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P. R. Taylor

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## EXECUTIVE SUMMARY

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This report addresses the objectives of Ministry of Fisheries project JMA9801, "Stock Assessment of Jack Mackerel": *Objective 1, To determine the seasonality and species composition of* Trachurus declivis, T. murphyi, *and* T. novaezelandiae *in the commercial catch in JMA 1, 3, and 7 from samples taken in fish sheds during the 1998/99 fishing year; Objective 2, To determine the seasonality and species composition of* Trachurus declivis, T. murphyi, *and* T. novaezelandiae *in the commercial catch in JMA 1, 3, and 7 from data collected at sea by Scientific Observers and other sources during the 1997/98 fishing year.* The specific name *T. murphyi* is synonymous with *T. s. murphyi*, but the latter has recently been adopted in New Zealand fisheries research documentation.

In JMA 1, species proportions were estimated for the purse-seine fishery from market sampling data collected during 1998–99. The estimated proportions were 0.14 for *T. declivis*, 0.29 for *T. s. murphyi*, and 0.57 for *T. novaezelandiae*. Inshore trawl survey data indicated a predominance of *T. novaezelandiae* from 1993 to 1995, with *T. s. murphyi* being most highly represented in the catch of the final survey in 1996.

Aerial sightings in JMA 1 indicate that the seasonal abundance of all jack mackerel species usually peaks during spring–early summer. In East Northland the mean monthly numbers of sightings of *T. s. murphyi* appear to be greater than for the combination of *T. declivis* and *T. novaezelandiae*. In the Bay of Plenty the monthly mean number of sightings of *T. s. murphyi* are less than half those of the other two species combined. Sightings of jack mackerels in JMA 1 and its two main sub-areas during 1998 were fewer, apart from an unusual peak in the Bay of Plenty in September. Sightings for *T. s. murphyi* in 1998 covered a much shorter season than the long-term means of monthly sightings.

In JMA 3, species proportions were estimated from scientific observer data collected on deepwater vessels during 1997–98 (0.01 for *T. declivis*, 0.99 for *T. s. murphyi*, and 0 for *T. novaezelandiae*), but observer coverage was not extensive enough to provide seasonal variations in species dominance. A time series from inshore trawl survey data indicate a predominance of *T. s. murphyi* in JMA 3.

In JMA 7, species proportions were estimated for the purse-seine fishery from market sampling data collected during 1998–99 (0.51 for *T. declivis*, 0.49 for *T. s. murphyi*, and less than 0.01 for *T. novaezelandiae*), from scientific observer data for the large-vessel offshore trawling fleet (0.42 for *T. declivis*, 0.37 for *T. s. murphyi*, and 0.21 for *T. novaezelandiae*), and a time series from inshore trawl survey data. Scientific observer data support an earlier observation that *T. s. murphyi* exhibit a winter peak, *T. novaezelandiae* a summer peak, and *T. declivis* a peak that lies between the two.

## 1. INTRODUCTION

Reliable estimates of the proportions of the three *Trachurus* species (*T. declivis*, *T. s. murphyi*, and *T. novaezelandiae*) from sources other than catch records are essential for assessment of their stocks. Because these species are aggregated in catch records under "JMA" (jack mackerel), separate information for each is unavailable, either as stock indices using catch per unit effort (CPUE) or in catch histories from the jack mackerel quota management areas. Reliable estimates of species proportions can be used to apportion the aggregated catch histories to provide individual catch histories and CPUE series for each species.

Two specific names are used in this document for the Chilean or Peruvian jack mackerel. In the objectives as quoted from the MFish contract, "*T. murphyi*" is used; everywhere else "*T. s. murphyi*" is used. "*T. murphyi*" is synonymous with "*T. s. murphyi*" and was previously used in New Zealand fisheries research documentation, but the latter has recently been adopted because it has been shown to be more taxonomically correct following work by Stepien & Rosenblatt (1996). "*T. s. murphyi*" is widely used in the primary literature.

Throughout the document *T. declivis* and *T. novaezelandiae* are referred to collectively as the "New Zealand species". This is based on their being endemic before the invasion by *T. s. murphyi*, as is discussed in Section 1.2.

The time frame for data collection referenced in both objectives is fishing year, which is defined as the 12 months between 1 October in any year and 30 September of the following year. Aerial sightings summaries, however, are presented by calendar year. The seasonal appearance of jack mackerel in JMA 1, as it is summarised using aerial sightings data, shows a peak that straddles the boundary between fishing years. Plots by calendar year provide a better illustration of monthly variations through this time.

### 1.1 Overview

This report updates recent estimates of the relative proportions of the three *Trachurus* species in the commercial catch summarised by Taylor (1999a). The proportions are based on market sampling data in JMA 1, 3, and 7, scientific observer data in JMA 3 and 7, and trawl survey data in JMA 1, 3, and 7 (Fishstock boundaries are shown in Figure 1). A time series of changes in estimated species proportions based on scientific observer data is presented as a summary of the seasonal variability in species composition in the commercial catch in JMA 3 and 7. The seasonality of their occurrence at the surface in JMA 1 is summarised from the aerial sightings data.

This work was completed under the Ministry of Fisheries Research Project JMA9801, "Stock Assessment of Jack Mackerel". Specific objectives were as follows.

1. To determine the seasonality and species composition of *Trachurus declivis*, *T. murphyi*, and *T. novaezelandiae* in the commercial catch in JMA 1, 3, and 7 from samples taken in fish sheds during the 1998/99 fishing year.

2. To determine the seasonality and species composition of *Trachurus declivis*, *T. murphyi*, and *T. novaezelandiae* in the commercial catch in JMA 1, 3, and 7 from data collected at sea by Scientific Observers and other sources during the 1997/98 fishing year.

The scope of this report goes beyond presenting the results of work completed under project JMA9801 only. Summaries of results by Taylor (1999a) are presented, and are updated with the estimates for 1997–98 and 1998–99 as defined in the objectives for JMA9801.

## 1.2 Distribution of jack mackerel

According to Annala *et al.* (2000), the three species have different geographical distributions, with some overlap in their ranges: *T. novaezelandiae* predominates in waters shallower than 150 m and warmer than 13 °C, and is uncommon south of latitude 42 °S; *T. declivis* generally occurs north of 45 °S in deeper waters than *T. novaezelandiae*, but shallower than 300 m and in temperatures less than 16 °C; and *T. s. murphyi* occurs to depths of least 500 m over a wide latitudinal range (e.g., from 0 ° to 50 °S off South America).

Until recently, only *T. declivis* and *T. novaezelandiae* were known from New Zealand waters (Jones 1990). The Chilean jack mackerel, *T. s. murphyi*, was first described here by Kawhara *et al.* (1988), and has become abundant only since the late 1980s. It appears to have become established off the south and east coasts of the South Island onto the Chatham Rise in the mid 1980s, expanded to the west coast of the South Island and the North and South Taranaki Bights by the late 1980s, reached the Bay of Plenty in appreciable quantities by 1992, and had become common on the east coast of Northland by June 1994 (Taylor 1999b). The total range of *T. s. murphyi* now extends along the entire west coast of South America, across the South Pacific, through much of the New Zealand EEZ, and into waters off southeast Australia.

The three jack mackerel species can all be caught by bottom trawl, midwater trawl, and by purse-seine targeting surface schools. Their vertical and horizontal movements are poorly understood, but they are presumed to generally be off the bottom at night, and surface schools can be common during the day.

## 1.3 Literature review

Relative proportions of the jack mackerel species were estimated by Horn (1991) for adjusting the aggregated catch history in JMA 7. Taylor (1998) used species proportions estimated from market sampling data collected from the JMA 1 purse-seine fleet between 1994 and 1996 to produce catch histories for the three species for use in a stock reduction model. Taylor (1999c) used the species proportions presented by Taylor (1999a) for JMA 7 to investigate the feasibility of developing CPUE stock indices and age-related stock assessment models. Taylor (1999b) used existing data to investigate the stock structure of *T. s. murphyi* in the South Pacific Ocean and examine the degree to which its population has become established in New Zealand waters.

# 2. METHODS

## 2.1 Species composition in JMA 1, 3, and 7 from market sampling

The sampling method used for purse-seine landings in JMA 1 was developed during sampling of jack mackerel landings at Sanford Limited, Tauranga, between 1994 and 1996, and the procedure was summarised by Taylor (1998). It was used by Taylor (1999a) for sampling Tauranga landings, but could not be applied in Nelson where jack mackerel are not graded.

Obtaining representative samples of jack mackerel purse-seine landings is hampered by the way that skippers often split their catch between holds to maintain balance of the vessel at sea. Given that inter-school variability in fish size and species composition may often be high, sampling should include all landed schools to ensure that all sources of variability are included in the data. Defining a strategy to ensure precise sampling from all schools is difficult, however, because of mixing that occurs in the hold during unloading.

Sampling by grade provides a set of sampling strata that are reasonably homogeneous with respect to fish size and species composition. For example, at the Sanford factory in Tauranga, jack mackerel grades are based on weight class (200–400 g, 400–600 g, 600 g–1 kg, over 1 kg), and generally the species composition of each is consistent, although there are some variations. As a rule of thumb, the lower grades are usually *T. novaezelandiae*, 600 g–1 kg fish are mostly *T. declivis*, and the largest fish are *T. s. murphyi*, with overlap between the grades and the occasional appearance of juvenile *T. declivis* in the smallest size classes (Taylor 1998). Each sampled landing is characterised by its grade weights, which are available from the weighbridge operator.

The stratification provided by the grading allows more precise estimates than can be derived from the ungraded catch. Mean species proportions for each grade, estimated using data from all sampled landings, can be applied to the annual total tonnage for each grade.

A further requirement is to determine the number of sampled landings required to produce estimates of species proportions with an acceptably low level of variability. This variability between landings was examined by estimating species proportions and coefficients of variation (*c.v.s*) for the 14 landings sampled by Taylor (1998) in Tauranga between 1994 and 1997 using the proportions and variance estimators defined in Case 1 of Appendix 1:

| | *T. declivis* | *T. s. murphyi* | *T. novaezelandiae* |
|---|---|---|---|
| Proportions | 0.17 | 0.31 | 0.52 |
| *c.v.* | 0.28 | 0.48 | 0.31 |

Considering a preferred target *c.v.* of about 0.10 (D. Gilbert, NIWA, pers. comm.) these values are very high. Simulated values for 20 sampled landings were 0.22, 0.38, and 0.25 for the three species respectively, which are also high at more than twice the target *c.v.* Given that 20 landings represent about 40% of the total landings between 1994 and 1997, it is clear that sampling a high proportion of landings will be required to reach the target *c.v.* in any one year.

### 2.1.1 Sampling at Sanford Ltd, Tauranga (JMA 1)

All 1998–99 landings were sampled. About 300 graded fish were selected at random from the top of up to about a dozen "alloys" (containers of about 300 kg capacity). Fish so selected are referred to as a sample.

Because the selection of fish from the "alloys" was random, no bias arises from this approach. The sample size varied somewhat, depending on the grade being sampled, the apparent proportions of the species in the landing, or the sample itself (e.g., a larger sample would be taken where a species was poorly represented), or the availability of fish in a grade (certain grades were poorly represented in some landings).

Once selected, the sample was sorted by species. These species samples were then weighed at the weighbridge, counted to determine the number of fish in each, and the data recorded. Species were distinguished according to known external features (Stephenson & Robertson 1977, Paulin *et al.* 1989).

Because all landings were sampled and all grades present in a landing were represented, the analysis was simpler than that followed by Taylor (1998). A series of equations (Case 2 of Appendix 1) was used to estimate the species composition of all landings in a year, based on the following steps:

1. Estimate grade proportions and weight of species l in the sampled landings (k).
1. Estimate total weight of each species in the grades of all landings.
2. Estimate proportions of *Trachurus* species in the annual landings.

### 2.1.2 Sampling at Sanford Ltd, Nelson (JMA 3 and 7)

The purse-seine catch was not graded at the Nelson factory. To ensure estimates as closely representative of the landing as possible within the logistical constraints of the project, all holds containing jack mackerel were sampled. A sample of about 800 kg of ungraded jack mackerel was taken from each hold. The sample weight was recorded and the sample sorted into species. The weights of these species samples were recorded. A series of equations (Appendix 2) was used to estimate the species proportions in the catch.

## 2.2 Species composition and seasonality from observer data (JMA 3 and 7)

Observers collect data on species composition, sample weight, and otoliths from the JMA 3 and 7 fisheries (*see* Figure 1). There has been no observer coverage in the JMA 1 fishery, which is almost exclusively purse-seine apart from a small bycatch taken by inshore trawlers. The sampling programme is documented in the Biological Data Collection Manual of the MFish Observer Programme.

Data were extracted from the Ministry of Fisheries observer database to provide estimates of monthly species proportions from September 1986 to April 1999 in JMA 3, and September 1986 to October 1999 in JMA 7. The method used was as follows.

1. Species composition data and total catch by tow were extracted from the database.
2. Species proportions were estimated by weight and number for each tow.
3. Species tow proportions were scaled to the tow tonnage.
4. Means of the species tow weights for each trip were estimated.
5. These species trip estimates were scaled to the trip tonnage.
6. The species estimates were summed for all landings and proportions of the species in the catch were estimated for a given time frame.

Annual species proportions were also estimated, using the method described in Appendix 3.

### 2.2.1 Seasonality from aerial sightings data (JMA 1, east Northland and Bay of Plenty)

The Ministry of Fisheries aerial sightings database (*aer_sight*) contains information on the surface abundance of schooling pelagic fish species recorded by pilots assisting in the operation of purse-seine vessels. Pilots identify the species composition of schools from fish colour and swimming behaviour. They summarise species composition and tonnage, and record the data as aggregated sightings of all schools of a particular species observed at a certain time in a particular area.

For each half degree square, the number of sightings by year and month, and the total flying hours as a measure of search effort, were extracted from the aerial sightings database for all months from June 1976 to August 1999. The number of sightings for each month was normalised by dividing by the flying time estimated from the number of 15 minute periods in each half degree square. The normalised sightings were plotted as a time series by month since May 1976. The month of greatest availability of jack mackerel to the JMA 1 fishery in each year was defined as the month when the major peak occurred in the normalised sighting plot. This method differed from that of Taylor (1999a) who used the inverse of total flying time to normalise the indices, which accounts for some differences between the time series presented there and the earlier part of the time series produced here.

To examine the seasonality of *T. s. murphyi* and compare it with that of the two "New Zealand species" combined, a simpler approach was taken. The rationale discussed by Taylor (1999d) was followed, and flying time was not used to normalise the sightings. To produce long-term mean sightings, the mean number of sightings was estimated for each month over the appropriate time frame

(1977–98 for the New Zealand species, 1990–98 for *T. s. murphyi*; data for 1999 were incomplete at the time of the data extract), thus providing a time series of the mean number of sightings by month throughout the year.

To compare data from the most recent year (1998) with the long term mean sightings series, total monthly sightings of the "New Zealand species" and *T. s. murphyi* were plotted as annual time series. To provide a good spatial coverage, these plots were produced for JMA 1, and the two sub-areas where most sightings of jack mackerels are made, East Northland and the Bay of Plenty. No sightings records distinguishing *T. s. murphyi* were available for JMA 3 or JMA 7, and no seasonal plots have been produced for those areas.

Confidence intervals of ± 2 standard errors were estimated for each month. Sometimes sightings for a particular month were made in only one year so the standard error could not be calculated. These months do not have accompanying error bars.

### 2.3 Species composition from the trawl database (JMA 1, JMA 3, JMA 7)

Catch weights of each of the three *Trachurus* species were extracted from the trawl survey database and voyage reports for inshore trawl surveys by R.V. *Kaharoa*. The following trawl series were analysed: east coast North Island (ECNI) for all years between 1993 and 1996, inclusive; west coast South Island (WCSI) in 1992, 1994, 1995, and 1997; east coast South Island (ECSI) in all years between 1993 and 1999, inclusive, except 1995 when there was no survey. Proportions of the three species were estimated as the proportion of the total of their combined sample weights during the survey. Where some of the jack mackerel catch was recorded as species code JMA (jack mackerel) (e.g., ECSI in 1991 and 1992) the data were difficult to separate and species proportions were not estimated.

## 3. RESULTS

### 3.1 Species composition from market sampling (JMA 1, 3, and 7)

There were 50 jack mackerel purse-seine landings in JMA 1 in 1998–99. All were sampled and the data used in the analysis. There were 10 landings at the Nelson factory during 1998–99: one on 16 September 1998 (from JMA 1) and nine between 4 April and 1 June 1999 (from JMA 7). The nine from 1999 were used in the analysis. There were no landings from JMA 3.

Estimates of species proportions in JMA 1, 3, and 7 from market sampling data are summarised below for 1997–98 and 1998–99. "North" refers to the catch landed at Tauranga and "South" to the catch landed at Nelson. There were no landings from JMA 7 in 1997–98.

| Shed | Fishstock & fishing year | *T. declivis* | *T. s. murphyi* | *T. novaezelandiae* |
|---|---|---|---|---|
| North | JMA 1 (1997–98, 1998–99) | 0.23, 0.14 | 0.35, 0.29 | 0.42, 0.57 |
| South | JMA 3 (1997–98), JMA 7 (1998–99) | 0.29, 0.51 | 0.69, 0.49 | 0.02, < 0.01 |

The relative proportion of *T. s. murphyi* is higher in the south and represented more than twice the catch of *T. declivis* in 1997–98. This changed in 1998–99 with a relative increase in the southern proportion of *T. declivis*. Proportions of *T. novaezelandiae* are high in the north. In JMA 1 a relative increase in the proportion of *T. novaezelandiae* over *T. declivis* is evident from 1997–98 to 1998–99.

## 3.2. Species composition and seasonality from scientific observer data (JMA 3 and JMA 7)

Overall species proportions estimates in JMA 3 and 7 from scientific observer data for 1997–98 were:

| Fishstock | *T. declivis* | *T. s. murphyi* | *T. novaezelandiae* |
|---|---|---|---|
| JMA 3 | 0.01 | 0.99 | 0.00 |
| JMA 7 | 0.42 | 0.37 | 0.21 |

Species composition from JMA 3 for months when observer records are available are shown in Table 1. Since 1988 a predominance of *T. s. murphyi* is evident in most records, although there are two months in 1994 (March and April) when the percentage of *T. declivis* exceeded 70% with a corresponding drop in the proportion of *T. s. murphyi.* Between April 1995 and April 1998, *T. declivis* did not exceed 7% of the sample, although sample sizes for 1996–97 in JMA 3 were very small (mean = 4). In 1999 the proportion of *T. declivis* increased to about 15%. There have been no records of *T. novaezelandiae* since 1988.

Although data from JMA 3 are too patchy to provide information on seasonal variations in species composition, a high proportion of *T. s. murphyi* is evident in all seasons throughout most of the time series.

Species composition from JMA 7 for those months when observer records are available are shown in Table 2. Before September 1989, there are no records of *T. s. murphyi*, although this is unlikely to be a true representation of what occurred because misidentifications were probably frequent before this species became commonly known. From 1991, *T. s. murphyi* has regularly dominated the JMA 7 catch sometime between July and September each year although the number of tows is often low.

Patterns in *T. declivis* and *T. novaezelandiae* are difficult to summarise and there is no evidence for any seasonal or monthly structure in their data. However, there is evidence for an inverse relationship between the peaks and troughs of *T. novaezelandiae* with the other two species — before 1991 the relationship is with *T. declivis*, but since then it has occurred more often with *T. s. murphyi.*

## 3.3 Seasonality from aerial sightings data (JMA 1, East Northland and Bay of Plenty)

The time series plot of normalised numbers of sightings by month (Figure 2) shows that in most years a single peak of availability of to the JMA 1 fishery occurs in late winter–spring (August–November), but in 1987, 1990, 1997, and 1999 it occurred earlier. Multiple peaks are evident in some years.

In JMA 1 (Figure 3) sightings of the "New Zealand species" (*T. declivis* and *T. novaezelandiae*) increases from a minimum in January to a peak in September, and a return to the minimum in December. The *T. s. murphyi* series shows a pronounced contrast between the first and second halves of the year, with a very low level of sightings before June. The variability of *T. s. murphyi* is greater, probably as a result of fewer data points, with sightings recorded only since the early 1990s.

Sightings of the "New Zealand species" in JMA 1 during 1998 (*see* Figure 3) show a different pattern from the long-term mean, and sightings between January and August are low, with an unusually large peak in September. The 1998 series for *T s. murphyi* shows a major peak between September and November and another in January. There were zero sightings in all other months.

In East Northland (Figure 4), sightings of the "New Zealand species" are characterised by gradual rises and falls throughout the year and a maximum in September. The contrast between the first and second halves of the year seen in the overall plot of *T. s. murphyi* in JMA 1 is also evident in this area.

Sightings of the "New Zealand species" in East Northland during 1998 (*see* Figure 4) are also characterised by gradual rises and falls throughout the year. They are lower than the long-term mean series, as is the "total sightings" series for *T. s. murphyi*. The latter is consistent with the overall pattern in JMA 1, with sightings in January and from August to November (*see* Figure 3).

Patterns in the Bay of Plenty (Figure 5) are similar to the pattern in JMA 1 as a whole, in that sightings of the "New Zealand species" increase gradually from January to peak around September. There are generally more sightings of the "New Zealand species" than of *T. s. murphyi*, which increase from July to peak in November. The seasonal pattern of *T. s. murphyi* in the Bay of Plenty is similar to that in East Northland and JMA 1 (few sightings during the first half of the year), although the amplitude of peak sightings is lower.

Sightings of the "New Zealand species" in the Bay of Plenty during 1998 (*see* Figure 5) are mostly lower than for the long-term mean, apart from the peak in September which corresponds to that in JMA 1 (*see* Figure 3). There were no sightings of *T. s. murphyi* between February and August in 1997–98.

### 3.4 Species composition from the research trawl database (JMA 1, 3, and 7)

Percentages of the three jack mackerel species in the total jack mackerel catch are shown in Table 3 for surveys in some *Kaharoa* inshore trawl survey series. Percentages were estimated for surveys from the east coast North Island, west coast South Island, and east coast South Island series.

The east coast North Island surveys were carried out in JMA 1 between Cape Runaway and Turakirae Head, except for some trawls in Palliser Bay (JMA 1) and between Port Robertson and Clarence Point (JMA 7) in the first survey of 1993 (Stevenson & Hanchet 2000a). The east coast South Island surveys were carried out in JMA 3 from Waiau River to Shag Point (Stevenson & Beentjes 1999), and the west coast South Island surveys in JMA 7 from Golden and Tasman Bays to Haast (Stevenson & Hanchet 2000b).

Trawl surveys on the east coast North Island indicate a predominance of *T. novaezelandiae* from 1993 to 1995 with a percentage ranging between 69.5 and 74.6%. In 1996, the last year of the survey, this dropped to 33.2%, with relative increases in both *T. declivis* and *T. s. murphyi*.

Data from west coast South Island trawl surveys show similar proportions (from 23 to 30%) of *T. declivis* for all years, except for 1995 when it declined to 14%. A high proportion of *T. novaezelandiae* in 1992 (48%) was followed by a declining trend to 6% in 1995, with a major increase to 64% for the final year. The inverse of this trend is evident for the proportions of *T. s. murphyi*, although it is not a case of simple replacement of one with the other.

The east coast South Island data show an increasing trend in *T. s. murphyi*, from 43% in 1993 to a maximum of 99% in 1998. Declining trends are evident for both *T. declivis* and *T. novaezelandiae*. This result is potentially invalidated by a change in the timing of this survey, resulting in the data comprising three years of winter surveys (1993, 1994, 1996), and three of summer surveys (1997, 1998, 1999). Nevertheless, high proportions of *T. s. murphyi* are evident from these plots.

## 4. DISCUSSION

Summaries of aerial sightings in JMA 1 indicate the peak presence of jack mackerel during spring, and, in some years, in winter. Comparison of the "New Zealand species" with *T. s. murphyi*, suggests seasonal similarities between the two groups in JMA 1 as a whole, but differences emerge when the Fishstock is broken down into sub-areas. The long-term mean suggests that in east Northland sightings of *T. s. murphyi* are greater than those of the "New Zealand species", but for the 1998 calendar year this is clear only in September. This apparent predominance of *T. s. murphyi* is probably the result of several years of high abundance however, and is unlikely to be consistent in the long term.

Market sampling data indicate changes in the species composition of both the northern (taken in JMA 1, landed at Tauranga) and southern (taken in JMA 3 and 7, landed at Nelson) purse-seine catches. In the north the 35% increase in the ratio of *T. novaezelandiae* between 1997–98 and 1998–99 is probably a result of changes in targeting from large to small fish; in the south the marked decline of about 20% in the proportion of *T. s. murphyi* between 1997–98 and 1998–99, with a corresponding increase in that of *T. declivis*, may be related to geographical changes in fishing activity, with a switch from JMA 3 to JMA 7 between the two years.

Results from scientific observer data indicating a high proportion of *T. s. murphyi* in JMA 3 since 1988 is reinforced by the trawl survey data for the ECSI in all years after 1993. The predominance of *T. novaezelandiae* in the ECNI trawl survey data in most years agrees with knowledge of its distribution, although there is no obvious explanation for its decrease in 1996. Its high proportion in the WCSI data is probably because these surveys include Golden and Tasman Bays and the area to Cape Foulwind, which are all north of 42° S and include extensive areas of shallow water. Annala *et al.* (2000) suggest that *T. novaezelandiae* is uncommon south of this latitude and that it is most common in waters shallower than 150 m. The absence of *T. novaezelandiae* in observer data from JMA 3 is understandable considering that coverage is of only deepwater trawlers in this Fishstock.

The high proportion of *T. s. murphyi* occurs in what is defined by Taylor (1999a, 1999c) as "the winter fishery", and is associated with cooler water. High proportions of *T. novaezelandiae* occur during the period of the "summer fishery", associated with warmer water. Peaks of high proportion of *T. declivis* occur during either the winter fishery (1991, 1992) or the summer fishery (1992, 1993).

## 5. IMPLICATIONS FOR STOCK ASSESSMENT

The continued estimation of species proportions from the catch is fundamental for stock assessments of these species. Results from the JMA 1 market sampling continue a series begun in 1994, and provide data that can be used in apportioning the total catch as catch histories for the three species.

Similarly, the results from JMA 3 and 7 can be used to provide catch histories, although there are complexities requiring the splitting of total catch between purse-seine and trawl landings. Furthermore, targeting can switch between Fishstocks from year to year, even though the actual geographical distance between areas where targeting occurs may not be great. Proportions from the inshore trawl survey in these areas could be used to apportion catch from inshore trawl vessels.

Scientific observer data suggest an almost exclusive predominance of *T. s. murphyi* in JMA 3, which simplifies the approach necessary for that area, assuming there are no major seasonal variations. JMA 7 is more complicated and it is unlikely that stock indices based on species proportions and catch data from only the large-vessel offshore trawling fleet can be indicative of the JMA 7 jack mackerel population. Current work under the Ministry of Fisheries project JMA1999/01 should provide species proportions for the small-vessel inshore trawling fleet in JMA 7, particularly in the South Taranaki Bight. Targeting in the JMA 7 large-vessel offshore trawling fishery is complex and undergoes geographical changes through the season. Current work under the Ministry of Fisheries projects MOF1999/04E and MOF1999/04F will provide information to better understand these variations.

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**Table 1: Species proportions estimated from scientific observer data for the three *Trachurus* species in JMA 3, for years and months in which sampling data were available; n is the number of trawls in which the particular species was present (Source: Observer database)**

| | | *T. declivis* | | *T. s. murphyi* | | *T. novaezelandiae* | |
|---|---|---|---|---|---|---|---|
| Year | Month | Proportion | n | Proportion | n | Proportion | n |
| 1986 | 9 | 0 | 0 | 1 | 1 | 0 | 0 |
| 1987 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| 1987 | 3 | 0.77 | 3 | 0 | 0 | 0.23 | 1 |
| 1987 | 6 | 0.78 | 3 | 0 | 0 | 0.22 | 3 |
| 1988 | 1 | 0.19 | 2 | 0.79 | 1 | 0.02 | 1 |
| 1989 | 2 | 0 | 0 | 1 | 1 | 0 | 0 |
| 1989 | 11 | 0.3 | 2 | 0.7 | 2 | 0 | 0 |
| 1990 | 10 | 0 | 0 | 1 | 2 | 0 | 0 |
| 1991 | 2 | 0 | 0 | 1 | 1 | 0 | 0 |
| 1991 | 3 | 0 | 0 | 1 | 4 | 0 | 0 |
| 1991 | 10 | 0.01 | 2 | 0.99 | 6 | 0 | 0 |
| 1991 | 11 | 0 | 1 | 1 | 2 | 0 | 0 |
| 1992 | 1 | 0 | 0 | 1 | 1 | 0 | 0 |
| 1992 | 2 | 0 | 0 | 1 | 2 | 0 | 0 |
| 1992 | 3 | 0 | 0 | 1 | 2 | 0 | 0 |
| 1992 | 4 | 0 | 0 | 1 | 1 | 0 | 0 |
| 1993 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| 1993 | 2 | 0 | 0 | 1 | 40 | 0 | 0 |
| 1993 | 3 | 0 | 1 | 1 | 26 | 0 | 0 |
| 1993 | 4 | 0.19 | 16 | 0.8 | 51 | 0 | 1 |
| 1993 | 5 | 0 | 0 | 1 | 2 | 0 | 0 |
| 1993 | 11 | 0 | 0 | 1 | 2 | 0 | 0 |
| 1994 | 2 | 0 | 0 | 1 | 9 | 0 | 0 |
| 1994 | 3 | 0.84 | 2 | 0.16 | 16 | 0 | 0 |
| 1994 | 4 | 0.74 | 2 | 0.26 | 3 | 0 | 0 |
| 1994 | 5 | 0 | 1 | 1 | 6 | 0 | 0 |
| 1994 | 6 | 0 | 0 | 1 | 2 | 0 | 0 |
| 1995 | 2 | 0 | 0 | 1 | 7 | 0 | 0 |
| 1995 | 3 | 0 | 0 | 1 | 4 | 0 | 0 |
| 1995 | 4 | 0.07 | 1 | 0.93 | 3 | 0 | 0 |
| 1995 | 5 | 0.04 | 1 | 0.96 | 1 | 0 | 0 |
| 1995 | 12 | 0.03 | 7 | 0.97 | 8 | 0 | 0 |
| 1996 | 1 | 0.02 | 17 | 0.98 | 22 | 0 | 0 |
| 1996 | 2 | 0 | 0 | 1 | 6 | 0 | 0 |
| 1996 | 3 | 0.01 | 6 | 0.99 | 15 | 0 | 0 |
| 1996 | 4 | 0.01 | 19 | 0.99 | 49 | 0 | 0 |
| 1996 | 5 | 0 | 0 | 1 | 2 | 0 | 0 |
| 1997 | 1 | 0 | 0 | 1 | 1 | 0 | 0 |
| 1997 | 2 | 0 | 0 | 1 | 3 | 0 | 0 |
| 1997 | 3 | 0 | 0 | 1 | 4 | 0 | 0 |
| 1997 | 4 | 0 | 0 | 1 | 5 | 0 | 0 |
| 1997 | 5 | 0.01 | 1 | 0.99 | 2 | 0 | 0 |
| 1997 | 12 | 0.02 | 10 | 0.98 | 15 | 0 | 0 |
| 1998 | 1 | 0.03 | 16 | 0.97 | 20 | 0 | 0 |
| 1998 | 2 | 0 | 0 | 1 | 17 | 0 | 0 |
| 1998 | 3 | 0.01 | 2 | 0.99 | 4 | 0 | 0 |
| 1998 | 4 | 0.04 | 3 | 0.96 | 4 | 0 | 0 |
| 1999 | 2 | 0.15 | 4 | 0.85 | 14 | 0 | 0 |
| 1999 | 3 | 0.15 | 16 | 0.85 | 17 | 0 | 0 |
| 1999 | 4 | 0.16 | 9 | 0.84 | 17 | 0 | 0 |

**Table 2: Species proportions estimated from scientific observer data for the three *Trachurus* species in JMA 7, for years and months in which sampling data were available; n is the number of trawls in which the particular species was present (Source: Observer database)**

| | | *T. declivis* | | *T. s. murphyi* | | *T. novaezelandiae* | |
|---|---|---|---|---|---|---|---|
| Year | Month | Proportion | n | Proportion | n | Proportion | n |
| 1986 | 9 | 0.68 | 3 | 0 | 0 | 0.32 | 3 |
| 1986 | 11 | 0.65 | 49 | 0 | 0 | 0.35 | 48 |
| 1986 | 12 | 0.57 | 92 | 0 | 0 | 0.43 | 84 |
| 1987 | 1 | 0.54 | 32 | 0 | 0 | 0.46 | 27 |
| 1987 | 4 | 0.08 | 1 | 0 | 0 | 0.92 | 1 |
| 1987 | 5 | 0.31 | 12 | 0 | 0 | 0.69 | 10 |
| 1987 | 11 | 0.99 | 1 | 0 | 0 | 0.01 | 1 |
| 1988 | 1 | 0.52 | 6 | 0 | 0 | 0.48 | 4 |
| 1988 | 2 | 0.92 | 3 | 0 | 0 | 0.08 | 1 |
| 1988 | 3 | 0.32 | 3 | 0 | 0 | 0.68 | 3 |
| 1988 | 12 | 0.53 | 18 | 0 | 0 | 0.47 | 15 |
| 1989 | 8 | 0.97 | 3 | 0.03 | 2 | 0 | 0 |
| 1989 | 9 | 0.74 | 7 | 0.18 | 3 | 0.08 | 2 |
| 1989 | 10 | 0.48 | 13 | 0.2 | 4 | 0.32 | 9 |
| 1989 | 11 | 0.47 | 66 | 0 | 7 | 0.52 | 47 |
| 1989 | 12 | 0.13 | 2 | 0 | 0 | 0.87 | 2 |
| 1990 | 3 | 0.03 | 5 | 0 | 0 | 0.97 | 16 |
| 1990 | 4 | 0.1 | 5 | 0 | 0 | 0.9 | 13 |
| 1990 | 6 | 0.68 | 1 | 0 | 0 | 0.32 | 1 |
| 1990 | 12 | 0.67 | 4 | 0 | 0 | 0.33 | 3 |
| 1991 | 2 | 0.57 | 9 | 0.01 | 2 | 0.43 | 6 |
| 1991 | 3 | 0.47 | 51 | 0 | 5 | 0.52 | 52 |
| 1991 | 4 | 0.3 | 89 | 0 | 2 | 0.7 | 89 |
| 1991 | 5 | 0.28 | 18 | 0 | 1 | 0.71 | 18 |
| 1991 | 7 | 0.66 | 3 | 0.34 | 3 | 0 | 0 |
| 1991 | 8 | 0.17 | 3 | 0.83 | 6 | 0 | 0 |
| 1991 | 9 | 0.48 | 13 | 0.39 | 9 | 0.13 | 4 |
| 1991 | 10 | 0.48 | 3 | 0.02 | 1 | 0.5 | 3 |
| 1991 | 11 | 0.51 | 33 | 0.04 | 24 | 0.45 | 28 |
| 1991 | 12 | 0.4 | 16 | 0.04 | 8 | 0.56 | 16 |
| 1992 | 3 | 0.33 | 17 | 0.02 | 1 | 0.65 | 23 |
| 1992 | 5 | 0.86 | 8 | 0.07 | 2 | 0.07 | 1 |
| 1992 | 7 | 0.15 | 6 | 0.7 | 6 | 0.15 | 6 |
| 1992 | 8 | 0 | 0 | 1 | 2 | 0 | 0 |
| 1992 | 9 | 0.48 | 5 | 0.52 | 3 | 0 | 0 |
| 1992 | 10 | 0.84 | 2 | 0.16 | 2 | 0 | 0 |
| 1992 | 12 | 0.67 | 51 | 0.11 | 42 | 0.22 | 45 |
| 1993 | 1 | 0.61 | 58 | 0.14 | 56 | 0.25 | 52 |
| 1993 | 2 | 0.5 | 47 | 0.21 | 47 | 0.3 | 47 |
| 1993 | 3 | 0.68 | 1 | 0.05 | 1 | 0.28 | 1 |
| 1993 | 6 | 0 | 0 | 1 | 1 | 0 | 0 |
| 1993 | 8 | 0 | 0 | 1 | 1 | 0 | 0 |
| 1993 | 10 | 0.18 | 2 | 0.16 | 2 | 0.65 | 7 |
| 1993 | 11 | 0.64 | 25 | 0 | 0 | 0.36 | 18 |
| 1993 | 12 | 0.69 | 11 | 0.05 | 1 | 0.27 | 5 |
| 1994 | 1 | 0.54 | 20 | 0.07 | 14 | 0.39 | 17 |
| 1994 | 2 | 0.32 | 24 | 0.26 | 24 | 0.42 | 24 |
| 1994 | 5 | 0.33 | 17 | 0.24 | 13 | 0.43 | 15 |
| 1994 | 6 | 0 | 29 | 0 | 28 | 0 | 18 |

Table 2 — *Continued*

| | | *T. declivis* | | *T. s. murphyi* | | *T. novaezelandiae* | |
|---|---|---|---|---|---|---|---|
| Year | Month | Proportion | n | Proportion | n | Proportion | n |
| 1994 | 7 | 0.08 | 14 | 0.92 | 20 | 0 | 0 |
| 1994 | 8 | 0 | 0 | 1 | 4 | 0 | 0 |
| 1994 | 9 | 0.65 | 4 | 0.35 | 3 | 0 | 0 |
| 1994 | 12 | 0.32 | 18 | 0.36 | 16 | 0.33 | 13 |
| 1995 | 1 | 0.31 | 98 | 0.22 | 84 | 0.47 | 92 |
| 1995 | 3 | 0.29 | 23 | 0.5 | 26 | 0.21 | 24 |
| 1995 | 7 | 0.06 | 1 | 0.94 | 1 | 0 | 0 |
| 1996 | 2 | 0.39 | 27 | 0.22 | 17 | 0.39 | 25 |
| 1996 | 3 | 0.56 | 31 | 0.21 | 19 | 0.23 | 24 |
| 1996 | 6 | 0 | 0 | 1 | 1 | 0 | 0 |
| 1996 | 8 | 0.05 | 3 | 0.95 | 4 | 0 | 0 |
| 1996 | 12 | 0.66 | 8 | 0.07 | 8 | 0.27 | 8 |
| 1997 | 1 | 0.59 | 53 | 0.07 | 49 | 0.34 | 53 |
| 1997 | 2 | 0.64 | 36 | 0.06 | 31 | 0.3 | 35 |
| 1997 | 3 | 0.51 | 6 | 0.22 | 6 | 0.26 | 6 |
| 1997 | 6 | 0.53 | 9 | 0.47 | 9 | 0 | 0 |
| 1997 | 7 | 0.09 | 1 | 0.91 | 2 | 0 | 0 |
| 1997 | 8 | 0.1 | 3 | 0.9 | 3 | 0 | 0 |
| 1997 | 9 | 0.08 | 12 | 0.92 | 15 | 0 | 0 |
| 1997 | 11 | 0.44 | 45 | 0.19 | 45 | 0.37 | 43 |
| 1997 | 12 | 0.38 | 40 | 0.12 | 36 | 0.5 | 40 |
| 1998 | 1 | 0.61 | 65 | 0.09 | 54 | 0.3 | 64 |
| 1998 | 2 | 0.52 | 18 | 0.04 | 13 | 0.44 | 18 |
| 1998 | 7 | 0.17 | 1 | 0.83 | 5 | 0 | 0 |
| 1998 | 12 | 0.44 | 13 | 0.15 | 13 | 0.41 | 13 |
| 1999 | 1 | 0.46 | 19 | 0.12 | 18 | 0.42 | 19 |
| 1999 | 4 | 0.87 | 11 | 0 | 0 | 0.13 | 5 |
| 1999 | 6 | 0.98 | 48 | 0.02 | 17 | 0 | 0 |
| 1999 | 7 | 0.79 | 23 | 0.21 | 15 | 0 | 0 |
| 1999 | 8 | 0 | 0 | 1 | 1 | 0 | 0 |
| 1999 | 9 | 0.41 | 7 | 0.26 | 3 | 0.33 | 3 |
| 1999 | 10 | 0.78 | 42 | 0.14 | 32 | 0.08 | 20 |

**Table 3: Percentages of jack mackerel (*Trachurus*) species in the total jack mackerel catch (t) for individual surveys in some *Kaharoa* inshore trawl survey series; catch weights are in kg. (Source: Trawl survey database and voyage reports)**

| Year | All *Trachurus* spp Catch | T. declivis Catch | T. declivis % of total | T. s murphyi Catch | T. s murphyi % of total | T. novaezelandiae Catch | T. novaezelandiae % of total |
|---|---|---|---|---|---|---|---|
| East coast North Island | | | | | | | |
| 1993 | 944.5 | 99.5 | 10.5 | 188.2 | 19.9 | 656.8 | 69.5 |
| 1994 | 2 275.7 | 179.7 | 7.9 | 509.1 | 22.4 | 1586.9 | 69.7 |
| 1995 | 2 319.6 | 193.8 | 8.4 | 394.3 | 17.0 | 1731.5 | 74.6 |
| 1996 | 10 579.5 | 1 909.7 | 18.1 | 5 157.5 | 48.7 | 3 512.3 | 33.2 |
| West coast South Island | | | | | | | |
| 1992 | 1 053.2 | 242.7 | 23.0 | 307.7 | 29.2 | 502.8 | 47.7 |
| 1994 | 836.8 | 248.4 | 29.7 | 415.1 | 49.6 | 173.3 | 20.7 |
| 1995 | 1 697.3 | 238.7 | 14.1 | 1 359.8 | 80.1 | 98.8 | 5.8 |
| 1997 | 1 140.2 | 303.0 | 26.6 | 109.5 | 9.6 | 727.7 | 63.8 |
| East coast South Island | | | | | | | |
| 1993 | 817.3 | 404.2 | 49.5 | 355.0 | 43.4 | 58.1 | 7.1 |
| 1994 | 430.0 | 56.0 | 13.0 | 356.0 | 82.8 | 18.0 | 4.2 |
| 1996 | 2 966.8 | 303.1 | 10.2 | 2609.4 | 88.0 | 54.3 | 1.8 |
| 1997 | 227.8 | 26.7 | 11.7 | 199.9 | 87.8 | 1.2 | 0.5 |
| 1998 | 26.2 | 0.1 | 0.4 | 26.0 | 99.2 | 0.1 | 0.4 |
| 1999 | 339.7 | 27.9 | 8.2 | 311.3 | 91.64 | 0.5 | 0.1 |

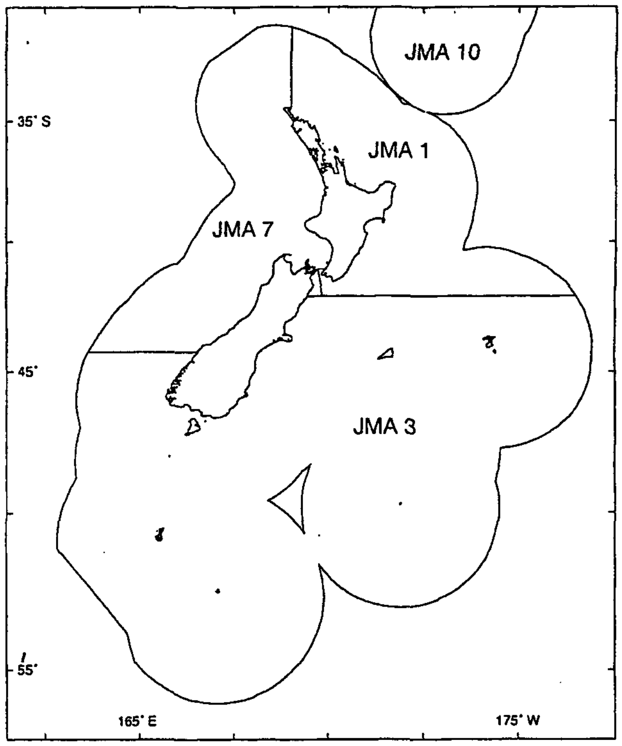


**Figure 1: Jack mackerel Fishstocks**

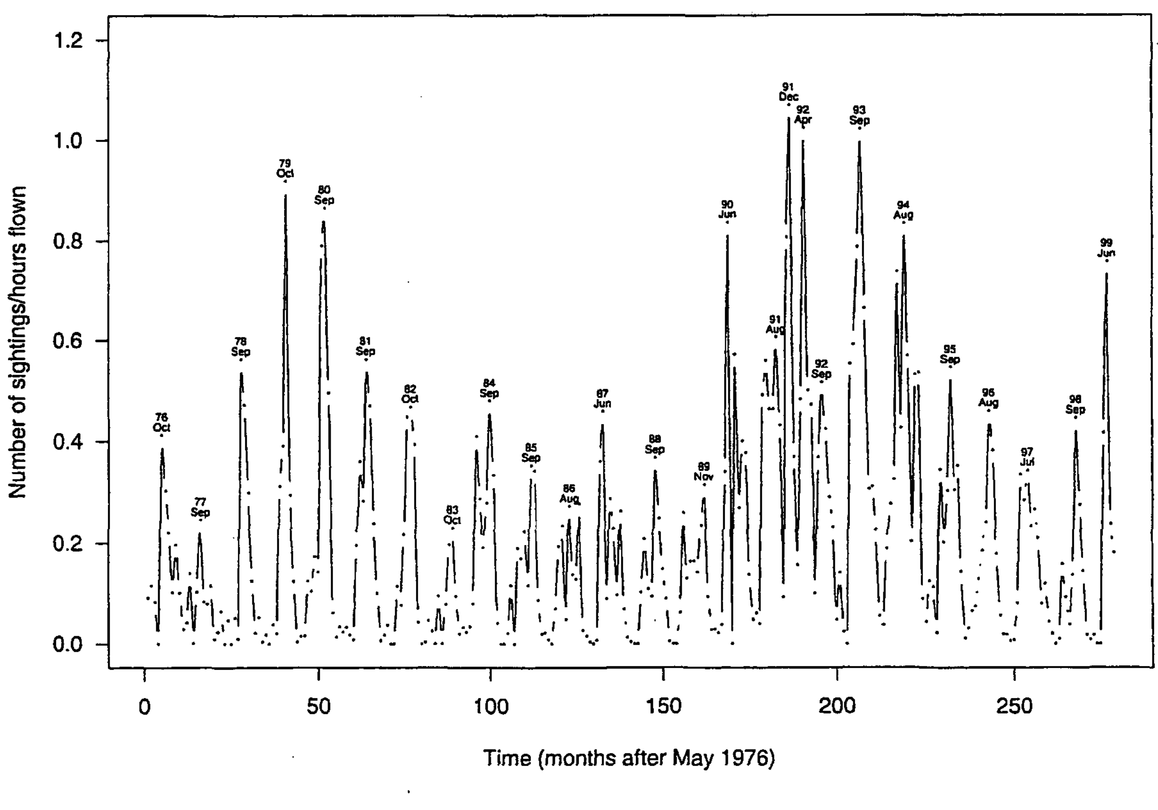


**Figure 2: Long-term summary of the seasonality of jack mackerel (all species combined) in JMA 1, from aerial sightings data.**

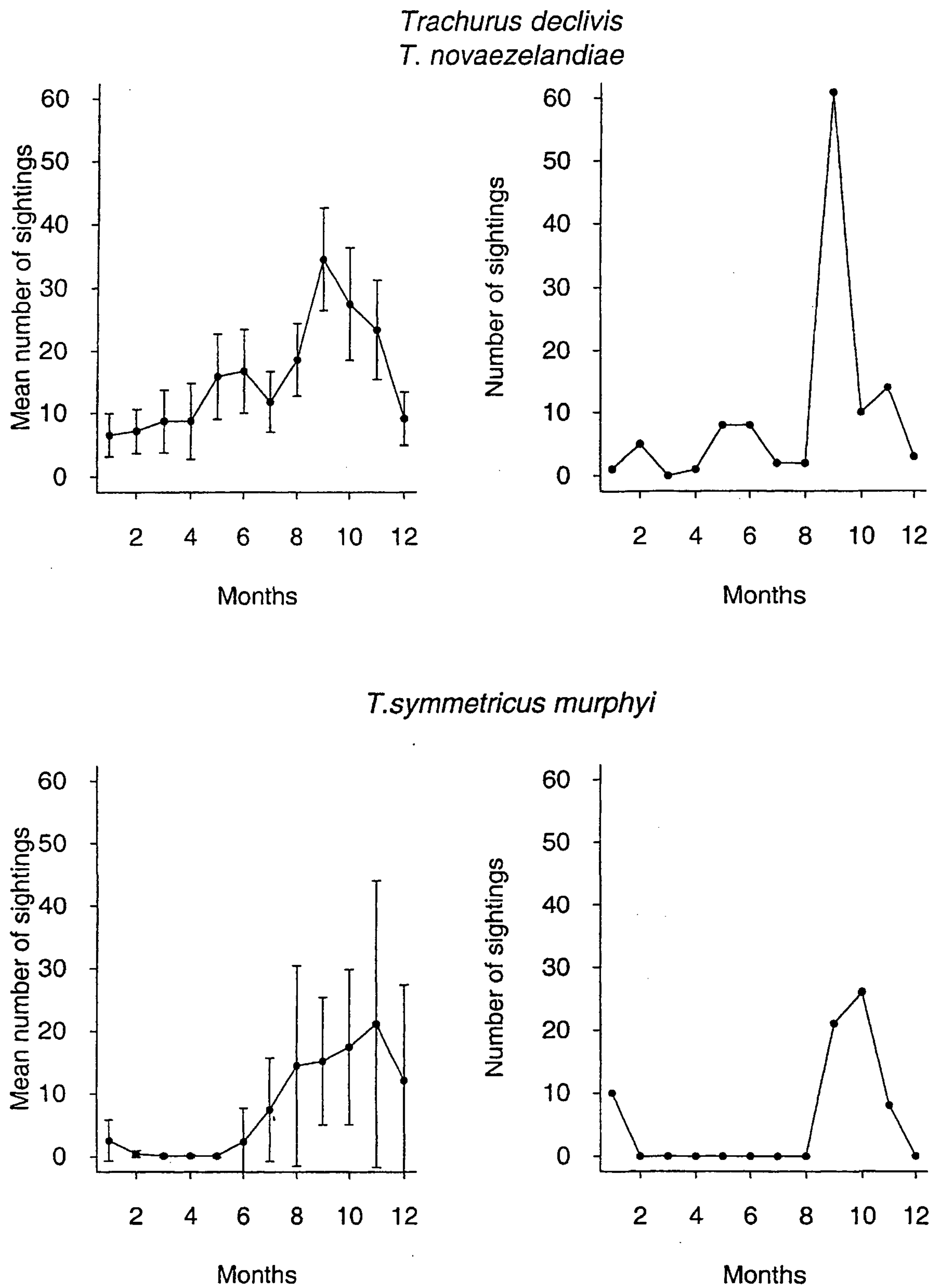


**Figure 3: Aerial sightings of jack mackerel in JMA 1. The left hand plots are of monthly means based on monthly totals from 1977 to 1998 for *T. declivis* and *T. novaezelandiae* and 1990 to 1998 for *T. s. murphyi*; the right hand plots show monthly totals for 1998. Confidence intervals are 2 standard errors.**

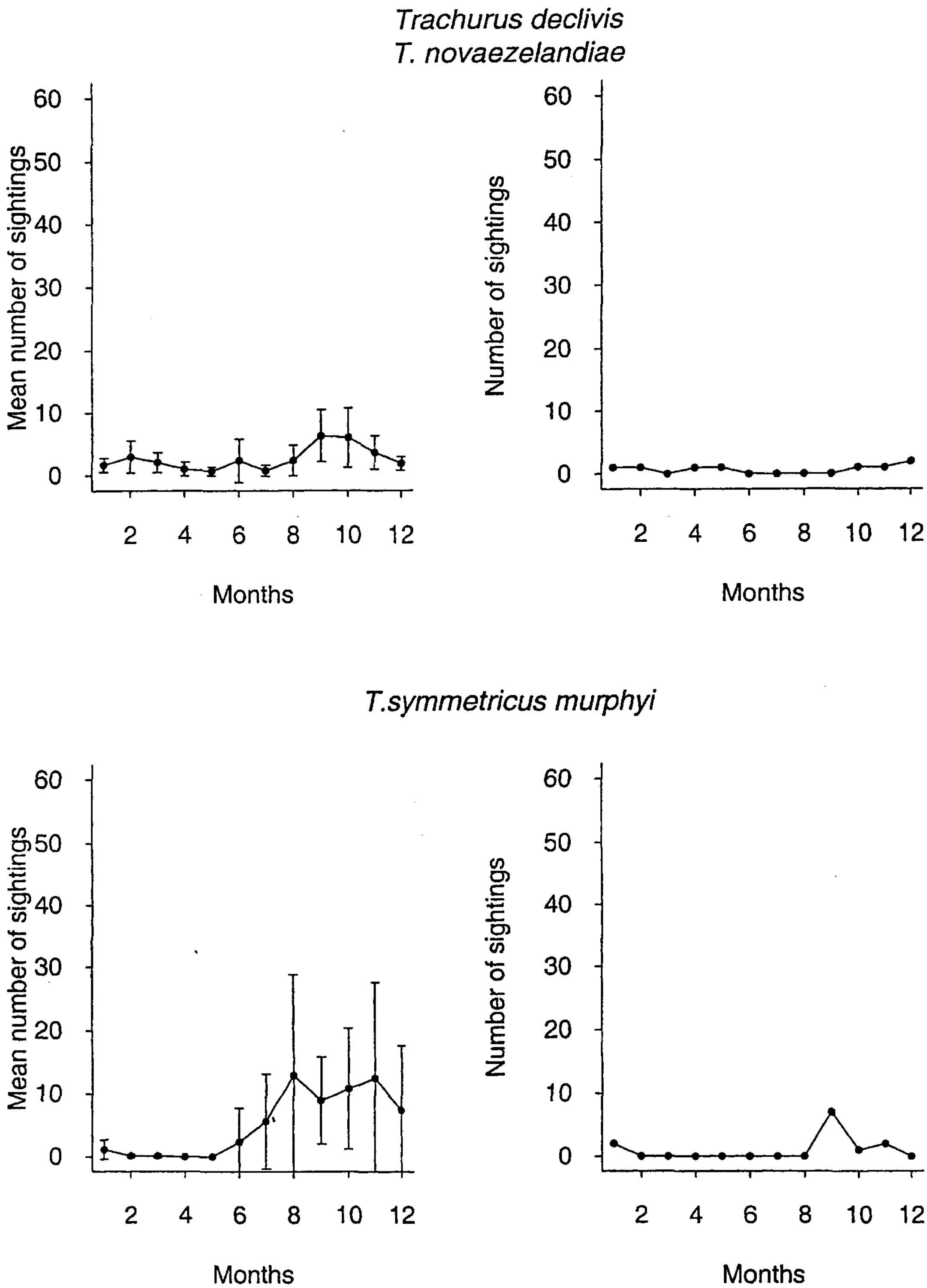


**Figure 4: Aerial sightings of jack mackerel in East Northland. The left hand plots are of monthly means based on monthly totals from 1977 to 1998 for *T. declivis* and *T. novaezelandiae* and 1990 to 1998 for *T. s. murphyi*; the right hand plots show monthly totals for 1998. Confidence intervals are 2 standard errors.**

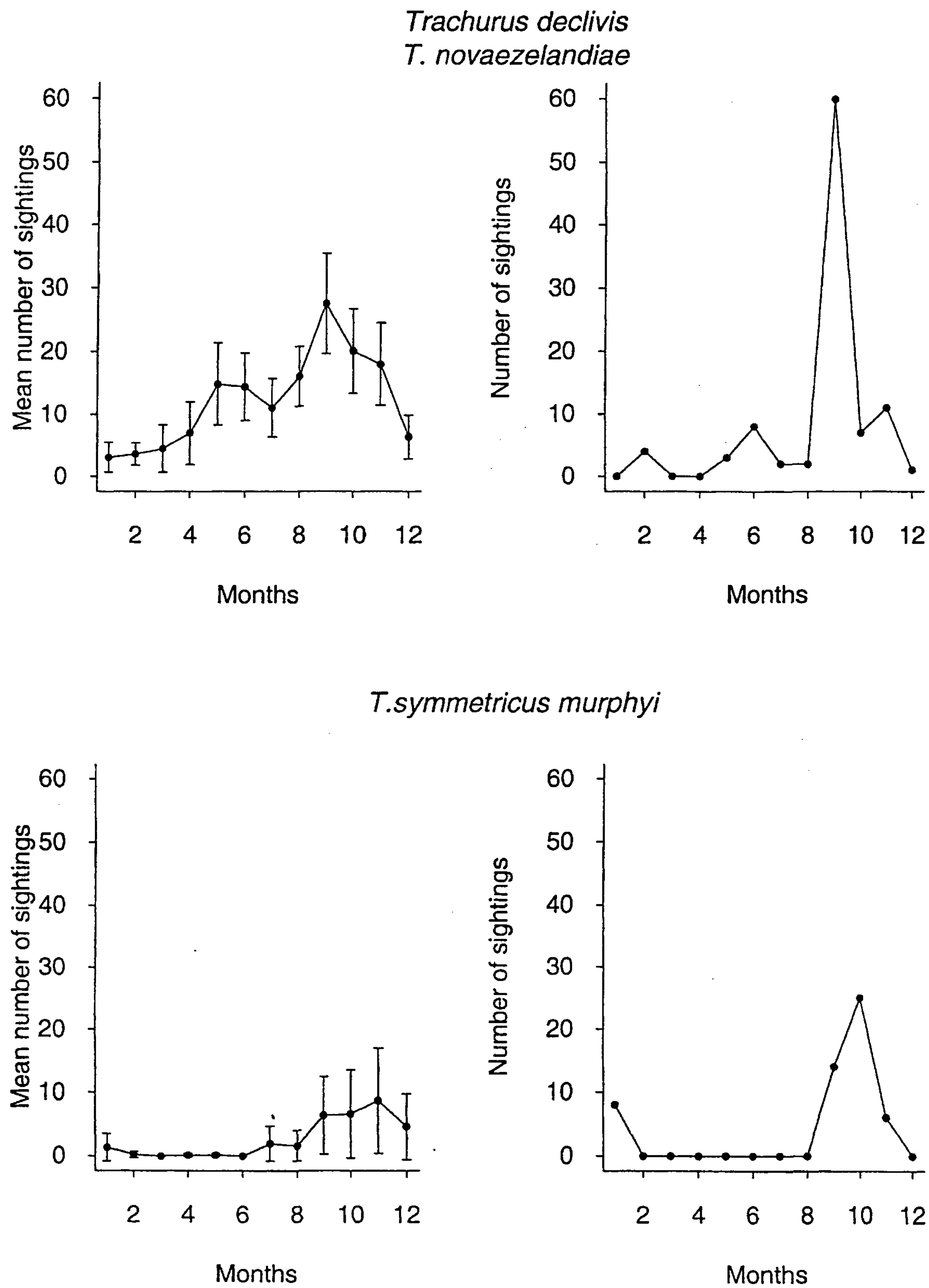


**Figure 5: Aerial sightings of jack mackerel in the Bay of Plenty. The left hand plots are of monthly means based on monthly totals from 1977 to 1998 for *T. declivis* and *T. novaezelandiae* and 1990 to 1998 for *T. s. murphyi*; the right hand plots show monthly totals for 1998. Confidence intervals are 2 standard errors.**

## Appendix 1: Estimating species composition (proportions of the three jack mackerels) of the total annual purse-seine catch of *Trachurus* species in JMA 1

### Definitions

$w_{jkl}$ is the weight of a sample of species $l$ in grade $j$ and sampled landing $k$

$W_{jk.}$ is the weight of grade $j$, in landing $k$

$W_{jkl}$ is the weight of species $l$ in grade $j$ and landing $k$

$p_{jkl}$ is the grade proportion of species $l$

### Case 1: Sampled landings are a subset of total landings in the fishery

### Step a: To estimate grade proportions and weight of a species in the sampled landings ($k$)

The proportion of species $l$ in grade $j$ and sampled landing $k$ was based on its weight in the sample

$$\hat{p}_{jkl} = \frac{w_{jkl}}{\sum_l w_{jkl}}$$

The proportion was applied to the total weight of grade $j$ in landing $k$ to determine its species composition by weight, using

$$W_{jkl} = \hat{p}_{jkl} \cdot W_{jk.}$$

An estimate of the weight of species $l$, in the sampled landing $k$ is given by $\sum_j W_{jkl}$. This measure is useful in summarising individual landings

### Step b: To estimate average species proportions in the grades of the sampled landings

The mean grade proportion of species $l$ was estimated for all of the sampled landings using the sum of the estimated weights in the sampled landings over the total of the grade weights in the sampled landings

$$\hat{p}_{j.l} = \frac{\sum_{sampled k} W_{jkl}}{\sum_{sampled k} W_{jk.}}$$

### Step c: To apply averages to grade totals of the annual catch

The mean species proportions were used to estimate the tonnage of species $l$ in grade $j$ of the $k$'th landing of all landings for the year (sampled and unsampled)

$$\hat{W}_{j.l} = \hat{p}_{j.l} \sum\nolimits_{k} W_{jk.}$$

### Step d: To estimate proportions of *Trachurus* species in the annual landings

The species were summed across each grade to get the totals for each species and these were divided by the grand total (of all species) to estimate the species proportions in the annual catch

$$\hat{P}_{..l} = \frac{\sum_{j} \hat{W}_{j.l}}{\sum_{jkl} W_{jkl}}$$

### Estimating variance

The estimated variance of the estimated proportions for catch over the period of interest is defined as

$$\hat{\mathrm{var}}(\hat{p}_{..l}) = \frac{\sum \hat{\mathrm{var}}(\hat{p}_{j.l}) \left( \sum_{k=1}^{k'} Wjk. \right)^2}{\left( \sum_{jkl} W_{jkl} \right)^2}$$

where $k'$ is all landings (sampled and unsampled), and the variance of the mean grade proportion of species $l$ is defined as

$$\hat{\mathrm{var}}(\hat{p}_{j.l}) = \left( \frac{1}{K} - \frac{1}{K'} \right) \frac{1}{K-1} \sum (\hat{p}_{jkl} - \hat{p}_{j.l})^2 \left[ \frac{KW_{jk.}}{\sum_{k=1}^{k} W_{jk.}} \right]^2$$

where $K$ is the number of sampled landings, and $K'$ is the total number of landings (Davies & Walsh 1995).

## Case 2: All landings in the fishery are sampled

### Step a: To estimate grade proportions and weight of a species in the sampled landings ($k$)

The proportion of species $l$ in grade $j$ and sampled landing $k$ was based on its weight in the sample

$$\hat{p}_{jkl} = \frac{w_{jkl}}{\sum_{l} w_{jkl}}$$

The proportion was applied to the total weight of grade $j$ in landing $k$ to determine its species composition by weight, using

$$W_{jkl} = \hat{p}_{jkl} \cdot W_{jk.}$$

An estimate of the weight of species $l$, in the sampled landing $k$ is given by $\sum_{j} W_{jkl}$ . This measure is useful in summarising individual landings

### Step b: To estimate total weight of species $l$ in grade $j$ of all landings

Because all landings are sampled, the total weight of species $l$ in grade $j$ for all sampled landings was estimated by summing weights by grade:

$$\hat{W}_{j.l} = \sum_{k} W_{jkl}$$

### Step c: To estimate proportions of *Trachurus* species in the annual landings

The species were summed across each grade to get the totals for each species and these were divided by the grand total (of all species) to estimate the species proportions in the annual catch

$$\hat{P}_{..l} = \frac{\sum_{j} \hat{W}_{j.l}}{\sum_{jkl} W_{jkl}}$$

## Appendix 2: Estimating species composition (proportions of the three jack mackerel species) of the total annual purse-seine catch of *Trachurus* species in JMA 3 and/or JMA 7

### Definitions

$w_{jk}$ is the weight of a sample of species *j* from hold *k*

$W_{k.}$ is the total weight of the sample (all species) from hold *k*

$\hat{p}_{jk}$ is the estimated proportion of species *j* in the sample from hold *k*

$\hat{P}_j$ is the estimated proportion of species *j* in the catch

### Estimating species proportions

The estimated proportion of species *j* in the sample from hold *k* is given by

$$\hat{p}_{jk} = {}^{w_{jk}}\!/_{W_k}$$

and the estimated proportion of species *j* in the catch is given as the mean of the estimated hold proportions of species *j*

$$\hat{P}_j = \frac{\sum_{k=1}^{n} \hat{p}_{jk}}{n}$$

where *n* is the overall number of holds sampled.

## Appendix 3: Estimating species proportions in the JMA 7 trawl fishery from observer data

### Definitions

$i$ denotes species

$j$ denotes tows

$k$ denotes trips

$S'_k$ is the set of all tows in trip $k$, sampled and unsampled

$S_k$ is the set of sampled tows

$w_{ijk}$ is the weight of a sample of species $i$ in sampled tow $j$ during trip $k$

$w'_{jk}$ is the total weight of jack mackerel (both species combined) in sampled tow $j$ during trip $k$

$w''_{jk}$ is the total weight of jack mackerel (both species combined) in the sample from sampled tow $j$ during trip $k$

### Estimating species proportions

The estimated proportion of species $i$ in sampled tow $j$ in trip $k$ is

$$\hat{p}_{ijk} = w_{ijk} / w''_{jk}$$

The estimated weight of species $i$ in trip $k$, is obtained by scaling up the total weight of catch

$$\hat{W}'''_{ik} = \sum_{j \in S_k} w'_{jk} \hat{p}_{ijk} \cdot \frac{\sum_{j \in S'_k} w'_{jk}}{\sum_{j \in S_k} w'_{jk}}$$

The estimated proportion of species $i$ in the total catch is obtained by summing over all trips

$$\hat{P}_i = \frac{\sum_k \hat{W}'''_{ik}}{\sum_i \sum_{j \in S'_k} w'_{jk}}.$$