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## EXECUTIVE SUMMARY

**Taylor, P.R. (2002). A summary of information on blue mackerel (*Scomber australasicus*), characterisation of its fishery in QMAs 7, 8, and 9, and recommendations on appropriate methods to monitor the status of this stock.**

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This report addresses the objectives of the MFish project EMA2000/01, "Monitoring of blue mackerel": *To review the current and historical data available for blue mackerel in QMA[s] 7 [, 8, and 9], characterise the fishery, and recommend methods to monitor the status of this Fishstock.*

Information on blue mackerel in QMAs 7, 8, and 9 was summarised. Catch and effort data showed a high number of records in most years since 1988–89. The observer database provided patchy biological data from 1986–87: 935 fish were measured, 899 sexed, and 498 females staged. The research trawl database contained 42 records of gonad staging and sex ratio data, and 368 records of annual length frequency data since 1977–78; they were too patchy in time and space for examining annual variations in size structure, but were used to summarise size ranges caught by the fishery. The aerial sightings database contained 428 sightings of "pure" blue mackerel schools unevenly distributed throughout QMAs 7, 8, and 9, and 693 mixed school sightings with jack mackerel, kahawai, skipjack tuna, and trevally.

Variations of catch in time and space were examined using estimated catch data. Peaks occurred in 1998–99 for both the CELR (vessels using catch effort landing returns) and TCEPR (vessels using trawl catch effort processing returns) fleets; other years of high catch occurred, but none were common to both.

Catch seasonality showed converse patterns for the two fleets: CELR catches (99% purse-seine) were taken in most months except winter (June–August); TCEPR catches (93% midwater trawl) were low for most of the year with a large peak in June–July. Aerial sightings were too few to provide a reliable seasonal pattern, but data for all areas combined suggested a minimum in surface aggregations during June. These patterns suggest that a large proportion of blue mackerel in QMAs 7, 8, and 9 is absent from surface schools during winter, but is present in subsurface schools mixed with jack mackerel.

Sex ratios were about equal except in December–January 1994–95 when there was a higher proportion (83 and 66%) of females. Spawning was evident (ripe and spent fish) in January–February 1997–98 and February 1989–90; fish with developing gonads were present in July 1997–98 and 1999–2000.

Length frequencies showed wider length ranges for research trawl data (9–50 cm), with a predominance of small fish, than for observer data (40–55 cm). One explanation is that small fish are more coastal, and therefore not vulnerable to the TCEPR fleet. Another is that small fish are vulnerable to *Kaharoa*'s gear, but not to that of the TCEPR fleet. Comparison of immature and adult fish distributions show that younger fish are found closer to the coast.

Information on the size of blue mackerel stocks is very patchy and requires more extensive sampling to improve the effectiveness of any proposed monitoring methods. For QMAs 7, 8, and 9, no monitoring method is clearly the best choice. CPUE probably has no value, and current aerial sightings data are too patchy for estimating relative abundance indices. Other options are expensive and require more knowledge: egg production methods require good understanding of spawning areas and seasons; acoustic survey requires extensive developmental work.

Evidence for at least two centres of spawning (Hauraki Gulf and the South Taranaki Bight) suggests that a single biological stock is unlikely. Determining stock structure is necessary before a clear management strategy can be defined. Tagging could be used to provide estimates of mortality and for studying migratory patterns, which are related to the question of stock structure.

Understanding niche overlap in our inshore pelagic species would be a first step in managing them as a group. Developing a multi-species approach for their monitoring (e.g., blue and jack mackerel in the TCEPR fishery) might be the most cost effective way of gathering information.

# 1. INTRODUCTION

## 1.1 Overview

Most of this report documents work completed under the Ministry of Fisheries Research Project EMA2000/01, "Monitoring of blue mackerel". Some of the information summarised for the Ministry of Fisheries Research Project MOF2000/03G, "Establishing potential area boundaries and indicative TACs for selected non-QMS species", which provided useful background to our understanding of blue mackerel, is also included here.

The original objective for Project EMA2000/01 was

- To review the current and historical data available for blue mackerel in QMA 7 [Figure 1], characterise the fishery, and make recommendations on appropriate methods to monitor the status of this Fishstock.

Modifications to the this objective were proposed under Schedule 2 (Exceptions and Deviations) of NIWA's tender to MFish for this project, which MFish accepted. The resulting tasks are as follows.

- To review the current and historical data available for blue mackerel (*S. australasicus*) in QMAs 7, 8, and 9, characterise the fishery, and make recommendations on appropriate methods to monitor the status of this stock.

- To include in the present study recommendations on the most appropriate selection of Fishstock boundaries for blue mackerel (in all areas, not just the west coast).

- To capitalise on observer coverage in this fishery by collecting data during 2000–01 from any blue mackerel bycatch, and use them in EMA2000/01 to determine the utility of future monitoring of the stock's biology.

The analysis for the first of the above tasks is based on data for the three areas, QMA 7, QMA 8, and QMA 9 (Figure 1). Results for the second task were submitted as part of MFish project MOF2000/03G, "Establishing potential area boundaries and indicative TACs for selected non-QMS species", and are not repeated here. For the third task, no data were collected; the delayed acceptance of this proposal by MFish, and reduction of scientific observer days in the JMA 7 fishery, resulted in work under this project being done when there were no scientific observers assigned to this fishery.

Because of the extensive nature of the information reviewed under this project and the requirement for research recommendations, the structure of this report comprises the following broad subject areas.

- A literature review, including an extensive biological summary and a summary of the blue mackerel fishery in all QMAs: this provides a basis for examining the fishery in QMAs 7, 8, and 9.
- The research section, with a review of the available data, methods, and results of the analyses carried out, and a discussion section that summarises and draws conclusions from the results: this discussion section provides a basis for development and discussion of the recommendations in the following sections; its early position in the document and focus on the research means that the structure of this report differs from the "standard" Fisheries Assessment Report.
- Two sections addressing stock assessment and management issues: these provide perspective for the research recommendations.
- The research recommendations: these form a second summary/set of conclusions, and are supported by all the previous information presented in the report.

The report includes eight appendices, some of which are figures from research results of other workers. These were used here to support conclusions from those studies and to emphasise points in the discussion. Their inclusion as appendices is non-standard. It has been done to separate them from the main body of the text because they are bulky, and because, in some cases, they rely on ancillary plots or information, which are also included in the particular appendix.

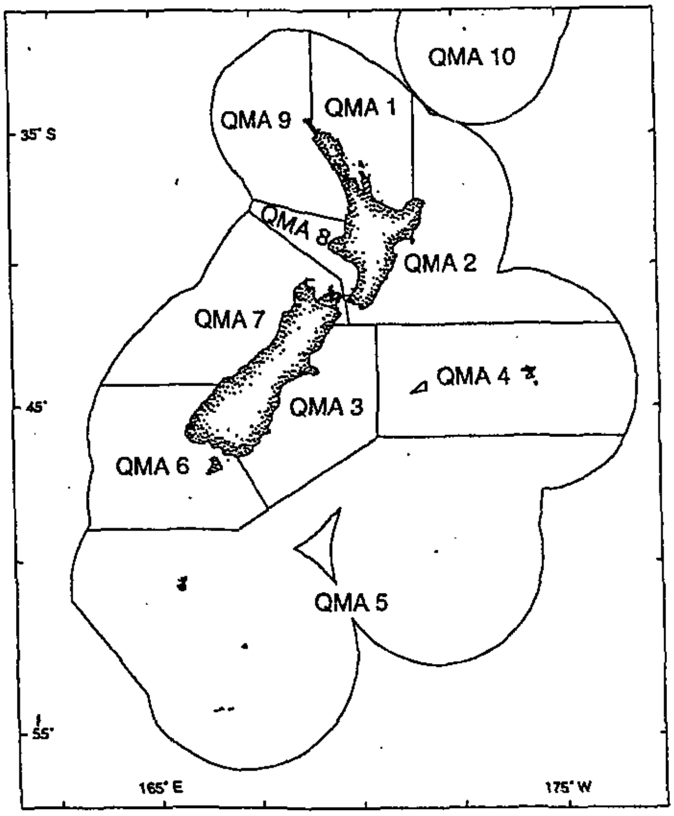


**Figure 1: Quota management areas**

## 2. LITERATURE REVIEW

Little is known about blue mackerel (*Scomber australasicus*), but an extensive literature is available for Atlantic mackerel (*S. scombrus*) and chub mackerel (*S. japonicus*). Given the close taxonomic relationship between these species (Quinteiro et al.1997, Scoles et al. 1998), some information for Atlantic and chub mackerel can be used in developing an understanding of blue mackerel. Because of the paucity of biological information for blue mackerel the biological summary is not restricted to New Zealand studies of this species, but incorporates information from all sources, including studies in Australian and Taiwanese waters.

### 2.1 Taxonomy

The number of species within the genus *Scomber* is somewhat unclear. According to Scoles et al. (1998), who based their classification on mitochondrial DNA, there are three: *S. scombrus*, *S. japonicus*, and *S. australasicus*. More recently, Collette (1999) described the distributions of four species: the three listed by Scoles et al. (1998) and *S. colias*, which was separated from *S. japonicus*. The four-species description is supported by a study using mitochondrial DNA (Quinteiro et al. 1997), which found "two genetically differentiated populations for chub mackerel (*Scomber japonicus*) in the Atlantic and Pacific oceans" although they did not define two species.

The common names used here are those defined by the Food and Agriculture Organization of the United Nations (FAO): Atlantic mackerel for *S. scombrus*, chub mackerel for *S. japonicus*, and blue mackerel for *S. australasicus*; although not listed by the FAO, *S. colias* is included here as chub mackerel. The term "mackerel" is used in this report to refer generally to species in the genus *Scomber*, which are members of the family Scombridae and commonly known as scombrid mackerel.

## 2.2 Distribution of blue mackerel

Only *S. australasicus* occurs in New Zealand waters. It is widespread in North Island and northern South Island waters, as well as being found in Australia (Robertson 1978). Work by Rohde (1987), using parasites as indicators, strongly suggests that New South Wales and New Zealand populations are separate stocks. The known range of *S. australasicus* is throughout the western Pacific from New Zealand and Australia in the south, north to China and Japan, and east to Hawaii; it has also been identified from the southwest coast of India (Gopakumar et al. 1993) and the northern Indian Ocean and Red Sea (Baker & Collette 1998).

Jones (1983) described the areas in New Zealand during summer where "blue mackerel are found in abundance" as Northland, Bay of Plenty, South Taranaki Bight, and Kaikoura and observed that in winter they "all but disappear except for occasional [fish] in Northland and the Bay of Plenty".

Bagley et al. (2000) presented summary distributions from various datasets. Catches taken by midwater trawl (MFish scientific observer database, *obs_lfs*, MFish research trawl survey database, *trawl*) were from North and South Taranaki Bights, west coast South Island southwards to the Hokitika Trench, and around Mernoo Bank, and most were caught over bottom depth shallower than 250 m (Appendix 1). Aerial sightings of blue mackerel (MFish aerial sightings database, *aer_sight*) were distributed over most of the range covered by pilots supporting purse-seine vessels, from the Three Kings Islands around the entire coastline of the North Island, and from the Kahurangi Shoals, outer Golden and Tasman Bays, to Kaikoura, with the highest density on the east coast from North Cape to Hawke Bay, and in the area including the South Taranaki Bight to Kahurangi and the outer Golden and Tasman Bays (Appendix 2).

A summary of bottom trawl data (MFish research trawl survey database, *trawl*) by Anderson et al. (1998) showed that blue mackerel were present all around the North Island, and around the South Island including Golden and Tasman Bays south to about 44° S on the west coast and about 45° S on the east coast (Appendix 3). Highest numbers in this dataset were from the inner and outer Hauraki Gulf. Most were caught at less than 250 m depth.

Shuntov (1969) suggested that the localised inshore distribution of juvenile blue mackerel in New Zealand waters is related to the abundance of suitably sized prey. Stevens et al. (1984) observed that most blue mackerel taken in nine research cruises using a variety of fishing gears (pelagic, midwater, and bottom trawl) in the Great Australian Bight between January 1979 and December 1980 were taken at 50–150 m depth and that no relationship between fish length and depth was found over this range. Working in east Northland waters, Kingsford (1992) showed that larval and juvenile blue mackerel are more likely to be found in open water than associated with drift algae, whereas for a number of other pelagic species or their early life history stages the reverse was true. Growth and migratory patterns of blue mackerel were investigated in Taiwanese waters using tags (Chang & Wu 1977 a, 1977b) but the recapture rate was very low (0.1 %).

## 2.3 Biological summary of blue mackerel

### 2.3.1 Reproduction

Blue mackerel is a serial spawner releasing eggs in batches over several months (Jones 1983); eggs are pelagic and development rate is dependent on temperature. According to Jones (1983), "Blue mackerel eggs have been found from East Cape to North Cape in FRD [Fisheries Research Division] plankton surveys, but the greatest concentrations outside the Hauraki Gulf were in the western Bay of Plenty in December 1974, and April 1975. Eggs were probably present in this area throughout the summer."

Large quantities of blue mackerel eggs and larvae were recorded in Northland and the Hauraki Gulf by Crossland (1981; 1982). Eggs occurred throughout the Gulf from November to the end of January. Surface temperatures were 17–23 °C in 1974–75, 15–19 °C in 1975–76. As Jones (1983) observed: "this corresponds well with temperatures of 16.7–20.6 °C for *S. japonicus* eggs [Collette & Nauen (1983) suggest 15–20 °C] in the Pacific, while *S. scombrus* is associated with lower temperatures (8.7–13.8 °C) [Sette (1943) suggests 9–12 °C]. Hatching of *S. scombrus* takes 9 days at 12 °C, the newly hatched larvae grow to 50 mm in 40 days, at which size they aggregate to form schools. Sporadic catches of small numbers of yearling blue mackerel have been made by otter trawl in New Zealand in shallow waters."

Hurst et al. (2000a) summarised information on blue mackerel from the MFish databases *trawl* and *obs_lfs* where gonad staging data had been recorded, and produced spatial distribution maps of fish in "ripe and running ripe" and "spent" condition. These maps show spawning blue mackerel from a few tows off Tasman Bay and Taranaki in QMAs 7, 8, and 9 (Appendix 4). A summary by life history stages of bottom trawl data from the MFish databases *trawl* and *obs_lfs* by Hurst et al. (2000b) showed that juvenile and immature blue mackerel were northerly in their distribution around the North Island and into Golden and Tasman Bays (Appendix 5). By contrast, adults followed a distribution around both the North and South Islands to Stewart Island and across the Chatham Rise to almost the Chatham Islands, although the data were somewhat patchy. The absence of any records from Fiordland is the result of no bottom trawling in this area.

Stevens et al. (1984), using gonad condition, estimated sexual maturity for blue mackerel (both sexes) taken in the Great Australian Bight between January 1979 and December 1980 to be about 28 cm FL, which relates to an age of about 2 years.

### 2.3.2 Age and growth

Two growth studies on blue mackerel from Taiwanese waters described very high growth rates. Hanado et al. (1968) estimated that individuals reached about 31 cm during the first year and 34 cm by the end of the second year. The estimates of Chang & Woo (1970) were only a little lower (27.5 and 32 cm at the end of years 1 and 2 respectively). These estimates seem very high compared with those from elsewhere.

There have been several recent ageing studies on blue mackerel by Australian and New Zealand workers. Annual rings in the otolith were validated by Stewart et al. (1999), and a method was developed by Stewart et al. (1998) with which the age structures of commercial and recreational catches were examined at three locations on the New South Wales coast. In the New Zealand study (Morrison et al. 2001), the age structure of catch in the Bay of Plenty purse-seine fishery was examined using otoliths collected in 1997, supplemented with small age classes from a research trawl survey off the west coast of the North Island in 1999. The results from these studies show that the age structures of catches in the two countries are very different: the Australian study found a peak at 1 y that accounts for more than 55% of the fish sampled, and a maximum age of 6 y; the New Zealand results show a much broader distribution, with a maximum age of 24 y and a peak in the data around 8 to 10 y.

Growth parameters estimated by Morrison et al. (2001) are shown in Table 1. Male blue mackerel reached a maximum age of 21+ years and females were aged to a maximum of 23+ years. Von Bertalanffy curves for male and female fish were similar, with females having a marginally greater asymptotic length ($L_\infty$), and a correspondingly lower value for the curvature parameter, $K$. Male and female fish had rapid growth for the first 4–5 years, but growth was negligible after about 12 years. The maximum ages produced estimates for the instantaneous rate of natural mortality ($M$) of 0.22 and 0.20 respectively. The samples were not from virgin populations, so these values may be overestimates of true $M$.

**Table 1: Von Bertalanffy growth parameters for blue mackerel (from Morrison et al. (2001)).**

| | Males and (Unsexed) | Females and (Unsexed) | Combined |
|---|---|---|---|
| $L_\infty$ | 48.77 | 51.11 | 50.02 |
| $K$ | 0.25 | 0.21 | 0.23 |
| $t_0$ | -0.89 | -1.06 | -1.01 |
| Age range (y) | 0.2–21.9 | 0.2–23.9 | 0.2–23.9 |
| $N$ | 177 (77) | 171 (77) | 425 |

According to Morrison et al. (2001), the relatively large negative value for the initial condition parameter ($t_0$) in this study might be explained by: (1) all samples being collected with large mesh nets, resulting in sampling bias towards larger individuals in any year class, and a concurrent bias towards negative values of $t_0$; and/or (2) inaccuracy in the assumed 1 January birth date for many fish, given a probable broad summer spawning pattern.

Shed sampling data used by Morrison et al. (2001) were from commercial catches taken in the Tauranga based purse-seine fishery, collected according to the sampling design and protocol described by Langley & Anderson (1998). An age-length key was constructed from the otolith data and applied to the scaled length frequency distribution from the catch sampling to provide an estimated age structure for the fished blue mackerel population. This was composed mainly of fish aged 4–12 y and included fish up to age 19 y. No females younger than 4 y, nor males younger than 3 y, were caught.

### 2.3.3 Feeding

Jones (1983) listed zooplankton, chiefly copepods, larval crustaceans, and molluscs, and fish eggs and larvae as the food of New Zealand blue mackerel. Stevens et al. (1984) described the diet for blue mackerel in the Great Australian Bight, with crustaceans the most common item, particularly euphausids and mysids, and siphonophores, fish, salps, natantians (decapod crustaceans with a swimming habit), and brachyurans also of importance. Feeding includes both filtering of the water and active pursuit of prey, with blue mackerel able to take much smaller animals than kahawai, below which it often schools (Jones 1983).

### 2.3.4 Parasites

Several studies have examined parasites in blue mackerel. Three of these were focused on the pathology and physiological response of the host (Perera 1992a, 1992b, 1994). Hayward et al. (1998) described in detail the species of parasites from 453 specimens of blue mackerel taken from 12 samples over 5 years from a single locality in southeast Australia. Ten species of ectoparasites were recorded: 6 monogeneans, 3 copepods and 1 isopod. Perera (1993) showed that there was no seasonal variation in abundance or prevalence of 15 species of ectoparasites (6 monogeneans, 5 trematodes, 2 copepods, 1 isopod, and 1 cestode). Rohde (1987) showed that, based on the morphometrics of monogenean ectoparasites with which they were infested, blue mackerel taken in southeast Australia and New Zealand are from different populations.

### 2.3.5 Behaviour

Williams & Pullen (1993) examined jack mackerel schooling off the east coast of Tasmania between 1985 and 1989 and discovered a seasonal variation in their occurrence with blue mackerel in mixed schools. This is a similar result to that seen from aerial sightings data in New Zealand (Taylor, unpublished data). Kim et al. (1993) used sonar images to measure the average speed of blue mackerel as 18–19 cm $s^{-1}$ in a setnet fishing area.

### 2.3.6 Stock discrimination

To investigate stock structure and recruitment in Taiwanese waters, Chang & Chen (1976) used seven morphometric features (body length, body depth, head length, snout length, eye depth, distance from snout to first dorsal fin, and mandible length) measured in 2106 specimens. They employed multi-discriminant analysis and Mahlanobis's generalised distance, concluding that there was a geographical cline, but also suggesting that their blue mackerel may belong to more than one stock. Caution over such conclusions is necessary (Murta 2000) and methodology can be critical (Winans 1987), given the influence of environment on morphometric features (Tudela 1999), but there are proponents who regard morphometrics as a powerful tool, despite problems with interpreting phenotypic features (Waldman et al. 1997, Cadrin 2000).

## 2.4 World fisheries for *Scomber* species

### 2.4.1 Catches

*Scomber* species support substantial pelagic fisheries (Sato 1990, Matsuda et al 1992, Villacastin-Herro et al. 1992, Gregoire 1996). Table 2 shows the main catches in thousands of tonnes from 1990 to 1998 — according to Collette's (1999) taxonomy, catches recorded as *S. japonicus* outside the Pacific Ocean are of *S. colias*. The catch of *S. australasicus* in the Pacific southwest includes the New Zealand catch and is modest compared with those of other species in other areas. There is some discrepancy in that New Zealand records (Table 3) indicate higher levels of catch (by about 10% over all years from 1990 to 1998) than the FAO records presented here.

**Table 2: Main global landings of *Scomber* spp. (x 1000 t). Source: FAO databases and statistics — http://www.fao.org/fi/statist/statist.asp.**

| Species | Area | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 |
|---|---|---|---|---|---|---|---|---|---|---|
| **S. scombrus** | Atlantic Northeast | 581 | 611 | 734 | 799 | 816 | 760 | 516 | 517 | 620 |
| | Atlantic Northwest | 67 | 62 | 41 | 32 | 30 | 26 | 37 | 37 | 32 |
| | Mediterranean, Black Sea | 10 | 9 | 10 | 10 | 9 | 7 | 7 | 5 | 5 |
| **S. japonicus** | Atlantic Eastern Central | 173 | 141 | 80 | 55 | 103 | 170 | 223 | 244 | 198 |
| | Atlantic Northeast | 9 | 11 | 9 | 8 | 5 | 5 | 6 | 6 | 7 |
| | Atlantic Southeast | 20 | 17 | 4 | 5 | 5 | 5 | 4 | 12 | 6 |
| | Atlantic Southwest | 9 | 11 | 10 | 12 | 15 | 21 | 17 | 19 | 13 |
| | Mediterranean, Black Sea | 24 | 20 | 27 | 32 | 34 | 28 | 20 | 22 | 16 |
| | Pacific Eastern Central | 78 | 68 | 38 | 31 | 22 | 31 | 23 | 42 | 43 |
| | Pacific Northwest | 612 | 618 | 669 | 1 153 | 1 235 | 1 096 | 1 604 | 1 466 | 1 105 |
| | Pacific Southeast | 402 | 294 | 118 | 171 | 106 | 212 | 275 | 610 | 518 |
| **S. australasicus** | Pacific Southwest | 8 | 12 | 13 | 10 | 6 | 8 | 3 | 9 | 7 |

### 2.4.2 Fishing methods, stock assessments, and management measures

Fisheries information is readily available for only some of the mackerel fisheries listed in Table 2. Fishing methods, approaches to stock assessment, and some management approaches used in some of the key mackerel fisheries are summarised in Appendix 6.

## 3. REVIEW OF THE NEW ZEALAND FISHERY

A review of the New Zealand fishery is presented to provide a reference for the fishery in QMAs 7, 8, and 9 in terms of the proportion of total catch taken, the fishing methods used, the amount of catch taken as target and bycatch, and the species targeted when blue mackerel is taken as bycatch.

### 3.1 Commercial catch history

Commercial landings from 1983–84 are shown in Table 3. Information for earlier years is available from Annual Reports on Fisheries, but is not included here because of the common use of the non-specific category "mackerel", which prevents distinction between blue and jack mackerel.

Since 1983–84 the catch of blue mackerel in New Zealand waters has grown substantially (Table 3), primarily through activity in the purse-seine fishery in QMA 1 (Figure 1). Purse-seine fishing effort targeting blue mackerel has been influenced by market demands and values, and the availability of other pelagic species. For example, fishing effort increased as limits were placed on the catch of kahawai. Landings peaked in 1991–92 at more than 15 000 tonnes, of which 60–70% was taken by purse-seine (Table 4) almost exclusively in QMA 1 (Table 1 in Appendix 7); substantial catches were also recorded from the TCEPR midwater trawl fishery in QMAs 7 and 8 (Table 2 in Appendix 7). Commercial landings were again high in 1998–99, totalling 13 493 t, with the largest catches taken in QMA 1 (4505 t), QMA 7 (5466 t), and QMA 8 (907 t). Most of this was either purse-seine or TCEPR midwater trawl catch.

**Table 3: Reported landings (t) of blue mackerel by QMA, and where area was unspecified (Unsp.), from 1983–84 to 1998–99; (see p. 16 for a discussion of discrepancies with Table 5. Source: Annala et al. 2001**

| QMA | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10# | Unsp | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1983–84* | 480 | 259 | 43 | 0 | <1 | 0 | 36 | 190 | 19 | 0 | 1 | 548 |
| 1984–85* | 565 | 222 | 18 | 0 | 0 | 0 | 144 | 716 | 5 | 0 | 73 | 1 743 |
| 1985–86* | 618 | 30 | 189 | 0 | <1 | 0 | 216 | 190 | 2 | 0 | 51 | 1 296 |
| 1986–87† | 1 431 | 7 | 423 | 0 | <1 | 0 | 248 | 231 | 10 | 0 | 49 | 2 399 |
| 1987–88† | 2 641 | 168 | 863 | <1 | <1 | 0 | 1 114 | 781 | <1 | 0 | 58 | 5 625 |
| 1988–89† | 1 580 | <1 | 1 115 | 0 | 0 | 26 | 662 | 332 | 27 | 0 | 469 | 4 211 |
| 1990–91† | 5 783 | 94 | 477 | 0 | <1 | 0 | 2 469 | 535 | 0 | 0 | 0 | 9 358 |
| 1991–92† | 10 926 | 530 | 65 | 0 | 0 | 0 | 2 255 | 1 352 | 0 | 0 | 0 | 15 128 |
| 1992–93† | 10 684 | 309 | 124 | 2 | 7 | 0 | 1 494 | 386 | 0 | 0 | 0 | 13 006 |
| 1993–94† | 4 178 | 218 | 219 | 3 | <1 | 0 | 975 | 367 | 60 | 5 | 0 | 6 025 |
| 1994–95† | 6 734 | 94 | 148 | 5 | <1 | 0 | 1 188 | 385 | 231 | 10 | 149 | 8 944 |
| 1995–96† | 4 170 | 119 | 171 | 1 | <1 | <1 | 1 205 | 12 | 1 | 0 | 1 | 5 680 |
| 1996–97† | 6 754 | 78 | 339 | <1 | <1 | 0 | 2 475 | 40 | 22 | 0 | <1 | 9 708 |
| 1997–98† | 4 595 | 122 | 77 | 0 | <1 | <1 | 2 116 | 106 | 88 | 0 | <1 | 7 104 |
| 1998–99† | 4 505 | 145 | 61 | <1 | 0 | 0 | 5 466 | 3 306 | 6 | 0 | 4 | 13 493 |
| 1999–00† | 3 602 | 73 | 3 | 0 | 0 | 0 | 2 780 | 385 | 4 | 0 | 0 | 6 847 |

* FSU data † CELR and CLR data

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

## 3.2 Catch by method and target species

Estimated catches, which are generally less than landings, are reported by method. Blue mackerel have been taken by a variety of methods, including bottom longline, bottom pair trawl, beach-seine, bottom trawl, drift net, dip net, Danish seine, handline, lampara, midwater trawl, purse-seine, lobster pot, ring net, surface longline, set-net, and troll, but the catch in many of these is very low. The largest and most consistent catches have been by purse-seine (Table 4) in a number of QMAs (Table 5, Figure 2,), which is mainly a target fishery (Table 6), and midwater trawl, which is mainly bycatch in the jack mackerel fishery (Table 7) in QMA 7 and QMA 8 (see Table 5, Figure 3).

**Table 4: Estimated catch (t) of blue mackerel by method and fishing year, all areas combined. Source: CELR estimated catch and TCEPR data from the MFish catch and effort database.**

| Fishing year | Bottom trawl | Danish seine | Midwater trawl | Purse-seine | Set-net | Other methods* |
|---|---|---|---|---|---|---|
| 1988–89 | 38 | 0 | 274 | 167 | 1 | 0 |
| 1989–90 | 136 | 0 | 63 | 4 161 | 7 | 1 |
| 1990–91 | 301 | 170 | 1 376 | 6 479 | 11 | 5 |
| 1991–92 | 411 | < 1 | 2 549 | 10 884 | 15 | 5 |
| 1992–93 | 163 | 0 | 634 | 9 570 | 26 | 7 |
| 1993–94 | 95 | 0 | 902 | 5 012 | 23 | 5 |
| 1994–95 | 17 | 0 | 1 339 | 5 931 | 32 | 154 |
| 1995–96 | 69 | < 1 | 641 | 5 376 | 17 | 22 |
| 1996–97 | 31 | 0 | 1 988 | 6 769 | 17 | 0 |
| 1997–98 | 221 | < 1 | 1 829 | 4 799 | 16 | 2 |
| 1998–99 | 23 | < 1 | 4 184 | 7 718 | 3 | 2 |
| 1999–2000 | 18 | 2 | 2 432 | 3 753 | 3 | 0 |
| Total | 1 524 | 172 | 18 212 | 70 618 | 169 | 203 |

* See text

**Table 5: Estimated catch (t) of blue mackerel by QMA and method, for fishing years 1988–89 to 1999–2000; (see p. 16 for a discussion of discrepancies with Table 3). Source: CELR estimated catch and TCEPR data from the MFish catch and effort database.**

| QMA | Bottom trawl | Danish seine | Midwater trawl | Purse-seine | Set-net | Other methods* |
|---|---|---|---|---|---|---|
| 1 | 9 | 172 | 1 | 55 863 | 90 | 172 |
| 2 | 2 | 0 | 5 | 1 608 | 9 | < 1 |
| 3 | 20 | 0 | 470 | 3 184 | 8 | 1 |
| 4 | 2 | 0 | 12 | 0 | 0 | 0 |
| 5 | < 1 | 0 | 2 | 0 | < 1 | 0 |
| 6 | 0 | 0 | 7 | 0 | | 0 |
| 7 | 900 | < 1 | 15 386 | 3 830 | 1 | 26 |
| 8 | 525 | 0 | 2 258 | 1 184 | 59 | 5 |
| 9 | 65 | 0 | 45 | 3 665 | 2 | < 1 |
| Unknown | 2 | < 1 | 26 | 1 284 | 1 | < 1 |
| Total | 1524 | 172 | 18 212 | 70 618 | 169 | 203 |
| % | 1.7 | 0.2 | 20.0 | 77.7 | 0.2 | 0.2 |

* See text

Fine-scale distribution of purse-seine catches (see Figure 2) shows the highest inter-annual consistency off east Northland and in the Bay of Plenty. Catches are taken less consistently in Hawke Bay and off Kaikoura, and there have been some catches in the South Taranaki Bight (1998–99 and 1999–2000). In some years, particularly 1992–93, catch has been taken off Northland, west of the QMA 1 boundary. Mostly, catch rates are less than 100 t per set (see Figure 5), but individual tow catches up to 200 t are not uncommon; the largest estimated catch recorded by purse-seine crews was 215 t.

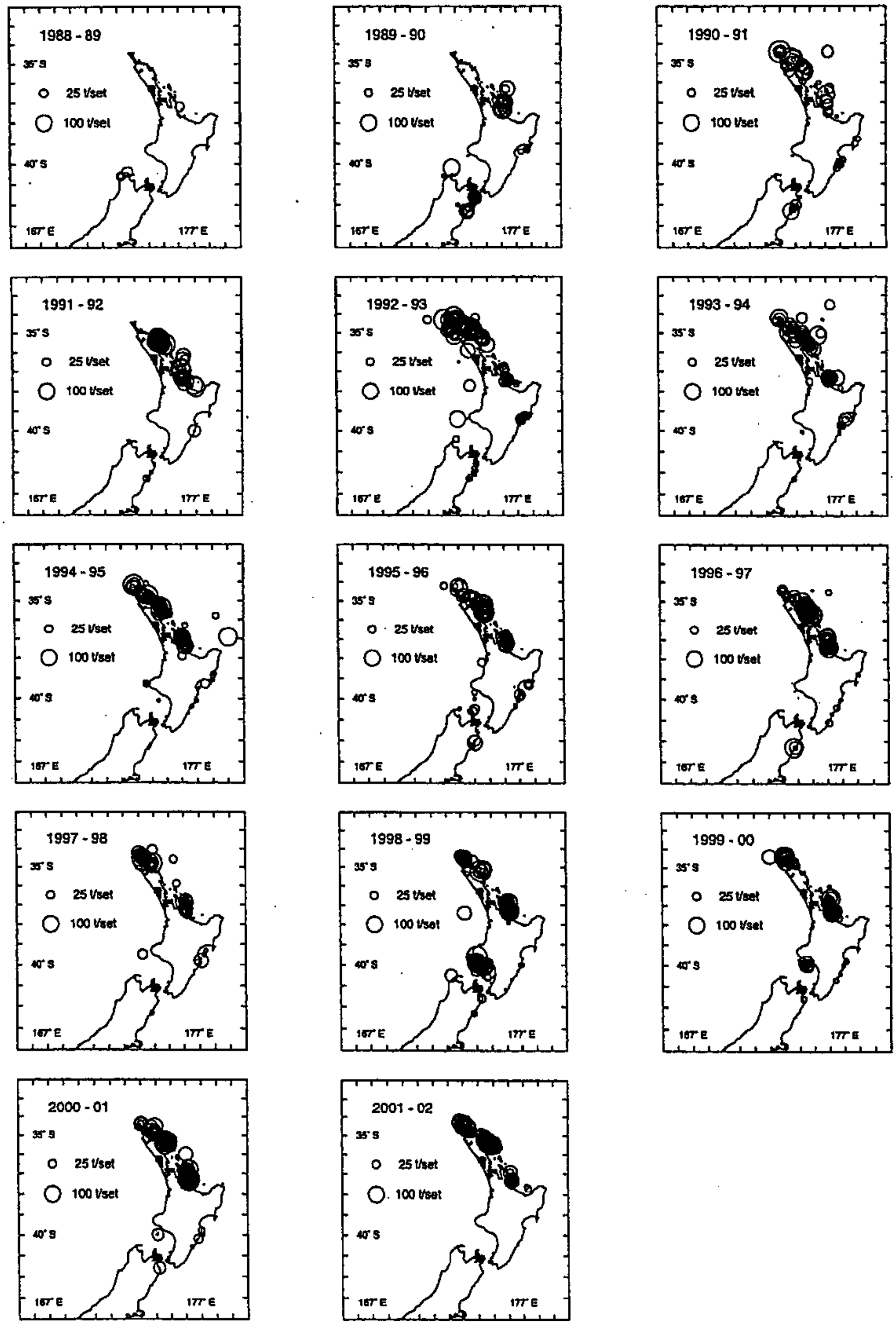


**Figure 2: Distribution and size of purse-seine catches of blue mackerel. Source: CELR estimated catch data from the MFish catch and effort database.**

Midwater trawl bycatch from the TCEPR fishery occurs mainly between 37° and 43° S on the west coast (Figure 3). Catch from Mernoo Bank is not uncommon, and there are catches from around the Chatham Islands and further south. In some cases these are corroborated by observer data (Figure 4), which indicates the presence of blue mackerel south of 49° S (see Figure 4, 1995–96). Blue mackerel have been recorded south of 51 °S (Figure 3, 1994–95).

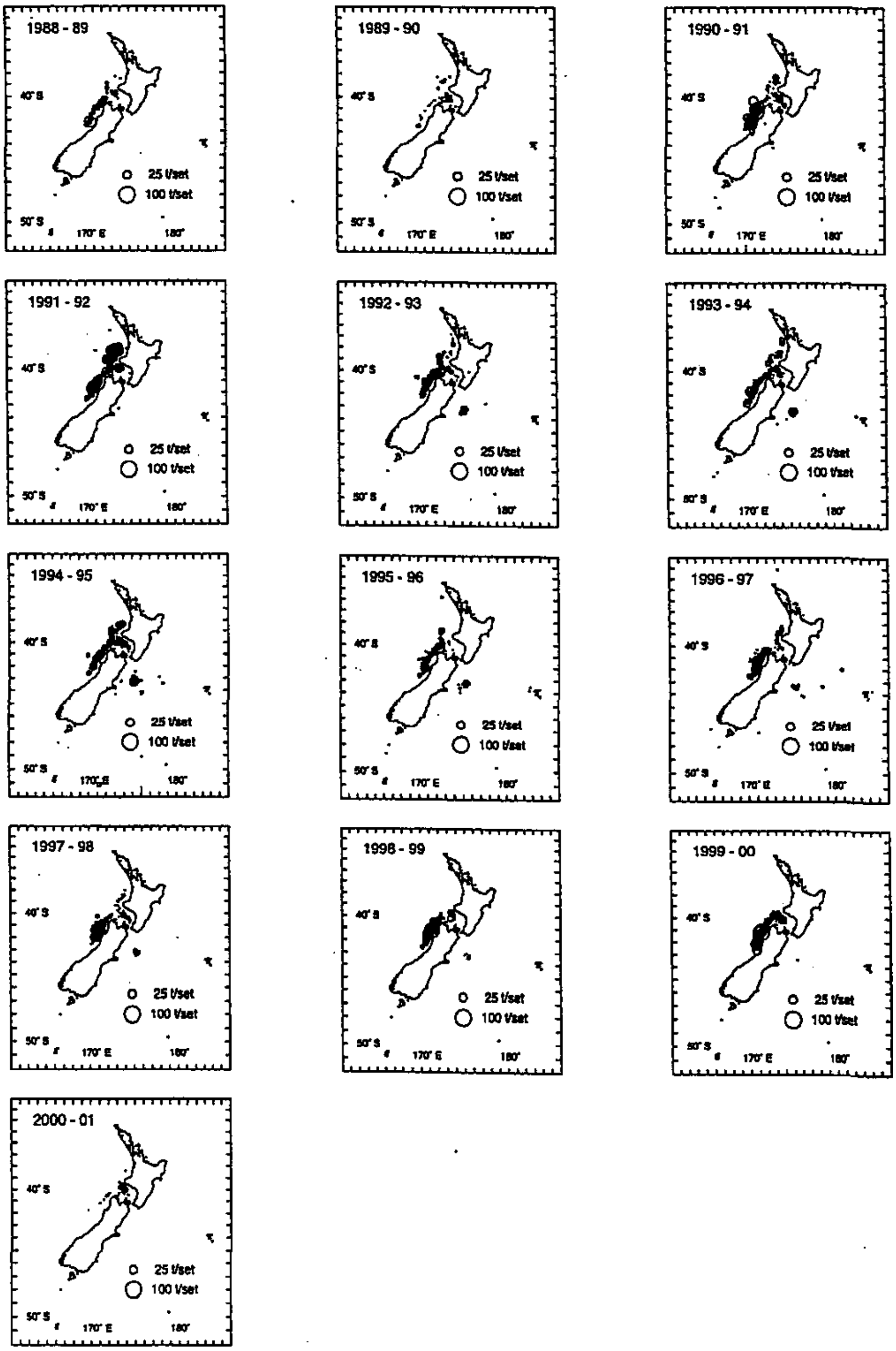


**Figure 3: Distribution and size of midwater trawl catches of blue mackerel in the TCEPR fishery. Source: MFish catch and effort database.**

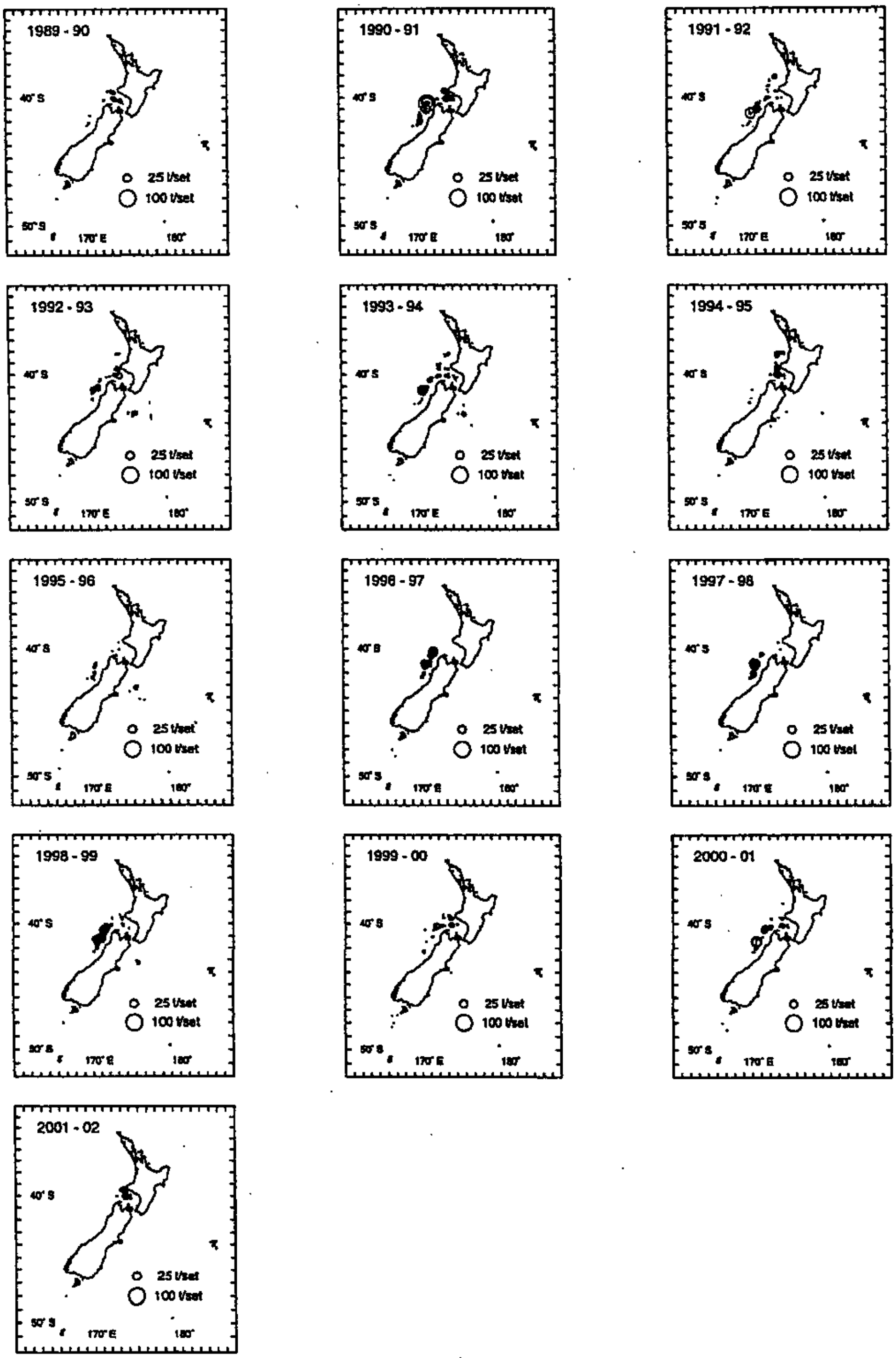


**Figure 4: Distribution and size of observed midwater trawl catches of blue mackerel in the TCEPR fishery in JMA 7. Source: MFish observer database, *obs*.**

Catch rates of blue mackerel from the purse-seine fishery ranged from 1 kg to 215 t per set. Almost 600 sets took 5 t or less, more than 250 took 1 t or less, and about 900 sets took between 1 and 50 t (Figure 5). TCEPR midwater trawl catch rates ranged from 1 kg to 71.3 t per tow, which is similar to the 1 kg to 53.2 t recorded by observers for this fishery. Most TCEPR midwater trawl catches were less than 1 t. During analysis of these data, three values of purse-seine catch (800, 750, 300 t) were obvious errors because they were considerably larger than the purse-seine gear capacity, and were retained in the dataset as values an order of magnitude lower. One value of midwater trawl catch recorded in the observer database (108.2 t) was well outside the range recorded on the fishing returns, but it is unknown whether this is a real observation or an erroneous data point; it was left unchanged in the data.

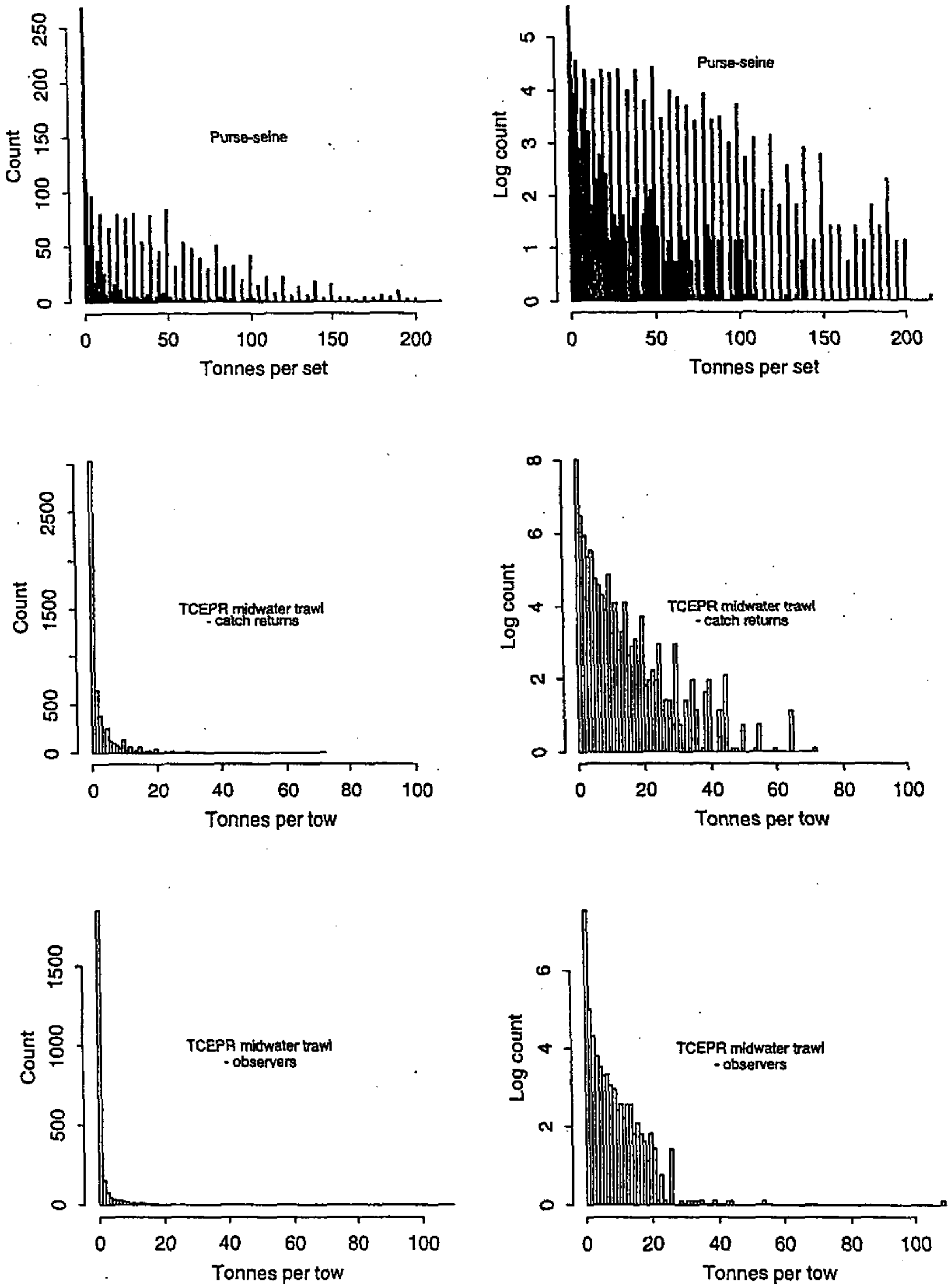


**Figure 5: Frequency distributions of catches of blue mackerel from the purse-seine and TCEPR (vessels using trawl catch effort processing returns) midwater trawl fisheries; cell sizes are 1 t in all cases with plots of log transformed frequencies included to illustrate the full range of individual set or tow catches, expressed as catch rates. Sources: MFish catch and effort database and MFish observer database *obs*.**

**Table 6: Estimated targeted/non-targeted catch (t) of blue mackerel, by method, for fishing years 1988–89 to 1999–2000. Source: CELR estimated catch and TCEPR data from the MFish catch and effort database.**

| | Bottom trawl | Danish seine | Midwater trawl | Purse-seine | Set-net | *Other | Total |
|---|---|---|---|---|---|---|---|
| Non-target | 1 518 | 2 | 17 285 | 5265 | 166 | 52 | 24 288 |
| Target | 6 | 170 | 927 | 65 353 | 3 | 151 | 66 610 |
| Total | 1 524 | 172 | 18 212 | 70 618 | 169 | 203 | 90 898 |

*See text

**Table 7: Estimated catch (t) of blue mackerel using midwater trawl by target species, for fishing years 1988–89 to 1999–2000. Source: TCEPR data from the MFish catch and effort database.**

| Target species | Midwater trawl catch | Target species | Midwater trawl catch |
|---|---|---|---|
| Barracouta | 239 | Jack mackerel | 15 937 |
| Blue mackerel | 927 | Ruby fish | 1 |
| Frostfish | 2 | Southern blue whiting | < 1 |
| Hake | 9 | Southern gemfish | 5 |
| Hoki | 1 085 | Squid | 2 |

A large discrepancy exists between blue mackerel landings and estimated catch data for QMAs 1 and 9 in Tables 3 and 5. The landings total for QMA 9 from 1988–89 to 1999–2000 in Table 3 is 439 t, which contrasts strongly with the 3777 t estimated catch in Table 5 and results in a difference of 3338 t between the two. Closer examination of estimated catch from CELR data shows that the largest component of QMA 9 purse-seine catch between 1988–89 and 1999–2000 occurred in 1992–93 (2647 t), with substantial catch in 1993–94 (224 t), 1994–95 (492 t), and 1995–96 (127 t) (Table 8). About 50% of the total QMA 9 purse-seine catch between 1988–89 and 1999–2000 was taken by one vessel.

**Table 8: Estimated catch (t) of blue mackerel by purse-seine vessels from QMA 9 between 1988–89 and 1999–2000, by vessel and fishing year. Source: CELR estimated catch from the MFish catch and effort database.**

| Vessel | 1988–89 | 1989–90 | 1990–91 | 1991–92 | 1992–93 | 1993–94 | 1994–95 | 1995–96 | 1996–97 | 1997–98 | 1998–99 | 1999–2000 | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | 20 | 135 | | | | | | | | 155 |
| 2 | | | | | 410 | | 12 | | | | | 80 | 502 |
| 3 | | | | 30 | 470 | 17 | 165 | 30 | | | 75 | | 787 |
| 4 | | | | | 392 | | 80 | 12 | | | | | 484 |
| 5 | | | | | 1 240 | 207 | 235 | 85 | | | | | 1 767 |
| Totals | | | | 50 | 2 647 | 224 | 492 | 127 | | | 75 | 80 | 3 695 |

Taking 1992–93 as an example, a comparison of shot by shot catch data (from the estimated catch section of the CELR form) with landings data (from the landings section of the CELR form) for particular purse-seine vessels, based on close agreement of catch dates to the landing dates (Table 9), showed that most, possibly all, of the estimated purse-seine catch of blue mackerel reported from QMA 9 during 1992–93 has been reported as blue mackerel landings from either QMA 1 or 7. This result offers a reasonable explanation for the discrepancy between Table 3 and 5. Although other years were not examined closely, it is not unreasonable to expect that the balance of the discrepancy can also be accounted for using this method, given the high level of agreement for 1992–93.

The purse-seine catch from QMA 9 is taken mainly around the coast of Northland (see Figure 3). Catches west of North Cape during 1992–93 are clearly evident. Similar distributions, though not as pronounced, can be seen in the other years identified in Table 8.

**Table 9: Comparison between CELR estimated catch weight and CELR landed weight for blue mackerel taken by purse-seine in QMA 9 during 1992–93. Source: MFish catch and effort database.**

| | Landing data | | | Estimated catch data | | | |
|---|---|---|---|---|---|---|---|
| Vessel | Landing date | QMA | Landing weight | Catch date | Target | Set weight | Total catch weight |
| 1 | 02031993 | 1 | 50.108 | 28021993 | EMA | 50 | 50 |
| | 25031993 | 1 | 85.096 | 25031993 | EMA | 30 | 85 |
| | | | | 24031993 | EMA | 55 | |
| Totals | | | 135.204 | | | | 135 |
| 2 | 07111992 | 1 | 154.969 | 06111992 | EMA | 25 | 145 |
| | | | | 07111992 | EMA | 120 | |
| | 28021993 | 1 | 2.893 | 20021993 | EMA | 12 | 13 |
| | | | | 27021993 | JMA | 1 | |
| | 25031993 | 1 | 102.504 | 21031993 | EMA | 40 | 135 |
| | | | | 24031993 | EMA | 95 | |
| Totals | | | 260.366 | | | | 293 |
| 3 | 23031993 | 1 | 93.801 | 20031993 | EMA | 40 | 80 |
| | | | | 21031993 | EMA | 40 | |
| | 31031993 | 7 | 1.999 | 28031993 | EMA | 0.04 | 0.09 |
| | | | | 29031993 | EMA | 0.03 | |
| | | | | 29031993 | EMA | 0.02 | |
| Totals | | | 95.8 | | | | 80.09 |
| 4 | 24111992 | 1 | 40.5 | 19111993 | EMA | 27 | 27 |
| | 10011993 | 1 | 56.5 | 08011993 | JMA | 50 | 50 |
| | 18011993 | 1 | 74.7 | 16011993 | EMA | 80 | 80 |
| | 23031993 | 7 | 139.973 | 21031991 | EMA | 130 | 130 |
| | 31031993 | 1 | 98.8 | 28031993 | EMA | 75 | 105 |
| | | | | 29031993 | EMA | 30 | |
| Totals | | | 410.473 | | | | 392 |
| 5 | 20101992 | 1 | 126.045 | 18101992 | EMA | 130 | 130 |
| | 05111992 | 1 | 258.943 | 04111992 | EMA | 65 | 255 |
| | | | | 05111992 | EMA | 190 | |
| | 28011993 | 1 | 229.383 | 26011993 | EMA | 120 | 120 |
| | 14021993 | 7 | 167.434 | 12021993 | EMA | 170 | 170 |
| | 26021993 | 1 | 247.485 | 22021993 | EMA | 150 | 240 |
| | | | | 24021993 | SKJ | 90 | |
| | 12031993 | 1 | 28.141 | 09031993 | JMA | 10 | 15 |
| | | | | 11031993 | JMA | 5 | |
| | 22031993 | 1 | 257.65 | 20031993 | EMA | 100 | 235 |
| | | | | 20031993 | EMA | 15 | |
| | | | | 21031993 | EMA | 50 | |
| | | | | 21031993 | EMA | 70 | |
| | 30031993 | 1 | 125.303 | 27031993 | EMA | 50 | 75 |
| | | | | 29031993 | EMA | 25 | |
| Totals | | | 1440.384 | | | | 1 240 |
| Overall totals | | | 2342.227 | | | | 2 140.09 |
| QMA 7 Totals | | | 309.406 | | | | 300.09 |
| QMA 1 Totals | | | 2032.821 | | | | 1 840 |

A second source of error in assignment of estimated catches to QMA arises from the approximation that is necessary when summing estimated catches from CELR data. Catch positions are recorded by statistical area, which do not always coincide with QMA boundaries. Figure 6 shows the best approximation to QMA boundaries available from northern statistical area boundaries. Comparison with Figure 1 indicates the extent of this approximation and illustrates how uncertainty in estimated catches from the CELR data may arise, particularly for QMAs 7, 8, and 9.

With purse-seine data, the extent of this approximation can be examined because catch positions from this fishery also include latitude and longitude. By reassigning blue mackerel catch from statistical areas 36, 37, 39, 40, and 41 using fine scale position data, estimated purse-seine catches recorded from QMAs 7, 8, and 9 changed markedly, particularly in QMAs 7 and 8 (Table 10): a decrease from 6874 t to 3671 t in QMA 7; an increase from 1184 t to 4357 t in QMA 8; and an increase from 3665 t to 3695 t in QMA 9. This change was greatest in 1998–99, when 92% of the 2634 t originally assigned to QMA 7 was correctly reassigned to QMA 8, where the catches occurred (see Figure 3).

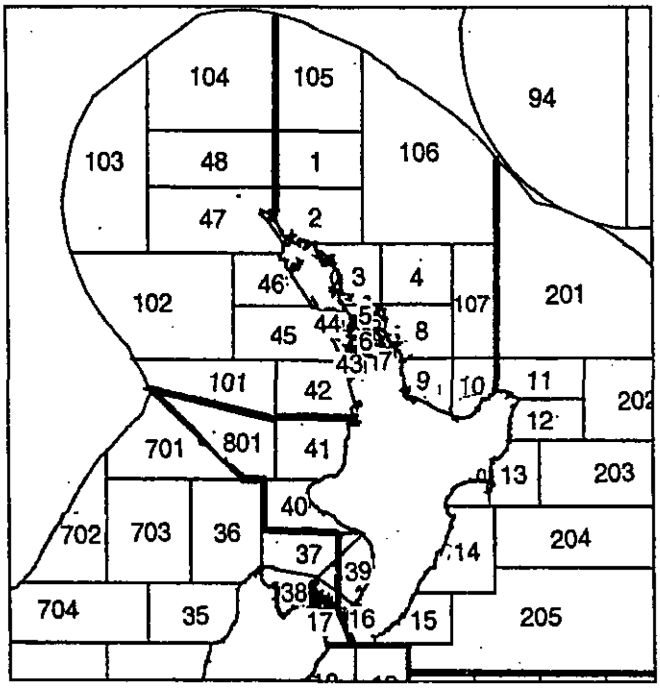


**Figure 6: Statistical areas around northern New Zealand; the bold boundaries indicate the best approximation to QMA boundaries possible from statistical area boundaries.**

**Table 10: Estimated purse-seine catch from QMAs 7, 8, and 9 by fishing year, before and after reassignment of catch to correct QMAs using fine scale position data (latitude and longitude). Source: CELR estimated data from the MFish catch and effort database.**

| | Before reassignment | | | | After reassignment | | | |
|---|---|---|---|---|---|---|---|---|
| Fishing year | QMA 7 | QMA 8 | QMA 9 | Totals | QMA 7 | QMA 8 | QMA 9 | Totals |
| 1988–89 | 132 | | | 132 | 47 | 85 | | 132 |
| 1989–90 | 1 831 | 18 | | 1 849 | 1 687 | 163 | | 1 849 |
| 1990–91 | 1 103 | 99 | | 1 202 | 1 103 | 99 | | 1 202 |
| 1991–92 | 79 | | 50 | 129 | 76 | 3 | 50 | 129 |
| 1992–93 | 133 | 107 | 2 647 | 2 887 | 116 | 124 | 2 647 | 2 887 |
| 1993–94 | 28 | | 224 | 252 | 19 | 9 | 224 | 252 |
| 1994–95 | 8 | 50 | 492 | 551 | 4 | 54 | 492 | 551 |
| 1995–96 | 240 | 40 | 97 | 377 | 173 | 77 | 127 | 377 |
| 1996–97 | 208 | 0 | | 208 | 208 | 0 | | 208 |
| 1997–98 | 36 | 40 | | 76 | 14 | 62 | | 76 |
| 1998–99 | 2 634 | 828 | 75 | 3 537 | 208 | 3 254 | 75 | 3 537 |
| 1999–2000 | 442 | 2 | 80 | 524 | 16 | 428 | 80 | 524 |
| Totals | 6 874 | 1 184 | 3 665 | 11 723 | 3 671 | 4 357 | 3 695 | 11 723 |

This feature of the analysis highlights the potential for error that can arise when estimating catch from the CELR data. It is only because of the inclusion of latitude and longitude in purse-seine data that catches can be reassigned to the correct QMA and an examination made.

### 3.3 Current management regime

Blue mackerel is to be introduced to the Quota Management System (QMS) on 1 October 2002. Currently there is no minimum legal size for blue mackerel, there are no commercial catch limits in place, and there is no minimum net mesh size applying to purse-seine or lampara net fishing methods for this species. There is no specific minimum net mesh size set for blue mackerel using commercial fishing methods other than purse-seine or lampara nets. Consequently the default of 100 mm applies (i.e., where specific measures applying to individual species do not exist) (Anon 2002).

### 3.4 Traditional Maori fishing

There is no information available to allow estimation of the amount of blue mackerel taken in the traditional Maori fishery.

### 3.5 Recreational fishery

The most recent information was summarised by Annala et al. (1998). Blue mackerel does not rate highly as a recreational species, although it is popular as bait. Recreational catch in the northern region (QMA 1) was estimated at 114 000 fish by a diary survey in 1993–94 (Bradford 1996) and 47 000 fish in a national recreational survey in 1996 (Bradford 1998). Catches in other regions are low (between 1000 and 3000 fish). There is some confusion between blue and jack mackerels in the recreational data.

## 4. RESEARCH

### 4.1 Review of the current and historical data available for blue mackerel in QMAs 7, 8, and 9

#### 4.1.1 The data

This review comprised a summary of the information available on blue mackerel from the MFish catch and effort database (*MOBY*), the observer databases (*obs* and *obs_lfs*), the research trawl database (*trawl*), the aerial sightings database (*aer_sight*), the recreational database (*rec_data*), and the market sampling database (*market*). Some data extracts from *MOBY* were provided by MFish for Project MOF2000/03G; all other data were extracted by NIWA staff.

**Catch and effort database.** A total of 8168 blue mackerel catch records were available from *MOBY* for QMAs 7, 8, and 9 over fishing years 1988–89 to 2000–01 (Table 11). The aggregated data for QMAs 7, 8, and 9 showed a consistently high number of records in most years. Because of geographic proximity, aggregation of data from QMAs 7 and 8 is usually justified. Data from QMA 9 were sparse and patchy.

**Observer database.** The observer database contained 171 records providing biological information (fish lengths, sex, and female gonad stages) on blue mackerel. This represented 935 fish measured for length, 899 sexed, and 498 females with gonad stages recorded, from QMAs 7, 8, and 9 (Table 12). These data were patchy in time and space, a feature that was reduced a little by aggregating over QMAs 7, 8, and 9.

**Table 11: Number of catch records (tows) for blue mackerel by fishing year and QMA. Source: MFish catch and effort database.**

| Fishing year | QMA 1 | QMA 2 | QMA 3 | QMA 4 | QMA 5 | QMA 6 | QMA 7 | QMA 8 | QMA 9 | QMAs 7, 8, 9 combined |
|---|---|---|---|---|---|---|---|---|---|---|
| 1988–89 | 9 | 2 | | | | | 171 | 34 | 2 | 207 |
| 1989–90 | 98 | 29 | 85 | | 1 | | 228 | 259 | 4 | 491 |
| 1990–91 | 283 | 70 | 72 | | 3 | 1 | 440 | 271 | | 711 |
| 1991–92 | 394 | 40 | 18 | | | | 457 | 506 | 6 | 969 |
| 1992–93 | 485 | 40 | 111 | 3 | | | 272 | 486 | 50 | 808 |
| 1993–94 | 370 | 24 | 201 | | 2 | | 332 | 418 | 16 | 766 |
| 1994–95 | 357 | 35 | 110 | 24 | 1 | 2 | 387 | 397 | 11 | 795 |
| 1995–96 | 268 | 31 | 100 | | 1 | | 376 | 80 | 16 | 472 |
| 1996–97 | 346 | 22 | 31 | 3 | 1 | | 512 | 88 | 9 | 609 |
| 1997–98 | 347 | 13 | 42 | | 4 | | 574 | 217 | 74 | 865 |
| 1998–99 | 144 | 34 | 24 | | | | 785 | 77 | 29 | 891 |
| 1999–00 | 169 | 16 | 12 | | | | 488 | 78 | 18 | 584 |
| Total | 3 270 | 356 | 806 | 30 | 13 | 3 | 5 022 | 2 911 | 235 | 8 168 |

**Table 12: Number of blue mackerel sampled for biological information by fishing year and QMA; the first value in each cell represents the number of fish length data available, the second represents the number of sexed fish, and the third represents the number of females with gonads staged. Source: MFish observer database *obs_lfs*.**

| Fishing year | QMA 3 | QMA 7 | QMA 8 | QMA 9 | QMAs 7, 8, 9 combined |
|---|---|---|---|---|---|
| 1986–87 | | 33, 33, 0 | | 1, 0, 0 | 34, 33, 0 |
| 1988–89 | | 197, 142, 0 | | | 197, 142, 0 |
| 1992–93 | 184, 184, 107 | | | | |
| 1993–94 | | 24, 24, 0 | | | 24, 24, 0 |
| 1994–95 | | | 135, 135, 127 | | 135, 135, 127 |
| 1996–97 | | 41, 41, 0 | | | 41, 41, 0 |
| 1997–98 | | 277, 277, 136 | 150, 150, 139 | | 427, 427, 275 |
| 1999–2000 | | 97, 97, 96 | | | 97, 97, 96 |
| Total | 184, 184, 107 | 669, 614, 232 | 285, 285, 266 | 1, 0, 0 | 935, 899, 498 |

**Research trawl database.** The research trawl database contained 1109 records providing annual length frequency data on blue mackerel since 1977–78; 368 records were for QMAs 7, 8, and 9 (Table 13). These data were very patchy in time and space. They were recorded on research vessels and a number of commercial vessels using different gear and fishing strategies. Consequently they do not offer a useful resource for examining inter-annual variations in size structure in QMAs 7, 8, and 9. However, they can be used for summarising the size range caught by the fishery. Under a single-stock assumption, data from all QMAs could be pooled for this type of summary.

**Table 13: Number of records containing annual length frequency data for blue mackerel by fishing year and QMA; each record represents data for one fish. Source: MFish research trawl database.**

| Fishing year | QMA 1 | QMA 2 | QMA 3 | QMA 4 | QMA 5 | QMA 6 | QMA 7 | QMA 8 | QMA 9 | QMAs 7, 8, 9 combined |
|---|---|---|---|---|---|---|---|---|---|---|
| 1977–78 | 10 | | | | | | | | | |
| 1978–79 | 3 | | | | | | 10 | | | 10 |
| 1979–80 | 3 | | | | | | | | | |
| 1980–81 | 38 | | | | | | | | | |
| 1981–82 | 28 | | | | | | 6 | | | 6 |
| 1982–83 | 42 | 1 | | | | | 2 | | | 2 |
| 1983–84 | | | | | | | 6 | | | 6 |
| 1984–85 | 31 | | | | | | | | | |
| 1985–86 | 80 | | | | | | | | | |
| 1986–87 | 35 | | | | | | | | 22 | 22 |
| 1987–88 | 46 | | | | | | | | 1 | 1 |
| 1988–89 | 34 | | | | | | | | | |
| 1989–90 | 41 | | | | | | 56 | 98 | 38 | 192 |
| 1990–91 | 24 | | 2 | | | | | | | |
| 1991–92 | 8 | | 3 | 1 | | | 2 | 2 | | 4 |
| 1992–93 | 35 | 1 | 4 | | 1 | | | | | |
| 1993–94 | 99 | 36 | 2 | | 1 | | | | | |
| 1994–95 | 19 | 2 | | | 1 | | 11 | | 37 | 48 |
| 1995–96 | 2 | 11 | 2 | 1 | | | 52 | | | 52 |
| 1996–97 | | | | 1 | | | 4 | | 26 | |
| 1997–98 | 29 | | | 2 | | | | | | |
| 1998–99 | 8 | | | | | | | | | |
| 1999–00 | 23 | | | | | | 5 | | 20 | 25 |
| Total | 638 | 51 | 14 | 5 | 3 | | 154 | 100 | 144 | 368 |

The research trawl database also contained 42 records providing gonad stage and sex ratio data; all were for QMAs 7, 8, and 9 (Table 14).

**Table 14: Number of records containing biological information (sex ratios and gonad staging) for blue mackerel by fishing year and QMA. Source: MFish research trawl database.**

| Fishing year | QMA 7 | QMA 8 | QMA 9 | Total |
|---|---|---|---|---|
| 1989–90 | 9 | 12 | | 21 |
| 1999–00 | | | 21 | 21 |

**Aerial sightings database.** The aerial sightings database contained 4945 sightings of "pure" schools of blue mackerel (Table 15). A total of 428 sightings were recorded from QMAs 7, 8, and 9, but they were not evenly distributed throughout the area (see Figure 2 of Appendix 2). Most were recorded from QMA 7 and QMA 8, throughout the area from immediately north of Golden and Tasman Bays to the coast of the South Taranaki Bight, with some distributed sparsely throughout inshore QMA 9.

**Table 15: Number of records of sightings of pure schools of blue mackerel by fishing year and QMA. Source: MFish aerial sightings database.**

| Fishing year | QMA 1 | QMA 2 | QMA 3 | QMA 7 | QMA 8 | QMA 9 | QMAs 7, 8, 9 aggregated |
|---|---|---|---|---|---|---|---|
| 1975–76 | 15 | | | | | | |
| 1976–77 | 116 | 4 | | 2 | 1 | 11 | 14 |
| 1977–78 | 89 | 8 | | 28 | 1 | | 29 |
| 1978–79 | 83 | 1 | | 17 | 3 | | 20 |
| 1979–80 | 149 | | | 39 | 20 | | 59 |
| 1980–81 | 173 | 4 | 1 | 31 | 12 | 9 | 52 |
| 1981–82 | 134 | 1 | | 17 | 12 | 14 | 43 |
| 1982–83 | 123 | | 2 | 1 | 17 | 3 | 21 |
| 1983–84 | 104 | 2 | | 4 | 2 | 2 | 8 |
| 1984–85 | 159 | | 1 | 21 | 7 | 6 | 34 |
| 1985–86 | 176 | | 1 | 10 | 1 | 4 | 15 |
| 1986–87 | 220 | 2 | 1 | 3 | | | 3 |
| 1987–88 | 218 | 2 | 2 | | | | |
| 1988–89 | 189 | 1 | 27 | 21 | | | 21 |
| 1989–90 | 260 | | 2 | 14 | 1 | | 15 |
| 1990–91 | 315 | 3 | 18 | 3 | 4 | | 7 |
| 1991–92 | 295 | 1 | 1 | 1 | 1 | 2 | 4 |
| 1992–93 | 274 | | | | | 13 | 13 |
| 1993–94 | 101 | | | | | | |
| 1994–95 | 169 | 4 | | | | | |
| 1995–96 | 157 | 1 | 2 | 2 | | | 2 |
| 1996–97 | 229 | 6 | | | | | |
| 1997–98 | 119 | 2 | | | 3 | | 3 |
| 1998–99 | 134 | | | 3 | 44 | 4 | 51 |
| 1999–00 | 82 | 3 | | | 9 | | 9 |
| 2000–01 | 234 | 2 | | 2 | 3 | | 5 |
| Total | 4 317 | 47 | 58 | 219 | 141 | 68 | 428 |

The aerial sightings database also contained 2113 sightings of blue mackerel mixed with jack mackerel (*Trachurus* sp.), kahawai (*Arripis trutta*), skipjack tuna (*Katsuwonus pelamis*), and trevally (*Pseudocaranx dentex*) (Table 16); 693 of these were from QMAs 7, 8, and 9. The spatial distribution of mixed blue mackerel schools in QMAs 7, 8, and 9 was a little different from that of monospecific schools (see Figure 3 of Appendix 2). Most were recorded from QMA 7, inside and immediately to the north of Golden and Tasman Bays, with a smaller amount sighted in QMA 8 (South Taranaki Bight), and less again distributed unevenly in QMA 9, to the far north and in the North Taranaki Bight.

**Recreational database.** The recreational database contained 93 records on blue mackerel. Because the measurement method is usually unavailable, these data cannot provide a reliable estimate of the size structure of fish in the recreational catch.

**Market sampling database.** A number of landings of blue mackerel have been sampled, and length data were available from the market sampling database (Table 17). Because these data were for catches from east Northland and the Bay of Plenty (QMA 1) they were not analysed here, but they could be useful in future analyses for examining the size structure of fish in these catches.

**Table 16: Number of records or sightings of schools containing blue mackerel in all areas, and in QMAs 7, 8, and 9 combined. Source: MFish aerial sightings database.**

| Species composition of school | All areas | QMAs 7, 8, 9 |
|---|---|---|
| Blue mackerel | 4 945 | 428 |
| Blue mackerel and bait (species undefined) | 10 | 0 |
| Blue mackerel and jack mackerel | 898 | 113 |
| Blue mackerel and jack mackerel (*T. s. murphyi*) | 194 | 3 |
| Blue mackerel and jack mackerel (including*T. s. murphyi*) | 38 | 0 |
| Blue mackerel, jack mackerel, and trevally | 4 | 0 |
| Blue mackerel and trevally | 12 | 0 |
| Blue mackerel, jack mackerel, and kahawai | 410 | 243 |
| Blue mackerel, jack mackerel (*T. s. murphyi*), and kahawai | 2 | 1 |
| Blue mackerel, jack mackerel, kahawai, and trevally | 2 | 0 |
| Blue mackerel, jack mackerel, and skipjack | 25 | 6 |
| Blue mackerel, jack mackerel (*T. s. murphyi*), and skipjack | 4 | 0 |
| Blue mackerel, jack mackerel (including *T. s. murphyi*), and skipjack | 1 | 0 |
| Blue mackerel and kahawai | 455 | 323 |
| Blue mackerel, kahawai, and trevally | 18 | 1 |
| Blue mackerel and skipjack | 40 | 3 |

**Table 17: Length data available from the market sampling database.**

| Area | Landing date | Number of records |
|---|---|---|
| Bay of Plenty | 30/10/97 | 233 |
| | 3/11/97 | 126 |
| East Northland | 23/9/97 | 124 |
| | 5/11/97 | 192 |
| | 9/11/97 | 254 |
| | 11/1197 | 147 |
| | 20/11/97 | 180 |
| | 26/11/97 | 166 |
| | 1/12/97 | 171 |
| | 4/12/97 | 248 |

## 4.2 Characterisation of the blue mackerel fishery in QMAs 7, 8, and 9

### 4.2.1 Characterisation by catches

Variations in time and space from the fishery were summarised using estimated catch data from the catch and effort database, which gave lower values than landings data and therefore varied from summaries shown in Table 3. Included were monthly summaries throughout the year for both the vessels using catch effort landing returns (the CELR fleet) and vessels using trawl catch effort processing returns (the TCEPR fleet).

**Annual variations.** To illustrate annual fluctuations in the combined catch of blue mackerel from QMAs 7, 8, and 9, and the relative contribution of catch in each QMA to the total, catches were aggregated by fishing year and plotted as time series for the CELR and TCEPR fleets. The aggregate plot for the CELR fleet (Figure 7) showed major peaks in 1992–93 (2127 t) and in 1998–99 (3480 t), with secondary peaks in 1989–90 (511 t) and 1994–95 (639 t), which were contributed mainly by QMA 7 in 1989–90, QMA 9 in 1992–93 and 1994–95, and QMA 7 and QMA 8 in 1998–99.

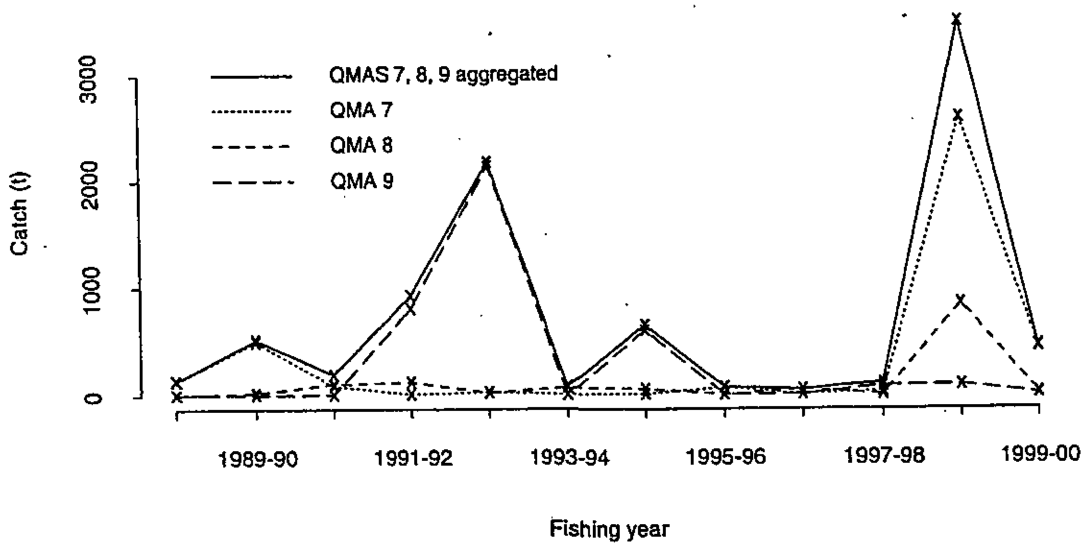


**Figure 7: Catches of blue mackerel (t) from the CELR fleet (mostly purse-seine) in QMAs 7, 8, and 9, summed by fishing year. Source: MFish catch and effort database.**

The aggregate plot for the TCEPR fleet (Figure 8) showed major peaks in 1991–92 (2945 t) and 1998–99 (4193 t), with what appeared to be an increasing trend throughout the time series. Catches from QMA 7 were the main contributor to the aggregate, with a similar amount coming from QMA 8 in 1991–92. Catch from QMA 9 is almost zero throughout the time series.

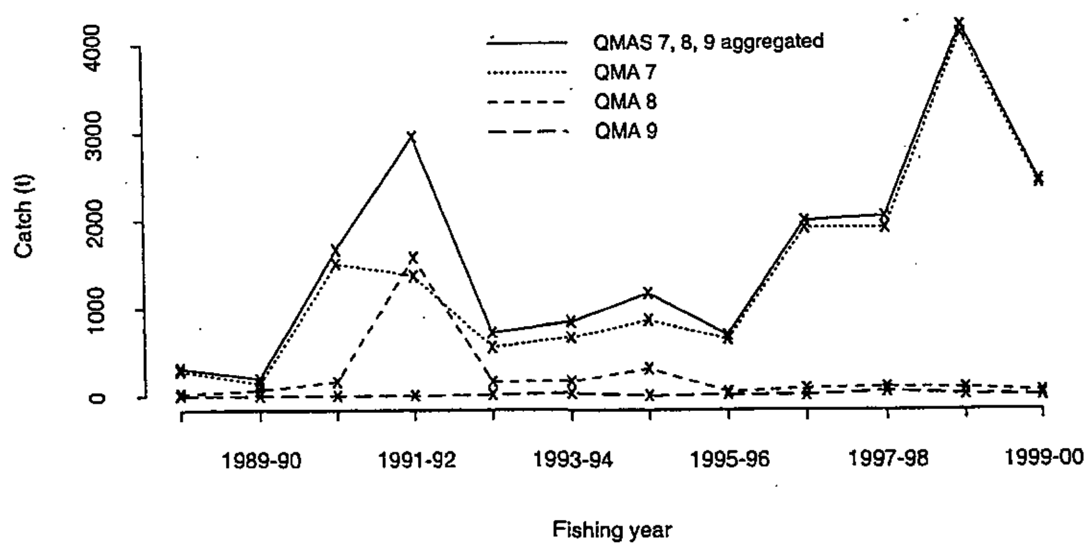


**Figure 8: Catches (t) of blue mackerel from the TCEPR fleet (mostly midwater trawl) in QMAs 7, 8, and 9, summed by fishing year. Source: MFish catch and effort database.**

**Seasonality.** To investigate the monthly distribution of catches in each fleet a three-step approach was taken. The first step consisted of plotting monthly totals for each year as separate curves on a single graph to determine the presence of any consistent patterns of seasonality in annual catches. In the CELR fishery (Figure 9), the overall pattern in the curve for aggregated catches suggested either two seasons, or, considering the possibility of reduced effort over the Christmas break, a season that continued from about September to May, with a major peak in March. Catches from the individual years supported this pattern with a period of very low catch in July and August of all years.

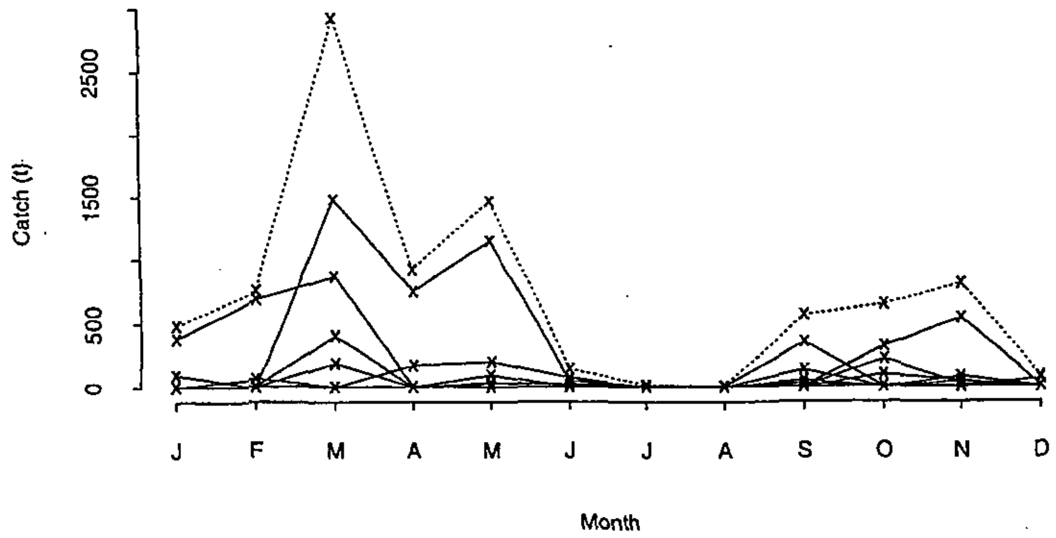


**Figure 9: Annual time series of monthly catches (t) of blue mackerel from the CELR fleet (mostly purse-seine) in QMAs 7, 8, and 9, for each month in the years from 1989–90 to 1999–2000 where data were available; the broken line is the time series of monthly totals aggregated over all years. Source: MFish catch and effort database).**

In the TCEPR fishery the seasonal pattern suggested a peak of catches in June and July that occurred in most years (Figure 10).

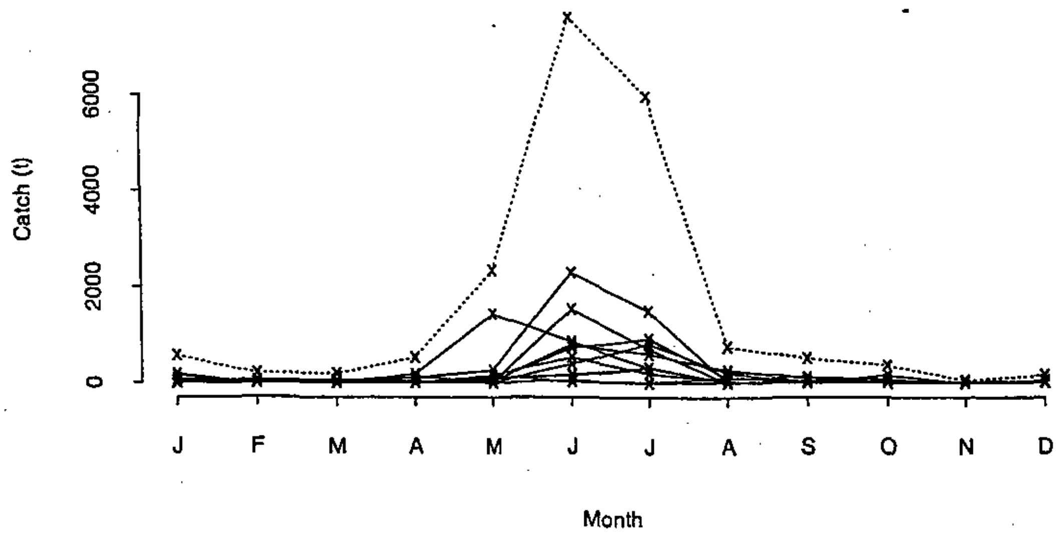


**Figure 10: Annual time series of monthly catches (t) of blue mackerel from the TCEPR fleet (mostly midwater trawl) in QMAs 7, 8, and 9, for each year from 1989–90 to 1999–2000; the broken line is the time series of monthly totals aggregated over all constituent years. Source: MFish catch and effort database.**

The second step consisted of investigating the contributions of each of the three QMAs to these seasonal patterns. This was done by plotting monthly catch summaries for each fleet, estimated from data summed by month over fishing years 1988–89 to 2000–01. In the CELR fishery (Figure 11) there was some suggestion that catches during what is roughly spring-summer (October–March) were mostly contributed by QMA 9. Catch taken through the remainder of the year was mostly contributed by QMA 7. Catches in QMA 8 occurred during both these periods. However, comparison with the monthly plots for individual years in Figure 9 indicated that most of the catch contributing to some of these peaks (e.g., QMA 7 in March–May; QMA 9 in January–March ) was taken in single years, showing that this pattern was not consistent annually.

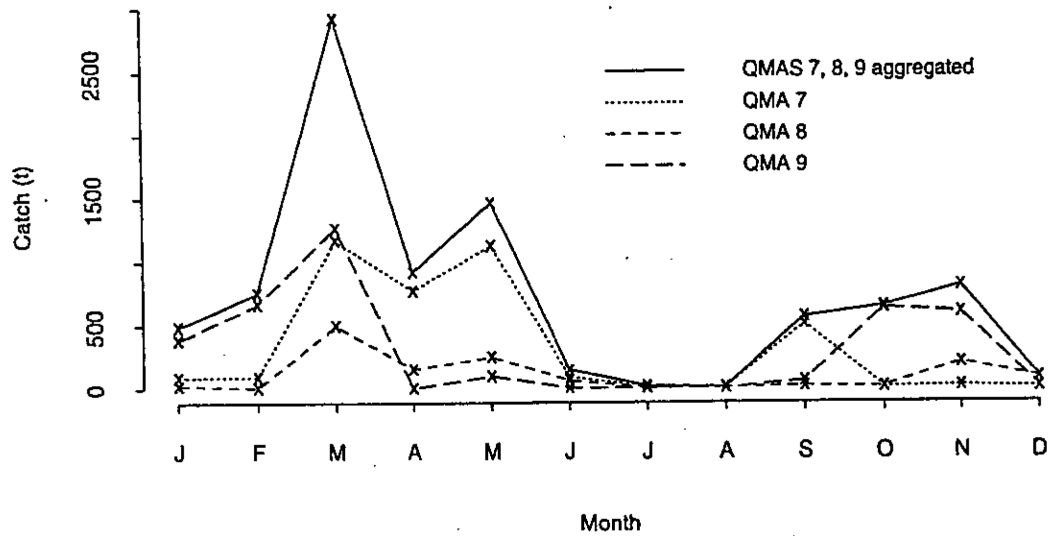


**Figure 11: Monthly time series of catches (t) of blue mackerel from the CELR fleet (mostly purse-seine) in QMAs 7, 8, and 9; catch estimates are aggregates for each month over all years from 1989–90 to 1999–2000. Source: MFish catch and effort database.**

In the TCEPR fishery there was a large contribution of catch from QMA 7 (Figure 12). The small catch in January and the balance throughout the remainder of the year came from QMA 8.

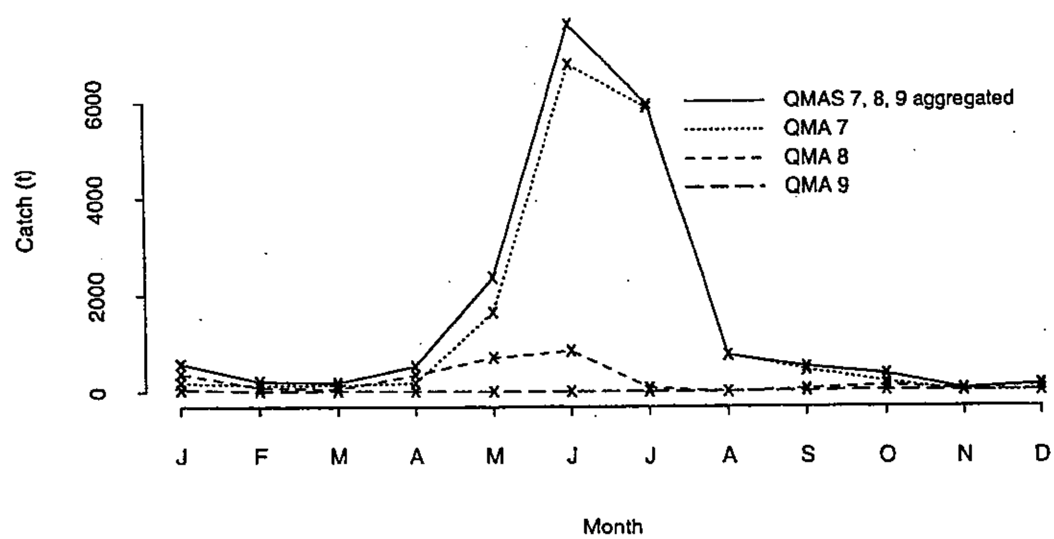


**Figure 12: Monthly time series of catches (t) of blue mackerel from the TCEPR fleet (mostly midwater trawl) in QMAs 7, 8, and 9; catch estimates are aggregates for each month over all years from 1989–90 to 1999–2000. Source: MFish catch and effort database.**

The third step consisted of examining catch rate and effort. Because of the unreliability associated with purse-seine fisheries (see Section 5.2) this analysis was limited to the TCEPR midwater trawl fishery. Catch rate was estimated as the average monthly number of tonnes per tow for those tows in QMAs 7, 8, and 9 (combined) for fishing years 1988–89 to 1999–2000 (combined) where blue mackerel were caught. The catch rate increased gradually from about 1.3 t per tow in January (Figure 13), accelerated in April–May to a peak of more than 5 t per tow in July, and decreased sharply in August and September to return to the January level. The lowest rates were in November and December.

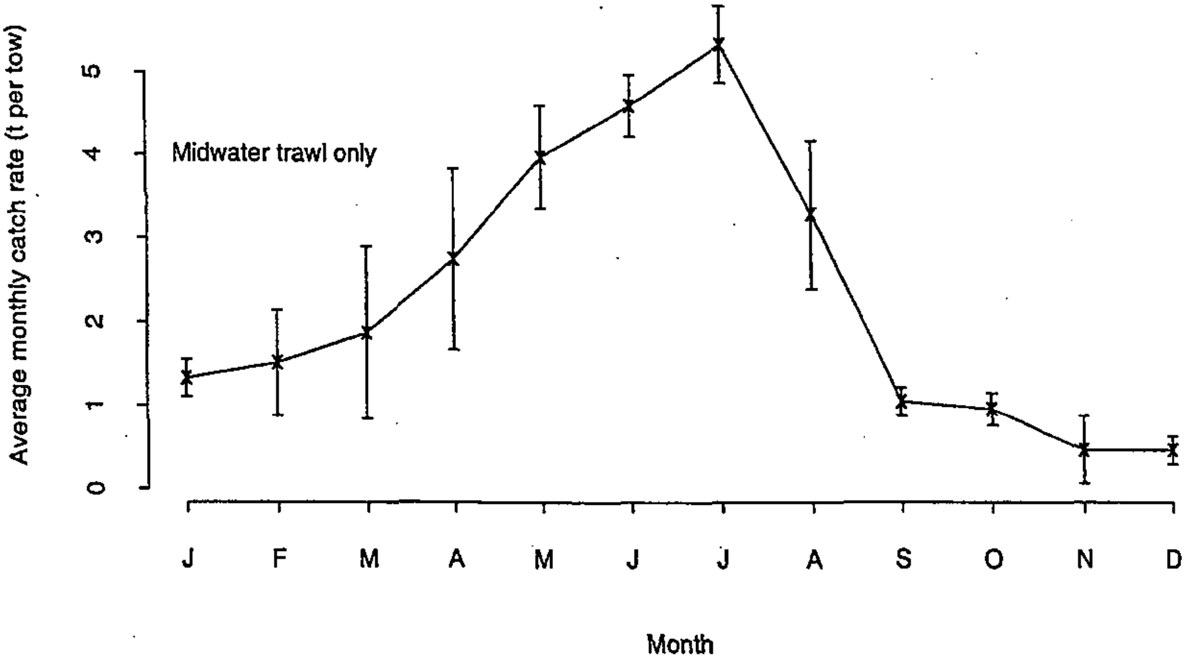


**Figure 13: Average monthly catch rates of blue mackerel for the TCEPR midwater trawl fishery in QMAs 7, 8, and 9 combined, during fishing years 1988–89 to 1999–2000; confidence intervals are two standard errors. Source: MFish catch and effort database.**

Effort was estimated as the average number of vessels catching blue mackerel by midwater trawl in QMAs 7, 8, and 9 combined, and in QMA 7 alone, where most of the catch was taken. For the three areas combined, the peak was about 3.5 vessels in July (Figure 14), with the monthly average remaining higher than two vessels in August and September.

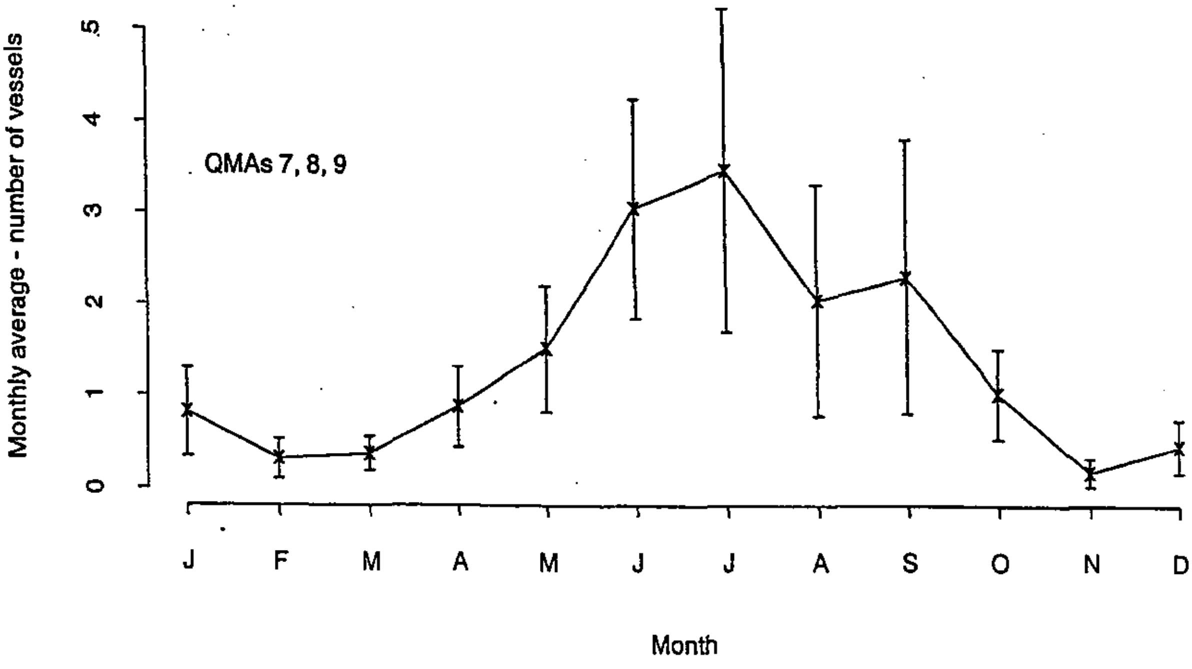


**Figure 14: Average number of vessels per month catching blue mackerel by midwater trawl in the TCEPR fishery in QMAs 7, 8, and 9, during fishing years 1988–89 to 1999–2000 combined; confidence intervals are two standard errors. Source: MFish catch and effort database.**

In QMA 7, the pattern was similar, the average number of vessels remaining high (6 to 9.5) from June to September (Figure 15). This contrasts with the trend in catch rate. The average catch rate decreased sharply in August and September (Figure 13) despite the number of vessels remaining high (see Figures 14 and 15). The average catch rate in June and July was significantly higher than that of August, which in turn was significantly higher than that of September.

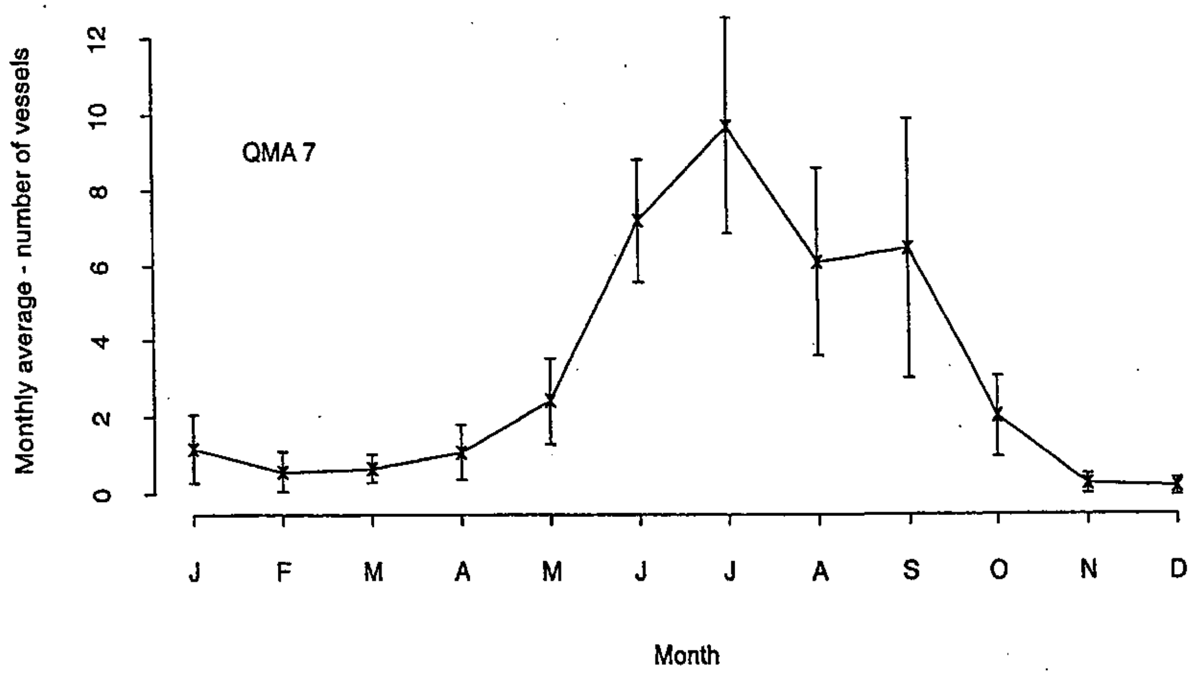


**Figure 15: Average number of vessels per month catching blue mackerel by midwater trawl in the TCEPR fishery in QMA 7, during fishing years 1988–89 to 1999–2000 combined; confidence intervals are two standard errors. Source: MFish catch and effort database.**

**Variations in catches by fishing method.** To determine the annual contributions of each fishing method to total catch in QMAs 7, 8, and 9, catch was summed for each fleet (CELR and TCEPR) over fishing year for each gear type (Table 18). Irregular fluctuations in catch are evident for the three main gear types, bottom trawl, midwater trawl, and purse-seine, but there is little indication of concurrence between gear types that could provide evidence for years of high or low abundance. For example, catch by midwater trawl showed peaks in 1990–91 and 1991–92 that were not reflected in the purse-seine catch. Conversely, the high purse-seine catch in 1992–93 was not paralleled in the midwater trawl catch. Such a basis is not rigorous however, and other factors like market demands need to be considered, but it is interesting to note that high catches occurred in 1998–99 for both midwater trawl and purse-seine, which might be indicative of a year with particularly high abundance.

Most catch in the CELR fishery is taken by purse-seine (99%). A little is taken by bottom longline, bottom trawl, and setnet, but none by midwater trawl. Catch in the TCEPR fishery is almost exclusively by midwater trawl (92%) and bottom trawl (7.6%).

### 4.2.2 Characterisation by aerial sightings

Aerial sightings data from the purse-seine fishery (Taylor, in press) were used to update spatial distributions of surface aggregations of monospecific schools of blue mackerel, and of schools where blue mackerel are mixed with other species (referred to as mixed schools), as published by Bagley et al. (2000). They are included in Appendix 2 and are discussed above in Section 2.2 and under the heading "Aerial sightings database" in Section 4.1.1.

**Table 18: Catch totals (t) of blue mackerel in QMAs 7, 8, and 9 by gear type, fishing year, and fleet (CELR is vessels using catch effort landing returns; TCEPR is vessels using trawl catch effort and processing returns). Source: MFish catch and effort database.**

| Fleet/fishery | Fishing year | Bottom long line | Bottom trawl | Midwater trawl | Purse-seine | Setnet | Other | Total |
|---|---|---|---|---|---|---|---|---|
| CELR | 1988–89 | 0 | < 1 | 0 | 132 | | < 1 | 132 |
| | 1989–90 | < 1 | < 1 | 0 | 508 | 2 | | 511 |
| | 1990–91 | < 1 | 0 | 0 | 182 | 3 | | 185 |
| | 1991–92 | < 1 | < 1 | 0 | 53 | 4 | 1 | 58 |
| | 1992–93 | < 1 | 4 | 0 | 2 771 | 11 | 2 | 2 788 |
| | 1993–94 | < 1 | < 1 | 0 | 233 | 15 | | 248 |
| | 1994–95 | < 1 | < 1 | 0 | 546 | 17 | < 1 | 565 |
| | 1995–96 | < 1 | < 1 | 0 | 204 | 3 | | 208 |
| | 1996–97 | < 1 | 0 | 0 | < 1 | 3 | < 1 | 3 |
| | 1997–98 | 0 | 0 | 0 | 68 | 3 | | 70 |
| | 1998–99 | 0 | 0 | 0 | 3 474 | < 1 | < 1 | 3 475 |
| | 1999–2000 | < 1 | 10 | 0 | 508 | < 1 | | 519 |
| CELR Total | | 2 | 17 | 0 | 8 679 | 61 | 3 | 8 763 |
| | | | | | | | | |
| TCEPR | 1988–89 | 0 | 37 | 274 | 0 | 0 | 0 | 312 |
| | 1989–90 | 0 | 135 | 63 | 0 | 0 | 0 | 198 |
| | 1990–91 | 0 | 294 | 1 364 | 0 | 0 | 4 | 1 662 |
| | 1991–92 | 0 | 406 | 2 539 | 0 | 0 | 0 | 2 945 |
| | 1992–93 | 0 | 155 | 562 | 0 | 0 | 0 | 718 |
| | 1993–94 | 0 | 93 | 753 | 0 | 0 | 0 | 846 |
| | 1994–95 | 0 | 17 | 1 154 | 0 | 0 | 0 | 1 171 |
| | 1995–96 | 0 | 68 | 605 | 0 | 0 | 21 | 694 |
| | 1996–97 | 0 | 29 | 1 949 | 0 | 0 | 0 | 1 978 |
| | 1997–98 | 0 | 219 | 1 813 | 0 | 0 | < 1 | 2 033 |
| | 1998–99 | 0 | 13 | 4 180 | 0 | 0 | < 1 | 4 193 |
| | 1999–2000 | 0 | 6 | 2 432 | 0 | 0 | 0 | 2 438 |
| TCEPR Total | | 0 | 1 472 | 17 690 | 0 | 0 | 26 | 19 187 |
| Grand Total | | 2 | 1 489 | 17 690 | 8 679 | 61 | 29 | 27 950 |

Aerial sightings data were used to determine if there were any seasonal trends in the presence of blue mackerel aggregations at the surface, based on a two step approach that examined the monthly distribution of blue mackerel sightings. Monthly totals were plotted for each year between 1989–90 and 1999–2000 as separate curves to determine any consistent patterns of seasonality in annual catches. Then a time series of mean monthly sightings was plotted using the same data. The two plots were produced for QMAs 7, 8, and 9 combined (Figure 16), and repeated for all QMAs combined where most data were from QMA 1 (see Table 15).

The plots of mean monthly sightings can be taken as approximate indicators of seasonal fluctuations. In QMAs 7, 8, and 9 this plot showed a peak in March but was otherwise quite flat; the composite plot showed that fluctuations in mean sightings were caused by peaks in few years. By contrast, the plots for all areas showed a seasonality that first rose in August–September, peaked in November, and trailed off to a minimum in June; in this case the composite plot showed a trend in mean sightings resulting from much greater consistency in sightings between years.

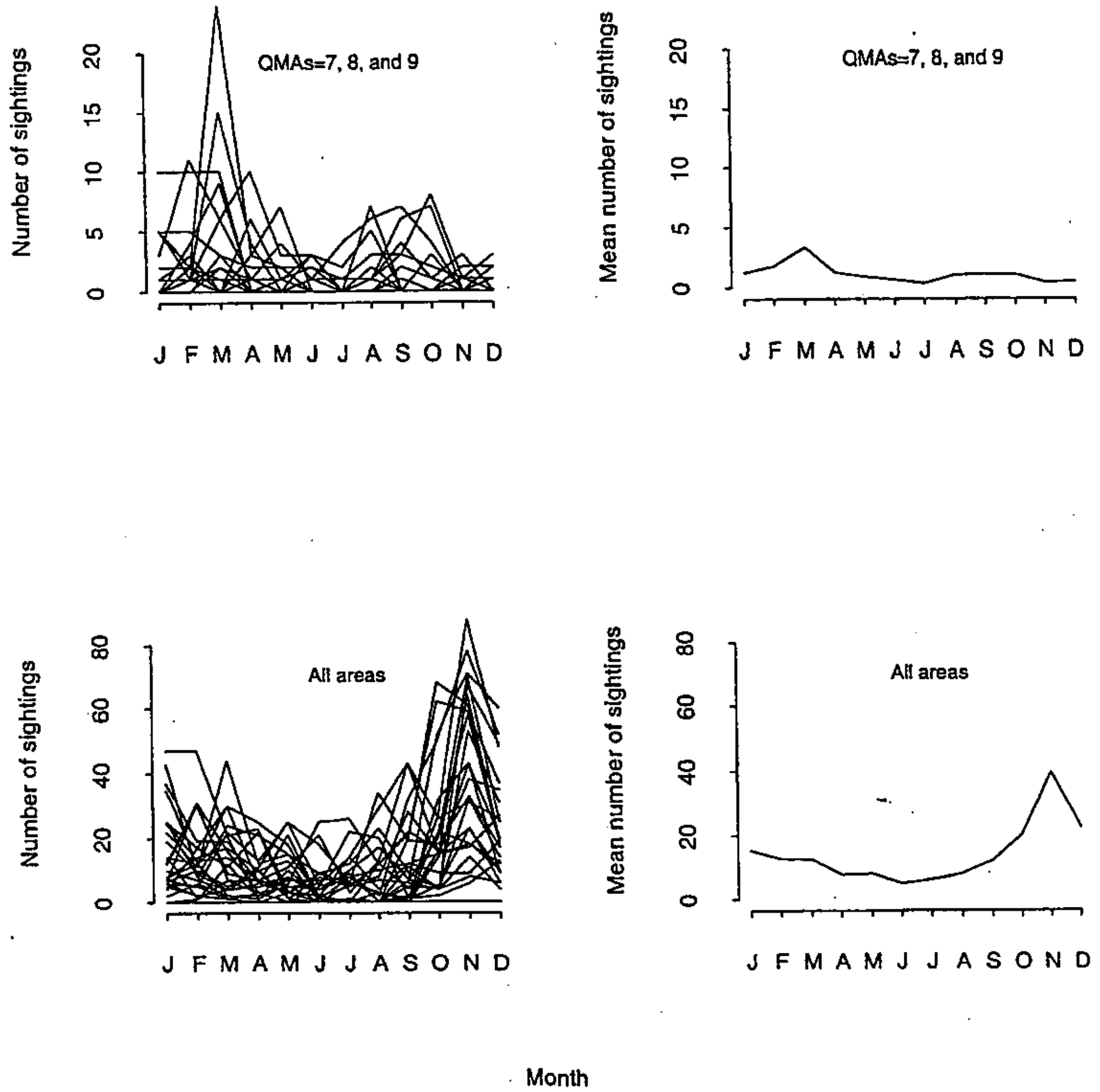


**Figure 16: Time series of monthly totals and monthly means of blue mackerel sightings over all years from 1989–90 to 1999–2000. Source: MFish aerial sightings database.**

### 4.2.3 Biological characterisation

Biological characterisation of fish in the exploited population was based on data from the research trawl and observer databases. The data were examined for their use in providing annual length frequency distributions, sex ratios, and spawning seasons and areas.

**Gonad stage frequencies.** Although there were few data available from either source, female gonad staging data from blue mackerel sampled in QMAs 7, 8, and 9 by scientific observers and on research trawl surveys were used to determine the presence and timing of spawning fish (Table 19).

These data were mostly the same as those summarised by Hurst et al. (2000a) (see Appendix 4) and provided some evidence that spawning of blue mackerel took place in QMAs 7, 8, and 9, particularly in January and February. An unexpected feature of the data was the presence of maturing fish during July in 1997–98 and 1999–2000. The reliability of the gonad staging data is unknown however, and there may be some difficulty in distinguishing between immature/resting gonads and early stage maturing.

**Table 19: Gonad stage ratios of female blue mackerel from data collected by observers and during trawl surveys in QMAs 7, 8, and 9. Sources: MFish observer database *obs_lfs*, MFish trawl survey database.**

| Source | Fishing year | Month | Gonad stage | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | no. of fish |
| Observer data* | 1994–95 | December | | 1 | | | | NA | 64 |
| | | January | | 0.97 | 0.03 | | | NA | 38 |
| | 1997–98 | January | 0.03 | 0.89 | | | 0.09 | NA | 80 |
| | | February | 0.05 | 0.85 | | | 0.1 | NA | 20 |
| | | July | 0.39 | 0.61 | | | | NA | 46 |
| | 1999–2000 | July | 0.98 | 0.02 | | | | NA | 41 |
| Trawl survey† | 1989–90 | February | | 0.18 | 0.06 | 0.06 | 0.06 | 0.64 | 17 |
| Trawl survey* | 1999–2000 | October | 1.00 | | | | | | 6 |

* 5 point scale female gonad staging (immature/resting, maturing, mature, running ripe, spent); stage 6 not applicable
† 6 point scale female gonad staging (immature, resting, maturing, mature, running ripe, spent)

**Sex ratios.** Although there were few data available from either source, counts of males and females from blue mackerel sampled in QMAs 7, 8, and 9 by scientific observers and on research trawl surveys were used to estimate sex ratios. Usually these estimates approximated a 50:50 sex ratio for the two sexes, but those for 1994–95 (December, January) suggested a higher frequency of female fish in QMAs 7 and 8 (Table 20). Gonad staging data for the same fish indicated that these females were maturing into spawning condition (see Table 19). Sample sizes in these cases are probably acceptable although there is no information about the sampling method used. The sample size for the trawl survey data from October 1999–2000 is too small for the estimated sex ratio to be reliable.

**Table 20: Sex ratios of blue mackerel from data collected by observers and during trawl surveys in QMAs 7, 8, and 9. Sources: MFish observer database *obs_lfs*, MFish trawl survey database.**

| Source | Fishing year | Month | QMAs sampled | Percentage of males | Percentage of females | Total number of Fish |
|---|---|---|---|---|---|---|
| Observer data | 1986–87 | January | 7 | 48 | 52 | 33 |
| | 1988–89 | August | 7 | 44 | 56 | 142 |
| | 1993–94 | June | 7 | 42 | 58 | 24 |
| | 1994–95 | December | 8 | 17 | 83 | 77 |
| | | January | 8 | 34 | 66 | 58 |
| | 1996–97 | July | 7 | 49 | 51 | 41 |
| | 1997–98 | January | 8 | 47 | 53 | 150 |
| | | February | 7 | 46 | 54 | 37 |
| | | July | 7 | 55 | 45 | 240 |
| | 1999–2000 | July | 7 | 58 | 42 | 97 |
| Trawl survey | 1989–90 | February | 7, 8 | 42 | 58 | 19 |
| | 1989–90 | March | 8 | 50 | 50 | 2 |
| | 1999–2000 | October | 9 | 36 | 64 | 11 |

**Fish length.** Length data were collected on a number of research voyages in QMAs 7, 8, and 9 (Table 21). To examine the size range of fish taken and to determine any possible interannual variation or trends over time, the length data were pooled by fishing year and summarised using length frequency distributions. These distributions were not scaled to catch.

**Table 21: Sources of fish length data collected from blue mackerel on research trawl voyages in QMAs 7, 8, and 9. Source: MFish research trawl database.**

| Fishing year | Trip code | Vessel | Number of fish measured | Minimum length | Maximum length |
|---|---|---|---|---|---|
| 1978–79 | WES7903 | *Wesermunde* | 6 | 44 | 51 |
| | WES7904 | *Wesermunde* | 4 | 36 | 45 |
| 1981–82 | KAH8205 | *Kaharoa* | 4 | 16 | 30 |
| | KAH8211 | *Kaharoa* | 2 | 51 | 53 |
| 1982–83 | KAH8216 | *Kaharoa* | 2 | 17 | 18 |
| 1983–84 | JCO8415 | *James Cook* | 6 | 47 | 51 |
| 1986–87 | KAH8612 | *Kaharoa* | 22 | 15 | 27 |
| 1987–88 | KAH8715 | *Kaharoa* | 1 | 20 | 20 |
| 1989–90 | COR9001 | *Cordella* | 178 | 15 | 53 |
| | KAH8918 | *Kaharoa* | 14 | 11 | 52 |
| 1991–92 | KAH9111 | *Kaharoa* | 2 | 48 | 51 |
| | KAH9204 | *Kaharoa* | 2 | 46 | 49 |
| 1994–95 | KAH9410 | *Kaharoa* | 37 | 13 | 22 |
| | KAH9504 | *Kaharoa* | 10 | 46 | 51 |
| | KAH9507 | *Kaharoa* | 1 | 18 | 18 |
| 1995–96 | KAH9608 | *Kaharoa* | 52 | 10 | 21 |
| 1996–97 | KAH9615 | *Kaharoa* | 26 | 12 | 26 |
| | KAH9701 | *Kaharoa* | 4 | 47 | 50 |
| 1999–00 | KAH0004 | *Kaharoa* | 5 | 48 | 50 |
| | KAH9915 | *Kaharoa* | 20 | 15 | 48 |

In most years, available length data were too few to provide useful length frequency distributions (Figure 17). The only exception was in 1989–90 when data were collected on two vessels (see Table 21), with the majority recorded on *Cordella*, although the length range was similar for both suggesting similar vulnerabilities with respect to size classes. The resulting frequency distribution showed a possible four modes, centred at about 12 (*Kaharoa* data), 20, 30, and 45 cm, two of which seem to be represented in a number of years — 20 cm in 1986–87, 1994–95, 1996–97, 1999–2000, and 50 cm in 1991–92, 1994–95, 1996–97, 1999–2000. This apparent consistency over years suggests that some size classes may be more vulnerable to the gear, but the small sample sizes prevent any reliable interpretation. In 1989–90 length ranged from 11 cm to 53 cm, which was similar to ranges recorded in 1981–82, 1994–95, 1996–97, and 1999–2000.

In an effort to improve the analysis, length data collected on research trawl voyages in all QMAs were pooled and frequency distributions generated. Although there was high variability in the numbers of fish contributed by each trip (Appendix 8a), length ranges for the pooled datasets in the frequency distributions were consistent between fishing years (Appendix 8b). Overall however, despite considerable increases in the amount of data available, there was still insufficient information to determine inter-annual variations.

Some length data were available from the observer database (see Table 12). They were pooled by fishing year, including data from QMA 3, and unscaled length frequency distributions generated (Figure 18). Most of these ranged between 40 and 55 cm (except for 1997–98) and provided more structure than frequency distributions based on the research trawl data shown in Figure 17, but did not show evidence of size class variations between years. The size range was much narrower than the research trawl data and represented only the larger fish. Scientific observer sampling of blue mackerel was mostly on TCEPR vessels fishing outside 12 miles. This contrasts with the bulk of research voyages, which were inshore on *Kaharoa*, closer to the coast.

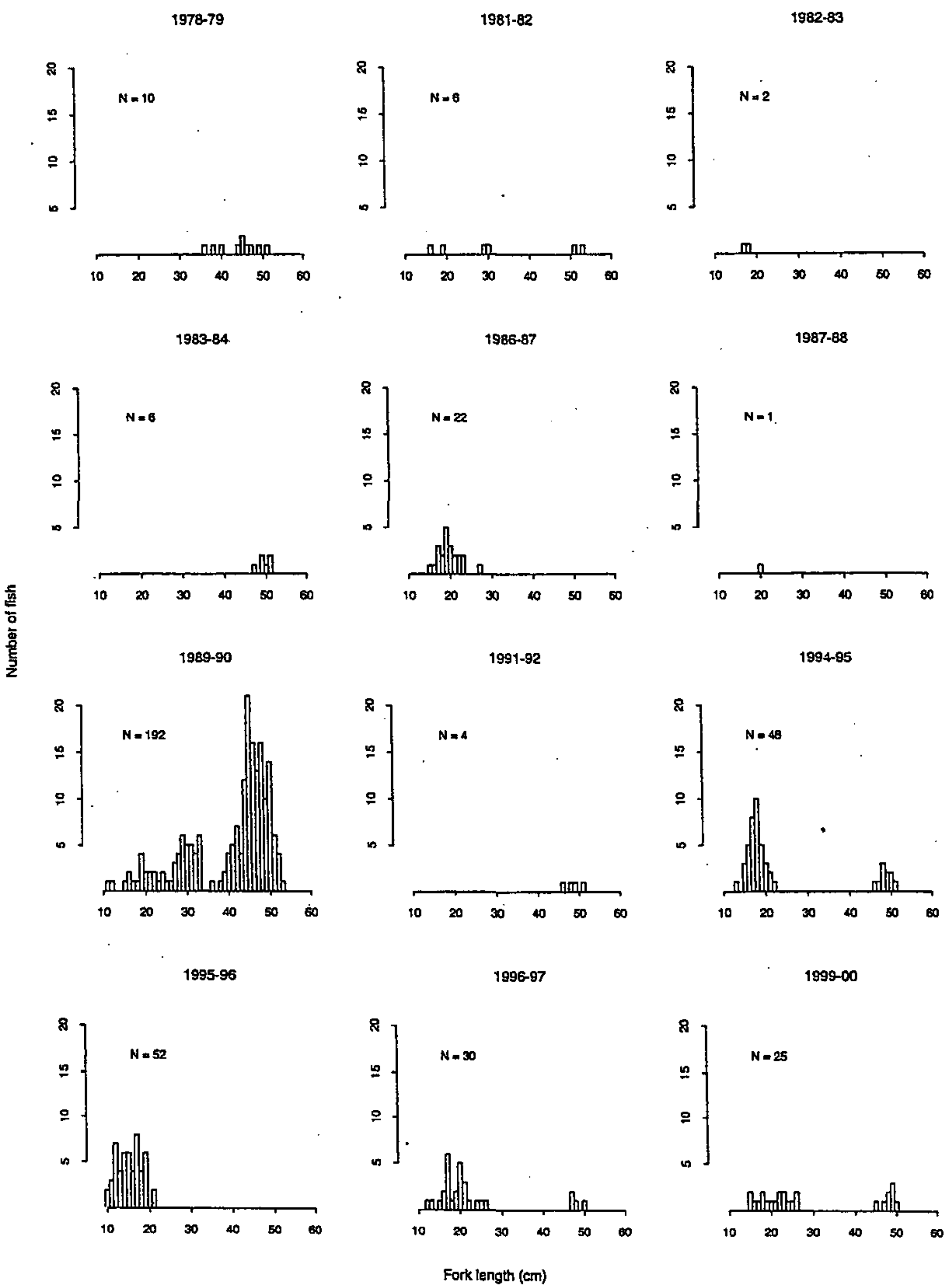


**Figure 17: Length frequency distributions for blue mackerel measured during research trawl voyages in QMAs 7, 8, and 9, aggregated by fishing year. Source: MFish research trawl database.**

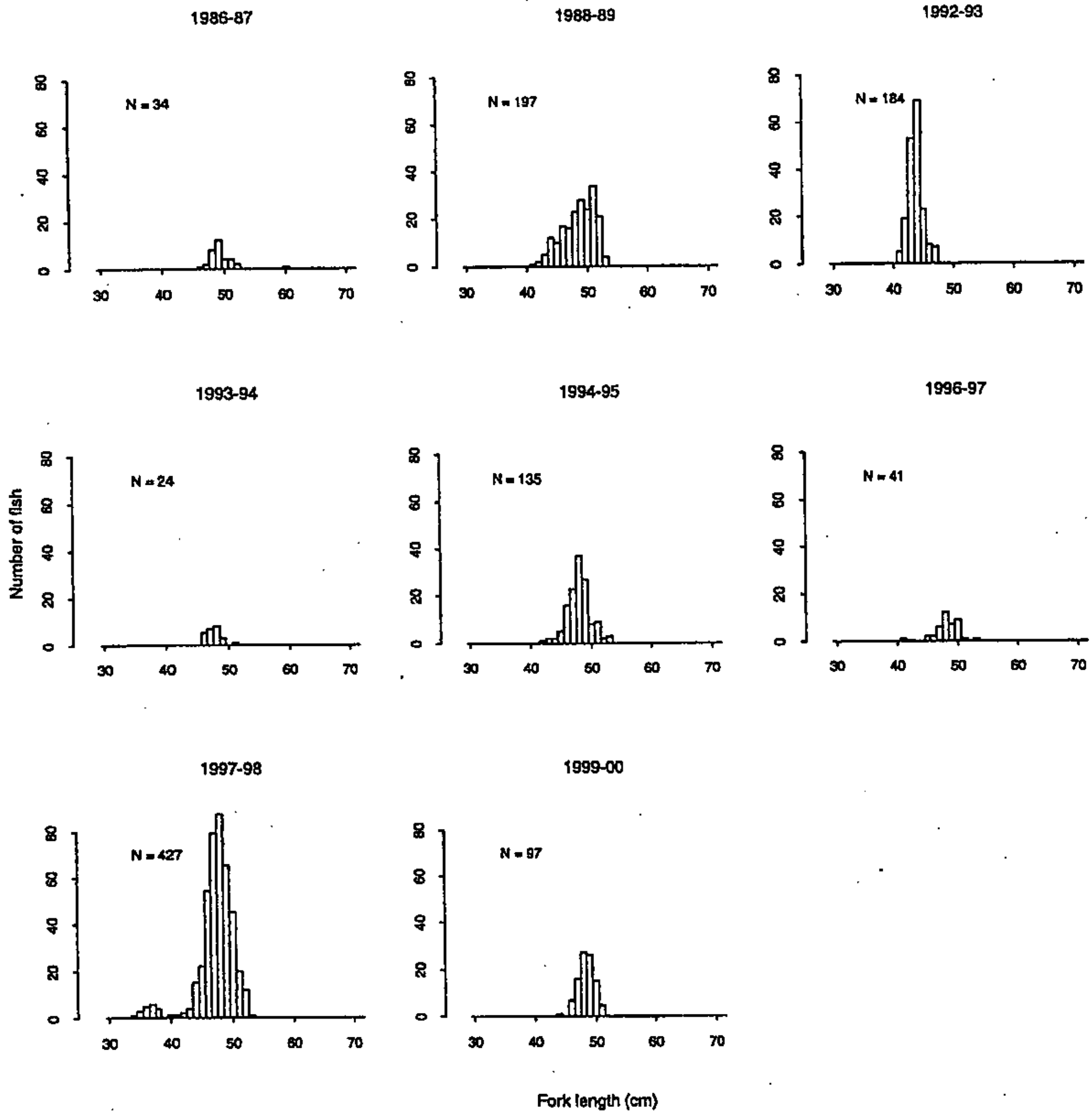


**Figure 18: Length frequency distributions for blue mackerel measured by scientific observers in QMAs 3, 7, 8, and 9, aggregated by fishing year. Source: MFish research trawl database.**

### 4.2.4 Summary and discussion

The main points from the characterisation of the blue mackerel fishery in QMAs 7, 8, and 9 are as follows.

- Catches from both the CELR and TCEPR fisheries showed a peak in 1998–99. Other years of high catch occurred for both but were not common to both.
- Seasonality of catches for each of the fisheries showed different, converse patterns: CELR catches were taken in most months but not during June–August (winter); TCEPR catches were low during most of the year with a large peak in June–August.
- Seasonal catch patterns in the CELR fishery suggested a possible switching between QMA 7 and QMA 9 but the data are mostly from single years and therefore not conclusive.
- The large winter peak in the TCEPR catch was taken mostly in QMA 7 with a little from QMA 8. There was no TCEPR catch from QMA 9.

- Catch in the CELR fishery was mostly by purse-seine (99%); none was taken by midwater trawl. Almost all catch in the TCEPR fishery was either by midwater trawl (93%) or bottom trawl (6.6%).
- Catches by midwater trawl and purse-seine each showed a fluctuating annual pattern with some years of high catch (i.e., 1400 t or more). However, concurrence between these peaks in both fisheries was only evident in one year, 1998–99, when individual peaks were the highest of the series (about 4000 and 3500 t for midwater trawl and purse-seine respectively).
- Aerial sightings of pure schools of blue mackerel indicated a possible peak in surface aggregations in March for QMAs 7, 8, and 9, but this pattern was not consistent over constituent years. By contrast, the seasonal pattern for sightings in all areas combined (mostly from QMA 1) was consistent over years and showed a rise from August-September to a peak in November followed by a gradual decline to a minimum in June.
- Most aerial sightings of pure schools recorded from QMAs 7, 8, and 9 were from the area immediately north of Golden and Tasman Bays to the coast of the South Taranaki Bight (QMA 7 and 8), and were sparse throughout inshore QMA 9.
- Blue mackerel have been recorded mixed in schools with all jack mackerel species, kahawai, trevally, and skipjack tuna. The distribution of sightings of mixed blue mackerel schools in QMAs 7, 8, and 9 was somewhat different from that of pure schools. Most mixed schools were recorded from QMA 7, inside Golden and Tasman Bays and outside immediately to the north, with a smaller amount from QMA 8 in the South Taranaki Bight, and less again distributed unevenly in QMA 9, to the far north and in the North Taranaki Bight.
- Sex ratios were roughly 50:50 except in December and January of 1994–95 when there was a higher proportion of females.
- There was some evidence of spawning from sampled running ripe and spent fish in January and February of 1997–98 (observer data) and February 1989–90 (research trawl data). There was also some evidence of fish with active gonads present in July 1997–98 and 1999–2000, but these were identified as early stage maturing, for which there is some potential difficulty in distinguishing from immature/resting gonads.
- Length frequency distributions showed wider length ranges for the research trawl data (about 9–50 cm) with a predominance of small fish. Length frequency distributions from observer data were tighter and more structured, with narrower ranges (40–55 cm).

**Seasonal patterns.** Perhaps the most significant result is the difference in seasonal catch patterns between the TCEPR and CELR fisheries, or effectively, between the midwater trawl and purse-seine fisheries. Catches for the two were almost mutually exclusive in time, with those of the TCEPR fishery occurring during midwinter when there was little catch by the CELR fleet.

This peak of catch for the TCEPR fishery is well defined. One possible explanation is that the TCEPR fleet switches its targeting in May-June so that blue mackerel become more vulnerable to its operation. This could include a switch in fishing strategy to midwater trawl. Another explanation is that the fish change their behaviour at this time, and so become more vulnerable to the fleet. It is also possible that a combination of these occurs, with fishers switching their strategy to exploit a behavioural change in the fish.

The seasonal pattern for catches of the CELR/purse-seine fishery is almost the exact converse of the TCEPR pattern. In a broad sense catches by these fleets represent sampling of blue mackerel from two different parts of its range or habitat: surface aggregations are taken by purse-seine, and subsurface aggregations by midwater trawl. An alternative and more extensive dataset providing information on the distribution of surface aggregations is the aerial sightings database, but the seasonal pattern of blue mackerel sightings for QMAs 7, 8, and 9 is unreliable because of inconsistencies in search effort by spotter pilots between years. By contrast, the data for all areas (most of which are recorded in QMA 1) is representative by year and month, and the seasonal pattern for sightings of blue mackerel from all areas is similar to the seasonal pattern of purse-seine catch in QMAs 7, 8, and 9, in that sightings in June represent the minimum in the time series.

Taken together, these seasonal patterns for surface schools provide evidence that a considerable proportion of blue mackerel are present somewhere other than in surface schools during these winter months. This is further supported by Jones (1983), who observed a similar pattern of seasonal presence/absence in Northland, Bay of Plenty, South Taranaki Bight, and Kaikoura. The seasonal pattern of catches by the TCEPR fleet offers evidence of a possible subsurface destination for fish that move from surface aggregations — over-wintering aggregations have been described for Atlantic mackerel by Sette (1950) when fish move from inshore surface waters to deeper waters offshore in late summer, although the aggregations in our case may comprise mixed schools of blue mackerel with jack mackerel.

The length of time that these subsurface aggregations remain coherent is unclear. Discussion with one manager of vessels in the TCEPR fishery indicated that, for their fleet at least, effort is split into two legs: one in the summer fishery in about December to March, the other during winter immediately before the hoki fishery, in about June. Only small catches of blue mackerel are taken on the summer leg, but they are caught in large quantities on the winter leg and are believed to remain available when the vessels move off to begin targeting hoki, although information presented here indicates that catch rates decrease rapidly in August and September, despite the number of vessels remaining relatively high. Information related to catches by the TCEPR fleet requires closer examination, however, to determine whether the timing of blue mackerel availability in this fishery can be established and used to infer the onset and cessation of coherence of these aggregations.

**Annual catches.** The results show a difference in the annual distribution of catches between the CELR and TCEPR fisheries, suggesting that the availability of fish in one does not mean coincident availability in the other. It could be argued that a high representation of fish in catches of both fisheries is indicative of a year of particularly high abundance — under the assumed flow-on relationship between surface and subsurface aggregations suggested above, catch in one would not result in a low catch in the other during years of high abundance; in years of medium abundance, high catch in one fishery could reduce the tonnage available to the other; and when abundance was low, catch would necessarily be low in both fisheries. This is of course based on the assumption that there is some consistency of effort in the TCEPR fishery, which may not be true. Furthermore, effort in the purse-seine fishery must be treated somewhat differently — during periods of high abundance, effort can be increased to exploit increased availability of fish in surface aggregations when it is reported by spotter pilots. This happened in 1998–99, when numbers of skipjack tuna in New Zealand waters were low and the northern fleet moved into QMAs 7, 8, and 9. However, as this example shows, it is not simply a case of the purse-seine fleet exploiting blue mackerel when they become available — the low abundance of skipjack tuna was the key factor allowing the northern purse-seine fleet to move into QMAs 7, 8, and 9, as in 1992–93, when the second highest catch of blue mackerel was taken in this area. Thus there are other factors which influence effort and therefore catch, thus reducing the validity of treating catch as an indicator of abundance in this manner.

For all gear types in the CELR fleet in all areas, purse-seine vessels provide the greatest tonnage of blue mackerel. To some degree the purse-seine blue mackerel fishery is market driven, although this has not been so true over recent years with reductions in catch limits for kahawai in KAH 1 (1993–94) and KAH 3 (1995–96) (Annala et al. 2000). Blue mackerel has become the more valuable alternative to jack mackerel as a replacement for kahawai during the skipjack tuna off-season. However, effort in targeting blue mackerel seems to be expended more frequently in QMA 1 where the highest catches are. What is unknown is whether this is a reasonable reflection of the blue mackerel distribution or a consequence of higher levels of flying/search effort in QMA 1 compared with other areas. Although there is no time series summary presented here, flying effort in QMAs 7, 8, and 9 has been much more sparse and patchy in time and space than in the areas close to the Tauranga purse-seine fleet (Taylor, unpublished data). Given a more sparse and patchy level of search effort, the probability of encountering blue mackerel while at the surface is reduced, and the possibility of collecting appropriate data to adequately characterise seasonal fluctuations or baseline measures of abundance is precluded.

For the TCEPR fleet in QMAs 7, 8, and 9, blue mackerel is taken as bycatch in the target jack mackerel fishery. The demand for blue mackerel from this fishery is also market driven, but blue mackerel markets for these vessels have been poor (the difference in value for blue mackerel from the two fisheries is currently unexplained) and fishers prefer to avoid blue mackerel if they can. However, this has not been possible, with fishers suggesting that a sounder mark for jack mackerel schools has the same appearance as a mark for mixed schools of jack mackerel-blue mackerel. Based on this description, the extent of the blue mackerel catch is largely beyond the control of vessel operators and tonnage will fluctuate annually according to the amount that is present and the effort that is expended in the fishery.

In most years since 1990–91 the TCEPR blue mackerel catch has fluctuated between about 500 t and 2500 t. In 1998–99 an unusually high catch of more than 4000 t was taken. According to the suggestions above, this could be indicative of a year of higher than usual abundance. Coupled with this was a particularly high catch in the purse-seine fishery (3500 t), which also suggests a year of high abundance. The total catch was almost 8000 t, and this occurred without any apparent reduction of catch in QMA 1 over the previous year.

**Size distribution.** Length frequency distributions from observer and research trawl presented here show differences in size ranges. One explanation for this size difference is that the distribution of small fish is more coastal, resulting in their not being vulnerable to the TCEPR fleet. Using the same observer and research trawl data, a comparison of the distributions of immature and adult fish, and also of 0+ and 1+ fish, suggest that younger fish are recorded from areas close to the coast (Hurst et al. 2000b). Another explanation is that small fish are vulnerable to gear used on *Kaharoa* but not to that used by the TCEPR fleet. Codend mesh sizes used on *Kaharoa* when blue mackerel were taken range from 30 to 80 mm (Appendix 8), which is always less than the 100 mm probably used by the TCEPR fleet. A number of different nets were used on *Kaharoa*, and vulnerability will also be related to other characteristics of these nets as well as towing speed and length of tow.

There is no information to investigate the suggestion by Shuntov (1969) that the inshore distribution of juvenile blue mackerel is related to the abundance of suitably sized prey. Available information on feeding does not include the preferred diet of juveniles.

**Spawning.** The presence of spawning fish in this area indicate a second spawning centre in addition to that known in east Northland and the Hauraki Gulf (Crossland 1981, 1982, Jones 1983). Stock separation work based on allozymes by Smith et al. (1978) showed differentiation of snapper (*Pagrus auratus*) between spawning centres in the Hauraki Gulf and Golden and Tasman Bays. Based on knowledge of pelagic fish generally, blue mackerel are considered highly mobile, but there is no information on migrations in New Zealand waters to determine whether fidelity to such spawning centres could be expected, or what level of gene flow occurs between them.

The presence of fish with active gonads in July was unexpected. Evidence from other sources (Crossland 1981, 1982, Jones 1983) has suggested summertime spawning of blue mackerel, and this has been observed to correspond favourably with temperatures coincident with the presence of *S. japonicus* eggs in the Pacific (16.7–20.6 °C). The presence of maturing blue mackerel during July, when the temperature was likely to be less than 15 °C, contradicts this previous information. One explanation is that spawning at the lower temperature (during late winter-early spring) is possible, given that eggs of the other closely related species *S. scombrus* have been reported only from water of 9–15° C (Sette 1943, Jones 1983, Fishbase 2001); another is that gonad staging, which in this case distinguished only between immature/resting and early stage maturing, was inaccurate.

## 5. STOCK ASSESSMENT

### 5.1 Previous yield estimates

Robertson (1978) provided conservative estimates of likely yield for several species, including one for blue mackerel of 3000 t, and stressed that these were "not the result of careful biological studies on population dynamics, but ... informed guesses based on my impressions of local abundance and to some extent on yields from similar species in other parts of the world". Habib et al. (1981) estimated the potential annual yield of blue mackerel in New Zealand to be 10 000 t, probably based on aerial sightings data, but no description of methodology was given.

The latter of these estimates is comparable with an indicative TAC estimated using MFish's recommended criteria. The most applicable criterion for blue mackerel is for a stable fishery and states that: *The TAC should be set on the basis of the average level of total landings over an appropriate number of years. For a stable fishery, where reported catches have remained relatively constant for more than three years, the total period of time for which landings data are available should be used* (Anon 2001). Because of the regularly fluctuating catch in the blue mackerel fishery (see Table 3), an appropriate period could include all but the earliest years, when low catches were probably the result of fishery development and a lack of knowledge. The level of fluctuation does not necessarily mean that the fishery is unstable, only that the availability/abundance is variable. A rounded average calculated from data in Table 3 over fishing years 1988–89 to 1999–2000 is 9000 t.

### 5.2 Methods for determining abundance

Stock assessments incorporating abundance indices from CPUE are likely to be unreliable for blue mackerel for the following reasons.

- Pelagic fish stocks are highly mobile, both vertically within the water column and geographically between areas.
- The tendency of mackerel species to school by size (see Sette (1950) and Collette & Nauen (1983) for schooling information on *S. scombrus* and the genus *Scomber* respectively).
- The tendency for fishers, particularly the purse-seine fleet, to target blue mackerel by size.
- The tendency for purse-seine catch rates to remain high when abundance is low (i.e., "hyperstability" (Cochrane 1999)).
- Our inability to interpret variations in the presence of blue mackerel at the sea surface in terms of any causative environmental factors.
- The main midwater trawl catch of blue mackerel is as bycatch in the jack mackerel TCEPR fishery.

Therefore, abundance indices from fishery-independent sources are highly desirable.

There is little use of CPUE as an index of abundance in fisheries for species of *Scomber* elsewhere (see Appendix 6). Instead, abundance and biomass estimates are based on egg production methods (batch fecundity, annual fecundity, and daily fecundity methods) in the northeast and northwest Atlantic fisheries, and midwater trawl and driftnet surveys in the northwest Pacific fishery. Recent work in the northeast Atlantic fishery has shown the success of deriving abundance indices using acoustic methods, but this approach has not yet been incorporated into stock assessments.

Two procedures are available which can determine the biomass of blue mackerel at a particular time: (1) egg and larval surveys — either estimating the biomass (or relative biomass) directly from the areal extent of eggs and larvae, or calculating the biomass using a number of reproductive parameters and the Daily Egg Production Model (DEPM), or one of the similar methods used overseas; (2) acoustic surveys — calculating the biomass from the sum of echoes received from identifiable blue mackerel schools.

Acoustic surveys are used in New Zealand for a number of QMS species and NIWA has developed considerable experience in the field. To date, however, there has been little attention paid to pelagic species, except for two experimental surveys of pelagic fish in Hawke Bay 1980: Francis (1985), which mentions pilchards but does not quantify them, and a survey of jack mackerel in Taranaki Bight in 1984 (MFish unpublished data).

A tradeoff exists between the use of DEPM and acoustic surveys (Cochrane 1999). Where acoustic surveys should provide a more precise estimate of abundance, it is likely to be biased, usually negatively, thus providing an under-estimate. In contrast, DEPM estimates should be unbiased, but their precision is low.

These surveys are costly and time consuming. An important consideration is the frequency with which they should be performed. Although a single survey would certainly provide a good basis for future work (see Cochrane 1999), these methods provide only a snapshot, and the high variability likely to exist in the New Zealand blue mackerel stock will require regular monitoring if reliable abundance indices are to be developed. As a prerequisite, spawning seasons and areas would first need to be identified.

Aerial sightings data may be a useful, cost-effective alternative for determining indices of relative abundance, with a time series from 1976. An MFish research project is currently investigating the feasibility of developing an abundance index for blue mackerel in QMA 1 (PEL2002/01). However, any such index is unlikely to be available for QMAs 7, 8, and 9 where data seem to be too patchy in time and space to provide reliable relative abundance indices.

### 5.3 Biomass estimates

Estimates of current and reference biomass are not available.

### 5.4 Estimates of Maximum Constant Yield (MCY)

The only possible method of estimating MCY for blue mackerel is using MCY = $cY_{av}$. The fishery does have good commercial catch history, but there is no reliable information on changes in effective fishing effort, or on mortality over the history of the fishery. Consequently, this method of determining MCY is unlikely to be reliable, based on current data.

### 5.5 Estimates of Current Annual Yield (CAY)

At present, CAY cannot be determined.

## 6. MANAGEMENT IMPLICATIONS

There are two consequences for biomass estimates of blue mackerel.

- Biomass estimates based on such procedures as acoustic surveys and the daily egg production method can produce a measure of the stock's size, but only a "snapshot" at that point in time.

- Potential differences in geographic distribution of the stock being assessed at different times must be taken into account; repeat surveys must be of the stock, and not necessarily of the same geographic region.

For robust assessments, regular monitoring is required. CPUE will not be indicative of changes in stock size, given that catches and CPUE can remain high even as the biomass declines, and that 65% of catch is taken as bycatch in the jack mackerel TCEPR fishery. Monitoring incoming recruitment may be useful in providing an approximate prediction of the state of the stock. Monitoring fish length and age at first maturity could provide information on structural changes to the spawning population.

It is unknown whether there are any sustainability issues with regards to blue mackerel. Catches since the mid 1980s show a fluctuating fishery, with what could be cyclical patterns of rise and fall over time. This, and considering the high growth rate for blue mackerel, suggests that this species has the ability to support the present level of fishing. However, some cautionary information comes from work examining switches in abundance or regime shifts between small pelagic fish species (see review by Paul et al. 2001). Overfishing (probably in association with natural declines) can have long-lasting effects on the abundance of small pelagics and, although recovery has occurred in the fisheries that have been investigated, it can be very slow.

Schwartzlose et al. (1999) pointed out that for small pelagic species with a very widely fluctuating biomass heavy fishing has the potential to decrease the magnitude and duration of peaks of abundance, and to depress and prolong the troughs. Although they were referring specifically to pilchard and anchovy, scombrid mackerel are sometimes included in the same trophic group because they feed largely on zooplankton (e.g., see information on *Scomber scombrus* by Sette (1950)); blue mackerel feeding includes both filtering of the water and active pursuit of prey, and appears to include a high proportion of zooplankton (Jones 1983). The conclusions of Schwartzlose et al. (1999) are reinforced by Beverton (1990), who noted that for fisheries of small pelagic species like herring, mackerel, anchovy, and pilchard, "there is a tendency for the most severe decline to be followed by the slowest recovery".

Extrapolating from overseas fisheries to New Zealand is not straightforward. The statements of Beverton (1990) and Schwartzlose et al. (1999) are based on trends in large stocks within large ecosystems, and are primarily focused on small pelagic fish species that stand squarely in the trophic position linking primary production with higher levels of the food chain. Implications may be similar for mackerel; Beverton (1999) and Serchuk et al. (1996) included an example of a stock of *Scomber scombrus* undergoing a collapse similar to the regime shifts of pilchard and anchovy. However, feeding of blue mackerel may be different from that of pilchard and anchovy in that phytoplankton have not been observed as a food item, but there is little information on blue mackerel diet that can be used to determine its importance at this trophic level. There is no evidence for regime shifts occurring in New Zealand waters, but the biology and inter-relationships of small pelagics have been little studied here.

## 7. RESEARCH RECOMMENDATIONS

### 7.1 Overview

The overall objective is to develop methods of monitoring the stock to provide reliable information for management decisions. Abundance indices are derived using a number of methods in large fisheries for scombrid mackerels overseas, which are then used as fishery indicators and inputs to stock assessment models. Existing information about the New Zealand stock of blue mackerel is patchy at best, and must be expanded to improve the effectiveness of any proposed monitoring methods. For QMAs 7, 8, and 9, there is no monitoring method that is clearly the best choice, although there are some that are of little use. CPUE probably has no value and aerial sightings in their present form provide data that are too patchy in time and space for estimating relative indices of abundance. Other options are expensive and require more knowledge than we currently have. One possibility is to employ an egg production method, and a number of these are either in use or have been used overseas. The prerequisite for this approach in New Zealand is to develop a greater understanding of blue mackerel spawning areas and seasons. Another possibility is acoustic survey, which recent research in the eastern Atlantic suggests is a feasible approach for *Scomber scombrus*. Extensive development work would be required in the New Zealand case.

In addition to monitoring the fisheries in QMAs 7, 8, and 9, there are other questions that require answers before a clear strategy for management can be defined. The first is to determine the stock structure. This is unknown for a number of the inshore pelagic species, and an answer would reduce uncertainty in managing blue mackerel, kahawai, and jack mackerel, in particular. The immediate importance of determining stock structure for blue mackerel is in determining implications of the proposed Fishstock boundaries and catch limits. The possibility of more than one stock, based on the evidence for two spawning centres, suggests that management by two Fishstocks would be the most effective, allowing best use of the resource. But this relies on fish spawned in an area remaining there, so that exploitation of any estimated yield, or according to any stock monitoring, can be realised. Given the potential lack of fidelity to spawning areas resulting from their high mobility, such assumptions for blue mackerel could be spurious. Splitting yields by artificial boundaries could well mean that migrations of fish would prevent the best exploitation of the stock. Information on stock separation (morphometrics, allozymes, DNA) and migration (tagging) could be used to develop strategies to overcome these uncertainties.

Tagging is used in the northeast Atlantic fishery to provide estimates of mortality. It also has the potential to be used to investigate migrations of blue mackerel within New Zealand waters. The reliability of this approach is highly uncertain, however, if methods similar to those used previously are employed. The first trade off is one of cost versus the impact of the tag on the physiology of the fish. Large plastic dart or spaghetti tags, which are the most visible in landed catch, have been used for schooling pelagic species (kahawai) in previous tagging studies in New Zealand (Wood et al. 1990, Griggs et al. 1998) and seemed to affect the behaviour, health, and growth of the fish (Griggs et al. 1998). Other tags are available that would have a less deleterious effect on the fish; they are considerably smaller, but rely on electronic equipment for detection after the recaptured fish are landed.

The question of niche overlap is one that could affect fishers exploiting blue mackerel, given the collapse of *Scomber japonicus* in the eastern Pacific (Beverton 1990) and the similar trophic niche it inhabits compared with pilchards and anchovy. There is no evidence for regime shifts between small pelagics in New Zealand, but it is a common phenomenon in large fisheries overseas and experiences there have resulted in strategies to best manage the constituent species. Whether there is any implication for our blue mackerel in this context is unknown. Understanding how niches of our pelagic species overlap would be a first step in managing this suite of species as a group to maximise our exploitation of each of them individually. Potential interactions occur between the following:

- Blue mackerel-jack mackerel.
- Blue mackerel-kahawai.
- Blue mackerel-pilchard-anchovy.
- The three jack mackerel species.

Development of a multi-species approach to monitoring inshore schooling pelagics might be the most cost-effective way of gathering information and could allow some progress to be made. For example, some 60% of the blue mackerel catch in QMAs 7, 8, and 9 is as bycatch in the TCEPR fishery for jack mackerel. Our understanding of, and poor information from, this fishery, has been a key issue hindering progress in developing methods of assessment or monitoring of the three jack mackerel species in this Fishstock (JMA 7) since at least 1998. The aggregated catch of jack and blue mackerels in QMAs 7, 8, and 9 is considerable in some years and exceeded 22 000 t in 1998–99 (Annala et al. 2001).

## 7.2 Summary

The following summarises the general research and monitoring methods discussed above. Recommendations are made in terms of the potential information each method can provide, with the inclusion of caveats related to costs and any particular difficulties in the method.

### 7.2.1 General requirements

These include recommended research topics that are either fundamental to our understanding of the blue mackerel stock and relationships with other pelagic species, or prerequisite to monitoring methods recommended in Section 7.2.2.

- **Stock structure.** Information from overseas indicates that scombrid mackerel are highly migratory within a coastal-offshore-coastal home range. The extent of blue mackerel migrations in New Zealand waters is unknown. Assuming a single stock may be misleading in stock monitoring, assessments, and management. The possibility of at least two stocks is indicated by evidence of two spawning centres, in the Hauraki Gulf and South Taranaki Bight. A project to determine stock separation would clarify this and provide background on the efficacy of managing a separate stock in QMAs 7, 8, and 9.

- **Niche overlap.** As a first step it would be informative to examine the relative catches of blue and jack mackerel in QMAs 7, 8, and 9 over time. This would include all fisheries and a breakdown to the fishery level. In addition, samples of gut contents from blue and jack mackerels from the same schools would not only provide information on baseline diets, but could be examined to determine whether they feed on the same items. Fish size would be required to allow stratification in the analysis and some information on prey size would also improve the scope of potential inference.

- **Reproductive cycle.** A study of various aspects of the reproductive cycle would provide three important pieces of information. (1 & 2) As an initial step in developing any stock assessment procedure based on egg and larval surveys, and as an indication of the number of spawning grounds, information is required on the spawning season and main spawning grounds of blue mackerel in New Zealand. (3) Estimation of age at first maturity would provide a baseline for monitoring this parameter for any changes resulting from fishing pressure.

### 7.2.2 Monitoring the status of the blue mackerel stock in QMAs 7, 8, and 9

- **Biomass from catch per unit effort.** Catch per unit effort will not provide reliable abundance information for blue mackerel in New Zealand waters. Almost 80% of landings are taken by purse-seine (see Table 5), which can remain effective as a fishing method, maintaining stable catch rates throughout periods of declining abundance. Data from the midwater trawl fishery in QMAs 7, 8, and 9 can do no better because of the high proportion of blue mackerel catch that is non-targeted, and because of the highly variable distribution of this species that is almost certainly encountered in this fishery. Like the Canadian fishery (DFO 2000), using CPUE from the trawl fishery would provide stock indices that are more reflective of fishing power and fish distribution than of stock abundance.

- **Relative abundance from aerial sightings data.** Aerial sightings data can provide information on the distribution of blue mackerel in New Zealand and may be useful in providing indices of relative abundance in QMA 1, but not for QMAs 7, 8, and 9. Bradford & Taylor (1995) produced relative abundance estimates for blue mackerel in QMA 1 and there is a current MFish research project investigating further the development of a stock index for blue mackerel using aerial sightings data. However, sightings of blue mackerel in QMAs 7, 8, and 9 are very patchy in time and space. Without a change in flying/search effort, indices of relative abundance for this area are not possible.

- **Biomass estimation by the Daily Egg Production Method (DEPM).** This approach generates estimates which have a relatively low precision but are unbiased. They require good knowledge of the spawning area and season, and very careful statistical design.

- **Biomass estimation by egg and larval surveys of spawning grounds.** This approach relates the area of spawning to the size of the spawning stock. It requires good knowledge of the reproductive cycle, fecundity, sex ratios, etc., and the distribution of spawning grounds, is probably better at measuring relative rather than absolute abundance, and because of its relatively high cost is likely to be most effective for large fisheries.

- **Biomass estimation by acoustic surveys.** NIWA has considerable expertise in undertaking acoustic surveys of middle depth and deepwater fish stocks, and it would be theoretically possible to use acoustics for blue mackerel assessment. Some experimental work would first be required on target strength, and the issue of distinguishing blue mackerel from other pelagic fishes of similar size would need to be resolved.

- **Year-class strength monitoring.** Blue mackerel stock size is almost undoubtedly influenced very strongly by recruitment (see summary of papers by Crawford & De Villiers (1984) on the relationship between year-class strength and biomass for *S. japonicus*). In conjunction with a study on ageing, the relative abundance of year-classes in the commercial catch, and also those about to enter it, should be monitored. This would involve regular and appropriate sampling of the catch, but would also require additional work to ensure that younger fish not normally targeted by fishers are adequately sampled. These are taken on inshore research voyages, but only in small numbers because tows during trawl surveys for non-pelagic species are too slow (about 3.5 kts) to catch representative samples of faster swimming pelagics. Dedicated, fast trawl shots in areas and at times of known blue mackerel presence may be required for adequate sampling.

- **Tagging.** Tagging could provide information on migrations within New Zealand waters and estimates of mortality. Blue mackerel are fragile compared with kahawai and jack mackerel, and may undergo higher levels of tagging-induced mortality. Appropriate tags rely on electronic equipment for detection when recaptured fish are landed within commercial catches. Detection equipment would need to be widespread in fish sheds and on TCEPR vessels, which process their catch at sea. Once established, such detection equipment could be used for other small pelagics (kahawai, jack mackerels) that are vulnerable to these fisheries and for which tagging information would provide similar information. Sources of major bias in previous tagging experiments could be overcome to a large extent using such an approach.

- **Age at first maturity.** Reduction in age at first maturity is indicative of heavy fishing pressure on the stock. Monitoring this parameter on an annual basis and comparing it with the baseline estimated in year one, would be a useful tool in determining the current status of the stock.

- **Monitoring fish length.** Fish length would provide useful information on size structure of the stock and expand our understanding of changes in distribution.

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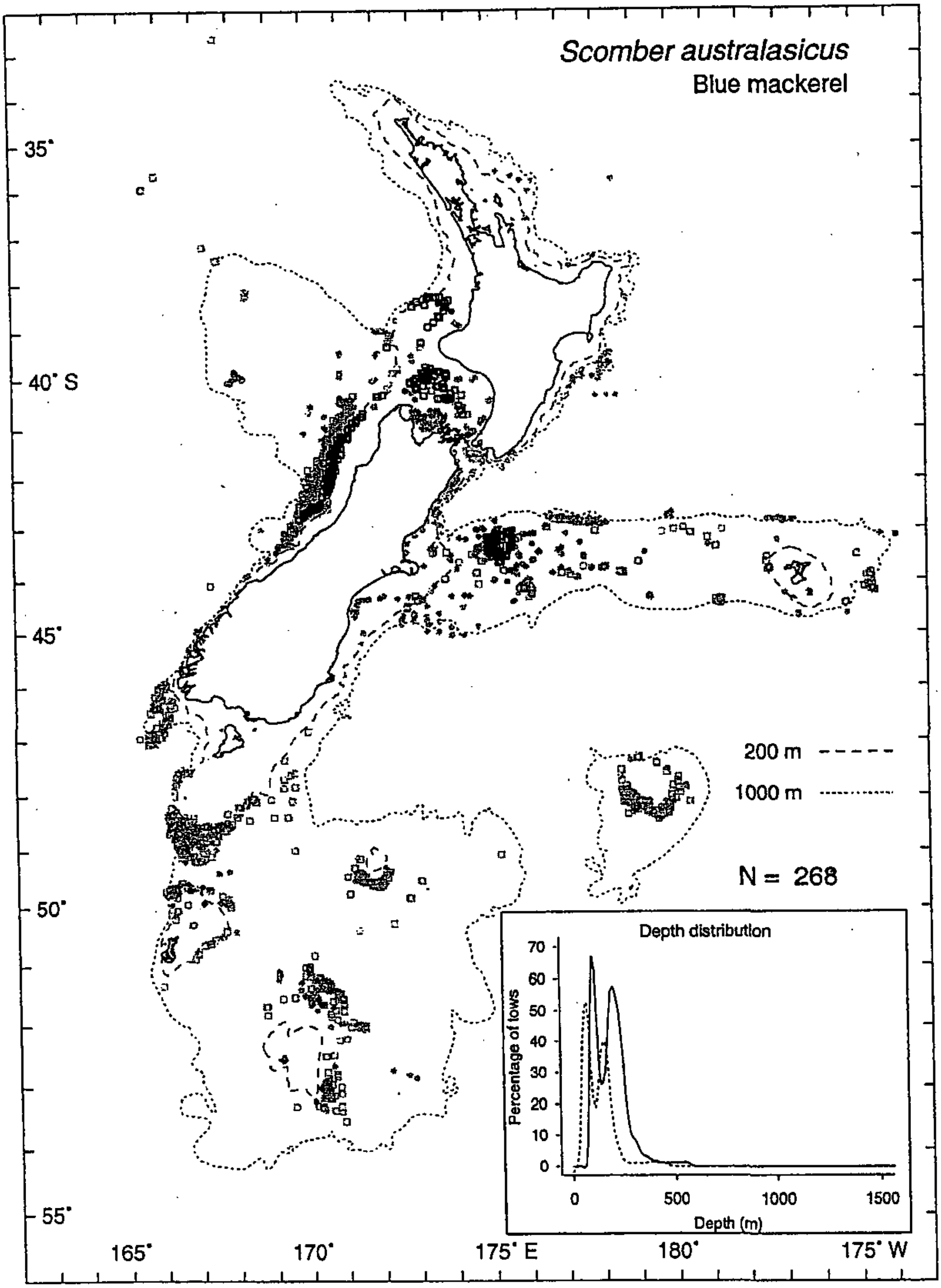
## APPENDICES

Eight appendices are included in this report. They perform three functions.

1. Appendices 1–5 are figures from reports published by other workers and are included to support conclusions from those studies and to illustrate ideas presented in this report. They are included as appendices instead of figures for two reasons.
    - In some cases (e.g., Appendix 2) ancillary information or figures are required and are also included in the appendix.
    - They provide information for the whole of New Zealand, not just QMAs 7, 8, and 9, and therefore confuse the focus of this report if included in the text.
2. Appendix 6 provides background information on fishing methods, approaches to stock assessments, and management strategies used in fisheries overseas. These are useful in developing methods for New Zealand.
3. Appendix 7 summarises catch data for the two main blue mackerel fisheries, purse-seine and TCEPR (vessels using *trawl catch effort processing returns*) midwater trawl, by year and month, for all areas combined and by QMA.
4. Appendix 8 provides length frequency data and distributions for all areas, not just QMAs 7, 8, and 9. These are included to provide a broader perspective than can be derived using data from those areas only.

**Appendix 1: Distribution of blue mackerel taken by midwater trawl (after Bagley et al. 2000)**




**Closed circles are midwater trawls from the research trawl database (*trawl*), open squares are midwater trawls from the observer database (*obs_lfs*); black symbols are tows where blue mackerel were caught, grey symbols show all midwater tow effort; research trawl data were recorded from 1979 to February 1999; observer data were recorded from 1990 to October 1998.**

**Appendix 2: Aerial sightings of blue mackerel — distribution of surface aggregations (after Bagley et al. 2000)**

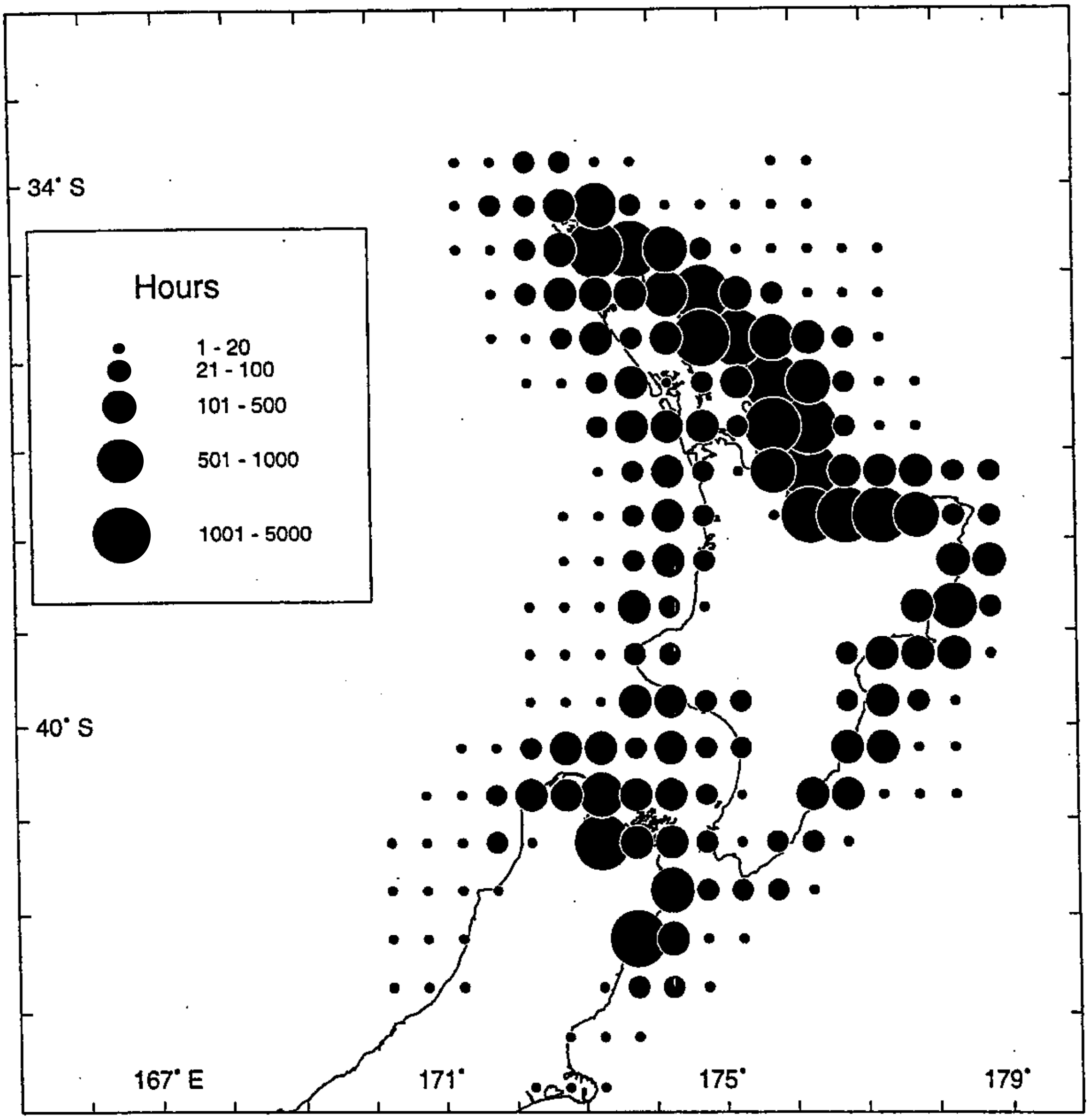



**Figure 1: Distribution of aerial sightings flying effort since 1976. Circle size represents the number of hours flown by half degree square.**

**Appendix 2: *continued***

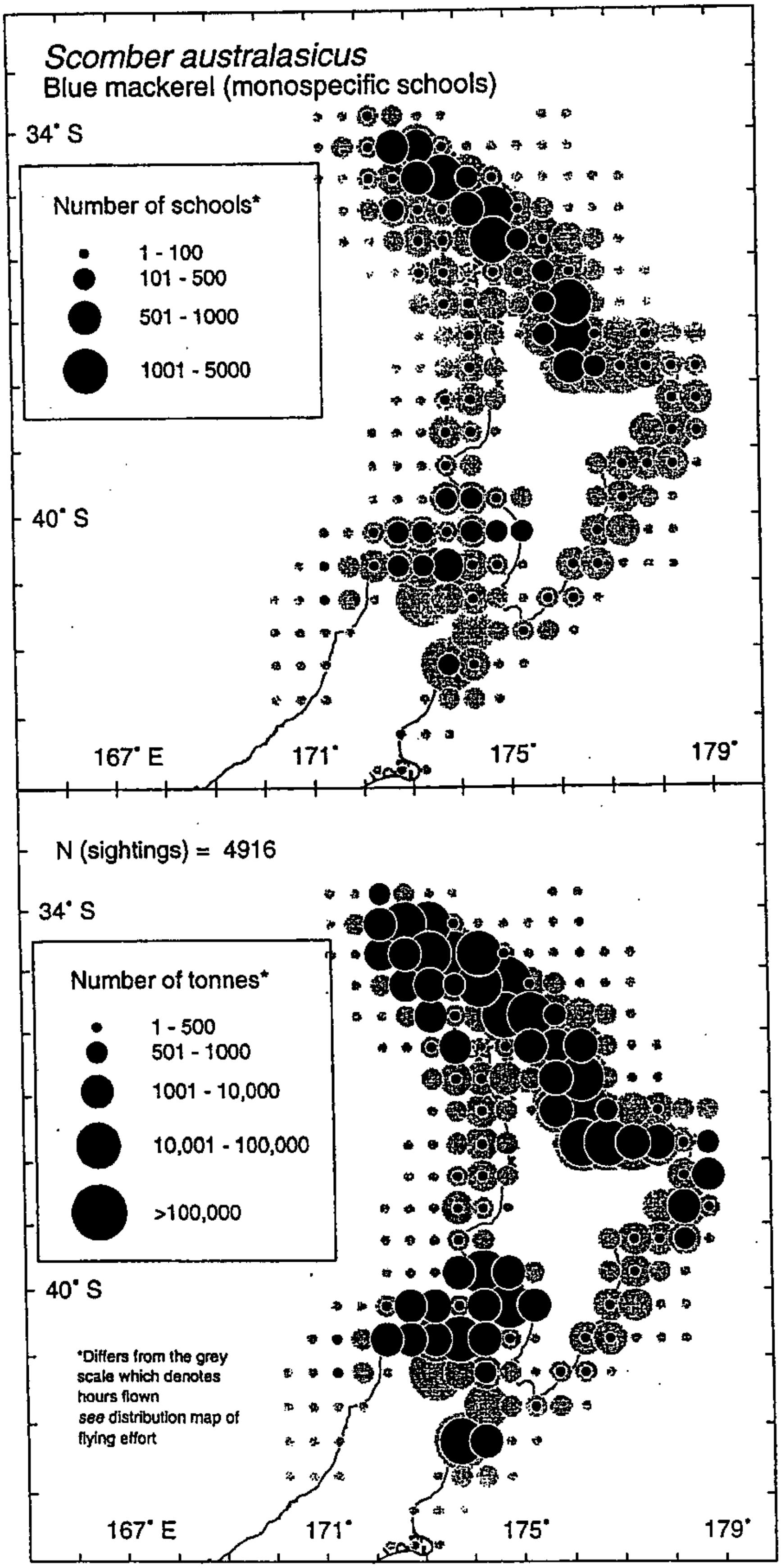



**Figure 2: Distribution of sightings of monospecific schools of blue mackerel since 1976, expressed as estimated abundance (number of schools and tonnes per half degree square) (after Bagley et al. 2000).**

**Appendix 2: *continued***

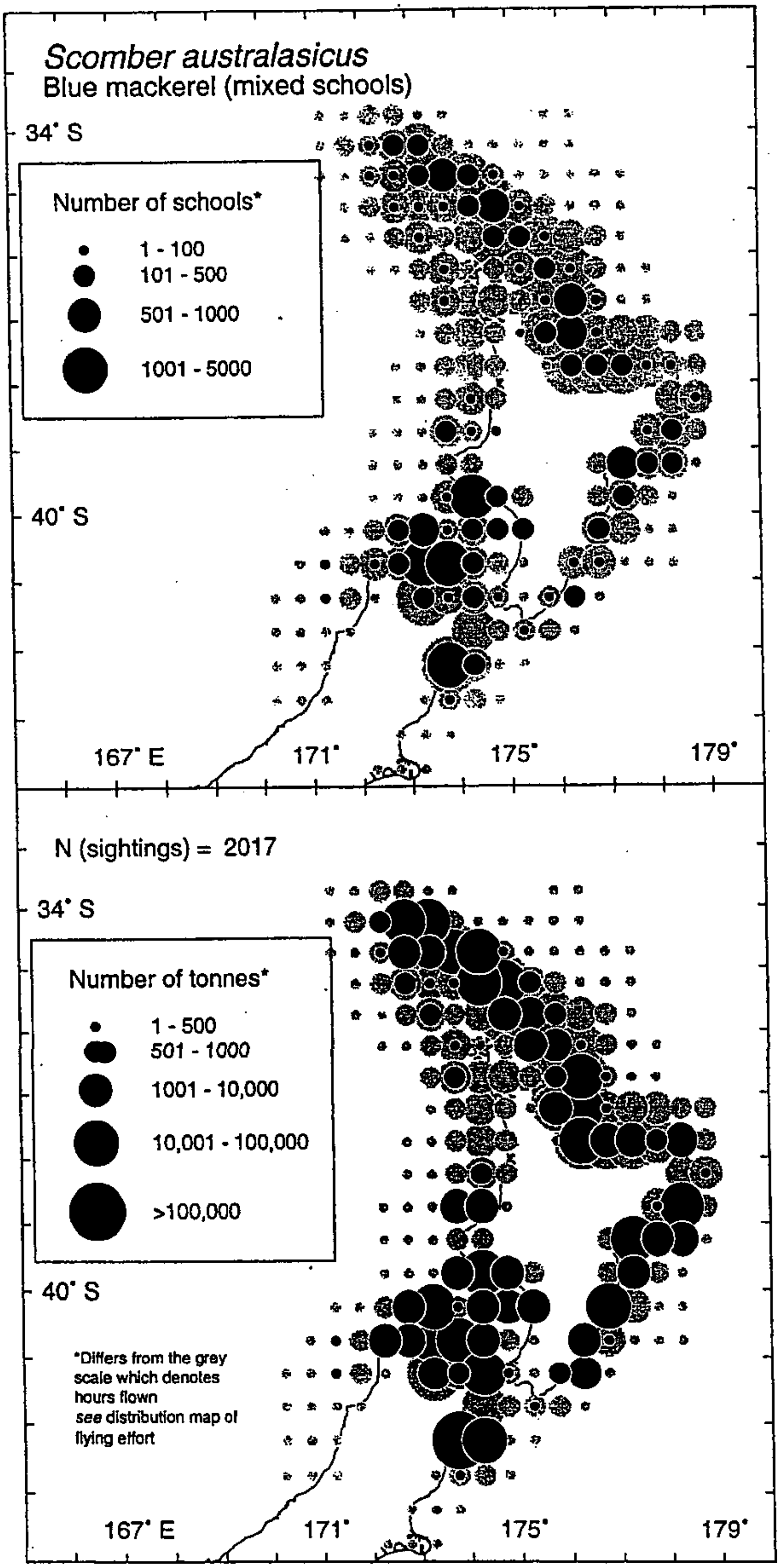
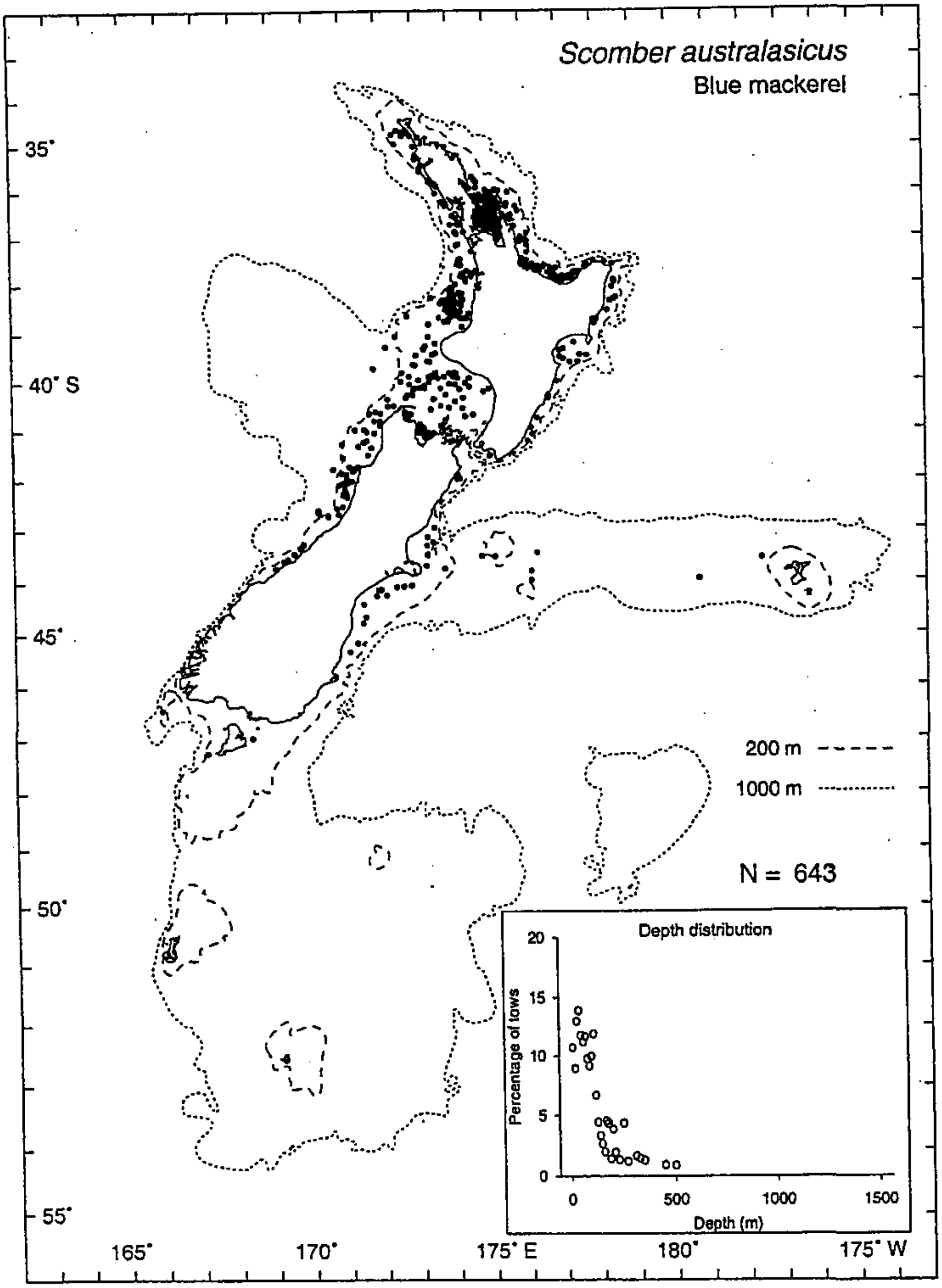
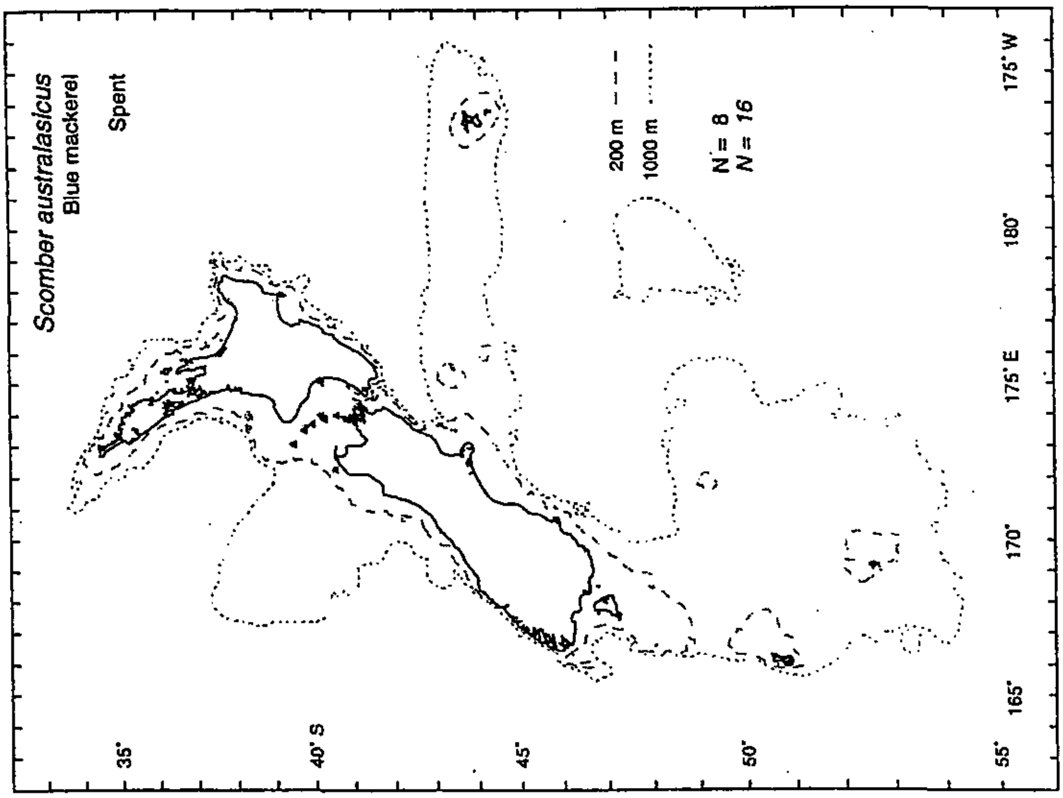


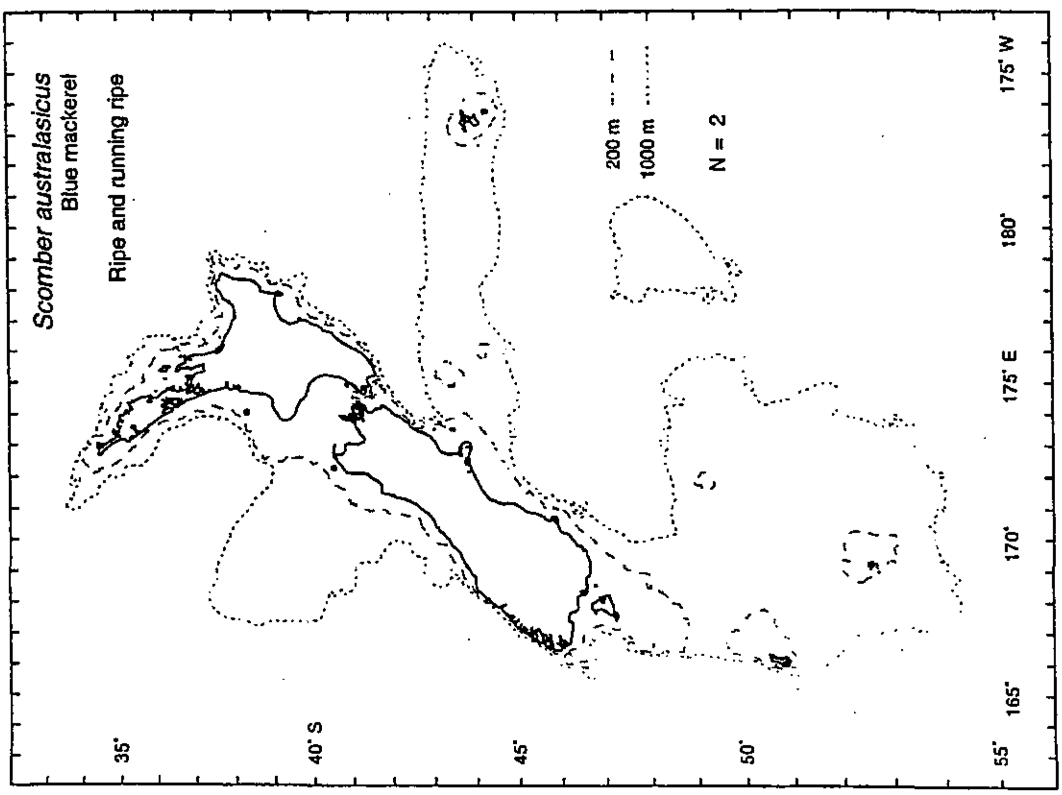

**Figure 3: Distribution of sightings of mixed schools of blue mackerel since 1976, expressed as estimated abundance (number of schools and tonnes per half degree square) (after Bagley et al. 2000).**

**Appendix 3: Distribution of bottom trawls from the research trawl database in which blue mackerel were recorded (after Anderson et al. 1998)**



**Appendix 4: Distribution of spawning blue mackerel from the research trawl and observer databases (after Hurst et al. 2000a)**



**Appendix 5: Summary of blue mackerel life history stages recorded from bottom trawl catches (after Hurst et al. 2000b)**

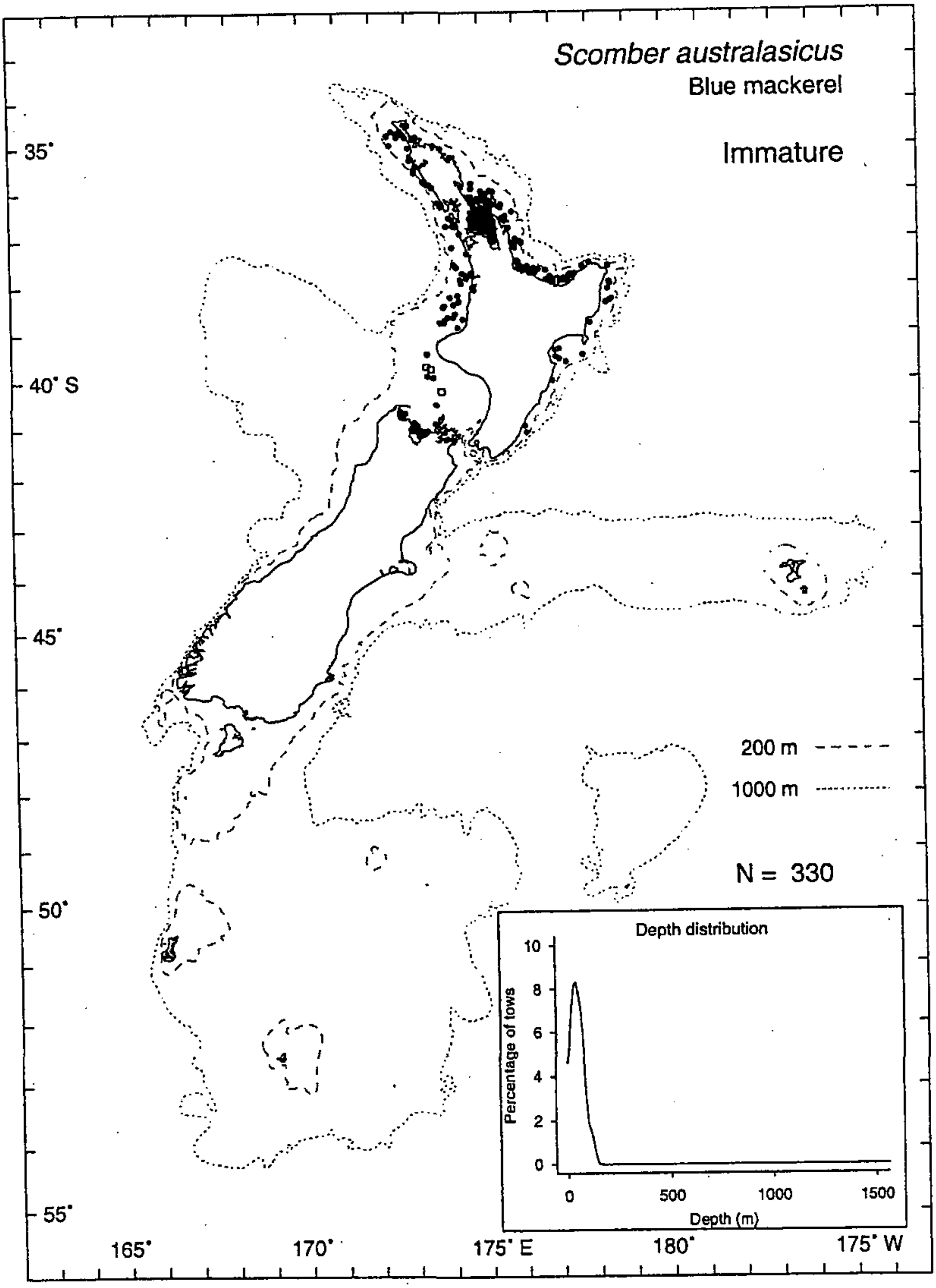



**Figure 1: Bottom trawls taking immature blue mackerel; closed circles are bottom trawls from the research trawl database (*trawl*), open squares are bottom trawls from the observer database (*obs_lfs*); these fish are divided into approximations of 0+ and 1+ age classes in Figures 3 and 4 of this appendix.**

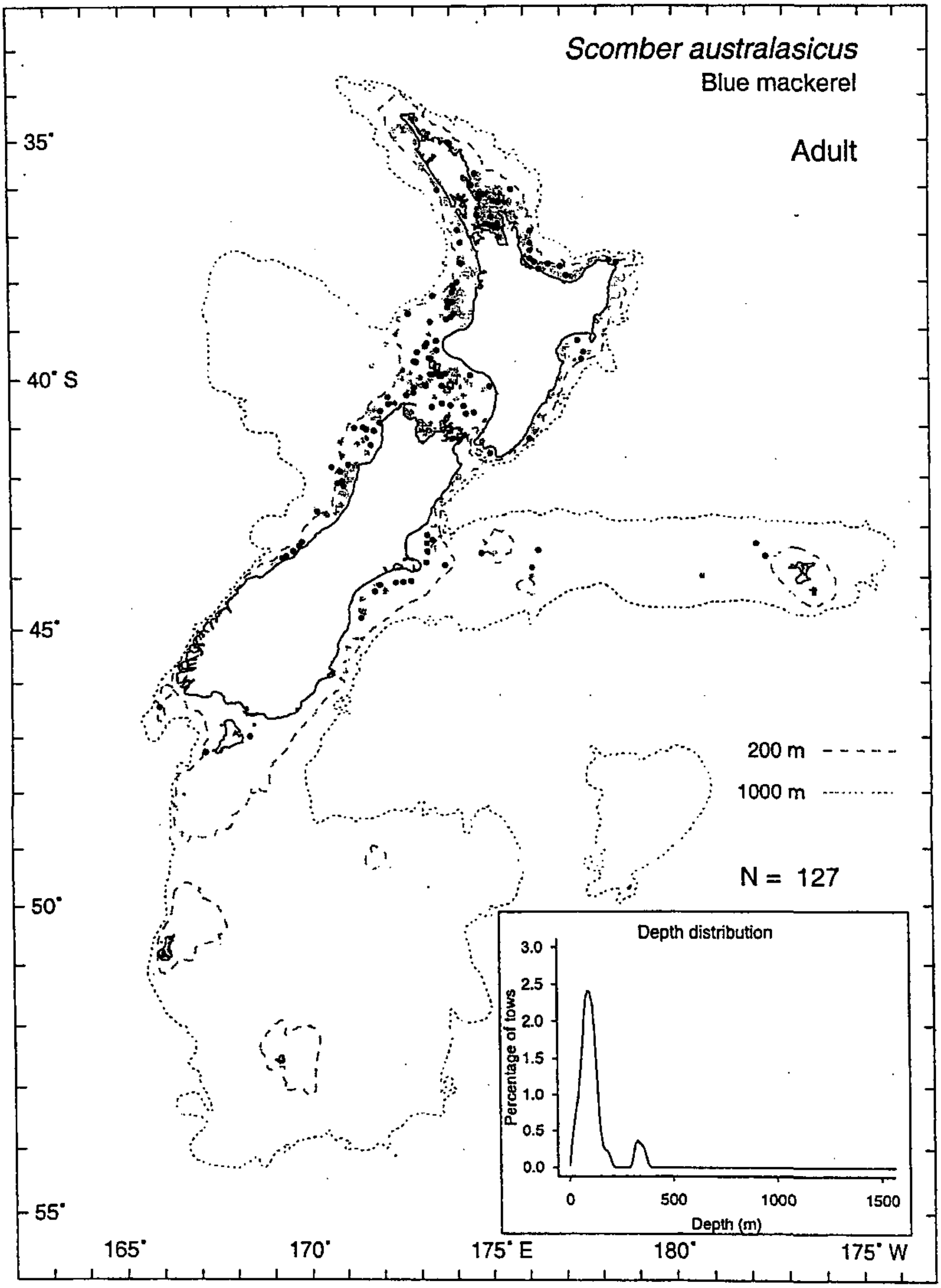



**Figure 2: Bottom trawls taking adult blue mackerel; closed circles are bottom trawls from the research trawl database (*trawl*), open squares are bottom trawls from the observer database (*obs_lfs*), where blue mackerel were caught; black symbols show adult blue mackerel, grey symbols show all blue mackerel caught.**

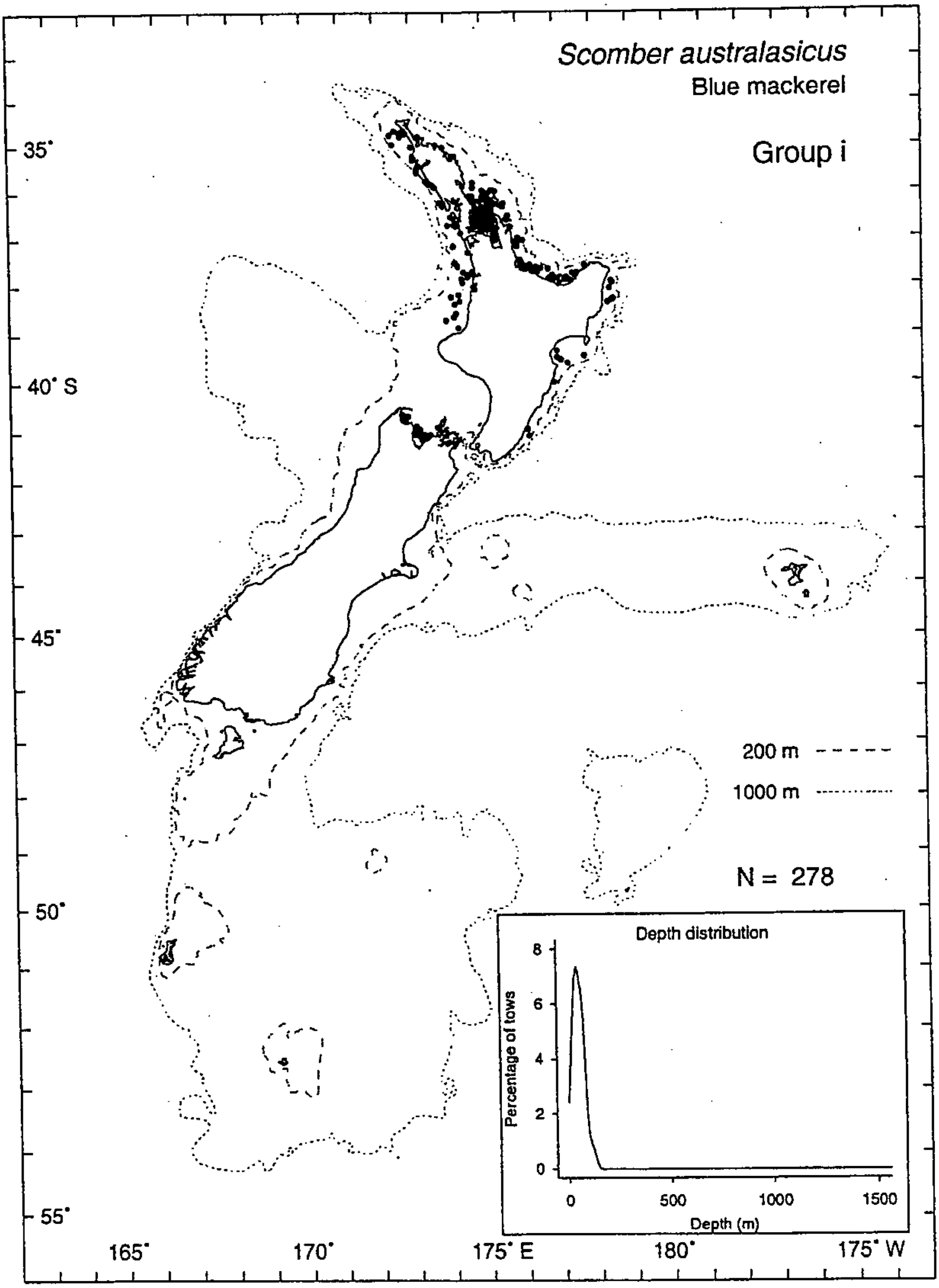



**Figure 3: Bottom trawls taking blue mackerel approximating 0+ year olds; closed circles are bottom trawls from the research trawl database (*trawl*), open squares are bottom trawls from the observer database (*obs_lfs*.**

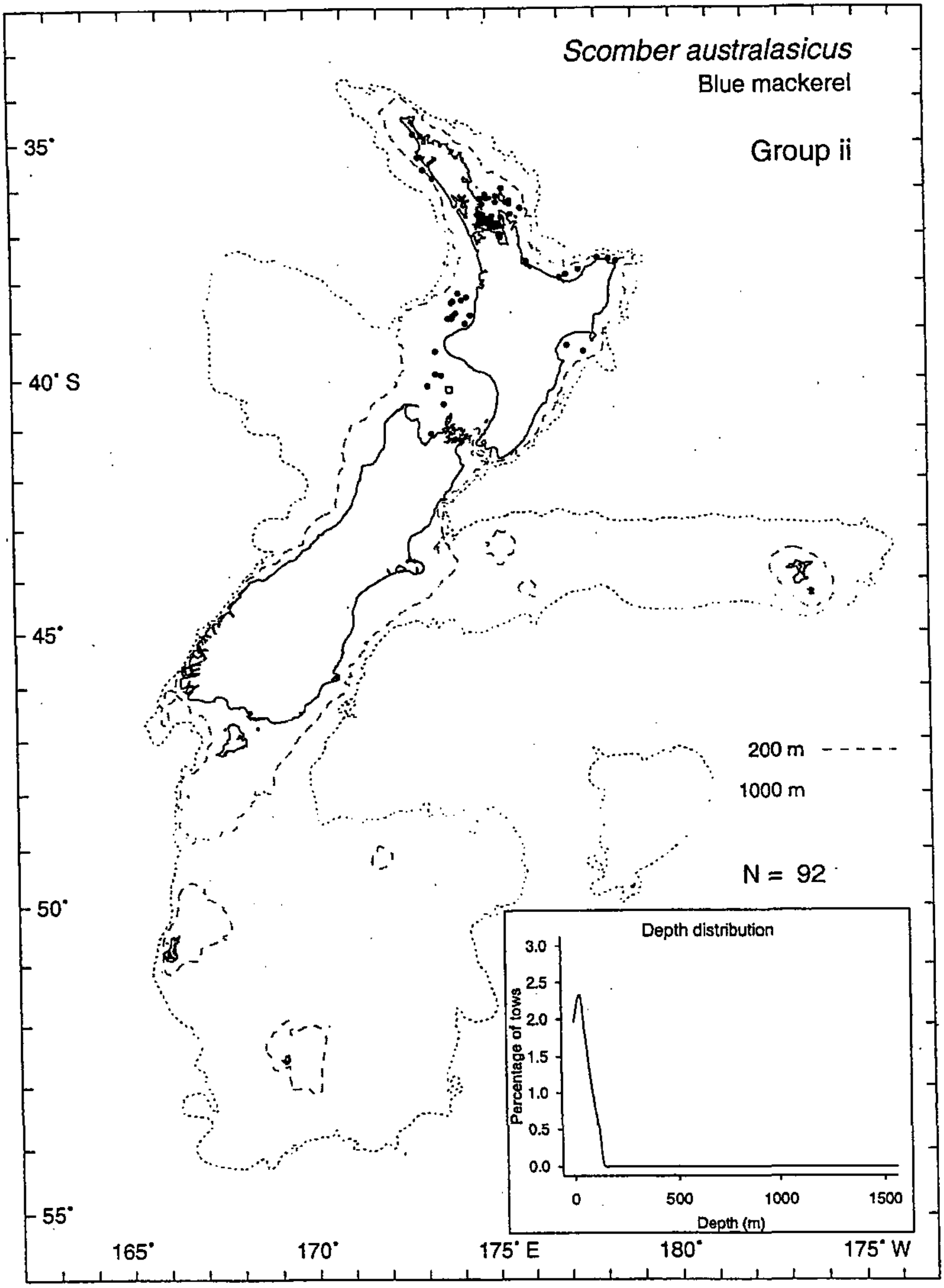



**Figure 4: Bottom trawls taking blue mackerel approximating to 1+ year olds; closed circles are bottom trawls from the research trawl database (*trawl*), open squares are bottom trawls from the observer database (*obs_lfs*).**

## Appendix 6: Fishing methods, approaches to stock assessments, and management measures used in some overseas fisheries for scombrid mackerels

### A. Fishing methods

In the northeastern Atlantic *Scomber* fishery, a wide range of vessel sizes is used; most fish are landed by purse-seine and pelagic trawl, with Danish seine and handlines also being used (Ward et al. 2001). In Canada's northwestern Atlantic fishery the most commonly used gear are gillnets, purse-seine, and, to a lesser extent, handlines and traps (DFO 2000). In Japanese waters mackerel are taken by purse-seine, angling and dipnets, and less commonly, lampara nets, set-nets, trolling, stake lines, and longlines.

### B. Stock assessment methods

**The northeast Atlantic fishery for Atlantic mackerel.** A comprehensive stock assessment is conducted through the ICES Working Group on the Assessment of Mackerel, Horse Mackerel, Sardine and Anchovy, based on a time series of data from 1984 that includes age-length relationships, estimates of recruitment, and the age-structure of the catch (ICES 2001). Standing stock biomass and spawning stock biomass (SSB) (using the batch fecundity method) are estimated using data collected during research cruises performed every three years; standing stock biomass and recruitment are used as fishery indicators. Integrated catch and age (ICA) models are fitted to the catch at age data, and egg production estimates are used to examine the relationship between the indices and catch at age data as estimated using a virtual population analysis (VPA). An AMCI model ("assessment model containing information from various sources") uses a large set of Norwegian tagging data to estimate mortality rates but its development is not yet complete. Catch per unit effort (CPUE) data from commercial fleets are available only from one sub-area.

The working group recognises that poor sampling in some parts of the fishery probably leads to large errors in the catch at age data (ICES 2001). By contrast, estimates of SSB from egg surveys are considered reliable. However, there is concern that the increases in SSB estimates has not been reflected by a pattern of strong recruitment of recent year classes in the fishery.

Distribution and migration of Atlantic mackerel in this region have been monitored using acoustic and aerial surveys. According to ICES (2001), acoustic surveys have been used to show successfully that mackerel "stocks are amenable to acoustic survey methodology, and that it was possible to observe the fish acoustically, without major mixing with plankton and other fish species". However, abundance estimates from acoustic surveys have not yet been incorporated into stock assessments for this fishery, although no reason for this omission is given.

**The northwest Atlantic fishery for Atlantic mackerel.** CPUE is not used as an abundance index in this fishery because the fluctuations in mackerel catch rates between localities and years are related more to mackerel distribution and fishing power than to variations in the size of the stock (DFO 2000). Instead, Fisheries and Oceans Canada use abundance estimates derived from egg production. The size composition of mackerel catches is used as a tool for tracking cohorts through the fishery, although it may be affected by the fishing gear. Information from a gonadosomatic index (GSI) is used to monitor the timing of spawning events.

The daily fecundity reduction method (DFRM) is now used to calculate spawning biomass from daily egg production surveys. The method requires knowledge of the main spawning locations of mackerel. Annual egg production models, which Fisheries and Oceans used in the past, are sensitive to mis-timing between the survey and peak spawning. The DFRM overcomes these sensitivities by extrapolating peak egg production from estimates of daily egg production (DFO 2000). Assessments also involve a catch at age model.

An exploratory VPA was performed in 2000 using catch at age and spawning biomass values from the egg survey to calibrate the model (DFO 2001). Preliminary results suggest that stock size is overestimated in some years as a result of the methods used to analyse the egg survey data. Difficulties in applying the VPA are listed as: (1) the abundance index not being age-disaggregated; (2) errors in the spawning biomass, linked to the possible lack of synchronism between spawning and the survey; (3) underestimation of the catch at age and landings totals; (4) natural mortality set at 0.2; and (5) the absence of key biological data such as weight at age for some months.

The United States models stock status using a VPA tuned with research survey estimates of mature mackerel abundance to estimate spawning biomass (Overholtz 2000).

Ward et al. (2001) noted that the presence of more than one spawning site creates considerable uncertainty in the reliability of stock assessments for Atlantic mackerel assuming a single stock.

**Japan's fishery for chub mackerel in the northwest Pacific.** Catches in the northwest Pacific have increased from low levels in the early 1990s. The Pacific stock biomass was reduced from 4 to 6 million t in the 1970s and declined to less than 1 million t in the early 1990s.

To determine abundance, Japan undertakes midwater trawl and driftnet surveys of mackerel. Official landings statistics are used to estimate total catch. A VPA tuned with stock abundance indices from the midwater trawl and driftnet surveys and the number of effective shots in the purse-seine fishery is used to estimate stock abundance. Size of the spawning stock is estimated using egg surveys, but patchiness in the distribution of spawning and non-spawning fish results in stock spawning rates being difficult and costly to estimate (Hunter & Wada 1993).

Ward et al. (2001) suggested that a combination of egg surveys and research trawls to the east of Japan provides information for a sound stock assessment, but there was no information available on assessment techniques in other areas of the North Pacific.

**The southwest Pacific fishery for blue mackerel.** No agency carries out stock assessment in the southwest Pacific fishery.

## B. Management measures

**The northeast Atlantic fishery for Atlantic mackerel.** Mackerel catches are reported by FAO sub-areas and divisions in the northeast Atlantic. Catch limits of 1.0 and 2.5 t per week per vessel having been set in several ICES divisions in the North Sea. There are no closed areas or seasons for mackerel in the northeast Atlantic Ocean and most fishing effort is concentrated in summer. Norway and the European Union have implemented a management strategy for herring, mackerel, and plaice in the North Sea, where management decisions apply for more than one year (ICES 1997). This includes the allocation of total allowable catches for these species in the North Sea

**The northwest Atlantic fishery for Atlantic mackerel.** Since April 1983, the United States fishery has been managed under the Mid-Atlantic Fishery Management Council's Atlantic Mackerel, Squid, and Butterfish Plan (Overholtz 2000). Management is based on annual quota specifications and, for 2000, a "domestic annual harvest" was set at 75 000 t within an "allowable biological catch" of 347 000 t. Fisheries and Oceans Canada manage the Canadian fishery, where the current total allowable catch is set at 100 000 t per year. Recent landings in both Canada and the United States are only a fraction of the quotas set by their national management agencies, and fishing activity is currently limited by market demand. There are moves to improve catch estimates by introducing a mandatory logbook for all fishers, including bait fishers with mackerel licences. The overall recreational catch in both countries is "probably high" and its estimation is considered important for management of this activity (DFO 2000).

## Appendix 7: Annual and monthly catches of blue mackerel in the purse-seine and midwater trawl (TCEPR fleet only) fisheries

**Table 1: Annual and monthly catches in the purse-seine fishery, by QMA. Source: MFish catch and effort database.**

| Fishing year | QMA 1 | QMA 2 | QMA 3 | QMA 7 | QMA 8 | QMA 9 | Unspecified | Total |
|---|---|---|---|---|---|---|---|---|
| 1988–89 | 35 | | | 132 | | | | 167 |
| 1989–90 | 2 259 | 45 | | 1 831 | 18 | | 8 | 4 161 |
| 1990–91 | 5 044 | 184 | | 1 103 | 99 | | 48 | 6 479 |
| 1991–92 | 9 803 | 300 | | 79 | | 50 | | 10 231 |
| 1992–93 | 6 155 | 221 | 140 | 133 | 107 | 2 647 | 167 | 9 570 |
| 1993–94 | 3 672 | 204 | | 28 | | 224 | 210 | 4 337 |
| 1994–95 | 4 703 | 229 | | 8 | 50 | 492 | 449 | 5 931 |
| 1995–96 | 3 809 | 180 | | 240 | 40 | 97 | 290 | 4 656 |
| 1996–97 | 6 475 | 60 | | 208 | 0 | | 25 | 6 769 |
| 1997–98 | 4 533 | 118 | | 36 | 40 | | 72 | 4 799 |
| 1998–99 | 4 133 | 33 | | 2 634 | 828 | 75 | 15 | 7 718 |
| 1999–2000 | 3 193 | 36 | | 442 | 2 | 80 | | 3 753 |
| Total | 53 815 | 1 608 | 140 | 6 874 | 1 184 | 3 665 | 1 284 | 68 570 |
| Month | | | | | | | | |
| January | 3 281 | 9 | | 204 | 12 | 380 | 82 | 3 968 |
| February | 1 705 | 2 | 140 | 1 012 | 2 | 663 | 256 | 3 779 |
| March | 1 350 | 15 | | 2 085 | 493 | 1 260 | 54 | 5 256 |
| April | 1 875 | 78 | | 1 793 | 145 | | 25 | 3 917 |
| May | 1 119 | 28 | | 1 148 | 241 | 92 | 216 | 2 844 |
| June | 16 | | | 83 | 49 | | 2 | 150 |
| July | 133 | 1 | | 11 | | | 0 | 145 |
| August | 211 | 37 | | 5 | | | 1 | 253 |
| September | 1 512 | 59 | | 502 | 6 | 50 | 52 | 2 179 |
| October | 10 839 | 822 | | 4 | 1 | 629 | 372 | 12 667 |
| November | 21 890 | 413 | | 11 | 185 | 591 | 90 | 23 180 |
| December | 9 886 | 146 | | 17 | 50 | | 135 | 10 234 |
| Total | 53 815 | 1 608 | 140 | 6 874 | 1 184 | 3 665 | 1 284 | 68 570 |

**Table 2: Annual and monthly catches in the TCEPR midwater trawl fishery, by QMA. Source: MFish catch and effort database.**

| Fishing year | QMA 1 | QMA 2 | QMA 3 | QMA 1 | QMA 2 | QMA 3 | QMA 7 | QMA 8 | QMA 9 | Unspecified | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1988–89 | | | | | | | 257 | 18 | | | 274 |
| 1989–90 | | | | | | | 48 | 15 | | | 63 |
| 1990–91 | | 0.05 | 0.4 | | 1 | 0.1 | 1 296 | 68 | | 10 | 1 376 |
| 1991–92 | | 1 | 0.2 | | | | 1 069 | 1 470 | 0.5 | 9 | 2 549 |
| 1992–93 | | | 71 | 0.5 | | | 489 | 63 | 10 | 0.2 | 634 |
| 1993–94 | 0.3 | | 144 | | 0.3 | | 612 | 115 | 26 | 4 | 902 |
| 1994–95 | | | 169 | 7 | | 7 | 860 | 295 | | 2 | 1 339 |
| 1995–96 | | | 36 | | 0.1 | | 581 | 23 | 0.9 | 0.6 | 641 |
| 1996–97 | 0.5 | 3 | 30 | 4 | 0.1 | | 1 886 | 63 | | 0.75 | 1 988 |
| 1997–98 | | | 16 | | | | 1 798 | 15 | | | 1 829 |
| 1998–99 | | | 4 | | | | 4 096 | 75 | 8 | | 4 184 |
| 1999–00 | | 0.1 | 0.1 | | | | 2 393 | 39 | | | 2 432 |
| Total | 0.8 | 5 | 470 | 12 | 2 | 7 | 15 386 | 2 258 | 45 | 26 | 18 212 |
| Month | QMA 1 | QMA 2 | QMA 3 | QMA 1 | QMA 2 | QMA 3 | QMA 7 | QMA 8 | QMA 9 | Unassigned | Total |
| Jan | 0.3 | 0.05 | 263 | 7 | 1 | | 104 | 232 | | 5 | 612 |
| Feb | | 0.035 | | | | | 59 | 48 | | | 107 |
| Mar | | | | | | | 70 | 36 | | | 106 |
| Apr | | | 48 | | | | 74 | 273 | 8 | | 403 |
| May | 0.5 | | 11 | | | | 1 316 | 674 | 0.5 | 6 | 2 008 |
| Jun | | 0.114 | 7 | | | | 6 666 | 796 | | 0.8 | 7 470 |
| Jul | | 3 | 0.135 | | | 7 | 5 776 | 65 | 0.9 | 15 | 5 867 |
| Aug | | 1.3 | | | | | 739 | | | | 740 |
| Sep | | | | 2 | 0.5 | 0.1 | 399 | 11 | 10 | 0.03 | 422 |
| Oct | | 0.1 | 29 | | | | 178 | 87 | 26 | | 320 |
| Nov | | | 53 | 3 | | | 4 | 4 | | | 65 |
| Dec | | | 59 | | | 0.1 | 2 | 31 | | | 92 |
| Total | 0.8 | 4.599 | 470 | 12 | 2 | 7 | 15 386 | 2 258 | 45 | 26 | 18 212 |

**Table 3: Catch from the purse-seine and TCEPR midwater trawl fisheries by calendar year and month, all areas combined. Source: MFish catch and effort database.**

| Year | January | February | March | April | May | June | July | August | September | October | November | December | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Purse-seine | | | | | | | | | | | | | |
| 1989 | | | | | | | | 35 | 132 | 42 | 625 | 708 | 1 542 |
| 1990 | 150 | 417 | 458 | 426 | 493 | 20 | 11 | 5 | 807 | 2 076 | 1 370 | 505 | 6 736 |
| 1991 | 23 | 445 | 623 | 253 | 144 | | 103 | 46 | 890 | 3 105 | 2 776 | 2 830 | 11 239 |
| 1992 | 807 | 353 | 244 | 704 | 9 | | | | 56 | 2 415 | 1 906 | 888 | 7 381 |
| 1993 | 1 511 | 1 549 | 970 | 141 | 131 | | 5 | 55 | | 610 | 1 915 | 1 822 | 8 708 |
| 1994 | 8 | 36 | 353 | 222 | | 4 | 2 | 3 | 39 | 1 272 | 1 396 | 664 | 3 998 |
| 1995 | 970 | 574 | 715 | 78 | 238 | 5 | 5 | 9 | 6 | 627 | 3 466 | 283 | 6 974 |
| 1996 | 104 | 392 | 133 | 238 | 12 | 6 | 15 | 67 | 34 | 873 | 2 765 | 1 431 | 6 070 |
| 1997 | 306 | | | 885 | 453 | 1 | 3 | 1 | 51 | 970 | 2 600 | 1 013 | 6 283 |
| 1998 | | | 25 | 0 | 8 | 1 | | 21 | 90 | 575 | 2 734 | 867 | 4 321 |
| 1999 | 10 | | 1 474 | 801 | 1 141 | 48 | 1 | 12 | 54 | 29 | 2 348 | 552 | 6 471 |
| 2000 | 81 | 13 | 261 | 168 | 214 | 65 | | | 22 | 1 465 | 3 018 | 2 170 | 7 477 |
| Total | 3 970 | 3 779 | 5 256 | 3 916 | 2 843 | 150 | 145 | 254 | 2 181 | 14 059 | 26 919 | 13 733 | 77 200 |
| Midwater trawl (TCEPR only) | | | | | | | | | | | | | |
| 1989 | | | | | 126 | 15 | 9 | 98 | 26 | 1 | | 5 | 280 |
| 1990 | 3 | 14 | 21 | 10 | | 3 | | 7 | 1 | 2 | 0 | 1 | 61 |
| 1991 | 9 | 17 | 17 | 1 | 4 | 361 | 756 | 200 | 9 | 6 | 9 | 6 | 1 393 |
| 1992 | 7 | 50 | 5 | 183 | 1 160 | 808 | 310 | 2 | 5 | | | 0 | 2 529 |
| 1993 | 39 | 22 | 11 | 41 | 63 | 138 | 302 | 0 | 18 | 60 | 35 | 21 | 750 |
| 1994 | 182 | 4 | | | 62 | 163 | 315 | 16 | 45 | 22 | | 31 | 838 |
| 1995 | 315 | | 51 | | 160 | 524 | 192 | 35 | 9 | 1 | | 8 | 1 296 |
| 1996 | 23 | | 0 | 0 | 121 | 137 | 277 | 24 | 50 | 67 | 21 | 18 | 738 |
| 1997 | | 0 | | | 29 | 735 | 907 | 95 | 116 | 0 | | 2 | 1 884 |
| 1998 | | | 0 | 45 | 36 | 785 | 599 | 258 | 103 | | | | 1 826 |
| 1999 | 10 | | | 112 | 246 | 2 274 | 1 493 | 7 | 42 | 162 | | 1 | 4 346 |
| 2000 | 24 | | | 11 | | 1 527 | 708 | | 0 | | | | 2 270 |
| Total | 612 | 107 | 106 | 403 | 2 008 | 7 470 | 5 867 | 740 | 422 | 320 | 65 | 92 | 18 212 |

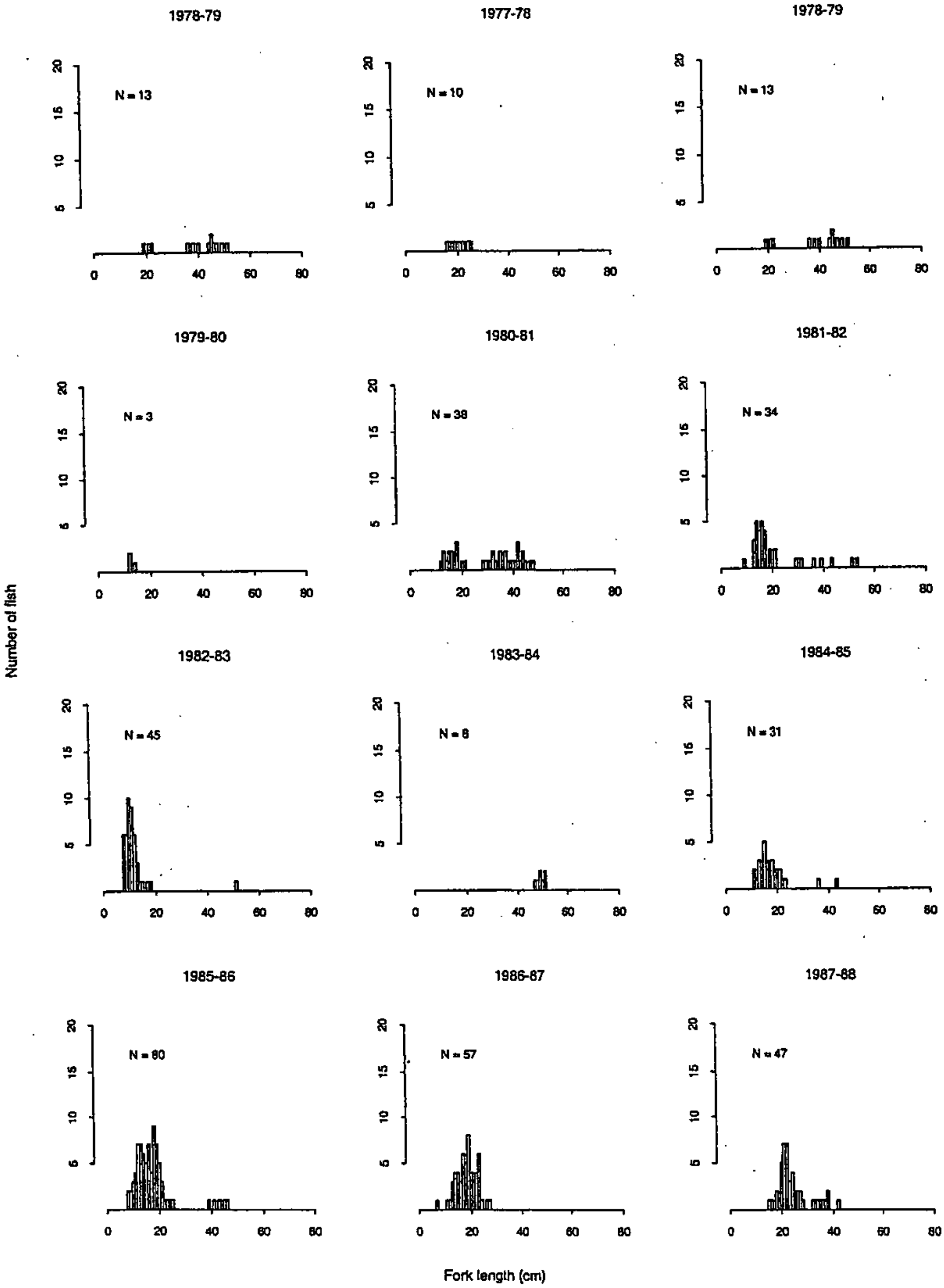
**Appendix 8a: Sources of fish length data and key information collected from blue mackerel on research trawl voyages in QMAs 7, 8, and 9. Source: MFish research trawl database.**

| Fishing year | Trip code | Vessel | Number of fish measured | Minimum length (cm) | Maximum length (cm) | Codend mesh size (mm) |
|---|---|---|---|---|---|---|
| 1977–78 | IKA7810 | *Ikatere* | 10 | 16 | 25 | 38 |
| 1978–79 | IKA7910 | *Ikatere* | 3 | 19 | 22 | 38 |
| | WES7903 | *Wesermunde* | 6 | 44 | 51 | 16 |
| | WES7904 | *Wesermunde* | 4 | 36 | 45 | 16 |
| 1979–80 | IKA8003 | *Ikatere* | 3 | 12 | 14 | 38 |
| 1980–81 | IKA8010 | *Ikatere* | 12 | 21 | 48 | 38 |
| | IKA8011 | *Ikatere* | 15 | 16 | 47 | 38 |
| | IKA8102 | *Ikatere* | 12 | 12 | 20 | 38 |
| 1981–82 | KAH8203 | *Kaharoa* | 28 | 9 | 43 | 35 |
| | KAH8205 | *Kaharoa* | 4 | 16 | 30 | |
| | KAH8211 | *Kaharoa* | 2 | 51 | 53 | |
| 1982–83 | KAH8216 | *Kaharoa* | 2 | 17 | 18 | |
| | KAH8303 | *Kaharoa* | 42 | 8 | 15 | 35 |
| | KAH8313 | *Kaharoa* | 1 | 51 | 51 | |
| 1983–84 | JCO8415 | *James Cook* | 6 | 47 | 51 | 100 |
| 1984–85 | KAH8421 | *Kaharoa* | 1 | 23 | 23 | 40 |
| | KAH8506 | *Kaharoa* | 30 | 11 | 43 | 40 |
| 1985–86 | KAH8517 | *Kaharoa* | 11 | 19 | 46 | 30 |
| | KAH8609 | *Kaharoa* | 69 | 8 | 23 | 30 |
| 1986–87 | KAH8612 | *Kaharoa* | 22 | 15 | 27 | 40 |
| | KAH8613 | *Kaharoa* | 18 | 16 | 24 | 30 |
| | KAH8711 | *Kaharoa* | 17 | 7 | 26 | 30 |
| 1987–88 | KAH8715 | *Kaharoa* | 1 | 20 | 20 | 40 |
| | KAH8716 | *Kaharoa* | 46 | 15 | 42 | 40 |
| 1988–89 | KAH8810 | *Kaharoa* | 34 | 17 | 47 | 40 |
| 1989–90 | COR9001 | *Cordella* | 178 | 15 | 53 | 60 |
| | KAH8917 | *Kaharoa* | 40 | 17 | 28 | 30 |
| | KAH8918 | *Kaharoa* | 14 | 11 | 52 | 40 |
| | KAH9004 | *Kaharoa* | 1 | 15 | 15 | 40 |
| 1990–91 | KAH9016 | *Kaharoa* | 22 | 17 | 35 | 40 |
| | KAH9017 | *Kaharoa* | 2 | 24 | 43 | 40 |
| | KAH9105 | *Kaharoa* | 2 | 51 | 51 | 74 |
| 1991–92 | KAH9111 | *Kaharoa* | 2 | 48 | 51 | 40 |
| | KAH9202 | *Kaharoa* | 8 | 6 | 11 | 40 |
| | KAH9204 | *Kaharoa* | 2 | 46 | 49 | 74 |
| | KAH9205 | *Kaharoa* | 3 | 52 | 56 | 40 |
| | TAN9106 | *Tangaroa* | 1 | 43 | 43 | 60 |
| 1992–93 | KAH9212 | *Kaharoa* | 27 | 14 | 35 | 40 |
| | KAH9302 | *Kaharoa* | 8 | 9 | 75 | 40 |
| | KAH9304 | *Kaharoa* | 1 | 35 | 35 | 74 |
| | KAH9306 | *Kaharoa* | 4 | 51 | 53 | 74 |
| | TAN9301 | *Kaharoa* | 1 | 46 | 46 | 60 |
| 1993–94 | KAH9311 | *Kaharoa* | 99 | 12 | 36 | 40 |
| | KAH9402 | *Kaharoa* | 36 | 5 | 47 | 80 |
| | KAH9406 | *Kaharoa* | 1 | 51 | 51 | 74 |

**Appendix 8a: *Continued***

| Fishing year | Trip code | Vessel | Number of fish measured | Minimum length (cm) | Maximum length (cm) | Codend mesh size (mm) |
|---|---|---|---|---|---|---|
| 1993–94 | TAN9401 | *Tangaroa* | 1 | 41 | 41 | 60 |
| | TAN9402 | *Tangaroa* | 1 | 44 | 44 | 60 |
| 1994–95 | KAH9410 | *Kaharoa* | 37 | 13 | 22 | 40 |
| | KAH9411 | *Kaharoa* | 19 | 19 | 44 | 40 |
| | KAH9502 | *Kaharoa* | 2 | 32 | 53 | 74 |
| | KAH9504 | *Kaharoa* | 10 | 46 | 51 | 74 |
| | KAH9507 | *Kaharoa* | 1 | 18 | 18 | 40 |
| | TAN9502 | *Tangaroa* | 1 | 45 | 45 | 60 |
| 1995–96 | KAH9601 | *Kaharoa* | 2 | 9 | 10 | 40 |
| | KAH9602 | *Kaharoa* | 11 | 10 | 47 | 74 |
| | KAH9606 | *Kaharoa* | 2 | 49 | 52 | 74 |
| | KAH9608 | *Kaharoa* | 52 | 10 | 21 | 40 |
| | TAN9601 | *Tangaroa* | 1 | 48 | 48 | 60 |
| 1996–97 | KAH9615 | *Kaharoa* | 26 | 12 | 26 | 40 |
| | KAH9701 | *Kaharoa* | 4 | 47 | 50 | 74 |
| | TAN9701 | *Tangaroa* | 1 | 48 | 48 | 60 |
| 1997–98 | KAH9720 | *Kaharoa* | 29 | 14 | 28 | |
| | TAN9801 | *Tangaroa* | 2 | 47 | 48 | |
| 1998–99 | KAH9902 | *Kaharoa* | 8 | 11 | 42 | |
| 1999–00 | KAH0004 | *Kaharoa* | 5 | 48 | 50 | |
| | KAH9915 | *Kaharoa* | 20 | 15 | 48 | |

**Appendix 8b: Length frequency distributions of blue mackerel based on research trawl data from all QMAs aggregated by fishing year. Source: MFish research trawl database.**



## Appendix 8b: *Continued*