seine in EMA 7 declined markedly and since 2010 the method has accounted for less than 3% of the annual EMA 7 catch (Table C8c). Bottom trawl was a moderately important EMA 7 fishing method during the 1990s, accounting for up to 16% of the TACC in some years. After 2000 the annual proportion of the EMA 7 catch taken by bottom trawl has not exceeded 1% (Table C8c). A variety of other fishing methods reported catches of blue mackerel including bottom pair trawl, set-net, and Danish seine but these accounted for only 1% of the catch for the study period (‘Other’ in Table C8c, Figure C8a). All catches taken by midwater trawlers were recorded on the TCEPR forms with some recorded by ERS in 2018, and those by purse seine were recorded on CELR forms (Figures C8b–c).

EMA 7 midwater trawl fisheries

In EMA 7, blue mackerel are caught predominantly by midwater trawling mainly targeting jack mackerel in (Table C8c, Figure C8a). In 1990 the catch was about 160 t, but it increased from 1991 and was over 1000 t in most years since then, and over 2000 t in most years from 1998 to 2013 (Table C8). Catches declined to 1200 t in 2014, to under 1000 t from 2015 to 2017, and increased again in 2018 to over 3300 t. Overall, the trawl catch was taken throughout the year, with higher catches in June and July, and from Statistical Areas 035 and 041 (Table C8a–b, Figure C8b).

The target catch of blue mackerel was usually small and variable and has accounted for 0–63% of the annual catches from midwater trawling (Table C8c, Figure C8b). Up to 1997, hoki target tows accounted for 1–28% of annual catches of blue mackerel by midwater trawl but since 1997 have not featured at all except for 1% and 4% in 2015 and 2017, respectively. Other target species in the fishery include barracouta and kahawai but catches from these fisheries are minor in comparison to the jack mackerel and blue mackerel target fisheries.

The spatial distribution of blue mackerel catch is more widespread for midwater trawl compared with purse seine (Figure C9). Midwater trawl catches have been taken from just south of Kaipara Harbour in the north to about as far south as the Hokitika Trench. Purse seine catches are mainly concentrated in a small area in the South Taranaki Bight. For the main target species, blue mackerel is caught mainly in depths less than 200 metres (Figure C10). The target hoki fishery catches blue mackerel deeper than the other main target fisheries but compared with those fisheries the quantities of blue mackerel caught are much lower.

Catches of blue mackerel from the midwater trawl fishery exhibited a clear seasonal pattern, with highest catches mostly in the winter with peaks in June to September from target blue mackerel, hoki, and barracouta target catches (Figure C11). Catches from the jack mackerel target fishery are spread over more of the year but peaks are still during the winter period as seen in the other target fisheries that report catching blue mackerel.

Fishing effort producing blue mackerel catch has shifted from the south to the north over time (Table C8b, Figure C12). This appears to be the result of a northward movement of midwater trawl jack mackerel targeted effort in JMA 7 (McKenzie 2008). Blue mackerel and jack mackerels can be considered separate elements of a single mixed-species midwater trawl fishery in the EMA 7 and JMA 7 areas (Fu 2013). Before 2000, blue mackerel catches were mainly taken in Statistical Areas 034–037 by target hoki and jack mackerel fishing (and to a much smaller extent barracouta and blue mackerel targeting in some years). From 2000 a fishery developed off the west coast of the North Island in Statistical Areas 040–042 and offshore in Statistical Area 801. The catches in Statistical Area 041 (north Taranaki Bight) have been consistently high from 2003 to 2013, although the target shifted from jack mackerel to blue mackerel during 2011–2013 and are from a mixture of target blue mackerel and jack mackerel fishing; 69–76% of catch was taken from Statistical Area 041 alone in 2009, 2010, and 2012. Catches of blue mackerel dropped between 2014 and 2017 in all statistical areas for all target fisheries and then increased back up to more than 3000 t in 2018, mainly in the blue mackerel target fishery in Statistical Area 041.

Unstandardised catch rates (kilogram per tow) of blue mackerel were variable for all the main target species (Figure C13). Data for target barracouta were variable and patchy, with relatively high catch rates in some years such as 2002, 2004, and 2005. Target catches of blue mackerel by midwater trawl were sporadic and infrequent before the early 2000s. Between 2005 and 2009, around 20 to 40 tows each year targeted blue mackerel and the average catch rates were about 15 to 25 t per tow. The mean catch rate increased to about 45 t per tow in 2010, but has decreased since then, even though effort was high in 2012 and 2013. For the hoki fishery, unstandardised catch rates of blue mackerel were variable and decreased to 2002, with little effort after that. The catch rate was high in 2017 but the amount of effort was still low. Unstandardised catch rates from target jack mackerel midwater trawl fishery increased from 1990 to about 1999, remained high from 1999 to 2002, but then appeared to decrease to 2017 and then increase in 2018.

Figure C14 shows the declining trend in effort in the southern areas over time with a decreasing number of tows in Statistical Areas 034–036 and an overall increasing number of tows in Statistical Areas 037, 040, 041, and 801 (for statistical area boundaries see Figure 1) although this was variable over time. Unstandardised catch rates were higher in the southern statistical areas, particularly in Statistical Area 035 with the highest catch rate of around 13 t per tow, but appeared to be more consistent in the more northern areas at around 1–2 t per tow since the mid-2000s. The highest unstandardised catch rates were in Statistical Area 801 with several years of over 20 t per tow, but catch rates in this area were highly variable through time.

Tow durations for midwater trawl catches of blue mackerel targeting barracouta, blue mackerel, and hoki were patchy and variable through time but typically under four hours (Figure C15). For the jack mackerel target fishery, tow duration decreased from a median of around 4 hours to 2 hours from 1990 to 2000 and then steadily increased to a median of around 4–5 hours. The depth of midwater trawl fishing for jack mackerel was generally less than 200 m and appeared to decrease after the late 1990s (Figure C16). Target hoki midwater tows had widely variable annual median depths from 200 to 500 m.

The distributions for data describing midwater trawl gear width (wingspread), gear height, distance towed, and vessel speed, tonnage, and length by target (when blue mackerel catches were reported) are shown in Figure C17. Gear width values were typically high, usually more than 80 m, often more than 100 m. Headline heights were also high, mostly over 30 m and up to 120 m. Towing speeds were typically around 4–4.5 kn., and the distance towed was usually more than 15 km. Interestingly, for direct targeting of blue mackerel, the distance towed was slightly lower than for the other main target species that report catching blue mackerel. The vessels involved were typically large, at more than 2000 gross tonnes and usually more than 80 metres in length.

EMA 7 Purse seine fisheries

The purse seine fishery in EMA 7 has been substantially smaller than the trawl fishery, accounting for just 17% of the total blue mackerel catch for 1990–2018 the study period and has not exceeded 10% since 2010 (Table C8c). The EMA 7 purse seine fishery is mostly a blue mackerel target fishery, with targeting accounting for 84–100% of the annual purse seine catch of blue mackerel from 1998 to 2013 (Table C8c, Figure C8c). Prior to 1998, a larger proportion of the blue mackerel purse seine catch was taken when targeting jack mackerel and kahawai, but those catches varied considerably between years (Figure C8c). The purse seine fishery for blue mackerel did not operate during 2010 or 2015–2018. Most blue mackerel catches in the purse seine fishery were from February to May, with a peak in March-April (Figure C18). Catches were almost non-existent in the winter months from June to August when they were generally absent from surface schools and unavailable to the purse seine fishery. This period coincided with peak catches in the trawl fishery. Purse seine catches of blue mackerel in target fisheries for jack mackerel and kahawai were also highest in the summer-autumn months and showed the same decline in the winter months.

Most of the EMA 7 purse seine catch was taken from Statistical Areas 037 and 040 (South Taranaki Bight) targeting blue mackerel (Table C8b, Figure C8c, Figure C19). Overall, purse seine catches have been negligible in recent years with between less than 1 and 25 t caught each year since 2014. Blue mackerel taken by EMA 7 purse seiners targeting jack mackerel and kahawai were predominantly caught in Statistical Areas 017 and 018 off the north-eastern coast of the South Island from Cloudy Bay to Kaikoura, but these blue mackerel bycatch fisheries had ceased by the end of the 1990s.

The catch rates of blue mackerel by the purse seine method generally ranged between 0 and 100 t per set but catches over 20 t from a single set were not uncommon (Figure C20). Before 1997, most effort was directed at jack mackerel and kahawai, and catch rates of blue mackerel were low. More effort was directed at blue mackerel from 1999. After 2005, total effort in the fishery decreased considerably although the target catch rates appeared to increase.

7. SUMMARY AND RECOMMENDATIONS

Blue mackerel are considered to consist of at least three biological stocks in EMA 1, 2, and 7 (Smith et al. 2005). Although the mandate of this project did not involve in-depth analyses of stocks outside EMA 7, the data presented here suggest no reason to revise this. Considering EMA 7 independently of other quota management areas of blue mackerel is not inappropriate.

Length frequency distributions from observer and market sampling data showed fewer small fish (under 40 cm) in the market sampling data. This might have been due to differences in blue mackerel selectivity between trawl (which provides most of the observer data) and purse seine effort (which provides all the market data). 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 nautical miles, but this does not explain the absence of small fish from the market sample data. The observer length frequencies show that commercial trawls can catch small mackerel in the 20–30 cm range, for example the 2017 west coast North Island observer length frequency plot (Figure A2a). However, it is not known whether the smaller mode is seen when there are stronger year classes present or because the fishery usually operates where larger blue mackerel occur. It could also be that the annual selectivity of the fishery varies; this would make it difficult to monitor recruitment strength from commercial data. Continued observation of the commercial fishery is still important for the purposes of understanding and monitoring exploitation but is unlikely to monitor abundance and productivity. Trawl surveys of Tasman Bay and Golden Bay and the west coast South Island by *R.V. Kaharoa* occasionally catch small (under 25 cm) blue mackerel which may support the idea that small fish are more common in coastal waters because trawl surveys in deeper water that also use 60 mm cod ends don’t tend to catch these smaller fish.

For commercial fisheries operating in areas where trawl surveys are not conducted, the lack of small fish could be due to selectivity, rather than absence as commercial vessels must use cod ends with at least 100 mm in most areas. Observers have seen more small fish during the WCSI and WCNI trawl fisheries since 2010. Collection of length, weight, and gonad data in EMA 1 and EMA 7 from market samples could increase knowledge of length-weight relationships, spawning biology and areas, and potential stock relationships. Ageing has not been validated but did lend support to age estimation protocols that have been used in past research programmes from New Zealand.

In EMA 7, most catch records are captured on TCEPR forms and the fisheries encountering blue mackerel have several dominant vessels. Observer sampling in EMA 7 has provided relatively consistent length frequency distributions for the midwater trawl fishery, but purse seine market sampling may not have been representative of the catch. The biology is reasonably well understood, but a directed study of reproductive development would enable robust maturity ogives to be determined (Ministry for Primary Industries 2015). This could be a useful input for a full quantitative stock assessment and may help determine stock structure if significant differences exist between areas. For the stock assessment one possible limiting factor is that no biomass estimates are available from existing fishery independent surveys (Ministry for Primary Industries 2015). Age data for 2004–2006, 2014, and 2018 from the observer programme are available as inputs for the stock assessment to be carried out under this project.

There are no current fishery independent trawl surveys suitable for monitoring blue mackerel abundance and their semi-pelagic nature means that they are unlikely to be good candidates for this method of monitoring. They also have strong swimming abilities, and the typical survey tow duration (about one hour) is unlikely to be long enough to adequately sample blue mackerel or would need to be increased to the point of being unfeasibly long.

A pilot survey aimed at using acoustics to monitor jack mackerel abundance in JMA 7 found schools were scattered over a wide area and targeting of individual schools by short mark identification trawling was not possible (O'Driscoll et al. 2013). Video work on this survey also showed jack mackerel swimming out of the net at hauling. It is quite likely that trawl and/or acoustic surveys aimed at estimating blue mackerel abundance would encounter the same difficulties, especially given the overlap of jack and blue mackerel fisheries.

Little is known about the status of the blue mackerel stock in EMA 7 and no estimates of current and reference biomass, reference fishing mortalities, or yield, are available for any blue mackerel area (Ministry for Primary Industries 2015). It is not known if recent catch levels are sustainable or at levels that will allow the stocks to move towards a size that will support the *MSY*. Objective 2 of this project, to be published as a separate report and using updated inputs from this report and an updated catch-per-unit-effort analysis will be the first attempt at a full quantitative stock assessment for blue mackerel in New Zealand waters.

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APPENDIX A: OBSERVER DATA

Table A1: Total number of observed trawl tows (a) and catches (b) sampled for blue mackerel, by area for fishing years 1991 to 2018. Areas are defined in Figure 1.

(a) Tows

Fishing year	CHAT	CSTR	EMA 1	EMA 2	SUBA	WCNI	WCSI	Other	Total
1990–91	6	-	-	-	3	189	66	-	264
1991–92	1	-	-	1	3	159	84	-	248
1992–93	104	-	-	-	2	220	47	-	373
1993–94	25	-	-	-	1	195	164	-	385
1994–95	9	-	1	-	-	301	19	-	330
1995–96	52	-	-	-	4	68	61	-	185
1996–97	1	-	-	-	2	138	108	-	249
1997–98	1	1	-	1	3	186	27	-	219
1998–99	8	2	-	-	1	53	268	-	332
1999–00	4	-	-	1	3	61	29	-	98
2000–01	4	-	-	-	1	64	62	-	131
2001–02	54	-	-	-	3	88	40	-	185
2002–03	9	-	-	-	1	154	36	-	200
2003–04	1	4	-	-	-	116	7	-	128
2004–05	-	-	-	2	-	403	26	-	431
2005–06	29	-	-	-	2	270	11	-	312
2006–07	24	4	4	-	-	403	170	-	605
2007–08	53	2	4	-	-	479	85	-	623
2008–09	2	-	-	-	-	423	79	-	504
2009–10	27	1	-	-	1	473	26	-	528
2010–11	19	-	-	1	-	363	28	-	411
2011–12	34	1	2	-	3	800	79	-	919
2012–13	124	1	2	-	8	1 023	162	-	1 320
2013–14	125	1	19	3	13	1 170	168	-	1 499
2014–15	206	9	35	5	3	504	166	-	928
2015–16	86	-	4	-	7	309	160	-	566
2016–17	106	-	15	6	1	343	147	-	618
2017–18	59	-	7	8	2	530	206	-	812
Total	1 173	26	93	28	67	9 485	2 531	-	13 403

(b) Catches (t) (-; no data)

Fishing year	CHAT	CSTR	EMA 1	EMA 2	SUBA	WCNI	WCSI	Other	Total
1990–91	1	-	-	-	<0.5	181	287	-	468
1991–92	<0.5	-	-	<0.5	<0.5	38	150	-	188
1992–93	21	-	-	-	<0.5	137	48	-	205
1993–94	9	-	-	-	<0.5	40	157	-	206
1994–95	<0.5	-	<0.5	-	-	240	1	-	241
1995–96	11	-	-	-	<0.5	9	26	-	47
1996–97	<0.5	-	-	-	<0.5	25	269	-	294
1997–98	32	<0.5	-	<0.5	<0.5	94	176	-	301
1998–99	4	<0.5	-	-	<0.5	23	1 453	-	1 480
1999–00	<0.5	-	-	<0.5	<0.5	29	35	-	64
2000–01	<0.5	-	-	-	<0.5	17	217	-	234
2001–02	14	-	-	-	<0.5	234	101	-	350
2002–03	<0.5	-	-	-	<0.5	61	16	-	77
2003–04	<0.5	<0.5	-	-	-	257	<0.5	-	257
2004–05	-	-	-	<0.5	-	731	61	-	792
2005–06	18	-	-	-	<0.5	833	31	-	882
2006–07	1	<0.5	<0.5	-	-	605	239	-	844
2007–08	46	<0.5	<0.5	-	-	559	147	-	753
2008–09	1	-	-	-	-	1 240	164	-	1 404
2009–10	9	<0.5	-	-	<0.5	1 107	70	-	1 186
2010–11	8	-	-	<0.5	-	313	63	-	383
2011–12	10	<0.5	<0.5	-	<0.5	1 112	277	-	1 400
2012–13	72	<0.5	<0.5	-	<0.5	1 743	132	-	1 947
2013–14	26	<0.5	<0.5	<0.5	3	792	175	-	996
2014–15	47	<0.5	<0.5	<0.5	<0.5	203	306	-	557
2015–16	12	-	<0.5	-	<0.5	179	279	-	470
2016–17	30	-	<0.5	<0.5	<0.5	135	95	-	260
2017–18	9	-	<0.5	<0.5	<0.5	1 396	152	-	1 557
Total	380	<0.5	1	<0.5	3	12 334	5 126	-	17 844

Table A2: Number of observed tows sampled for blue mackerel in EMA 7 by month for fishing years 1992 to 2018.

(a) EMA 7 (WCNI)

Fishing year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1992–93	-	-	-	-	-	-	-	-	-	-	-	-	-
1993–94	-	-	-	-	-	-	-	-	-	-	-	-	-
1994–95	-	-	2	3	-	-	-	-	-	-	-	-	5
1995–96	-	-	-	-	-	-	-	-	-	-	-	-	-
1996–97	-	-	-	-	-	-	-	-	-	-	-	-	-
1997–98	-	-	-	4	1	-	-	-	-	-	-	-	5
1998–99	-	-	-	-	-	-	-	-	-	-	-	-	-
1999–00	-	-	-	-	-	-	-	-	-	-	-	-	-
2000–01	-	-	-	-	-	-	-	-	-	-	-	-	-
2001–02	15	-	-	-	-	-	-	-	-	-	-	2	17
2002–03	30	1	-	-	-	-	5	-	-	-	-	-	36
2003–04	3	-	27	1	-	-	-	-	-	-	3	5	39
2004–05	-	10	4	-	-	-	2	-	-	13	-	-	29
2005–06	-	4	40	-	-	-	-	-	7	18	-	-	69
2006–07	12	2	19	47	-	-	3	-	1	6	7	4	101
2007–08	21	10	79	3	-	-	-	-	10	7	-	1	131
2008–09	29	10	56	10	-	-	-	-	16	-	-	-	121
2009–10	48	3	52	1	-	-	-	1	18	1	-	-	124
2010–11	6	9	14	1	-	-	5	4	24	-	-	-	63
2011–12	1	13	72	29	-	-	-	2	25	-	2	10	154
2012–13	12	14	60	35	-	14	35	-	36	1	-	-	207
2013–14	8	10	33	18	2	1	21	12	45	11	-	-	161
2014–15	18	28	83	22	29	2	2	9	4	-	-	-	197
2015–16	15	6	64	39	2	-	4	2	13	-	-	-	145
2016–17	17	6	7	13	1	-	4	-	2	-	-	-	50
2017–18	9	12	25	44	1	4	7	-	22	-	-	-	124
Total	244	138	637	270	36	21	88	30	223	57	12	22	1 778

(b) EMA 7 (WCSI)

Fishing year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1992–93	-	-	-	-	-	-	-	-	-	-	-	-	-
1993–94	-	-	-	-	-	-	-	-	1	-	-	-	1
1994–95	-	-	-	-	-	-	-	-	-	-	-	-	-
1995–96	-	-	-	-	-	-	-	-	-	-	-	-	-
1996–97	-	-	-	-	-	-	-	-	-	1	-	-	1
1997–98	-	-	-	-	-	-	-	-	-	2	-	-	2
1998–99	-	-	-	-	-	-	-	-	-	-	-	-	-
1999–00	-	-	-	-	-	-	-	-	-	1	-	-	1
2000–01	-	-	-	-	-	-	-	-	-	-	-	-	-
2001–02	-	-	-	-	-	-	-	-	-	4	1	5	10
2002–03	16	-	-	-	-	-	-	-	-	-	2	3	21
2003–04	-	-	-	-	-	-	-	-	-	-	-	-	-
2004–05	-	-	-	-	-	-	-	-	-	6	-	-	6
2005–06	-	-	-	-	-	-	-	-	-	2	1	-	3
2006–07	-	-	-	-	-	-	-	-	14	23	-	1	38
2007–08	-	-	-	-	-	-	-	-	23	3	8	-	34
2008–09	2	-	-	-	-	-	-	-	6	4	3	-	15
2009–10	2	-	-	-	-	-	-	-	-	-	-	-	2
2010–11	2	-	-	-	-	-	-	-	2	-	-	-	4
2011–12	1	-	-	-	-	-	-	-	6	2	5	-	14
2012–13	3	-	-	-	-	-	-	2	26	8	3	-	42
2013–14	-	-	-	-	-	-	-	4	31	7	1	-	43
2014–15	1	-	-	-	-	-	-	1	42	2	-	-	46
2015–16	-	-	-	-	-	-	-	2	22	3	-	-	27
2016–17	2	-	-	-	-	-	1	-	14	2	4	1	24
2017–18	-	-	-	-	-	-	-	1	-	10	6	-	17
Total	29	-	-	-	-	-	1	10	187	80	34	10	351

Table A3: Total number of blue mackerel measured in EMA 7 by month for fishing years 1992 to 2018, where data exist collected by the Observer Programme.
(a) EMA 7 (WCNI)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1992–93	-	-	-	-	-	-	-	-	-	-	-	-	-
1993–94	-	-	-	-	-	-	-	-	-	-	-	-	-
1994–95	-	-	77	58	-	-	-	-	-	-	-	-	135
1995–96	-	-	-	-	-	-	-	-	-	-	-	-	-
1996–97	-	-	-	-	-	-	-	-	-	-	-	-	-
1997–98	-	-	-	150	37	-	-	-	-	-	-	-	187
1998–99	-	-	-	-	-	-	-	-	-	-	-	-	-
1999–00	-	-	-	-	-	-	-	-	-	-	-	-	-
2000–01	-	-	-	-	-	-	-	-	-	-	-	-	-
2001–02	160	-	-	-	-	-	-	-	-	-	-	23	183
2002–03	254	10	-	-	-	-	60	-	-	-	-	-	324
2003–04	29	-	1 351	15	-	-	-	-	-	-	304	301	2 000
2004–05	-	729	70	-	-	-	5	-	-	2 386	-	-	3 190
2005–06	-	162	1 584	-	-	-	-	-	254	1 408	-	-	3 408
2006–07	676	52	934	605	-	-	20	-	20	304	486	234	3 331
2007–08	1 032	337	3 212	60	-	-	-	-	140	635	-	41	5 457
2008–09	1 500	458	2 792	526	-	-	-	-	1 475	-	-	-	6 751
2009–10	3 371	178	2 074	158	-	-	-	64	962	58	-	-	6 865
2010–11	189	385	345	52	-	-	656	362	3 039	-	-	-	5 028
2011–12	47	485	3 057	1 381	-	-	-	129	1 460	-	19	625	7 203
2012–13	451	262	2 373	1 537	-	435	1 007	-	2 148	20	-	-	8 233
2013–14	165	334	1 101	547	40	20	578	300	1 105	395	-	-	4 585
2014–15	452	664	2 857	596	753	22	33	130	21	-	-	-	5 528
2015–16	265	116	1 527	866	36	-	76	32	202	-	-	-	3 120
2016–17	289	152	115	304	5	-	85	-	40	-	-	-	990
2017–18	642	240	521	1 192	20	60	122	-	872	-	-	-	3 669
Total	9 522	4 564	23 990	8 047	891	537	2 642	1 017	11 738	5 206	809	1 224	70 187

(b) EMA 7 (WCSI)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1992–93	-	-	-	-	-	-	-	-	-	-	-	-	-
1993–94	-	-	-	-	-	-	-	-	24	-	-	-	24
1994–95	-	-	-	-	-	-	-	-	-	-	-	-	-
1995–96	-	-	-	-	-	-	-	-	-	-	-	-	-
1996–97	-	-	-	-	-	-	-	-	-	41	-	-	41
1997–98	-	-	-	-	-	-	-	-	-	240	-	-	240
1998–99	-	-	-	-	-	-	-	-	-	-	-	-	-
1999–00	-	-	-	-	-	-	-	-	-	97	-	-	97
2000–01	-	-	-	-	-	-	-	-	-	-	-	-	-
2001–02	-	-	-	-	-	-	-	-	-	121	10	64	195
2002–03	116	-	-	-	-	-	-	-	-	-	20	97	233
2003–04	-	-	-	-	-	-	-	-	-	-	-	-	-
2004–05	-	-	-	-	-	-	-	-	-	113	-	-	113
2005–06	-	-	-	-	-	-	-	-	-	20	81	-	101
2006–07	-	-	-	-	-	-	-	-	580	1 182	-	2	1 764
2007–08	-	-	-	-	-	-	-	-	639	252	630	-	1 521
2008–09	30	-	-	-	-	-	-	-	546	189	241	-	1 006
2009–10	253	-	-	-	-	-	-	-	-	-	-	-	253
2010–11	51	-	-	-	-	-	-	-	299	-	-	-	350
2011–12	31	-	-	-	-	-	-	-	269	37	349	-	686
2012–13	115	-	-	-	-	-	-	40	588	278	100	-	1 121
2013–14	-	-	-	-	-	-	-	75	803	350	20	-	1 248
2014–15	20	-	-	-	-	-	-	20	1 146	40	-	-	1 226
2015–16	-	-	-	-	-	-	-	40	499	118	-	-	657
2016–17	40	-	-	-	-	-	20	-	279	39	65	20	463
2017–18	-	-	-	-	-	-	-	4	-	250	97	-	351
Total	656	-	-	-	-	-	20	179	5 672	3 367	1 613	183	11 690

Table A4: Number of otolith pairs collected by observers by fishstock for fishing year. NB: no otoliths were collected before the 1995 fishing year.

Year	EMA1	EMA2	EMA3	EMA7
1995	-	-	-	1
1996	-	-	-	-
1997	-	-	-	-
1998	-	-	-	31
1999	-	-	-	-
2000	-	-	-	6
2001	-	-	-	-
2002	-	-	-	209
2003	-	-	-	422
2004	-	-	-	262
2005	-	-	-	457
2006	-	-	10	487
2007	67	-	41	1134
2008	35	-	8	1065
2009	-	-	-	1057
2010	-	-	18	769
2011	-	-	-	519
2012	-	-	-	962
2013	-	-	91	1765
2014	2	-	67	1168
2015	-	-	109	1313
2016	-	-	28	833
2017	-	-	9	348
2018	-	-	4	722
Total	104	0	385	13530

Table A5: Number of blue mackerel female gonad stages collected by the Observer Programme in EMA 7.
(a) EMA 7 (WCNI)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1992–93	-	-	-	-	-	-	-	-	-	-	-	-	-
1993–94	-	-	-	-	-	-	-	-	-	-	-	-	-
1994–95	-	-	64	38	-	-	-	-	-	-	-	-	102
1995–96	-	-	-	-	-	-	-	-	-	-	-	-	-
1996–97	-	-	-	-	-	-	-	-	-	-	-	-	-
1997–98	-	-	-	80	20	-	-	-	-	-	-	-	100
1998–99	-	-	-	-	-	-	-	-	-	-	-	-	-
1999–00	-	-	-	-	-	-	-	-	-	-	-	-	-
2000–01	-	-	-	-	-	-	-	-	-	-	-	-	-
2001–02	78	-	-	-	-	-	-	-	-	-	-	10	88
2002–03	123	7	-	-	-	-	19	-	-	-	-	-	149
2003–04	12	-	796	13	-	-	-	-	-	-	118	121	1 060
2004–05	-	358	43	-	-	-	1	-	-	11	-	-	413
2005–06	-	118	779	-	-	-	-	-	101	588	-	-	1 586
2006–07	348	26	455	372	-	-	9	-	10	150	251	71	1 692
2007–08	424	217	2 058	28	-	-	-	-	63	317	-	27	3 134
2008–09	695	375	1 495	295	-	-	-	-	681	-	-	-	3 541
2009–10	1 552	94	1 341	101	-	-	-	30	448	24	-	-	3 590
2010–11	92	212	228	46	-	-	335	166	1 576	-	-	-	2 655
2011–12	25	326	1 961	670	-	-	-	76	919	-	6	234	4 217
2012–13	209	190	1 359	889	-	214	589	-	979	8	-	-	4 437
2013–14	72	167	599	253	19	7	233	124	521	139	-	-	2 134
2014–15	221	438	1 825	315	374	13	14	72	17	-	-	-	3 289
2015–16	135	58	937	479	23	-	36	14	95	-	-	-	1 777
2016–17	126	79	50	141	1	-	44	-	11	-	-	-	452
2017–18	303	112	251	573	8	25	43	-	413	-	-	-	1 728
Total	4 415	2 777	14 241	4 293	445	259	1 323	482	5 834	1 237	375	463	36 144

(b) EMA 7 (WCSI)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1992–93	-	-	-	-	-	-	-	-	-	-	-	-	-
1993–94	-	-	-	-	-	-	-	-	-	-	-	-	-
1994–95	-	-	-	-	-	-	-	-	-	-	-	-	-
1995–96	-	-	-	-	-	-	-	-	-	-	-	-	-
1996–97	-	-	-	-	-	-	-	-	-	-	-	-	-
1997–98	-	-	-	-	-	-	-	-	-	46	-	-	46
1998–99	-	-	-	-	-	-	-	-	-	-	-	-	-
1999–00	-	-	-	-	-	-	-	-	-	41	-	-	41
2000–01	-	-	-	-	-	-	-	-	-	-	-	-	-
2001–02	-	-	-	-	-	-	-	-	-	41	10	42	93
2002–03	72	-	-	-	-	-	-	-	-	-	10	58	140
2003–04	-	-	-	-	-	-	-	-	-	-	-	-	-
2004–05	-	-	-	-	-	-	-	-	-	33	-	-	33
2005–06	-	-	-	-	-	-	-	-	-	11	22	-	33
2006–07	-	-	-	-	-	-	-	-	266	416	-	2	684
2007–08	-	-	-	-	-	-	-	-	310	117	311	-	738
2008–09	17	-	-	-	-	-	-	-	259	88	110	-	474
2009–10	122	-	-	-	-	-	-	-	-	-	-	-	122
2010–11	24	-	-	-	-	-	-	-	173	-	-	-	197
2011–12	18	-	-	-	-	-	-	-	131	21	154	-	324
2012–13	53	-	-	-	-	-	-	18	284	134	71	-	560
2013–14	-	-	-	-	-	-	-	28	436	179	9	-	652
2014–15	7	-	-	-	-	-	-	8	601	14	-	-	630
2015–16	-	-	-	-	-	-	-	9	215	57	-	-	281
2016–17	23	-	-	-	-	-	15	-	138	21	29	7	233
2017–18	-	-	-	-	-	-	-	-	-	131	42	-	173
Total	336	-	-	-	-	-	15	63	2 813	1 350	768	109	5 454

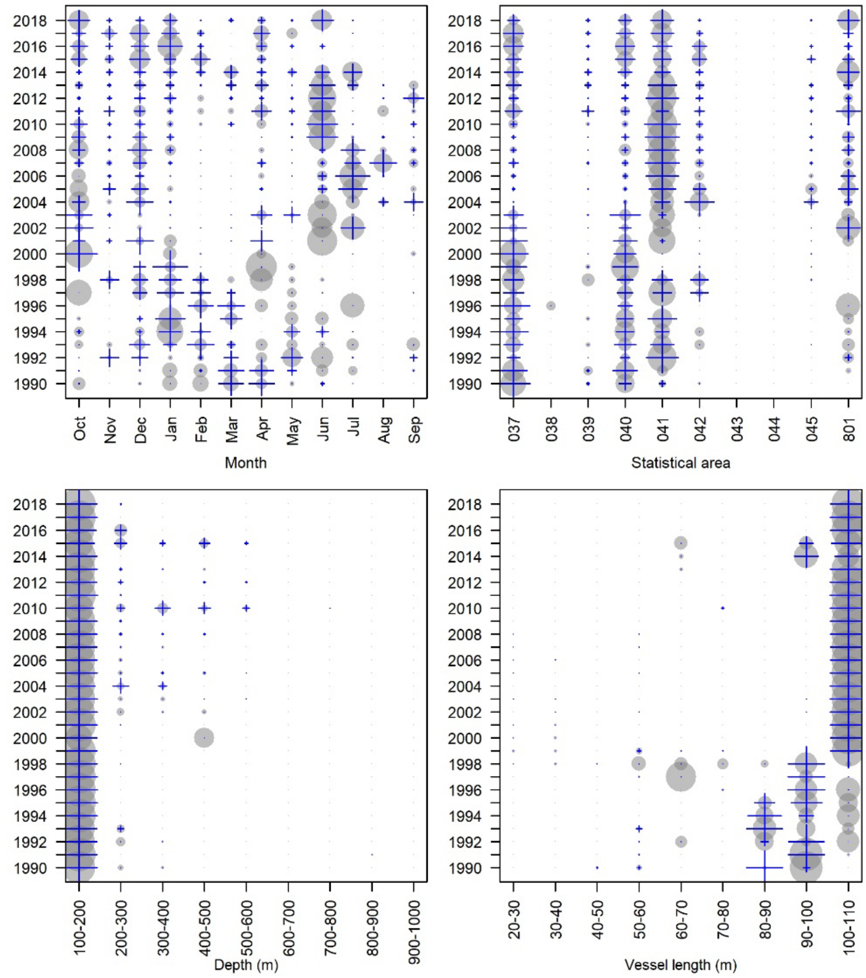

Figure A1a: Representativeness of observer sampling of mid-water trawl blue mackerel EMA 7 (WCNI) catch by fishing year and month, statistical area, depth (m), and vessel size (m). Circles show the proportion of catch by month within a year; crosses show the proportion of observed catch for the same cells. Representation is demonstrated by how closely the cross matches the circle diameter.

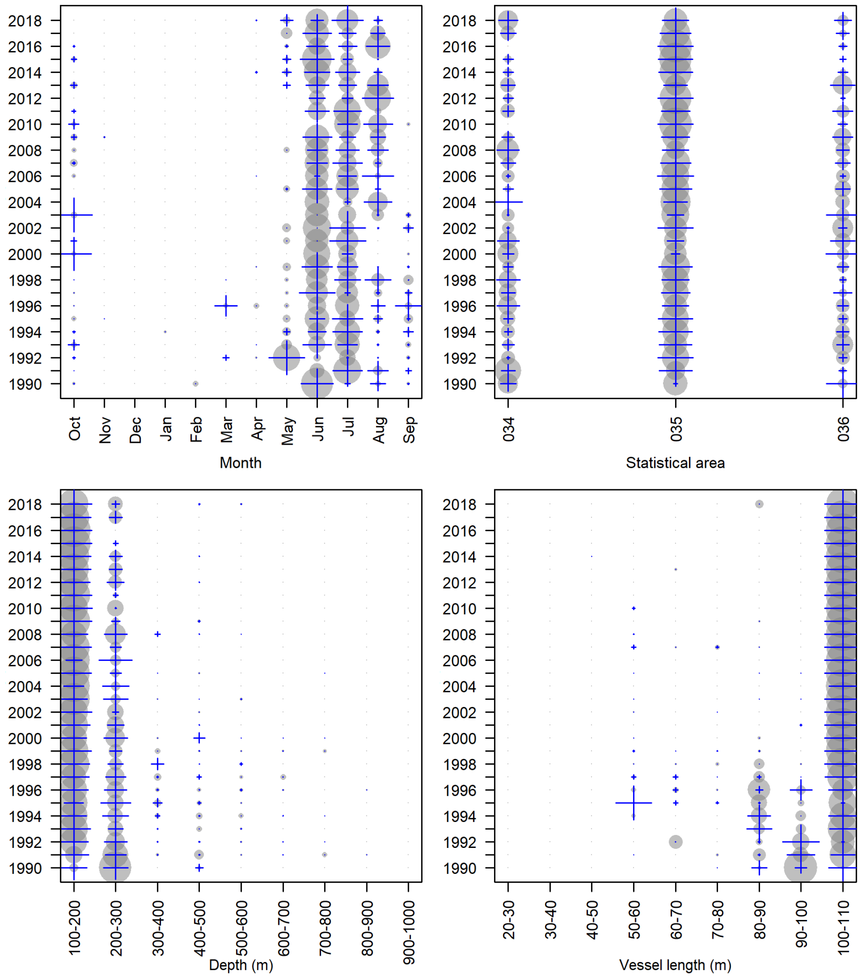

Figure A1b: Representativeness of observer sampling of mid-water trawl blue mackerel EMA 7 (WCSI) catch by fishing year and month, statistical area, depth (m), and vessel size (m). Circles show the proportion of catch by month within a year; crosses show the proportion of observed catch for the same cells. Representation is demonstrated by how closely the cross matches the circle diameter.

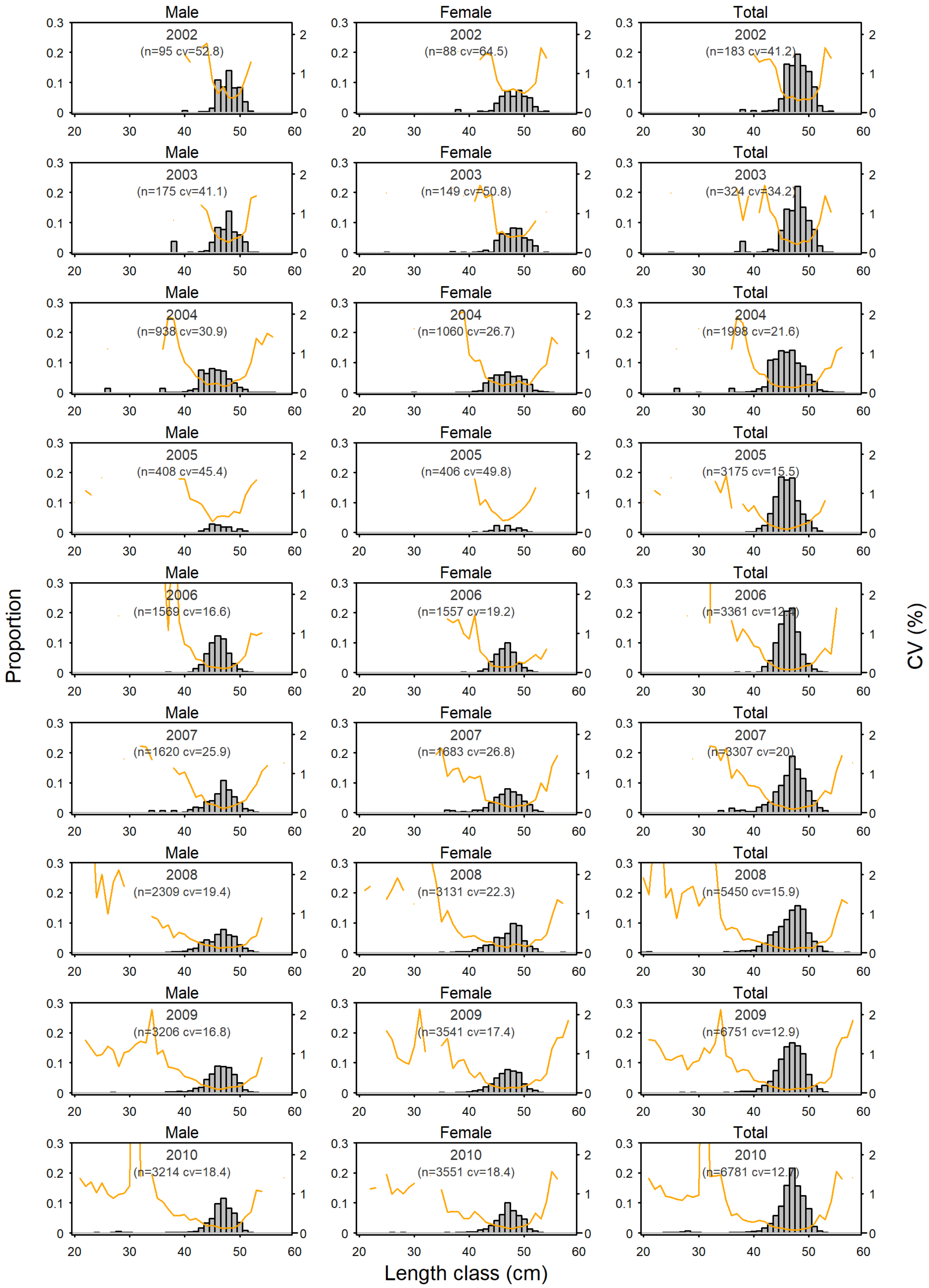

Figure A2a: Scaled length frequency distributions of midwater trawl-caught blue mackerel from observer sampling programme in EMA 7 (WCNI) 2002–2010 (grey bars) with coefficient of variation (orange line).

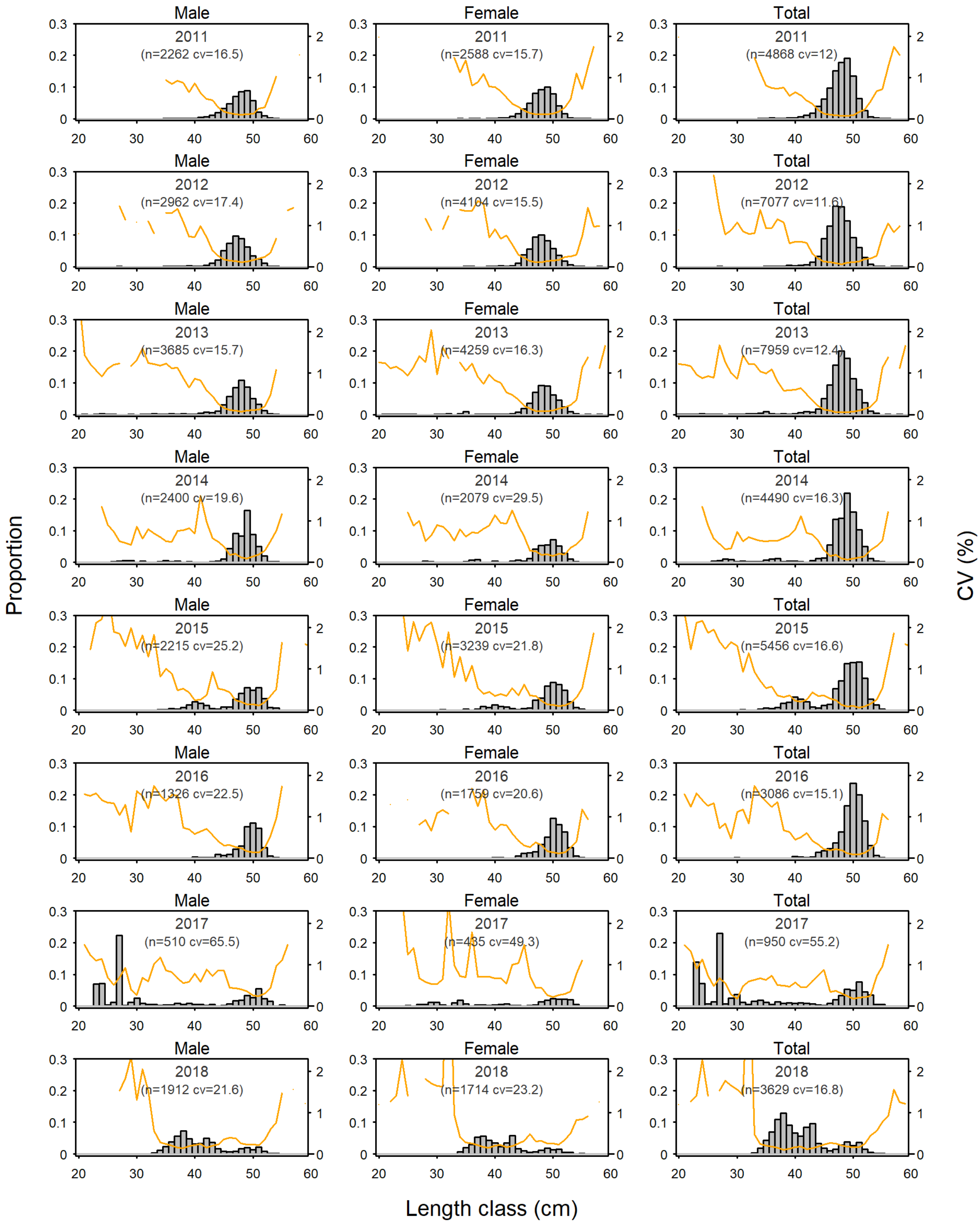

Figure A2a continued: Scaled length frequency distributions of mid-water trawl-caught blue mackerel from observer sampling programme in EMA 7 (WCNI) 2011–2018 (grey bars) with coefficient of variation (orange line).

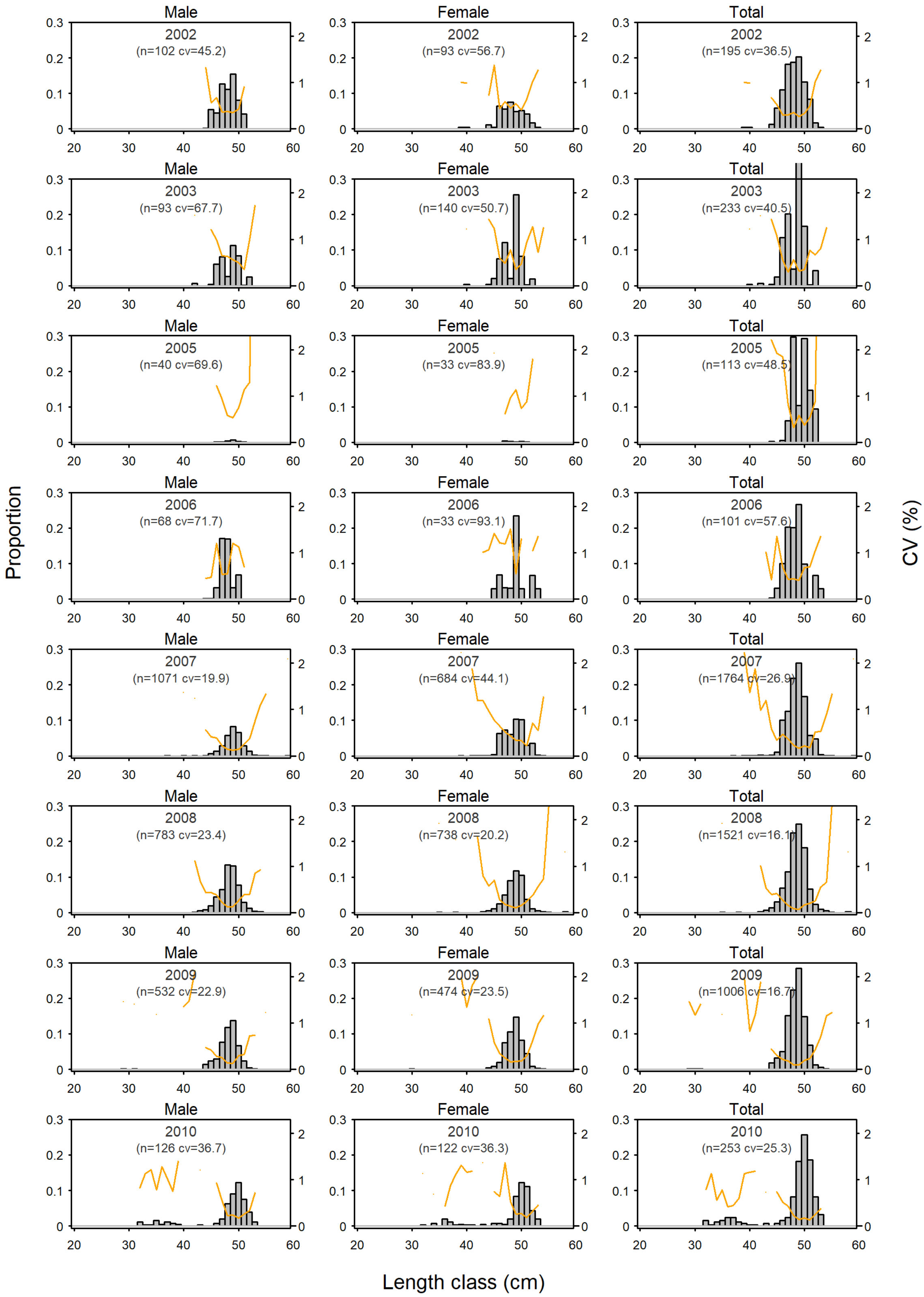

Figure A2b: Scaled length frequency distributions of mid-water trawl-caught blue mackerel from observer sampling programme in EMA 7 (WCSI) 2002–2010 (grey bars) with coefficient of variation (orange line).

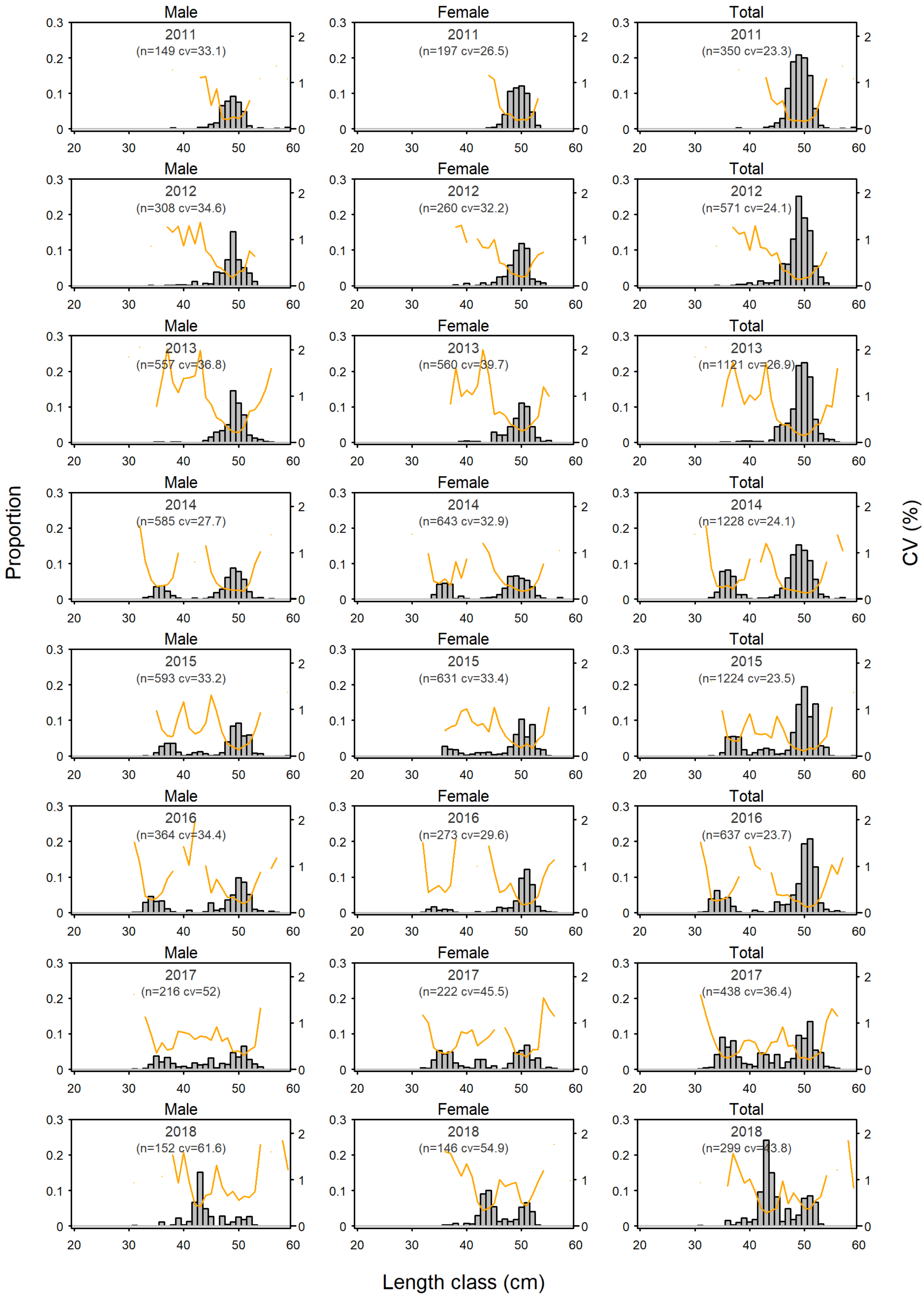

Figure A2b continued: Scaled length frequency distributions of mid-water trawl-caught blue mackerel from observer sampling programme in EMA 7 (WCSI) 2011–2018 (grey bars) with coefficient of variation (orange line).

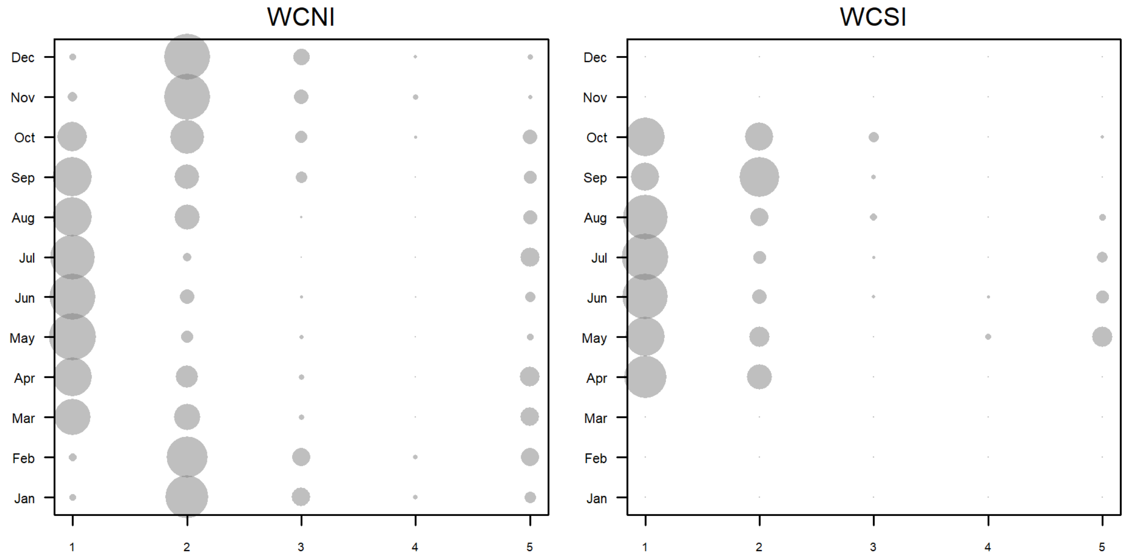

Figure A3: Proportion of gonad stages of female mid-water trawl-caught blue mackerel by month sampled by observers from commercial catches, by month for EMA 7. Stages are: 1, resting/immature; 2, maturing; 3, ripe; 4, running ripe; 5, spent.

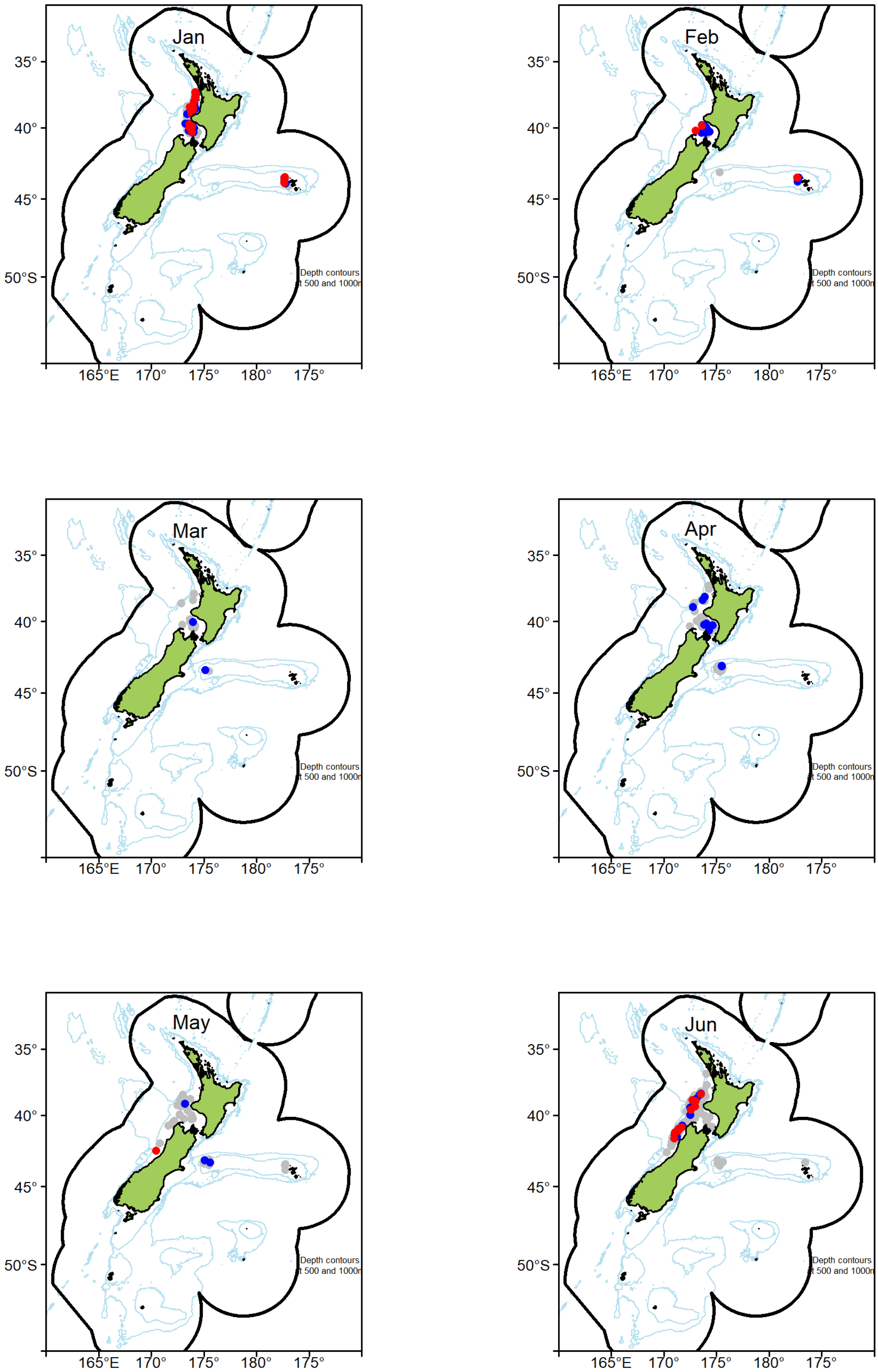

Figure A4: Location of female blue mackerel gonad stages sampled by observers by month for all years combined January to June. Grey: stage 1(immature), stage 2 (maturing), or stage 5 (spent); blue = stage 3 (ripe), red = stage 4 (running ripe).

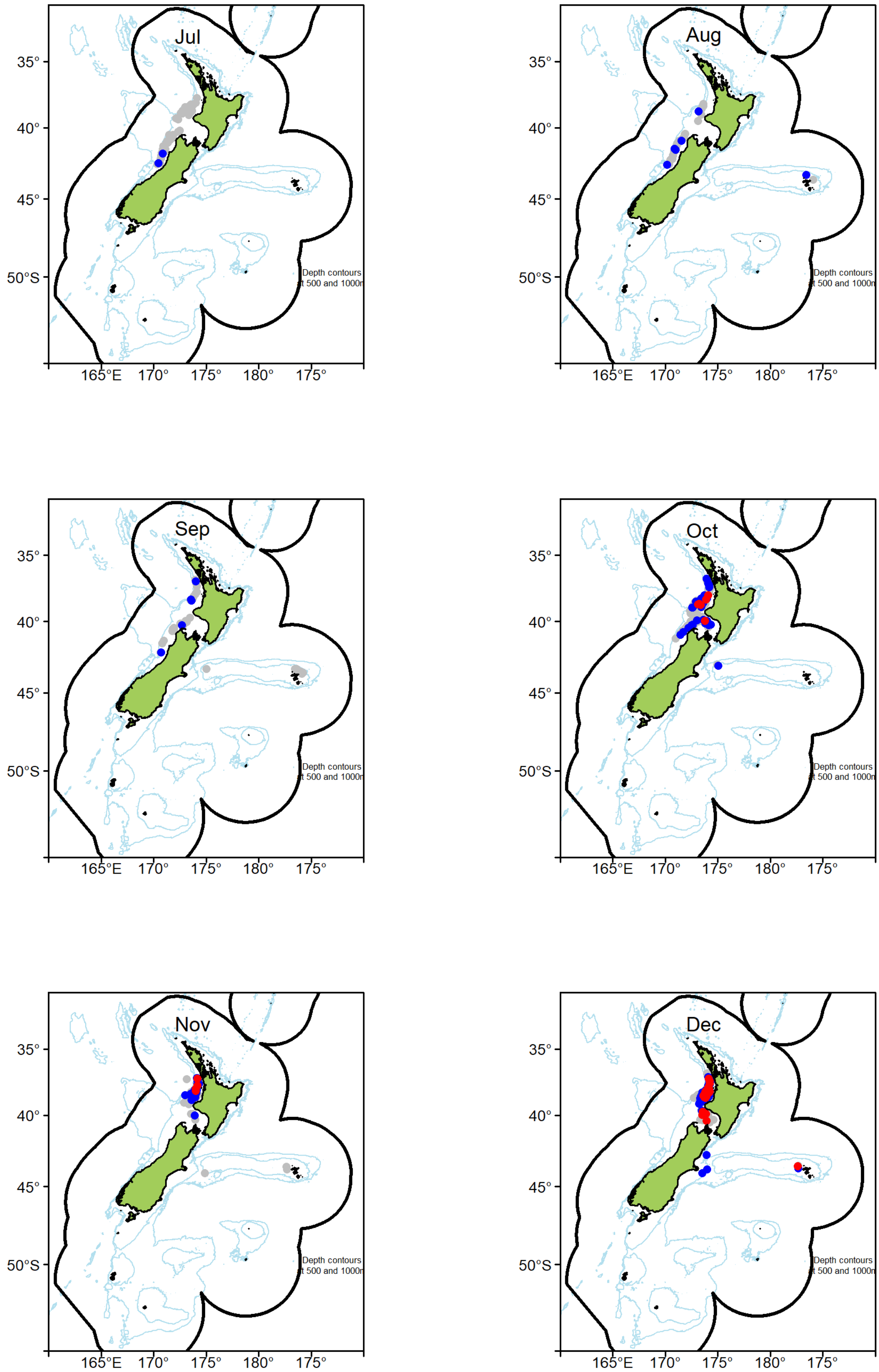

Figure A4 continued: Location of female blue mackerel gonad stages sampled by observers by month for all years combined July to December. Grey: stage 1(immature), stage 2 (maturing), or stage 5 (spent); blue = stage 3 (ripe), red = stage 4 (running ripe).

APPENDIX B: MARKET SAMPLE DATA

Table B1: Number of landings and fish measured for length for blue mackerel caught by purse seine collected from the market sampling programme in EMA 7 for fishing years in which data exist.

EMA 7				
Fishing year	Landings	Males	Females	Total
2004	3	30	26	56
2005	2	200	224	424
2006	2	105	95	200

Table B2: Number of otolith pairs collected from market samples for EMA 7 caught by purse seine for calendar years for which data exist.

Year	EMA 7
2004	363
2005	176
2006	123
Total	662

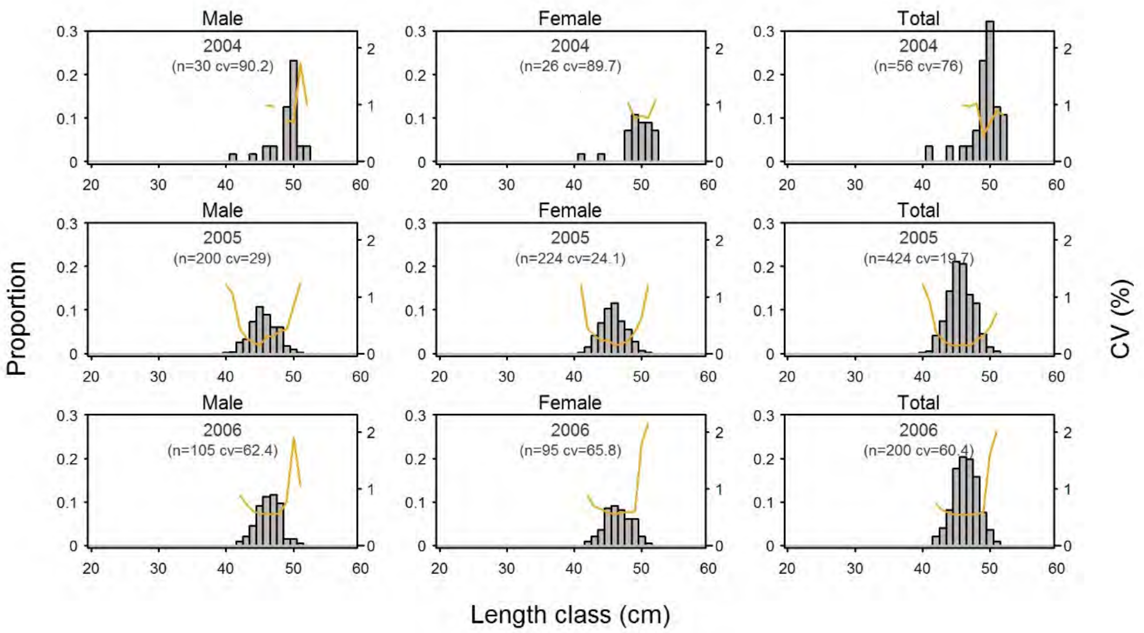

Figure B1: Scaled length frequency distributions of blue mackerel caught by purse seine from market sampling in EMA 7 2004–2006 calendar years (grey bars) and coefficient of variation (orange line).

APPENDIX C: COMMERCIAL DATA CHARACTERISATION

Table C1: List of tables and fields requested in the Fisheries New Zealand extract 12560.

Fishing events table

FishingEventKey	FishingDepth	TotalHookCount	ColumnA
SourceIdentifierKey	EffortHeight	LiningSetEndDatetime	ColumnB
DcfKey	EffortCount	LiningHaulStartDatetime	ColumnC
StartDatetime	SetNetMeshCount	StartLatitude	ColumnD
EndDatetime	SequenceNumber	StartLongitude	Display_fishyear
FishingMethodCode	EffortTotalCount	EndLatitude	StatisticalAreaCode
TargetSpeciesCode	EffortWidth	EndLongitude	vessel_key
FishingDuration	TrawlSpeed	PairTrawlYn	FormType
TotalCatchWeight	TotalNetLength	BottomDepth	TripId

Landing events table

EventKey	SpeciesCode	unit_weight	TripId
SourceIdentifierKey	SpeciesPreferredCommonName	convert_factor	TripStartDatetime
DcfKey	FishstockCode	GreenweightKgQuantity	TripEndDatetime
lfr_no	state_code	GreenWeightType	vessel_key
lfr_name	DestinationTypeCode	ProcessedWeight	
Landing_datetime	unit_type	ProcessedWeightType	
LandingName	unit_num	FormType	

Estimated subcatch table

EventKey	DCFKey	SpeciesCode	MeatweightKgQuantity
SourceIdentifierKey	FormType	GreenweightKgQuantity	UnitQuantity

Processed catch table

EventKey	SpeciesCode	GreenWeight	FormType
SourceIdentifierKey	ProductStateCode	GreenWeightType	TripId
DcfKey	UnitNum	ProcessedWeight	
SpecprodActionType	UnitWeight	ProcessedWeightType	
processed_datetime	ConversionFactor	vessel_key	

Vessel history table

HistoricalPublicVesselKey	HistoricalBuiltYear	HistoricalGrossTonnes
HistoricalFlagNationalityCode	HistoricalEngineKilowatts	HistoricalOverallLengthMetres

Table C2: Destination codes, total landing weight, number of landings, and whether the records were kept or dropped, for blue mackerel catch reported for fishing years 1990–2018, for EMA 7.

EMA7

Destination code	**Greenweight (t)**	**No. records**	**Description**	**Action**
L	75 421.46	7 532	Landed in New Zealand to a Licensed Fish Receiver	Keep
T	3 811.49	250	Transferred to another vessel	Keep
O	127.52	29	Conveyed outside New Zealand	Keep
E	59.08	993	Eaten	Keep
D	30.82	43	Discarded	Keep
A	3.94	11	Accidental loss	Keep
J	2.28	15	Observer authorised discard	Keep
U	1.70	27	Used as bait	Keep
S	0.20	2	Seized by the Crown	Keep
F	0.13	17	Recreational catch	Keep
H	0.02	1	Loss from holding pot	Keep
C	0.01	1	Disposed to the Crown	Keep
W	<0.01	1	Sold at wharf	Keep
R	2 375.49	334	Retained on board	Drop
B	23.28	243	Stored as bait	Drop
Invalid	10.40	5	Invalid destination type code recorded	Drop
Q	1.79	65	Holding receptacle on land	Drop

Table C3: Number of landing events by major destination code and form type for EMA 7 for fishing years 1990–2018. CLR is Catch Landing Return; CELR is Catch Effort Landing Return; L: landed to NZ; T: transferred to another vessel; R: retained on board. Note: The 'Total' column includes counts of destination codes other than L, R and T, 2018 CLR forms include some electronic reporting system forms as well.

EMA7

	CLR form					**CELR and NCELR form**				
	L	**T**	**R**	**Other**	**Total**	**L**	**R**	**Other**	**Total**	**Total**
1990	17	22	34	13	86	119	-	1	120	206
1991	22	44	40	10	116	141	-	4	145	261
1992	32	56	42	4	134	182	-	14	196	330
1993	29	45	34	8	116	363	-	34	397	513
1994	58	25	46	26	155	344	-	29	373	528
1995	83	17	13	29	142	267	-	20	287	429
1996	65	12	2	5	84	151	4	16	171	255
1997	99	17	14	13	143	94	5	27	126	269
1998	155	11	11	42	219	42	-	19	61	280
1999	204	1	7	35	247	85	1	2	88	335
2000	176	-	2	15	193	73	-	9	82	275
2001	186	-	2	32	220	62	-	13	75	295
2002	265	-	6	43	314	26	1	15	42	356
2003	200	-	1	32	233	71	-	12	83	316
2004	170	-	7	36	213	30	3	24	57	270
2005	197	-	1	40	238	29	1	15	45	283
2006	155	-	5	32	192	32	1	10	43	235
2007	184	-	9	52	245	52	-	12	64	309
2008	202	-	7	46	255	69	-	21	90	345
2009	150	-	9	46	205	120	-	7	127	332
2010	160	-	3	46	209	110	-	4	114	323
2011	170	-	4	34	208	109	-	8	117	325
2012	161	-	5	38	204	108	-	16	124	328
2013	175	-	3	43	221	115	-	13	128	349
2014	175	-	1	36	212	120	-	9	129	341
2015	195	-	2	37	234	87	-	9	96	330
2016	155	-	1	42	198	103	1	7	111	309
2017	188	-	5	45	238	98	-	6	104	342
2018	67	-	-	9	76	98	-	5	103	500
Total	4 095	250	316	889	5 550	3 300	17	381	3 698	9 569

Table C4: The reported Quota Management Report (QMR) or Monthly Harvest Return (MHR) catch, annual retained landings in the groomed and unmerged dataset, and retained landings in the groomed and merged dataset, and estimated catches in the groomed and merged dataset for EMA 7 for fishing years 1990–2018. All catch and landings data are in tonnes.

EMA7

Year	MHR	Unmerged landings	Merged landings	Estimated catch	Percent MHR
1990	1 492	1 489	1 236	1 465	98
1991	3 004	2 383	1 879	2 095	70
1992	3 607	3 468	2 972	2 953	82
1993	1 880	1 475	1 367	1 131	60
1994	1 402	1 236	1 143	1 010	72
1995	1 804	1 658	1 505	1 380	76
1996	1 218	687	622	503	41
1997	2 537	2 308	2 431	1 921	76
1998	2 310	2 315	2 436	2 082	90
1999	8 756	8 761	8 924	7 452	85
2000	3 169	3 169	3 339	2 922	92
2001	3 278	3 278	3 450	2 636	80
2002	5 101	5 086	5 346	4 338	85
2003	3 563	3 317	3 403	2 514	71
2004	2 701	2 565	2 730	2 330	86
2005	4 817	4 946	5 225	4 698	98
2006	3 784	3 662	3 886	3 367	89
2007	2 698	2 714	2 868	2 520	93
2008	2 929	2 851	2 948	2 528	86
2009	3 503	3 221	3 403	2 941	84
2010	3 260	3 249	3 461	2 928	90
2011	1 996	2 016	2 134	1 657	83
2012	2 707	2 573	2 710	2 183	81
2013	2 401	2 276	2 411	1 755	73
2014	1 200	1 161	1 210	901	75
2015	892	889	939	526	59
2016	761	761	808	387	51
2017	625	623	654	258	41
2018	3 254	3 196	3 392	2 413	74

Table C5: Total number of trips, number of trips with zero estimated catch, and proportion of trips with zero estimated catch, by form type for EMA stocks for fishing years 1990–2018. Areas are shown in Figure 1. TCEPR includes ERS forms in the 2017–18 fishing year.

EMA7

	CELR/TCE estimated catch			**TCEPR estimated catch**		
	Total	**Zero**	**Proportion**	**Total**	**Zero**	**Proportion**
1990	106	42	0.40	41	20	0.49
1991	138	75	0.54	47	14	0.30
1992	184	112	0.61	55	14	0.25
1993	364	123	0.34	41	11	0.27
1994	338	136	0.40	51	16	0.31
1995	263	116	0.44	67	16	0.24
1996	117	69	0.59	56	24	0.43
1997	89	58	0.65	74	25	0.34
1998	46	28	0.61	111	31	0.28
1999	69	20	0.29	151	95	0.63
2000	65	38	0.58	133	92	0.69
2001	60	30	0.50	126	93	0.74
2002	27	19	0.70	142	93	0.65
2003	66	34	0.52	134	87	0.65
2004	30	18	0.60	104	70	0.67
2005	27	14	0.52	130	80	0.62
2006	31	25	0.81	93	49	0.53
2007	18	8	0.44	106	53	0.50
2008	32	25	0.78	94	48	0.51
2009	28	19	0.68	89	52	0.58
2010	35	30	0.86	80	37	0.46
2011	41	37	0.90	93	60	0.65
2012	16	10	0.62	91	52	0.57
2013	34	29	0.85	84	43	0.51
2014	38	35	0.92	67	22	0.33
2015	42	39	0.93	78	42	0.54
2016	48	41	0.85	66	31	0.47
2017	39	36	0.92	87	55	0.63
2018	40	33	0.82	8	3	0.38

Table C6: Total catch (t) for each stock from groomed and merged data, for fishing years 1990–2018. Stock areas are shown in Figure 1. 0: catch < 0.1 t.

Year	EMA1	EMA2	EMA3	EMA7	Total
1990	2 153	76	2	1 687	3 919
1991	5 687	93	12	2 295	8 086
1992	11 198	285	1	3 035	14 520
1993	7 630	284	70	1 391	9 375
1994	4 067	218	162	1 177	5 624
1995	6 467	94	112	1 517	8 189
1996	3 469	118	52	657	4 297
1997	6 744	75	34	2 733	9 586
1998	4 575	105	9	2 464	7 152
1999	4 505	172	22	8 930	13 631
2000	3 601	74	2	3 340	7 016
2001	9 738	113	2	3 452	13 305
2002	6 664	155	18	5 382	12 219
2003	7 748	114	93	3 403	11 359
2004	6 564	109	1	2 730	9 404
2005	7 899	9	0	5 225	13 133
2006	6 590	13	140	3 887	10 630
2007	8 025	133	19	2 869	11 047
2008	6 154	4	100	2 949	9 206
2009	3 310	2	103	3 403	6 818
2010	8 859	2	39	3 461	12 362
2011	6 846	2	11	2 136	8 995
2012	8 311	2	12	2 711	11 035
2013	7 346	3	121	2 411	9 881
2014	6 996	4	29	1 210	8 239
2015	8 089	16	92	939	9 137
2016	7 379	18	28	808	8 234
2017	7 639	83	125	654	8 501
2018	7 980	33	52	3 394	11 460
Total	192 232	2 411	1 464	80 253	276 359

Table C7: Total catch (t) by vessel nationality from groomed and merged data, for fishing years 1990–2018 for all EMA stocks.

Year	NZ	Ukraine	Unknown	Dominica	Belize	Russia	Vanuatu	Other	Total
1990	2 981	<0.1	839	-	-	98	-	<0.1	3 919
1991	5 632	140	2 062	-	-	177	-	75	8 086
1992	8 993	137	5 084	-	-	299	-	7	14 520
1993	8 565	183	604	-	1	10	-	12	9 375
1994	4 825	383	325	-	8	22	53	6	5 624
1995	7 021	522	422	-	14	-	78	134	8 189
1996	3 811	402	47	-	10	9	<0.1	17	4 297
1997	8 059	843	370	-	4	5	254	51	9 586
1998	5 892	906	1	-	66	93	106	88	7 152
1999	9 974	1 623	<0.1	1 124	857	-	33	20	13 631
2000	5 683	1 036	<0.1	288	<0.1	-	-	10	7 016
2001	11 571	1 182	-	550	-	-	-	2	13 305
2002	9 256	2 040	-	914	-	-	-	10	12 219
2003	9 867	1 047	-	352	-	-	-	94	11 359
2004	8 236	813	-	356	-	-	-	<0.1	9 404
2005	11 045	1 471	-	616	-	-	-	1	13 133
2006	9 619	382	-	629	-	-	-	<0.1	10 630
2007	9 977	454	-	414	-	156	-	45	11 047
2008	8 147	574	-	463	-	-	-	22	9 206
2009	5 573	749	-	458	-	-	-	38	6 818
2010	11 362	403	-	590	-	-	-	6	12 362
2011	8 587	256	-	152	-	-	-	<0.1	8 995
2012	10 479	144	-	402	-	-	-	9	11 035
2013	9 497	239	-	145	-	-	-	<0.1	9 881
2014	7 977	85	-	177	-	-	-	<0.1	8 239
2015	8 857	163	-	116	-	-	-	<0.1	9 137
2016	8 166	45	-	22	-	-	-	-	8 234
2017	8 501	-	-	-	-	-	-	-	8 501
2018	11 460	-	-	-	-	-	-	-	11 460
Total	239 614	16 220	9 754	7 768	961	870	525	647	276 359

Table C8: Proportion of blue mackerel catch reported from EMA 7 by a) month, b) statistical area, c) method, and d) target species for fishing years 1990–2018 separated by trawl and purse seine methods.

C8a) Month
Trawl

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1990	-	-	-	0.24	0.14	0.22	0.02	0.02	0.29	-	0.02	0.05	160
1991	-	-	-	0.08	0.01	-	-	0.01	0.36	0.38	0.14	0.01	1 356
1992	-	0.01	0.01	0.02	0.01	-	0.11	0.41	0.35	0.07	-	0.01	2 852
1993	0.02	0.03	0.02	0.04	0.08	0.01	0.08	0.06	0.28	0.30	-	0.09	826
1994	-	-	0.08	0.10	0.06	-	-	0.08	0.33	0.32	0.01	0.01	832
1995	0.02	-	0.13	0.03	-	0.07	-	0.18	0.45	0.05	0.05	0.02	1 327
1996	-	-	-	-	0.02	0.01	0.04	0.04	0.61	0.18	0.07	0.02	543
1997	-	0.01	0.01	-	-	-	-	0.01	0.54	0.37	0.03	0.03	1 866
1998	-	0.02	0.02	0.02	0.01	0.01	0.05	0.02	0.44	0.24	0.11	0.06	2 434
1999	-	-	0.01	-	-	-	0.02	0.19	0.66	0.12	-	-	4 668
2000	0.04	-	0.02	-	-	-	-	0.02	0.88	0.03	-	0.01	2 906
2001	-	0.01	0.06	-	-	-	-	0.16	0.59	0.17	-	-	2 903
2002	0.06	-	0.03	-	-	-	-	0.05	0.54	0.32	-	0.01	4 860
2003	0.07	-	0.03	-	-	-	0.09	0.01	0.70	0.10	-	0.01	2 389
2004	0.40	0.04	0.12	-	-	-	-	0.02	0.32	0.03	0.08	-	2 674
2005	0.25	0.09	0.11	-	-	-	-	-	0.15	0.34	-	0.05	4 652
2006	0.15	0.02	0.02	-	-	0.01	0.02	-	0.17	0.60	0.01	0.01	3 624
2007	0.06	0.11	0.05	0.01	-	-	0.03	-	0.31	0.11	0.28	0.06	2 508
2008	0.16	0.10	0.15	0.07	-	-	0.02	-	0.12	0.20	0.06	0.12	2 615
2009	0.14	0.03	0.10	0.01	-	-	-	-	0.63	0.02	0.03	0.04	2 946
2010	0.08	0.03	0.08	0.03	-	-	0.08	0.24	0.39	0.02	0.01	0.02	3 459
2011	0.03	0.07	0.15	0.02	0.06	-	0.16	0.15	0.21	0.07	0.08	0.01	1 905
2012	0.02	0.03	0.07	0.01	0.03	-	0.01	0.02	0.61	0.01	0.08	0.10	2 517
2013	0.08	0.07	0.09	0.03	-	0.12	0.04	-	0.42	0.08	0.02	0.06	2 200
2014	0.01	0.08	0.10	0.05	0.03	0.12	0.05	0.04	0.34	0.18	0.01	-	1 207
2015	0.13	0.12	0.14	0.16	0.01	0.01	0.02	0.15	0.27	-	-	-	938
2016	0.12	0.03	0.18	0.18	0.01	-	0.04	0.03	0.16	0.18	0.07	-	782
2017	0.06	0.15	0.17	0.11	-	-	0.12	0.07	0.20	0.05	0.09	-	640
2018	0.31	0.01	0.07	0.08	-	0.05	0.04	0.03	0.40	0.03	-	-	3 371
Total	0.09	0.03	0.06	0.02	0.01	0.01	0.03	0.07	0.43	0.17	0.04	0.03	65 961

C8a) Month continued
Purse seine

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1990	-	-	-	0.12	0.24	0.26	0.23	0.02	0.01	0.01	-	0.10	1 521
1991	-	-	-	0.02	0.27	0.56	0.14	0.01	-	-	-	-	934
1992	-	-	-	0.25	0.05	0.18	0.23	0.01	-	-	-	0.28	179
1993	-	-	0.01	0.03	0.62	0.33	0.01	-	-	-	-	-	553
1994	0.78	0.09	0.05	-	0.02	0.01	0.05	-	-	-	-	-	329
1995	0.01	-	0.28	-	0.07	0.01	0.01	0.63	-	-	-	-	170
1996	-	0.02	-	-	0.61	0.20	0.12	0.05	-	-	-	-	107
1997	-	-	0.30	0.20	-	-	0.49	-	-	-	-	-	607
1998	-	-	-	-	-	-	-	1	-	-	-	-	28
1999	-	-	-	-	-	0.41	0.29	0.28	0.01	-	-	-	3 992
2000	-	-	-	0.02	-	-	0.37	0.46	0.14	-	-	-	432
2001	-	-	0.20	-	0.01	0.18	0.57	0.04	-	-	-	-	545
2002	0.93	-	-	-	-	0.01	-	0.06	0.01	-	-	-	522
2003	-	-	-	-	0.20	0.71	0.09	-	-	-	-	-	1 012
2004	-	-	-	-	-	1	-	-	-	-	-	-	55
2005	-	-	-	-	-	-	0.94	0.06	-	-	-	-	572
2006	-	-	-	-	0.45	-	-	0.55	-	-	-	-	260
2007	-	-	-	-	-	0.17	0.83	-	-	-	-	-	359
2008	-	-	-	-	-	0.59	-	0.41	-	-	-	-	332
2009	-	-	-	0.02	-	0.51	0.48	-	-	-	-	-	454
2010	-	-	-	-	0.83	0.17	-	-	-	-	-	-	<1
2011	-	-	-	-	-	-	1	-	-	-	-	-	224
2012	-	-	-	-	-	0.68	0.02	-	-	-	0.29	-	190
2013	-	-	-	-	-	-	-	1	-	-	-	-	209
2014	-	-	0.02	-	0.10	0.54	0.34	-	-	-	-	-	<1
2015	-	1	-	-	-	-	-	-	-	-	-	-	<1
2016	-	-	-	-	0.01	0.99	-	-	-	-	-	-	25
2017	-	-	1	-	-	-	-	-	-	-	-	-	12
2018	-	-	-	-	-	0.01	-	-	-	-	0.97	0.01	20
Total	0.05	-	0.03	0.03	0.10	0.32	0.28	0.15	0.01	-	0.01	0.01	13 644

C8b) Statistical Area
Trawl

Year	017	018	034	035	036	037	038	039	040	041	042	045	047	801	Total
1990	-	-	0.11	0.16	0.04	0.43	-	0.01	0.22	0.02	-	-	-	-	160
1991	-	-	0.49	0.30	0.06	0.05	-	0.01	0.04	0.02	-	-	-	0.01	1 356
1992	-	-	0.07	0.29	0.10	0.03	-	-	0.05	0.40	-	-	-	0.06	2 852
1993	-	-	0.07	0.36	0.23	0.09	-	0.01	0.08	0.12	-	-	-	0.04	826
1994	-	-	0.16	0.43	0.14	0.11	-	-	0.10	0.05	-	-	-	0.01	832
1995	-	-	0.13	0.39	0.14	0.06	-	-	0.12	0.13	-	-	-	0.03	1 327
1996	-	-	0.38	0.37	0.17	0.03	0.01	-	0.01	-	-	-	-	0.04	543
1997	-	-	0.32	0.61	0.04	-	-	-	-	0.01	-	-	-	-	1 866
1998	-	-	0.23	0.58	0.05	0.05	-	0.02	0.02	0.02	0.03	-	-	-	2 434
1999	-	-	0.13	0.74	0.11	-	-	-	0.02	-	-	-	-	-	4 668
2000	-	-	0.39	0.43	0.12	0.04	-	-	0.02	-	-	-	-	-	2 906
2001	-	-	0.21	0.31	0.16	0.02	-	-	0.06	0.19	-	-	-	0.04	2 903
2002	-	-	0.03	0.09	0.13	0.05	-	-	0.04	0.23	-	-	-	0.42	4 860
2003	-	-	0.03	0.16	0.05	0.08	-	-	0.10	0.43	0.01	-	-	0.14	2 389
2004	-	-	-	0.01	0.02	-	-	-	0.02	0.47	0.35	0.06	-	0.06	2 674
2005	-	-	-	0.03	0.04	-	-	-	0.02	0.45	0.14	0.11	-	0.21	4 652
2006	-	-	0.03	0.18	0.03	0.02	-	-	0.03	0.52	0.06	0.02	-	0.11	3 624
2007	-	-	0.03	0.19	0.03	0.02	-	-	0.03	0.56	0.05	0.01	-	0.07	2 508
2008	-	-	0.08	0.06	0.04	0.04	-	-	0.12	0.54	0.02	-	-	0.09	2 615
2009	-	-	0.01	0.07	0.05	0.01	-	-	0.02	0.69	0.04	0.01	-	0.11	2 946
2010	-	-	-	0.03	0.01	0.08	-	0.02	0.05	0.76	0.05	-	-	-	3 459
2011	-	-	0.03	0.10	0.04	0.19	-	0.02	0.07	0.39	0.05	-	-	0.11	1 905
2012	-	-	0.01	0.11	-	0.06	-	-	0.02	0.70	0.02	0.02	-	0.06	2 517
2013	-	-	0.01	0.03	0.03	0.16	-	0.03	0.03	0.56	0.07	0.02	-	0.08	2 200
2014	-	-	0.01	0.19	0.03	0.17	-	0.02	0.10	0.15	0.07	-	-	0.25	1 207
2015	-	-	0.04	0.38	-	0.12	-	-	0.12	0.17	0.10	-	-	0.06	938
2016	-	-	-	0.41	0.03	0.16	-	-	0.19	0.12	0.07	-	-	0.02	782
2017	-	-	0.07	0.27	0.05	0.18	-	-	0.11	0.29	0.02	-	-	0.01	640
2018	-	-	0.05	0.04	0.02	0.10	-	0.02	0.12	0.31	-	-	-	0.35	3 371
Total	-	-	0.09	0.23	0.06	0.05	-	0.01	0.05	0.34	0.04	0.01	-	0.11	65 961

C8b) Statistical Area continued
Purse seine

Year	017	018	034	035	036	037	038	039	040	041	042	045	047	801	Total
1990	0.34	0.42	-	-	0.02	0.16	0.05	-	0.01	-	-	-	-	-	1 521
1991	0.02	0.79	-	-	-	-	0.08	0.11	-	-	-	-	-	-	934
1992	0.04	0.65	-	-	0.04	-	-	-	-	-	-	-	0.16	-	179
1993	0.08	0.10	-	-	-	0.04	-	-	-	-	-	-	0.78	-	553
1994	0.01	0.10	-	-	0.02	0.02	-	-	-	-	-	-	0.84	-	329
1995	0.01	0.07	-	-	-	0.01	-	-	0.28	-	-	-	0.63	-	170
1996	-	0.38	-	-	-	0.62	-	-	-	-	-	-	-	-	107
1997	-	0.49	-	-	-	0.04	-	-	0.46	-	-	-	-	-	607
1998	-	1	-	-	-	-	-	-	-	-	-	-	-	-	28
1999	-	-	-	-	0.02	0.75	-	0.06	0.17	-	-	-	-	-	3 992
2000	0.03	-	-	-	-	0.97	-	-	-	-	-	-	-	-	432
2001	0.22	-	-	-	-	0.52	-	-	0.25	-	-	-	-	-	545
2002	0.01	0.06	-	-	-	-	-	-	0.01	-	-	-	0.93	-	522
2003	0.03	-	-	-	0.01	0.91	-	-	0.05	-	-	-	-	-	1 012
2004	-	-	-	-	-	0.98	-	-	-	0.01	0.01	-	-	-	55
2005	-	-	-	-	-	0.71	-	0.29	-	-	-	-	-	-	572
2006	-	-	-	-	0.03	0.07	-	0.45	-	-	-	-	-	-	260
2007	0.01	-	-	-	-	0.05	-	-	0.67	0.11	-	-	0.17	-	359
2008	-	-	-	-	-	0.40	-	0.39	-	-	0.21	-	-	-	332
2009	-	-	-	-	-	0.29	-	-	0.70	-	-	-	0.02	-	454
2010	-	-	-	-	-	-	-	-	-	0.17	0.83	-	-	-	<1
2011	-	-	-	-	-	1	-	-	-	-	-	-	-	-	224
2012	-	-	-	-	-	0.02	0.68	-	-	-	-	-	0.29	-	190
2013	-	-	-	-	-	1	-	-	-	-	-	-	-	-	209
2014	-	-	-	-	0.15	0.05	0.02	-	0.10	0.47	0.19	-	0.02	-	<1
015	-	-	-	-	-	-	-	-	-	-	-	-	1	-	<1
2016	-	-	-	-	-	-	-	-	-	0.16	-	0.07	-	-	25
2017	-	-	-	-	-	-	-	-	-	-	-	-	1	-	12
2018	-	-	0.01	-	-	-	-	-	-	-	-	-	0.99	-	20
Total	0.06	0.15	-	-	0.01	0.45	0.02	0.05	0.13	-	0.01	-	0.11	-	13 644

C8c) Method. BT: bottom trawl; MB: midwater trawl on the bottom (within 5 metres of the seabed); MW: midwater trawl; PS: purse seine.

Year	BT	MB	MW	PS	Other	Total
1990	0.06	0.01	0.02	0.90	0.00	1 687
1991	0.11	0.23	0.25	0.41	0.00	2 295
1992	0.16	0.34	0.44	0.06	0.00	3 035
1993	0.15	0.23	0.21	0.40	0.01	1 391
1994	0.06	0.39	0.26	0.28	0.01	1 177
1995	0.02	0.39	0.47	0.11	0.01	1 517
1996	0.08	0.26	0.48	0.16	0.01	657
1997	0.01	0.27	0.40	0.22	0.10	2 733
1998	0.12	0.21	0.65	0.01	0.00	2 464
1999	0.00	0.16	0.36	0.45	0.03	8 930
2000	0.01	0.31	0.56	0.13	0.00	3 340
2001	0.00	0.50	0.34	0.16	0.00	3 452
2002	0.00	0.56	0.34	0.10	0.00	5 382
2003	0.00	0.54	0.16	0.30	0.00	3 403
2004	0.00	0.60	0.38	0.02	0.00	2 730
2005	0.00	0.62	0.27	0.11	0.00	5 225
2006	0.00	0.72	0.21	0.07	0.00	3 887
2007	0.00	0.54	0.33	0.13	0.00	2 869
2008	0.00	0.55	0.34	0.11	0.00	2 949
2009	0.00	0.46	0.41	0.13	0.00	3 403
2010	0.00	0.30	0.70	0.00	0.00	3 461
2011	0.00	0.42	0.47	0.10	0.00	2 136
2012	0.00	0.29	0.64	0.07	0.00	2 711
2013	0.00	0.22	0.69	0.09	0.00	2 411
2014	0.00	0.38	0.62	0.00	0.00	1 210
2015	0.00	0.31	0.69	0.00	0.00	939
2016	0.00	0.43	0.54	0.03	0.00	808
2017	0.00	0.41	0.57	0.02	0.00	654
2018	0.00	0.18	0.81	0.01	0.00	3 394
Total	0.02	0.39	0.41	0.17	0.01	80 253

C8d) Target species
Trawl

Year	BAR	EMA	HOK	JMA	KAH	Other	Total
1990	0.01	-	0.01	0.98	-	-	160
1991	-	0.27	0.24	0.48	-	-	1 356
1992	-	0.02	0.01	0.97	-	-	2 852
1993	0.07	-	0.12	0.81	-	0.01	826
1994	-	-	0.28	0.72	-	-	832
1995	0.03	-	0.10	0.87	-	0.01	1 327
1996	0.03	-	0.28	0.70	-	-	543
1997	0.01	0.01	0.06	0.93	-	-	1 866
1998	0.04	0.03	-	0.93	-	-	2 434
1999	-	0.07	-	0.93	-	-	4 668
2000	-	-	-	0.99	-	0.01	2 906
2001	0.01	-	-	0.99	-	-	2 903
2002	0.01	-	-	0.98	-	0.01	4 860
2003	-	0.05	-	0.95	-	-	2 389
2004	0.04	0.05	-	0.90	-	-	2 674
2005	0.10	0.09	-	0.80	-	-	4 652
2006	-	0.22	-	0.78	-	0.01	3 624
2007	0.02	0.15	-	0.83	-	-	2 508
2008	0.01	0.11	-	0.86	-	0.01	2 615
2009	-	0.17	-	0.83	-	-	2 946
2010	-	0.29	-	0.70	-	-	3 459
2011	-	0.04	-	0.96	-	-	1 905
2012	-	0.63	-	0.37	-	-	2 517
2013	-	0.49	-	0.50	-	0.01	2 200
2014	0.03	0.06	-	0.91	-	-	1 207
2015	0.08	-	0.01	0.92	-	-	938
2016	0.04	0.14	-	0.82	-	-	782
2017	0.05	-	0.04	0.91	-	-	640
2018	0.01	0.35	-	0.63	-	-	3 371
Total	0.02	0.13	0.02	0.83	-	-	65 961

d) Target species continued
Purse seine

Year	BAR	EMA	HOK	JMA	KAH	Other	Total
1990	-	0.51	-	0.13	0.36	-	1 521
1991	-	0.83	-	0.07	0.11	-	934
1992	-	0.28	-	0.49	0.23	-	179
1993	-	0.78	-	0.18	0.04	-	553
1994	-	0.64	-	0.33	0.03	-	329
1995	-	0.63	-	0.08	0.29	-	170
1996	-	0.29	-	0.63	0.08	-	107
1997	-	0.49	-	0.30	0.21	-	607
1998	-	-	-	1	-	-	28
1999	-	0.99	-	0.01	-	-	3 992
2000	-	0.97	-	-	0.03	-	432
2001	-	0.96	-	-	0.04	-	545
2002	-	0.93	-	0.07	0.01	-	522
2003	-	0.92	-	0.03	0.06	-	1 012
2004	-	0.98	-	-	-	0.02	55
2005	-	0.94	-	-	0.06	-	572
2006	-	0.97	-	-	0.03	-	260
2007	-	0.84	-	-	0.06	0.11	359
2008	-	1	-	-	-	-	332
2009	-	0.98	-	-	-	0.02	454
2010	-	-	-	-	-	1	<1
2011	-	1	-	-	-	-	224
2012	-	0.95	-	-	0.05	-	190
2013	-	1	-	-	-	-	209
2014	-	0.02	-	0.12	0.10	0.77	<1
2015	-	-	-	-	-	1	<1
2016	-	-	-	1	-	-	25
2017	-	-	-	-	-	1	12
2018	-	-	-	-	-	1	20
Total	-	0.84	-	0.07	0.08	0.01	13 644

Table C9: Species codes used in this report

Code	Common name	Scientific name
BAR	Barracouta	*Thyrsites atun*
EMA	Blue mackerel	*Scomber australasicus*
HOK	Hoki	*Macruronus novaezelandiae*
JMA	Jack mackerels	*Trachurus declivis, T. novaezelandiae, T. symmetricus murphyi*
KAH	Kahawai	*Arripis trutta, A. xylabion*
RBT	Redbait	*Emmelichthys nitidus*
SKJ	Skipjack tuna	*Katsuwonus pelamis*
TRE	Trevally	*Pseudocaranx dentex*

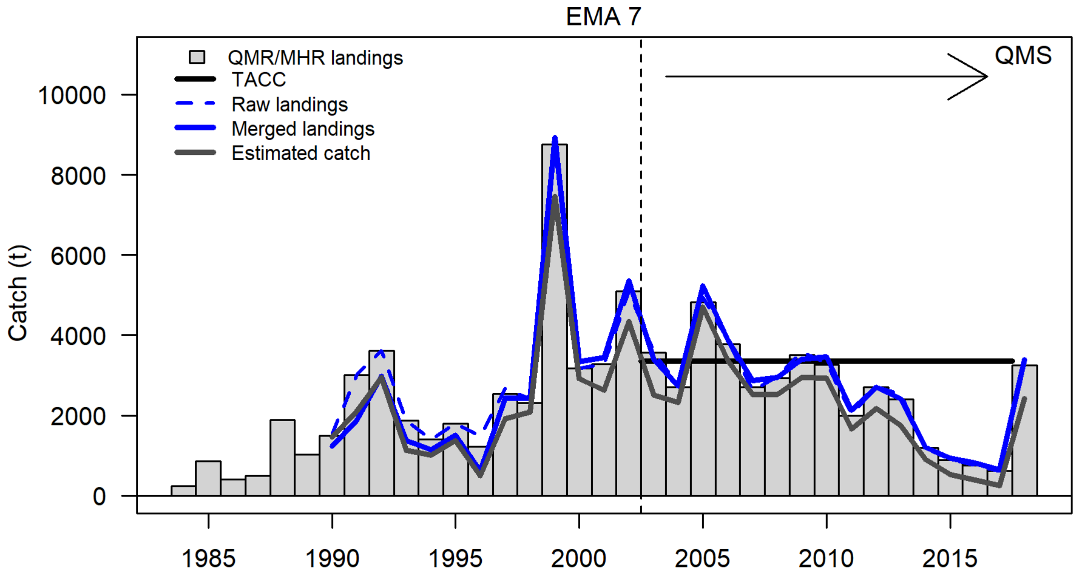

Figure C1: QMR/MHR landings, raw landings, groomed and merged landings, groomed and merged estimated catch, and TACC for EMA 7 for fishing years 1984–2018.

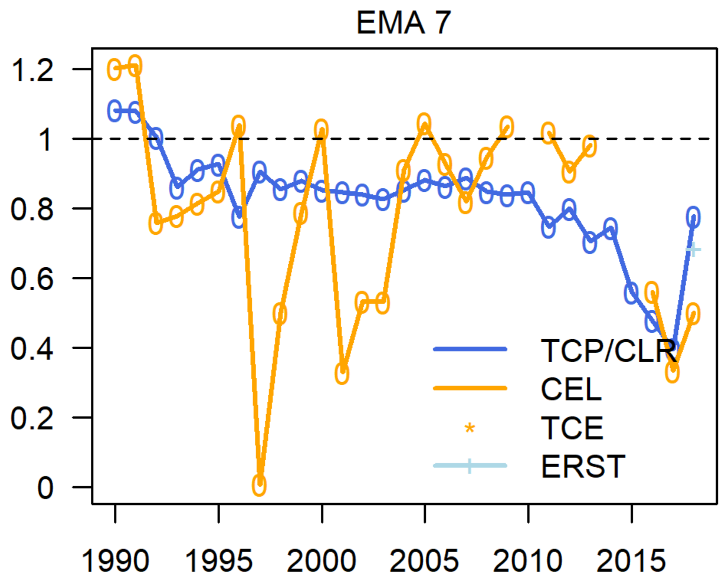

Figure C2: The reporting rate, defined as the ratio of the estimated catch as a proportion of retained landings in the groomed and merged dataset, for EMA stocks for fishing years 1990–2018. The reporting rates for each stock were calculated by form type, where TCP is Trawl Catch Effort Processing Return; CLR is Catch Landing Return; CEL is Catch Effort Landing Return; TCE is Trawl Catch Effort Return, and ERST is Electronic Reporting System where primary method is any method of trawl.

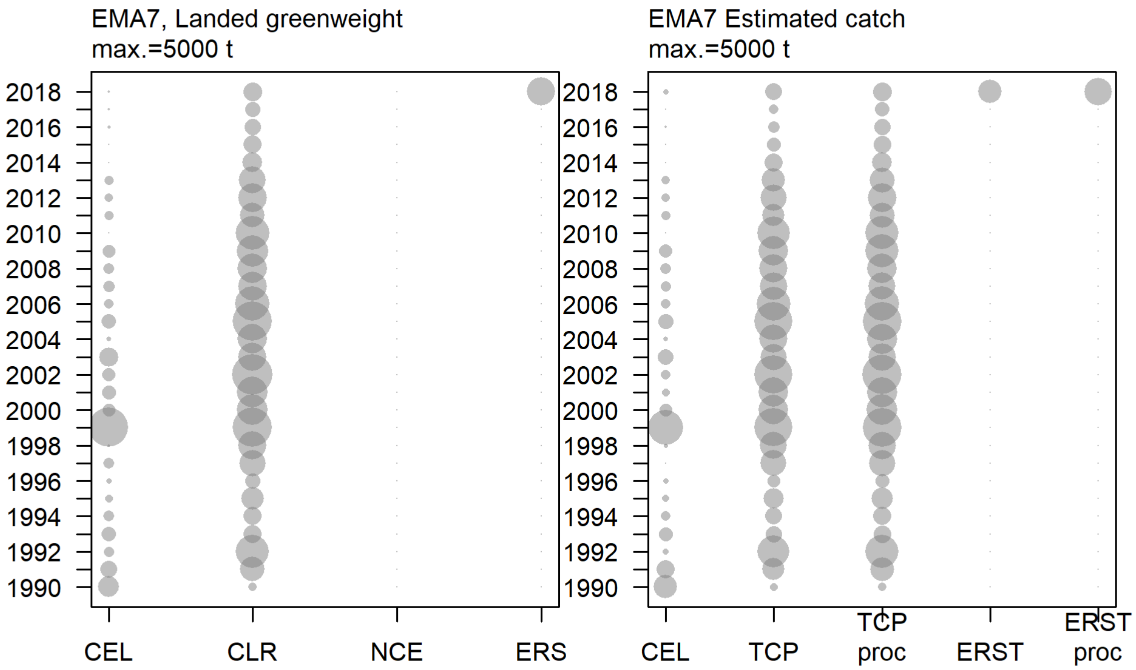

Figure C3: Landings by form type in the groomed and unmerged dataset, and estimated catches by form type in the groomed and merged dataset, for EMA 7 for fishing years 1990–2018, where CEL is Catch, Effort, Landing Return; CLR is Catch Landing Return; NCE is Netting Catch Effort Return; ERS is Electronic Reporting System; TCP is Trawl Catch Effort and Processing Return; TCP proc is processed catch from TCP form; ERST is Electronic Reporting System where primary method was reported as bottom or midwater trawling; ERST proc is processed catch from ERST forms. The area of the circle is proportional to the annual catches (only comparable within each panel).

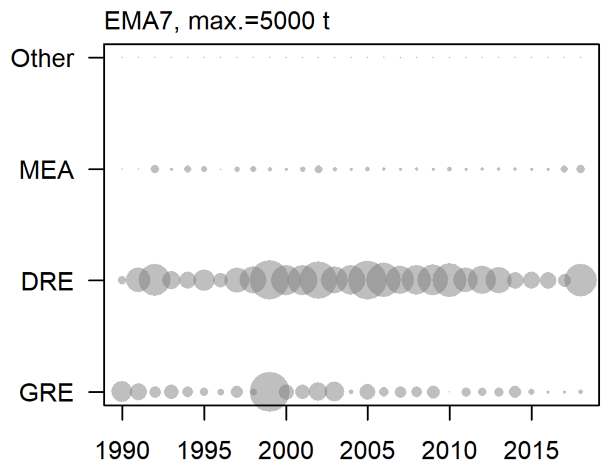

Figure C4: Retained landings (greenweight in tonnes) by processed state for EMA 7 for fishing years 1990–2018 in the groomed and unmerged dataset. GRE, Green; DRE, dressed or headed, gutted, and tailed; MEA, mealed.

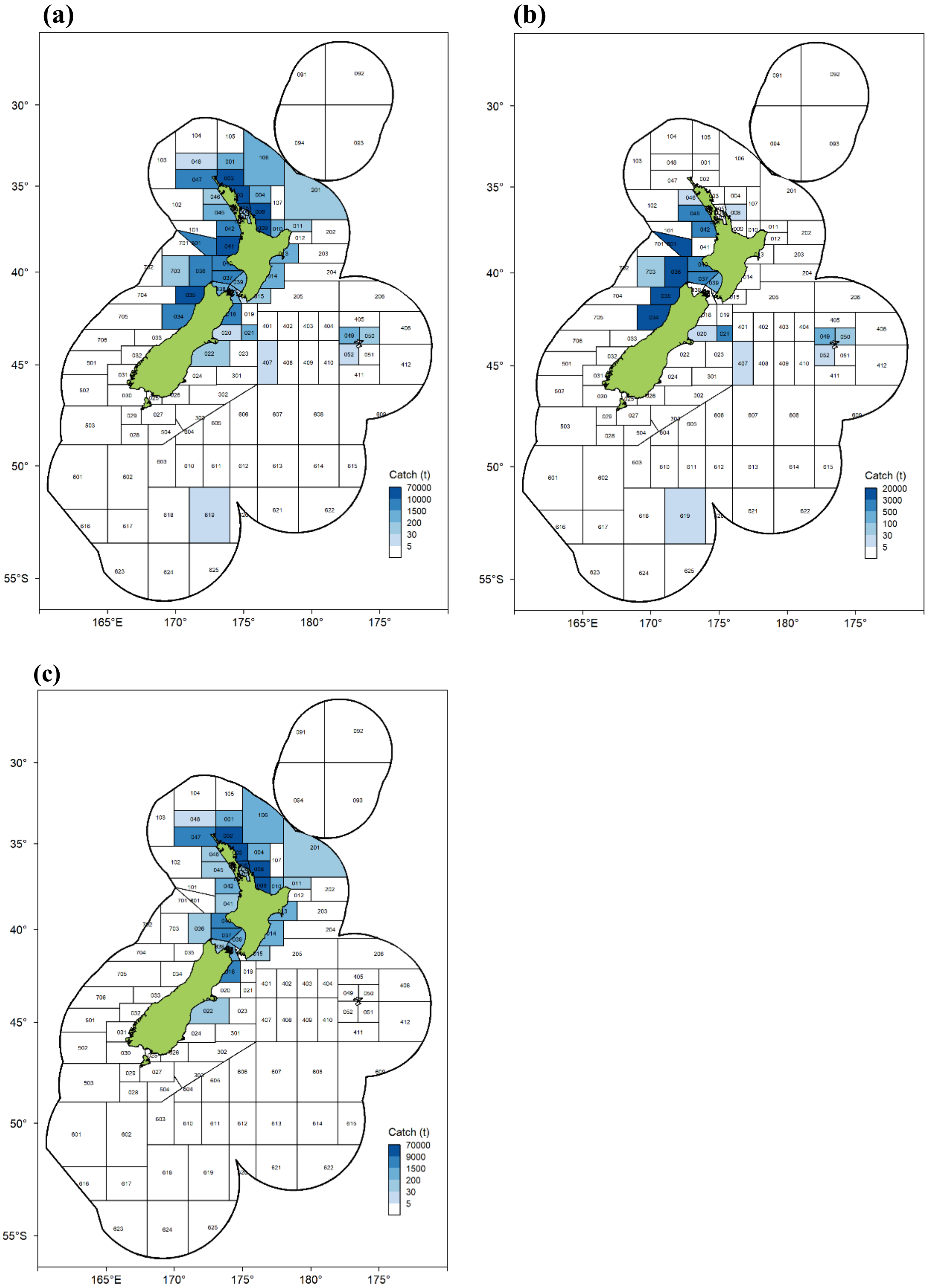

Figure C5: Annual commercial blue mackerel catches (in tonnes) by statistical area over all fishing years 1990–2018 (a) for all forms and methods (b) TCEPR trawl catch, and (c) purse seine catch.

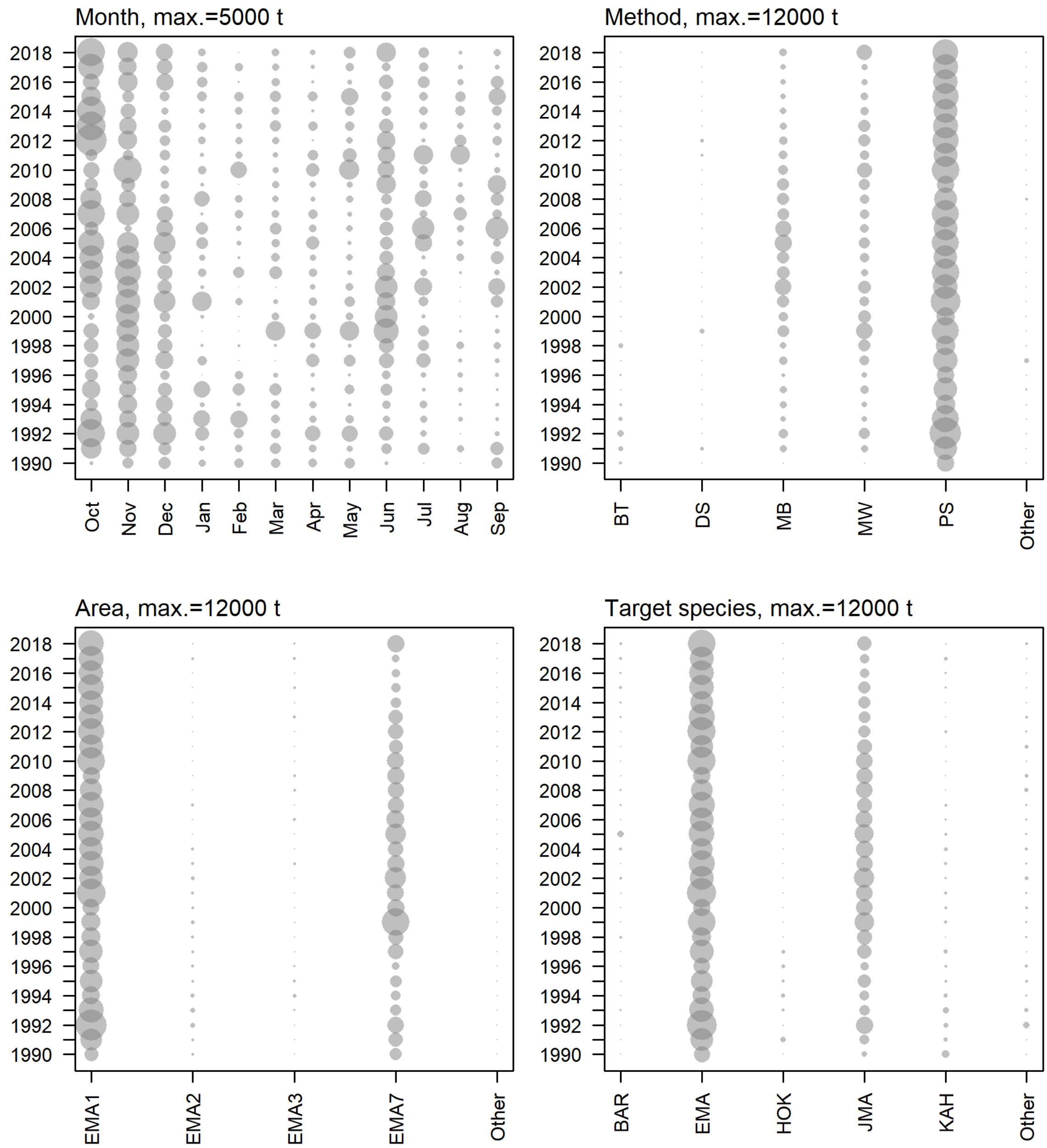

Figure C6a: Distribution of annual groomed and merged catch (t) by month, area, method, and target species for all merged data for fishing years 1990–2018 for all EMA stocks. Circle size is proportional to catch; maximum circle size is indicated on each plot. Statistical areas are shown in Figure 1. BT is bottom trawl; DS is Danish seine; MB is midwater trawl within 5 m of the seabed; MW is midwater trawl; PS is purse seine. Target species codes are defined in Table C9.

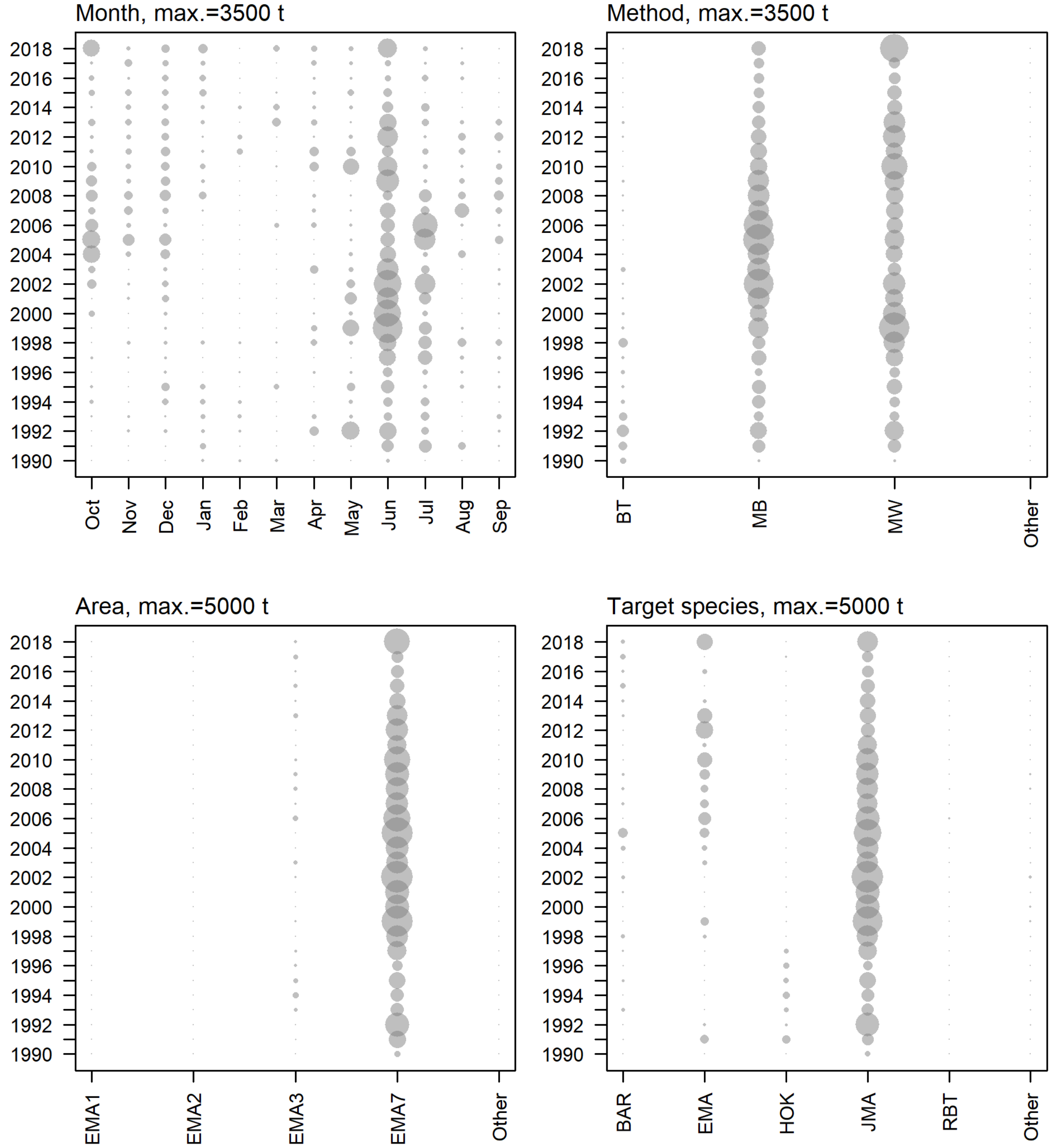

Figure C6b: Distribution of annual groomed and merged catch (t) by month, QMA area, method, and target species for all merged trawl data for fishing years 1990–2018 for all EMA stocks. Circle size is proportional to catch; maximum circle size is indicated on each plot. BT is bottom trawl; MB is midwater trawl within 5 m of the seabed; MW is midwater trawl. Target species codes are defined in Table C9.

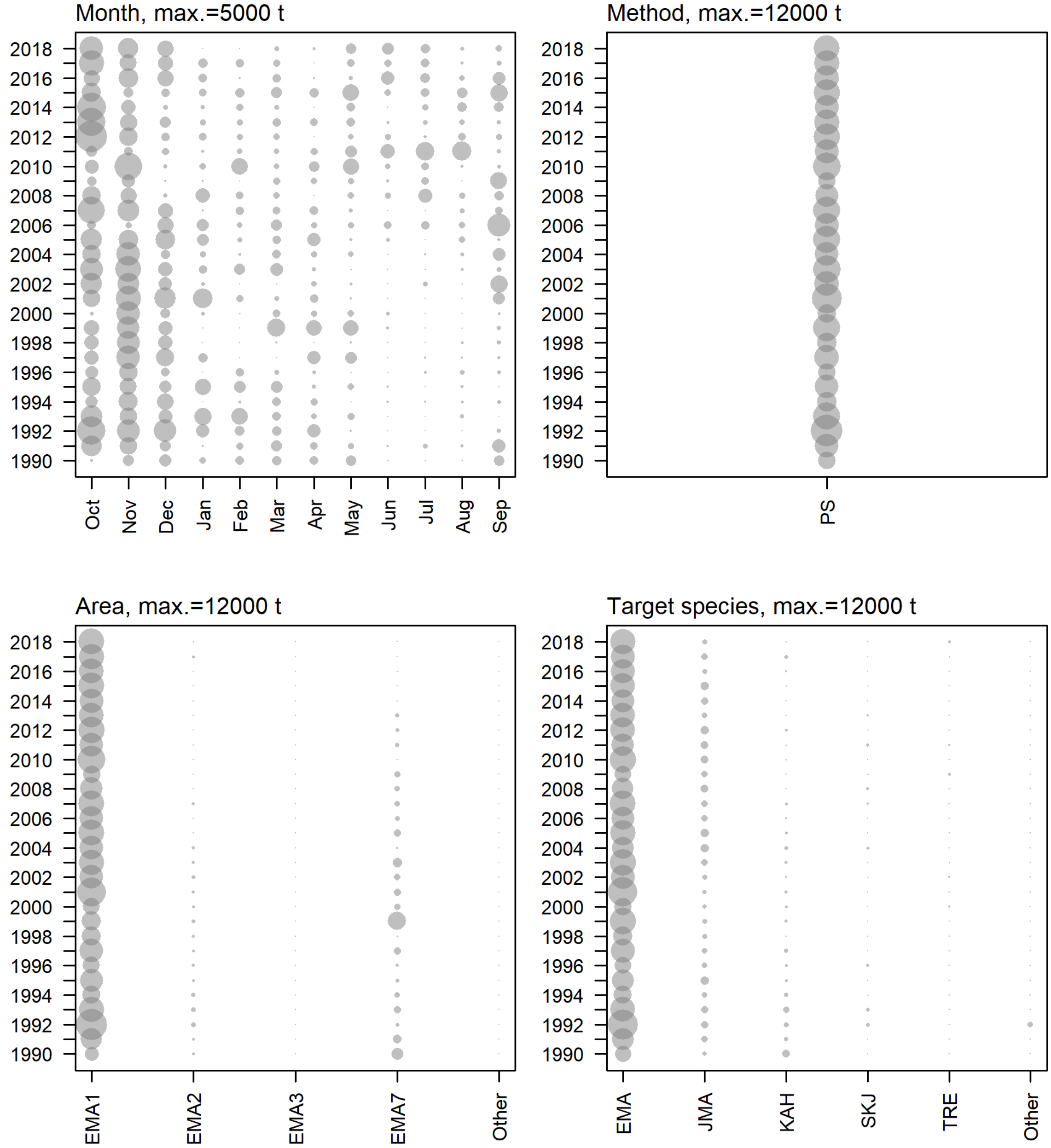

Figure C6c: Distribution of annual groomed and merged catch (t) by month, QMA area, method, and target species for all merged purse seine data for fishing years 1990–2018 for all EMA stocks. Circle size is proportional to catch; maximum circle size is indicated on each plot. PS is purse seine. Target species codes are defined in Table C9.

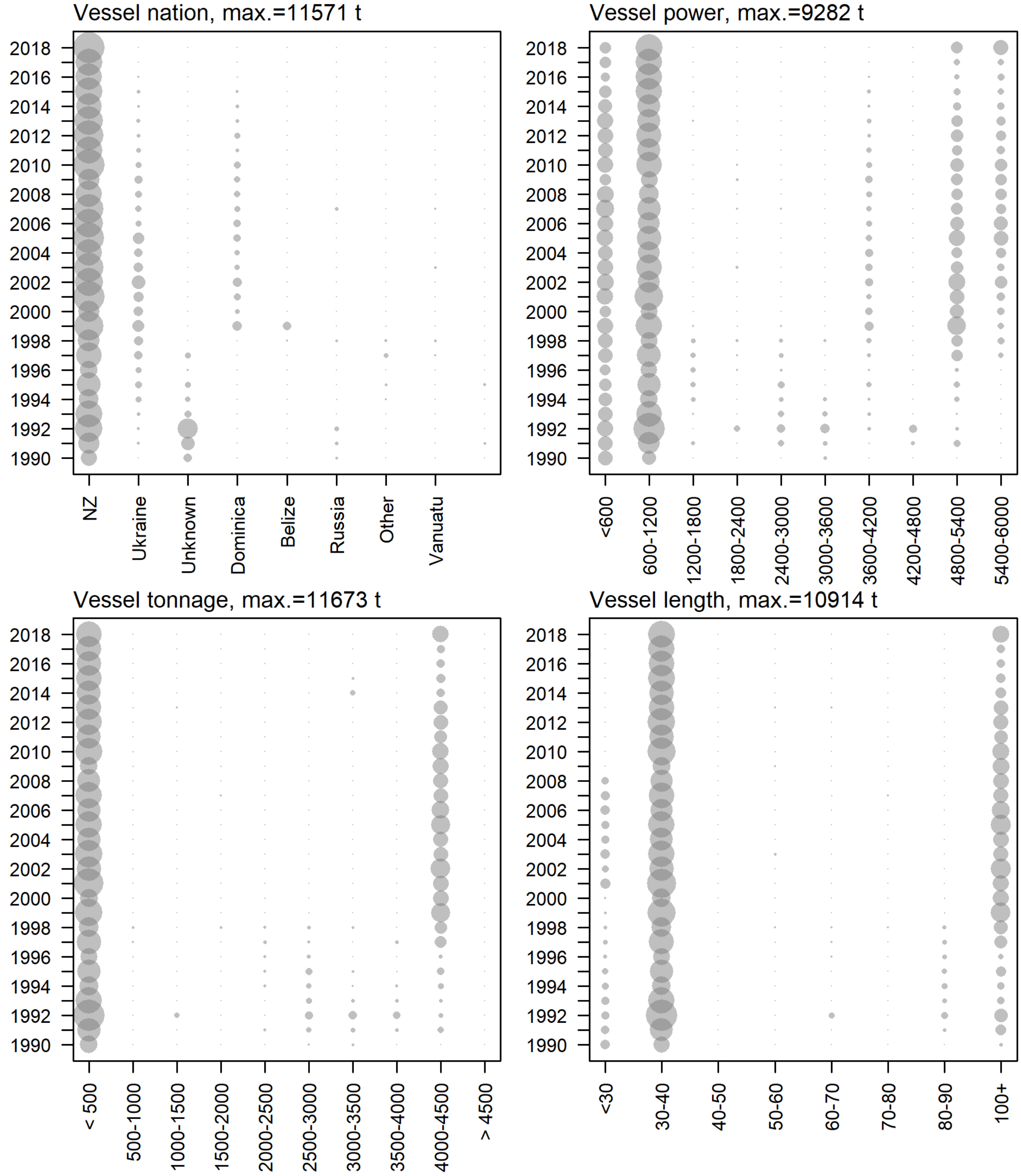

Figure C7: Distribution of annual groomed and merged catch (t) by nationality, vessel power (kW), vessel gross tonnage, and vessel length (m) for all estimated merged data for fishing years 1990–2018 for all EMA stocks. Circle size is proportional to catch; maximum circle size is indicated on each plot.

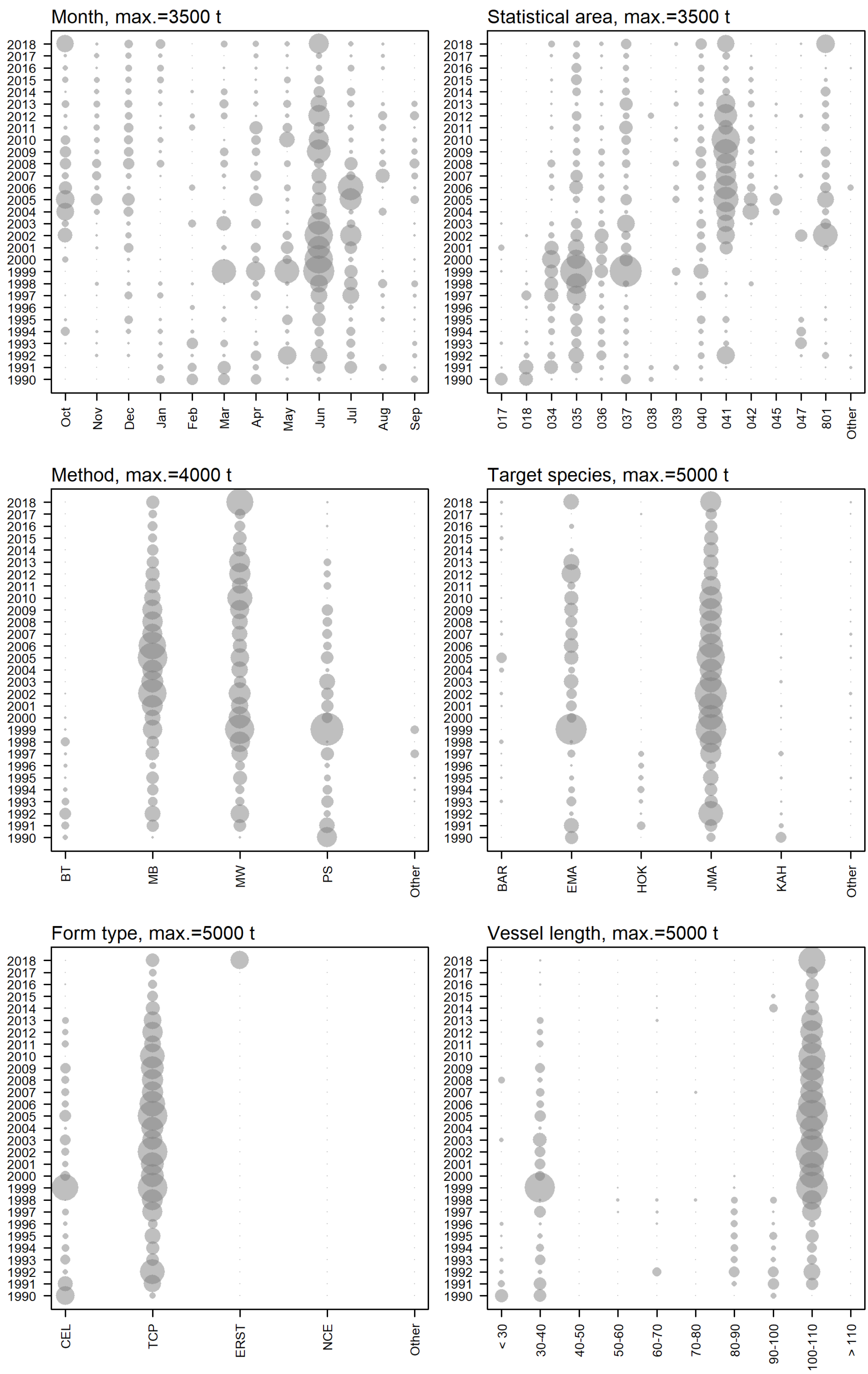

Figure C8a: Distribution of annual groomed and merged catch (t) by month, statistical area, method, target species, form type, and vessel length for EMA 7 merged data for fishing years 1990–2018. Circle size is proportional to catch; maximum circle size is indicated on the top left hand corner of each plot. Statistical areas are shown in Figure 1. BT is bottom trawl; MB is midwater trawl within 5 m of the seabed; MW is midwater trawl; PS is purse seine; target species codes are given in Table C9; and form types are defined in Figure C3.

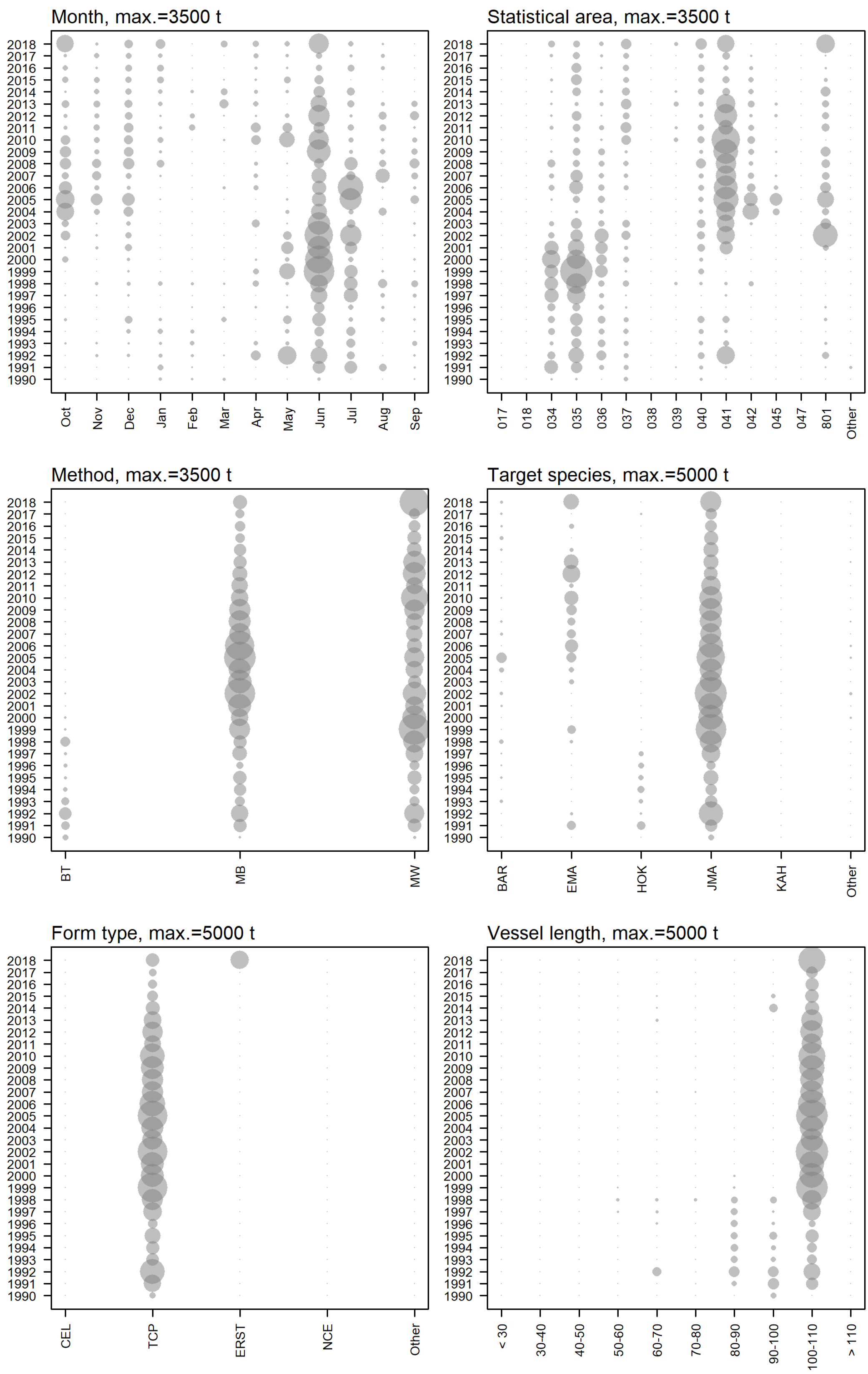

Figure C8b: Distribution of annual groomed and merged catch (t) by month, statistical area, method, target species, form type, and vessel length for EMA 7 merged data for fishing years 1990–2018 for trawl methods only. Circle size is proportional to catch; maximum circle size is indicated on the top left hand corner of each plot. Statistical areas are shown in Figure 1. BT is bottom trawl; MB is midwater trawl within 5 m of the seabed; MW is midwater trawl; target species codes are given in Table C9; and form types are defined in Figure C3.

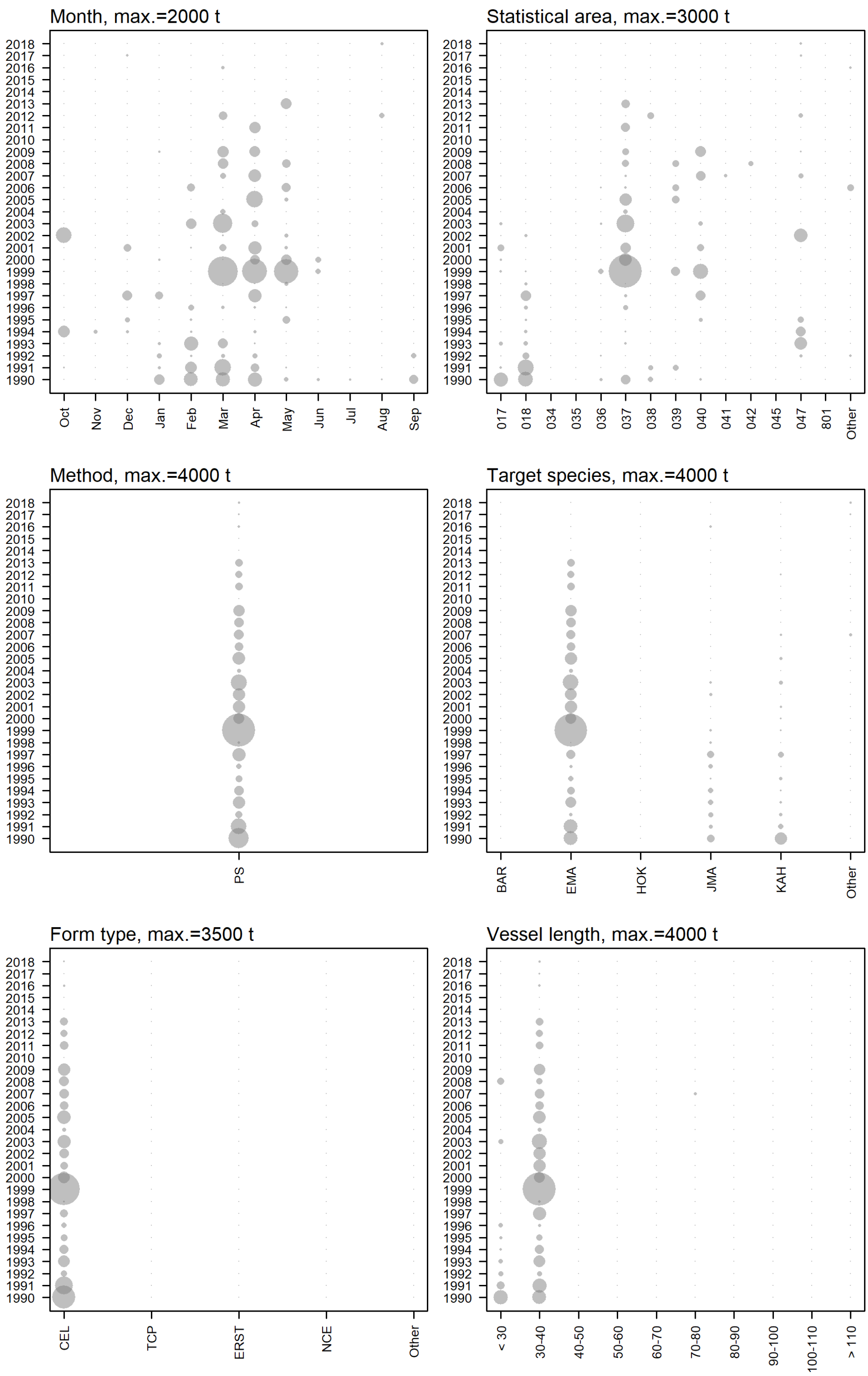

Figure C8c: Distribution of annual groomed and merged catch (t) by month, statistical area, method, target species, form type, and vessel length for EMA 7 purse seine merged data for fishing years 1990–2018. Circle size is proportional to catch; maximum circle size is indicated on the top left hand corner of each plot. Statistical areas are shown in Figure 1. BT is bottom trawl; MB is midwater trawl within 5 m of the seabed; MW is midwater trawl; PS is purse seine; target species codes are given in Table C9; and form types are defined in Figure C3.

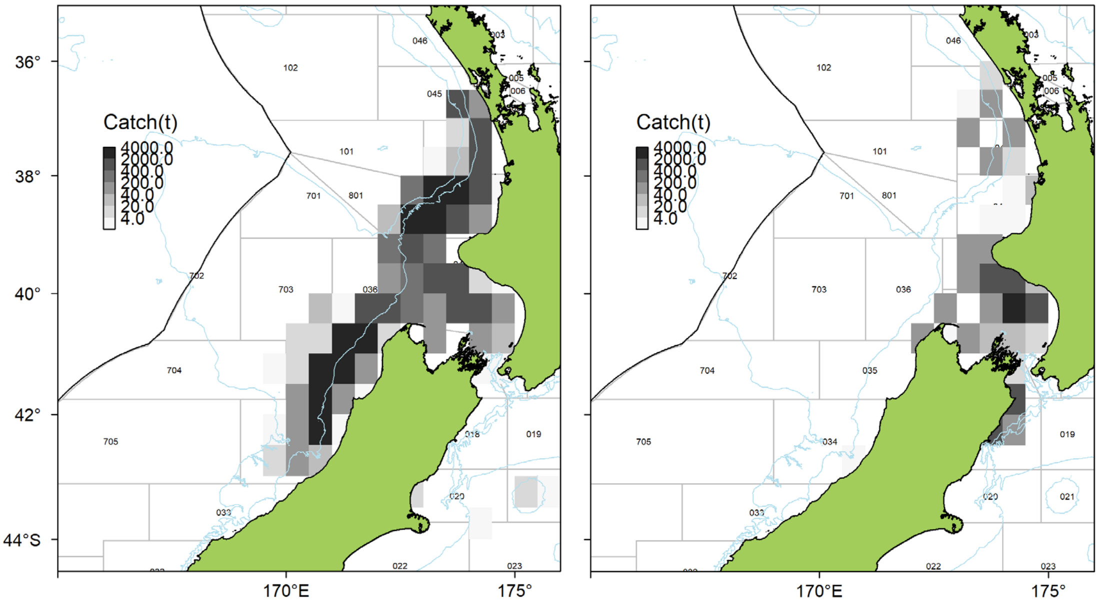

Figure C9: Distribution of blue mackerel catch by 0.5 degree grid for the midwater trawl (left) and purse seine (right) fisheries in EMA 7, for fishing years 1990–2018 combined.

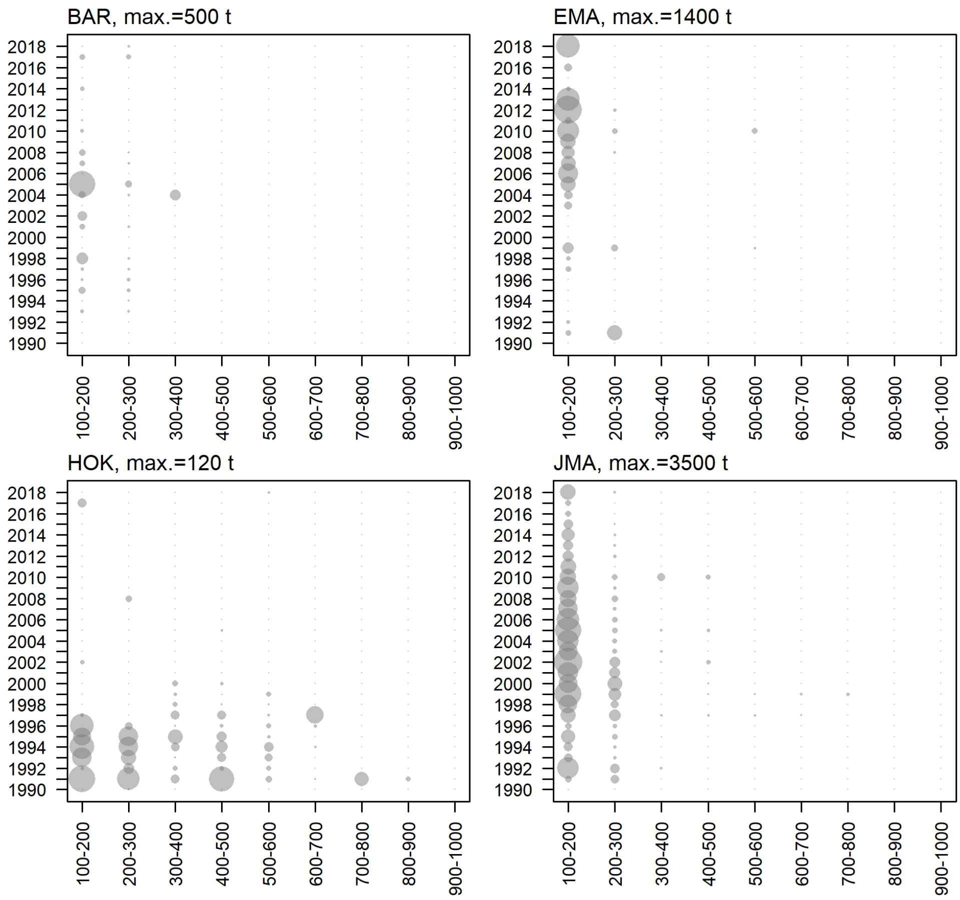

Figure C10: Distribution of annual groomed and merged catch (t) for midwater trawl by depth for EMA 7 for fishing years 1990–2018 for the main target species. Circle size is proportional to catch; maximum circle size is indicated on the top left hand corner of each plot. Target species codes are given in Table C9 and form types are defined in Figure C3.

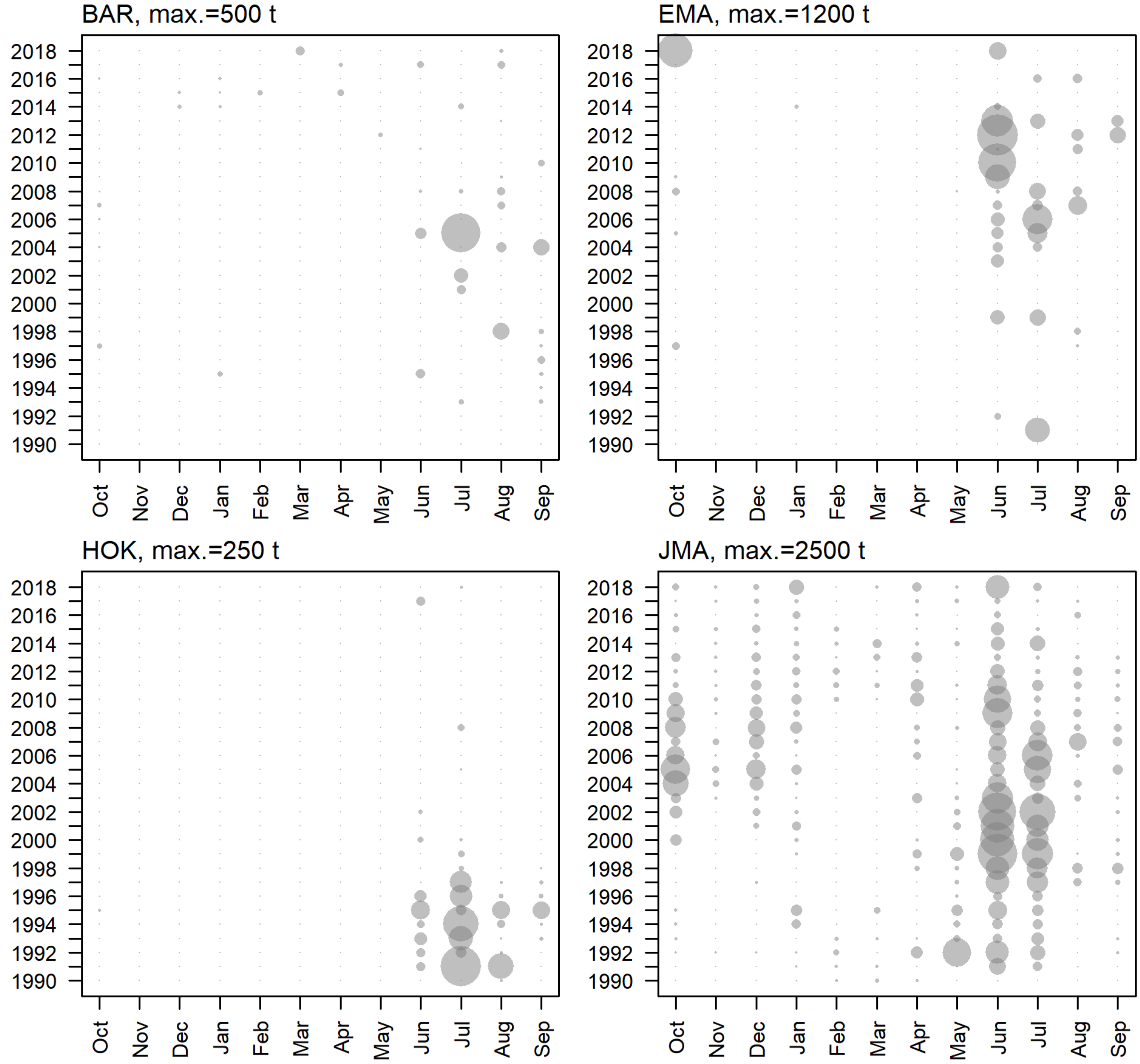

Figure C11: Distribution of annual groomed and merged catch (t) for midwater trawl by month for EMA 7 for fishing years 1990–2018 for the main target species. Circle size is proportional to catch; maximum circle size is indicated on the top left hand corner of each plot. Target species codes are given in Table C9 and form types are defined in Figure C3.

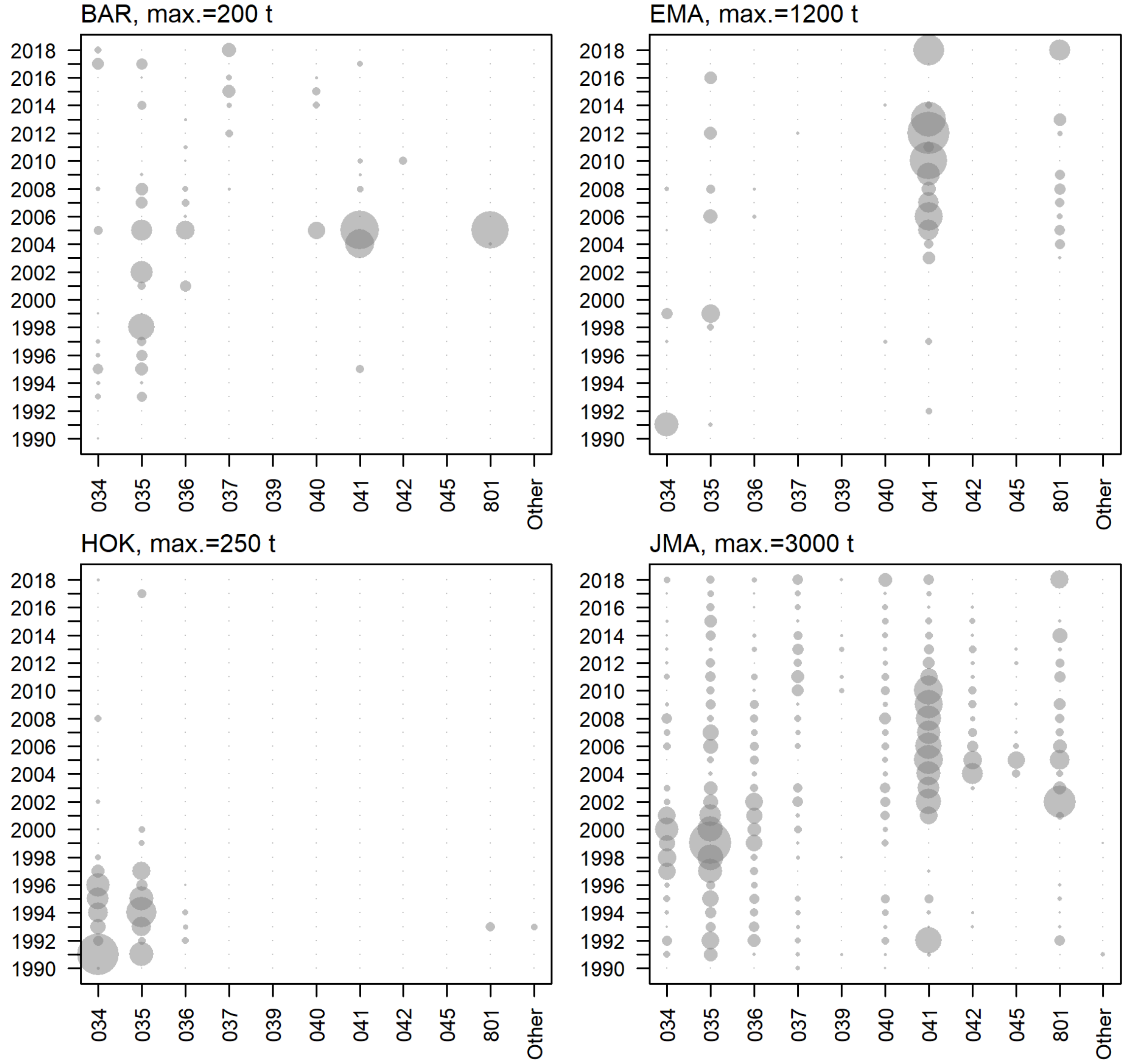

Figure C12: Distribution of annual groomed and merged catch (t) for midwater trawl by statistical area for EMA 7 for fishing years 1990–2018 for the main target species. Circle size is proportional to catch; maximum circle size is indicated on the top left hand corner of each plot. Statistical areas are shown in Figure 1.

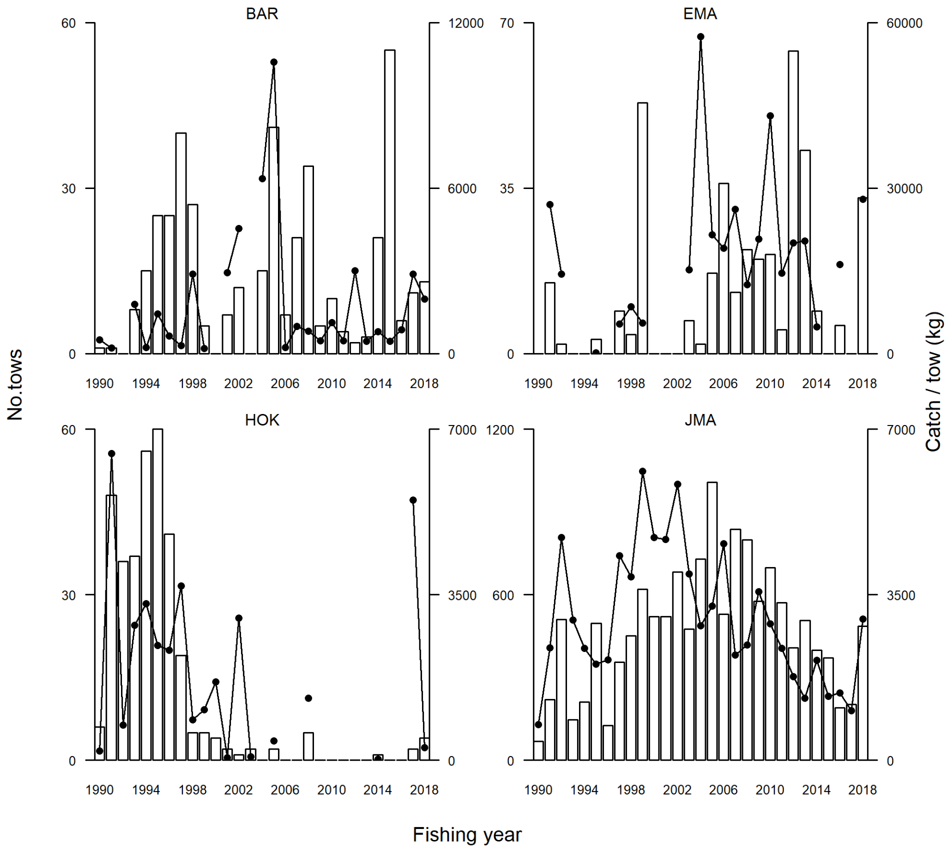

Figure C13: EMA 7 unstandardised blue mackerel midwater trawl catch rates (kg/tow) (lines), and the number of tows (bars), by the main target species for fishing years 1990–2018. Target species codes are given in Table C9. NB: Data series comprises mostly unstandardised TCEPR catch and effort data except for the 2018 fishing year which also includes catches from ERS forms where the primary method is reported as midwater trawl.

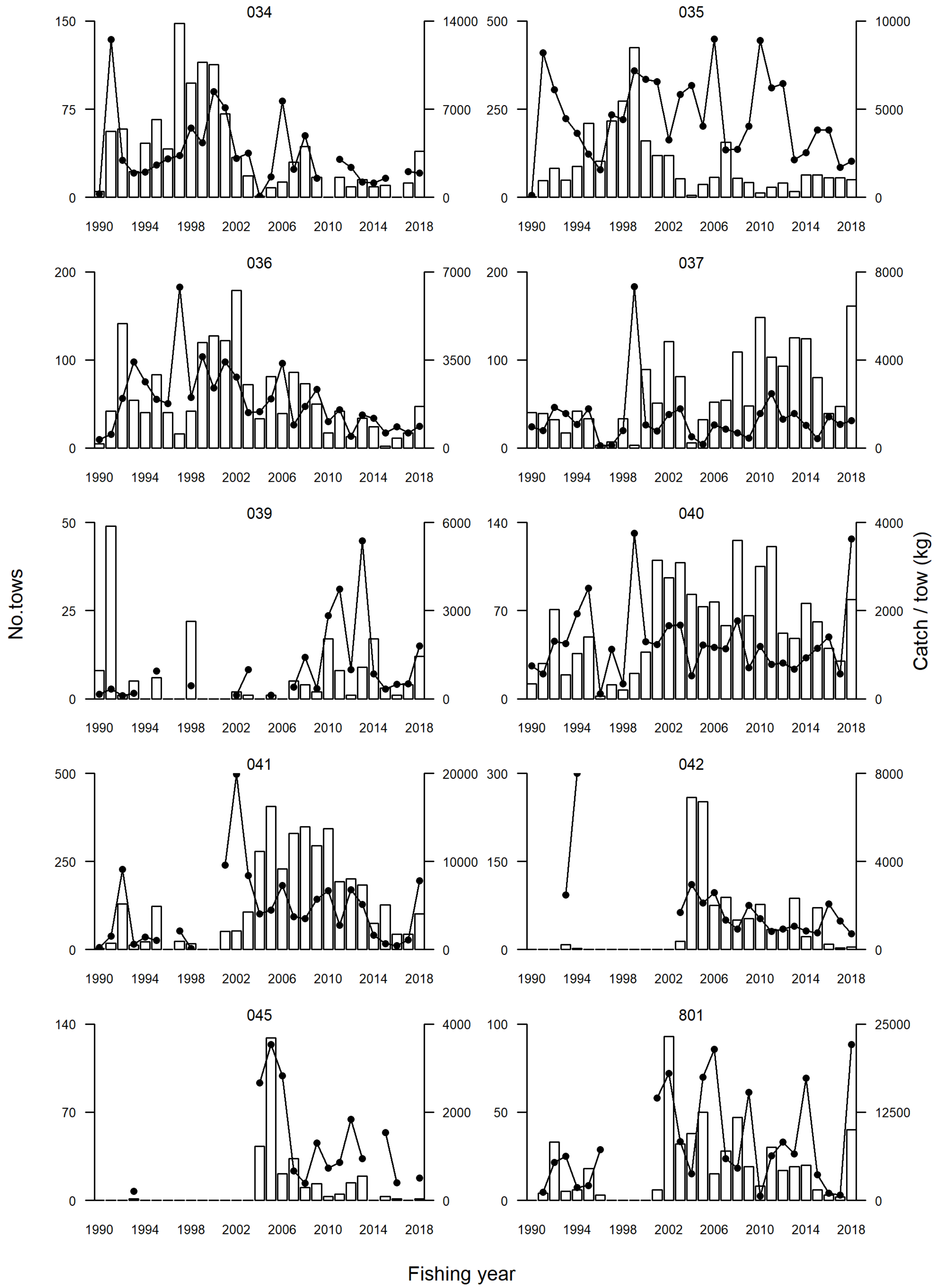

Figure C14: Unstandardised target blue mackerel catch rate (kg/tow) of blue mackerel (lines), and the number of tows (bars) for EMA 7, by main statistical areas for unmerged estimated TCEPR midwater trawl data for fishing years 1990–2018. Statistical areas are given in Figure 1. NB: the 2018 fishing year also includes catches from ERS forms where the primary method is reported as midwater trawl when this form was introduced.

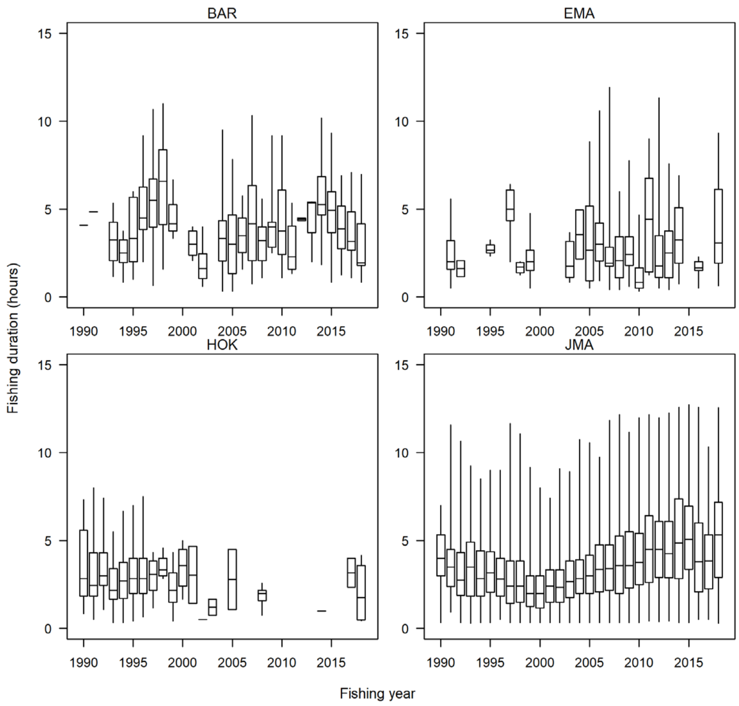

Figure C15: Annual median (horizontal line), inter-quartile ranges (box), and range (vertical lines) for fishing duration during unmerged estimated TCEPR midwater trawls that caught blue mackerel in EMA 7, by main target species and fishing year for fishing years 1990–2018. Target species codes are given in Table C9. NB: the 2018 fishing year also includes catches from ERS forms where the primary method is reported as midwater trawl when this form was introduced.

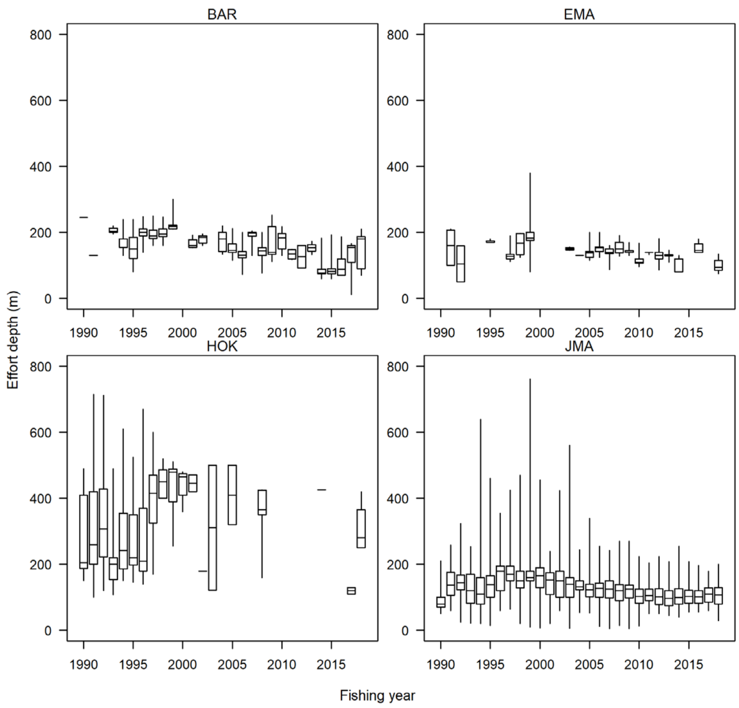

Figure C16: Annual median (horizontal line), inter-quartile ranges (box), and range (vertical lines) for depths (m) fished during unmerged estimated TCEPR midwater trawls that caught blue mackerel in EMA 7, by main target species and for fishing years 1990–2018. Target species codes are given in Table C9.

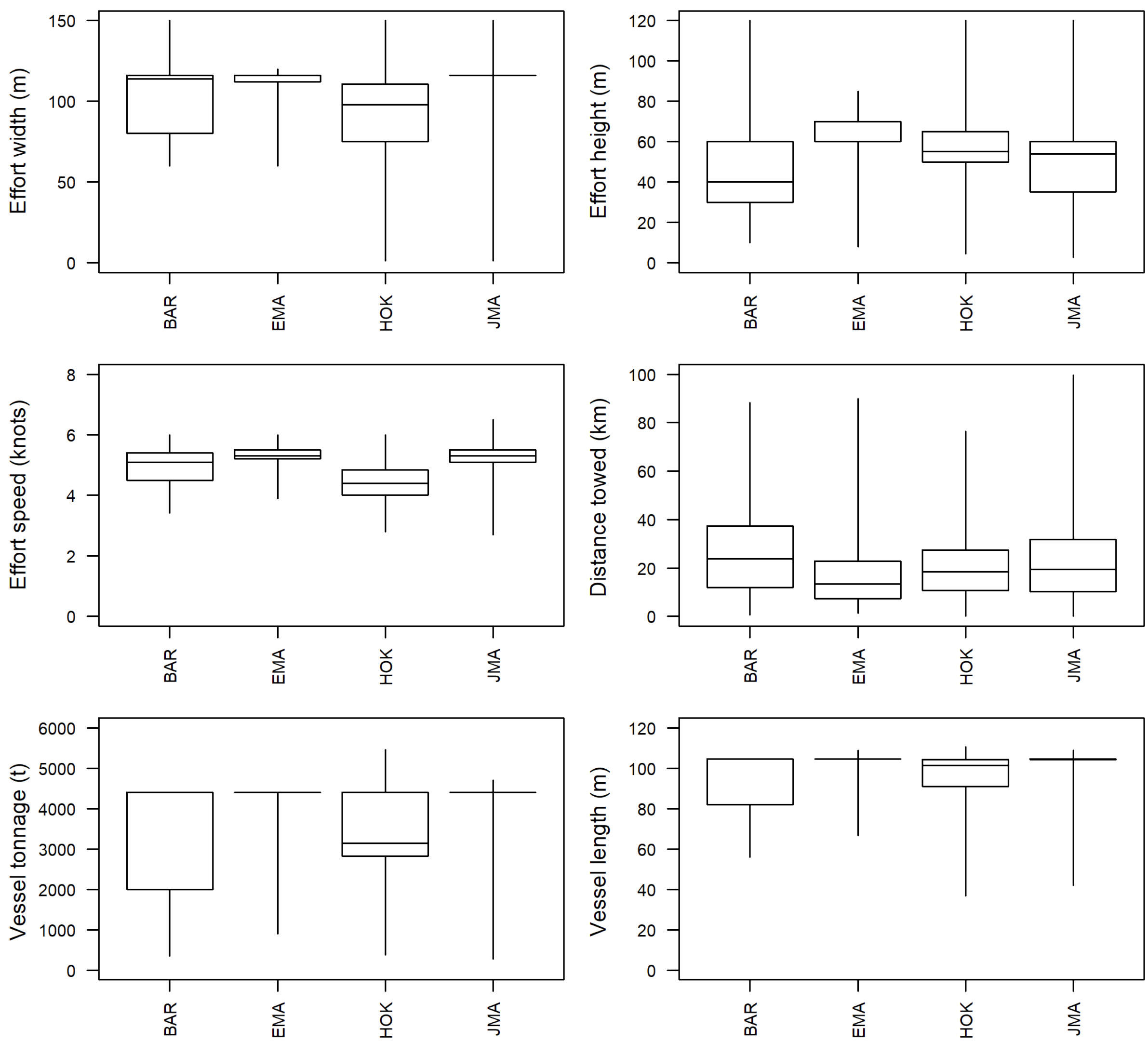

Figure C17: Distribution of fishing effort variables and vessel characteristics for EMA 7 for unmerged estimated TCEPR midwater fishing that caught blue mackerel by main target species for fishing years 1990–2018. Target species codes are given in Table C9.

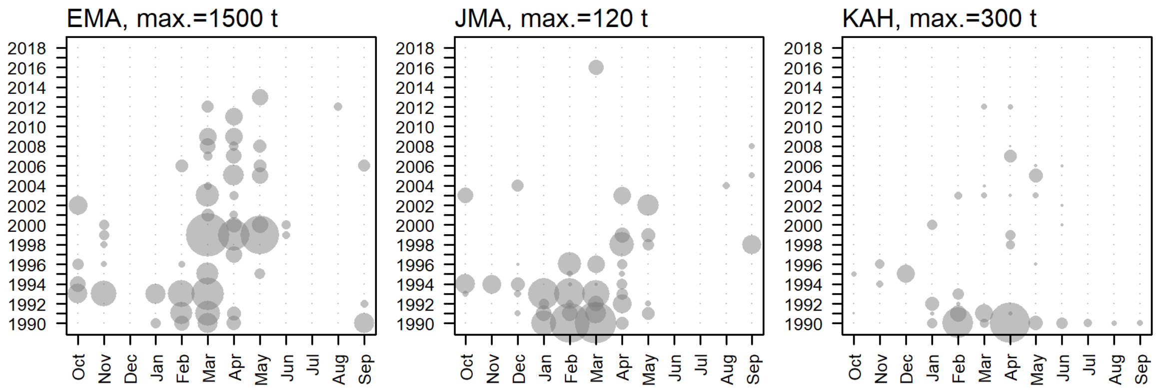

Figure C18: Distribution of blue mackerel catch by month in the purse seine fishery in EMA 7, by main target species for fishing years 1990–2018. Target species codes are given in Table C9.

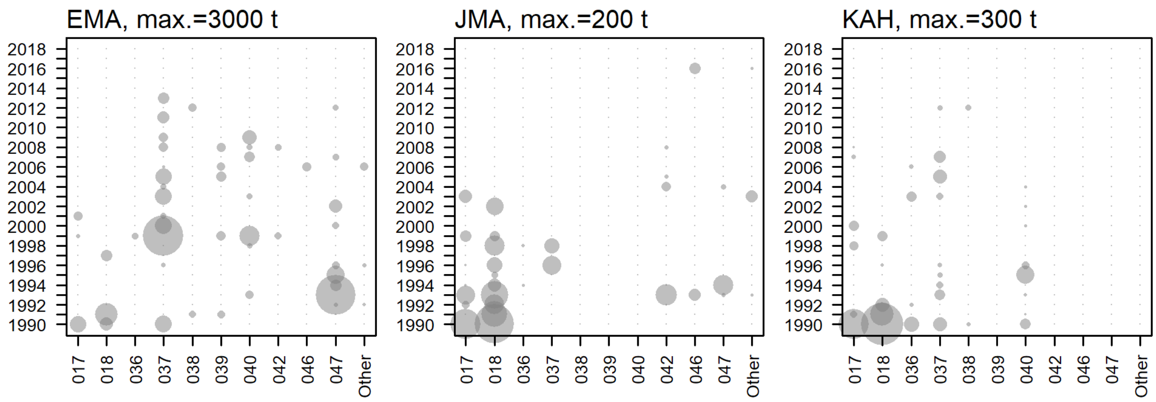

Figure C19: Distribution of blue mackerel catch by statistical area for the main target species in the purse seine fishery in EMA 7, for fishing years 1990–2018. Target species codes are given in Table C9.

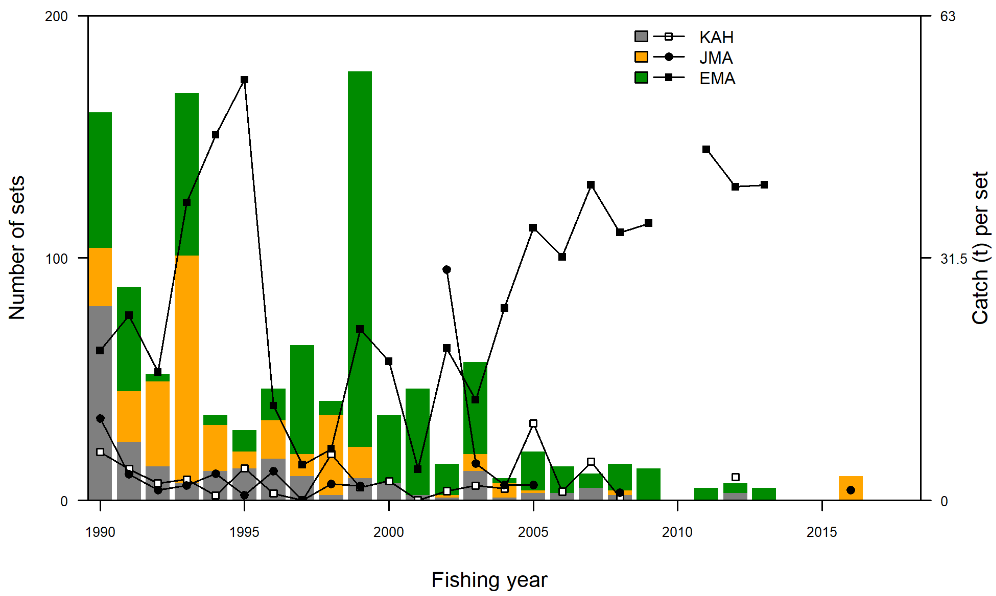

Figure C20: Number of sets (bars) and catch per set (lines) by target species for the purse seine fishery in EMA 7 for fishing years 1990–2018. Target species codes are given in Table C9.