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S. M. Hanchet
K. Field

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S. M. Hanchet[1]
K. Field[2]

[1]NIWA
PO Box 893
Nelson

[2]NIWA
PO Box 109 695
Newmarket
Auckland

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EXECUTIVE SUMMARY

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Tarakihi are one of the most important inshore commercial finfish species in New Zealand, with annual landings averaging over 5000 t for the past 30 years. Although a considerable amount of research has been carried out on the various fisheries and on its biology, there has been no modelling of the stocks to estimate long term biomass trends and yields. The current report stems from objective 2 carried out under contract to MFish "To review the current and historical data available for the tarakihi Fishstocks, and make recommendations on appropriate methods to monitor the status of the Fishstocks" in project TAR1999/01.

This review includes an evaluation of the usefulness of estimates of pre-recruit and recruited tarakihi biomass from *Kaharoa* trawl surveys carried out around the North and South Islands, CPUE indices, historical estimates of fishing and total mortality, and a review of biological parameters.

A number of information gaps will need to be addressed before a full stock assessment can be undertaken. These include the development of a catch history for all Fishstocks, a review of stock structure, and the calculation of biological parameters (e.g., length-weight parameters, growth parameters, maturity ogive) for each Fishstock. Otoliths should be read from the *Kaharoa* trawl surveys to determine proportion-at-age. Lastly, the size and age composition of the main fisheries should be determined through catch sampling, so that fishing selectivity ogives can be estimated for each Fishstock.

Recommendations on the monitoring of the Fishstocks take into account the size of the fishery, the usefulness of the abundance indices, and the biology of the species.

- In TAR 1W, tarakihi should be monitored using the west coast North Island trawl survey series. The survey proportions at age, together with updated CPUE indices, should provide the basis for an assessment of that stock once three or four surveys have been completed (in 3–5 years time).
- In TAR 1E, a CPUE index has been developed, but it is unknown whether this is adequately monitoring abundance. The timing of the first and future assessments will depend on the ability of the CPUE to monitor abundance and trends in the fishery.
- In TAR 2, a CPUE index has been developed. Reasonable agreement between the CPUE series and an earlier series of *Kaharoa* trawl surveys suggests this may be monitoring abundance. We recommend that a stock assessment be carried out in the near future using all available data.
- In TAR 3, pre-recruit and small adult fish (under 35 cm) should be monitored using the east coast South Island trawl survey series. We recommend the development of a method for monitoring adult abundance from north of Pegasus Bay to Cook Strait (areas 016–018). A stock assessment could be carried out using all available data once an adequate monitoring tool for adults has been developed.
- In TAR 7, tarakihi should be monitored using the west coast South Island trawl survey series. The trawl survey proportions at age, together with other existing data, would provide the basis for a stock assessment in the near future.

1. INTRODUCTION

Tarakihi is an important inshore commercial fish species caught in coastal waters off the North and South Islands, Stewart Island, and the Chatham Islands, down to depths of about 250 m (Annala et al. 2000). The major fishing grounds are west and east Northland (TAR 1), the western Bay of Plenty to Cape Kidnappers (TAR 1 and 2), Cook Strait (TAR 2), Cape Campbell to the Canterbury Bight (TAR 3), and Jackson Head to Cape Foulwind (TAR 7) (Figure 1). The main commercial fishing method is trawling, except near Kaikoura where the main method is set netting. The major target trawl fisheries occur at depths of 100 to 200 m. The fishery has been relatively stable since 1983–84 with total landings ranging between 4000 and 5500 t (Annala et al. 2000).

Considerable research has been carried out on tarakihi. Early studies validated age and growth (Tong & Vooren 1972). A review of the fishery and aspects of the biology and ecology of the species (including reproduction, early life history, movements, feeding) were reported by Annala (1987). Estimates of mortality and yield per recruit analyses were summarised by Annala et al. (1990). Little work has focused on the derivation of abundance indices for the tarakihi stocks. Inshore trawl surveys have often been too shallow for tarakihi or have been optimised for other species. Preliminary standardised CPUE analyses were carried out on TAR 1 and TAR 2 but they covered a short time period and were inconclusive (Starr 1995).

Although it is one of the main inshore commercial fisheries, no quantitative stock assessments have been carried out. The current estimates of yield are based on average catches and have not changed since 1989 (Annala et al. 2000). It is unknown whether current TACCs and recent catch levels will allow the stock to move towards a size that will support MSY. There is also a proposal by the Northern Inshore Fisheries Company Ltd to introduce TAR 1 into the Adaptive Management Programme.

Project TAR1999/01 was initiated by MFish, with two objectives. The first was to carry out a standardised CPUE analysis of TAR 1, 2, 3, and 7. This has recently been completed by Field & Hanchet (2001). The second objective was "To review the current and historical data available for the tarakihi Fishstocks, and make recommendations on appropriate methods to monitor the status of the Fishstocks", and is the subject of this report.

This review includes an evaluation of the usefulness of current CPUE indices (Field & Hanchet 2001); a compilation of estimates of pre-recruit and recruited tarakihi biomass from *Kaharoa* trawl surveys carried out around the North and South Islands; a re-evaluation of the estimates of fishing and total mortality calculated by Annala et al. (1990); and a review of biological parameters. Recommendations on the monitoring of the Fishstocks take into account the size of the fishery, the usefulness of the abundance indices and mortality estimates, and the biology of the species.

2. TARAKIHI FISHERY AND LANDINGS

2.1 Tarakihi landings

2.1.1 Commercial

Complete catch histories for the various tarakihi Fishstocks are not available. Domestic and foreign landings of tarakihi were given up to 1985 by Annala (1988). Domestic landings are given by fishing region for the period 1931 to 1985; these could be amalgamated by Fishstock or other management unit if needed. Landings by foreign licensed and New Zealand chartered vessels from 1970 to 1985–86 are incomplete, lacking data from Soviet vessels up to 1977–78, and use boundaries inconsistent with current Fishstocks (Annala 1988).

Given the available catch data and making some assumptions about the Soviet catches and main fishing grounds it should be possible to develop a complete catch history of tarakihi for each of the Fishstocks. This should include some estimates of underreporting and discards as for other inshore fisheries such as trevally and snapper (Annala et al. 2000). A summary of the commercial landings by Fishstock since 1983–84 is given in Table 1.

2.1.2 Recreational

Tarakihi are taken by recreational fishers using lines and set nets. The 1996 national diary survey of recreational fishers estimated the recreational catch in TAR 1 to be about 300 t, which represents about 20% of the total landings. Recreational catches in other tarakihi Fishstocks were 65 t in TAR 2 and 24 t in TAR 7. Estimates of recreational catch over the time period of the fishery need to be developed.

2.1.3 Maori customary fisheries

No quantitative information on the level of Maori customary fishing is available.

2.2 Tarakihi fishery

A description of the development of the main tarakihi fisheries around New Zealand has been given by several authors and were summarised by Annala (1987). A descriptive analysis of the current tarakihi fisheries in TAR 1, 2, 3, and 7 was given by Field & Hanchet (2001).

3. ABUNDANCE INDICES

Raw and standardised catch per unit effort (CPUE) analyses have been carried out for each area for the period 1989–90 to 1998–99 (Field & Hanchet 2001). The main features of the fisheries and the results of the analyses are summarised below.

Tarakihi biomass estimates from bottom trawl surveys from 1980 to 1985 were summarised by Hurst & Fenaughty (1985) and Annala (1988). As surveys were carried out using a variety of vessels at different times of year, they are not considered useful as abundance indices. More recent time series of trawl surveys carried out using *Kaharoa* are considered in detail below. The results of studies where proportion-at-age data have been collected are also considered in this section. Codend mesh sizes given in the text below are nominal mesh sizes only.

Generally, abundance indices derived from trawl survey or CPUE data relate to a particular stock. However, TAR 1 covers FMAs 1 and 9 and has been divided into TAR 1W and TAR 1E at Cape Reinga.

3.1 TAR 1W (west coast North Island)

3.1.1 Catch and CPUE indices

The annual catch of tarakihi in TAR 1W has increased from 150 t to over 300 t during the past 10 years (Field & Hanchet 2001). The main fishing method is bottom trawl, with most of the catch taken from tows targeted at tarakihi off the west Northland coast (particularly area 047 off Ninety Mile Beach and Cape Reinga). Smaller amounts are taken further south (areas 045 and 046) and in the target snapper and trevally trawl fisheries.

Despite the doubling of catch and effort over the past 10 years, raw CPUE showed a slight increase over the period. A standardised CPUE analysis was carried out using all data from the bottom trawl fishery (Field & Hanchet 2001). Target species was the most important variable. The standardised CPUE has increased by about 25% over the period (Table 2). A standardised index based on a subset of the data yielded very similar results (Table 2). Because of the targeted nature of the tarakihi fishery in this area (Field & Hanchet 2001.) considered that the index is probably monitoring abundance.

3.1.2 Trawl survey data

A series of spring surveys on the west coast North Island using *Kaharoa* (with a 40 mm codend) has been carried out since 1986, but the earlier surveys did not go deep enough to fully cover tarakihi depths (Morrison et al. 2001a). The two most recent surveys, in November 1996 and 1999 (Morrison 1998, Morrison & Parkinson 2001), were extended to 200 m depth to target tarakihi. Most tarakihi were 30–45 cm long: 170 otoliths were collected and read from the 1996 survey (Table 3). The peak of fish occurred at age 4–5, and the age composition was dominated by fish aged 3 to 10 (Morrison 1998). Despite the small mesh size, few small pre-recruits (under age 3) were caught, suggesting recruitment from elsewhere. Results of the 1996 and 1999 surveys suggest that this series will be useful for monitoring tarakihi abundance in FMA 9. It is recommended that tarakihi otoliths continue to be collected and read from each of the surveys.

3.1.3 Comparison of indices

Only two trawl surveys have been carried out deep enough to cover tarakihi depths, so the comparison is weak. There was a slight decline in both CPUE and trawl survey indices between 1996 and 1999.

3.2 TAR 1E (Cape Reinga to Bay of Plenty)

3.2.1 Catch and CPUE indices

The annual catch of tarakihi in TAR 1E has averaged about 1000 t over the past 10 years (Field & Hanchet 2001). The main fishing method is bottom trawl, and most of the catch is taken from tows targeted at tarakihi off east Northland (particularly area 002), and in the Bay of Plenty (areas 009 and 010). Smaller amounts are taken in the target snapper and gemfish trawl fisheries.

Raw CPUE showed a steady increase to 1993–94 and then a steady decline to 1998–99. A standardised CPUE analysis was carried using all data from the bottom trawl fishery (Field & Hanchet 2001). Target species was the most important variable, explaining over 30% of the variation in the model. Standardised CPUE dropped in 1990–91, but has since steadily increased to above the 1989–90 level (Table 4). A standardised index based on a subset of the data yielded very similar results (Table 4). Because of the targeted nature of the tarakihi fisheries in this area, Field & Hanchet (2001) considered that the index is probably monitoring abundance.

3.2.2 Trawl survey data

East Northland/Hauraki Gulf

A series of *Kaharoa* surveys (using a 40 mm codend) in the Hauraki Gulf and East Northland has been carried out since 1984, but the surveys have not extended deep enough to fully cover tarakihi depths.

Bay of Plenty

Since 1983, a series of summer *Kaharoa* surveys (using a 40 mm codend) in the Bay of Plenty (from Mercury Islands to Cape Runaway) has been carried out, but the early surveys did not go deep enough to fully cover tarakihi depths (Morrison et al. 2001b). The two most recent surveys, in February 1996 and 1999 (Morrison 1997, Morrison & Parkinson 2000), were extended to 250 m so that tarakihi depths would be covered. However, few tarakihi were caught during either survey, and estimated biomass was low (35–50 t) with high c.v.s (27–46%). The tarakihi were mainly 35–40 cm long. Otoliths were collected from both surveys but the fish have not been aged (see Table 3). Given the low biomass and high c.v.s it seems unlikely that this survey will be useful for monitoring tarakihi abundance in FMA 1 (Morrison et al. 2001b).

3.3 TAR 2 – Cape Runaway to Cook Strait

3.3.1 Catch and CPUE indices

The annual catch of tarakihi in TAR 2 has averaged about 1500 t over the past 10 years (see Table 1). The main fishing method is bottom trawl, and most of the catch is taken from tows targeted at tarakihi between East Cape and Cape Kidnappers (areas 011–013). Smaller amounts are taken further south and in several fisheries targeted at a variety of other species.

Raw CPUE has been reasonably stable; it declined slightly to a low in 1994–95, but has since recovered to the 1989–90 level. A standardised CPUE analysis was carried using all data from the bottom trawl fishery (Field & Hanchet 2001). Target species was again the most important variable, explaining over 25% of the variation. The standardised CPUE index has shown a similar trend to the raw CPUE with little overall change since 1989–90 (Table 5). A standardised index based on a subset of the data yielded very similar results (Table 5). Given the targeted nature of the tarakihi fishery in this area, Field & Hanchet (2001) considered that the index is probably monitoring abundance.

3.3.2 Trawl survey data

Surveys of the east coast North Island which targeted tarakihi were summarised by Vooren & Tong (1973) and Stevenson & Hanchet (2000b). In March 1971, a short exploratory survey of the East Cape fishing grounds was carried out using *James Cook* (Vooren & Tong 1973). Most of the fish were in spawning condition. No biomass estimates are available, but proportion at age data were collected (see below).

Between 1993 and 1996, a time series of four autumn *Kaharoa* trawl surveys (using a 100 mm codend) was carried out between Cape Runaway and Turakirae Head (Stevenson & Hanchet 2000b). Biomass indices fluctuated by a factor of 1.5 and c.v.s were moderate (15–30%) (Table 6). Highest catch rates and much of the biomass came from the area north of Tolaga Bay, adjacent to foul ground (Figure 2). Stevenson & Hanchet (2000b) considered that part of the annual fluctuation could have been caused by changes in the availability of the stock to the trawl survey between years.

The series caught few pre-recruit fish (Table 6). A paucity of juveniles on this section of coast was also noted by Vooren (1975). Fish were not aged, but the age structure of the population, inferred from the modes in the length frequency data, appeared stable over the course of the surveys (Figure 3). A sample of about 250–300 otoliths was collected from each survey, but has not been read (see Table 3).

3.3.3 Proportion-at-age data

Tarakihi from the March 1971 *James Cook* survey (Vooren & Tong 1973) were aged, and the data scaled by the trawl catches to derive a "population" estimate. The age composition was dominated mainly by 6 and 7 year old fish (60%), with about 10% of fish at ages 5, 8, and 9, and few fish (less than 10%) older than age 10. Vooren (1973) discussed two possible interpretations of the age composition data, and concluded that the stock had been moderately to heavily exploited during the 1960s.

3.3.4 Comparison of indices

Trends from the CPUE and trawl survey abundance indices were similar over the four years of overlap. The trawl survey indices from 1993 to 1996 were somewhat erratic, peaking in 1994 and again in 1996, and showed no trend through time. The CPUE indices were more stable and also showed no trend over the same time period.

3.4. TAR 3 – east coast South Island

3.4.1 Catch and CPUE indices

The annual catch of tarakihi in TAR 3 has averaged about 1000 t over the past 10 years (see Table 1). The main fishing method for tarakihi is bottom trawl, and most of the trawl catch is taken between Cape Campbell and Oamaru (areas 018–022). Only about 30% of the trawl catch is targeted, the remainder coming as bycatch from fisheries targeting red cod and barracouta. Smaller amounts are taken further south and in several fisheries targeted at a variety of other species. In addition to the trawl fishery, about 25% of TAR 3 is taken in a target set net fishery off Kaikoura.

Raw CPUE increased steadily in the bottom trawl fishery since 1989–90. Two standardised CPUE analyses were carried out (i) using all data from the bottom trawl fishery, and (ii) using just data from the target tarakihi trawl fishery. The standardised CPUE indices from all vessels, and from the vessel subset, both showed an increase to 1995–96 followed by a slight decline until the present (see Table 7). The standardised index based on the target tarakihi fishery was quite variable, again peaking in 1995–96, and dropping away more recently (Table 8). The indices based on the target "all species" fishery will depend to a large extent on the red cod fishery which varies considerably in size and location from year to year. The target tarakihi fishery indices were erratic, probably because they were based on a small dataset and covered a number of small fisheries along the large length of coast. For these reasons Field & Hanchet (2001) concluded that that the CPUE indices were probably not monitoring abundance and recommended that they be treated with caution.

The target tarakihi set net fishery is almost entirely confined to area 018 south of Kaikoura, and appears to be based on adult fish migrating to spawn as it takes place over two 6 week periods centred around January and May (Field & Hanchet 2001). The fishery has been very stable over the past 10 years, with similar numbers of vessels, mesh size, etc. Two standardised CPUE analyses were carried out using (i) all data from the set net fishery, and (ii) just data from the target tarakihi set net fishery. Vessel id, net length, and month were the most important variables in each analysis, explaining over 50% of the variation in CPUE. Both standardised CPUE's declined slightly through the mid 1990s, but have increased back to the 1989–90 levels (see Table 9). Because it was based on migrating fish, and the method was highly selective, Field & Hanchet (2001) were unsure how well the CPUE would monitor adult tarakihi abundance.

3.4.2 Trawl survey data

Trawl surveys have been carried out off the east coast South Island using *W.J. Scott* from 1978 to 1980 (Fenaughty & Bagley 1981), *James Cook* from 1980 to 1982 and in 1987 (Hurst & Fenaughty 1985, Annala et al. 1990), and *Kaharoa* since 1991 (Beentjes & Stevenson 2000, 2001).

Between August 1978 and October 1980, a systematic survey of the east coast between Cape Campbell and Nugget Point was carried out using *W.J. Scott* (with a 100 mm codend) covering depths of 55–366 m (Fenaughty & Bagley 1981). Spawning fish were found in January and February off Cape Campbell and the northern reaches of Pegasus Bay, including Conway Ridge. Trawling was not random but targeted on fish marks and so biomass was not estimated. Tarakihi were mainly 25–45 cm long north of Banks Peninsula, but under 35 cm long in the Canterbury Bight (Fenaughty & Bagley 1981).

Between March 1980 and December 1982, a series of nine systematic bottom trawl surveys was carried out in the Canterbury Bight using *James Cook* (with a 100 mm codend) covering depths of 20–450 m (Hurst & Fenaughty 1985). Biomass estimates were variable with high c.v.s (mostly over 50%) and showed no consistent seasonal pattern. No other details on tarakihi have been published.

In April 1987, an exploratory trawl survey specifically targeted at tarakihi was carried out using *James Cook* (with a 30 mm codend) between Cook Strait and Banks Peninsula (Annala et al. 1990). Spawning fish were located throughout the area. Fish ranged mainly from 20 to 45 cm, with a peak at 25–35 cm, and were mostly aged 2 to 7. Biomass was not estimated.

From 1991 to 1996, a series of five winter *Kaharoa* trawl surveys (using a 80 mm codend) was carried out between Pegasus Bay and Shag Point (Beentjes & Stevenson 2000). Total biomass estimates had moderate to high c.v.s (mainly 25–35%) and varied 4–fold during the series (Table 10). However, the high estimate from 1993 was the result of a single large catch in the Canterbury Bight (Figure 4) which led to a biomass estimate of 3000 t in a stratum which in other years had 300–400 t. Excluding this large catch, the biomass estimates were more consistent between years with no apparent trend. The size distribution shows that most tarakihi caught in the surveys were pre-recruits and small adults (under 30 cm) (Figure 5).

From 1997 to 2001 a series of four summer *Kaharoa* trawl surveys (using a 40 mm codend) was carried out from Pegasus Bay to Shag Point (Beentjes & Stevenson 2001). Total biomass estimates had low to moderate c.v.s (15–25%) and varied 2–fold during the series (Table 11). The size distribution shows that most tarakihi caught in the surveys were again pre-recruits and small adults (under 30 cm) (Figure 6). Although the summer series covered the same general area and depth range as the winter series, the biomass from each of the summer surveys was over double that from the winter surveys. This is even true for 1996 when the two surveys were carried out in the same year. This difference reflects a change in the seasonal availability of the fish.

Both summer and winter trawl surveys appear to be monitoring pre-recruits and small adults in Canterbury Bight/Pegasus Bay, although the c.v.s are slightly higher than desirable. With slight changes to the stratification and station allocation the surveys could easily be optimised for tarakihi. It is unclear how well the surveys are monitoring the younger age classes. No otoliths were collected during any of the surveys as tarakihi was not a target species (see Table 3), and it is difficult to identify appropriate length cut-offs for individual age classes beyond 1+ due to the merging of length frequency modes (Figure 6). It is recommended that otoliths are collected and read from future surveys.

3.4.3 Proportion-at-age data

Proportion-at-age data are available from several research trawl surveys, although non-standardisation of trawl gear, timing, and location make inter-survey comparison difficult. Samples collected from Pegasus Bay–Kaikoura in 1970 and 1971 were aged 5–10, with a peak at age 5 and 6 respectively in the two years (Vooren 1973). Samples collected between Cape Campbell and Pegasus Bay in 1978 were aged 5–10, with a peak at age 6 from Cape Campbell–Kaikoura and at age 5 from Pegasus Bay (Tong 1979). Samples collected between Cook Strait and Banks Peninsula in 1987 were aged 2–7, with a peak at age 4, but the distribution was highly skewed with a long tail out to age 42 (Annala et al. 1990).

3.4.4 Comparison of indices

It is difficult to compare the indices because they are monitoring different parts of the population. The commercial trawl CPUE indices are based on the entire east coast fishery, the set net fishery indices are highly selective and are based on large migrating adults, whilst the trawl survey indices are based on pre-recruits and small adults in Canterbury Bight–Pegasus Bay. Despite these differences, all the indices were either stable or had shown a slight increase since 1989–90.

3.5 TAR 7 – west coast South Island

3.5.1 Catch and CPUE indices

The annual catch of tarakihi in TAR 7 has averaged about 800 t over the past 10 years (see Table 1). The main fishing method for tarakihi is bottom trawl, and most of the trawl catch is taken between Cape Foulwind and Jacksons Bay (areas 033 and 034). Only about 30% of the trawl catch is targeted, the remainder coming as bycatch from fisheries targeting barracouta and jack mackerel. Smaller amounts are taken further north and east (including areas 017 and 018) and in fisheries targeting a variety of other species.

Raw CPUE in the bottom trawl fishery increased steadily until 1994–95, but fell sharply the following year and has since been stable. A standardised CPUE analysis was carried out using all data from the bottom trawl fishery (Field & Hanchet 2001). Vessel breadth and target species were the two most important variables in the analysis, together explaining over 25% of the variation. The standardised CPUE indices have increased steadily since 1989–90 (Table 12).

3.5.2 Trawl survey data

Trawl surveys have been carried out off the west coast South Island using *James Cook* in 1971, 1972, 1983, and 1984 (Vooren 1977, Hurst & Fenaughty 1985), *W.J. Scott* from 1981 to 1983 (Hurst & Fenaughty 1985), and *Kaharoa* from 1992 to 2000 (Stevenson & Hanchet 2000a). In 1971 and 1972, three depth zones were fished at 25–67 m, 72–146 m, and 270–360 m between Cape Foulwind and Jackson Head using *James Cook* (with a 40 mm codend) (Vooren 1977). Tarakihi were most abundant in the midshelf zone and catches there comprised 30–50 cm long fish. Biomass was not estimated.

Between June 1981 and April 1983, a systematic survey of the west coast between Cape Farewell and Hokitika Trench was carried out using *W.J. Scott* (with a 100 mm codend) covering depths of 20–652 m (Hurst & Fenaughty 1985). They calculated biomass estimates for six different time periods and found the lowest estimates were in February–April 1983. This coincides with the spawning season, and it is possible that part of the tarakihi stock had migrated south out of the survey area for spawning. No tarakihi catch details have been published.

During winter 1983 and 1984, two surveys were carried out on the west coast between Cape Farewell and Abut Head using *James Cook* (with a 100 mm codend) covering depths of 25–450 m (Hurst & Fenaughty 1985). The surveys were targeted at barracouta. Tarakihi biomass was estimated and presented, but no other tarakihi details have been published.

Between 1992 and 1997, a time series of four autumn *Kaharoa* trawl surveys (with a 80 mm codend) was carried out in Tasman Bay/Golden Bay and between Cape Farewell and Haast (Stevenson & Hanchet 2000a). Subsequently, a fifth survey was carried out in March-April 2000 (M.L. Stevenson, NIWA, Unpubl. results). Total tarakihi biomass estimates were consistent for the first three surveys but declined by about 30% for the last two surveys (Table 13). Coefficients of variation for total biomass estimates have been low (10–19%), but for pre-recruit age classes have been relatively high (11–82%). Small tarakihi were caught in Tasman Bay/Golden Bay (Figure 7a), and larger tarakihi were caught on the west coast (Figure 7b). Strong year classes could be tracked through the survey series and Stevenson & Hanchet (2000a) concluded that the series was monitoring tarakihi abundance.

Otoliths were collected during the last three *Kaharoa* surveys but have not been read (see Table 3).

3.5.3 Proportion-at-age data

Samples were collected from the west coast South Island using *James Cook* in March 1972 (Vooren 1977), and in October–November 1977 (Tong 1979). However, non-standardisation of trawl gear, timing, and location make inter-survey comparison difficult. The two age distributions are quite different. The peak of fish occurred at age 8–9 in 1972, and the age composition was dominated by fish aged mainly 7 to 16, but with some fish up to age 35. In 1977 the proportion of older fish (over 10 years) had halved and the age structure was dominated by ages 5–8.

3.5.4 Comparison of indices

Trends from the CPUE and trawl survey abundance indices were different over the period of overlap. Trawl survey indices were stable from 1992 to 1995 but dropped in 1997 and 2000. In contrast, CPUE indices gradually increased over the time period peaking in 1998–99. Field & Hanchet (2001) concluded that the CPUE indices were unreliable and were probably not monitoring abundance. This is because the CPUE index is based predominantly on a bycatch fishery (over 50% of tarakihi caught on the west coast is taken in the barracouta fishery), and so changes in the CPUE index may not necessarily reflect changes in tarakihi abundance. Furthermore, there was a reduction in the reporting of tarakihi as a target species in the forms, probably as a result of the bycatch trade system, which has had an unknown effect on the analysis. For example, in recent years CPUE values for tarakihi have been higher when tarakihi is taken as a bycatch than when it is targeted.

4. REVIEW OF STOCK STRUCTURE

On the basis of a long pelagic larval phase of 7–12 months, the large scale movements from tagging, and the lack of genetic isolation, Annala et al. (2000) considered that all tarakihi around North and South Islands should be considered as a single stock for stock assessment. They further noted that fish around the Chatham Island's should be treated as a separate stock. Whilst a review of stock structure is not specified within the objectives of this work, an understanding of the stock structure forms a vital part of any stock assessment. We therefore briefly review the literature and selected trawl survey which have relevance to stock structure.

4.1 Genetic data

Gauldie & Johnston (1980) compared allele frequencies from tarakihi collected all around New Zealand and showed that variation over the whole region was not significantly different from the yearly variation at Pegasus Bay. They concluded that slight differences between adjacent areas were more likely to constitute selective climes than genetically isolated stocks.

4.2 Spawning grounds

Tarakihi are serial spawners (Tong & Vooren 1972), with spawning occurring mainly between January and April, and in some areas extending into June (Annala 1987).

Annala (1987) identified three main spawning grounds for tarakihi: Fiordland–South Westland, Bay of Plenty–East Cape, and Conway Ridge–Pegasus Bay, and hypothesised a fourth at the Chatham Islands. The location of ripe, running ripe, and spent tarakihi from the research trawl database is shown in Figure 8a, and the timing of the spawning and monthly sampling in Figure 8b. The wide distribution of fish in spawning condition between Cape Foulwind and Haast on the west coast South Island and along the entire east coast North Island is surprising given the literature which suggests more localised spawning locations (Vooren 1975, Annala 1987). However, it is consistent with the widespread distribution of tarakihi eggs (Figure 9). The occurrence of spent tarakihi off the Chatham Islands supports the hypothesis of a separate spawning ground there. Ripe and running ripe fish were also caught in a number of areas off the west coast North Island, around Banks Peninsula, and off Southland (see Figure 8a). Other spawning areas around New Zealand have been reported in the literature west of Auckland and off Manawatu (Vooren 1975), off Motiti Island in the western Bay of Plenty (Tong & Vooren 1972), and off Cape Campbell (Fenaughty & Bagley 1981, Annala 1987).

4.3 Nursery grounds

Vooren (1975) considered the main nursery grounds occurred in Tasman Bay–Golden Bay, along the entire east coast South Island from Cape Campbell to Otago Peninsula, and around the Chatham Islands. He identified smaller grounds off the North Taranaki Bight, Hawke's Bay, eastern Bay of Plenty, Castlepoint, the Manawatu coast, and Foveaux Strait.

The results from *Kaharoa* trawl surveys are consistent with those of Vooren (1975). Age 0+ and 1+ tarakihi were found in large numbers on the east coast South Island and in Tasman Bay–Golden Bay, but in only very low numbers from surveys around the North Island and the west coast South Island (Figure 10). Although abundance indices are only relative, estimates of pre-recruits from the trawl surveys ranged from 1 to 1.5 million fish in Tasman Bay–Golden Bay (Stevenson & Hanchet 2000a) to 10–20 million fish on the east coast South Island (Beentjes & Stevenson 2001), with pre-recruits represented by 3–4 age classes. In comparison, trawl survey estimates of adults (comprising at least 10 age classes) from west coast North Island, east coast North Island and west coast South Island were much lower (0.5–1 million individuals).

4.4 Adult fish

Adult populations of tarakihi occur around most of New Zealand. Although Annala (1987) reported widespread movements of tagged fish, the sizes of the fish were not given and it is unclear how far the adult fish might move. Fishers believe that the seasonal set net fishery off Kaikoura is based on migrating fish. Pre-spawning fish are caught during a 6-week period in December–January, and spent fish are caught during a 6-week period in April–May. Spawning is known to take place between February and April on the Conway Ridge and off Cape Campbell, so the origin and destination of these fish is uncertain.

The ability to follow modes representing strong year classes in the trawl survey length frequency data from the west coast South Island suggests some stability of the adult population in this area (see Figure 7b). Strong year classes are less evident in the length frequency data from the east coast North Island surveys (see Figure 3), and otoliths would need to be read to determine whether this population is also stable. There are insufficient data on adults from surveys of the other areas to examine the consistency of the adult population over time. From the limited amount of data available we consider that once recruited to a particular area most adult tarakihi probably remain in that area.

4.5 Distribution of commercial catches

Based on the location of the main commercial catches (over 1000 t over the past 10 years), there are four main fishing grounds for tarakihi around New Zealand (Figure 11). These are around North Cape (Areas 002 and 047), around East Cape (Areas 009–014), on the east coast of the South Island (Areas 017–022), and on the west coast South Island (Areas 033–034). These areas overlap existing Fishstock boundaries used for management. However, it is unclear whether these four areas contain separate "populations", or whether they form part of a continuous distribution of fish around New Zealand.

4.6 Recruitment mechanisms

Annala (1987) postulated four recruitment pathways for tarakihi in New Zealand waters based on the four main spawning grounds. He proposed that larvae from Fiordland–South Westland could be transported either north to settle in Tasman Bay and off Manawatu, or be transported south and east through Foveaux Strait to the east coast South Island by the Southland Current. Larvae from Bay of Plenty–East Cape would probably mainly settle on the east coast North Island. Larvae from Conway Ridge–Pegasus Bay would also mainly settle on the east coast between Pegasus Bay and East Cape. Larvae on the Chatham Islands could originate from the North and South Island spawning grounds or from the Chatham Islands itself.

The hypothesised settlement patterns are not entirely consistent with the location of the main tarakihi nursery grounds. The main areas of juvenile abundance from the trawl survey results appear to be the east coast South Island between Pegasus Bay and the Otago Peninsula, and to a lesser extent in Tasman Bay–Golden Bay. Few juvenile tarakihi were caught on the east coast North Island, where settlement is predicted to be high. Both Vooren (1975) and Annala (1987) noted that considerable numbers of juveniles may occur over rocky grounds and shallow bays on the east coast and so not be available to the bottom trawls. However, in the other main nursery areas juvenile tarakihi tend to occur at depths of 20–100 m, and mostly between 10 and 30 km from shore (Vooren 1975). It seems more likely that the main nursery ground for tarakihi juveniles is the east coast South Island. However, the mechanism by which such large numbers of juveniles recruit there remains unclear.

How juveniles migrate and recruit to the adult populations is also unclear. Both Vooren (1975) and Annala (1987) hypothesised that as tarakihi matured they migrated out of Tasman Bay–Golden Bay and joined the west coast stock, spawning on the grounds off Fiordland and South Westland. The results of the *Kaharoa* surveys provide strong evidence to support this hypothesis (Stevenson & Hanchet 2000a). They showed that strong and weak year classes present in Tasman Bay–Golden Bay as pre-recruits could be seen in later years on the west coast as adults, and also noted a gradation in size of fish along the coast with younger fish predominating to the north and older fish to the south.

Vooren (1975) suggested that juveniles on the east coast South Island may remain on the east coast. However, if this is the case then where are the nursery grounds for the large population of tarakihi around the North Island? It seems more likely that the east coast South Island is in fact the main nursery ground for the entire east coast of both islands and possibly other areas as well. The trawl survey estimates of 10–20 million pre-recruits on the east coast South Island and of 0.5–1 million adults from the west coast North Island, east coast North Island, and west coast South Island are also more consistent with this explanation. A link between the east coast South Island and the other areas is also consistent with the extensive movements of tagged fish, most of which have been to the north (Annala 1987).

Until relationships between the main spawning, nursery, and fishing grounds are better understood it is probably adequate to use the existing Fishstock boundaries for assessing the various "fisheries". However, we should be aware of possible interrelationships between these "fisheries", and that heavy exploitation of pre-recruits in one area such as the east coast South Island could have major repercussions for other tarakihi fisheries around the country.

5. MODEL PARAMETERS

5.1 Length–weight relationships

To derive an appropriate length–weight relationship requires data from the full age range of fish in the population being modelled. Existing estimates for TAR 3 in the Plenary document (Annala et al. 2000) were obtained from a relatively small sample size (n = 100 for each sex), and excluded fish under 25 cm (Annala et al. 1990). Larger numbers of tarakihi have since been weighed and measured in other trawl surveys (e.g., Beentjes & Stevenson 2000, Stevenson & Hanchet 2000a, 2000b). It is recommended that length-weight data are extracted from the *trawl* database and length–weight parameters estimated for each sex and area.

5.2 Age and growth

5.2.1 Ageing studies

Ageing studies have been carried out on fish collected from East Cape (McKenzie 1961, Vooren & Tong 1973), Bay of Plenty (Tong & Vooren 1972), west coast of the South Island (Vooren 1977), and Kaikoura (Annala et al. 1990). Growth appears to be very similar between areas, and is rapid for the first five years, slows down for the next five years, and virtually ceases after age 10 (Annala 1987).

Maximum age estimates for the early studies ranged from 18 to 27 years, but these were carried out using whole otoliths or scales, which often underestimate ages (Beamish 1979). Estimates of maximum age using cross-sections of otoliths range from 35 years for the west coast South Island (Vooren 1977) to 42 years for Kaikoura (Annala et al. 1990).

5.2.2 Growth parameters

The only recent growth parameters were estimated for Kaikoura fish by Annala et al. (1990). Although there was a large sample size, they had few young (1+) fish in their study and the estimate of t_0 was −1.1 years, suggesting a poor fit to the early growth of the fish. Growth parameters were calculated for the Bay of Plenty (Tong & Vooren 1972) and East Cape (Vooren & Tong 1973) using Ford-Walford plots, but these studies also had only small sample sizes of young fish. No growth parameters are available for fish from the other Fishstocks.

It is recommended that a sample of about 500 otoliths are read from fish from each of Fishstocks TAR 1, 2, 3, and 7, and von Bertalanffy growth parameters calculated from these data.

5.2.3 Proportion-at-age data

Proportion-at-age data derived from these ageing studies have been considered earlier in Section 3, in the context of estimating year class strengths. Proportion-at-age data from single one-off samples are probably of limited value in estimating year class strengths, trawl survey selectivity, or total mortality (Z) (see also below). This is because the estimation of year class strengths is confounded with the trawl survey selectivity. However, it may be of interest to explore the sensitivity of any stock assessment results to runs where historical estimates of proportion-at-age are fitted to the predicted population estimates. Estimation of proportion-at-age from recent *Kaharoa* trawl surveys will allow the estimation of year class strength, trawl survey selectivity, and recruitment variability in any future stock assessment (see also Sections 5.5, 5.8).

5.2.4 Readability of the otoliths

The ageing methodology, validation of the early growth, and the repeatability of otolith readings was described in detail by Vooren & Tong (1972). They found that tarakihi otoliths had a consistent pattern of alternating opaque and hyaline zones. A wide opaque zone was laid down in spring–summer and a narrow hyaline zone in autumn–winter, but irregular hyaline checks (within year checks) occasionally occurred in the spring–summer opaque zone. Good correspondence occurred between the number of opaque zones and estimated ages from following juvenile length frequency modes. Variability between otolith readers was low with 83% agreement between two independent age readings of 409 otoliths. They concluded that the age of individual tarakihi can be reliably determined from the zonation patterns of the otoliths.

5.3 Natural mortality

Estimates of natural mortality for tarakihi were reviewed by Annala (1987) and Annala et al. (1990). Based on age frequency distributions of unexploited and lightly exploited populations, Vooren (1977) concluded that M was no greater than 0.1. Annala et al. (1990) derived a similar estimate of M using the equation:

$$M = \frac{\log_e 100}{\max age}$$ where max *age* was 42 years.

Annala et al. (2000) also considered that the best available estimate of M is 0.1. We agree with the findings of the earlier research and recommend that a value of M of 0.1 continue to be used for stock assessment in all areas. Sensitivity analyses should be carried out using values of 0.07 and 0.13, to examine the sensitivity of the model results to changes in the parameter estimate.

5.4 Total mortality (Z)

Estimates of total mortality for tarakihi from the west coast South Island, East Cape, and Kaikoura have been obtained from catch curve analysis (Vooren 1973, 1977, Annala et al. 1990). Age composition data for the west coast were fitted by eye (Vooren 1977), whereas data from off Kaikoura were estimated using the Chapman-Robson estimator (Annala et al. 1990).

Catch curve analysis makes several assumptions (Ricker 1975, Dunn et al. 1999).
1. The population has a stable age structure (i.e., recruitment and mortality are constant).
2. Fish of age greater than the age at recruitment are equally vulnerable to sampling.
3. There are no age estimation errors

It is not known how well these assumptions are met for tarakihi and for the data sets in question. Recruitment can be quite variable between years (see Section 5.8), and this could have a large impact on the estimation of Z (Dunn et al. 1999). Estimates of Z from one-off research surveys are probably of limited value in population modelling. A more appropriate way to deal with proportion-at-age data is to fit them in a population model and at the same time estimate trawl survey selectivity and year class strength.

We recommend that historical estimates of total mortality are not used in any population modelling. However, it may be useful to explore the sensitivity of any stock assessment results to runs where historical estimates of proportion-at-age are fitted to the predicted population estimates.

5.5 Trawl survey selectivity

There are no published trawl survey selectivity ogives for tarakihi, although a number of studies have considered the peak in the age distribution in the trawl samples (e.g., Vooren & Tong 1973, Annala et al. 1990). Trawl survey selectivity appears to vary considerably depending on the location and timing of the survey, and the codend mesh size being used (see Section 3). Age composition data from trawl surveys using a 40 mm codend have also varied considerably. On the west coast South Island fish were not fully selected until age 8 and the selectivity of age 5 fish was only about 0.1 (Vooren 1975). In the East Cape area fish were fully selected at age 7 and the selectivity of age 5 fish was 0.17 (Vooren 1973). In comparison, on the east coast South Island fish were fully selected at age 4, and the selectivity of age 2 fish was about 0.8 (Annala et al. 1990).

5.6 Fishing selectivity

There are no published age compositions of commercial tarakihi catches. Fishing selectivity will probably vary considerably depending on the location of the ground being fished, and the codend mesh size being used. Vooren (1975) noted that tarakihi smaller than 20 cm consistently occurred in commercial catches in some areas, although many would escape the large commercial codend meshes.

Annala et al. (1990) presented the proportion of tarakihi retained by a 100 mm codend by age class, which was derived by applying von Bertalanffy growth parameters for the Kaikoura area to the results of a mesh selection study by Massey (1988). About 50% of fish were selected at age 3 and fish were fully selected by age 5 (Table 14). This is the best estimate of fishing selectivity currently available.

5.7 Maturity ogive

Published data on age at sexual maturity were given for the Bay of Plenty by Tong & Vooren (1972) and for East Cape by Vooren & Tong (1973) and are summarised in Table 14. Fish in both areas were immature at age 3 and mostly mature by age 6. Differences in maturity at age between areas and sexes may be real, but are more likely to be due to small sample sizes and younger fish not being fully sampled (Vooren & Tong 1973). Gonad stage data are available from the east coast North Island and west coast South Island surveys which were carried out during the spawning season, and it is recommended that these data are used to derive maturity ogives for these areas.

5.8 Recruitment variability

Annala (1988) cited several studies which suggested substantial variation in recruitment of tarakihi. For example, there was large between year variation in the number of 0+ fish moving into Tasman Bay (Vooren 1975). As part of the current project objectives we were asked to estimate recruitment variability for tarakihi. A better estimate of year class strengths, and hence recruitment variability, would be obtained from a population model fitted to proportion-at-age data. However, in the interim a crude estimate of recruitment variability was obtained from the west coast South Island trawl survey data in the following way:

1. Biomass of age classes 1 to 3 was converted to estimated numbers using mean weight at age.
2. The standard deviation of the logs of the 15 values was calculated to estimate recruitment variability.
3. Mortality, differential trawl selectivity with age, and observation error (of both trawl surveys and ages) were ignored.

Recruitment variability was estimated to be 0.91 (Table 15). This is similar to the value of 1.0 used for hoki (Ballara et al. 2000) and southern blue whiting (Hanchet 2000) in New Zealand waters, which are considered to have moderate to high recruitment variability. It is recommended that this value be revised once model estimates of year class strength become available.

6. GENERAL DISCUSSION

A number of issues need to be addressed before methods of monitoring and assessing the Fishstocks can be considered.

6.1 Stock structure

We reviewed the available information on stock structure in Section 4, and concluded that the stock structure is complex and poorly understood. We can see no immediate way to address stock structure issues, because genetic and tagging studies which have already been attempted suggest widespread dispersal and a single tarakihi stock. That said, there may be some merit in analysing the tarakihi tagging data by fish length, if there are enough data available, to determine movements of adult and pre-recruit tarakihi. Consideration could also be given to tagging pre-recruit tarakihi from Tasman Bay/Golden Bay to determine movement patterns. This could be included as objectives in the ongoing *Kaharoa* trawl surveys of the two areas. We consider that assessments of the main Fishstocks (or sub-Fishstocks) is probably the most practical way forward, and is probably the most realistic, on the basis that once tarakihi have recruited to a particular ground they probably remain there.

6.2 Biological parameters

A summary of biological parameters available for each of the fisheries is shown in Table 15. For most areas the available biological parameters should be updated. Data are currently available on the *trawl* database to estimate length–weight relationships of tarakihi in each of the areas. Otoliths are available for fish from the *Kaharoa* surveys of the west coast North Island, west coast South Island, east coast North Island, and Bay of Plenty and should be used to calculate new growth curves for those areas. Growth parameters for the east coast South Island appear adequate, although they could be updated if more data become available. The estimate of natural mortality appears appropriate for each of the areas.

Trawl survey selectivity ogives are best estimated for each of the trawl series (once proportion-at-age data are available). This is because they appear to vary considerably depending on the location and timing of the survey, and the codend mesh size being used. Maturity ogives are available only for the Bay of Plenty (TAR 1E) and East Cape (TAR 2) (Table 15). Gonad stage data are available from the east coast North Island and west coast South Island *Kaharoa* surveys which were carried out during the spawning season, and could be used to derive maturity ogives for these areas.

Probably the most important piece of data not available for tarakihi is the size of fish taken by the commercial fisheries. It is recommended that commercial catches (as opposed to commercial landings) be sampled from each of the main tarakihi fisheries around New Zealand for at least a one year period.

6.3 Population models

The choice of population model, and to some extent the long term monitoring and management of the stocks, depends on the age structure and recruitment variability inherent in the populations. We have seen above (Section 5.8) that recruitment variability in tarakihi is moderately high. There are strong signals in the trawl survey estimates of pre-recruits, which can sometimes be tracked through into the adult population. A crude estimate using the pre-recruit data for the west coast South Island trawl survey suggested a recruitment variability of 0.9. Ageing reliability and precision appear to be moderately good for tarakihi. We therefore strongly recommend the inclusion of proportion-at-age data, where available, in any stock assessments of tarakihi.

6.4 Monitoring Fishstocks

Recommendations on methods of monitoring the Fishstocks take into account the size and value of each fishery, the usefulness of the abundance indices and mortality estimates, and the biology of the species, including productivity and recruitment variability. There is a potentially large amount of data with which to carry out a stock assessment to estimate virgin and current biomass, and current and long-term sustainable yields. Recommendations on the type of data which should be incorporated into the model, the type of population model (e.g., age structured, catch-at-age), and the frequency of monitoring the stock and carrying out stock assessments will now be considered for each area. The available abundance indices and stock assessment parameters are summarised in Table 16.

6.4.1 TAR 1

Currently about 1500 t per year are landed from TAR 1, which includes the main fishing grounds off the west coast North Island, East Northland, and the Bay of Plenty. We have separated TAR 1 into TAR 1W and TAR 1E with a line at North Cape, and recommend that any assessment is carried out separately for each area.

6.4.1.1 TAR 1W

A time series of CPUE indices is available for the period 1989–90 to 1998–99, and is probably monitoring abundance. A time series of relative abundance is being developed from the *Kaharoa* west coast North Island trawl surveys. We recommend that tarakihi continue to be a target species for this survey and that otoliths continue to be collected and read and proportion-at-age calculated for each survey. It has been recommended that these surveys be carried out every 2 years for sampling tarakihi (Sampson 2000, Morrison et al. 2001a). Because it is a relatively small fishery (under 500 t), we recommend that assessments should be given a low to medium priority. The first assessment could be carried out once three or four trawl surveys in the series have been completed. CPUE should be updated at the same time, and compared with the trawl survey indices. Biomass estimates from the trawl surveys could then be used to monitor the stock and new assessments be contingent on changes in the abundance indices by more than a given amount (say 20–30%).

6.4.1.2 TAR 1E

The TAR 1E fishery is the second largest in New Zealand, averaging over 1000 t/yr. The main fisheries are off East Northland and Bay of Plenty, but trawl surveys of both areas are not monitoring abundance. A time series of CPUE indices has been developed for the TAR 1E fishery, based primarily on target tarakihi tows. The indices are relatively stable but it is unknown whether they are monitoring abundance. More confidence in their use as abundance indices would be justified if the trends in trawl survey and CPUE indices in other target tarakihi fisheries (e.g., on the west coast North Island) are similar. It is recommended that a stock assessment be delayed until the reliability of the CPUE as an index of abundance can be properly addressed. The frequency of future assessments will depend on the ability of the CPUE to monitor abundance and trends in the fishery. A new assessment could be carried out once the abundance indices had changed by a given amount (say 20–30%).

6.4.2 TAR 2

The TAR 2 fishery is the largest in New Zealand, and has averaged about 1500 t per year since 1983–84. There is a large spawning ground in the East Cape area and substantial catches are taken between there and Cape Kidnappers. A short time series of trawl survey indices is available for TAR 2 for the period 1993 to 1996. It has been recommended that two or three *Kaharoa* trawl surveys (starting after 2005) be carried out in this area to extend the time series for comparison with the earlier results (Stevenson & Hanchet 2000b, Sampson 2000), with the caveat that some form of sampling be added for the areas of foul ground (e.g., fixed stations with short tows) (Sampson 2000). A time series of CPUE indices has been developed for the TAR 2 fishery, based primarily on target tarakihi tows. The indices are relatively stable, and showed a similar trend to the trawl survey indices from 1993 to 1996.

Because of the moderate variability in tarakihi recruitment seen in other areas, it is recommended that otoliths are read from each *Kaharoa* survey and used to determine proportion-at-age. Proportion-at-age data are also available from sampling carried out in 1971. As they are derived from only 20 trawls, we recommend they be used only to explore the sensitivity of any stock assessment results to alternative assumptions about historical proportion-at-age.

Given the importance of the fishery we recommend that stock assessment be given medium to high priority and be carried out in the near future using all available data. The frequency of future assessments will depend on the ability of the CPUE to monitor abundance and trends in these indices. A new assessment could be carried out once the abundance indices had changed by a given amount (say 20–30%).

6.4.3 TAR 3

The TAR 3 fishery has averaged about 1000 t/year since 1983–84, and comprises catches from bottom trawl and set net. Although no catch sampling has been carried out, fishers have reported that the tarakihi size composition differs considerably along the coast (Field & Hanchet 2001). Pre-recruits and small adults (under 32 cm) occur in the Canterbury Bight–Pegasus Bay area, large adults (over 35 cm) occur seasonally off Kaikoura (where they are caught by set net), on the Conway Ridge and in Cook Strait, whilst intermediate size adults (25–35 cm) occur between Kaikoura and Cape Campbell.

The Canterbury Bight–Pegasus Bay area is being monitored by the east coast South Island trawl surveys, although better optimisation of tarakihi is desirable. Otoliths were not collected so estimation of proportion-at-age using otoliths is not possible. However, juvenile length frequency data can be split up using software such as MIX (McDonald & Green 1988), and this has been used successfully for other trawl survey data (e.g., Ballara et al. 2000). Although there is uncertainty surrounding the destination of the pre-recruit fish in this area, a MIX analysis of these survey data should be considered. If the stock issues of tarakihi are resolved, the estimates of year class strength from the area may provide an important tool in gauging future recruitment to the tarakihi fishery, not only on the east coast South Island, but also around parts of the North Island.

The region north of Pegasus Bay to Cook Strait (areas 016–018), which includes parts of Fishstocks TAR 2, 3, and 7, also needs a monitoring tool. Larger adults could be monitored using a CPUE index developed from the Kaikoura set net fishery. However, this is a highly selective and seasonal fishery on migrating tarakihi, and the CPUE may not be monitoring abundance. The commercial trawl indices were based on the entire east coast fishery and there are concerns that they may not be monitoring abundance. One possibility could be to try to derive an index of abundance from the trawl fishery in this area. When interviewed, several trawl fishers (from different QMAs) stated that they specifically targeted tarakihi in this area. It is therefore recommended that catch and effort data are re-examined for areas 016–018. It is possible that enough tarakihi are targeted in this area to derive a satisfactory index of abundance. A stock assessment could be carried out using all available data once an adequate monitoring tool for adults has been developed.

There are several historical estimates of age composition in this area for 1970, 1971, 1978, and 1987. Because they are mostly derived from small numbers of trawls, we believe they should be used only to explore the sensitivity of any stock assessment results to alternative assumptions about historical proportion-at-age.

It is important to determine the size of the fish caught in the commercial fishery in this area, to confirm the observations from fishermen considered above. The trawl survey proportions at age, together with the set net CPUE indices and other existing data, could provide the basis for a stock assessment in the near future.

6.4.4 TAR 7

The TAR 7 fishery has averaged about 800 t/yr since 1983–84, and the main fishery occurs between Cape Foulwind and Jacksons Bay. Recruitment mechanisms for TAR 7 appear to be more straightforward than in the other tarakihi areas, with well defined adult spawning grounds off South Westland, adult feeding grounds all along the west coast, and nursery grounds in Tasman Bay–Golden Bay (Section 4.4).

Time series of adult and pre-recruit relative abundance indices covering the period 1992 to 2000 are available from the *Kaharoa* surveys for this area (Stevenson & Hanchet 2000a). It has been recommended that these surveys need to be carried out at 2-yearly intervals to adequately monitor the abundance of tarakihi and other species in this area (Stevenson & Hanchet 2000a, Sampson 2000). We recommend otoliths from these and future surveys be read and used to calculate proportion at age for this area. Time series of CPUE indices, derived from the predominantly bycatch fishery, do not appear to be monitoring abundance.

Historical estimates of the age composition in this area are available for 1972 and 1977. The two age distributions were quite different, but it is unclear whether this is due to differences in gear type, mesh size, time of year, or specific sampling sites or whether it reflects real population differences. We recommend they are used to explore the sensitivity of any stock assessment results to alternative assumptions about historical proportion-at-age.

Although it is a relatively small fishery, abundance data are available which suggest a 30% decline in abundance. We therefore recommend that monitoring and assessments be given a medium–high priority. The first assessment should be carried out once the proportion-at-age data have become available. Biomass estimates from the trawl surveys could then be used to monitor the stock and new assessments be contingent on changes in the abundance indices by more than a given amount (say 20–30%).

7. RECOMMENDATIONS FOR MONITORING AND FURTHER WORK

All areas

- Develop catch history for all Fishstocks
- Catch sampling from main fisheries for one year to determine fishing selectivity ogives for each Fishstock
- Review stock structure once more biological data are available
- Summarise movements from tagging studies by length class
- Consider tagging pre-recruits from Tasman Bay–Golden Bay and east coast South Island trawl surveys to track movements and help delineate stock structure
- Revise biological parameters (length–weight parameters, growth parameters, maturity ogive) for each Fishstock

TAR 1W

- Monitor using biannual *Kaharoa* west coast North Island trawl surveys
- Continue to collect and read otoliths from surveys
- Repeat CPUE analysis after 3–4 surveys completed
- Carry out age structured stock assessment fitted to proportion-at-age data after 3–4 surveys completed

TAR 1E

- Monitor using CPUE indices (if we can be confident that they are monitoring adult abundance).
- Assess using age structured stock reduction analysis fitted to CPUE indices

TAR 2

- Monitor using CPUE indices (if we can be confident that they are monitoring adult abundance)
- Read otoliths and determine proportion-at-age for *Kaharoa* east coast North Island trawl surveys
- Carry out age structured stock assessment fitted to trawl survey proportion-at-age data and CPUE indices
- Fit historical proportion-at-age data as a sensitivity analysis
- Consider 2–3 *Kaharoa* trawl surveys after 2005 to extend the earlier series of abundance indices, and to test whether CPUE is monitoring abundance

TAR 3

- Monitor pre-recruit/small adults using *Kaharoa* east coast South Island trawl surveys optimised for tarakihi
- Develop method of monitoring adult abundance in northern area (areas 016–018)
- Estimate proportion-at-age for *Kaharoa* trawl surveys using MIX
- Collect and read otoliths from future *Kaharoa* east coast South Island trawl surveys
- Carry out age structured stock assessment fitted to trawl survey proportion-at-age data and adult abundance indices (if one becomes available)
- Fit historical proportion-at-age data as a sensitivity analysis

TAR 7

- Monitor using biannual *Kaharoa* west coast South Island surveys
- Read otoliths and determine proportion-at-age from recent and future surveys
- Carry out age structured stock assessment fitted to proportion-at-age data
- Fit historical proportion-at-age data as a sensitivity analysis
- Explore relationship between west coast adults and Tasman Bay–Golden Bay pre-recruits

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Table 1: Reported landings (t) of tarakihi by Fishstock from 1983–84 to 1998–99 and TACs (t) from 1986–87 to 1998–99.

Fishstock	TAR 1		TAR 2		TAR 3		TAR 4		TAR 5	
QMA (s)	1 & 9		2		3		4		5 & 6	
	Landings	TAC	Landings	TAC	Landings	TAC	Landings	TAC	Landings	TAC
1983–84*	1326	–	1118	–	902	–	287	–	115	–
1984–85*	1022	–	1129	–	1283	–	132	–	100	–
1985–86*	1038	–	1318	–	1147	–	173	–	48	–
1986–87†	912	1210	1382	1410	938	970	83	300	42	140
1987–88†	1093	1286	1386	1568	1024	1036	227	314	88	142
1988–89†	940	1328	1412	1611	758	1061	182	314	47	147
1989–90†	973	1387	1374	1627	1007	1107	190	315	60	150
1990–91†	1125	1387	1729	1627	1070	1148	367	316	35	153
1991–92†	1415	1387	1700	1627	1132	1148	213	316	55	153
1992–93†	1477	1397	1654	1633	813	1168	45	316	51	153
1993–94†	1431	1397	1594	1633	735	1169	82	316	65	153
1994–95†	1390	1398	1580	1633	849	1169	71	316	90	153
1995–96†	1422	1398	1551	1633	1125	1169	209	316	73	153
1996–97†	1425	1398	1639	1633	1088	1169	133	316	81	153
1997–98†	1509	1398	1678	1633	1026	1169	202	316	21	153
1998–99†	1436	1398	1594	1633	1097	1169	104	316	51	153

	TAR 7		TAR 8		TAR 10			
	7		8		10		Total	
	Landings	TAC	Landings	TAC	Landings	TAC	Landings§	TAC
1983–84*	896	–	109	–	0	–	5430	–
1984–85*	609	–	102	–	0	–	4816	–
1985–86*	519	–	122	–	0	–	5051	–
1986–87†	904	930	185	190	0	10	4446	5160
1987–88†	840	1046	197	196	0	10	4855	5598
1988–89†	630	1059	121	197	0	10	4090	5727
1989–90†	793	1069	114	208	0	10	4473	5873
1991–92†	710	1087	190	225	2	10	5417	5953
1992–93†	929	1087	189	225	0	10	5158	5989
1990–91†	629	1087	131	225	<1	10	5086	5953
1993–94†	780	1087	191	225	0	10	4878	5990
1994–95†	978	1087	171	225	0	10	5129	5991
1995–96†	890	1087	105	225	0	10	5375	5991
1996–97†	1013	1087	133	225	0	10	5512	5991
1997–98†	685	1087	153	225	0	10	5287	5991
1998–99†	1041	1087	175	225	0	10	5501	5991

* FSU data.
† QMS data.
§ Includes landings from unknown areas before 1986–87.

Table 2: Standardised CPUE indices for successful vessel–days (i.e., catch of TAR >0 t) in the tarakihi single bottom trawl fishery in TAR 1W (west coast North Island) from 1989–90 to 1998–99.

	All vessels			Vessel subset		
Fishing year	*n*	Index	s.d.	*n*	Index	s.d.
1989–90	309	1.00	–	102	1.00	–
1990–91	332	0.88	0.073	124	0.74	0.106
1991–92	362	1.07	0.088	221	1.04	0.132
1992–93	560	0.85	0.064	400	0.73	0.086
1993–94	544	1.05	0.080	385	0.85	0.103
1994–95	528	1.27	0.097	407	1.19	0.142
1995–96	592	1.40	0.105	429	1.33	0.160
1996–97	723	1.38	0.100	533	1.33	0.156
1997–98	716	1.25	0.092	483	1.15	0.137
1998–99	597	1.23	0.092	379	1.30	0.160

– Criteria for inclusion in vessel subset was vessel fished ≥ 10 days for each of ≥ 5 years, giving 15 vessels with 3463 records.

Table 3: Number of tarakihi otoliths collected from the various *Kaharoa* trawl surveys. –, not surveyed. *, otoliths read.

Year	WCNI	BOP	ECNI	ECSI	WCSI
1991	0	–	–	0	–
1992	–	0	–	0	0
1993	–	–	326	0	–
1994	0	–	301	0	0
1995	–	–	214	0	269
1996	*170	55	251	0	–
1997	–	–	–	0	259
1998	–	–	–	0	–
1999	201	122	–	0	–
2000	–	–	–	0	279

Table 4: Standardised CPUE indices for successful vessel–days (i.e., catch of TAR >0 t) in the tarakihi single bottom trawl fishery in TAR 1E (east Northland and Bay of Plenty) from 1989–90 to 1998–99.

	All vessels			Vessel subset		
Fishing year	*n*	Index	s.d.	*n*	Index	s.d.
1989–90	1 485	1.00	–	791	1.00	–
1990–91	2 052	0.77	0.028	954	0.89	0.043
1991–92	2 320	0.86	0.031	1 101	0.89	0.041
1992–93	2 193	0.90	0.033	920	0.96	0.047
1993–94	2 088	0.97	0.036	1 008	1.03	0.050
1994–95	1 955	1.04	0.039	1 076	0.99	0.047
1995–96	2 107	1.05	0.038	1 139	0.98	0.046
1996–97	2 279	1.08	0.040	1 204	1.01	0.047
1997–98	2 351	1.19	0.043	1 273	1.03	0.048
1998–99	2 205	1.16	0.043	1 100	1.13	0.054

Criteria for inclusion in vessel subset was vessel fished ≥ 10 days for each of ≥ 9 years, giving 20 vessels with 10,569 records.

Table 5: Standardised CPUE indices for successful vessel–days (i.e., catch of TAR >0 t) in the tarakihi single bottom trawl fishery in TAR 2 (east Northland and Bay of Plenty) from 1989–90 to 1998–99.

	All vessels			Vessel subset		
Fishing year	*n*	Index	s.d.	*n*	Index	s.d.
1989–90	1 977	1.00	–	740	1.00	–
1990–91	2 609	0.94	0.029	1 155	0.92	0.042
1991–92	3 061	0.85	0.026	1 337	0.91	0.041
1992–93	2 832	0.87	0.027	1 239	0.90	0.041
1993–94	2 831	0.81	0.025	1 341	0.89	0.040
1994–95	3 076	0.81	0.025	1 646	0.87	0.038
1995–96	2 878	0.82	0.025	1 636	0.90	0.040
1996–97	3 118	0.95	0.029	1 654	0.98	0.043
1997–98	2 716	0.94	0.030	1 739	0.98	0.043
1998–99	2 241	1.02	0.033	1 435	1.00	0.046

Criteria for inclusion in vessel subset was vessel fished ≥ 10 days for each of ≥ 7 years, giving 23 vessels with 13,923 records.

Table 6: Estimates of tarakihi biomass (t) from *Kaharoa* trawl surveys on east coast North Island (from Stevenson & Hanchet 2000b).

		Age 2		Total	
Year	Trip code	Biomass	c.v. %	Biomass	c.v. %
1993	KAH9304	7.6	62	736	30
1994	KAH9402	3.6	51	1 052	20
1995	KAH9502	0.7	31	791	23
1996	KAH9602	5.8	41	925	15

Table 7: Standardised CPUE indices for successful vessel–days (i.e., catch of TAR >0 t) in the tarakihi single bottom trawl fishery in TAR 3 (east coast South Island) from 1989–90 to 1998–99 for all target species.

	All vessels			Vessel subset		
Fishing year	*n*	Index	s.d.	*n*	Index	s.d.
1989–90	1 561	1.00	–	611	1.00	–
1990–91	1 793	1.15	0.047	734	0.99	0.061
1991–92	1 907	1.15	0.047	916	1.28	0.076
1992–93	1 504	1.01	0.044	826	1.07	0.065
1993–94	1 545	1.08	0.046	850	1.16	0.070
1994–95	1 491	1.49	0.064	802	1.45	0.089
1995–96	1 576	1.83	0.077	850	2.02	0.122
1996–97	1 537	1.59	0.067	807	1.80	0.110
1997–98	1 627	1.49	0.063	790	1.78	0.112
1998–99	1 501	1.37	0.059	798	1.52	0.095

Criteria for inclusion in vessel subset was vessel fished ≥ 10 days for each of ≥ 7 years, giving 26 vessels with 7,984 records.

Table 8: Standardised CPUE indices for the single bottom trawl, target tarakihi fishery in TAR 3 from 1989–90 to 1998–99.

Fishing	Vessel–days			Standardised indices		
year	total	zero catch	Prop. Zero	linear	binomial	combined
1989–90	384	58	0.15	1.00	1.00	1.00
1990–91	273	26	0.10	0.86	0.96	0.87
1991–92	260	18	0.07	0.97	0.39	1.07
1992–93	177	24	0.14	0.73	0.82	0.75
1993–94	440	83	0.19	0.73	0.98	0.73
1994–95	302	38	0.13	0.99	0.82	1.02
1995–96	243	27	0.11	1.36	1.04	1.35
1996–97	295	40	0.14	1.36	1.14	1.33
1997–98	145	34	0.23	1.25	0.93	1.26
1998–99	283	61	0.22	1.01	1.33	0.96

Table 9: Standardised CPUE indices for successful vessel–days (i.e., catch of TAR >0 t) in the tarakihi set net fishery in TAR 3 from 1989–90 to 1998–99.

	Target tarakihi			Target all species		
Fishing year	*n*	Index	s.d.	*n*	Index	s.d.
1989–90	789	1.00	–	839	1.00	–
1990–91	869	1.00	0.045	978	1.09	0.051
1991–92	862	1.06	0.049	1 023	1.21	0.058
1992–93	841	0.98	0.048	1 025	0.99	0.050
1993–94	676	0.69	0.035	876	0.79	0.041
1994–95	700	0.91	0.046	917	0.97	0.050
1995–96	557	0.87	0.047	739	0.82	0.046
1996–97	518	0.85	0.046	750	0.81	0.045
1997–98	680	1.01	0.056	932	0.99	0.055
1998–99	497	1.13	0.073	540	1.17	0.077

Table 10: Estimates of tarakihi biomass (t) from winter Kaharoa trawl surveys of east coast South Island (after Beentjes & Stevenson 2000).

		Age 1		Age 2		Total		> Age 2
Year	Trip code	Biomass	c.v. %	Biomass	c.v. %	Biomass	c.v. %	Biomass
1991	KAH9105	16	25	158	38	1 712	33	1 538
1992	KAH9205	7	26	178	29	932	26	747
1993	KAH9306	43	54	1 990	64	3 805	55	1 772
1994	KAH9406	11	62	355	32	1 219	31	853
1996	KAH9606	5	43	372	31	1 656	24	1 279

Table 11: Estimates of tarakihi biomass (t) from summer Kaharoa trawl surveys of east coast South Island (after Beentjes & Stevenson 2000).

		Age 0		Age 1		Total		> Age 1
Year	Trip code	Biomass	c.v. %	Biomass	c.v. %	Biomass	c.v. %	Biomass
1996/97	KAH9618	13	53	577	30	3818	21	3228
1997/98	KAH9704	3	78	159	30	2036	21	1874
1998/99	KAH9809	< 1	29	208	27	4277	24	4068
1999/00	KAH9917	< 1	51	105	24	2606	15	2501
2000/01	KAH0014	<1	54	34	26	1540	13	1506

Table 12: Standardised CPUE indices for successful vessel–days (i.e., catch of TAR >0 t) in the tarakihi single bottom trawl fishery in TAR 7 (west coast South Island) from 1989–90 to 1998–99.

	All vessels			Vessel subset		
Fishing year	*n*	Index	s.d.	*n*	Index	s.d.
1989–90	1 116	1.00	–	539	1.00	–
1990–91	1 238	1.04	0.045	660	0.98	0.059
1991–92	1 202	1.07	0.047	643	0.90	0.055
1992–93	1 393	1.29	0.055	862	1.03	0.062
1993–94	1 121	1.29	0.058	681	1.02	0.064
1994–95	1 143	1.37	0.063	545	1.19	0.079
1995–96	1 160	1.05	0.047	822	1.00	0.060
1996–97	1 436	1.17	0.051	887	1.10	0.067
1997–98	881	1.26	0.061	502	1.19	0.079
1998–99	1 252	1.46	0.065	661	1.17	0.075

Criteria for inclusion in vessel subset was vessel fished ≥ 10 days for each of ≥ 6 years, giving 21 vessels with 6,802 records.

Table 13: Estimates of tarakihi biomass (t) from Kaharoa trawl surveys for west coast South Island, Tasman Bay/Golden Bay, and both areas combined (from Stevenson & Hanchet 2000a, Stevenson 2001). –, estimate not available.

		Age 1		Age 2		Age 3		Total	
Year	Trip code	Biomass	c.v. %	Biomass	c.v. %	Biomass	c.v. %	Biomass	c.v. %
West coast									
1992	KAH9204	<0.5	27	20	25	7	28	1 296	13
1994	KAH9404	<0.5	100	1	83	30	58	1 231	13
1995	KAH9504	<0.5	44	<0.5	62	8	30	1 288	11
1997	KAH9701	<0.5	100	1	49	32	58	865	12
2000	KAH0002	–	–	–	–	–	–	928	20
Tasman Bay/Golden Bay									
1992	KAH9204	4	88	106	86	2	85	113	86
1994	KAH9404	5	28	26	36	108	65	163	58
1995	KAH9504	11	20	75	39	12	42	101	34
1997	KAH9701	18	27	45	36	151	39	222	34
2000	KAH0002	–	–	–	–	–	–	36	32
Total									
1992	KAH9204	5	82	127	73	9	30	1 409	14
1994	KAH9404	5	28	27	34	139	52	1 394	13
1995	KAH9504	11	20	75	39	29	27	1 389	10
1997	KAH9701	18	27	48	34	187	34	1 087	12
2000	KAH0002	3	11	30	49	102	62	964	19

Table 14: Proportion mature at age from the Bay of Plenty (Vooren & Tong 1972), and East Cape (Tong & Vooren 1973), and proportion of fish retained by a 100 mm codend (Annala et al. 1990).

Age	Bay of Plenty		East Cape		Fishing selectivity
	Males	Females	Males	Females	
1	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.27
3	0.00	0.00	0.00	0.00	0.66
4	0.52	0.22	0.88	0.67	0.81
5	0.94	0.67	0.78	0.88	1.00
6	1.00	1.00	0.99	0.94	1.00
7	1.00	1.00	1.00	0.99	1.00

Table 15: Estimation of recruitment variability from the west coast South Island trawl surveys.

Year	Age class	Biomass (t)	Mean length (cm)	Mean weight (g)	Estimated N ('000)	Log_eN ('000)
1992	1+	5	11.0	22.0	227.4	5.4
1994	1+	5	12.0	28.8	173.6	5.2
1995	1+	11	12.0	28.8	381.9	5.9
1997	1+	18	12.5	32.7	550.7	6.3
2000	1+	3	13.0	36.9	81.3	4.4
1992	2+	127	19.0	119.7	1061.0	7.0
1994	2+	27	19.0	119.7	225.6	5.4
1995	2+	75	20.0	140.3	534.5	6.3
1997	2+	48	20.0	140.3	342.1	5.8
2000	2+	30	20.5	151.5	198.0	5.3
1992	3+	9	24.0	246.9	36.4	3.6
1994	3+	139	23.0	216.4	642.3	6.5
1995	3+	29	24.0	246.9	117.4	4.8
1997	3+	187	23.5	231.3	808.3	6.7
2000	3+	102	24.0	246.9	413.0	6.0
Standard deviation						**0.91**

Table 16: Summary of abundance indices and biological parameters available for tarakihi stocks TAR 1, 2, 3, and 7. *, possibly unreliable for stock assessment purposes.

	TAR 1		TAR 2	TAR 3	TAR 7
	FMA 9	FMA 1			
Catch history	No	No	No	No	No
Abundance indices					
Kaharoa trawl surveys					
Adult indices	96, 99	*96, 99	93–96	No	92, 94, 95, 97, 00
Pre–recruit indices	No	No	No	91–96; 97–00	92, 94, 95, 97, 00
Otoliths collected	Yes	Yes	Yes	No	95, 97, 00
Proportion-at-age	96, 99?	No	No	No	No
Other trawl surveys					
Proportion-at-age*	No	No	71	70, 71, 78, 87	72, 77
CPUE indices	Yes	*Yes	Yes	*Yes	*Yes
Biological parameters					
LW relationship	No	*Yes	*Yes	*Yes	*Yes
Growth parameters	No	*Yes	*Yes	*Yes	No
Natural mortality	Yes	Yes	Yes	Yes	Yes
Trawl survey selectivity	No	No	No	No	No
Fishing selectivity	No	No	No	Yes	No
Maturity ogive	No	Yes	Yes	No	No

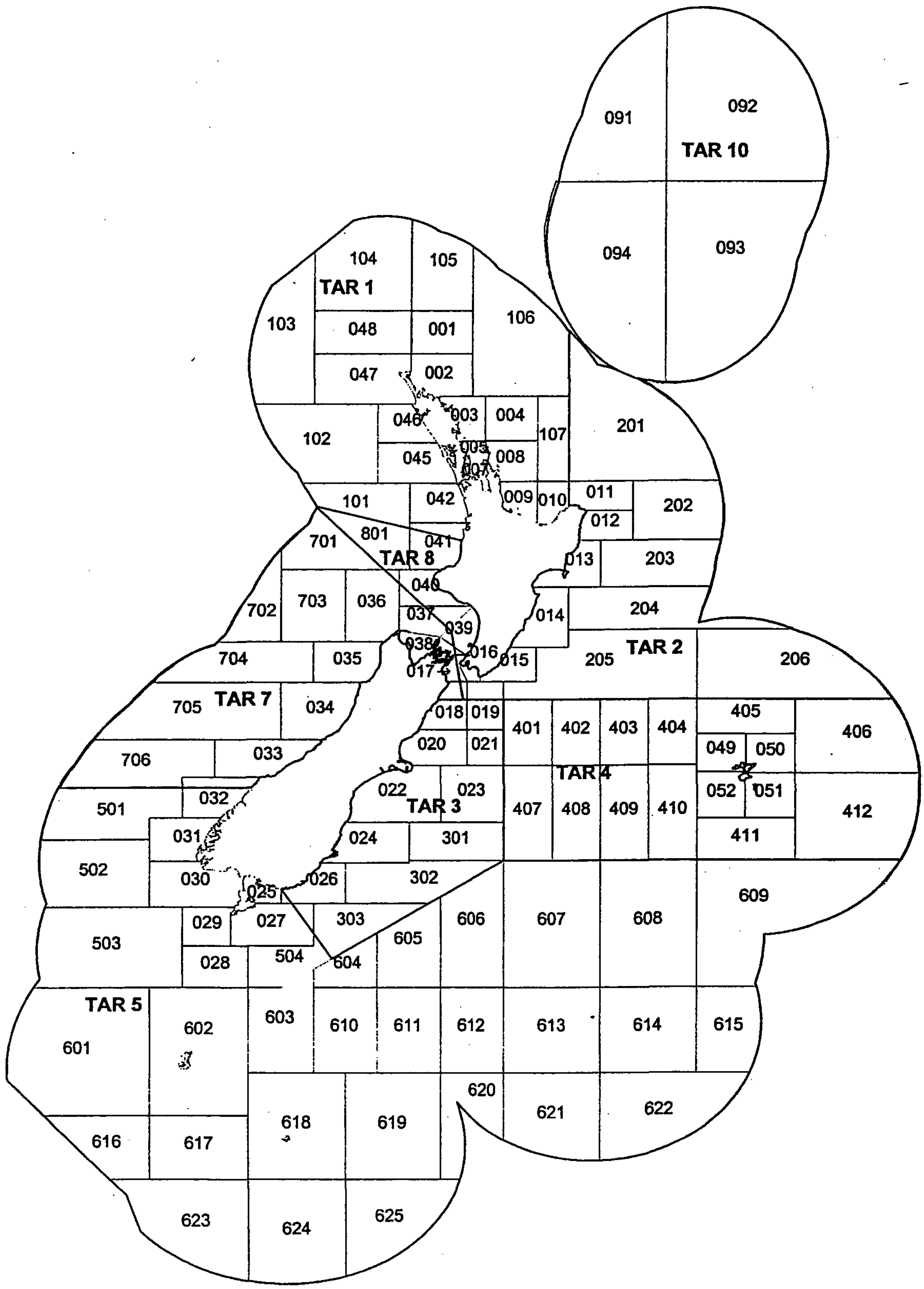

Figure 1: Statistical areas with QMA boundaries.

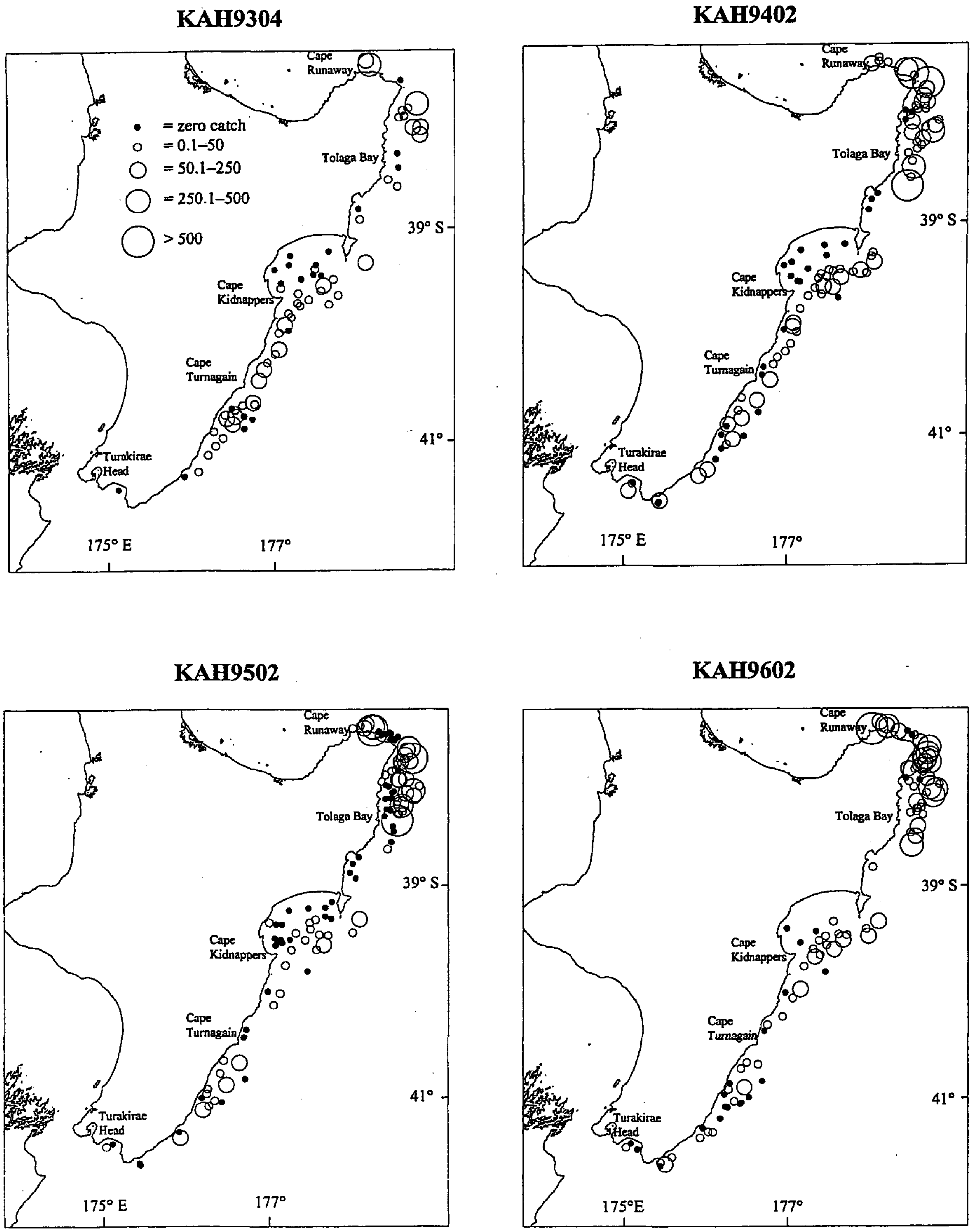

Figure 2: Distribution and catch rates (kg.km^{-2}) of tarakihi on the east coast North Island, 1993–96 (maximum catch rate 2837 kg.km^{-2}).

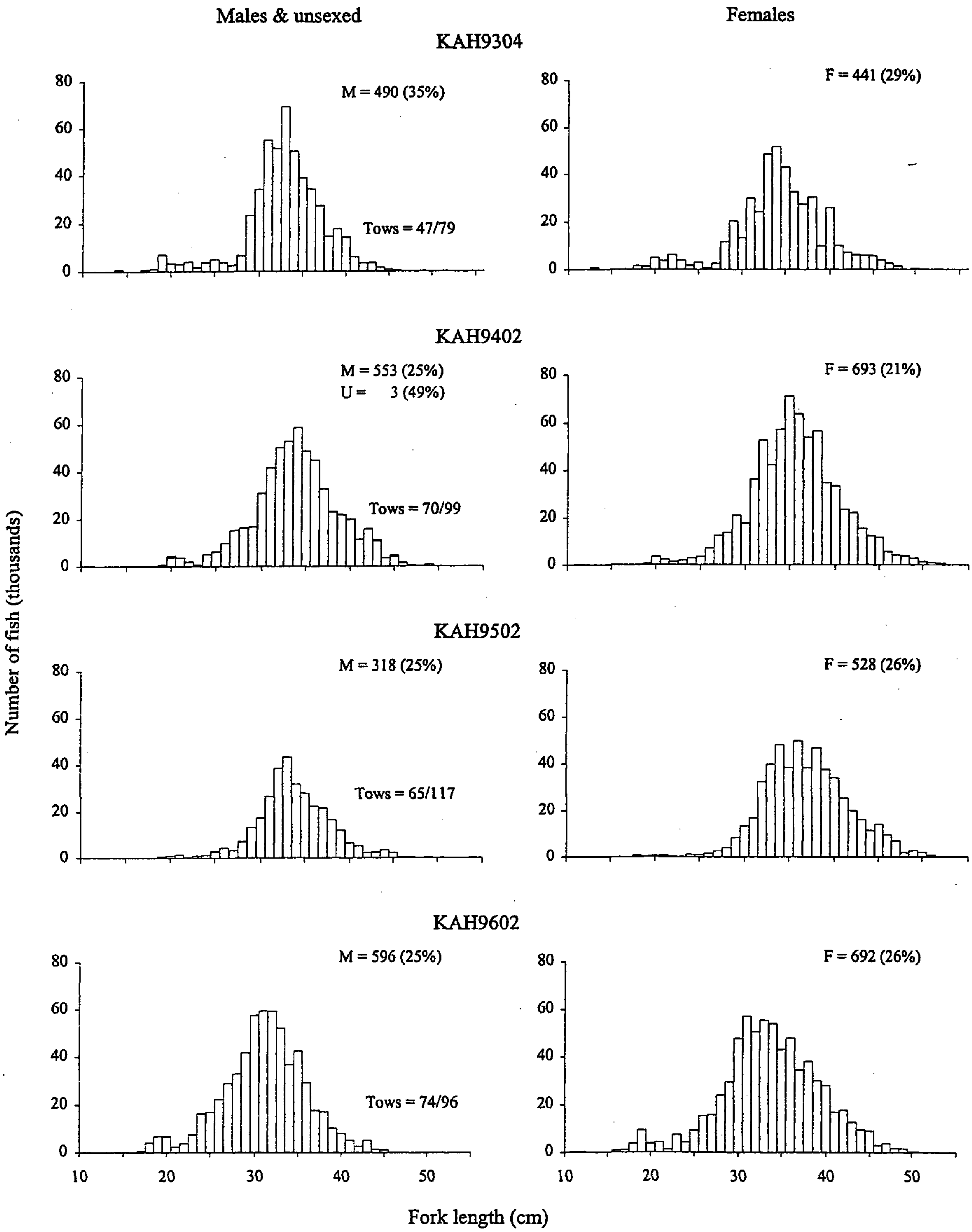

Figure 3: Scaled length frequency distribution of tarakihi on the east coast North Island, 1993–96 with the estimated total number of fish in the population (thousands) (and percentage coefficient of variation). M, number of males; F, number of females; U, number of unsexed fish (shaded); Tows, number of stations where the species was caught/total number of stations (from Stevenson & Hanchet 2000b).

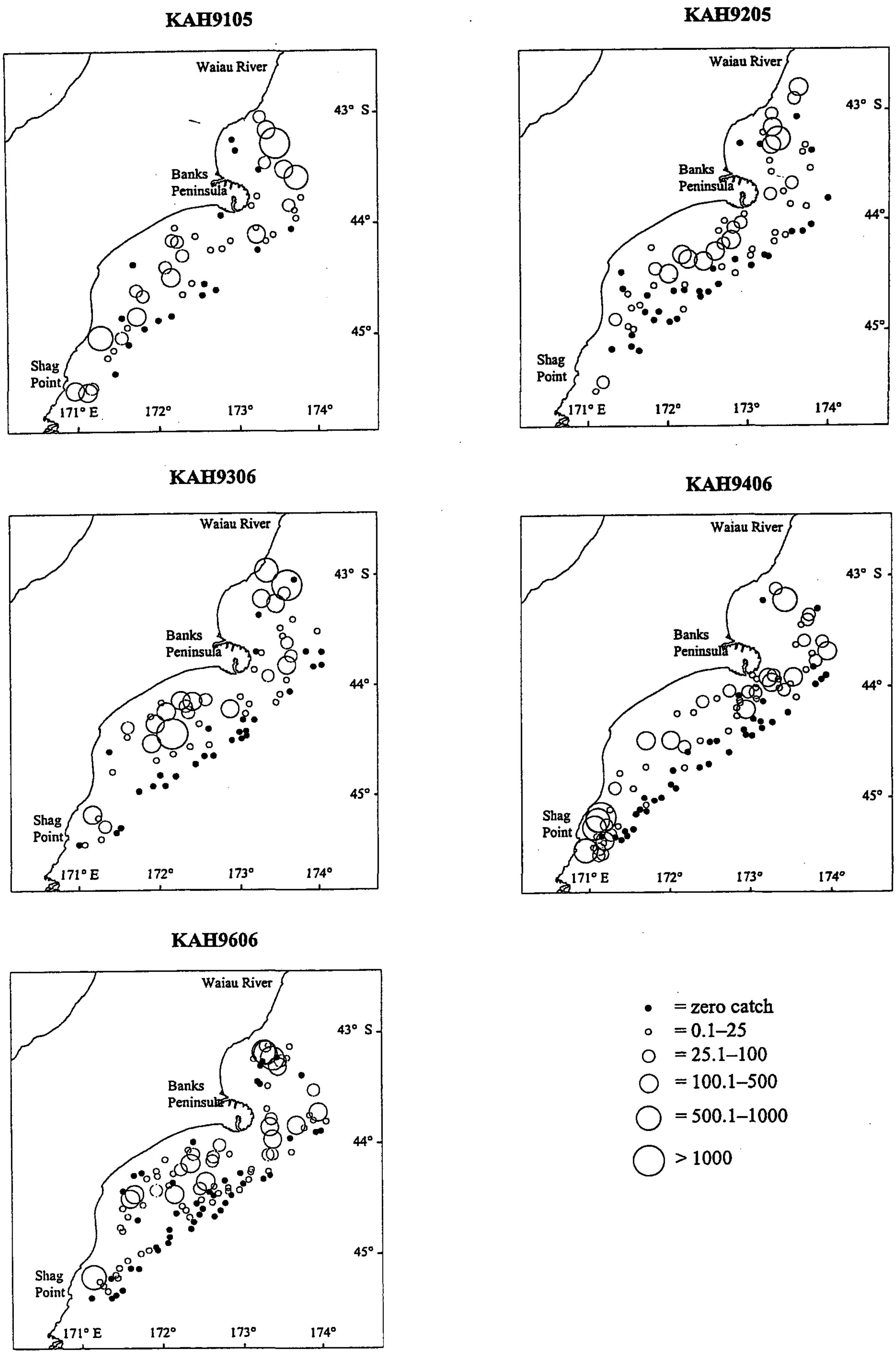

Figure 4: Distribution and catch rates (kg.km^{-2}) of tarakihi on the east coast South Island, 1991–96 (maximum catch rate 5471 kg.km^{-2}).

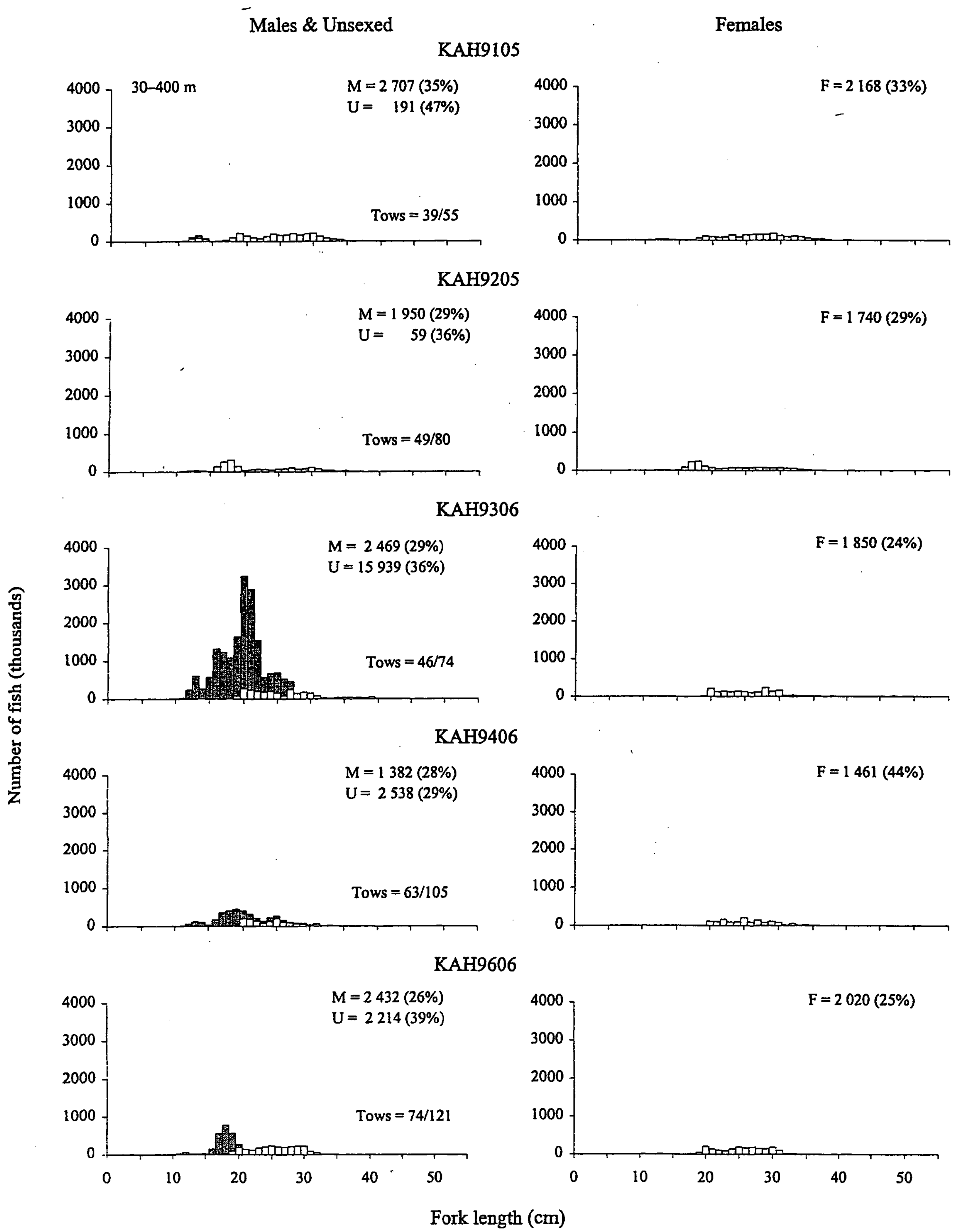

Figure 5: Scaled length frequency distribution of tarakihi on the east coast South Island, 1991–96 with the estimated total number of fish in the population (thousands) (and percentage coefficient of variation). M, number of males; F, number of females; U, number of unsexed fish (shaded); Tows, number of stations where the species was caught/ total number of stations (from Beentjes & Stevenson 2000).

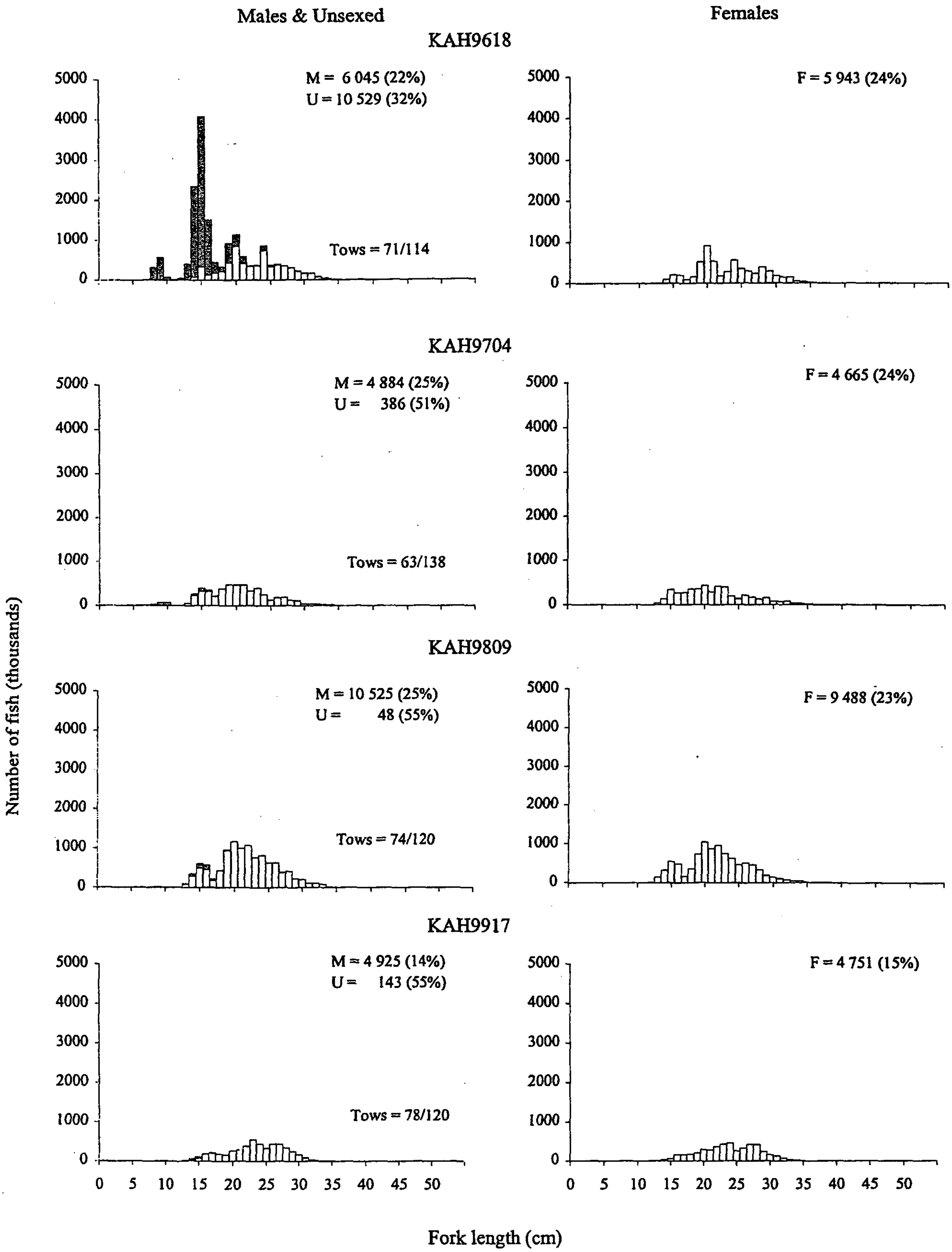

Figure 6: Scaled length frequency distribution of tarakihi on the east coast South Island, 1996/97–99/00 with the estimated total number of fish in the population (thousands) (and percentage coefficient of variation). M, number of males; F, number of females; U, number of unsexed fish (shaded). Tows, number of stations where the species was caught/total number of stations (*from* Beentjes & Stevenson 2001).

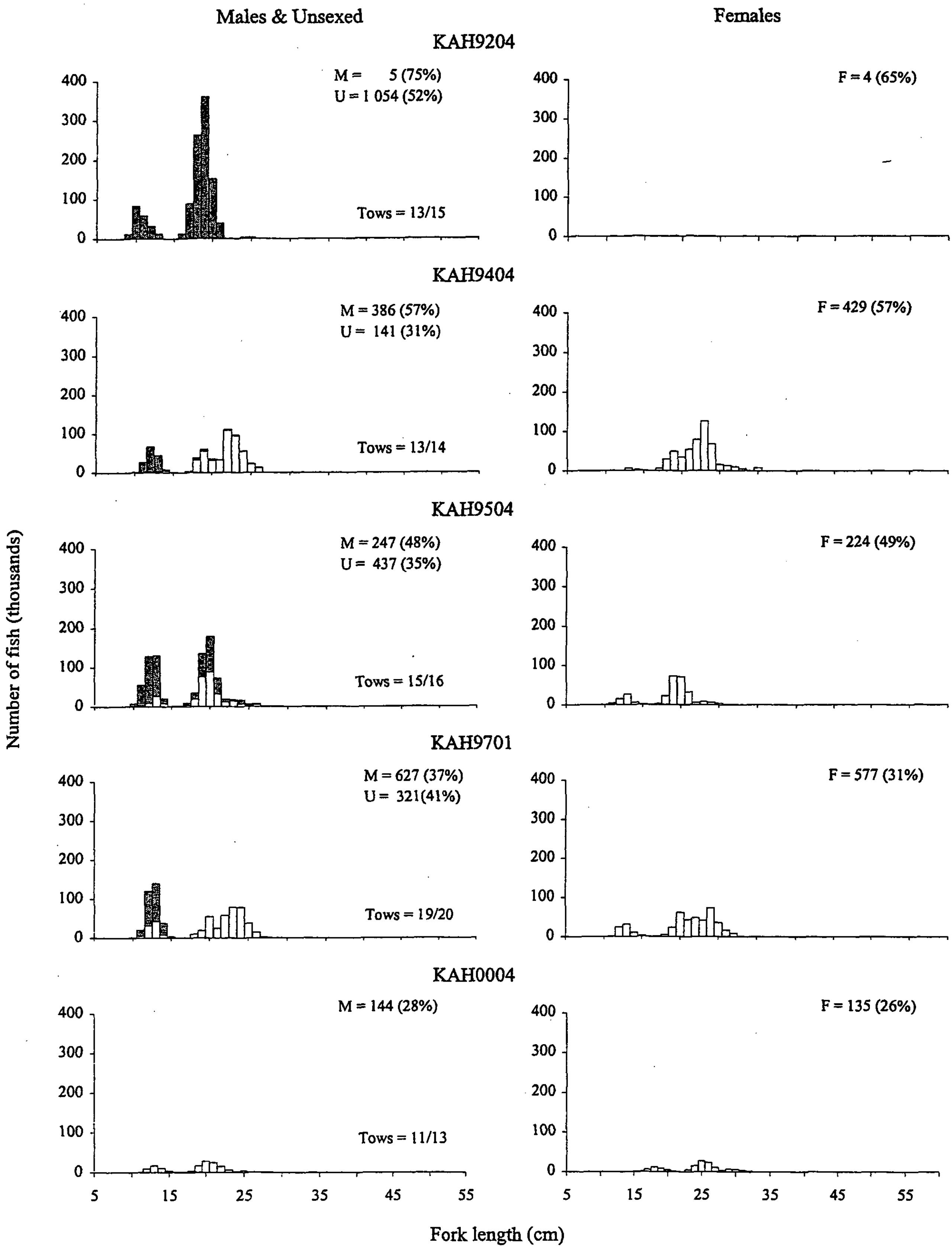

Figure 7a: Scaled length frequency distribution of tarakihi from Tasman and Golden Bays, 1992–2000 with the estimated total number of fish in the population (thousands) (and percentage coefficient of variation). M, number of males; F, number of females; U, number of unsexed fish (shaded); Tows, number of stations where the species was caught/total number of stations (from Stevenson & Hanchet 2000a).

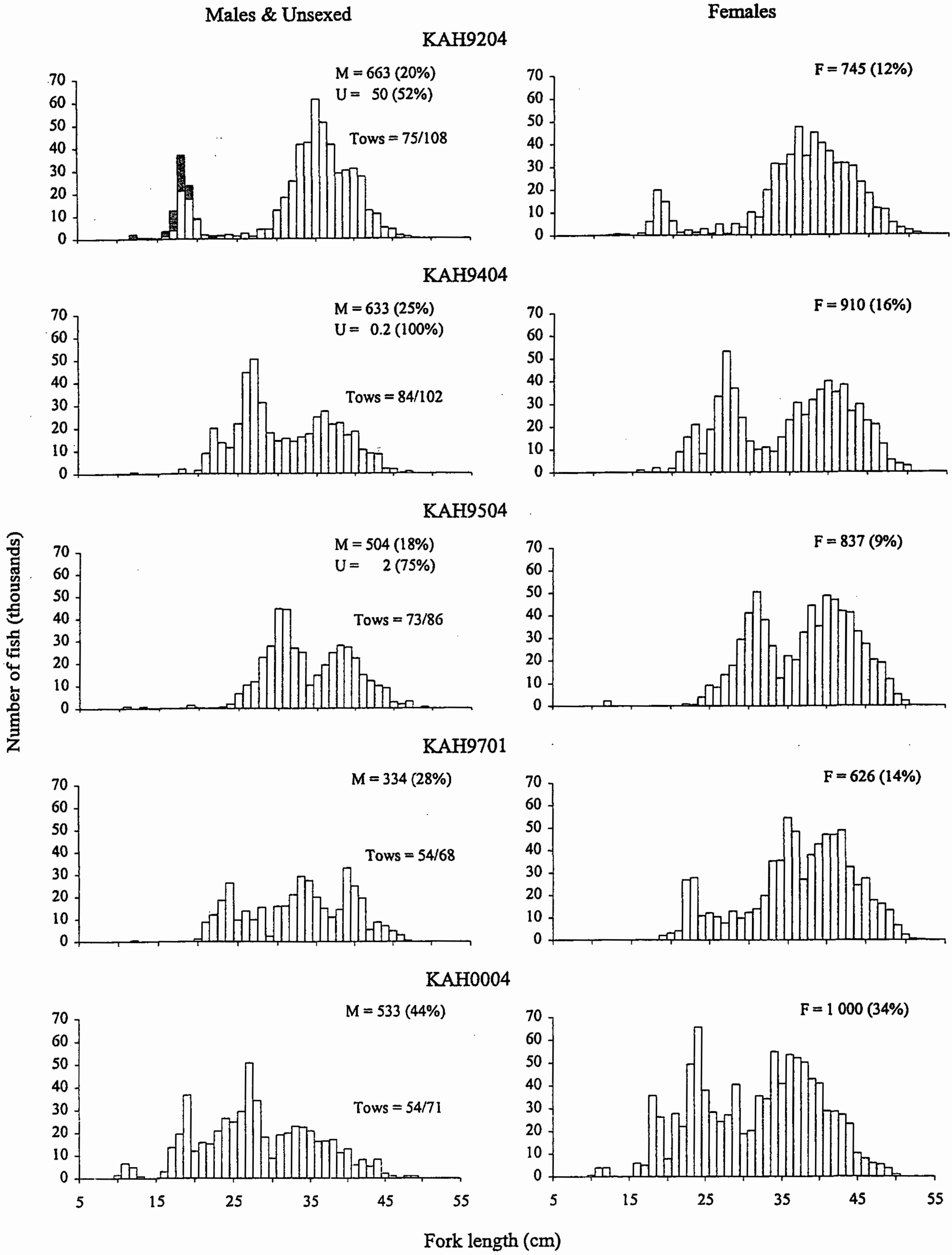

Figure 7b: Scaled length frequency distribution of tarakihi on the west coast South Island, 1992–2000 with the estimated total number of fish in the population (thousands) (and percentage coefficient of variation). M, number of males; F, number of females; U, number of unsexed fish (shaded); Tows, number of stations where the species was caught/total number of stations (from Stevenson & Hanchet 2000a).

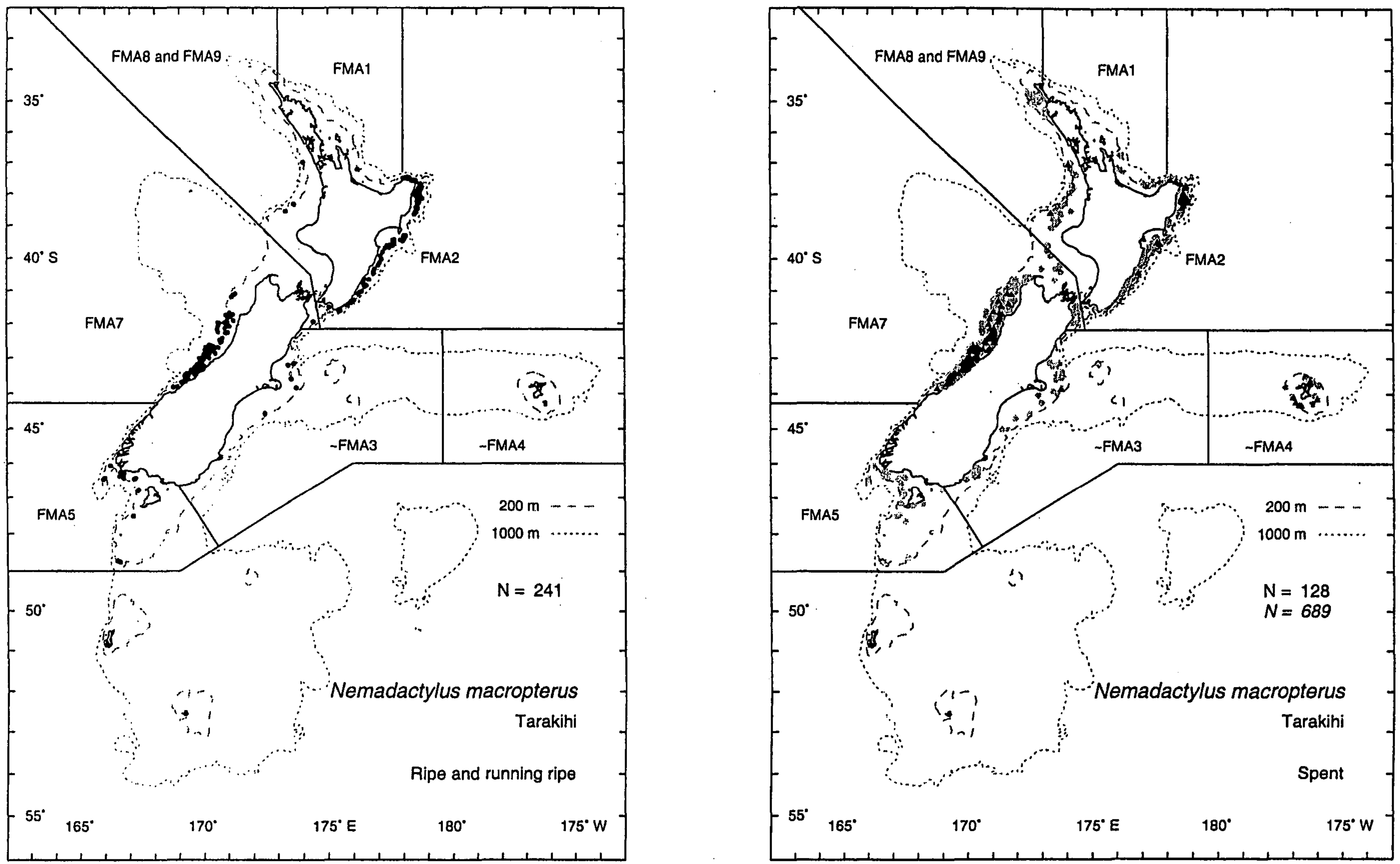

Figure 8a: Distribution of female tarakihi by gonad stage (black) and location of tows where fish were staged (grey). It should be noted that not all surveys are on the *trawl* database, or had reliable staging data, and that in some areas surveys have never been carried out at the time of spawning (from Hurst et al. in press).

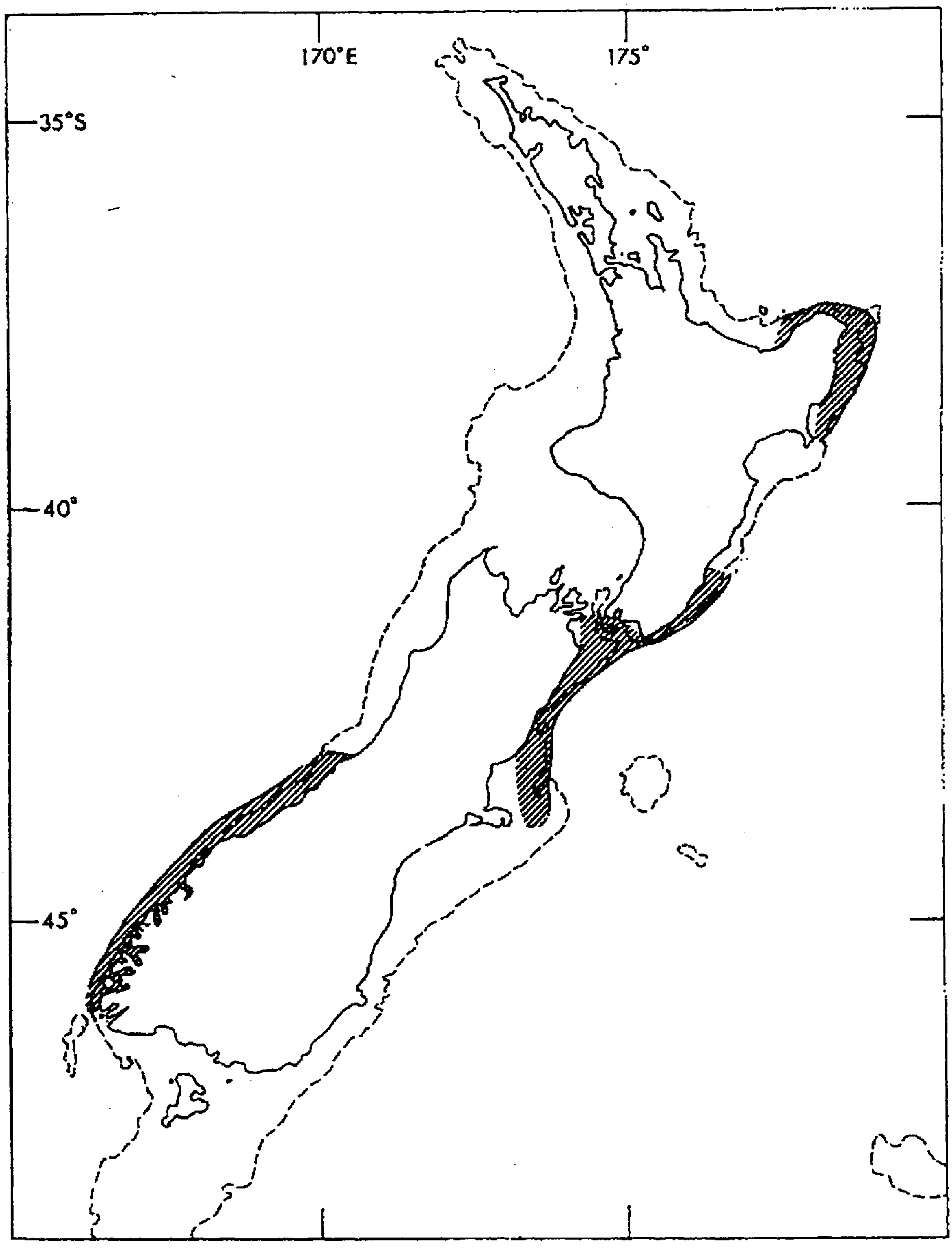

Figure 9: Areas of occurrence of tarakihi eggs (from Robertson 1978).

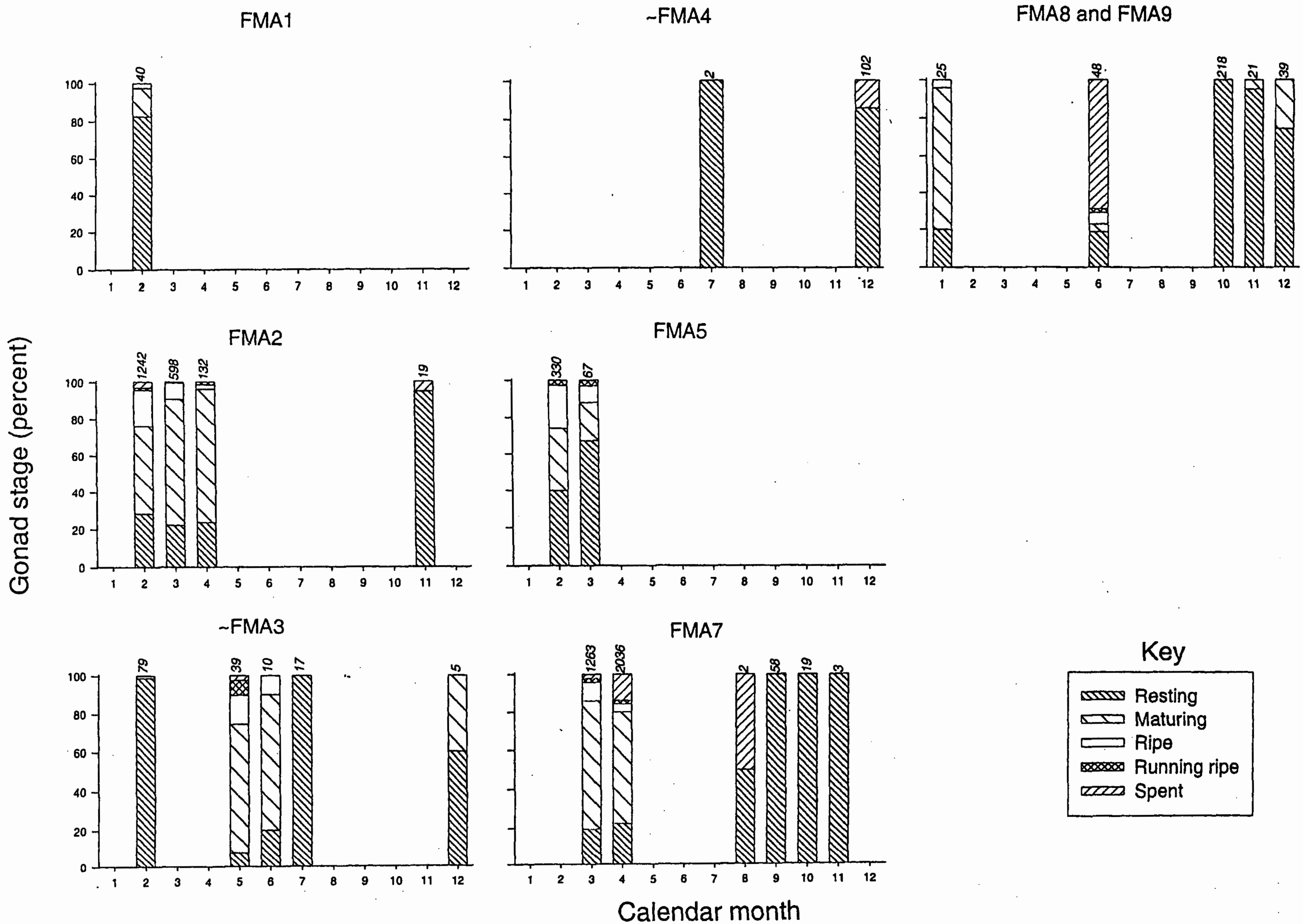

Figure 8b: Female tarakihi gonad stages by area and month. Numbers in italics are the numbers of mature sized fish staged per month (from Hurst et al. in press).

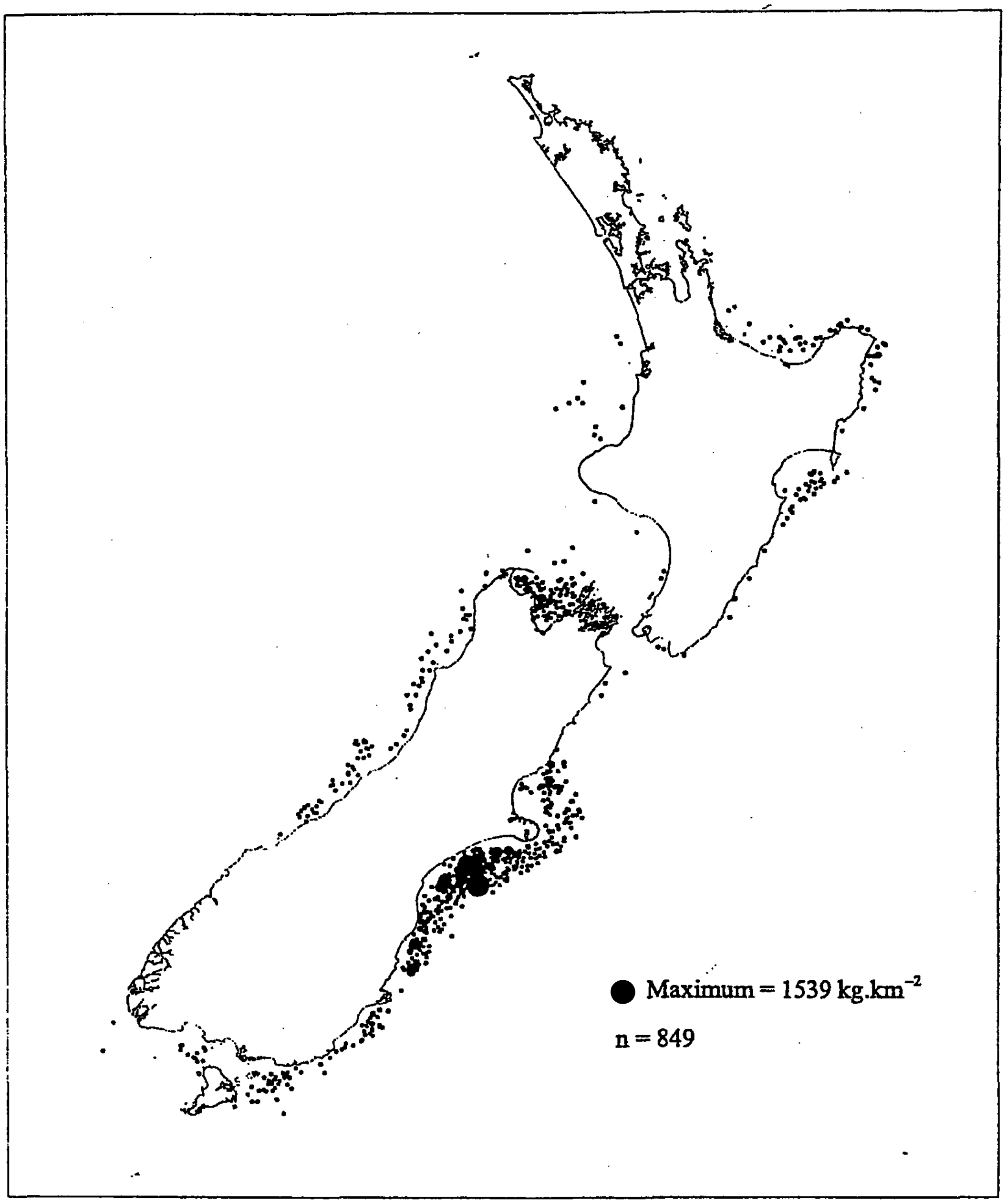

Figure 10: Catch rates (kg.km^{-2}) catching tarakihi ≤ 20 cm (from *Kaharoa* research trawls).

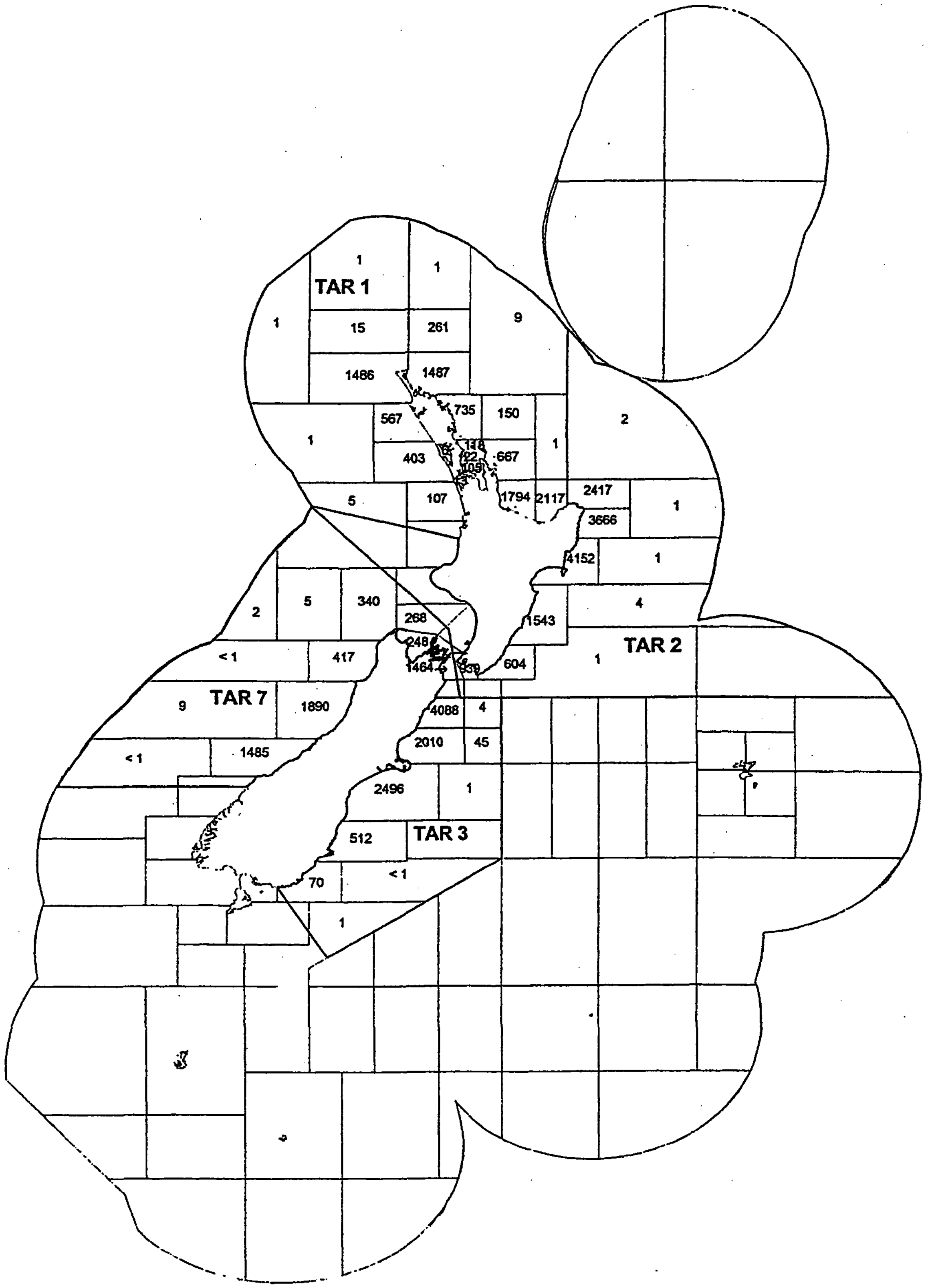

Figure 11: Total catch (t) of tarakihi for 1989–90 to 1998–99 fishing years by statistical area for TAR 1, TAR 2, TAR 3, and TAR 7, with FMA boundaries. Catches for blank areas are not available.