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Review of the inshore trawl survey series along the east coast North Island 1993–96

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Final Research Report

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Executive Summary:

A series of four stratified random trawl surveys was carried out along the east coast of the North Island from Cape Runaway to Turakirae Head at depths from 20 to 400 m by RV *Kaharoa* in 1993–96. Time series trends in the estimated biomass, catch distribution, and population length frequency for the 25 major species are described.

Over the 1993–96 period no species showed a significant change in biomass. The time series also appeared to monitor adult tarakihi and snapper (up to at least 45 cm F.L.) reasonably well. The surveys also appeared to monitor pre-recruit gemfish, although the estimate of biomass by year class is relatively imprecise. However, the main areas of abundance of all three species are adjacent to large areas of foul ground and there is concern that proportions of each stock may be over foul ground and these proportions may vary between years. Trevally were not monitored successfully because of problems with catchability of this species. Biomass estimates for other species fluctuated widely and/or had unacceptably high *c.v.*s.

The ECNI trawl survey time series was discontinued in 1996. Given the concerns with monitoring both target and non-target species noted above, we can find no strong reasons for changing that decision. We therefore, recommend that no new surveys be carried out in the short term. Consideration could be given to carrying out a further short series of surveys in the medium term (10–15 years after the first series was completed). This would provide a more powerful test of the usefulness of the surveys in monitoring more gross changes in abundance of both target and non-target species. Because of the variability between surveys, a minimum of three surveys would be required. For the reasons stated, this would be regarded as a relatively high risk project.

It is also recommended that an ageing study be carried out with two objectives. Firstly, to determine biological parameters for each of the species; and secondly, to determine proportion at age from each of the surveys so that year class strength can be estimated.

Objectives:

Programme Objective:

1. To analyse and document the results of the trawl survey time series using RV *Kaharoa* east coast North Island (1993, 1994, 1995, 1996).

Specific Objectives

1. To determine for all commercial species with a total catch greater than 200 kg in each survey in each survey of a series, trends in the following factors over the trawl survey time series:
   - relative abundance
   - distribution
   - length frequency distribution
   - reproductive condition
   - other relevant biological parameters

2. To make recommendations on the benefits of undertaking future trawl surveys off the east coast of the North Island based on the results of the review. This should include, as a minimum, information on the species for which the surveys are successfully monitoring biomass, and the appropriate frequency of future surveys for each of these species. To help determine which species are being successfully monitored the following analyses will be conducted where data exists:
   - comparison of biomass estimates from the trawl surveys with other available estimates of abundance (*i.e.* CPUE data)
   - examination of the catch-at-age and length frequency data for each trawl survey of the respective time series
   - comparison of the catch-at-age data from the trawl survey with the catch-at-age data from shed sampling.

Methods: See the attached report

Results: See the attached report

Conclusions: See the Executive Summary of this report and the Discussion section of the attached report

Publications: Report attached.

Data Storage: No new raw data was generated by this project.

Introduction

Background

A series of four annual trawl surveys March-April was conducted along the east coast of the North Island at dêpths of 20–400 m from Cape Runaway to Turakirae Head from 1993–96. Each of the surveys have been reported in individual reports with little comparison of between survey results (Kirk & Stevenson, 1996, Stevenson & Kirk 1996, Stevenson 1996a, 1996b). This report compares the estimated biomass, catch distribution, and population length frequency of the 25 major species from the four surveys.

Trawl surveys were initiated following the introduction of the Quota Management System (QMS) in 1986 to provide data on relative biomass and population age and length frequency to assess the sustainability of Total Allowable Commercial Catch (TACC) quotas for some key species. The series was initiated to fill a gap in trawl survey coverage between Cape Runaway and Kaikoura. The survey area supports fisheries of commercial importance, particularly gemfish (*Rexea solandri*), snapper (*Pagrus auratus*), tarakihi (*Nemadactylus macropterus*), and trevally (*Pseudocaranx dentex*) and these species were originally chosen as key target species for the series for optimisation of station allocation.

March-April was initially chosen as the most appropriate time of the year to carry out the series because the timing would avoid spawning aggregations of snapper and allow the series to alternate with the west coast South Island series. Subsequently the surveys were changed to February-March to accommodate other research programmes.

Following the first survey, strata adjacent to the South Island were omitted because the rough bottom condition caused significant damage to the net. New longitudinal boundaries were established at Tolaga Bay, Cape Kidnappers, and Castle Point (Figure 1) following analysis of the distribution of target species and discussions with commercial fishers. Gemfish were no longer treated as a target species in 1994 because the survey did not cover the full depth range of this species (50–600 m). Stevenson & Kirk (1996) discussed problems of availability of adult snapper and trevally to bottom trawl. For 1996, snapper and trevally were also dropped as target species, while pre-recruit gemfish (less than 65 cm T.L.) were included because they were recorded from the previous surveys and information on pre-recruit gemfish was urgently needed.

The trawl surveys were not considered appropriate for monitoring other inshore and middle depth species because of extensive areas of untrawlable ground in the 200–400 m depth range north of Cape Kidnappers and other large areas of foul ground in the 20–50 m depth range. Pre-recruits were poorly sampled by the large (80 mm) codend mesh size.

After the fourth survey in 1996, the series was discontinued because it was considered the survey was not able to adequately monitor trevally, adult snapper and recruited gemfish, and although the survey did appear to be monitoring tarakihi and pre-recruit gemfish, this was not considered to be sufficient to justify continuation of the series. This report reviews the usefulness of this survey for monitoring the target species and other species in the survey area.

Wording of the project objectives varied slightly between surveys but can be summarised as follows:

1. To determine the distribution and develop a time series of relative abundance indices for gemfish, snapper, tarakihi, and trevally in the inshore waters of the east coast of the North Island.
2. To provide parameter inputs for the stock assessment of the target species by collecting and analysing biological data, i.e., length and age frequency, weight, and reproductive condition.

There were three earlier inshore trawl surveys along the east coast of the North Island, by FV *Wesermunde* in 1979 (WES7903) for mixed species (Kerstan & Sahrhage 1980), and GRV *James Cook* in 1984 (JCO8416) and 1985 (JCO8513) which targeted barracouta. Reports were not prepared on the results of the *James Cook* voyages which mainly covered the Bay of Plenty (Neil Bagley, NIWA, Wellington, pers. comm.).

East coast North Island fisheries

The east coast of the North Island supports several fisheries of commercial importance in particular gemfish, snapper, tarakihi, bluenose, alfonsino, and red gurnard. The gemfish fishery (SKI 2) has been in decline for several years and TACC's have been reduced from 1300 t in 1996–97 to 528 t in 1998–99 (Annala et al. 1999). The TACC for the snapper fishery (SNA 2) (252 t since 1992–93) has been consistently over-caught (*see* Annala et al. 1999). There is little information available on recruitment to this fishery other than ageing of commercial catch samples. Tarakihi (TAR 2) form the largest inshore fishery in the survey area. Catches have fluctuated around the TACC of 1633 t since 1990–91 (*see* Annala et al. 1999). Trevally (TRE 2) form a small fishery in the area with a TACC of 241 t and commercial catches fluctuate slightly around that figure.

Hydrology and bathymetry of the east coast North Island

Oceanic water flow off the east coast of the North Island is determined primarily by the East Cape and Southland Currents. Inshore components of the Southland Current flow into Cook Strait and up the Wairarapa coast (Heath 1972), sometimes as far north as Hawke Bay (Ridgway & Stanton 1969). The East Cape current derives from the East Auckland Current flowing around East Cape south past Hawke Bay to meet the northward moving Southland Current, generally about Cape Turnagain (Heath 1975, Chiswell & Roemmich 1998). The source of inflow into Hawke Bay is usually from the East Cape Current and comprises a westward flow that splits into two large eddies flowing north and south (Bradford et al. 1980). The source of the inflow into Hawke Bay depends on the northward extension of the Southland Current. Water in Hawke Bay is usually less saline and cooler than open shelf water (Ridgway & Stanton 1969).

The continental shelf is relatively narrow, (less than 20 km wide) between East Cape and Castle Point, except in Hawke Bay (about 70 km wide), which is a shallow, semi-enclosed bay. South of Castle Point the shelf is less than 10 km wide. The shelf edge is very irregular with many reef systems and submarine canyons, and it slopes steeply into the Hikurangi trough and Kermadec Trench which run parallel to the coast.

Methods

Survey area and design

The survey area included the east coast of the North Island from Cape Runaway to Turakirae Head (Figure 1). The surveys used a two-phase stratified random design (*after* Francis 1984).

The first survey (1993) had a total of 18 strata with latitudinal boundaries at Cape Runaway, Portland Island, Cape Turnagain, and Turakirae Head along the North Island, and Port Underwood, the Clarence River mouth and Kaikoura along the South Island. (Kirk & Stevenson 1996). Difficulties with net damage resulted in elimination of the strata along the east coast of the South Island (strata 1–

6). For the remaining surveys (1994, 1995, & 1996) a total of 15 strata were used with new longitudinal boundaries at Tolaga Bay, Cape Kidnappers and Castle Point (*see* Figure 1).

A total of up to 84 phase one stations were planned for each survey, with a minimum of 3 stations per stratum. Phase 1 stations were allocated to minimise the variance of the expected catch rates of the target species, where the expected catch rates were assumed to be the combined catch rates from the preceding survey, (in 1993, the total stratum area was used). Phase two stations were allocated to improve the precision of the biomass estimates for the target species from phase 1. Before each survey began sufficient stations to cover both first and second phase within each stratum were randomly generated for each stratum separately using the computer programme rand_stn v2.1 (*see* Vignaux 1994). Stations were required to be a minimum of 3 n mile (5.6 km) apart.

Because of the difficulty in locating suitable trawl positions during the 1993 survey, previously successful stations were repeated for 1994–96. If there were insufficient previous station positions to fill the required number, additional stations were randomly generated and checked to ensure the required minimum distance was maintained.

Surveys were optimised for snapper, tarakihi, and trevally in 1994 and 1995, and for pre-recruit gemfish (less than 65 cm FL) and tarakihi in 1996.

Stratification allowed three depth ranges (20–100, 100–200, and 200–400 m) which represent inshore, shelf edge and continental slope habitats. Strata were digitised from bathymetric charts using depth contours as boundaries. Bathemetry was updated during each survey and recorded on the survey charts, improving knowledge of foul ground and ensuring that stations were allocated to the proper depth range.

Vessel and gear specifications

RV *Kaharoa*, a 28 m stern trawler with a beam of 8.2 m, a displacement of 302 t, and engine power of 522 kW, is capable of trawling to depths of 500 m. The high-lift bottom wing net used during the surveys was designed and constructed specifically for the soft substrate in the survey area. The net design was based on a design used by commercial fishers in the area and fitted with an 80 mm (inside measurement) knotless codend. Gear parameters and net plan are given in Appendix 1.

Before the 1995 survey, *Kaharoa* was equipped with new trawl doors based on the design of the old doors but heavier (Appendix 2). For 1993 and 1994, doorspread was estimated using the method of Koyama (1974) but for 1995 and 1996 Scanmar sensors fitted to the new doors enabled doorspread to be measured directly. Gear trials in March 1996 provided comparisons between the performance of the old and new doors and more accurate estimates of doorspread using the old doors (*see* Stevenson 1996b, appendix 4a).

When Scanmar recordings were available, doorspread was recorded every 10–15 min and averaged over the tow. Headline height was recorded from a netsonde in 1993 and 1994 and by the Scanmar sensor in 1995 and 1996 and averaged over the tow. Sea surface temperature was recorded from a hull mounted sensor. Bottom temperatures were recorded in 1995 and 1996.

Other environmental conditions regularly recorded included wind speed and direction, sea state and colour, barometric pressure, and swell height and direction.

Catch and biological sampling

Each catch was sorted on deck by species and weighed on electronic motion-compensating Seaway scales to the nearest 0.1 kg. Each species' weight was recorded separately for all finfish (excluding rattails), squid, bivalves and crustaceans (except crabs). Rattails and crabs were not sorted to species level because of time constraints.

Length to the nearest whole centimetre below actual length, and sex (where possible) were recorded for all ITQ species, either for the whole catch or a randomly selected sub-sample of up to 200 fish per tow. Biological data of individual fish including one or more of the following, weight to the nearest 10 g, reproductive condition, and otoliths, were collected from a sample of up to 20 fish per tow for the target species. Additional biological data for blue moki, giant stargazer, John dory, kahawai, red cod, red gurnard were collected from at least one survey in the series. Biological samples were selected non-randomly from the random length frequency samples to ensure that a full size range of each species was sampled.

Tagging

School shark that were likely to survive were tagged during all four surveys. Each fish was measured, sexed, tagged, and released within minutes of being removed from the codend.

Data analysis

Relative biomass estimates and *c.v.s* were estimated by the area-swept method described by Francis (1981, 1989) using the Trawlsurvey Analysis Program (Vignaux 1994). Doorspread values for the 1993 and 1994 surveys were based on the doorspread:depth relationship calculated from the 1996 gear trials (Stevenson 1996b), whereas values for 1995 and 1996 were measured directly. Only tows with acceptable performance (gear codes 1 & 2) were used for biomass estimates.

For analysis of 1993 data, strata 1–6 were excluded to maintain comparability. In addition, areas for strata 14 & 18 were reduced to 665.16 km^2 and 762.9 km^2 respectively because from 1994, the 200–400 m depth range from Tolaga Bay to Cape Kidnappers was excluded from the survey area, because there was no trawlable ground.

The following assumptions were made for standardising the time series:

1. The area swept during each tow equalled the distance between the doors multiplied by the distance towed.
2. Vulnerability was 1.0. This assumes that all fish in the volume swept were caught and there was no escapement.
3. Vertical availability was 1.0. This assumes that all fish in the water column were below the headline height and available to the net.
4. Areal availability was 1.0. This assumes that the fishstock being sampled was entirely within the survey area at the time of the survey.
5. Within the survey area, fish were evenly distributed over both trawlable and untrawlable ground.

Although these assumptions are unlikely to be met, they were used for the original analyses of the surveys and have been retained for this analysis.

A combined biomass and length frequency analysis was used for species for which size class biomass estimates were required, and for deriving population length frequencies. The length-weight coefficients used are given in Appendix 3. The coefficients were calculated from data collected during a survey when possible. When data were unavailable coefficients were chosen from those available on the *trawl* database and a selection made which best matched the size range of the fish used to calculate the coefficients and the sample size range. All population length frequencies were scaled by the percentage of catch sampled, area swept, and stratum area using the Trawlsurvey Analysis Program.

Linear regression analysis was used to examine whether trends in biomass were statistically significant. The slope of the regression was considered to be significantly different from zero if P was equal to or less than 0.05.

Results

Stations surveyed and catches

The number of completed stations and station density for each survey are given in Table 1. The number of phase 2 stations depended on the time remaining after the completion of phase 1.

Mean catch rate per station varied from a low of 485 $kg.km^2$ in 1993 to a high of 1305 $kg.km^2$ in 1996 (*see* Table 1).

Biomass and precision

Estimates of biomass and *c.v.s* for the 25 major commercial species and all species combined are given in Table 2. Barracouta was the most abundant species caught during the surveys and the only species with an estimated biomass greater than 1000 t in each survey. The five most abundant species (in order of abundance) and the percent of total biomass in each survey were: 1993, barracouta, hoki, red gurnard, spiny dogfish and tarakihi, 34%; 1994, barracouta, hoki, red cod, frostfish, and tarakihi. 65%; 1995, hoki, barracouta, tarakihi, spiny dogfish, and frostfish (*Lepidopus caudatus*), 48%; 1996, barracouta, Chilean jack mackerel (*Trachurus murphyi*), N.Z. jack mackerel (*T. novaezelandiae*), red cod, and hoki, 42% (Table 2).

Estimates of biomass for gemfish decreased from 323 t in 1993 to 190 t by 1996. Snapper biomass decreased sharply from 1993 to 1994 and then increased slightly to 1996. Tarakihi biomass fluctuated from 700 t to 1100 t, averaging about 900 t. The trevally biomass decreased from 331 t in 1993 to a low of 140 t in 1996. Barracouta biomass was consistent for three of the four surveys at about 2000 t but increased to 7000 t in 1994. The biomass of a number of other species (notably the three jack mackerels, red cod, and red gurnard) also fluctuated considerably between years. The biomass estimate for all species combined was highest for 1996 mainly because of large catches of jack mackerel which increased their total biomass estimates from 570 t to 4474 t. The biomass estimates for all species combined were considerably lower in 1993 and 1995 than in 1994 and 1996.

The range of *c.v.s* for the original target species were: gemfish, 30–37%,; snapper, 13–32%; tarakihi, 15–32%; and trevally, 19–35%. The mean *c.v.* for the top 25 species remained virtually unchanged for all years (30–38%), however the *c.v.* for all species combined increased markedly from 1995 to 1996 (14% to 24%). No species had *c.v.s* less than 20% for all years, whilst only rig, rough skate, and school shark had *c.v.s* of 30% or less each year.

Biomass trends

Changes in biomass estimates are plotted in Figure 2. No species showed a statistically significant trend in biomass. The strongest trends were for declining biomass estimates of gemfish and John dory ($P = 0.11$). The reliability of these trends is limited by the small sample size of only four surveys.

Changes in total biomass and recruited biomass are shown for 11 species in Figure 3. Where total and recruited biomass are the same indicates that most of the catch was of commercial size. There were no statistically significant trends in increasing or decreasing recruited biomass among the species examined. Pre-recruit biomass was a larger portion of total biomass for rig than for any other species. Pre-recruit biomass was a large proportion of total biomass for red cod in 1994, however, this did not lead to an increase in total biomass.

Biomass estimates by year classes of 8 species are shown in Figure 4. Strong and weak year classes for gemfish can be followed as they progress from one year to the next. Also, for silver warehou, strong 0+ year class in 1994 can be followed to 1995 as the strongest 1+ age group for any of the surveys. The 0+ age group for *T. declivis* in 1994 can be tracked through to 1+ in 1995 and 2+ in 1996, but the relative strength of this year class was not determined. The youngest age class for all species probably have low vulnerability to capture by the large codend mesh size used.

Water temperature and catch rates

Surface temperatures were collected for all surveys and showed that in 1995, the mean temperature was warmer by 1–2 C° than in other years (Figure 5a). Bottom temperatures were recorded in 1995 and 1996 and a decreasing trend from north to south and also decreases with depth.

Satellite derived sea surface temperatures (SST) were extracted from the NIWA SST database for locations off Tolaga Bay (38.5° S, 178.5° E) and Hawke Bay (39.5° S, 177.5° E). Mean monthly SST for 1°x1° square grids (= resolution) that included the above locations were used to provide SST for the period 1993–1996. Mean SST for March 1993–1996 and mean surface and bottom temperatures recorded during the survey are shown in Figure 6 (top). The trend in SST shows little difference between Tolaga Bay and Hawke Bay except that the temperatures were warmer in the north. Mean survey recorded surface and bottom water temperature displays the same trends as SST in temperature and confirms that 1993 was the coolest year, after which water temperature increased to a maximum in 1995 and cooled slightly in 1996. The difference in SST between 1993 and 1995 was about 2 C°.

Total biomass of all species has been plotted against Tolaga Bay SST in Figure 6 (bottom). The lowest total biomass estimates correspond with the temperature extremes.

Distribution and length frequency

The distribution and catch rates ($kg.km^2$) for the major species are shown in Figure 7 and population length frequency distributions in Figure 8. Data presented for 1993 included only strata along the North Island.

Arrow squid

Arrow squid (*Nototodarus sloanii & N. gouldi*) were distributed throughout the survey area in low numbers and were caught at between 78% and 88% of all stations (Figure 7a). Catch rates were lowest in 1993 and resulted in the low biomass that year (*see* Table 2). Highest catch rates were generally south of Mahia Peninsula. There was a higher percentage of squid under 20 cm length in 1993 and 1994 than in 1995 (Figure 8a).

Barracouta

Barracouta were caught throughout the survey area with the highest catch rates in the 100–200 m depth range at between 89% and 96% of stations (Figure 7b). The large increase in barracouta biomass in 1994 came mainly from the south of the survey area and comprised fish of all sizes, but the 35–45 cm (1+ fish) predominated. There was considerable difficulty determining biomass at age from the length frequency distributions without otoliths particularly because of bimodality in some of the younger age groups. There was little evidence of follow through of strong year classes (e.g. the strong 1+ in 1994) (Figure 8b).

Blue moki

Blue moki were mainly caught at depths less than 50 m with the highest catch rates south of Castlepoint (Figure 7c). They were caught at between 9% and 18% of stations. No fish less than 40 cm F.L. were caught and the low numbers of fish prevented distinguishing separate year classes.

Chilean jack mackerel

Chilean jack mackerel were caught mainly at depths greater than 100 m throughout the survey area. Highest catch rates were north of Cape Kidnappers (Figure 7d). A single very large catch of 5 t off Tolaga Bay in 1996 (*see* Figure 7d) is reflected in the high biomass for that year (*see* Table 2, Figure 2). They were caught at between 18% and 46% of stations. Most Chilean jack mackerel caught were adults. Juveniles (less than 20 cm) have not been reported from New Zealand before and may have been misidentified N.Z. jack mackerel (*T. declivis*) (Figure 8d).

Frostfish

Frostfish were caught throughout the survey area mostly in depths greater than 50 m at between 65% and 75% of all stations (Figure 7e). Frostfish were not measured.

Gemfish

Gemfish were caught all along the east coast North Island in depths greater than 100 m (Figure 7f). They were caught at between 12% and 45% of stations. The length frequency distributions show the progression of year classes between surveys (Figure 8e). A mode at 32–39 cm with a peak at 37 cm in 1993 can be tracked to a modal peak at 48 cm in 1994, 57 cm in 1995, and about 65 cm in 1996. This corresponds to the 1991 year class which was estimated to be a strong year class by Hurst *et al.* (1999). The preceding and following year classes were weaker.

Giant stargazer

Giant stargazer were caught throughout the survey area with the highest catch rates at depths between 100–200m on the continental slope south of Mahia Peninsula (Figure 7g). They were caught at between 12% and 40% of stations. Not enough giant stargazer were caught to be able to determine age groups or year class strengths from the length frequency distributions (Figure 8f).

Hapuku

Hapuku were caught mainly south of Castlepoint at depths greater than 50 m (Figure 7h). They were caught at between 22% and 34% of stations. Most hapuku caught were less than 75 cm total length but too few were caught to determine age groups or year class strengths (Figure 8g).

Hoki

Hoki were caught throughout the survey area with the highest catch rates in depths greater than 100 m mainly south of Cape Kidnappers (Figure 7i). They were caught at between 26% and 35% of stations. The length frequency distributions showed a strong 0+ age group in 1994 with a modal peak at 18 cm but the age group can not be tracked through to 1995 or 1996 (Figure 8h).

Jack mackerel (*T. declivis*)

This species of jack mackerel was caught mainly in low numbers throughout the survey area in depths of 100–200 m (Figure 7j). They were caught at between 27% and 45% of stations. A single large catch of 1.6 t in 1996 comprising adults resulted in the high biomass estimate for that year (*see* Table 2). In addition, greater numbers of juveniles were caught in 1996 throughout the survey area. There was a 0+ mode at 9–15 cm in 1994 with a peak at 10 cm. This age group can be tracked through the length frequency distributions to 1+ with a peak at 17 cm in 1995 and a 2+ peak at 23 cm in 1996. (Figure 8i). Adult fish formed a broad mode from about 40 to 55 cm.

Jack mackerel (*T. novaezelandiae*)

N.Z. jack mackerel were caught throughout the survey area in depths less than 200 m (Figure 7k). They were caught at between 61% and 78% of stations. There was a large increase in biomass in 1996 but, unlike the other jack mackerel species, the increase was the result of larger catches in most areas. Age group modes were most evident in 1997 with peaks at 5, 12, and 22 cm representing the 0+, 1+, and 2+ year classes (Figure 8j). Similar but weaker modes were apparent for the 1+ and 2+ age groups in 1993 and 1994. There was a broad mode of adult fish at 30–40 cm that was composed of multiple year classes.

John dory

John dory (*Zeus faber*) were caught throughout the survey area at depths less than 100 m with the highest catch rates in Hawke Bay (Figure 7l). They were caught at between 35% and 54% of stations. In each of the length frequency distributions, there was a variable amount of fish of the 0+ age group at 15–30 cm (Figure 8k). There was a broad mode from about 35 cm to 50 cm but year classes can not be tracked through the surveys.

Kingfish

Kingfish (*Seriola lalandi*) were caught in low numbers throughout the survey area mostly at depths less than 200 m with the highest catch rates north of Tolaga Bay (Figure 7m). They were caught at between 11% and 39% of stations. Most fish were less than 80 cm length but it was very difficult to discriminate any modes or year classes because of the low numbers caught (Figure 8l).

Ling

Ling were caught mainly south of Cape Kidnappers at depths greater than 50 m with the highest catch rates south of Castlepoint.(Figure 7n). They were caught at between 36% and 67% of stations. Only small numbers were caught and no clear age groups or strong year classes were visible in the length frequencies.

Red cod

Red cod were caught throughout the survey area with the highest catch rates usually south of Tolaga Bay (Figure 7o). They were caught at between 61% and 68% of stations. The length frequency distribution for 1994 and 1996 were dominated by 1+ fish (25–40 cm) (Figure 8n). There is no evidence of younger or older fish of these year classes.

Red gurnard

Red gurnard were caught throughout the survey area at depths less than 100 m with the highest catch rates usually north of Cape Kidnappers (Figure 7p). They were caught at between 54% and 69% of stations. The length frequency distributions comprised broad modes with no clear age groups and there was no evidence of year classes progressing through the surveys (Figure 8o).

Rig

Rig were caught throughout the survey area at low rates mostly at depths less than 100 m (Figure 7q). They were caught at between 32% and 62% of stations. The length frequency distributions did not show any consistent modes and, because of the low numbers caught, modal peaks may not accurately represent actual frequency (Figure 8p). Males consistently outnumbered females.

Rough skate

Rough skate were caught throughout the survey area with the highest catch rates along the inner continental shelf at depths less than 200 m (Figure 7r). They were caught at between 39% and 69% of stations. Rough skate were measured only in 1996 and therefore, length frequencies are not shown.

School shark

School shark were caught throughout the survey area but most consistently north of Cape Kidnappers at depths greater than 50 m (Figure 7s). They were caught at between 26% and 64% of stations. The low numbers of fish caught makes it difficult to identify modes or track year classes between surveys (Figure 8q).

Sea perch

Sea perch where caught throughout the survey area with the highest catch rates south of Cape Kidnappers on the shelf edge in depths of 200–400 m (Figure 7t). They were caught at between 30% and 58% of stations. Sea perch were not measured.

Silver warehou

Silver warehou were caught mostly south of Mahia Peninsula at depths greater than 50 m with the highest catch rates south of Castlepoint (Figure 7u). They were caught at between 9% and 24% of stations. Although only small numbers of fish were caught, juvenile modes of 0+ fish (11–21 cm) were identified in 1994 and 1996 and of 1+ fish (25–31 cm) in 1994, 1995, and 1996 (*see also* Horn & Sutton 1995). There appears to be a good correlation between estimates of 0+ and 1+ fish for the period of the surveys.

Snapper

Snapper were mostly caught north of Cape Kidnappers in depths less than 100 m with the highest catch rates north of Tolaga Bay (Figure 7v). They were caught at between 31% and 53% of stations. Although reasonable numbers of fish were caught, modes were not particularly easy to identify and were difficult to follow between years (Figure 8s). The two main modes in males in 1993 at about 30 and 35 cm, appear to progress through to about 34 and 42 cm in 1996. For females, the main mode in 1994 at 31 cm appears to progress through to 35 cm in 1996. Confirmation that these modes comprise year classes, and confirmation of actual age of these fish, could only be done by ageing the otoliths. Preliminary ageing of the 1993 survey otoliths suggests that fish from 26–30 cm were mainly 4–5 years old and fish at about 36 cm were between 7–9 years old (NIWA unpublished data). It is known that larger snapper are not particularly vulnerable to bottom trawl (Drury & Hartill 1993) and fish smaller than about 20 cm fork length did not appear to be vulnerable to the codend mesh size used during the series.

Spiny dogfish

Spiny dogfish were caught throughout the survey area with the highest catch rates at stations south of Castlepoint in depths of 100–200 m (Figure 7w). They were caught at between 83% to 96% of stations. Spiny dogfish were measured only in 1996 and therefore, length frequency distributions are not shown.

Tarakihi

Tarakihi were caught throughout the survey area with the highest catch rates north of Tolaga Bay and they were caught at between 56% and 77% of stations (Figure 7x). The length frequency distributions were dominated by a broad mode for adult fish from about 30–45 cm (Figure 8t). Modal peaks varied slightly between years but were at about 32–34 cm for males and 34–36 for females except in 1996 when the female peak was at 31 cm and there were fewer fish over 40 cm length. There were minor modes at about 17–22 cm (probably the 2+ age group) with a peak at 19 or 20 cm. It was difficult to track progression of year classes because of the merging of modes and the lack of ageing data.

Trevally

Trevally were caught mostly north of Castlepoint with the highest catch rates north of Cape Kidnappers (Figure 7y). They were caught at between 32% and 50% of stations. The strongest mode in the length frequency distributions was in 1993 at 24–32 cm for males and 27–31 cm for females, with peaks at 29 cm for both sexes (Figure 8u). There was another strong mode in 1995 at 30–39 cm with a peak at 35 cm but there was no corresponding strong mode in 1994 at an intermediate length so, without ageing data, it was not certain if these modes represent the same year class. There was a steady decline in the number of larger fish (greater than 45 cm) from 1993 to 1996 (*see* Figure 8u).

Reproductive condition

The percentage of mature fish at each gonad stage for giant stargazer, red cod, red gurnard, and tarakihi is shown in Table 4.

Male gemfish gonads were mostly in the resting or maturing stages with not more than 4% maturing and none running ripe or spent. Female gonad development was also mostly resting or maturing, however, in 1993, 16% of were spent. Development was consistent with gemfish spawning in early winter (*see* Annala *et al.* 1999). Gemfish gonads were not staged in 1995.

Male snapper gonads were mostly in the resting or maturing stages with 4–23% mature and not more than 5% running ripe and spent. Females showed less variation with 88–100% resting and maturing. Gonad development was consistent with snapper spawning in summer (*see* Annala *et al.* 1999).

Tarakihi male gonads showed considerable variation in maturity between years. For 1993, 1994, and 1996 most males were in the maturing and mature stages but in 1995, 36% were running ripe and 12% spent. Female gonad development was more consistent with 60–97% resting or maturing. In 1994, there were a further 35% of females in the mature stage. Very few females were found to be running ripe or spent. Gonad development was consistent with tarakihi spawning in autumn (*see* Annala *et al.* 1999).

A higher percentage of trevally were at later stages of development than any of the other target species. For males, 11–18% were maturing whilst most were in the mature or running ripe stages. Amongst females, gonad development was mainly in the maturing and mature stages. In 1993, there were more fish in the resting stage than in any other year. This may be because the survey was run one month later in the year than in 1994–96 and trevally are known to spawn in summer (*see* Annala *et al.* 1999).

Objective 2

To make recommendations on the benefits of undertaking future trawl surveys off the east coast of the North Island based on the results of the review. This should include, as a minimum, information on the species for which the surveys are successfully monitoring biomass, and the appropriate frequency of future surveys for each of these species. To help determine which species are being successfully monitored the following analyses will be conducted where data exists:

- comparison of biomass estimates from the trawl surveys with other available estimates of abundance (*i.e.* CPUE data)
- examination of the catch-at-age and length frequency data for each trawl survey of the respective time series
- comparison of the catch-at-age data from the trawl survey with the catch-at-age data from shed sampling.

Background

The usefulness of trawl survey time series depends on a number of factors such as the length of the time series, the variance of the biomass indices, the availability and catchability of the stock to the survey technique and the availability of appropriate stock assessment models to utilise the data. The information obtained from the trawl survey series could be formally assessed using a quantitative approach such as that advocated by Cordue (1998). However, for the target species of this survey there are no current stock assessments which could easily be used to evaluate the time series. Instead, other less formal ways of identifying the benefits need to be investigated.

Recommendations on the benefits of undertaking future trawl surveys on the east coast of the North Island are addressed by considering the following questions:

1. Does the survey design adequately cover the known distribution of the target species?
2. Are the levels of precision adequate to monitor trends in biomass?
3. Are there any significant trends in biomass and how might they be interpreted?
4. Have there been trends in the spatial patterns of the species abundance?
5. How do changes in abundance indices from the trawl surveys compare with other available estimates of abundance?
6. Are there trends detectable in the fish size frequency and age composition data?

7. What frequency of surveys would be required to monitor the biomass of the key species through time?
8. What are the benefits of developing time series of age data for any of the key species?

The focus of this work was on the four target species (gemfish, snapper, tarakihi, and trevally). The other species are considered in less detail

Results and Discussion

A number of species (e.g. giant stargazer, red gurnard, John dory, and red cod) which had low *c.v.*s in other areas generally had less consistent biomass estimates and higher *c.v.*s on the ECNI survey. Estimated *c.v.*s for all species combined ranged from 6–9% for the west coast South Island (Stevenson & Hanchet in prep), 10–12 % for the east coast South Island (Beentjes & Stevenson in press) but 11–24% for ECNI. The reason for this high variability is not known but may be related to the large amount of foul ground present in the ECNI survey area. Slight shifts in fish distribution between years could affect fish availability causing changes in estimated biomass and *c.v.*s. The species are considered in more detail below.

Target species

Gemfish

The northern gemfish stock (SKI1, SKI 2) are caught mainly on the east coast in spring, summer, and autumn and are believed to migrate to the Bay of Plenty–North Cape area in May–June to spawn (Annala *et al.* 1999). The stock is thought to reside on the east coast of the North Island between Cape Runaway and Cook Strait during summer-early autumn when the surveys were carried out. The SKI 2 stock includes the east coast of the North Island from Cape Runaway south to Cook Strait and west to Cape Terawhiti. The east coast North Island (ECNI) trawl survey covered most of this area, except the southwestern extremity. Gemfish are however, known to occur to depths of about 50–600 m and the survey only extends to 400 m. In addition, there is extensive foul ground in the 200–400 m depth range throughout the survey area (*see* Figure 1). During the series, the highest catch rates were in depths of 100–400 m. It appears therefore, that the survey area does not extend deep enough to cover the recruited part of the SKI 2 stock.

Total biomass decreased over the period of the surveys, and *c.v.*s were moderate (30–37%). The recruited biomass declined sharply from 1993 to 1994 but then remained fairly constant. The size structure of the recruited population mirrors the decrease in the biomass estimates with a decrease in the number of larger fish especially those greater than 75 cm F.L. Although the survey does not cover the entire depth range of the stock, it may be monitoring pre-recruit gemfish. A mode at 37 cm in 1993 can be tracked through to a mode at about 65 cm in 1996 (*see* Figure 8e). However, the precision of the biomass estimates of this year class was poor with *c.v.*s ranging from 42–47% (*see* Table 3). Horn & Hurst (1999) showed that this mode represents the 1991 year class, and catch at age data has shown that this is the strongest year class in the commercial fishery (SKI 1 and SKI 2) since 1996 (Hurst *et al.* 1999). Using only CPUE and age data from the commercial fishery, Hurst *et al.* (1999) estimated the 1991 year class to be about ten times stronger than the adjacent 1990, 1992, and 1993 year classes and about three times stronger than the 1989 year class. This agrees well with the trawl survey estimates of relative abundance of 3+ fish (*see* Table 3). However, estimates of relative abundance of 2+ fish (particularly of the 1993 year class) from the trawl survey appears too high relative to the 1991 year class. The 1993 year class is only partially recruited to the fishery, and is not well estimated by the model, and may prove to be stronger than originally thought.

Commercial catch and effort data for SKI 2 were examined by Hurst *et al.* (1999). Gemfish from SKI 2 were caught throughout the year except in winter and the fishery was made up of non-spawning fish. Standardised CPUE was calculated for SKI 2 normalised to 1.0 for the 1989–90 fishing year. CPUE declined slightly from 1992–93 to 1995–96 (Table 5). The recruited trawl survey indices follow a similar trend. Commercial catches declined by about 25% during the same period (*see* Hurst *et al.* 1999).

Ageing of otoliths from the commercial catch has been carried out since 1989. However, only otoliths from the 1996 trawl survey have been aged (Horn & Hurst 1999). If the data were to be used for modelling, it is recommended that samples of otoliths from each survey were aged because of overlap between modes as the fish became older.

The survey appears to be monitoring pre-recruit gemfish, although the estimate of biomass by year class is relatively imprecise. The trawl surveys show a pattern consistent with the commercial catch and CPUE data. Because of the high recruitment variability, relatively large number of ages in the population and the relatively high *c.v.*s, trawl surveys would need to be carried out at least every 2 years to monitor year class strength within this stock.

Snapper

Snapper are caught around the North Island and the north and west of the South Island to about 39° S at depths less than 200 m (*see* Anderson *et al.* 1998). The SNA 2 stock includes the east coast of the North Island from Cape Runaway south to Cook Strait and west to Cape Terawhiti. The ECNI trawl survey covered most of this area, except the southwestern extremity. During the survey the highest catch rates were in the 20–100 m depth range north of Tolaga Bay. The area of snapper abundance has a large amount of foul ground and there is some concern that a proportion of the snapper population would not be surveyed and that this proportion may vary between years. There were no strong spatial patterns evident between years.

The biomass estimates fluctuated by a factor of 1.5 and *c.v.*s were moderate (13–32%). Part of this fluctuation could be caused by changes in availability of the stock to the trawl survey between years. The length frequency distributions have several modes each year, some of which can be tracked through the time series (*see* Figure 8s). In particular, the main mode in both sexes at 31 cm in 1994 can be followed through to 35–35 cm in 1996. And a second mode at 36 cm in males in 1993 can be followed through to 42 cm in 1996. Preliminary age determination of otoliths collected in 1993 suggested that 26–30 cm fish in 1993 were 4–5 years old (1989 and 1990 year classes) and 36 cm fish in 1993 were 7–9 years old (1984, 1985, and 1986 year classes) (NIWA unpublished data). Catch sampling of the SNA2 stock during the 1997–98 season showed that the current fishery is dominated by the strong 1988 and 1990 and 1985 year classes (Blackwell *et al.* 1999), which is consistent with the trawl survey results from the earlier years.

The surveys did not catch many pre-recruits (less than age 3) probably because of the 80 mm mesh size used in the codend. Year class strengths in other snapper stocks have been found to be highly variable and possibly correlated with water temperatures (Annala *et al.* 1999). Use of a smaller codend mesh size in the survey may allow a better estimate of pre-recruit snapper but may also lead to a greater escapement of adult snapper.

No analysis of commercial catch and effort data for SNA 2 has been undertaken since before the series started, and there are no other estimates of abundance for this area. Trawl survey abundance indices of recruited snapper are not currently used for monitoring abundance. Gilbert & Sullivan (1994) reviewed the trawl survey data for recruited snapper in the Hauraki Gulf. They concluded that because of the high (3-fold) variability in the biomass estimates, the variable size selectivity, and the apparent relationship between the biomass estimates and SST, trawl survey estimates should not be used as indices of adult biomass. In the east coast North Island series the biomass estimates appeared to be less variable (1.5-fold), and there was no obvious relationship between biomass and SST. It is likely that the trawl survey series does not fully sample the larger (>45 cm) snapper, but it is unknown whether the proportion (selectivity) of these larger fish would vary between years. This could only be determined through ageing the fish.

Estimates of recruited biomass are reasonably consistent between years and have moderate *c.v.*s, however, a proportion of the stock may be over foul ground and this proportion may vary between years. Although there have been concerns that large snapper are not vulnerable to the bottom trawl, the survey does appear to catch commercial size snapper reasonably well, up to at least 45 cm F.L. (age 11). Because of probable moderate to high recruitment variability, the large number of age classes in the fishery (*ca* 10–15), and variable biomass estimates, surveys would need to be carried out every 2 years to monitor SNA 2 abundance. Any uncertainty over the selectivity and abundance of large snapper would be reflected in uncertainty over any assessment of this stock.

Tarakihi

The TAR 2 stock includes the east coast of the north Island from Cape Runaway south to Cook Strait and west to Cape Terawhiti. The ECNI trawl survey covered most of this area, except the southwestern extremity. During the series tarakihi were caught mostly north of Tolaga Bay. Tarakihi are most commonly caught around New Zealand between 50 and 300 m (*see* Anderson *et al.* 1999), and the main fisheries operate in 100–200 m. During the series the highest catch rates were in depths of 100–200 m. There are no strong spatial patterns evident between years. The area of tarakihi abundance has a large amount of foul ground and there is some concern that a proportion of the tarakihi population would not be surveyed and that this proportion may vary between years.

Biomass estimates fluctuated by a factor of 1.5 and *c.v.*s were moderate (15–30%). Part of this fluctuation could be caused by changes in the availability of the stock to the trawl survey between years. The fish were not aged but the age structure of the population, as inferred from the modes in the length frequency data, did not appear to change much over the course of the surveys.

The series did not catch many pre-recruit fish probably because of the large size of the codend mesh used on the surveys. Low numbers of fish 15–20 cm (possibly 2+ fish) were caught during each survey, so pre-recruit fish do occur in the survey area (*see* Figure 8t, Table 3). No other estimates of abundance are available for this stock.

Although no ageing study has been carried out on otoliths collected during the surveys, it appears from other stocks (e.g. *see* Stevenson & Hanchet in prep) that recruitment variability is moderate and that the population consists of a large number of age classes (*see also* Annala *et al.* 1999). If the data are to be fitted in a population model, it is strongly recommended that an ageing study be completed using otoliths collected from the surveys. The aims of the ageing study would be to determine biological parameters such as growth, maximum age (and hence M), and trawl survey selectivity. Because of the moderate recruitment variability, proportion at age should be determined from each survey to allow estimation of year class strength within the model.

Estimates of recruited biomass are reasonably consistent between years and have moderate *c.v.*s, however, a proportion of the stock may be over foul ground and this proportion may vary between years. Because of the probable moderate recruitment variability of this stock, the probable large number of age classes in the population, and the variable biomass estimates, trawl surveys would need to be carried out every 2 years to monitor this stock.

Trevally

The TRE 2 stock includes the east coast of the North Island from Cape Runaway south to Cook Strait and west to Cape Terawhiti. The ECNI trawl survey covered most of this area, except the southwestern extremity. Trevally are caught mainly around the North Island and the north of the South Island at depths less than 200 m (*see* Anderson *et al.* 1999). During the series trevally were most abundant north of Cape Kidnappers. There were no strong spatial patterns evident between years. Trevally vulnerability to trawl varies considerably because of their mixed demersal-pelagic nature, trawl survey gear efficiency is not optimal for sampling trevally, and a direct correlation has been found between sea surface temperatuie during surveys and relative biomass (*see* Annala *et al.* 1999).

Biomass estimates have decreased over 50% through the series, and the *c.v.s* were low to moderate (19–35%) with the highest estimate in 1993. The size structure of the population changed considerably between surveys which suggests that the surveys were not consistently sampling the same part of the population. The proportion of large fish (greater than 45 cm) steadily decreased but this may have been caused by changes in areal and vertical availability The decline in biomass is consistent with the decrease in large adult fish, and a slight drop in commercial catch over the period (Annala *et al.* 1999).

The series did not monitor pre-recruits and no ageing study has been completed to determine if the 25–32 cm mode in 1993 is the same year class as the 30–39 cm mode in 1995. The length frequency data indicate considerable recruitment variability, however, there is no other data to support this and changes to trevally catchability to trawl survey gear may be a factor in the apparent variability.

Because of uncertainties in trevally catchability, variability in biomass estimates, and poor precision, recruit and pre-recruit abundance are unlikely to be determined with certainty using trawl surveys. It is therefore recommended that trevally not be considered as a target species.

Non-target species

Although the focus of the analysis was on the four target species, other species were also examined to determine whether the survey is useful for monitoring them. In this analysis we have focused mainly on the consistency of the biomass indices and the length frequency distributions between years, and on the precision of the indices (*c.v.*s).

Elasmobranchs tend to be reasonably long lived with low recruitment variability and so would be predicted to have consistent biomass estimates between years. During the series, the biomass estimates of rig, rough skate, school shark, and spiny dogfish varied from 1.5 fold for spiny dogfish to almost 6 fold for rough skate. Although some of their *c.v.*s were reasonably low, in general the numbers of fish actually caught was low or the biomass too variable.

The biomass estimates of spiny dogfish were the most consistent between years however, the *c.v.*s were usually high (25–78%). The *c.v.*s for rig were reasonably low (13–26%) but the size distribution varied between years. It is likely that for both rig and school shark the larger fish in the population are under-represented when sampled with the bottom trawl gear, and for rig the highly skewed sex ratio suggests that females were also undersampled. Vignaux (1997) carried out a CPUE analysis of the target rig set net fishery for SPO 2 (*see* Table 5). She found that CPUE fluctuated between years with higher values in 1993–94 and 1995–96 and lowest in 1994–95 which is consistent with the results of the surveys, however, the quantity of data was low and she concluded that CPUE was probably not monitoring biomass satisfactorily.

Biomass estimates for blue moki varied by a factor of almost 2 and *c.v.*s were moderate to high (29–45%). No pre-recruits were caught and catch rates were low. Juveniles are found inshore, usually around rocky reefs (*see* Annala *et al.* 1999) and are therefore unlikely to be caught by bottom trawl. In addition, the series was at the wrong time of the year to adequately sample blue moki as they undergo a spawning migration into the area in winter (Francis 1981). It is therefore unlikely that the survey satisfactorily monitors blue moki abundance or would be suitable to estimate year class strength.

Biomass estimates for jack mackerels were highly variable with at times high *c.v.*s (24–97%) and could not be monitored by the surveys. For *T. novaezelandiae*, up to three pre-recruit year classes were apparent in the length frequency data but they can not be tracked between years and high *c.v.*s prevent estimates of year class strength.

John dory biomass estimates declined from about 265 t in 1993 and 1994 to 170 t in 1995 and 1996. While *c.v.*s were low in 1993 (17%) and 1995 (18%), they were moderate to high in 1994 (31%) and 1996 (48%). The size distributions were reasonably consistent between years except for numbers of fish. Some 1+ fish (20–30 cm T.L.) were caught during each survey and the estimates varied 6 fold suggesting high recruitment variability but the *c.v.*s were moderate to high (22–74%) (*see* Table 3). Standardised CPUE analyses for this stock were examined by Horn *et al.* (1999) who considered that CPUE data from JDO 2 were not reliable indices of stock abundance because of low catch rates (less than 10 fish per tow). The JDO 2E stock was modelled by Horn *et al.* (1999). The model was unable to fit the decline in abundance indices observed during the survey series. It is unclear whether this is due to problems in the trawl survey indices of model mis-specification.

Biomass estimates of silver warehou were highly variable between years and had high *c.v.*s (49–92%). There appeared to be a good correlation between relative abundance of 0+ and 1+ fish (Table 3) but estimates had high *c.v.*s (always greater than 40%). The abundance of pre-recruits may have been affected by the large codend mesh used. Because of the poor precision in biomass estimates of both adults and pre-recruits, it is unlikely that the surveys are useful for monitoring silver warehou abundance.

There was a large decline in the biomass estimates for giant stargazer from 1993 to 1994 and the *c.v.*s were moderate to high (17–46 %). The decline in biomass was mirrored by a decline in CPUE (Vignaux 1997, Table 5) and biomass estimates from scampi surveys (Annala *et al.* 1999), and in commercial landings. However, low numbers of fish caught during surveys, and the decline in biomass indices could only be fitted in the model by assuming very high exploitation rates which are unrealistic (Annala *et al.* 1999). It is uncertain whether the survey is monitoring abundance of this stock.

Other inshore species had variable biomass estimates (e.g. arrow squid, hapuku, red gurnard, red cod, sea perch) and/or high *c.v.*s (e.g. red cod).

For other middle depth species (e.g. hoki, ling) the series did not go deep enough to cover the full range of adult distribution, the estimates of adult biomass were too variable (e.g. barracouta, frostfish,), the *c.v.*s were moderate to high (e.g. giant stargazer), or the species is found in mainly untrawlable areas (e.g. hapuku). In addition, few pre-recruits were caught for any species.

Some pre-recruits were taken for barracouta specially in 1994 but the year class could not be tracked through the series. The large size of the codend mesh was probably a major reason for the lack of pre-recruits in the catch.

Conclusions and Recommendations

- A number of species (e.g. giant stargazer, red gurnard, John dory, and red cod) which had low *c.v.*s in other areas generally had less consistent biomass estimates and higher *c.v.*s on the ECNI survey. Estimated *c.v.*s for all species combined ranged from 6–9% for the west coast South Island (Stevenson & Hanchet in prep), 10–12 % for the east coast South Island (Beentjes & Stevenson in press) but 11–24% for ECNI. The reason for this high variability is not known but may be related to the large amount of foul ground present in the ECNI survey area. Slight shifts in fish distribution between years could affect fish availability causing changes in estimated biomass and *c.v.*s.

- The trawl survey did not cover the depth range of the adult gemfish (SKI 2) stock. The surveys did appear to monitor pre-recruits, although the estimate of biomass by year class was relatively imprecise. The trawl surveys showed a pattern consistent with the commercial catch and CPUE data. Because of the high recruitment variability, relatively large number of ages in the population and the relatively high *c.v.*s, trawl surveys would need to be carried out at least every 2 years to monitor year class strength within this stock.

- Estimates of recruited snapper biomass were reasonably consistent between years and had moderate *c.v.*s, however, a proportion of the stock may be over foul ground and this proportion may vary between years. Although there have been concerns that large snapper are not vulnerable to the bottom trawl, the survey did appear to catch commercial size snapper reasonably well, up to at least 45 cm F.L. (age 11). Because of probable moderate to high recruitment variability, the large number of age classes in the fishery (*ca* 10–15), and the variable biomass estimates, surveys would need to be carried out every 2 years to monitor SNA 2 abundance. Any uncertainty over the selectivity and abundance of large snapper would be reflected in uncertainty over any assessment of this stock.

- Estimates of recruited tarakihi biomass were reasonably consistent between years and had moderate *c.v.*s, however, a proportion of the stock may be over foul ground and this proportion may vary between years. Because of the probable moderate recruitment variability of this stock, the probable large number of age classes in the population, and the variable biomass estimates trawl surveys would need to be carried out every 2 years to monitor this stock.

- The survey appeared to cover most of the trevally (TRE 2) stock, and the biomass estimates moderately precise. However, the size distribution was inconsistent between years. Because of uncertainties in trevally catchability and variability in biomass estimates, recruit and pre-recruit abundance are unlikely to be adequately monitored using trawl surveys. It is therefore recommended that trevally not be considered as a target species.

- The surveys do not appear to be useful for monitoring any other species because recruited biomass estimates were too variable or too imprecise to consider they were reliably monitored.

- The survey caught pre-recruits from a wide range of commercial species but it is difficult to determine the reliability of the indices. Species including barracouta, hoki, jack mackerel (*T. novaezelandiae*), John dory, and silver warehou all have variable estimates of juveniles, but we are unable to determine whether these are indicative of year class strength. The large size mesh codend (80 mm) used during the survey limited the ability to sample juveniles.

- Otoliths collected from the three target species should be aged, if the data are to be used for stock assessment. Some of the pre-recruit year classes can be determined from the length frequencies for some species, but these need to be verified and adult population structures determined. It is recommended that an ageing study be carried out with two objectives. Firstly, to determine biological parameters for each of the species; and secondly, to determine proportion at age from each of the surveys so that year class strength can be estimated.

- The ECNI trawl survey time series was discontinued in 1996. Given the concerns with monitoring both target and non-target species noted above, we can find no strong reasons for changing that decision. We therefore, recommend that no new surveys be carried out in the short term. Consideration could be given to carrying out a further short series of surveys in the medium term (10–15 years after the first series was completed). This would provide a more powerful test of the usefulness of the surveys in monitoring more gross changes in abundance of both target and non-target species. Because of the variability between surveys, a minimum of three surveys would be required. For the reasons stated, this would be regarded as a relatively high risk project.

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R.V. *Kaharoa*, Trip KAH9809, benthic invertebrate bycatch

Station number	58	62	65	71	75	80	86	89	90	91	96	101	104	108	109	110	112
CRUSTACEA: BRACHYURA																	
Leptomithrax garricki	2																
Leptomithrax longipes	1	1														1	11
Nectocarcinus bennetti					5								1				
Ovalipes catharus					1												
Paromola petterdi	3		2														
Thacanophrys filholi		6															2
CRUSTACEA: ANOMURA																	
Sympagurus dimorphus	1																
Diacanthurus rubricatus	2		1	3													
Paguristes sp. (purple claw)		7									1						2
Lophopagurus (Lophopagurus) sp.		2															1
Lophopagurus (Australeremus) sp.		1															
ECHINODERMATA: ASTEROIDEA																	
?Peribolaster sp.								1									
Dipsachaster magnificus	1																
Patiriella regularis													1				
Sclerasterias mollis		1															
ECHINODERMATA: HOLOTHUROIDEA																	
Holothurian indet.	2																
Stichopus mollis		5											2	1		1	
MOLLUSCA: BIVALVIA																	
Atrina pectinata zelandica													1				
Chlammys delicatula		5						1									
Lima colorata zelandica														1			
MOLLUSCA: OPISTHOBRANCHIA																	
Pleurobranchaea maculata		1															
MOLLUSCA: GASTROPODA																	
Alcithoe jaculoides				1													
Austrofusus glans				3													
Calliostoma mauii		3	1														2

Fusitriton magellanicus								3		2							
Neojanacus perplexus															1		
MOLLUSCA: CEPHALOPODA																	
Nototodarus sp. (no body, juv, female)		1															
Octopus huttoni		2															
Octopus kaharoa							1			2							
Pinnoctopus cordiformis													3				
ACTINARIA (sea anemones)																	
?*Hormathia lacunifera*			1	2													
Actinaria (large, orange)			3	2						9					1	1	
Actinaria (large, white, smooth)			2														
Actinaria (large, white, warty)		2	2					5	9	1					1		3
Actinaria (small, brown, conical, warty)		9		2						3							
Actinaria indet.	4										1			4			
ZOANTHARIA																	
Bathyzoanthus sp.											1						
CIRRIPEDIA (barnacles)																	
Balanus decorus				7									20				
Balanus vestitus		30		1													
Bryozoa indet.															1		
ANNELIDA (HIRUDINEA) - leeches																	
Pontobdella benhami						1											
ANNELIDA (POLYCHAETEA)																	
Chaetopterus sp.				many												many	many
UROCHORDATA																	
Pyura sp				60	3										1	40	15
Pyura pachydermatina			1														
Asterocarpa sp.				1									2			1	
Orange compound ascidian																1	
PORIFERA																	
Callispongia sp.		3	1									1					

Table 1 : **Number of stations, total catch, and mean catch rate per tow for the core strata, 1993–96**

Trip code	KAH9304	KAH9402	KAH9502	KAH9602
Dates	6/3–6/4	4/2–2/3	5/2–5/3	17/2–15/3
Phase 1 stations	54	80	78	77
Phase 2 stations	25	19	39	19
Total stations	79	99	117	96
Total catch (t)	34.8	70.2	38.8	69.2
Mean catch rate per tow ($kg.km^2$)	485	977	522	1 305

Table 2 : **Estimated biomass (t) and coefficient of variation (*c.v.* %) for the commercial species where at least 100 kg was caught in each survey and more than 200 kg was caught in at least two surveys and all species combined, 1993–96**

	KAH9304		KAH9402		KAH9502		KAH9602	
	Biomass	*c.v.* (%)	Biomass	*c.v.* (%)	Biomass	*c.v.* (%)	Biomass	*c.v.* (%)
Arrow squid	50	14	300	34	398	23	124	40
Barracouta	2 153	15	7 081	33	2 103	29	2 487	23
Blue moki	119	45	114	29	224	43	137	36
Chilean jack mackerel	11	38	98	31	141	44	1 881	97
Frostfish	462	31	1 079	40	493	22	662	17
Gemfish	323	30	225	33	237	37	190	31
Giant stargazer	117	24	58	46	44	35	58	17
Hapuku	108	17	117	27	69	39	97	26
Hoki	543	24	2 729	47	2 937	42	1 411	50
NZ jack mackerel								
Trachurus declivis	13	33	40	41	63	51	748	78
T. novaezelandiae	243	24	461	32	366	30	1 845	66
John dory	265	17	268	31	170	18	172	48
Kingfish	103	27	39	35	58	19	161	19
Ling	60	25	172	31	65	21	184	21
Red cod	261	51	1 242	50	470	36	1 597	76
Red gurnard	439	44	871	16	178	26	708	29
Rig	141	26	185	13	82	24	180	22
Rough skate	76	28	189	12	52	20	310	24
School shark	315	16	235	23	148	24	229	23
Sea perch	54	28	150	45	94	34	220	39
Spiny dogfish	963	78	988	47	658	25	1 026	51
Silver warehou	13	92	53	73	23	51	18	49
Snapper	540	32	317	21	298	13	364	24
Tarakihi	736	30	1 052	20	791	23	925	15
Trevally	331	35	202	24	215	26	140	19
All species combined	14 483	11	20 131	16	11 264	14	22 196	24

Table 3 : **Estimated biomass(t) and coefficient of variation (*c.v.*) by year class (determined by length frequencies, size range given is across all surveys and varies slightly for individual surveys)**

	Size range (cm)	Age	KAH9304 Biomass	KAH9304 *c.v.* (%)	KAH9402 Biomass	KAH9402 *c.v.* (%)	KAH9502 Biomass	KAH9502 *c.v.* (%)	KAH9602 Biomass	KAH9602 *c.v.* (%)
Gemfish	30–44	1+	4.4	43	0		1.0	66	*	100
	40–57	2+	11.3	51	63.4	42	2.5	51	24.2	35
	53–67	3+	43.5	40	12.4	43	111.7	47	10.3	41
Hoki	10–30	0+	0.2	61	10.6	41	4.7	40	0.1	55
	29–44	1+	0.7	69	74.9	77	5.0	39	0.6	73
	43–54	2+	2.5	44	136.8	50	15.1	47	3.0	64
Jack mackerel										
T. novaezelandiae	10–20	1+	5.2	59	0.8	40	0.4	87	7.9	33
	17–27	2+	13.4	34	4.2	27	19.4	41	98.8	73
John dory	20–33	1+	6.0	22	5.5	74	0.9	58	4.7	31
Silver warehou	10–23	0+	0.2	59	2.7	45	0.2	43	2.9	49
	23–36	1+	0		1.2	59	5.9	80	2.8	47
Snapper	20–29	3+	33.9	66	0.8	13	5.5	66	0	
Tarakihi	16–23	2+	7.6	62	3.6	51	0.7	31	5.8	41
Trevally	21–35	2+	70.8	80	0.7	100	0.5	74	1.7	44
	30–39	3+	43.4	37	9.7	31	93.7	46	27.1	37

* Less than 0.05

Table 4 : **Percentage of mature fish at various gonad stages. Mature fish are all fish above a specified length (snapper > 24 cm; trevally > 29 cm; gemfish > 59 cm; and tarakihi > 29 cm), Annala et al. 1998)**

	Males						Females					
	Gonad stage						Gonad stage					
	1	2	3	4	5	*n*	1	2	3	4	5	*n*
Gemfish												
KAH9304	50	46	4	0	0	96	93	6	0	0	1	124
KAH9402	50	46	4	0	0	50	53	31	0	0	16	32
KAH9502	Not staged											
KAH9602	63	36	1	0	0	78	92	6	0	0	2	63
Snapper												
KAH9304	64	32	4	0	0	94	86	14	0	0	0	118
KAH9402	23	54	18	4	1	149	43	45	6	0	6	143
KAH9502	54	32	11	2	1	304	74	20	3	0	3	360
KAH9602	27	49	23	1	0	175	69	26	1	1	3	226
Tarakihi												
KAH9304	30	31	38	1	*	269	28	66	6	*	0	431
KAH9402	9	45	40	5	2	390	22	38	35	2	3	572
KAH9502	17	19	15	36	12	267	26	56	13	1	4	520
KAH9602	19	46	20	15	1	310	37	60	2	*	*	617
Trevally												
KAH9304	11	23	61	3	2	94	35	58	3	0	4	105
KAH9402	2	18	32	48	0	133	4	24	54	14	4	155
KAH9502	5	11	37	46	1	150	1	76	17	6	1	161
KAH9602	1	18	39	41	0	109	18	79	1	2	0	126

* < 0.5%

Gonad stages used were: 1, immature or resting; 2, maturing (oocytes visible in females); 3, mature (hyaline oocytes in females, milt expressible in males); 4, running ripe (eggs and milt free flowing); 5, spent.

Table 5 **: Standardised CPUE indices for SKI 2 (*from* Hurst *et al.* 1999) and various target fisheries for log linear and combined models for STA 2 and for unstandardised SPO 2 (*from* Vignaux 1997)**

Fishing Year	SKI 2	STA 2		SPO 2
				Target SPO
	Categorical	Linear	Combined	CPUE
89–90	1	–	–	–
90–91	0.86	–	–	–
91–92	0.61	1	1	70
92–93	0.36	1.01	0.93	94
93–94	0.33	0.76	0.55	149
94–95	0.2	0.87	0.64	64
95–96	0.33	0.62	0.30	167
96–97	0.21	–	–	–
97–98	0.11	–	–	–

– Not available

Table 6 **: Numbers of otoliths collected from target species**

Year	SKI	SNA	TAR	TRE
1993	0	280	326	199
1994	0	230	301	180
1995	0	269	214	198
1996	204	137	251	153

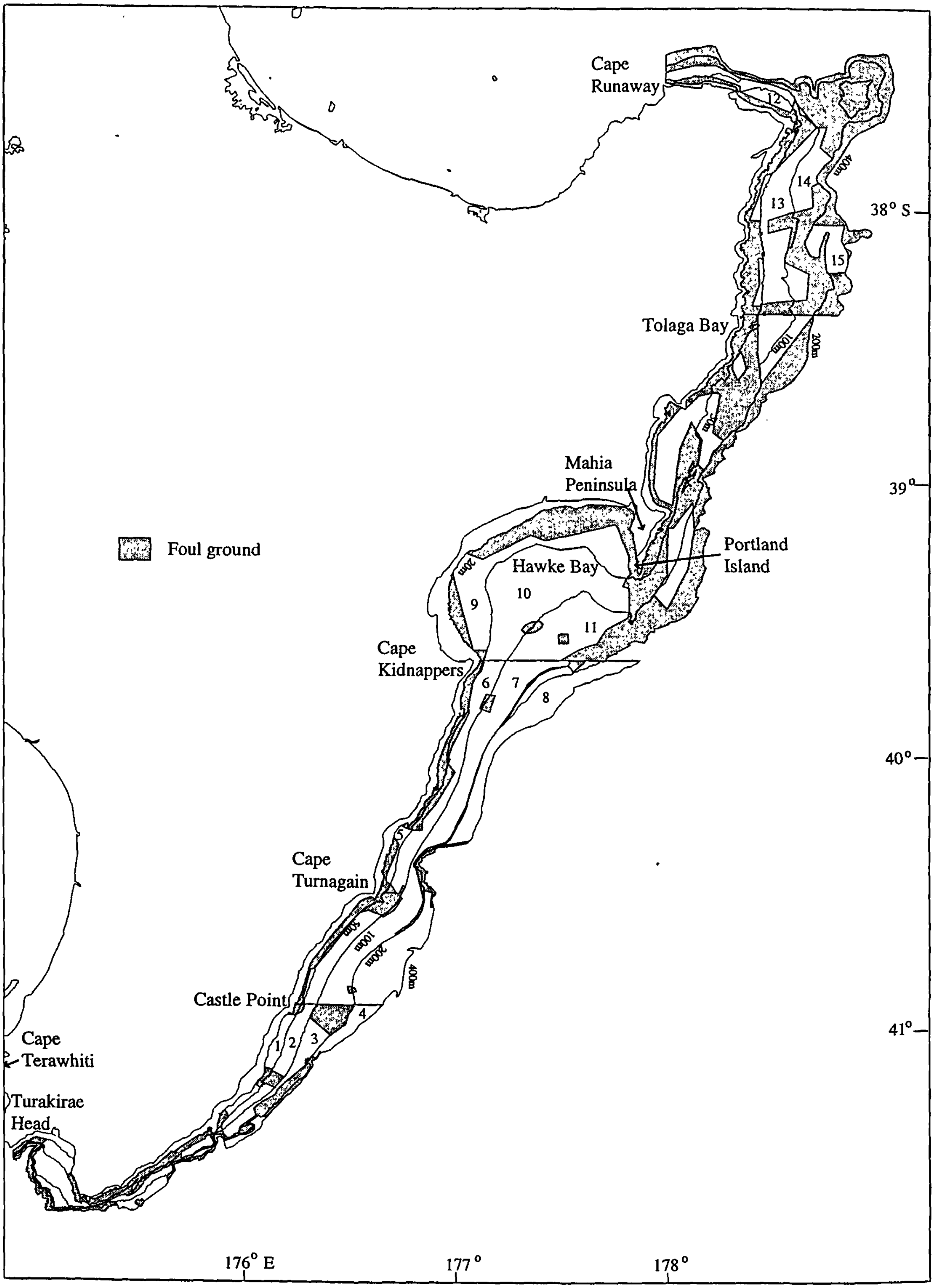


***Figure 1*: Stratum boundaries 1994–96 with locations mentioned in the text.**

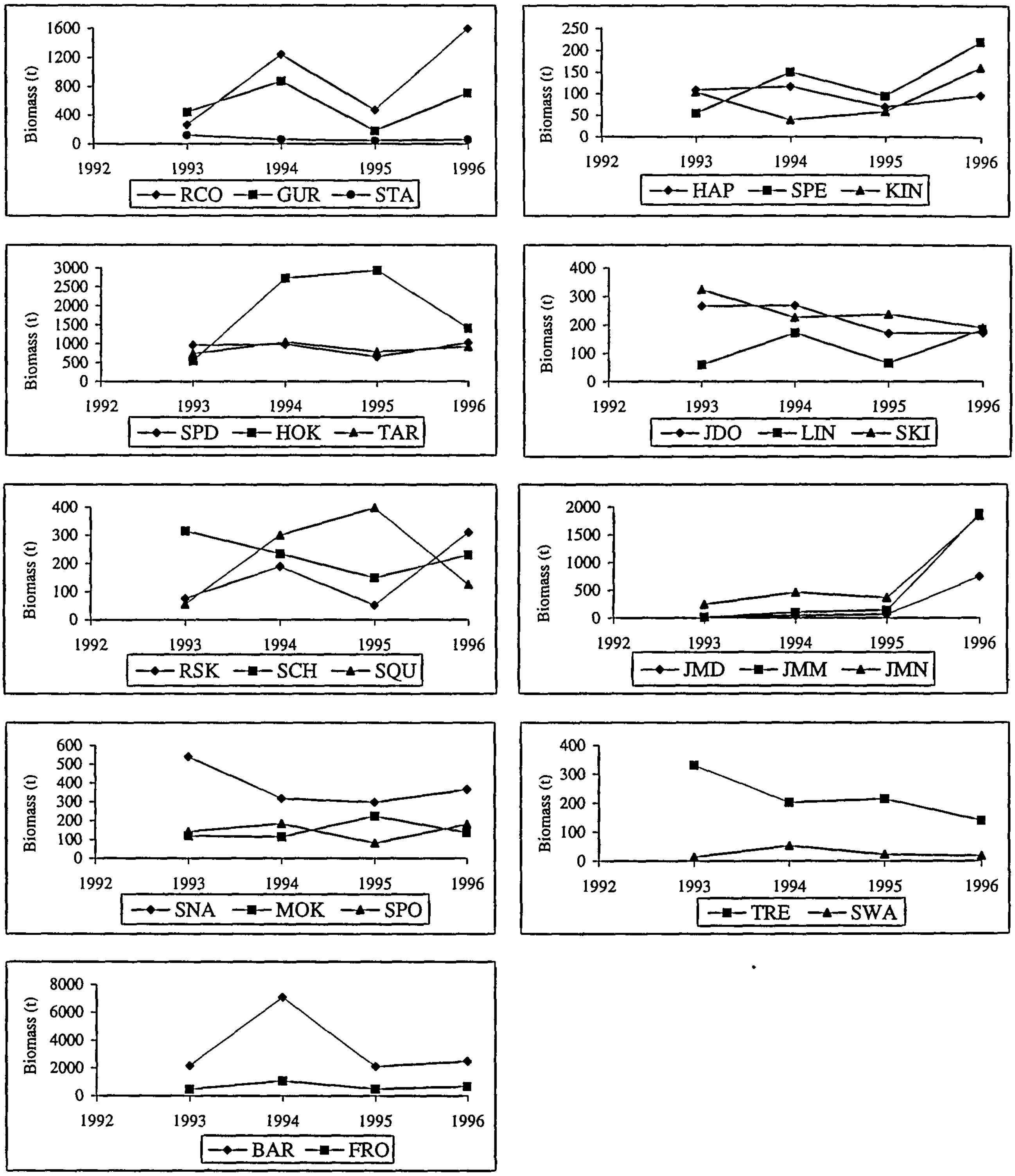


Figure 2 : **Estimated biomass of the 25 major species, 1993–96, all areas. (RCO, red cod; GUR, red gurnard; STA giant stargazer; HAP, hapuku; SPE, sea perch; KIN, kingfish; SPD, spiny dogfish; HOK, hoki; TAR, tarakihi; JDO, John dory; LIN, ling; SKI, gemfish; RSK, rough skate; SCH, school shark; SQU, arrow squid; JMD, jack mackerel (*T. declivis*); JMM, Chilean jack mackerel; JMN, jack mackerel (*T. novaezelandiae*); SNA, snapper; MOK, blue moki; SPO, rig; TRE, trevally; SWA, silver warehou; BAR, barracouta; FRO; frostfish).**

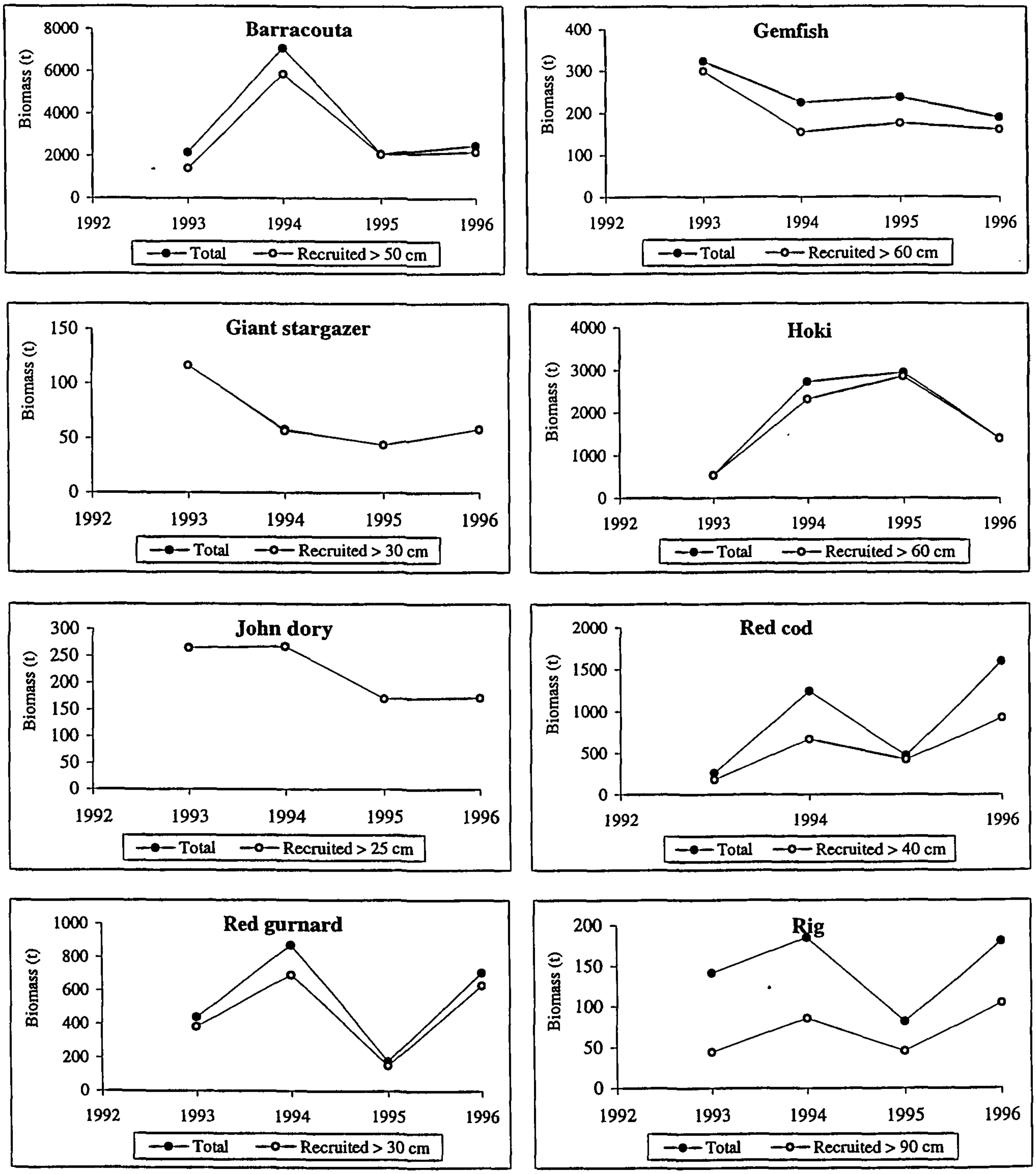


Figure 3 : **Estimates of total and recruited biomass (t), 1992–97, all areas, for barracouta, blue cod, blue warehou, elephantfish, hake, hoki, lemonsole, New Zealand sole, red cod, red gurnard, rig, sand flounder, school shark, silver warehou and tarakihi.**

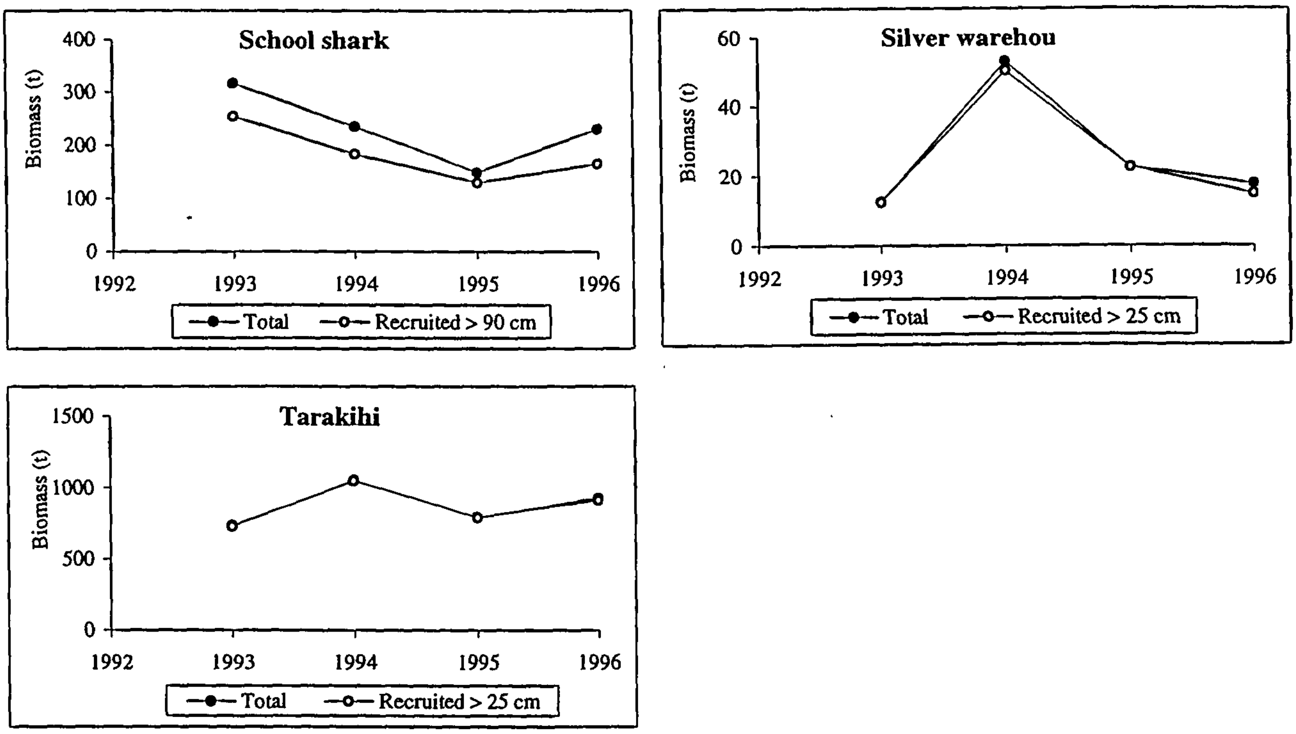


Figure 3—continued

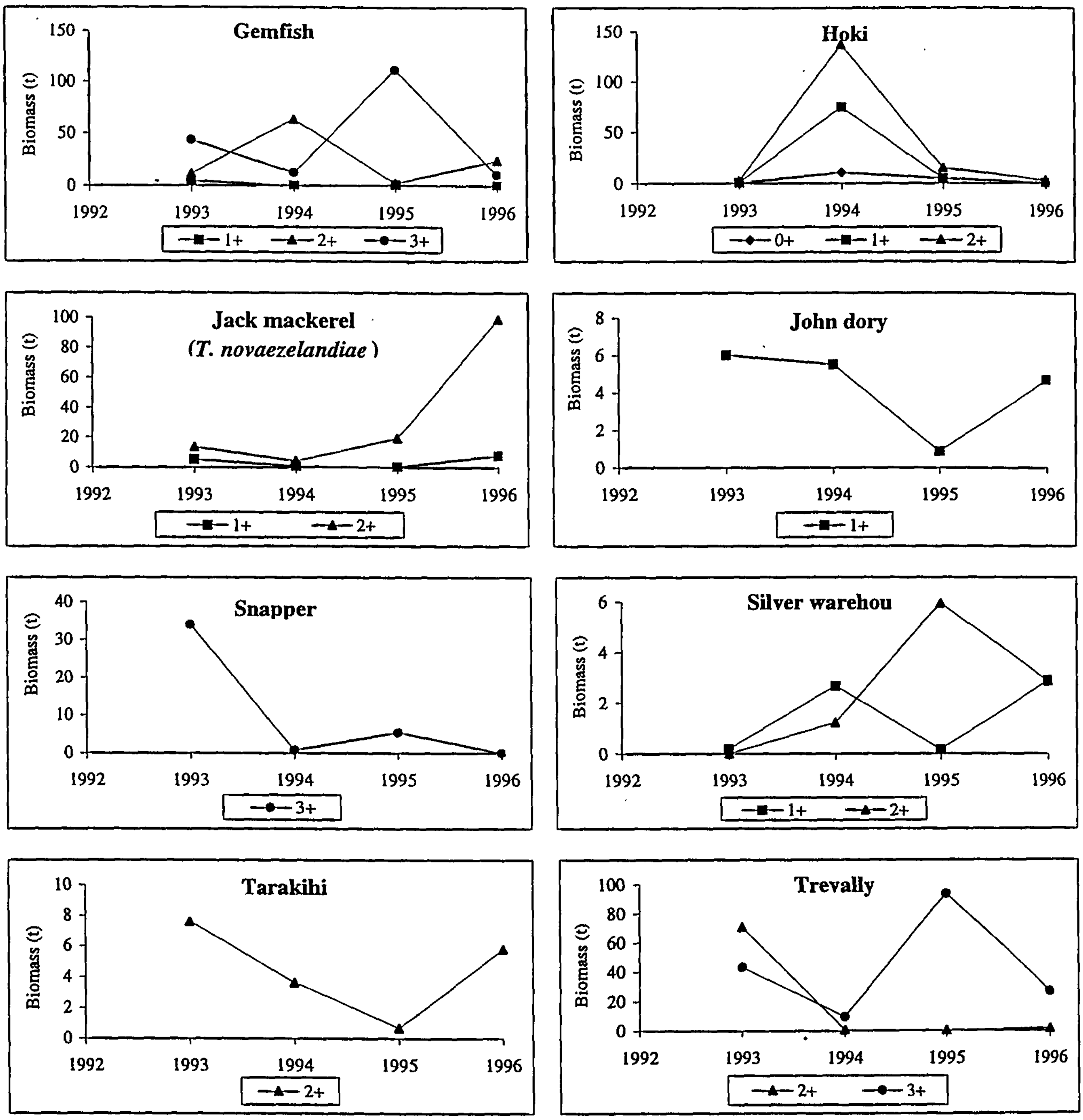


Figure 4 : **Estimated biomass (t) by year class, 1992–97, all areas, for blue warehou, elephantfish, giant stargazer hake, hoki, horse mackerel, NZ jack mackerel, red cod, red gurnard, silver warehou, and tarakihi.**

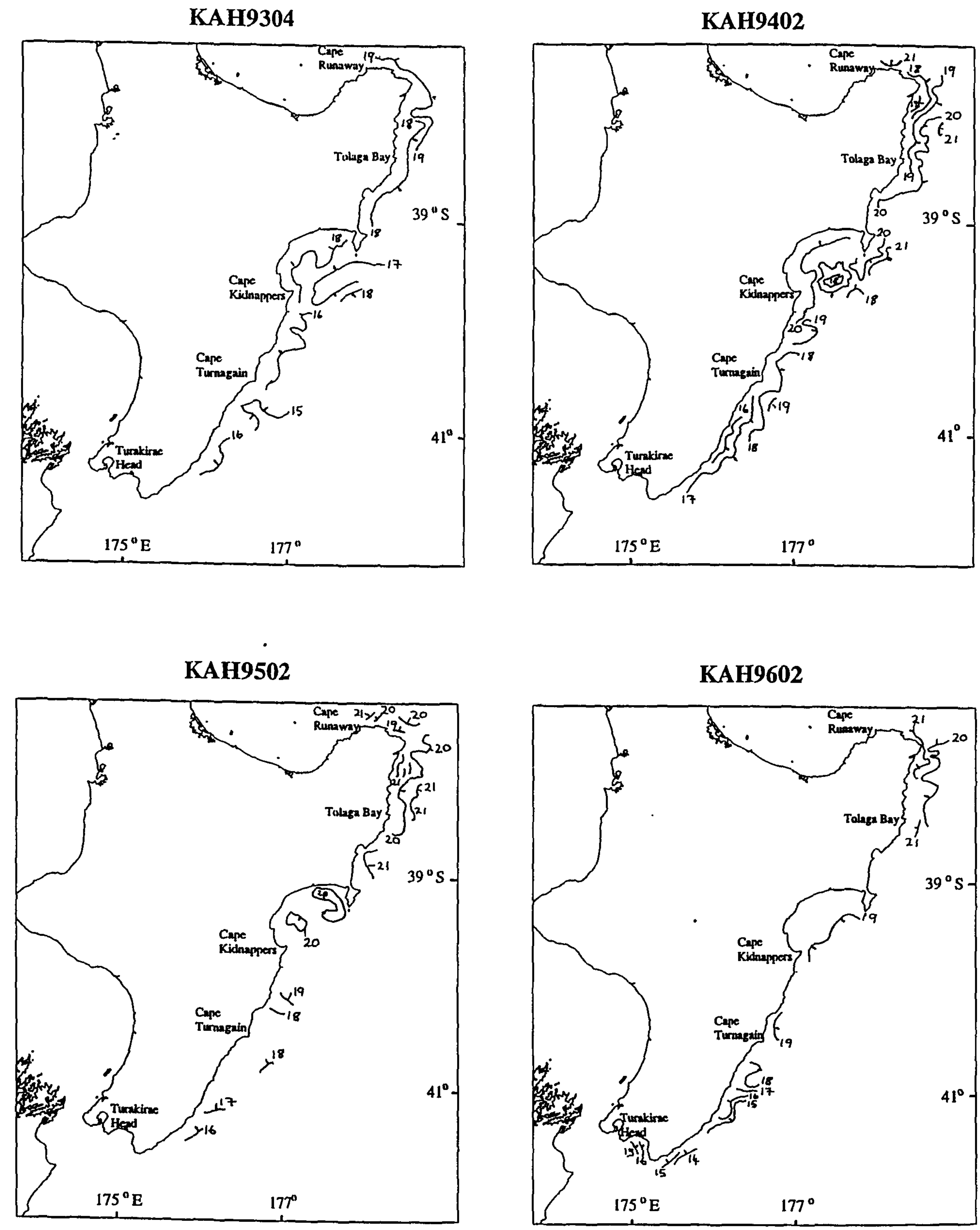


Figure 5a: **Sea surface isotherms estimated from station data.**

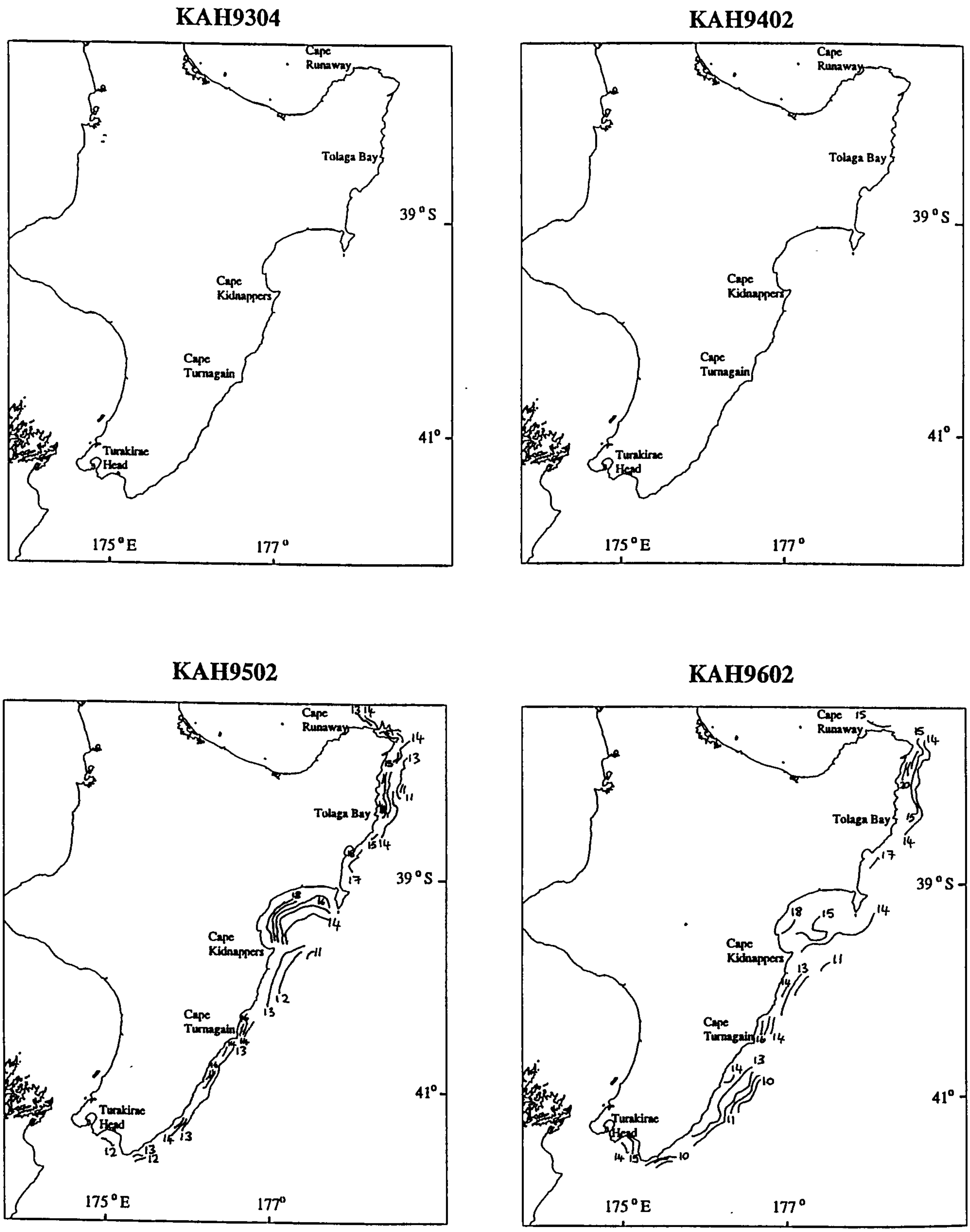


***Figure 5b*: Bottom isotherms estimated from station data.**

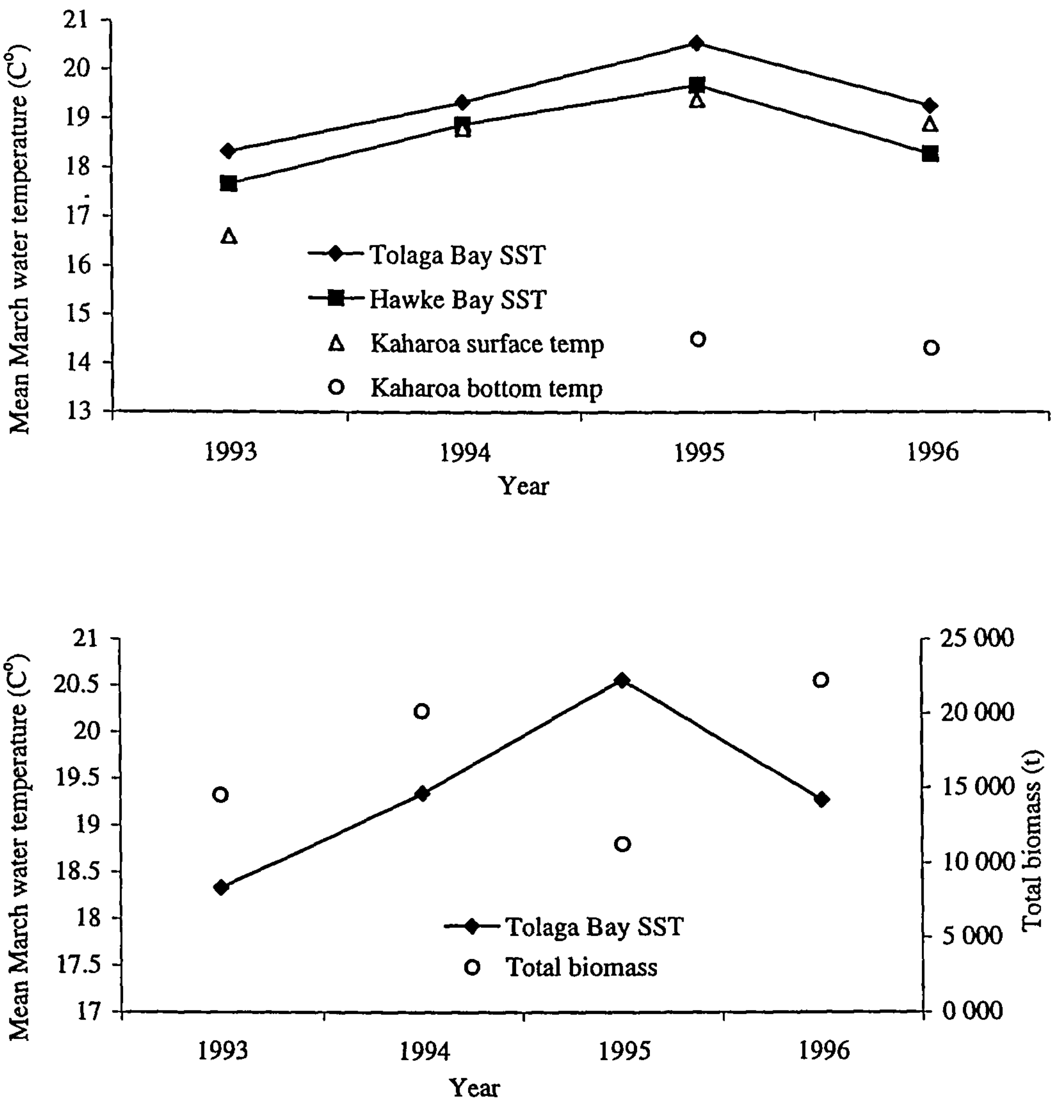


Figure 6 **: Top, Mean monthly sea surface temperature (SST) in March for Tolaga Bay and Hawke Bay with bottom and surface temperatures recorded during the surveys.**
Bottom, Mean monthly SST in March for Tolaga Bay and total biomass for each survey.

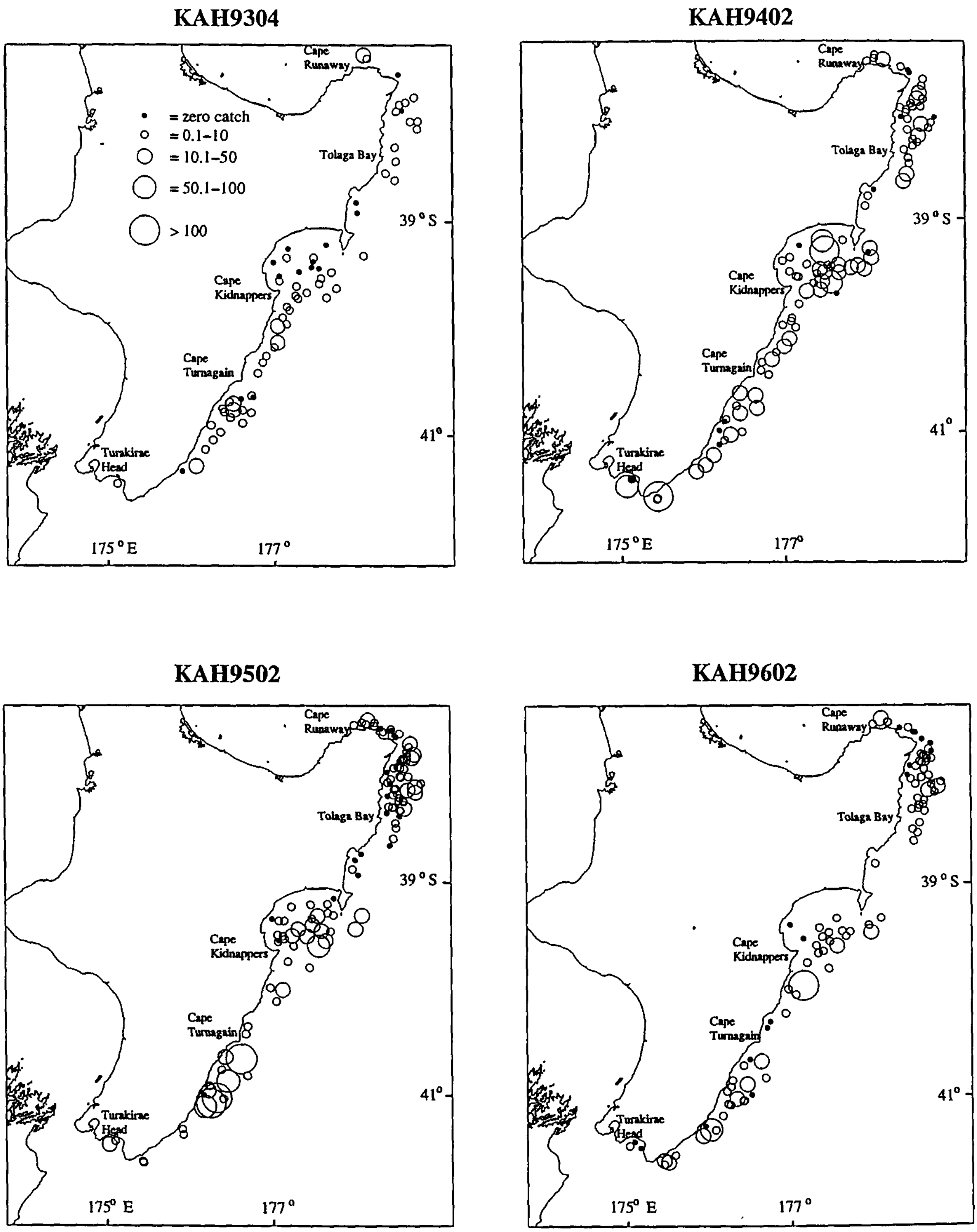


Figure 7 **: Distribution and catch rates (kg.km^{-2}) of the major species.**
a **: Arrow squid (maximum catch rate 388 kg.km^{-2})**

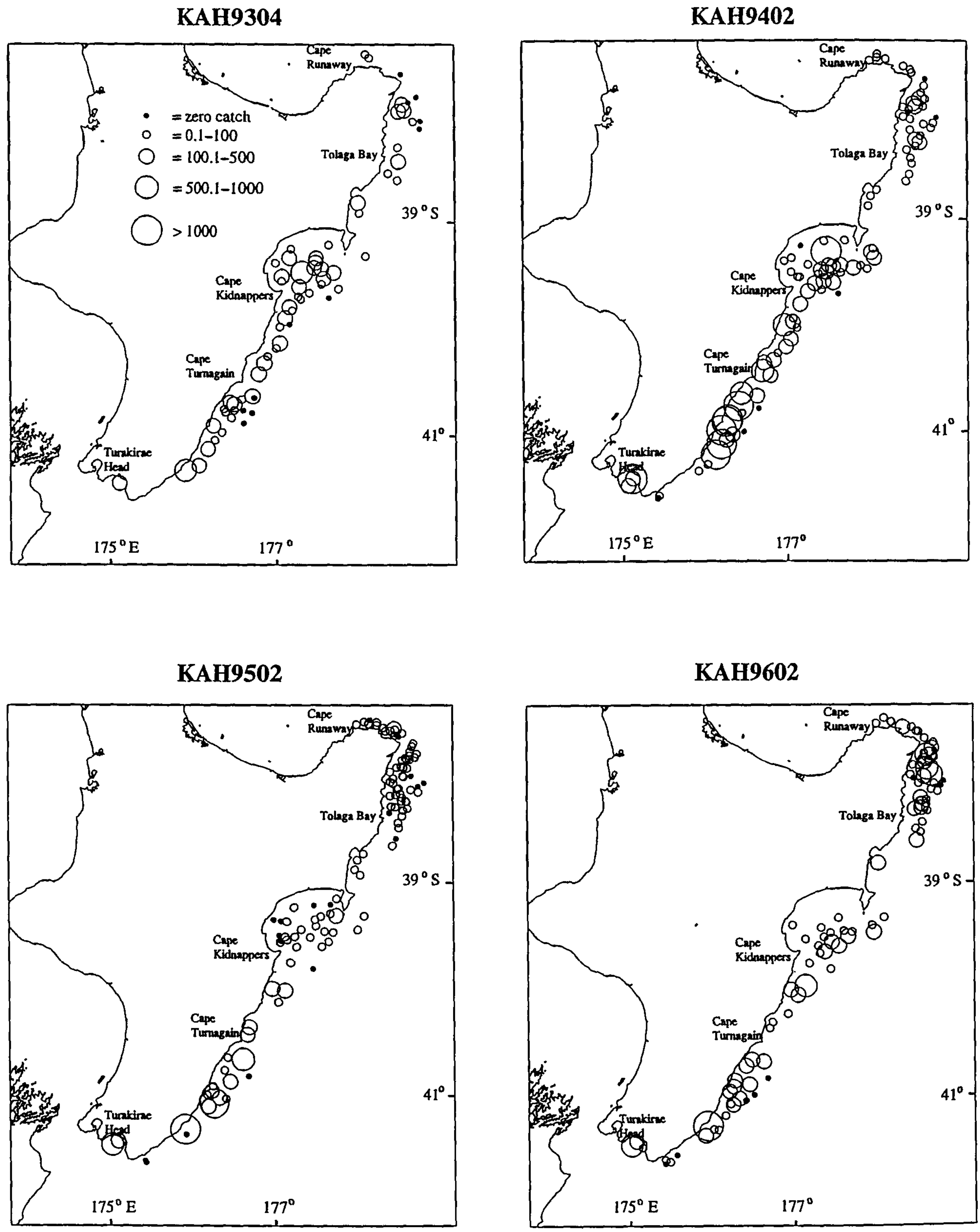


Figure 7b: **Barracouta (maximum catch rate 4812 kg.km^{-2})**

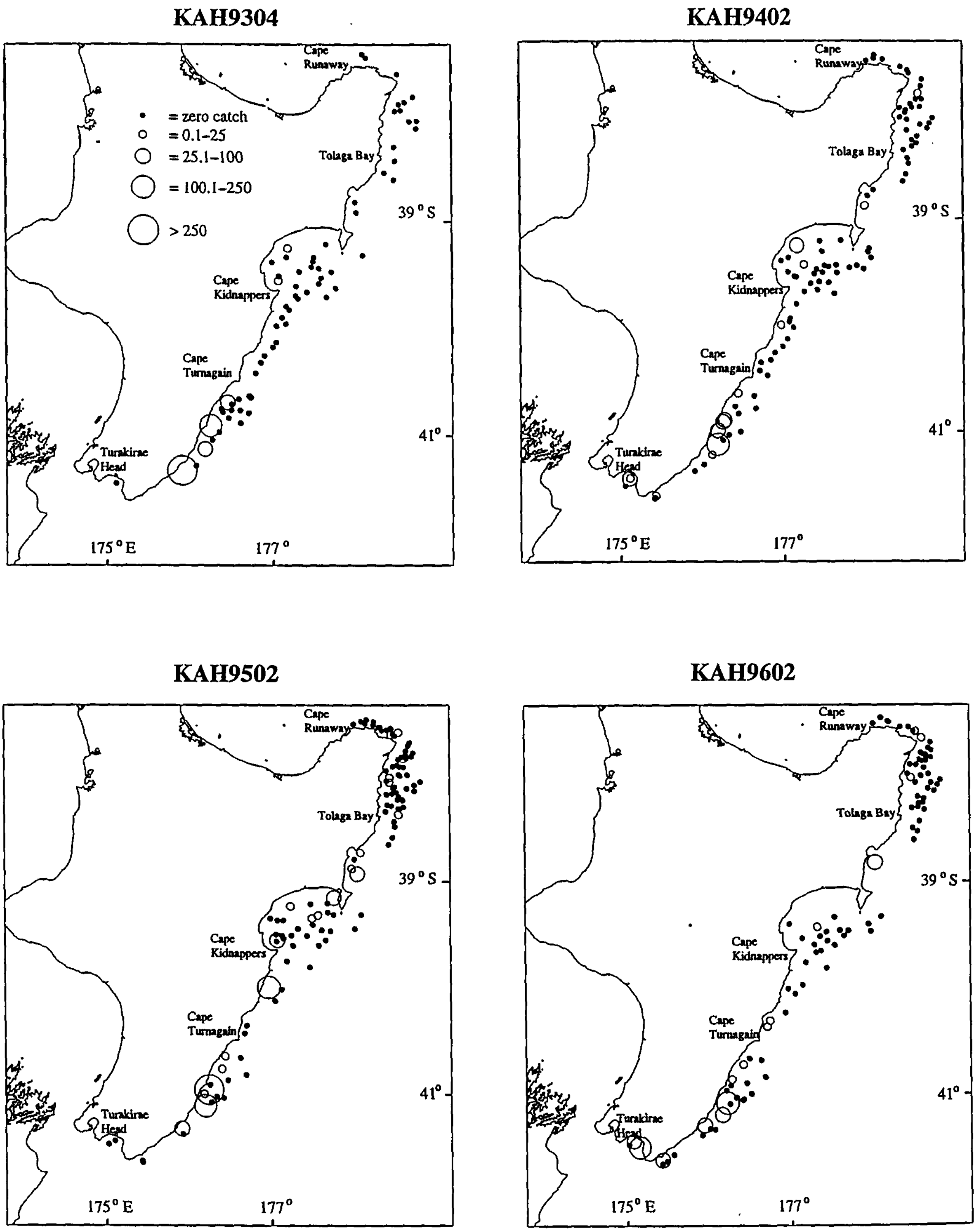


Figure 7c: **Blue moki (maximum catch rate 490 kg.km^{-2})**

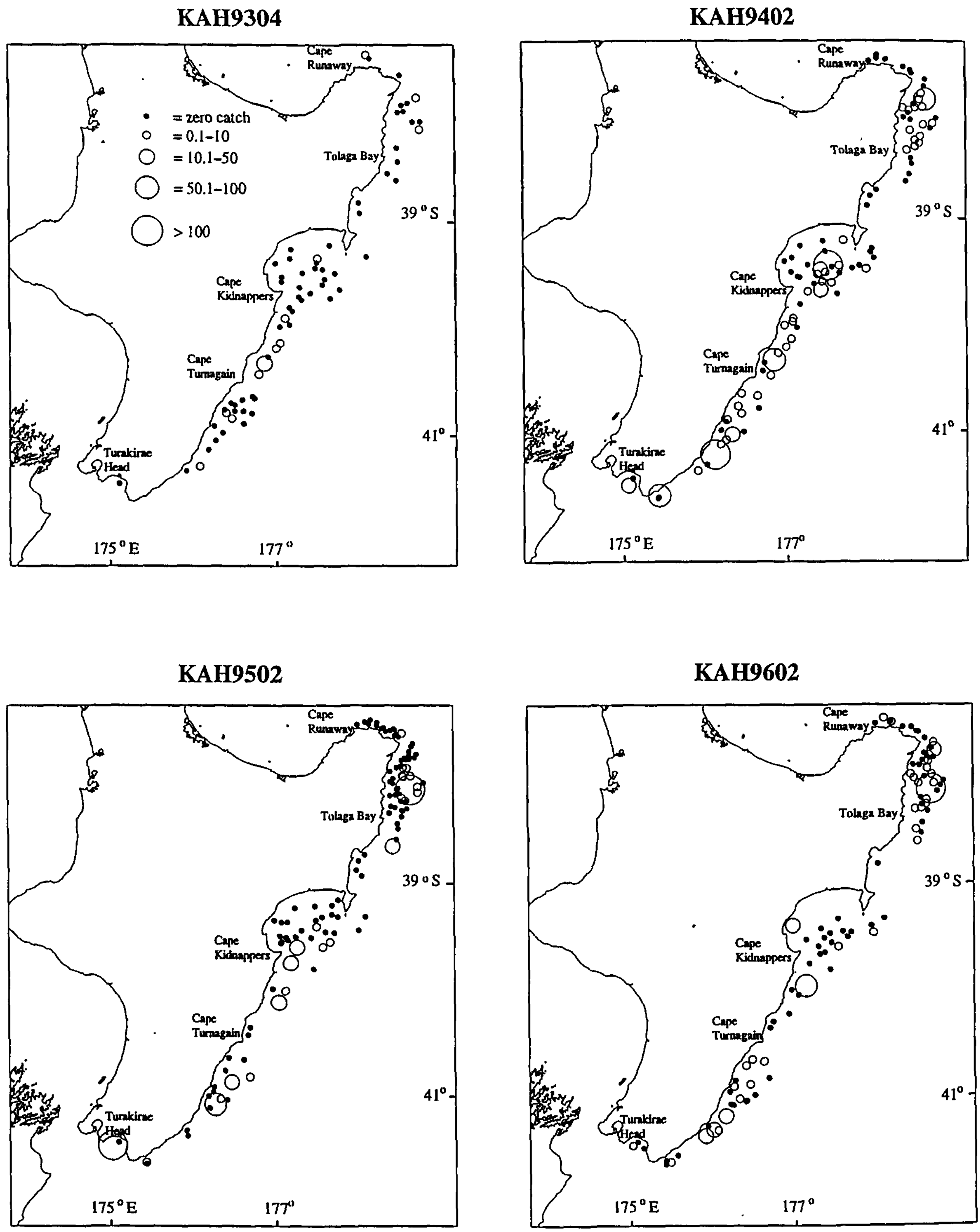


Figure 7d: **Chilean jack mackerel (maximum catch rate 8915 kg.km^{-2})**

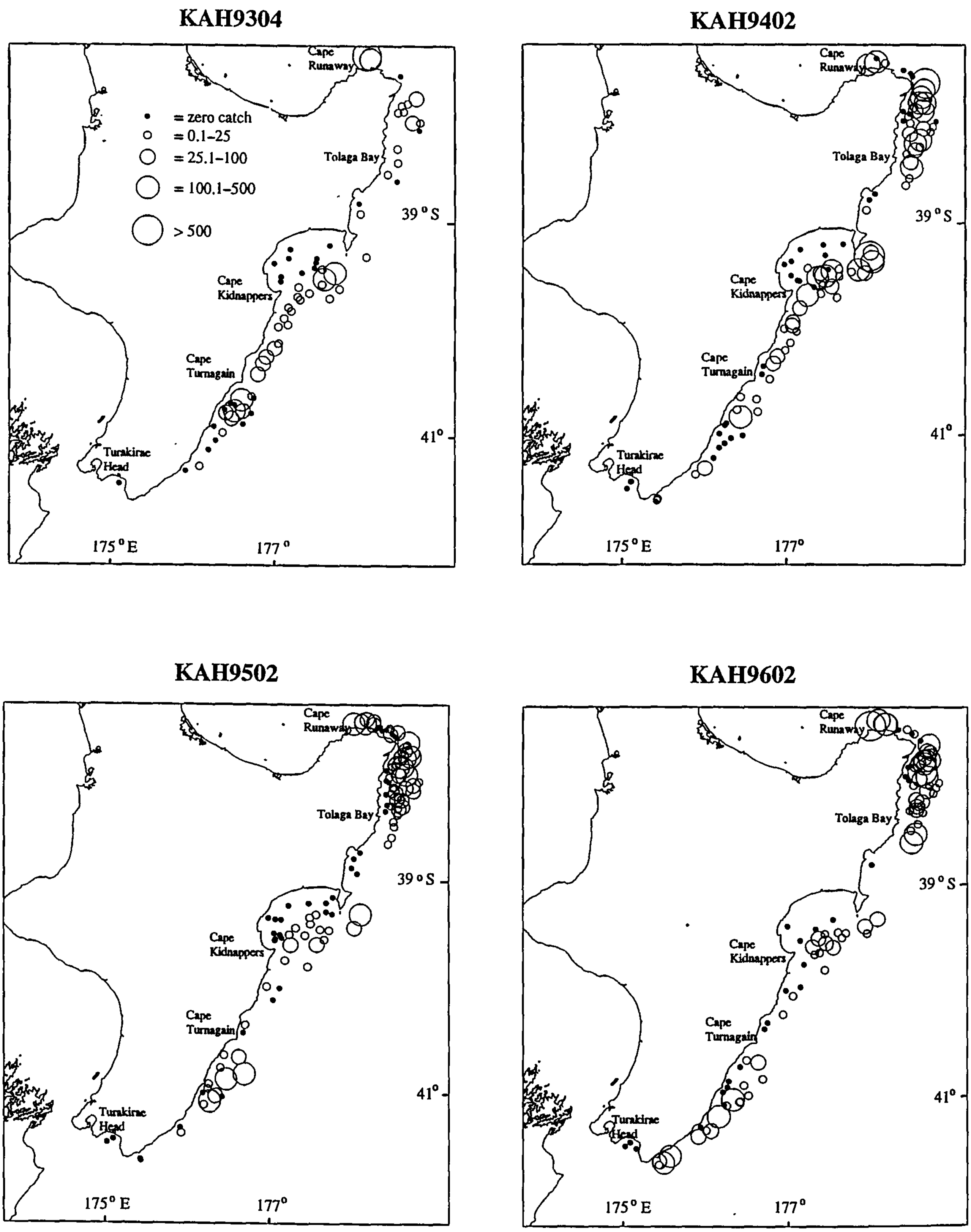


Figure 7e: **Frostfish (maximum catch rate 3618 kg.km^{-2})**

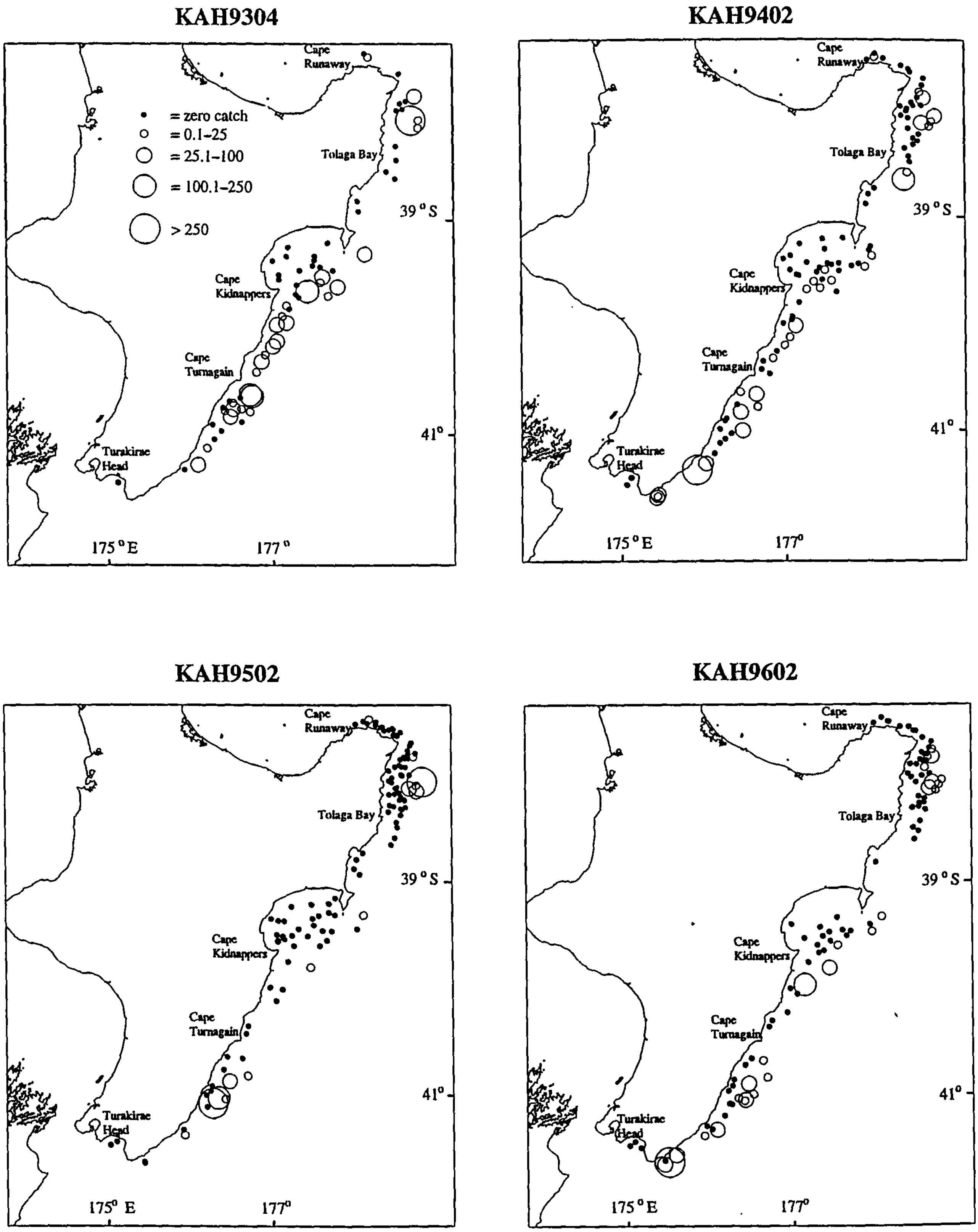


Figure 7f: **Gemfish (maximum catch rate 591 kg.km^{-2})**

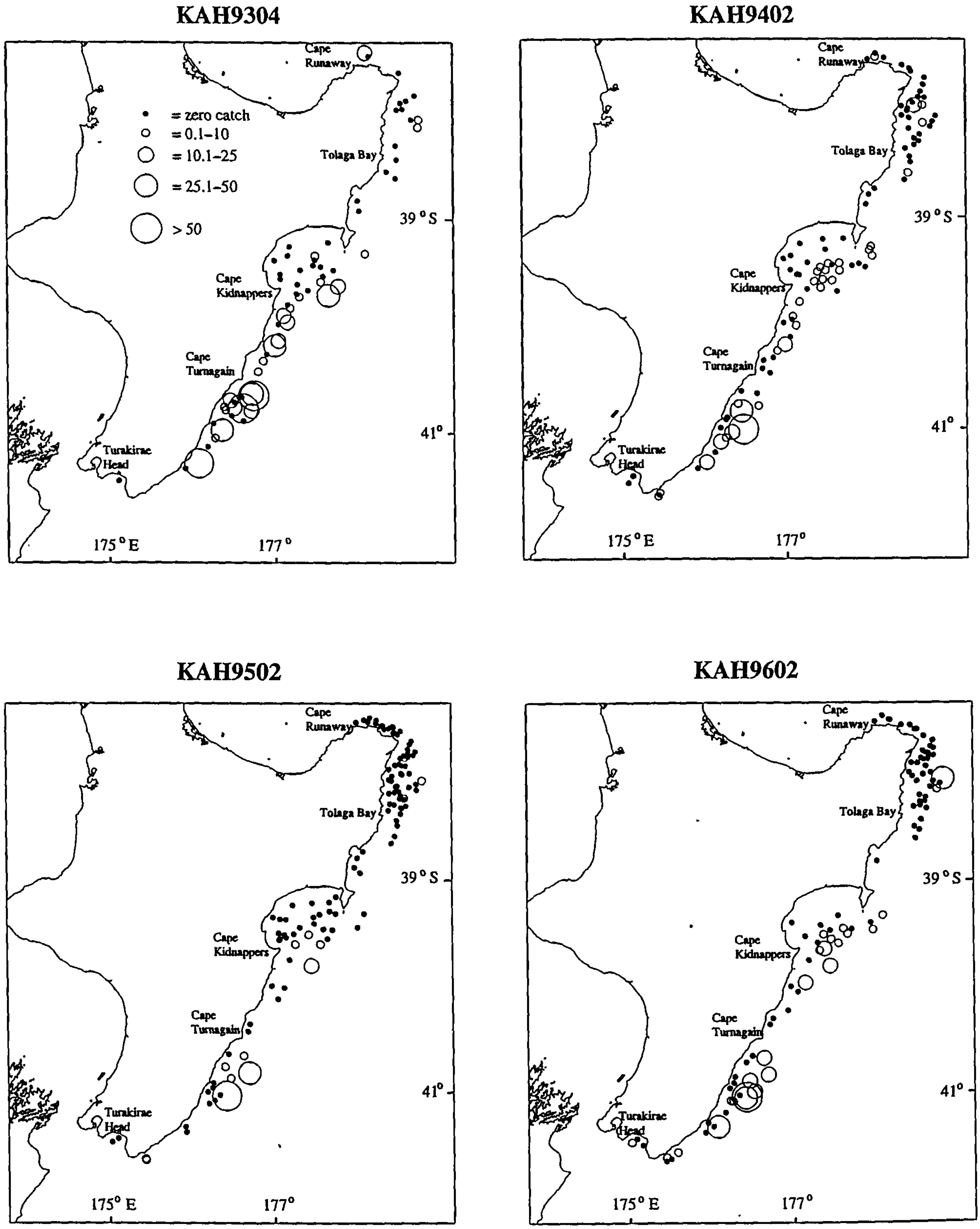


Figure 7g: **Giant stargazer (maximum catch rate 104 kg.km^{-2})**

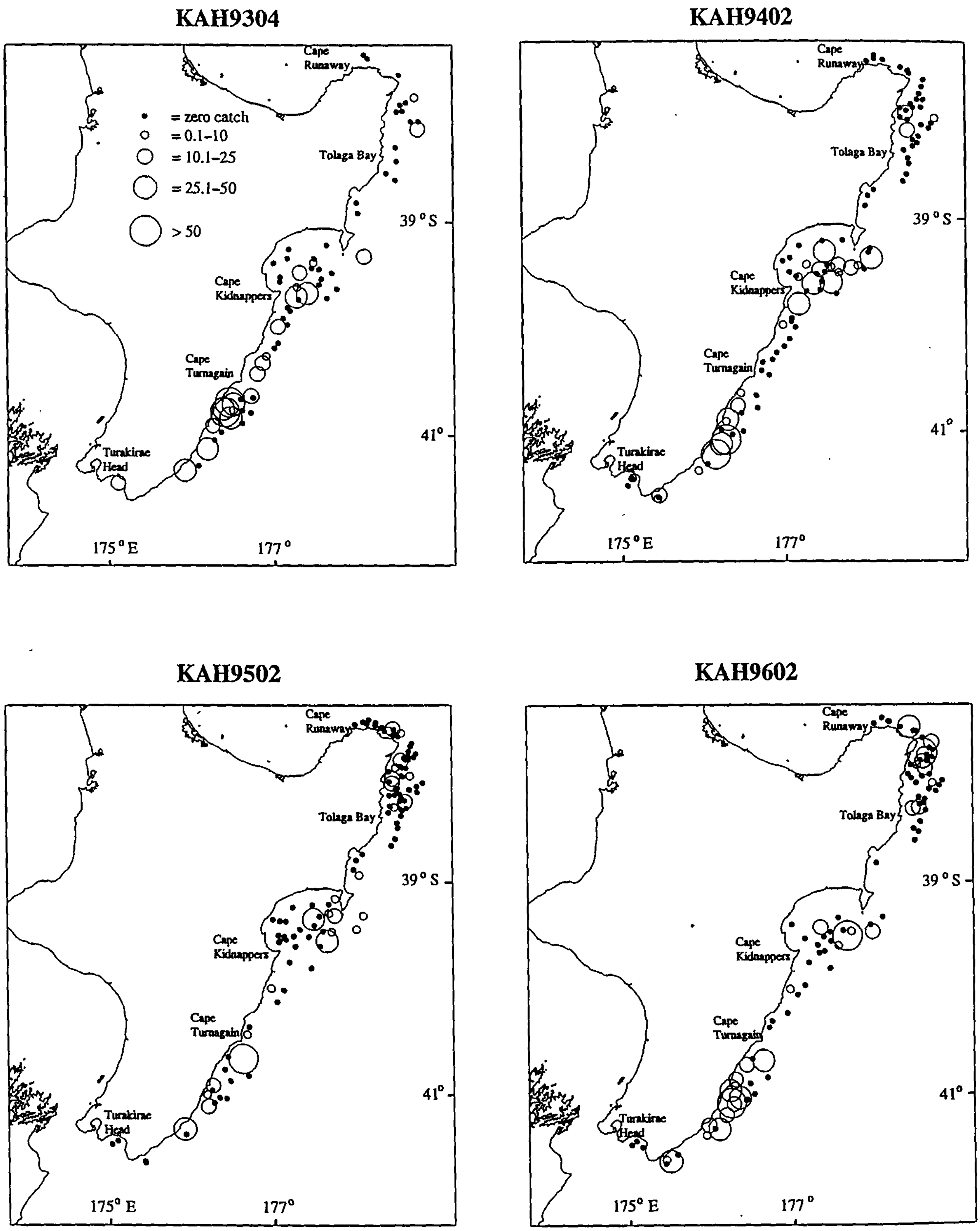


Figure 7h: **Hapuku (maximum catch rate 92 kg.km^{-2})**

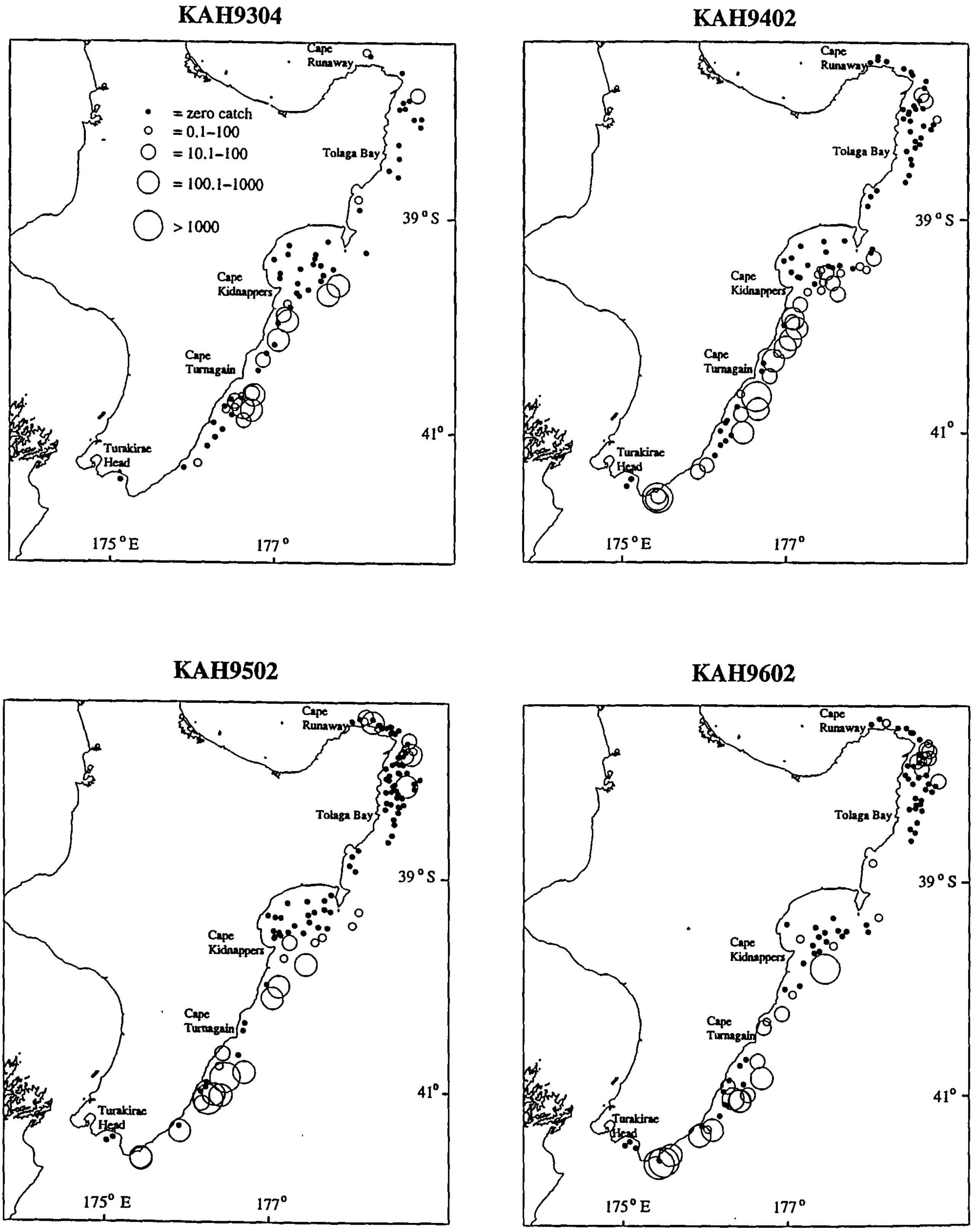


Figure 7i: **Hoki (maximum catch rate 4632 kg.km^{-2})**

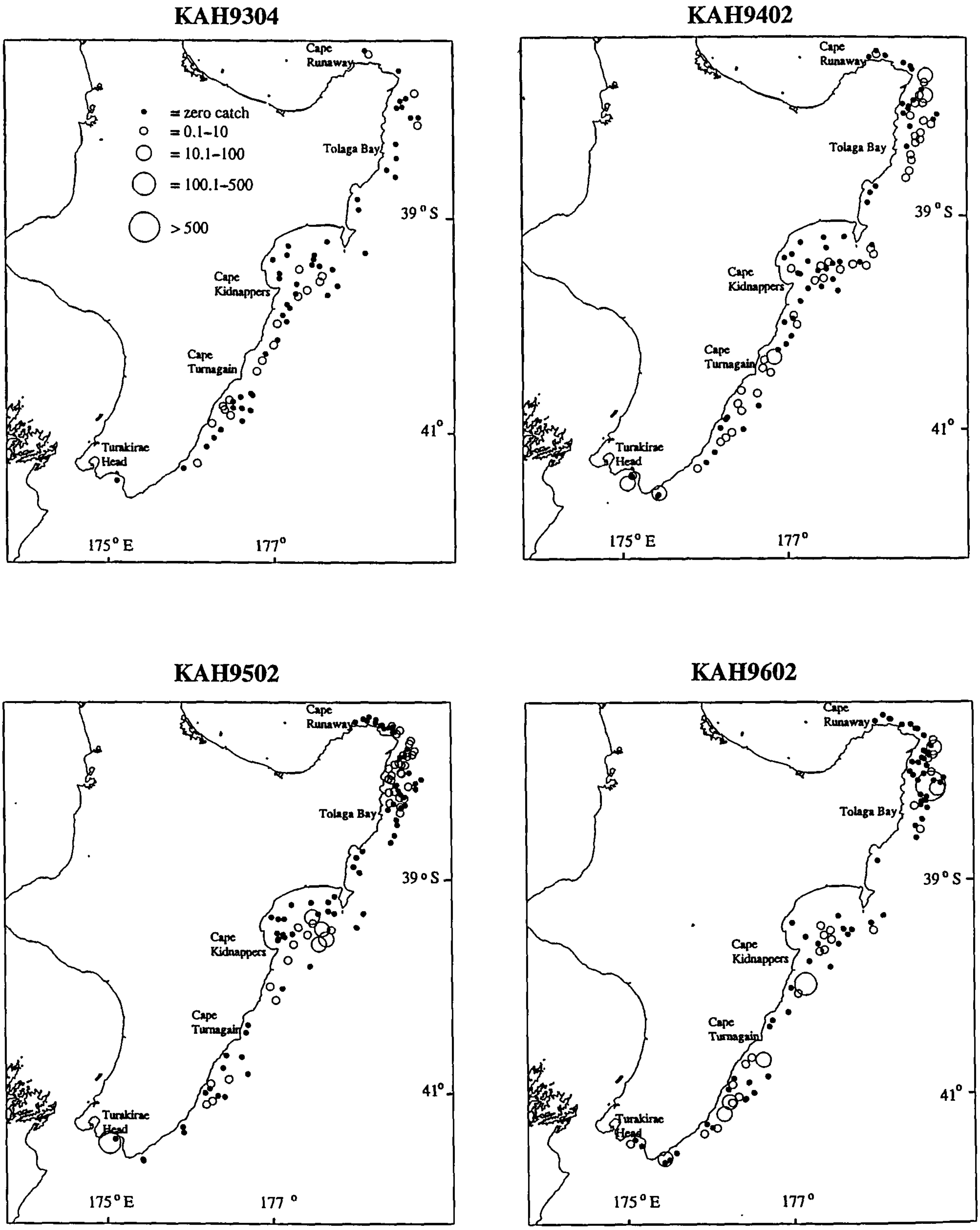


Figure 7j **: N.Z. jack mackerel (*T. declivis*) (maximum catch rate 2803 kg.km^{-2})**

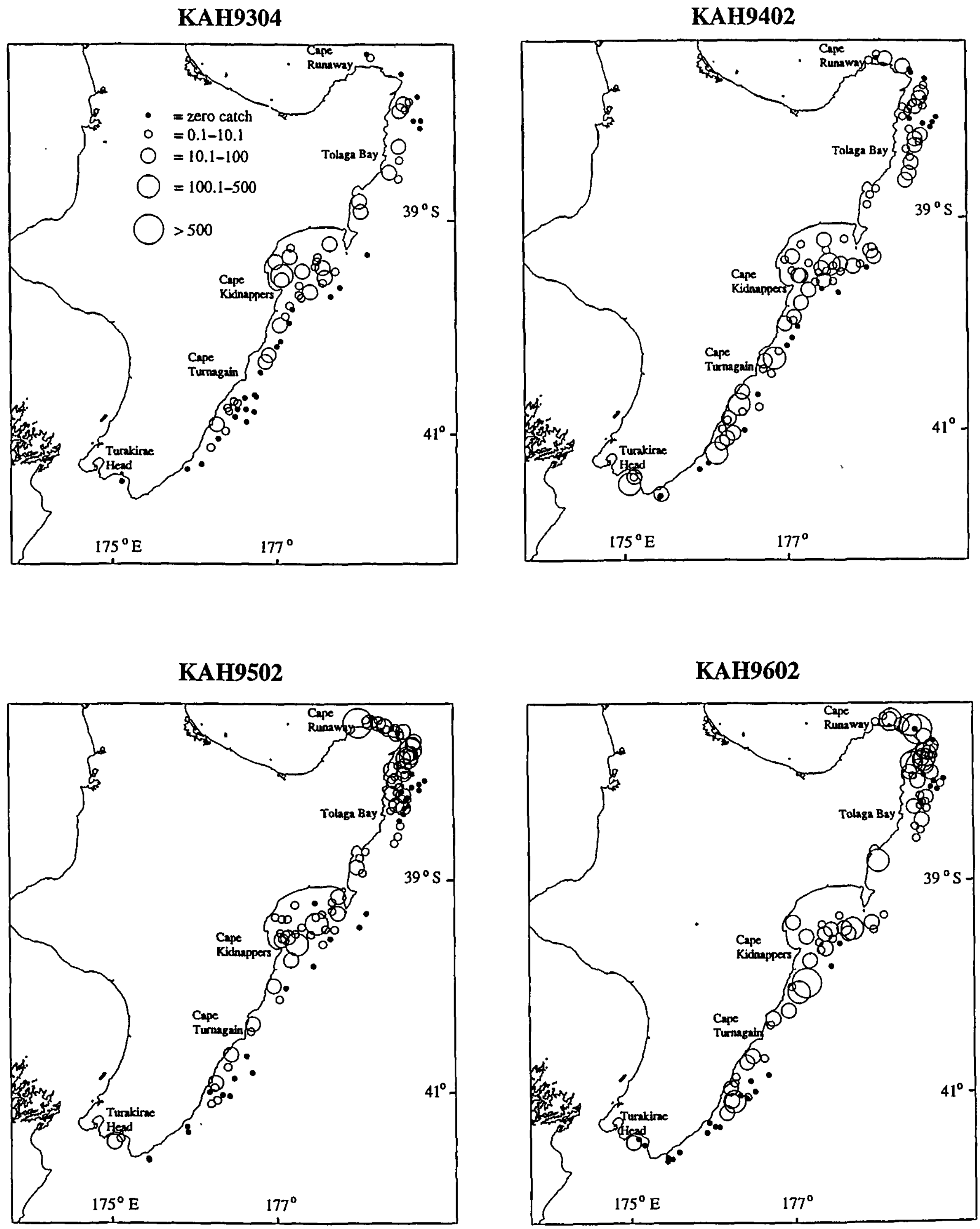


Figure 7k: **N.Z. jack mackerel (*T. novaezelandiae*) (maximum catch rate 2658 kg.km^{-2})**

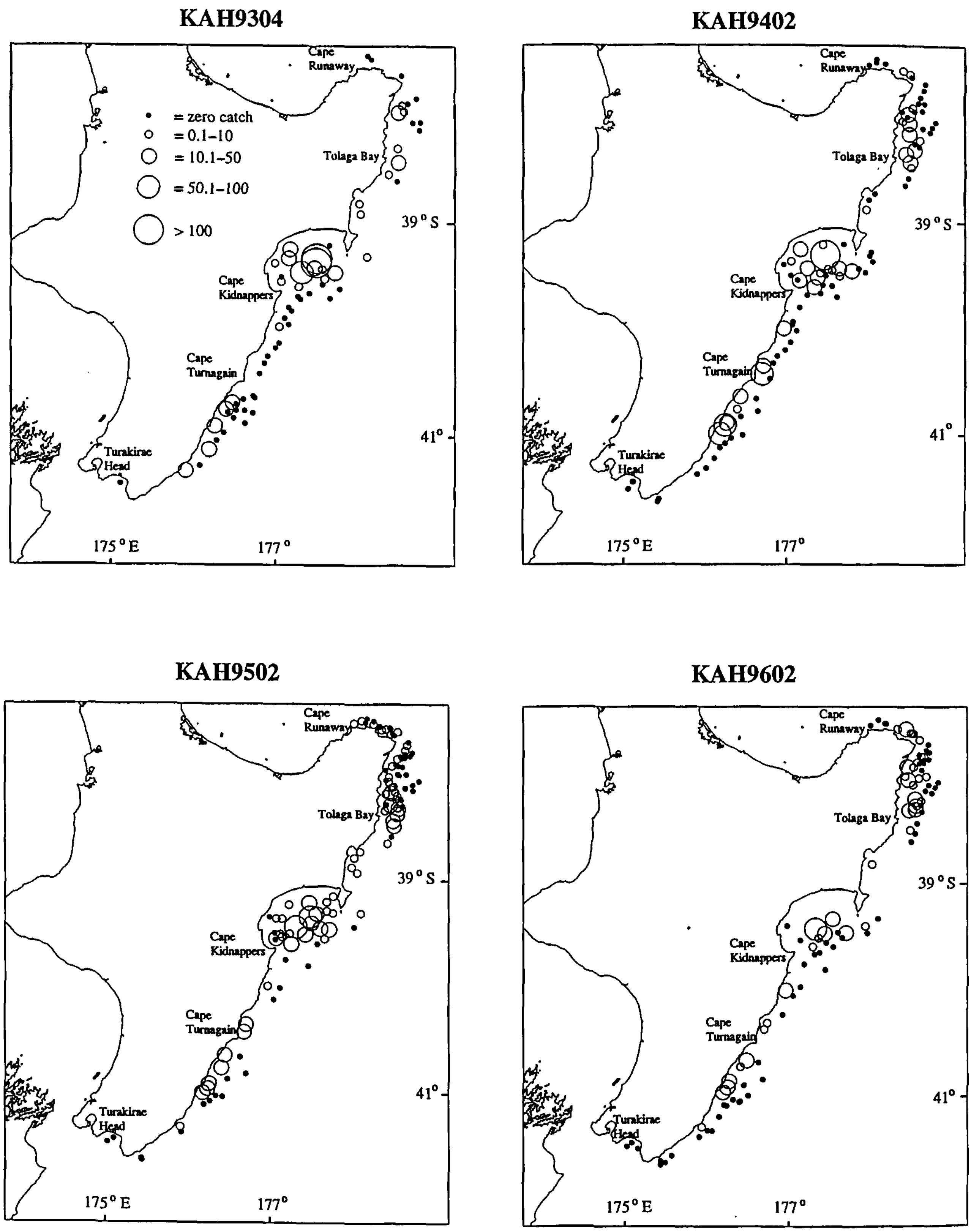


Figure 71: **John dory (maximum catch rate 140 kg.km^{-2})**

KAH9304

KAH9402

KAH9502

KAH9602

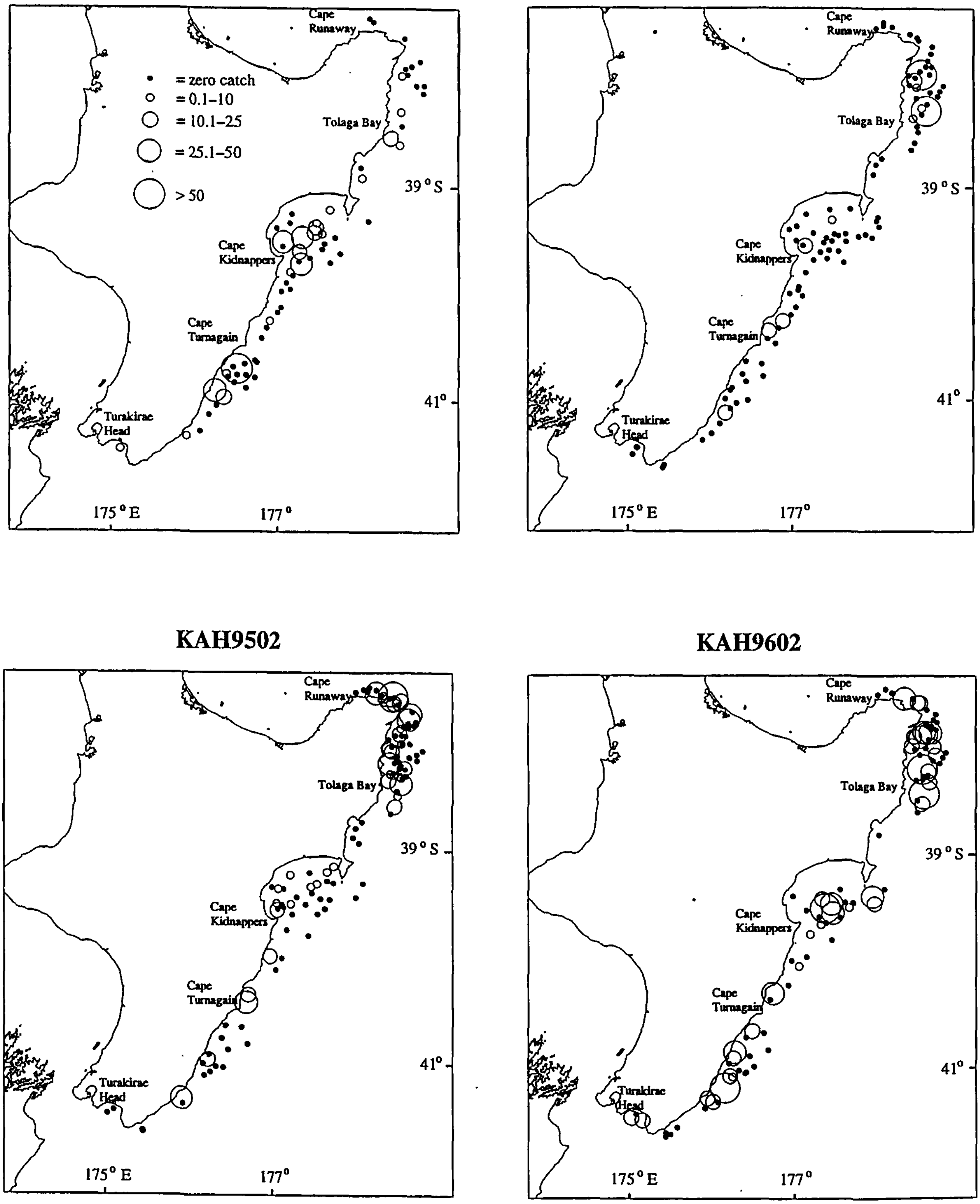


Figure 7m: **Kingfish (maximum catch rate 105 kg.km^{-2})**

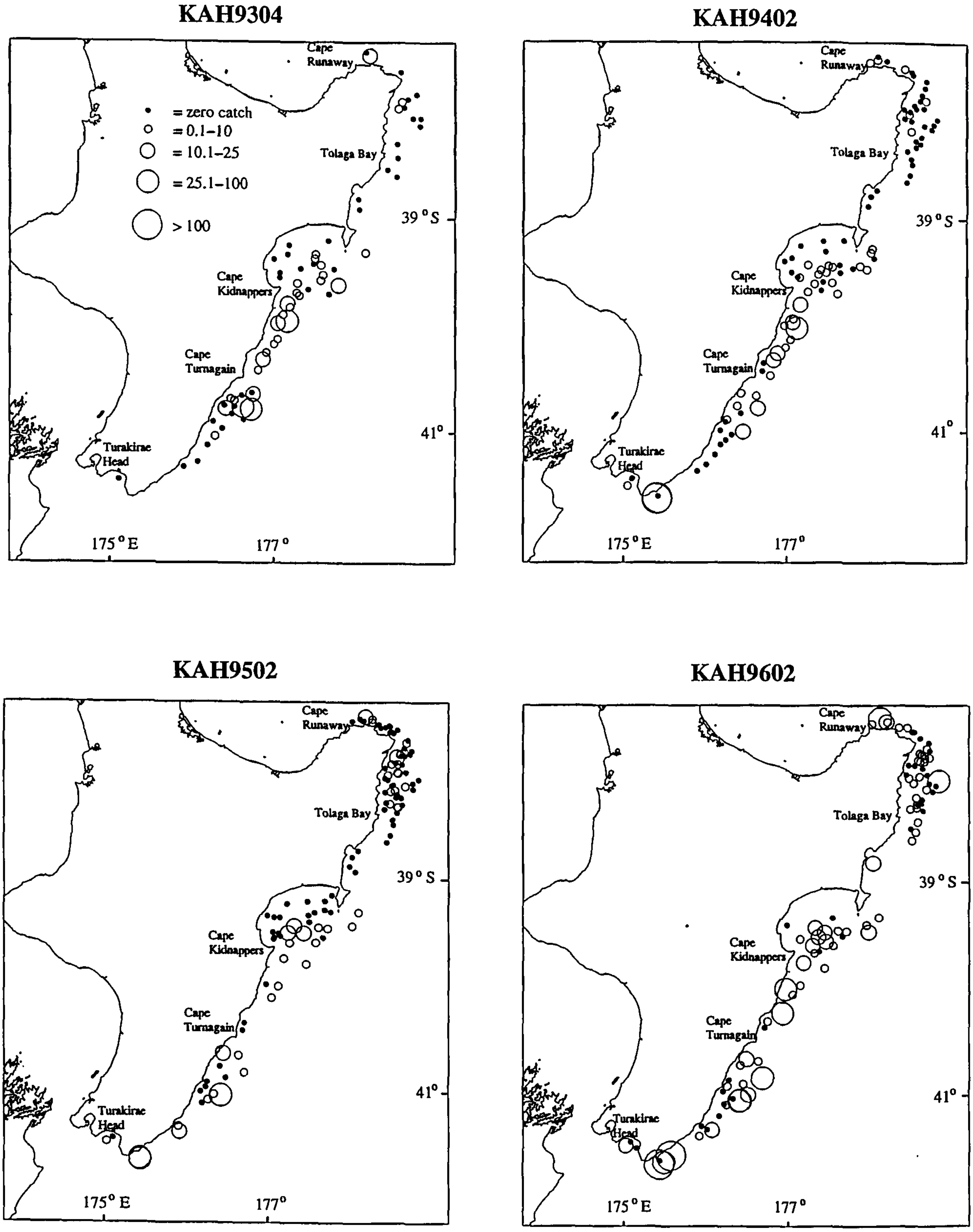


Figure 7n : **Ling (maximum catch rate 463 kg.km^{-2})**

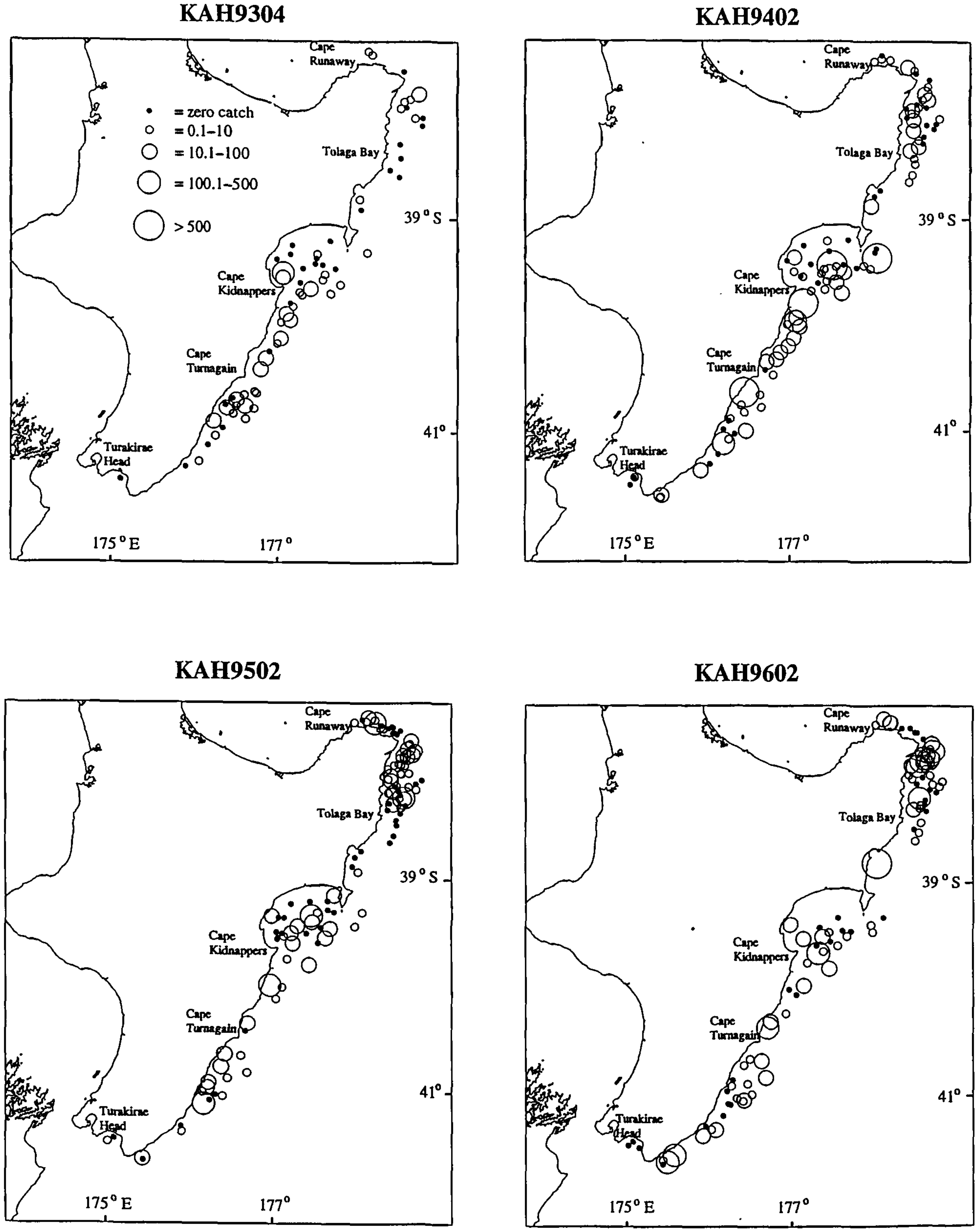


Figure 7o : **Red cod (maximum catch rate 3485 kg.km^{-2})**

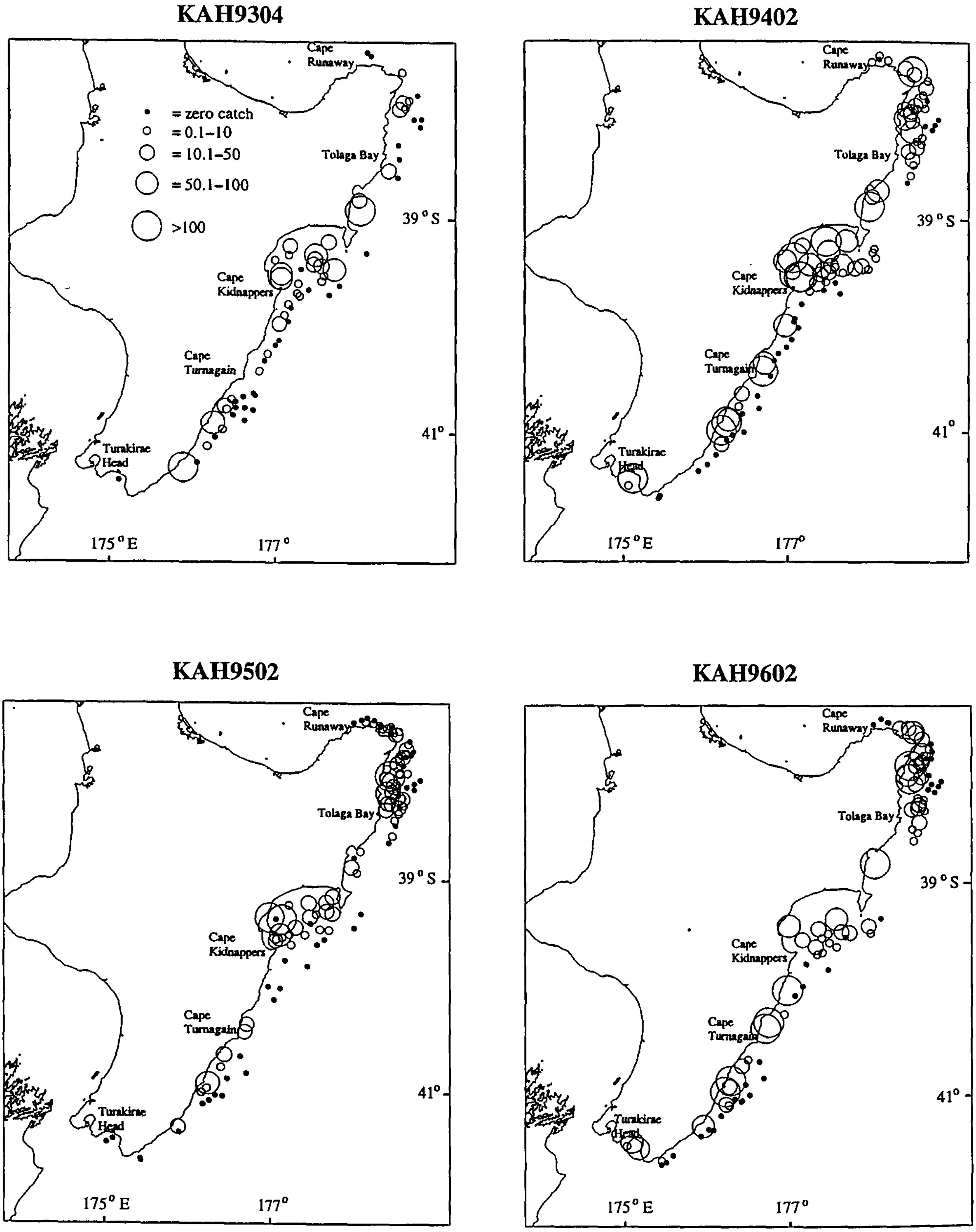


Figure 7p : **Red gurnard (maximum catch rate 460 kg.km^{-2})**

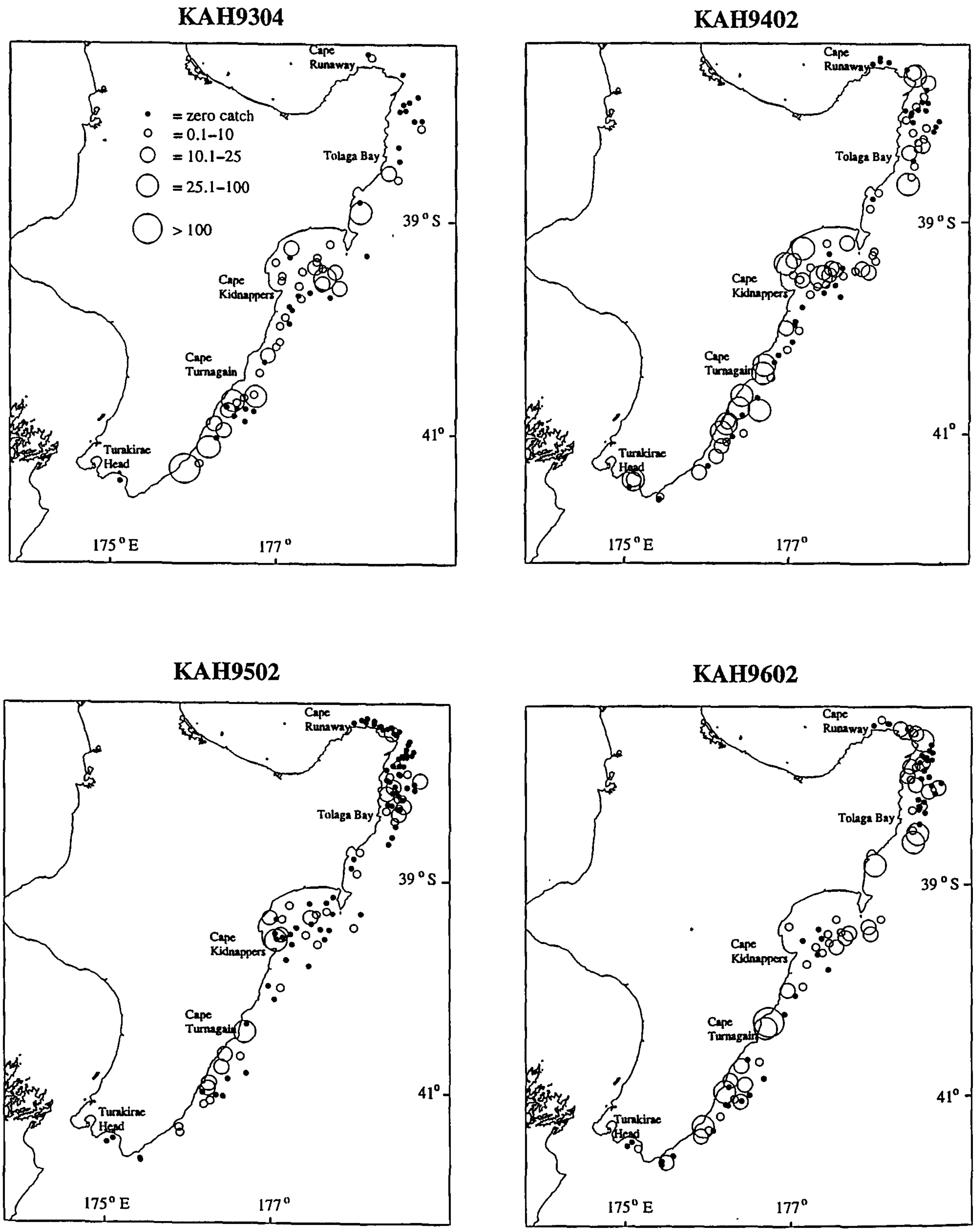


Figure 7q : **Rig (maximum catch rate 112 kg.km^{-2})**

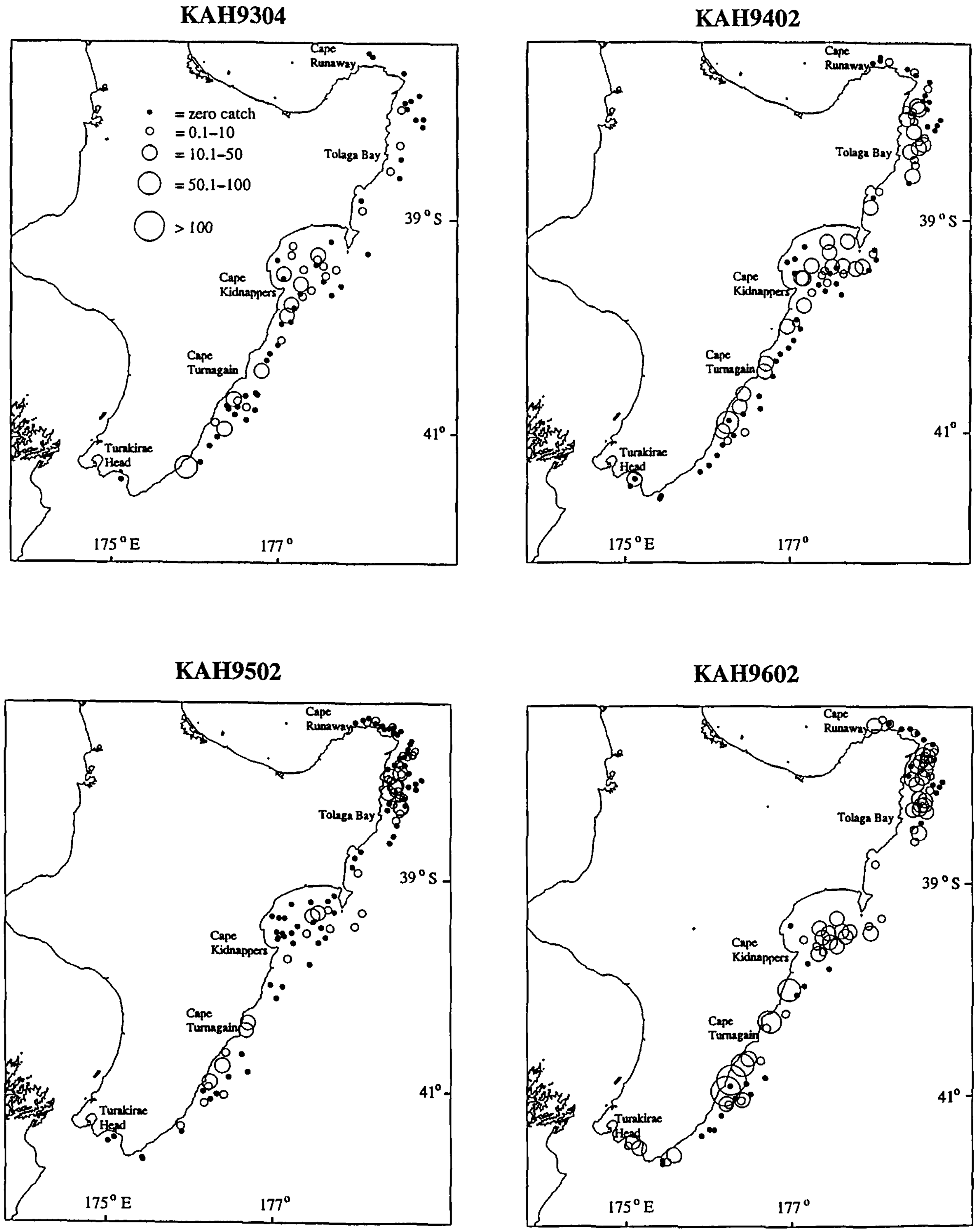


Figure 7r : **Rough skate (maximum catch rate 504 kg.km^{-2})**

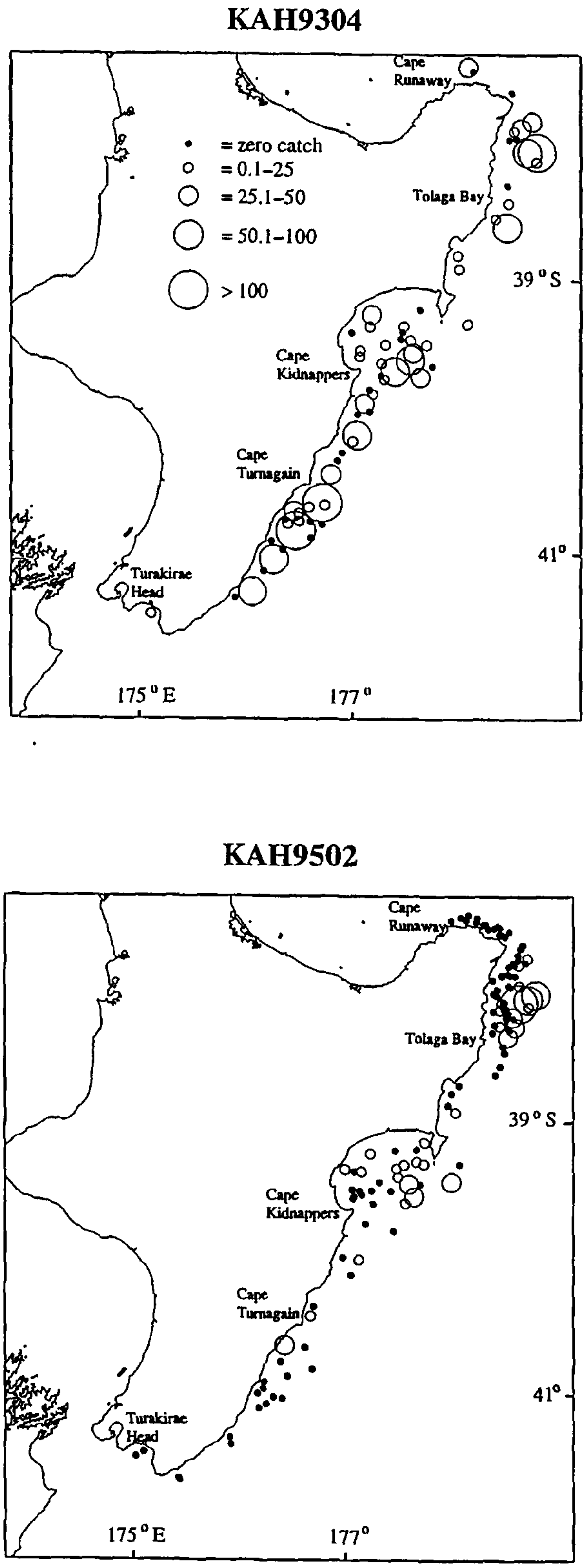


Figure 7s : **School shark (maximum catch rate 208 kg.km^{-2})**

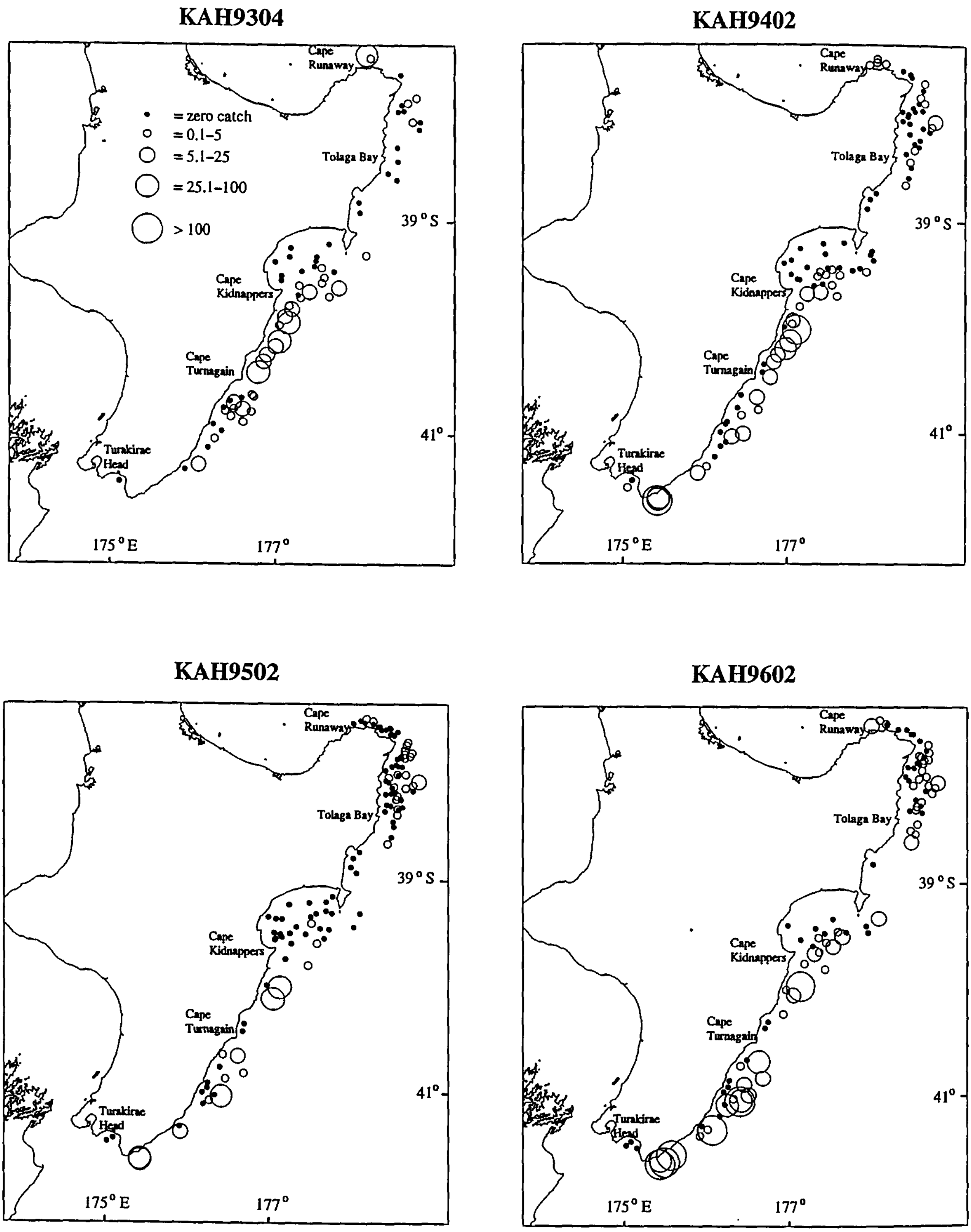


Figure 7t : **Sea perch (maximum catch rate 342 kg.km^{-2})**

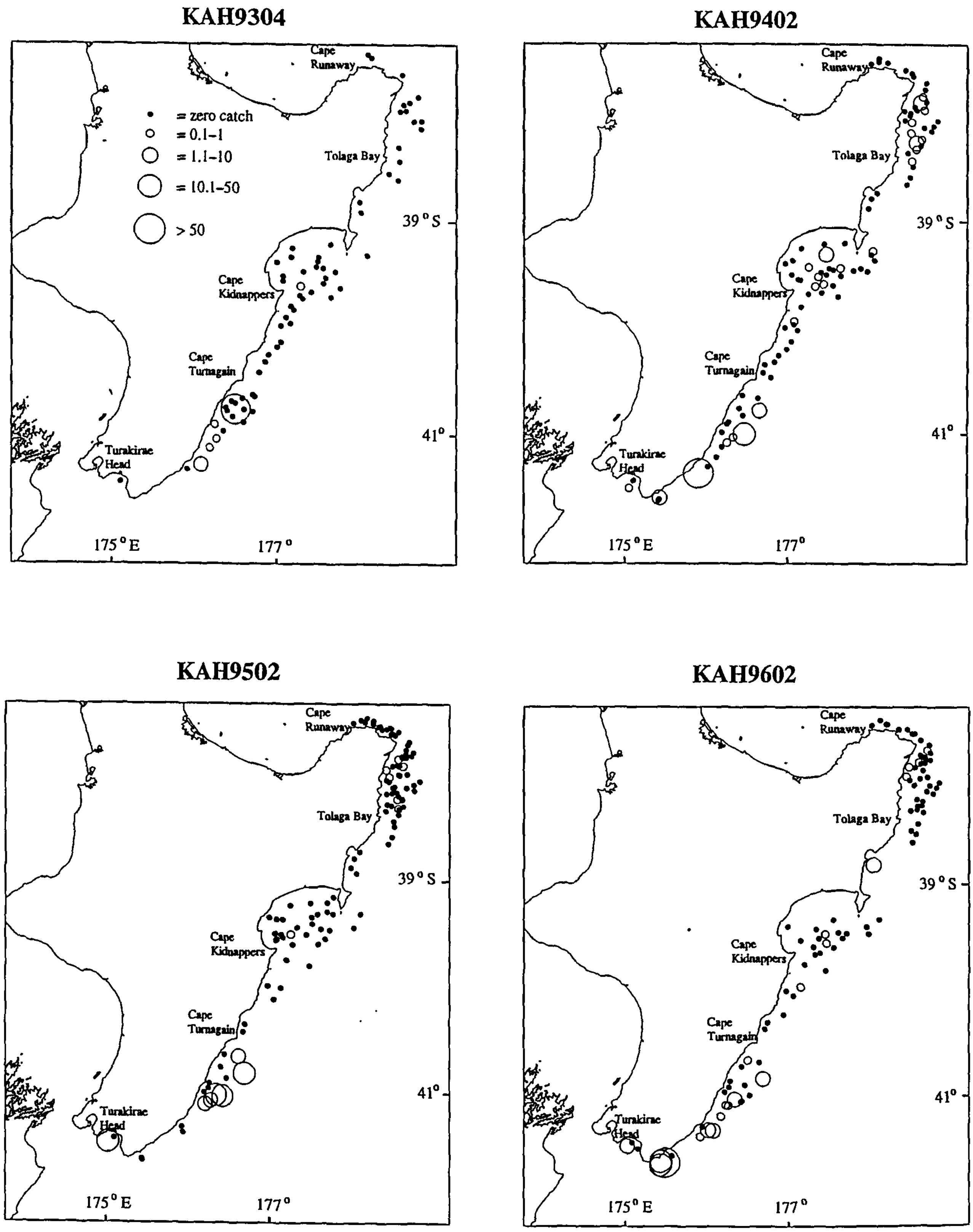


Figure 7u: **Silver warehou (maximum catch rate 321 kg.km^{-2})**

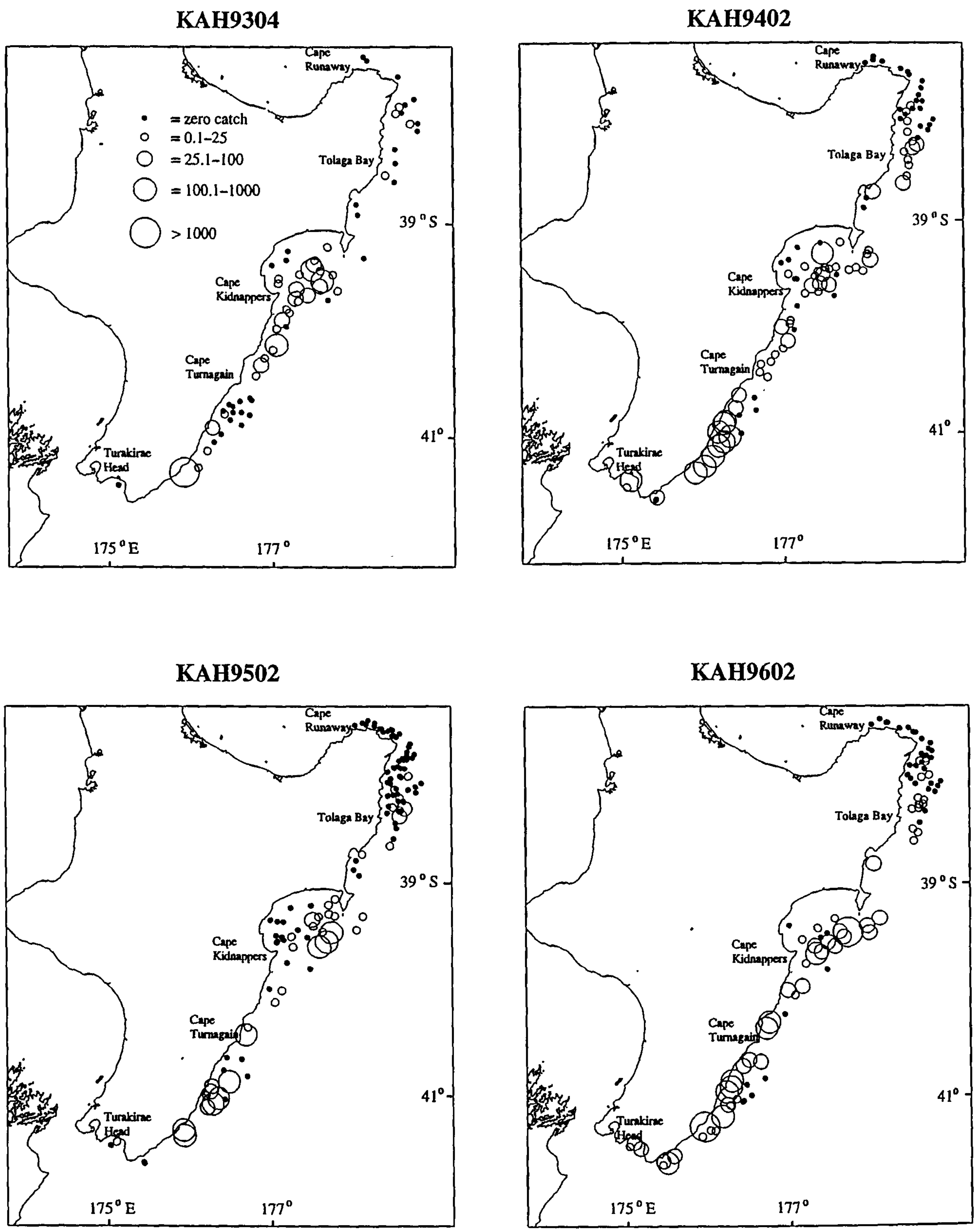


***Figure 7w*: Spiny dogfish (maximum catch rate 26 001 kg.km^{-2})**

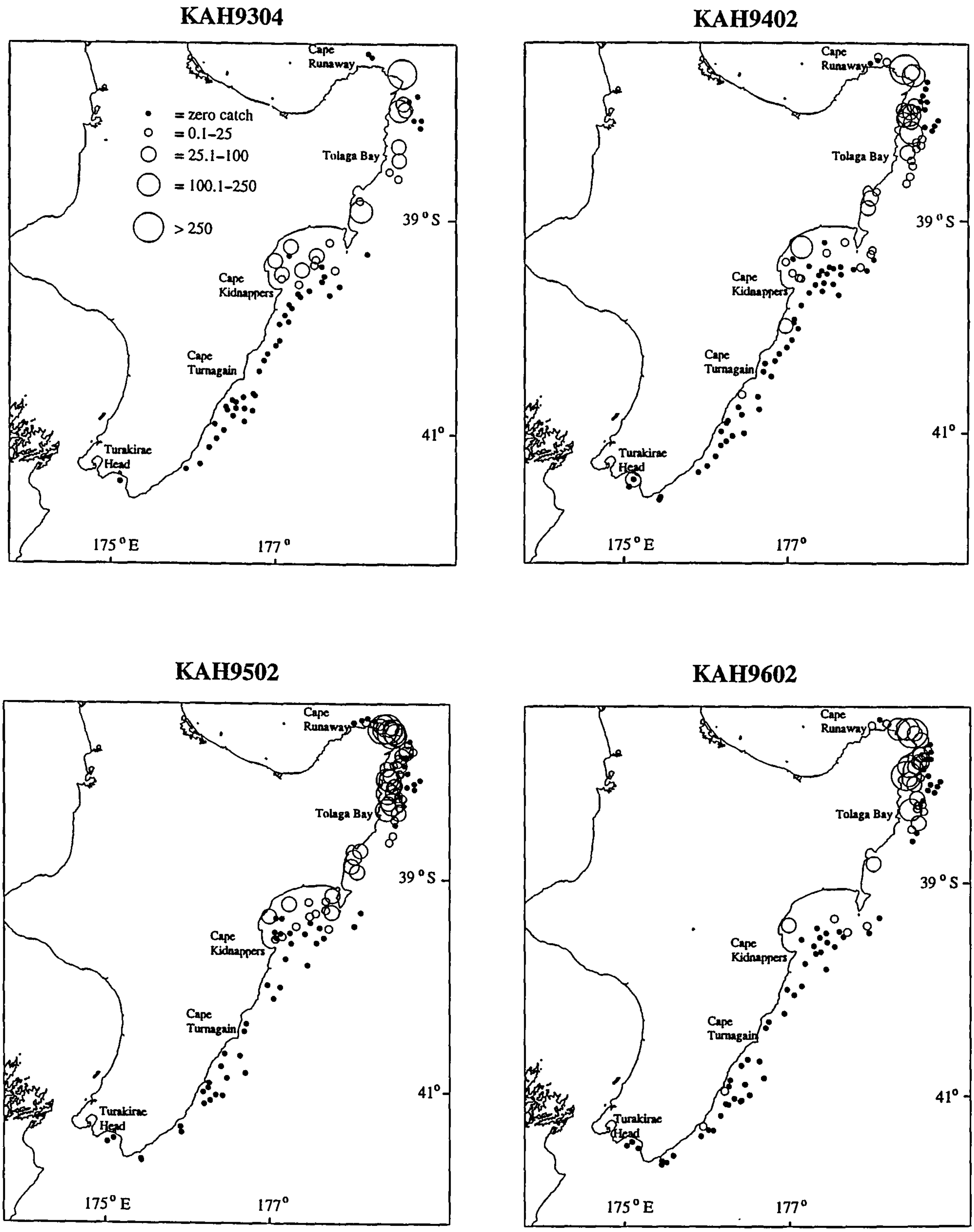


Figure 7v : **Snapper (maximum catch rate 598 kg.km^{-2})**

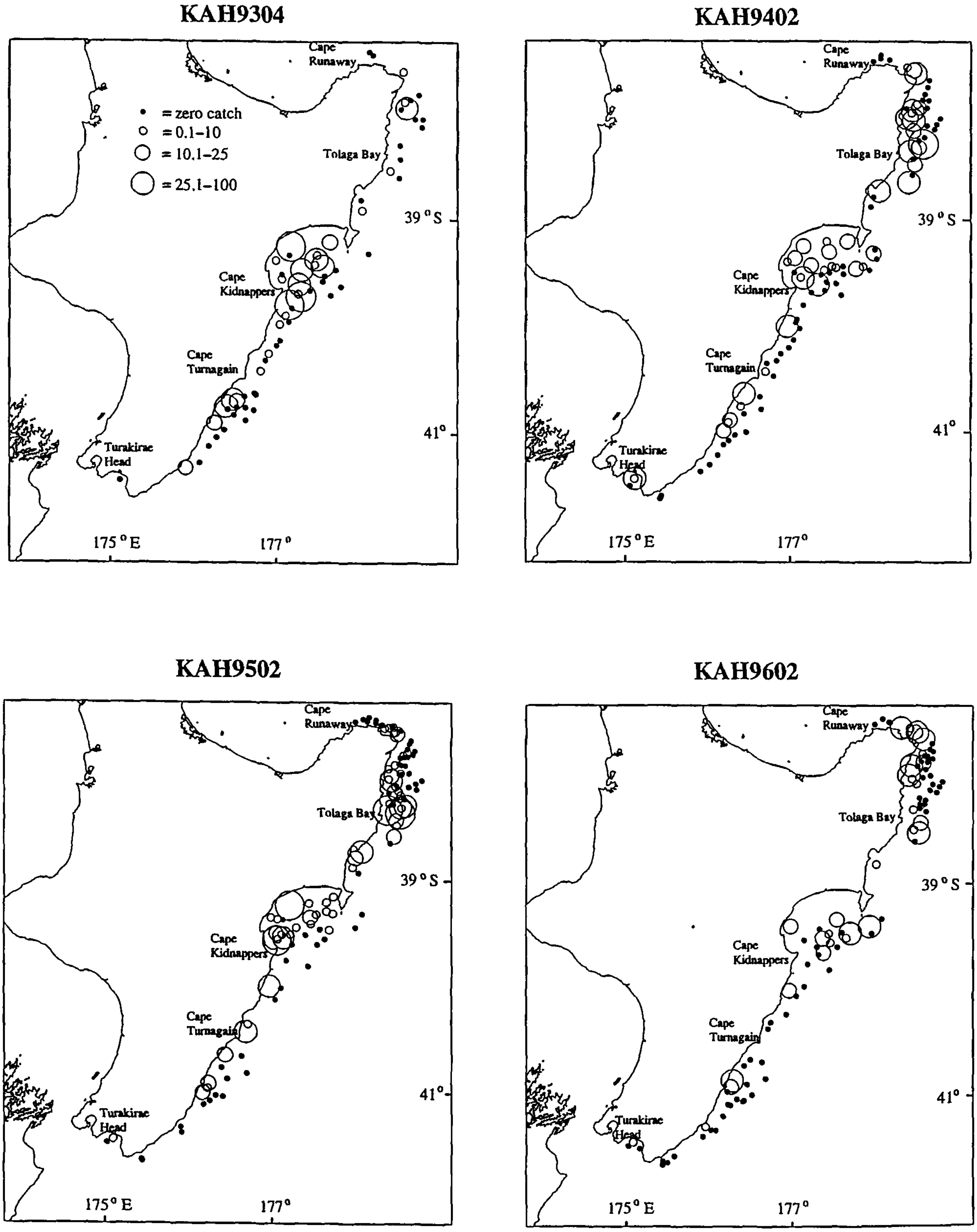


Figure 7y: **Trevally (maximum catch rate 569 kg.km^{-2})**

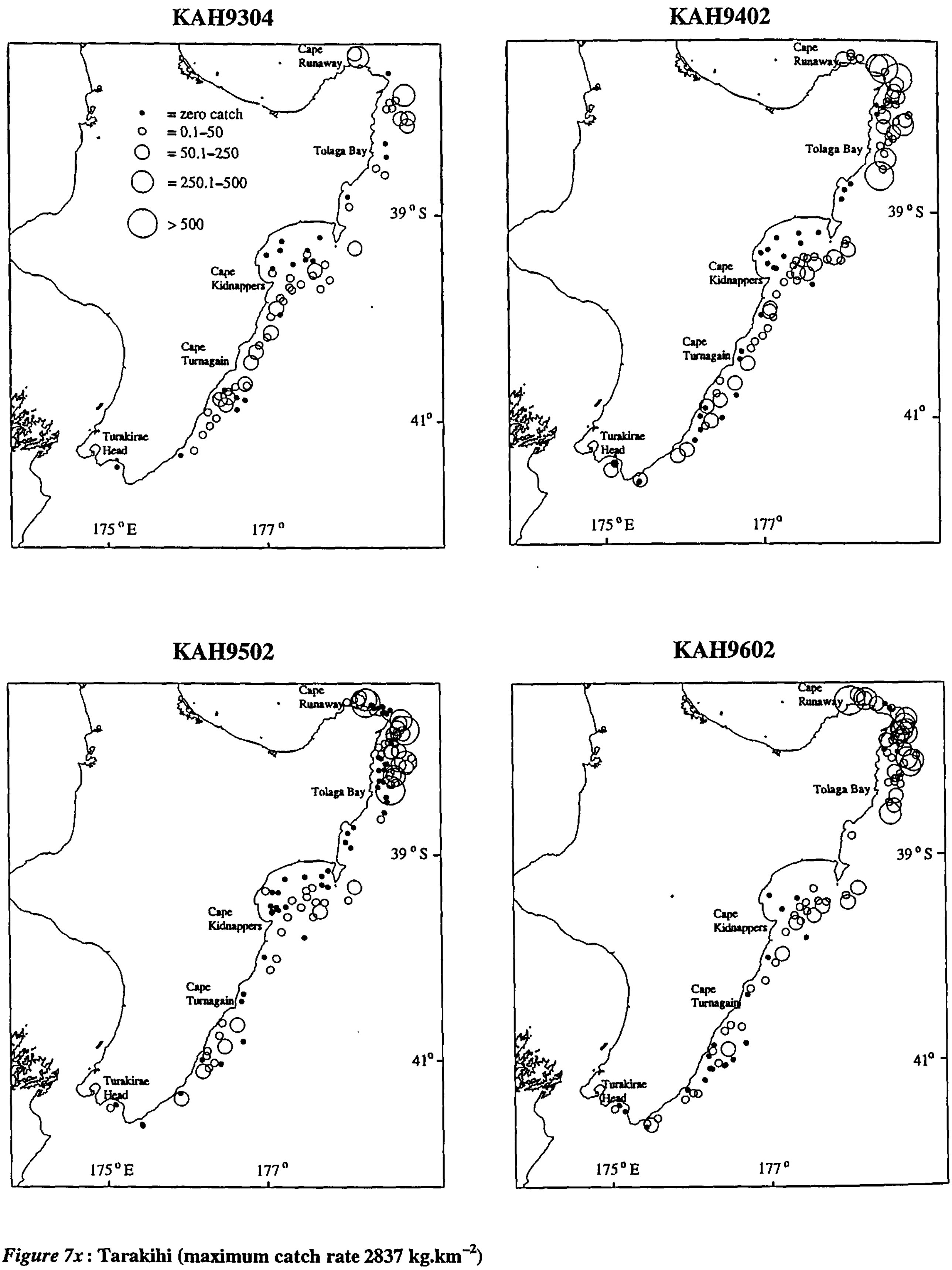


Figure 7x : **Tarakihi (maximum catch rate 2837 kg.km^{-2})**

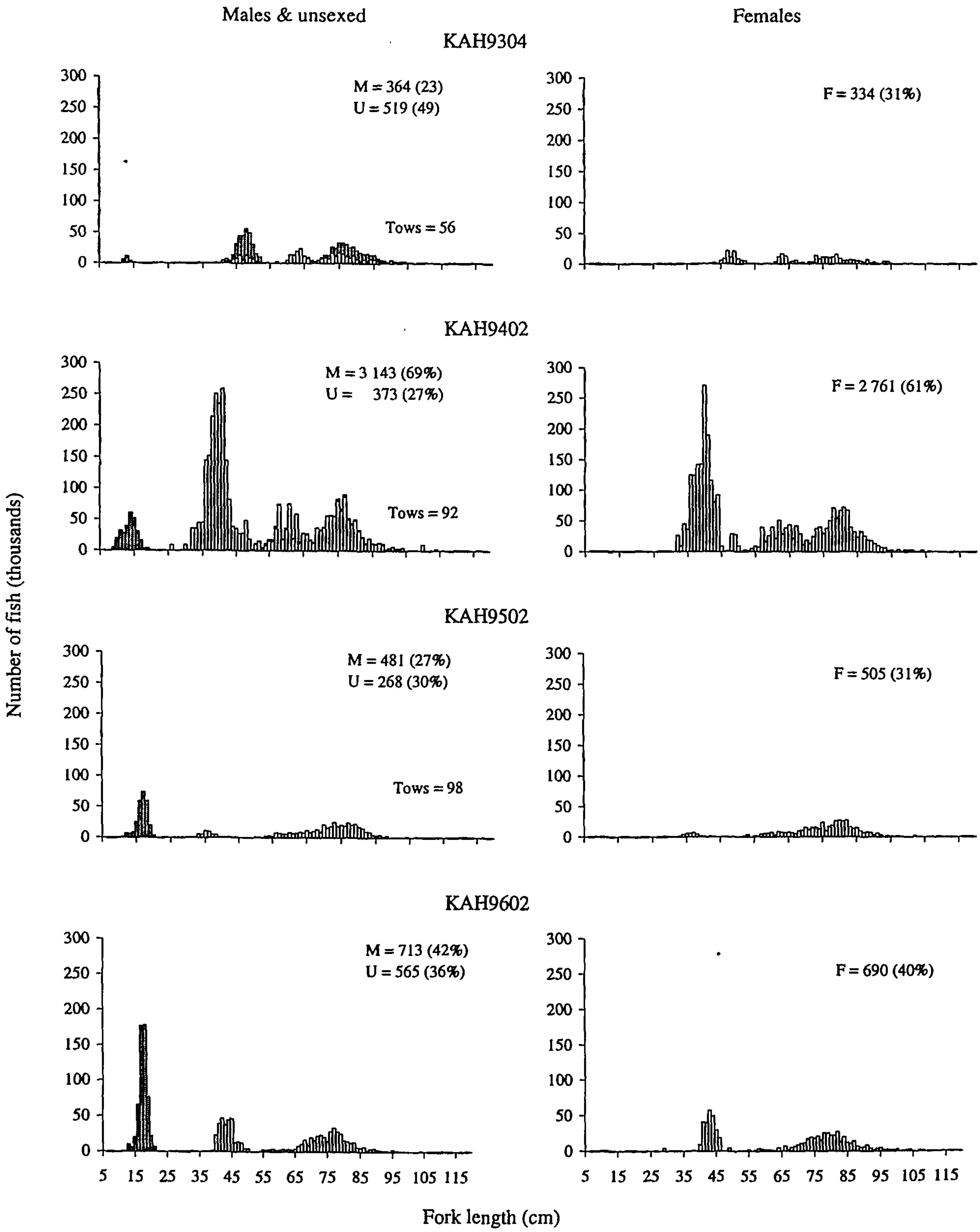


Figure 8b: **Barracouta.**

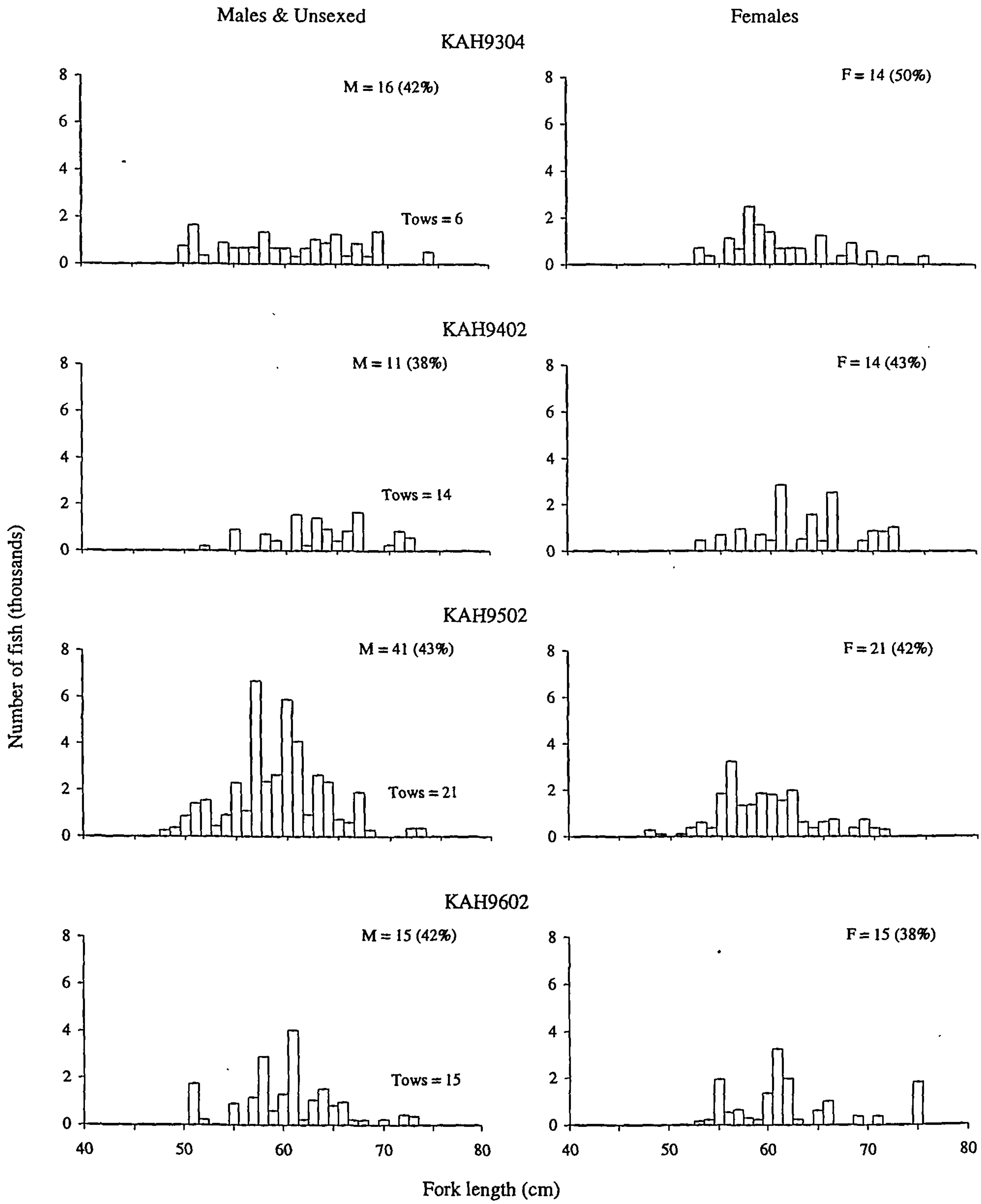


Figure 8c: **Blue moki.**

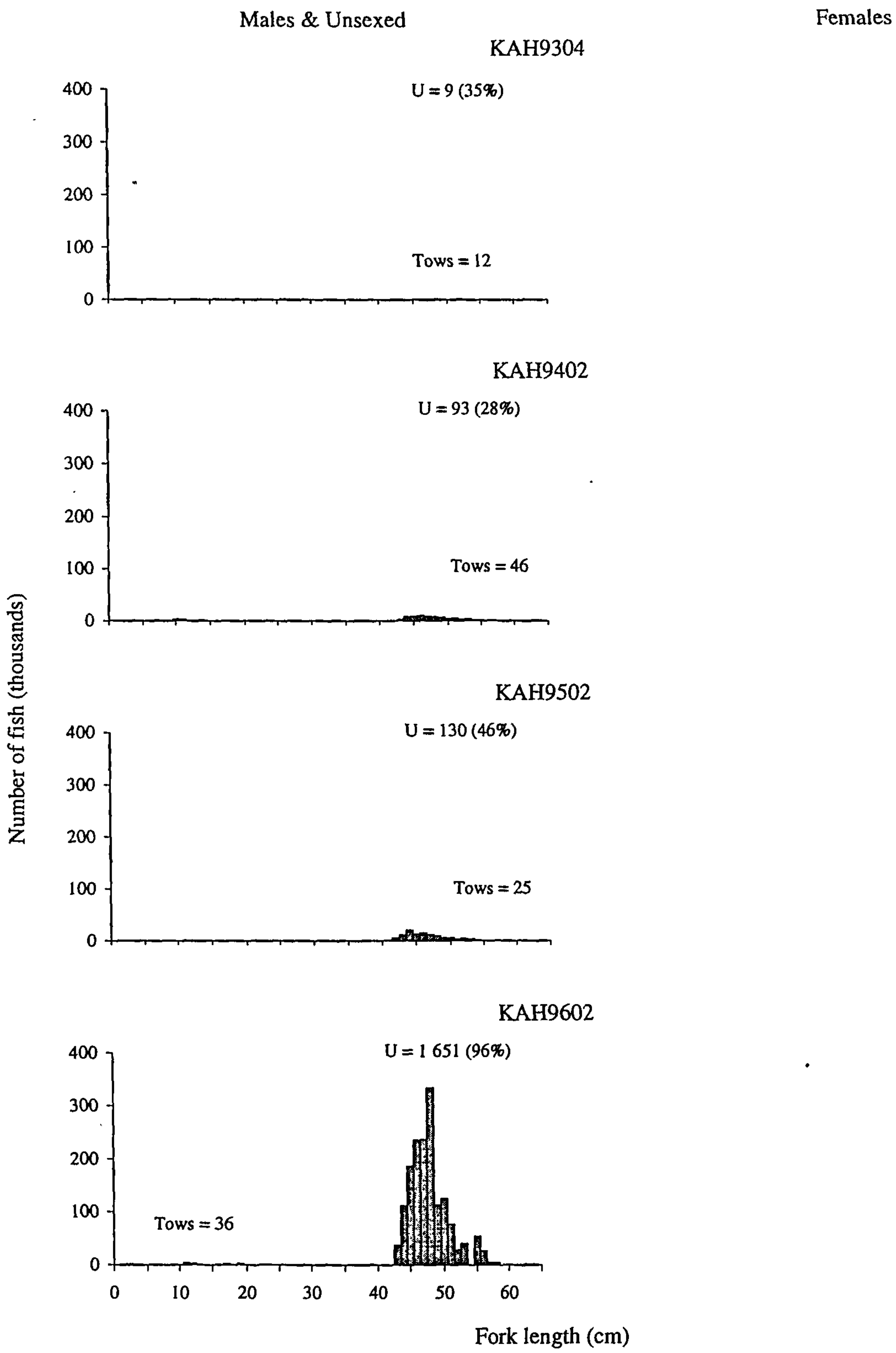


Figure 8d: **Chilean jack mackerel.**

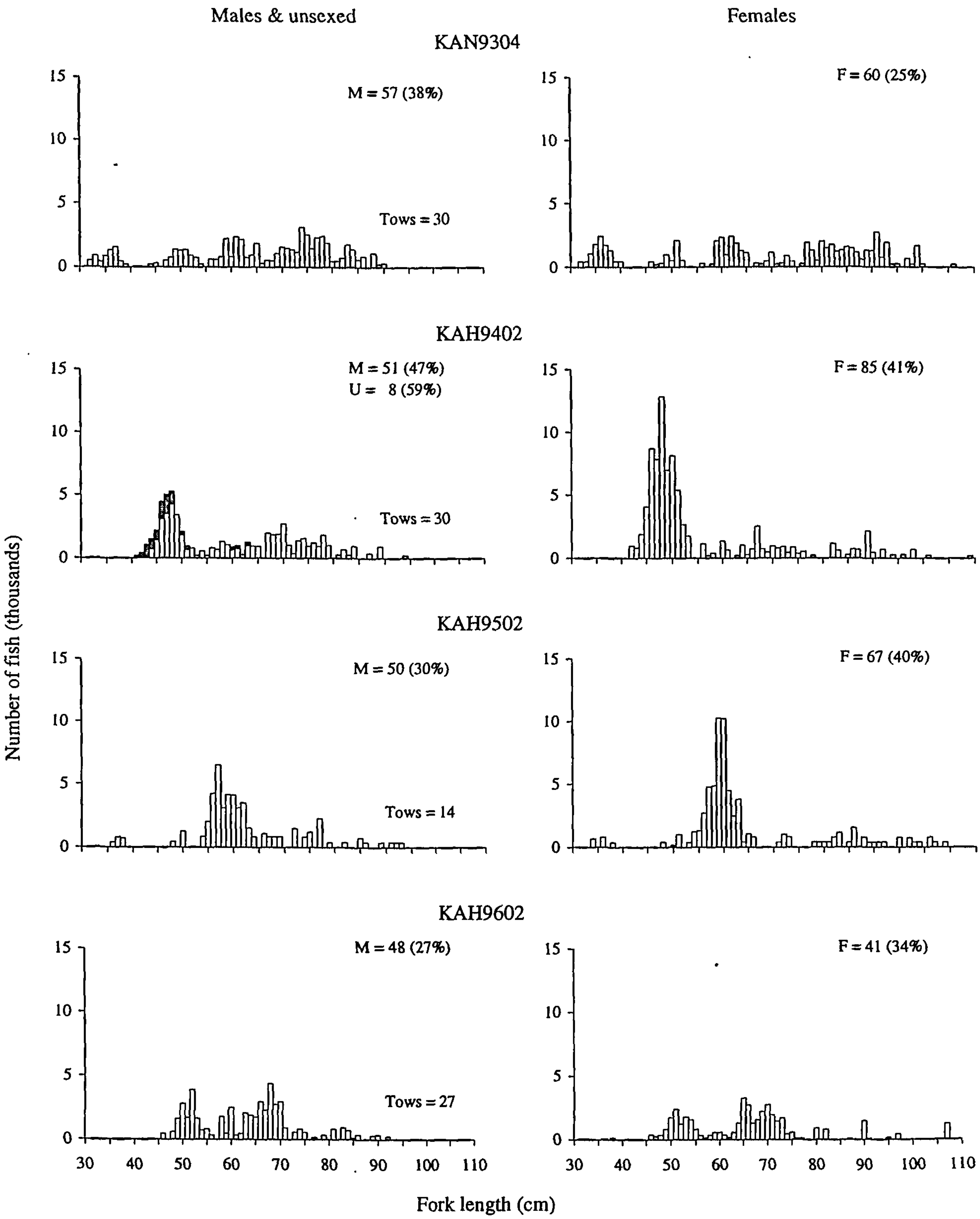


Figure 8e **: Gemfish.**

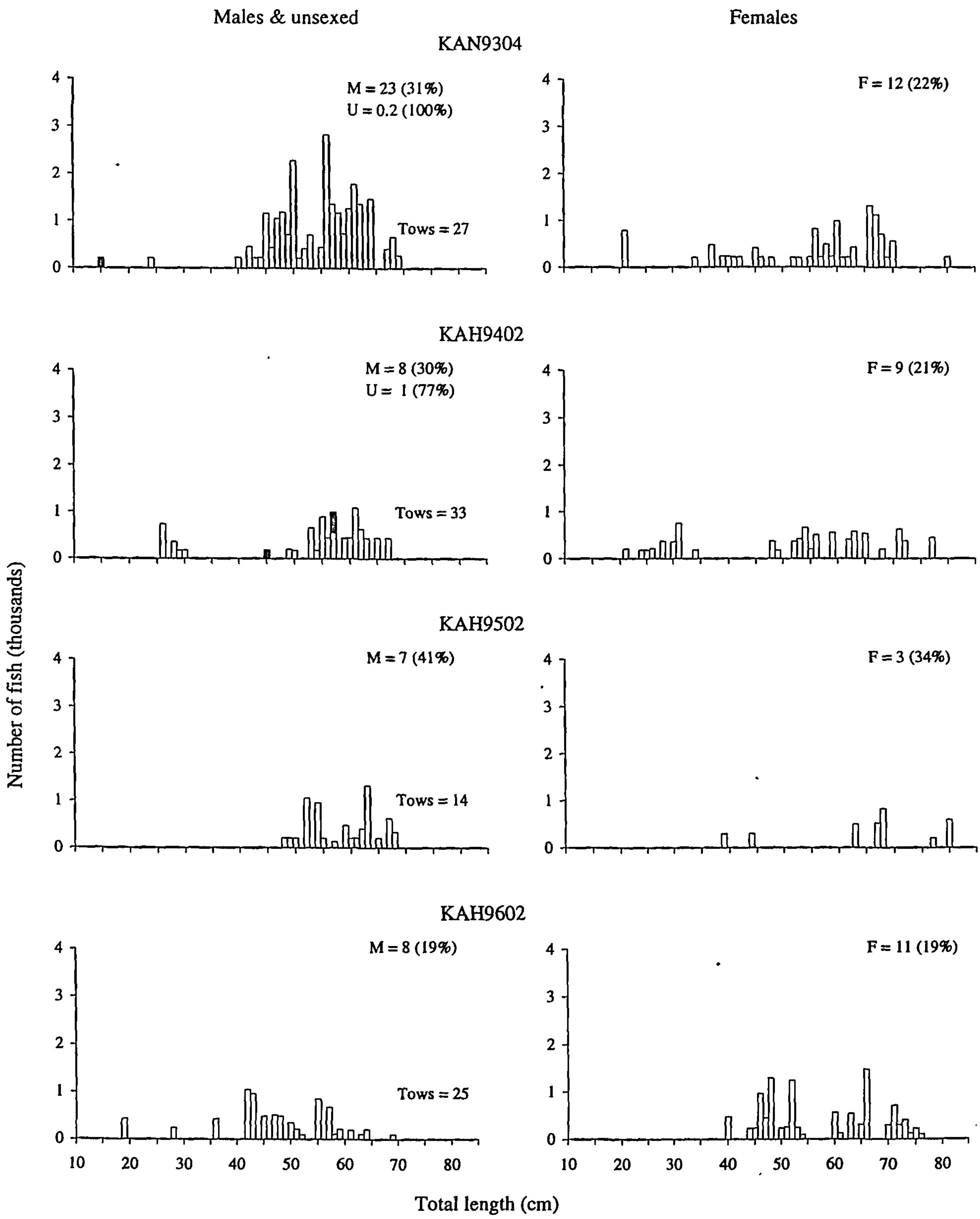


Figure 8f: **Giant stargazer.**

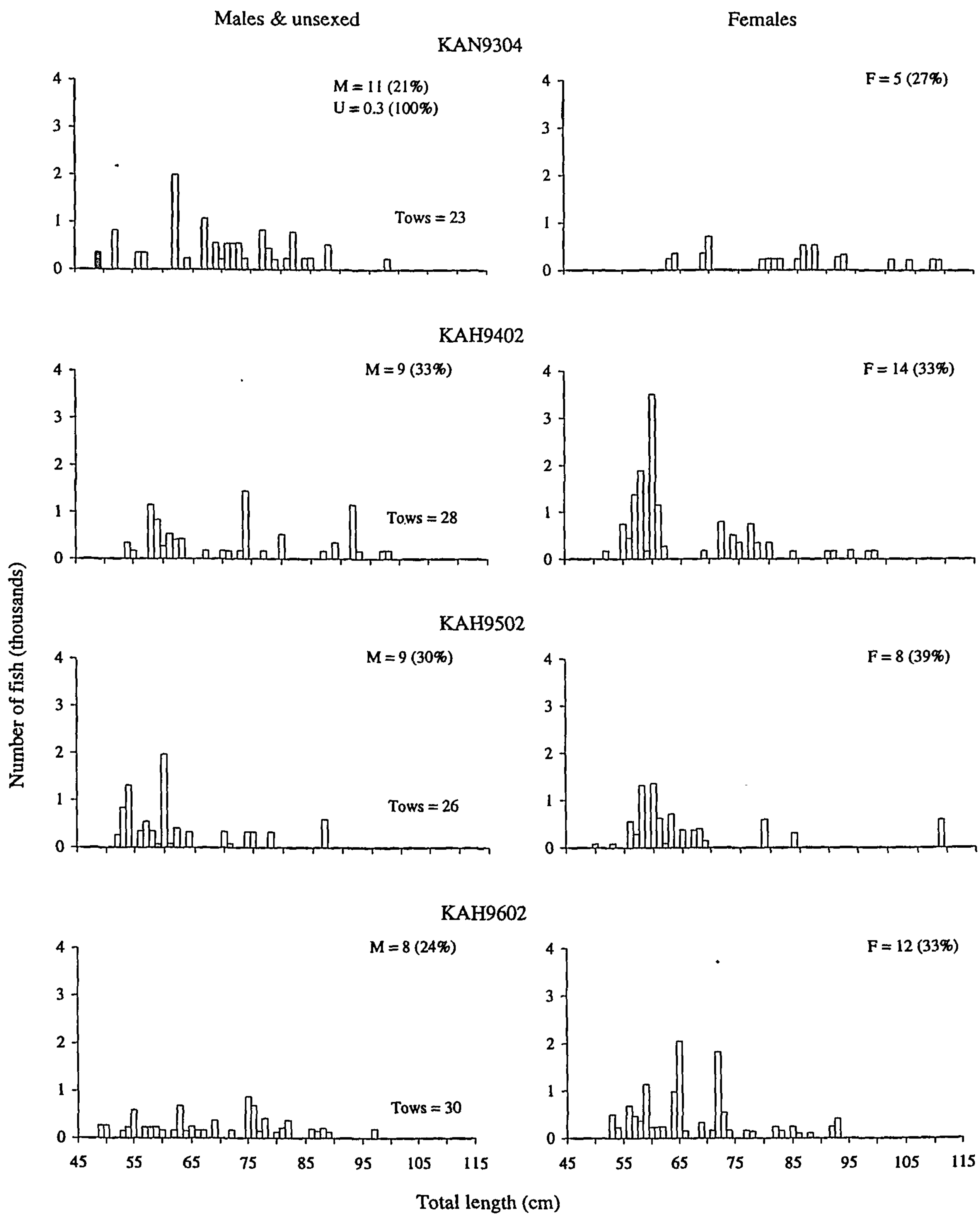


Figure 8g **: Hapuku.**

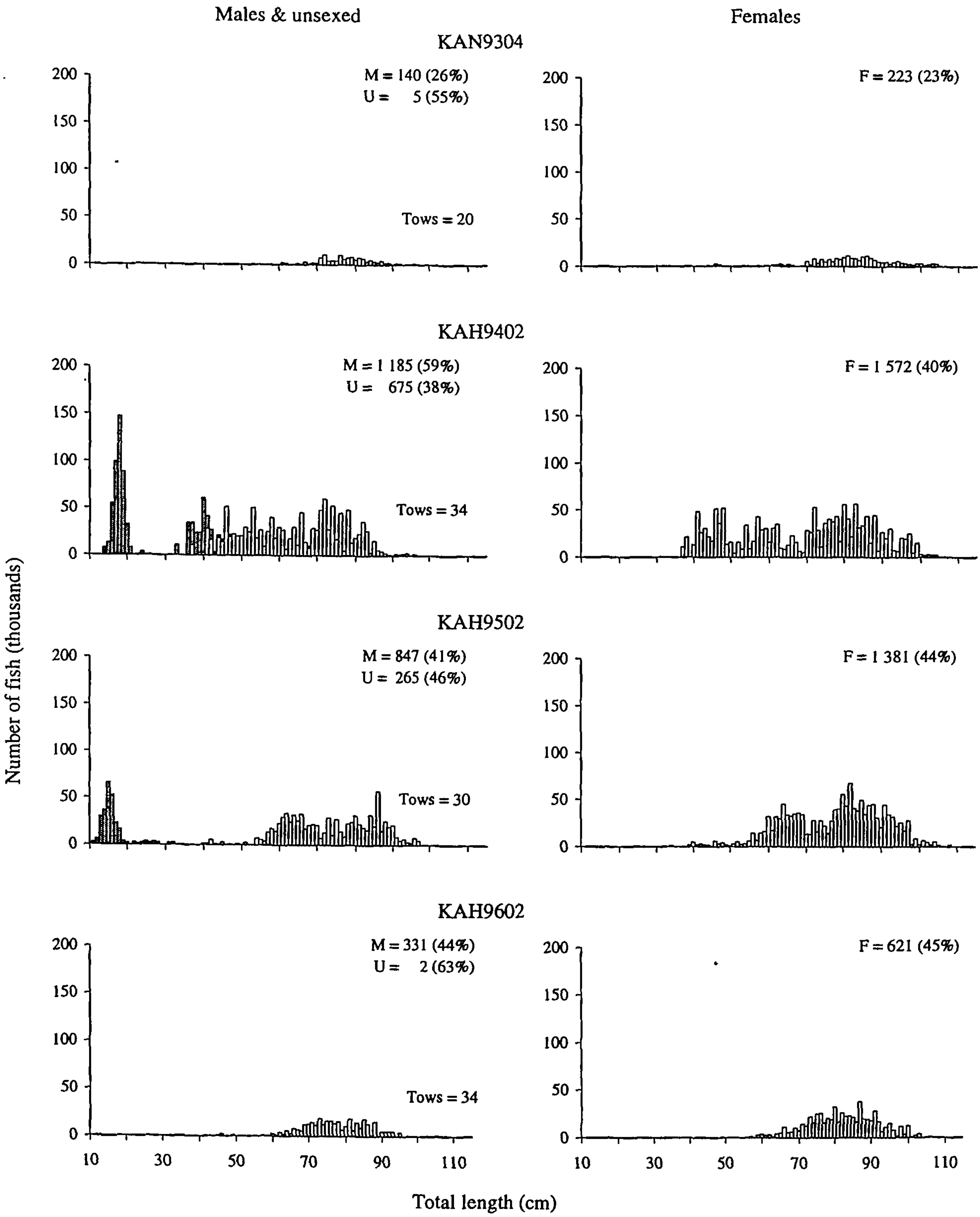


Figure 8h **: Hoki.**

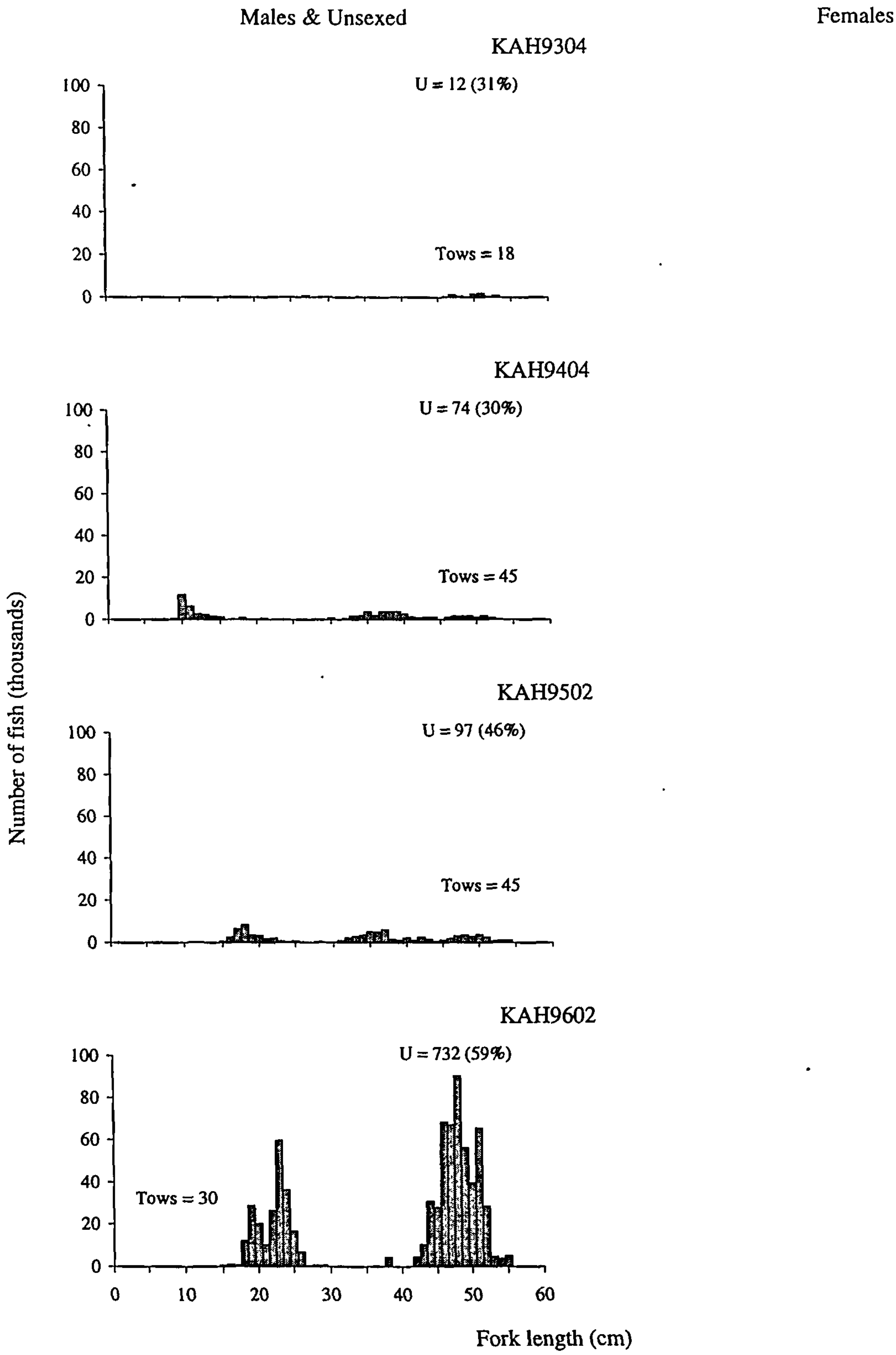


Figure 8i: **Jack mackerel (*Trachurus declivis*).**

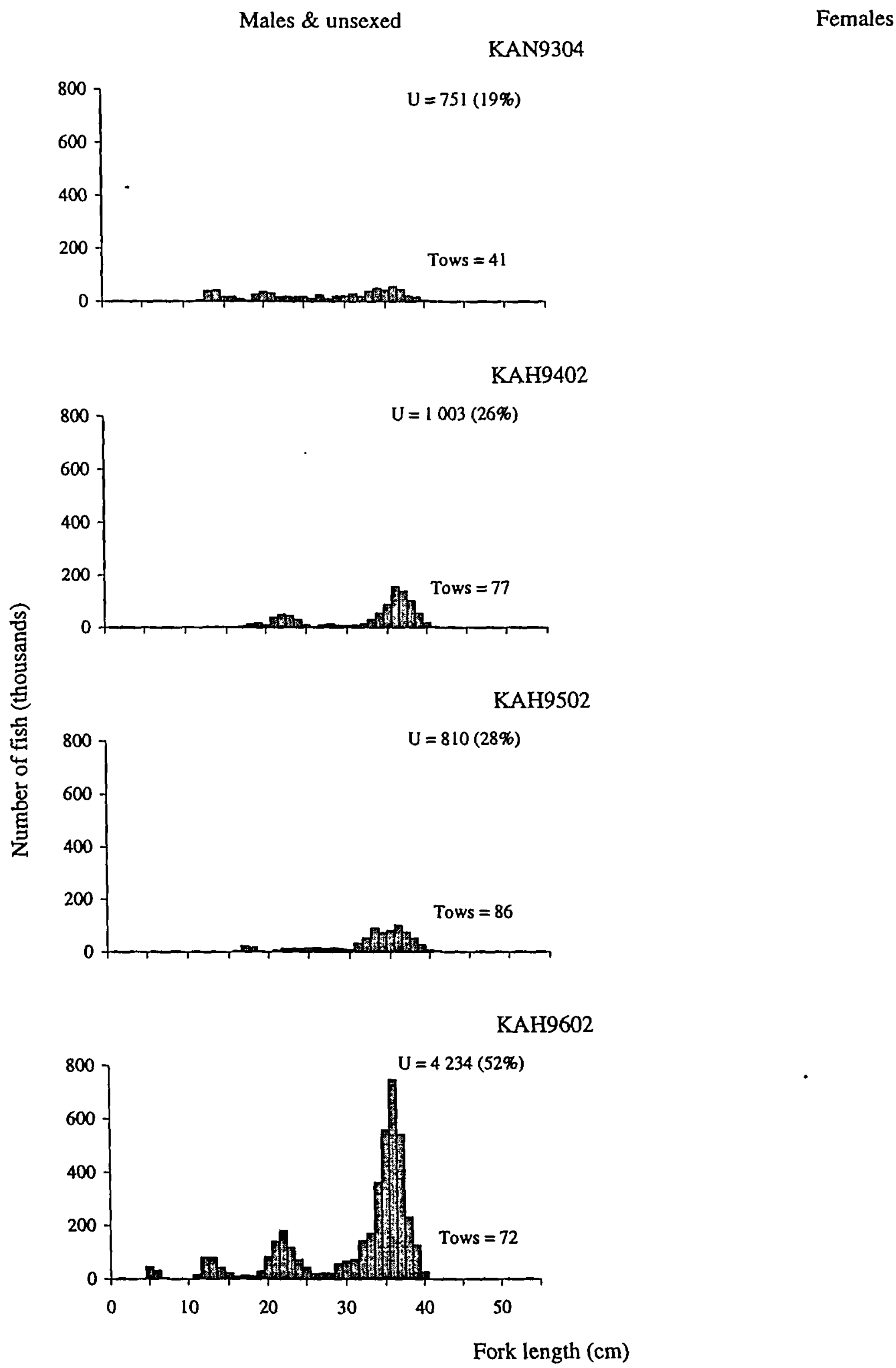


Figure 8j **: Jack mackerel (*T. novaezelandiae*).**

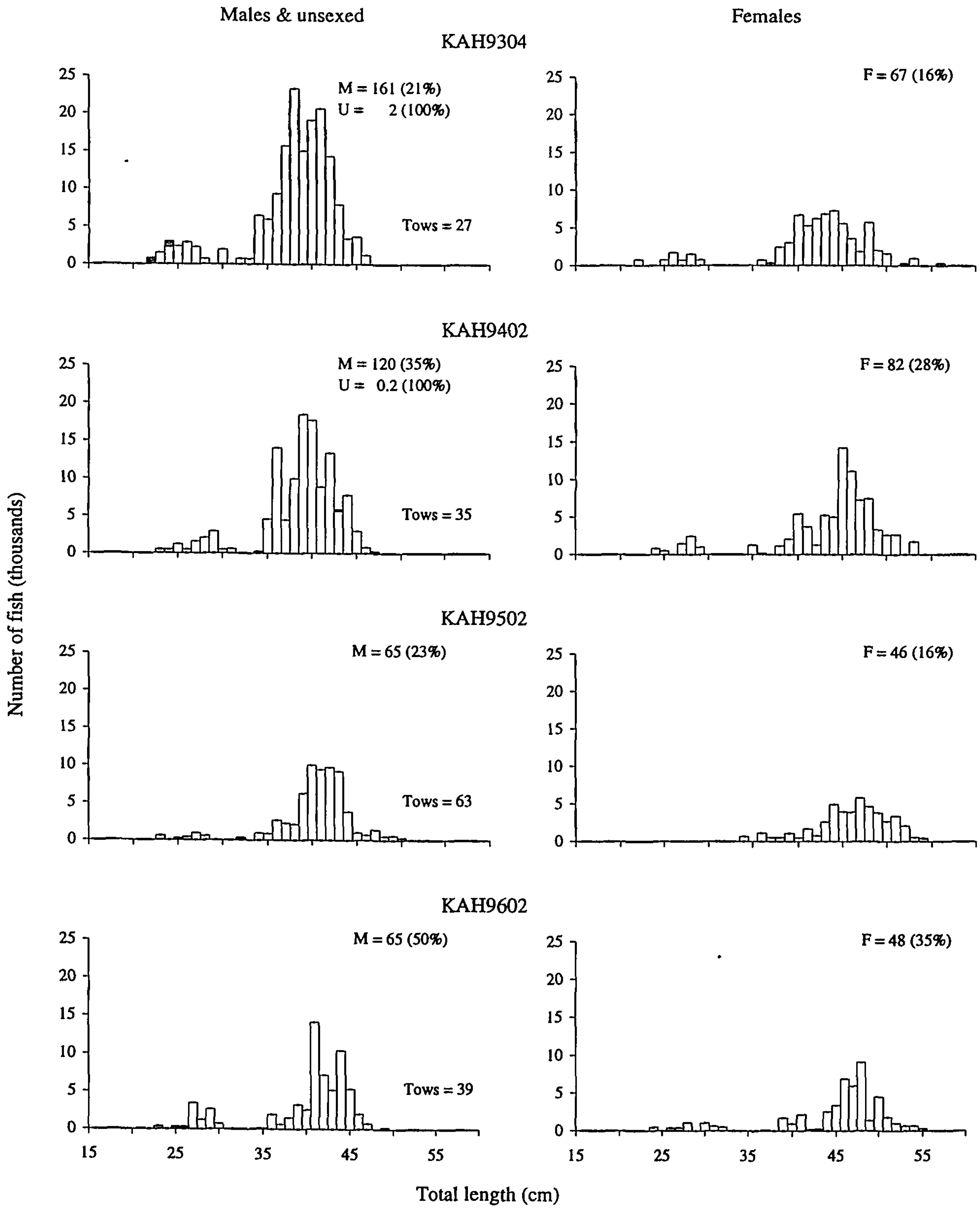


Figure 8k : **John dory.**

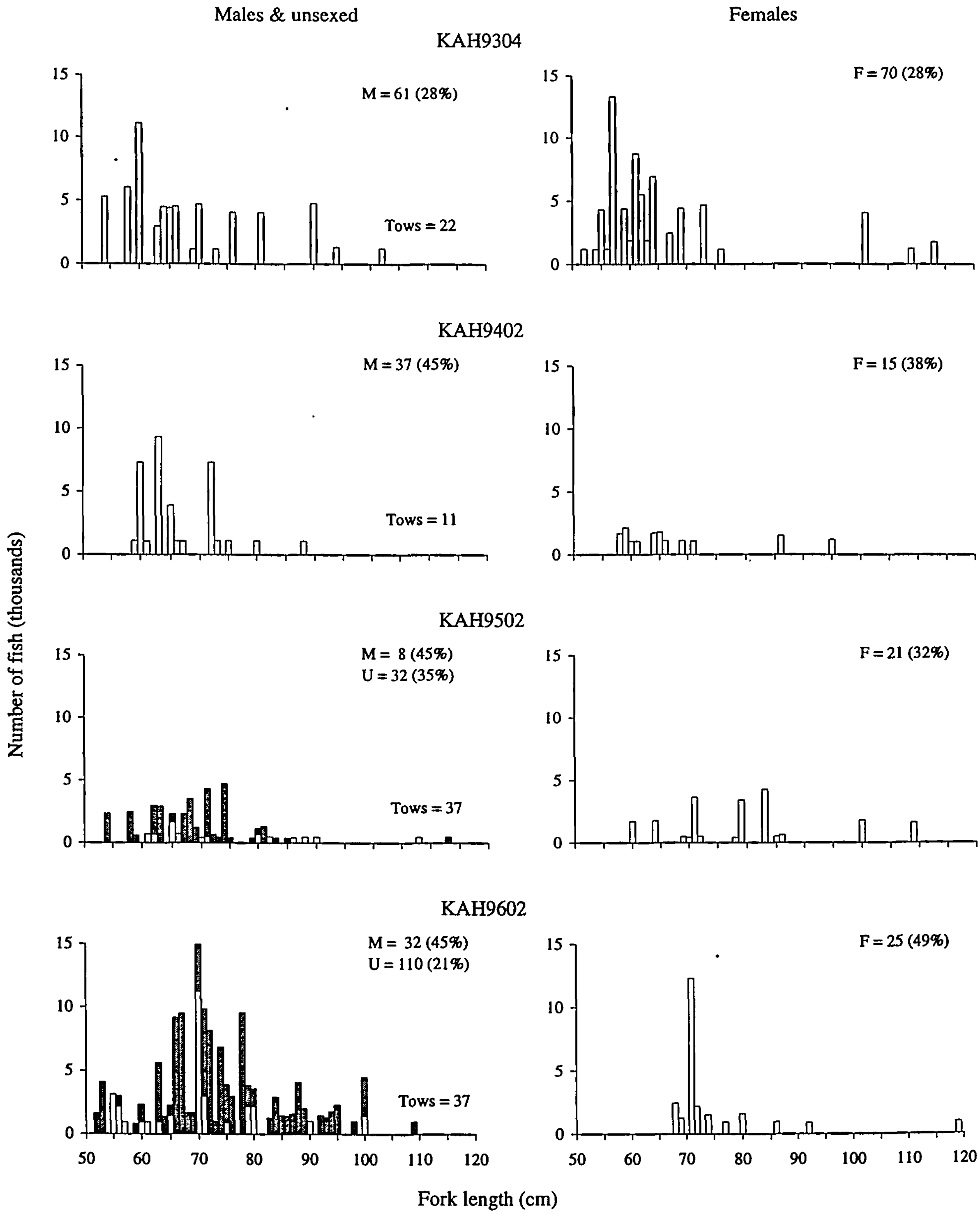


***Figure 8l*: Kingfish.**

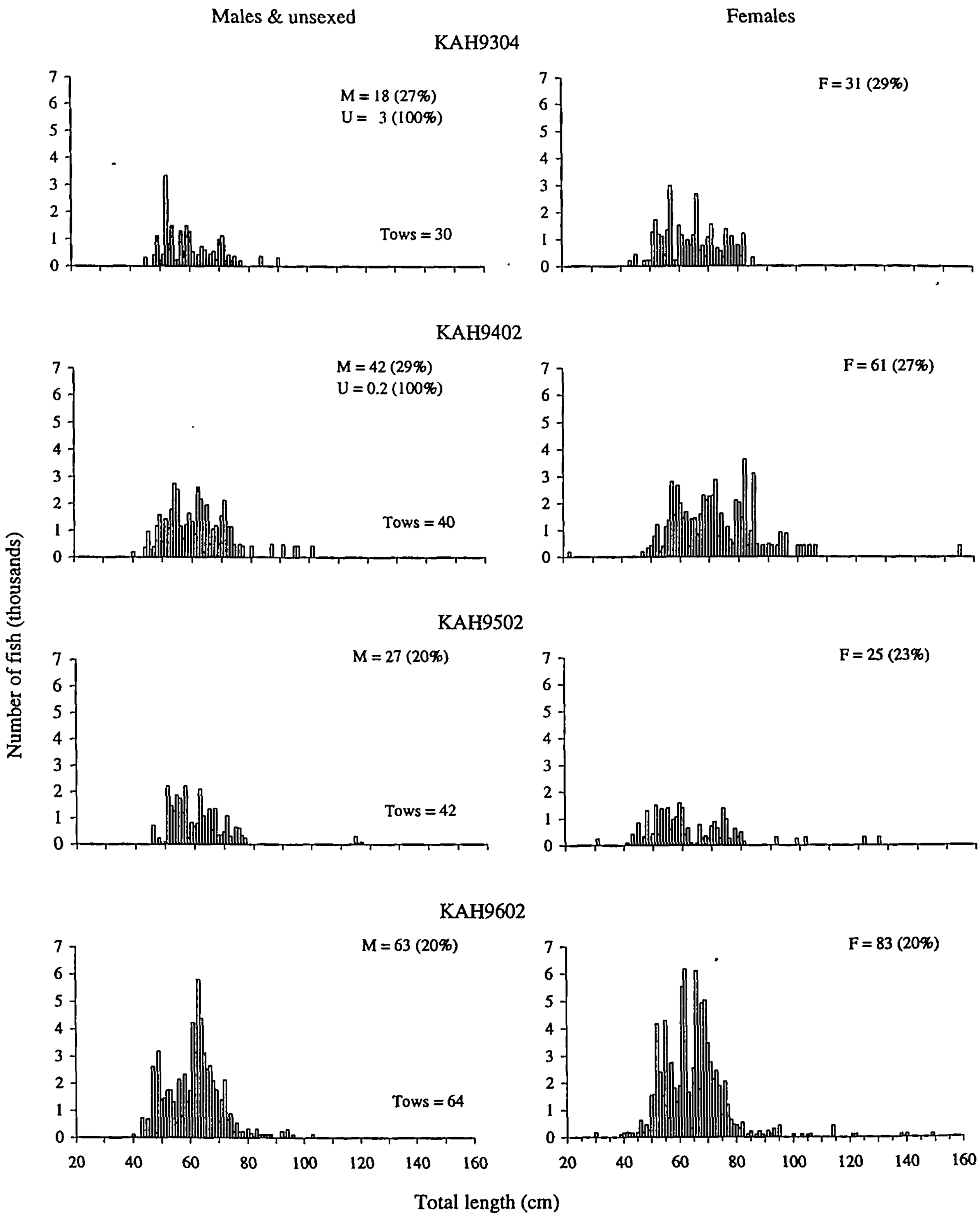


Figure 8m : **Ling.**

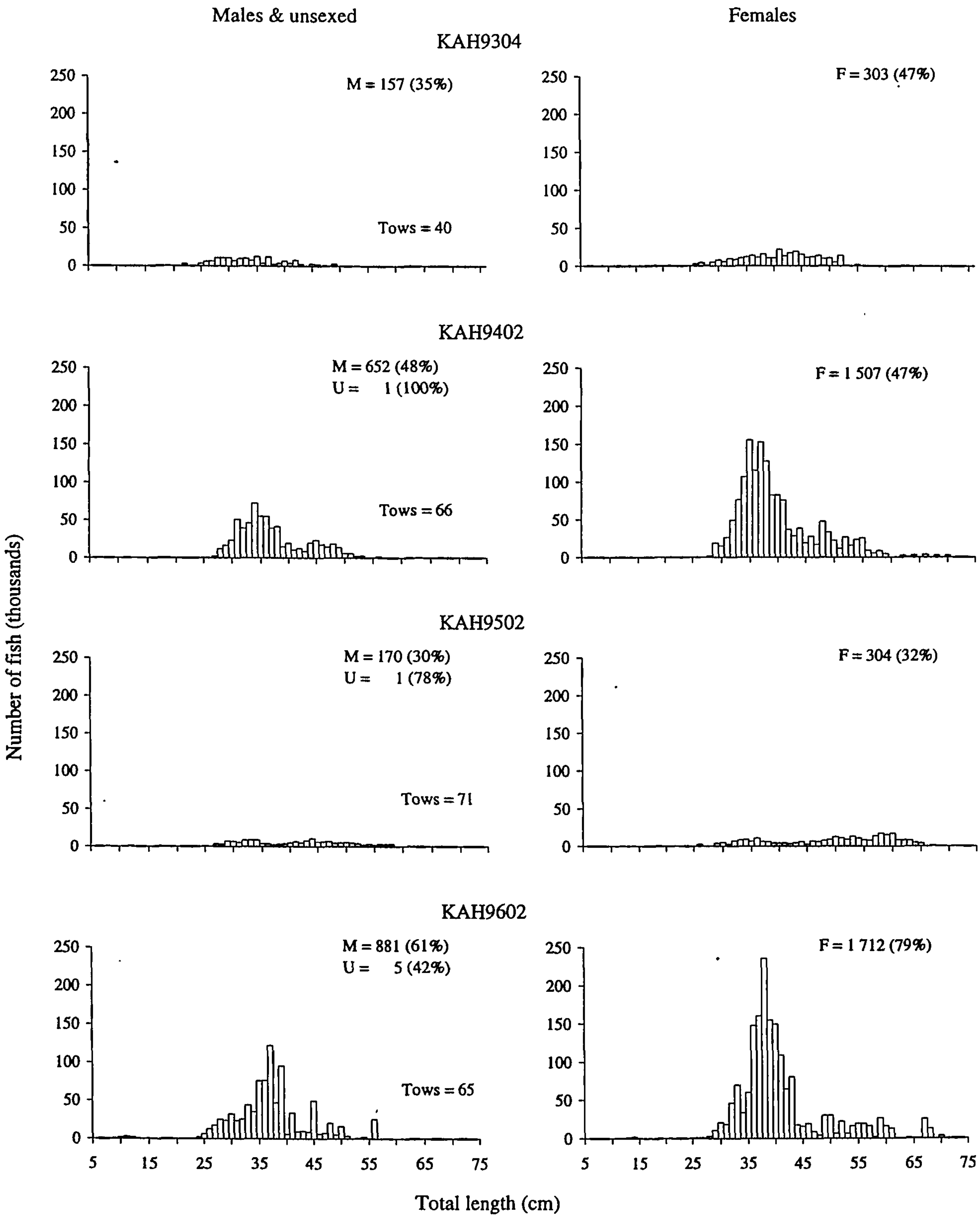


Figure 8n **: Red cod.**

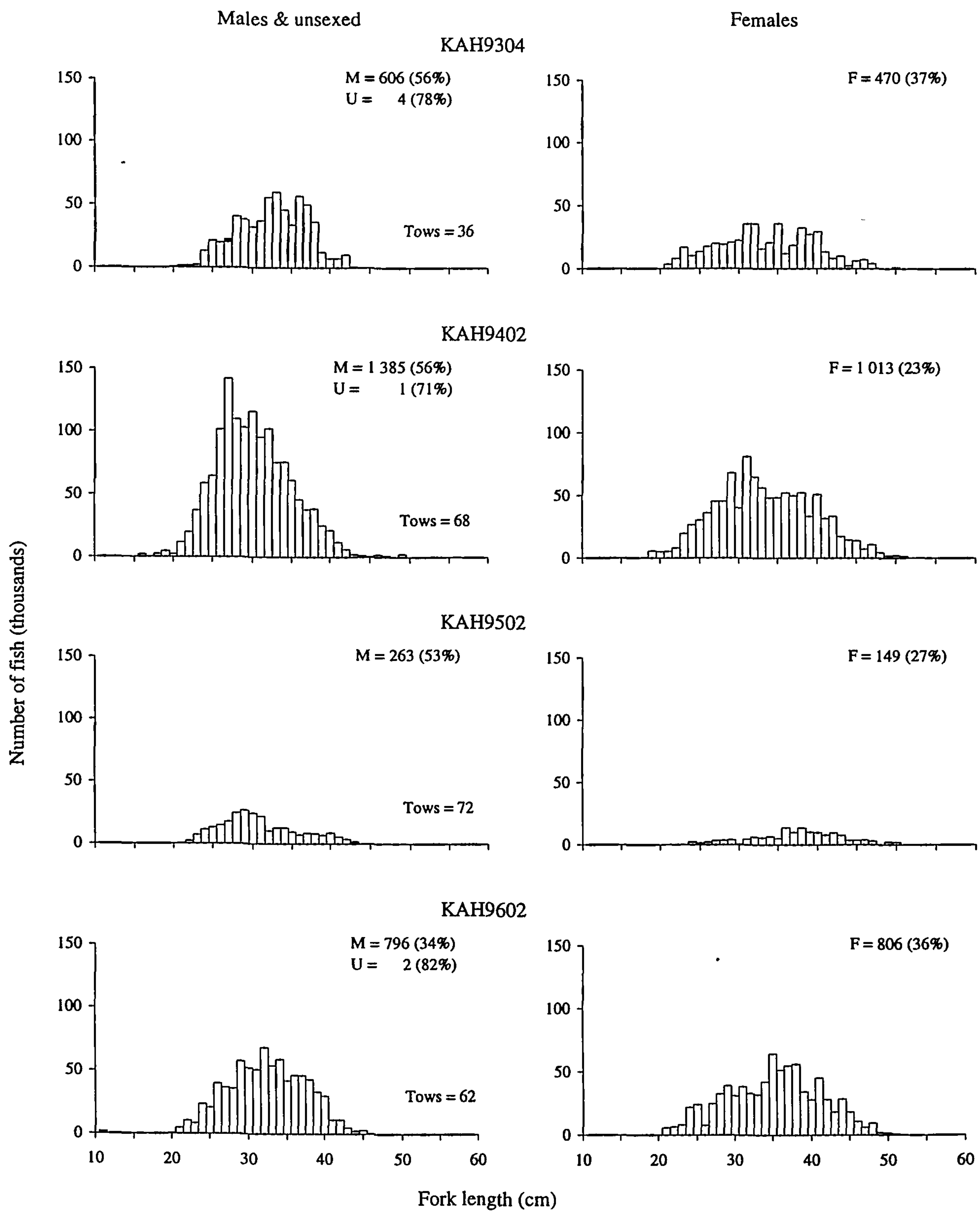


Figure 8o **: Red gurnard.**

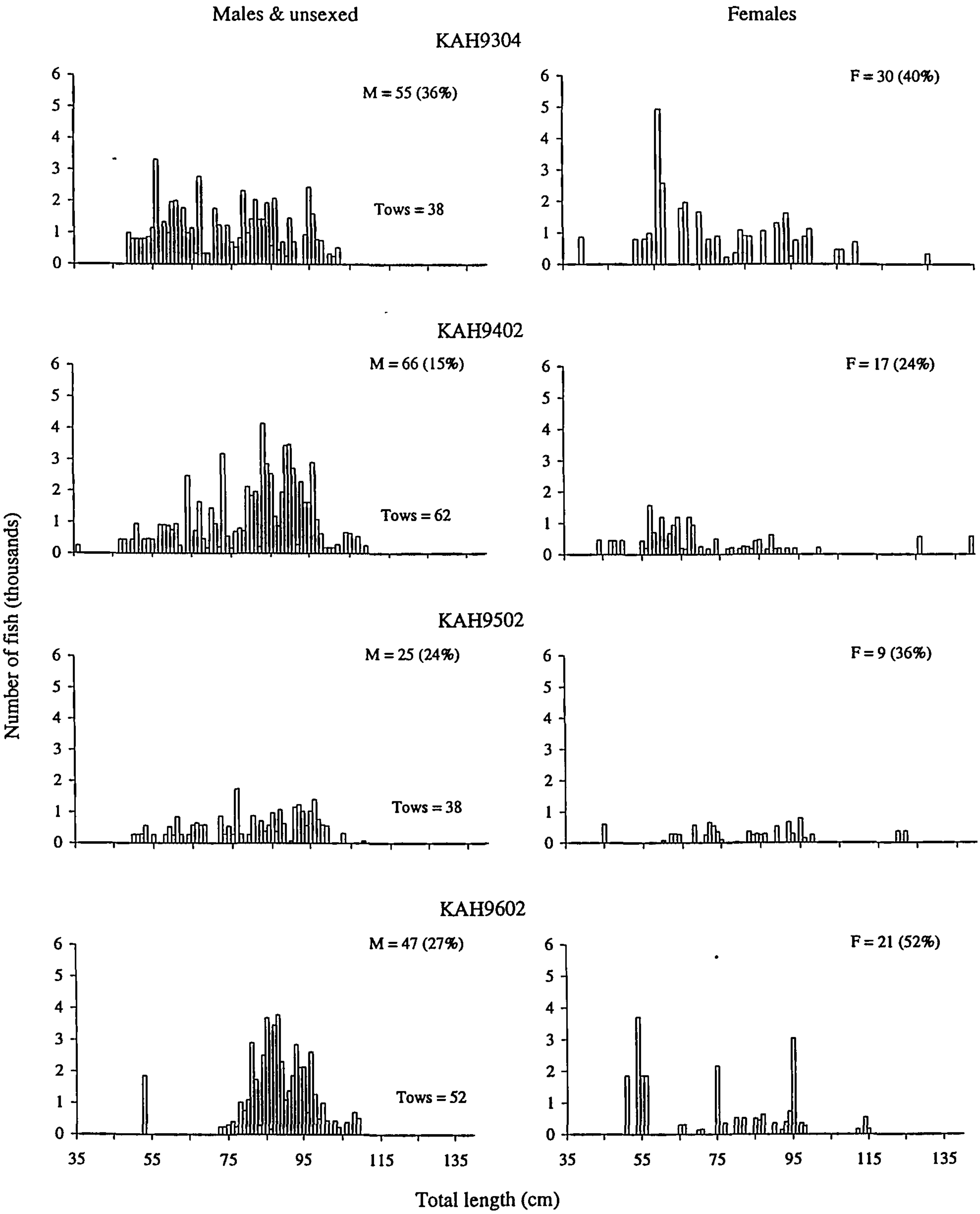


Figure 8p **: Rig.**

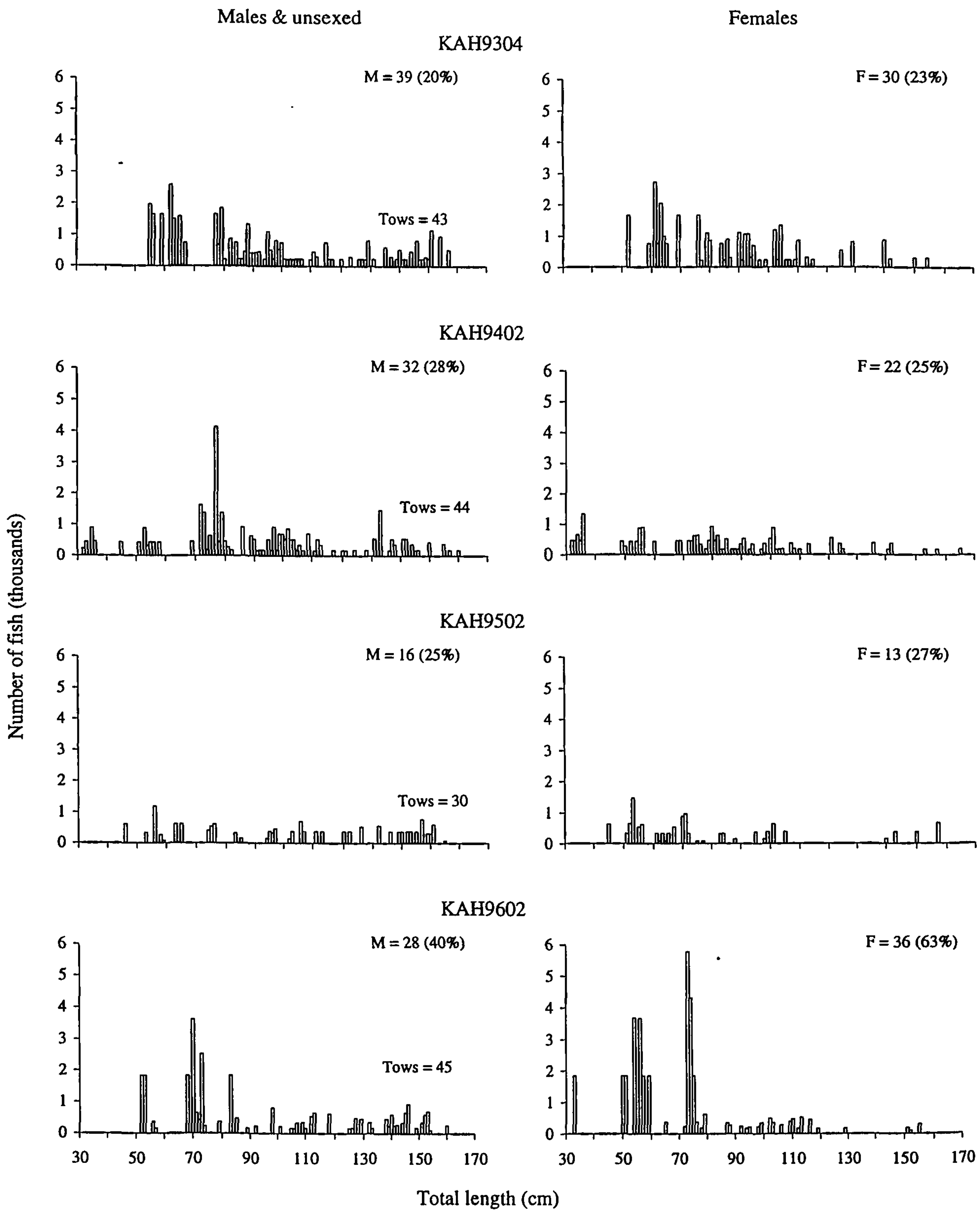


Figure 8q **: School shark.**

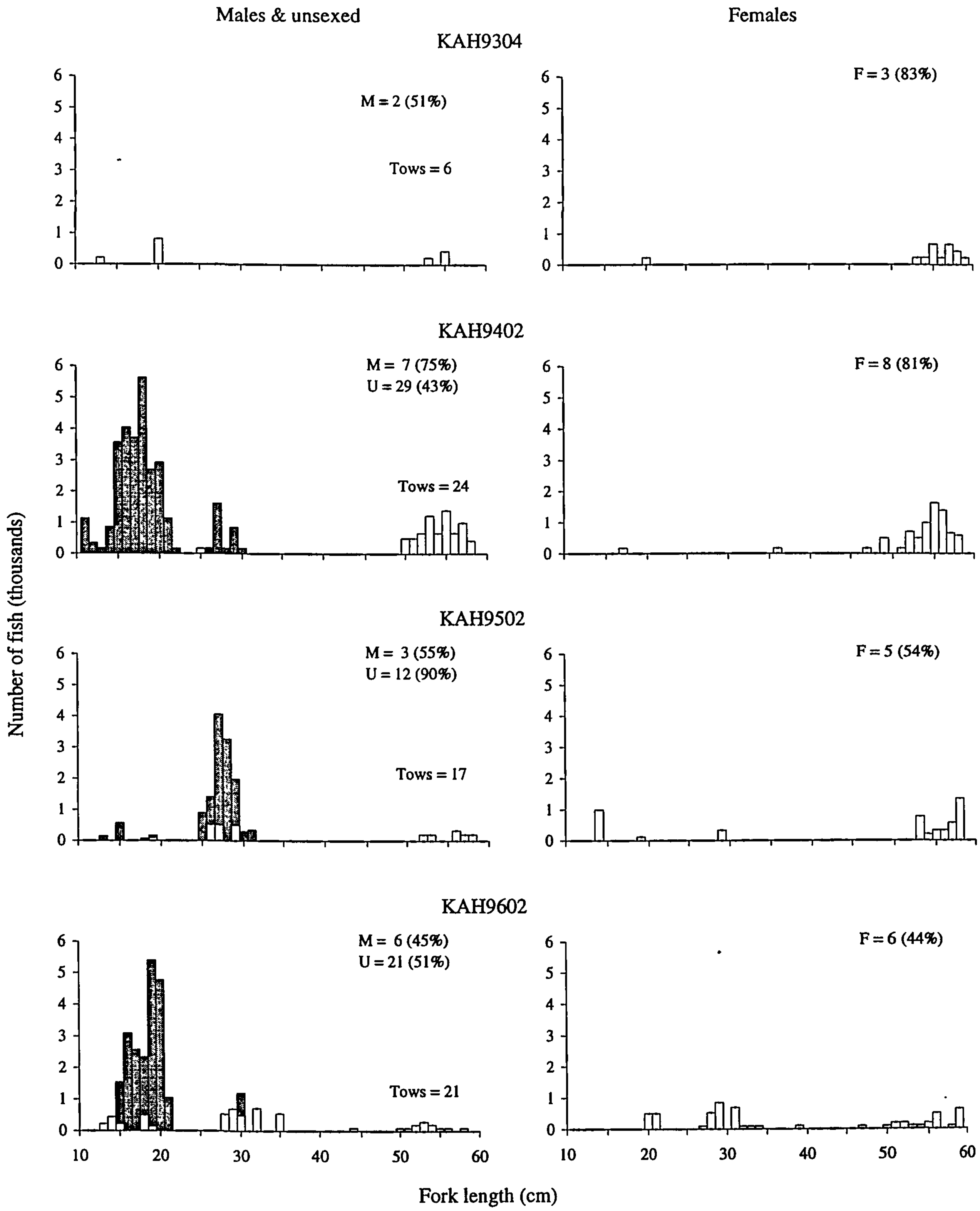


Figure 8r **: Silver warehou.**

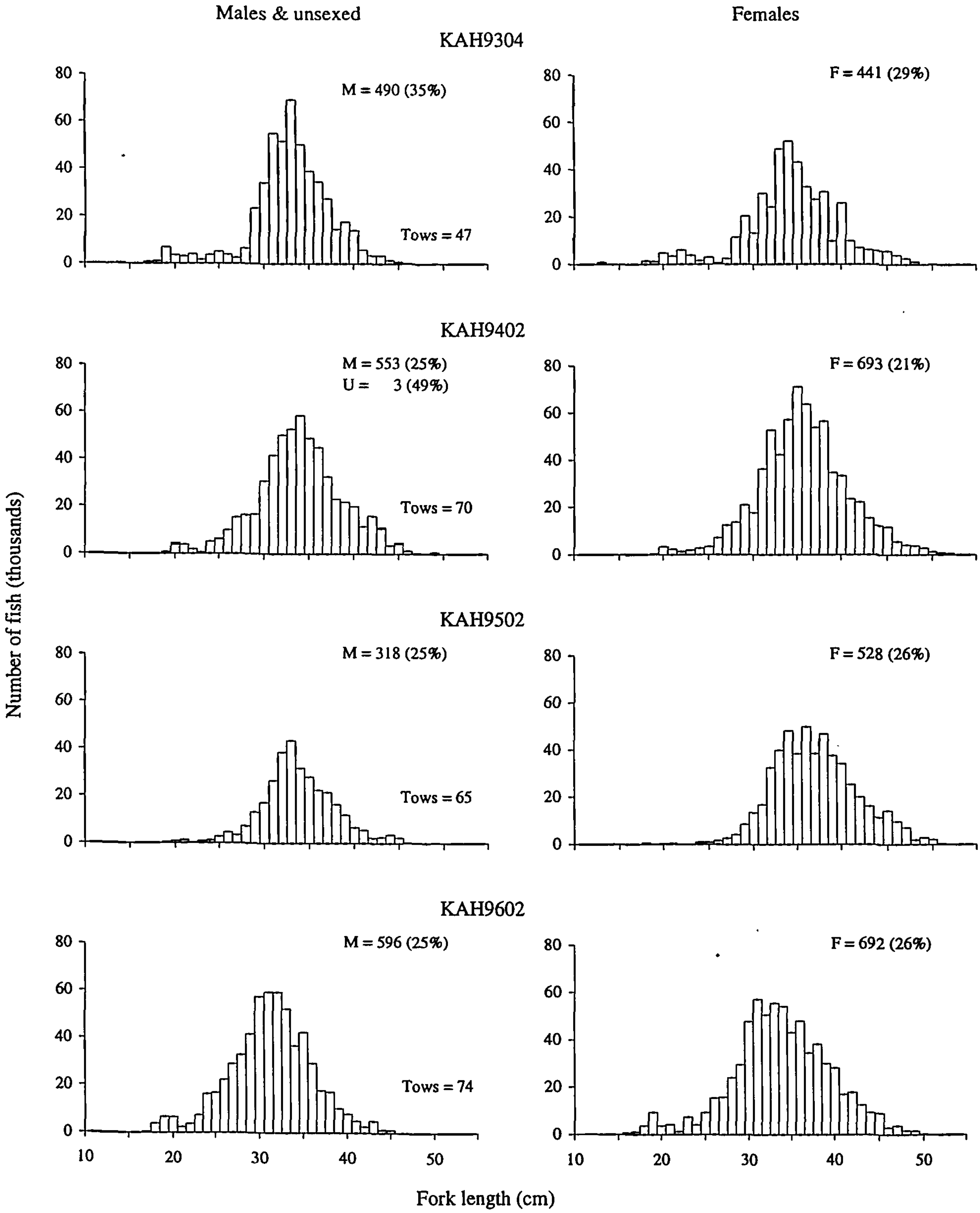


Figure 8t: **Tarakihi.**

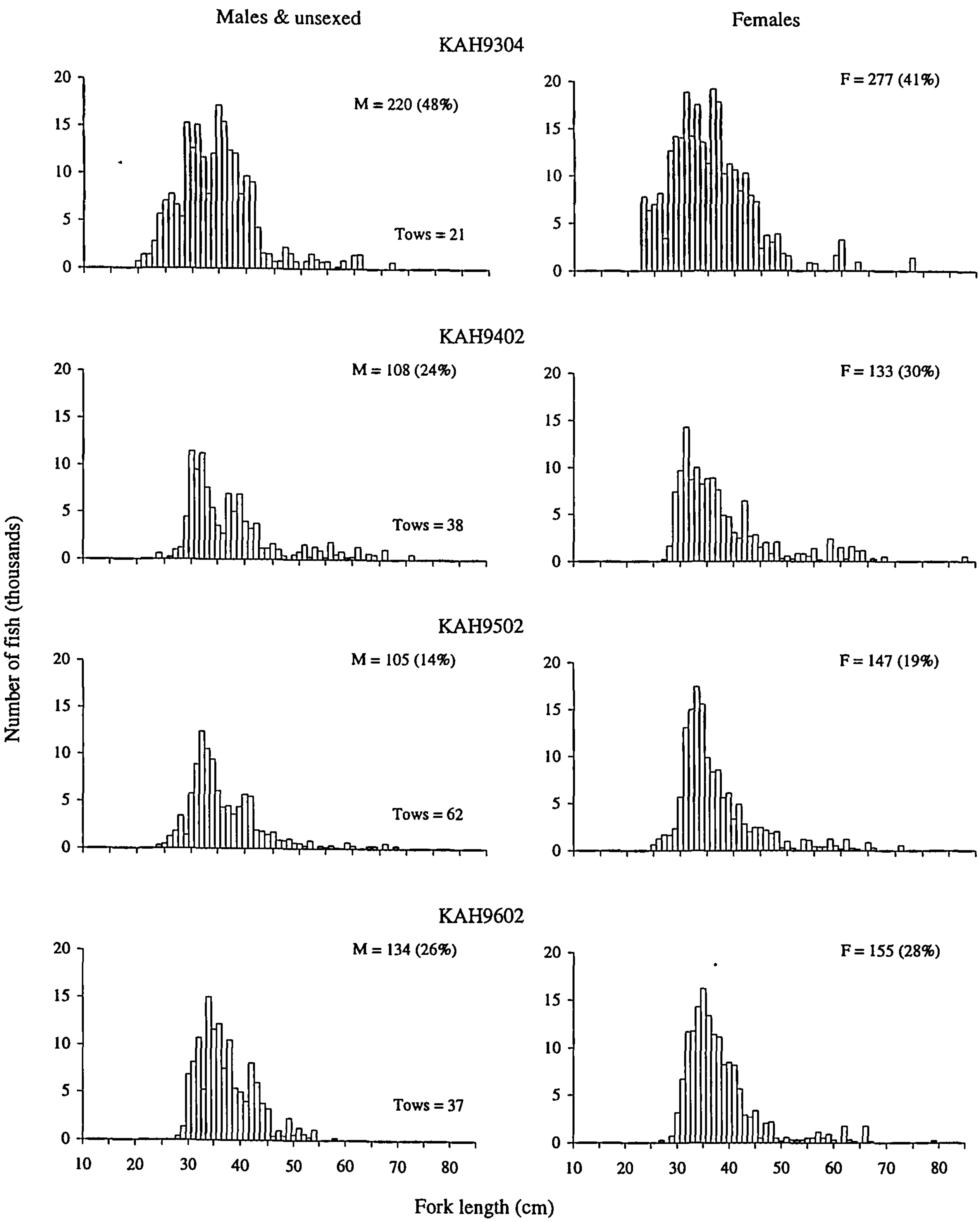


Figure 8s **: Snapper.**

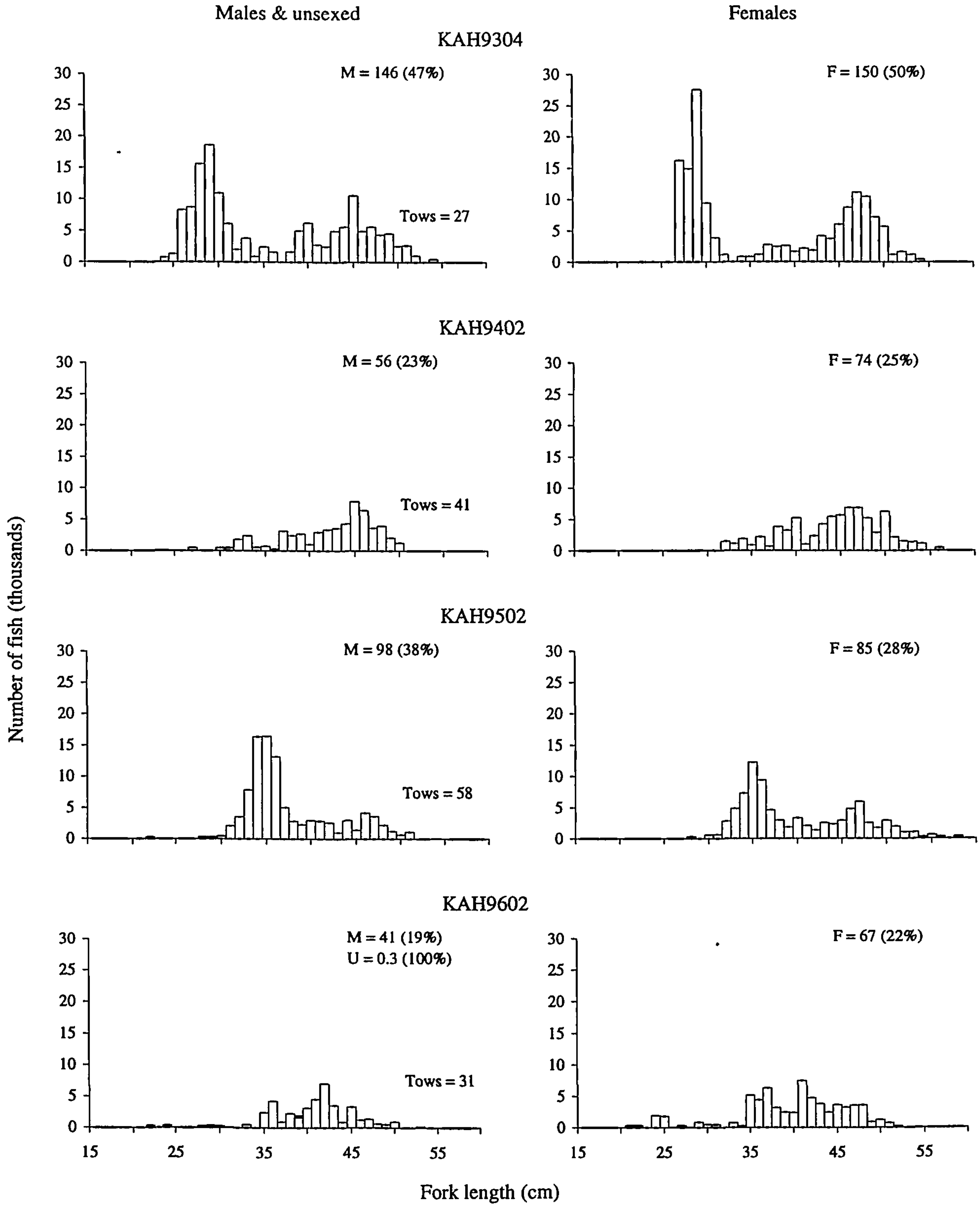
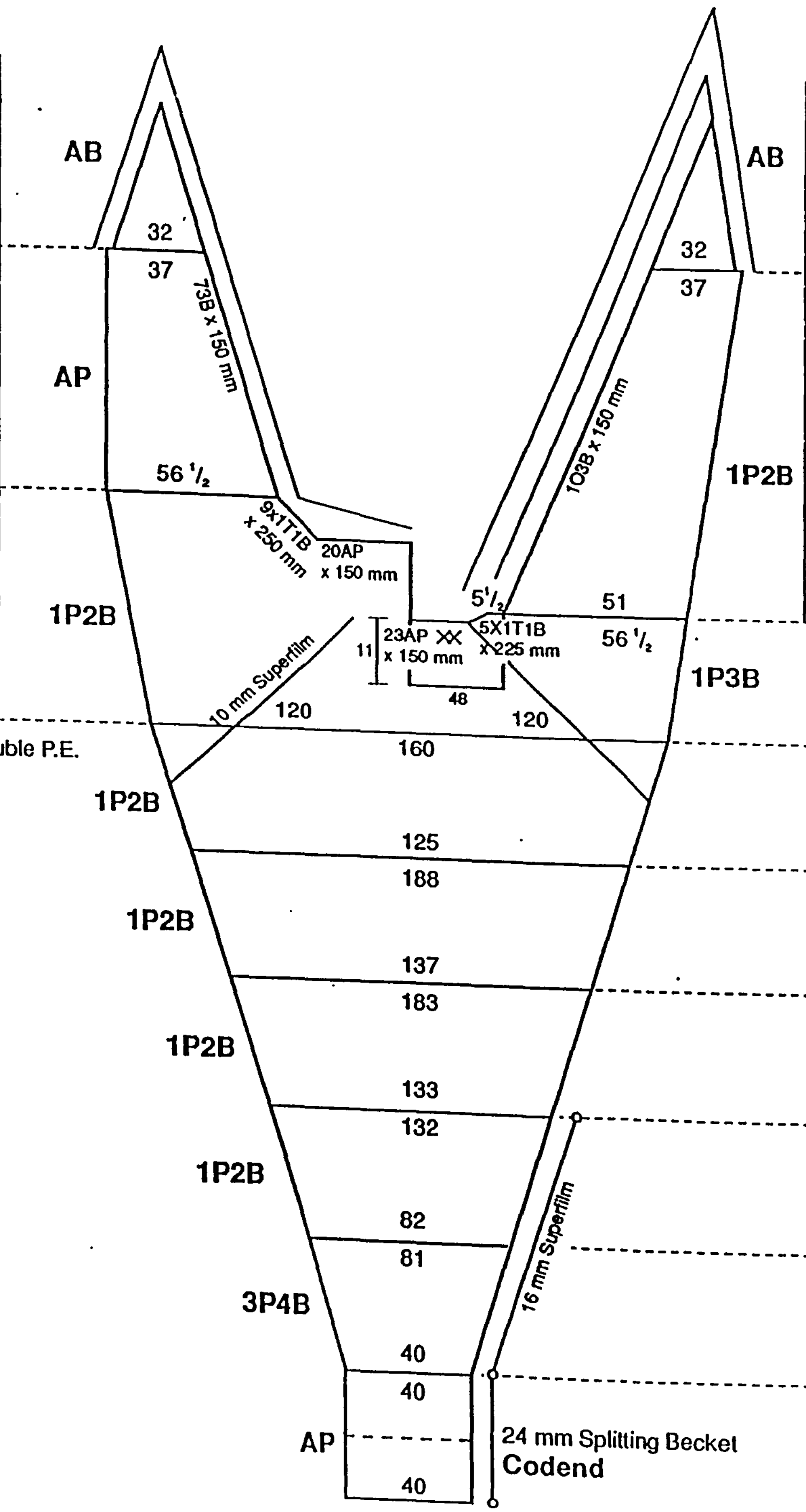


Figure 8u **: Trevally.**

Mesh Size	Twine Size	No. of Meshes
12"	380/90	16
12"	380/90	20
12"	380/90	40



✕✕ 5 mm Double P.E.

Mesh Size	Twine Size	No. of Meshes	
12"	5 mm Duralene	16	5 ½ meshes 5 mm Duralene
12"	380/90 P.E. Twist	35	
12"	380/90	25	
9"	380/60	35	
6"	380/60	50 ½	
4"	380/60	50	
4"	3.5 mm Duralene	50	
4"	5 mm Duralene	50	
80 mm	7 mm PE	49 ½	

Total length 60.5 metre's

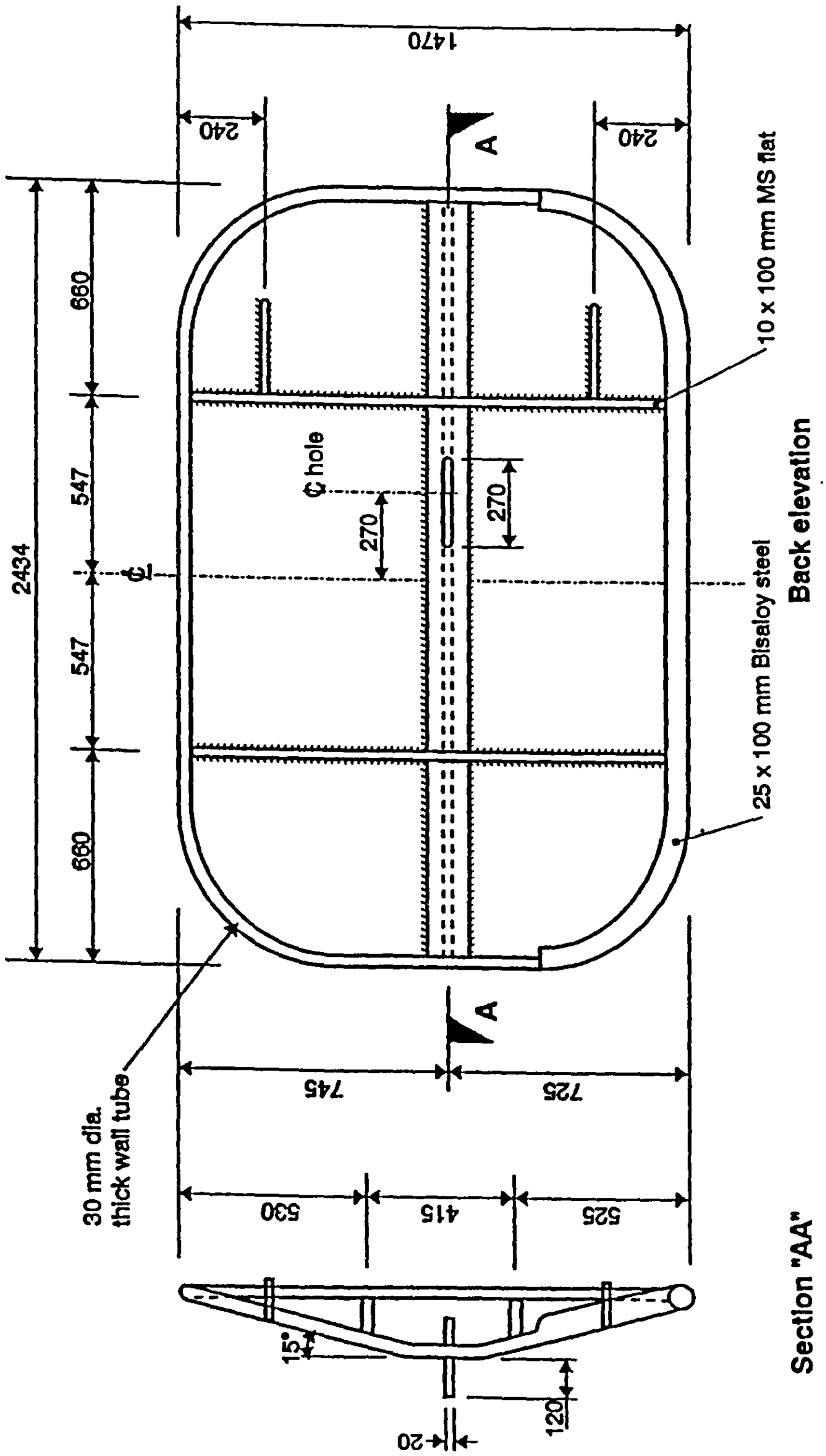
Appendix 1: Trawl net plan and gear specifications

Trawl warp	16 mm	
Trawl doors—rectangular vees	3.4 m, 630 kg	
Backstrop length	6.6 m	
Sweep length	55 m	
Bridle length	55 m	
Headline	length	29.75 m
	rope	14 mm Spectra rope
	flotation	210–220 kg
Vee lines	length	9.75 m
	rope	14 mm Spectra rope
Layback	1.03 m	
Ground rope	length	60.9 m
	wire rope	14 mm B/C wire
	total weight	170–270 kg

Appendix 2 : **Specifications for the old (used during 1992 and 1994) and new (1995 and 1997) trawl doors.**

Attribute	Old	New
Aspect ratio (area/span^2)	Low	Low
Surface area	3.2 m^2	3.2 m^2
Shape	Rectangular "V"	Rectangular "V"
Scanmar brackets fitted	No	Yes
Weight	500 kg (with weighted shoes)	630 kg (dispersed over entire door)

Back elevation and side section of new doors



Appendix 3 : **Length-weight relationship parameters used to scale length frequencies and calculate length class biomass estimates. Source of data was NIWA *trawl* database**

Group A: $W = a L^b$ where W is weight (g) and L is length (cm)

Species	Year	*a*	*b*	n	Range (cm)	Raw data source
Barracouta	All	0.0091	2.8800	731	25–96	Hurst & Bagley (1984)
Blue moki	All	0.0144	3.1050	92	49–75	KAH9602
Chilean jack mackerel	All	0.0255	2.7700	90	44–62	TAN9301
Gemfish	1993	0.0018	3.3396	168	32–106	KAH9304
	1994–96	0.0020	3.2980	225	38–107	KAH9602
Giant stargazer	All	0.0119	3.1052	662	13–78	KAH9701
Hapuku	All	0.0142	2.9980	164	50–130	Johnston (1983)
Hoki	All	0.0046	2.8840	0 510	22–110	SHI8301
Jack mackerel						
Trachurus declivis	All	0.0165	2.9300	200	15–53	COR9001
T. novaezelandiae	All	0.0163	2.9230	200	15–40	COR9002
John dory	All	0.0024	3.5457	353	13–52	KAH9720
Kingfish	All	0.0246	2.4491	–	–	McGregor (in prep)
Ling	All	0.0011	3.3411	482	32–162	TAN9501
Red cod	All	0.0120	2.9182	1712	13–71	KAH9404
Red gurnard	All	0.0065	3.1356	657	17–51	KAH9404
Rig	All	0.0005	3.4660	120	65–137	Francis (1979)
School shark	All	0.0070	2.9100	804	30–166	Seabrook-Davidson (unpub.)
Silver warehou	All	0.0065	3.2990	111	14–50	SHI8301
Snapper	1993	0.0386	2.8461	226	23–73	KAH9304
	1994	0.0232	2.9690	127	29–83	KAH9402
	1995	0.0369	2.8516	663	27–71	KAH9502
	1996	0.0314	2.8969	401	29–66	KAH9602
Tarakihi	1993	0.0161	3.0486	671	13–55	KAH9304
	1994	0.0161	3.0423	212	19–48	KAH9402
	1995	0.0111	3.1546	847	19–52	KAH9502
	1996	0.0140	3.0872	1185	11–51	KAH9602
Trevally	1993	0.0201	2.9881	237	24–54	KAH9304
	1994	0.0254	2.9130	107	32–56	KAH9402
	1995	0.0387	2.8060	329	22–56	KAH9502
	1996	0.0173	3.0234	248	21–53	KAH9602

Group B: $W = a L^b L^{c (\ln L)}$

	a	*b*	*c*	n	Range (cm)	Source
Arrow squid	0.2777	1.4130	0.2605	2 792	3–45	*James Cook*, east coast South Island 1982–83

– Data not available

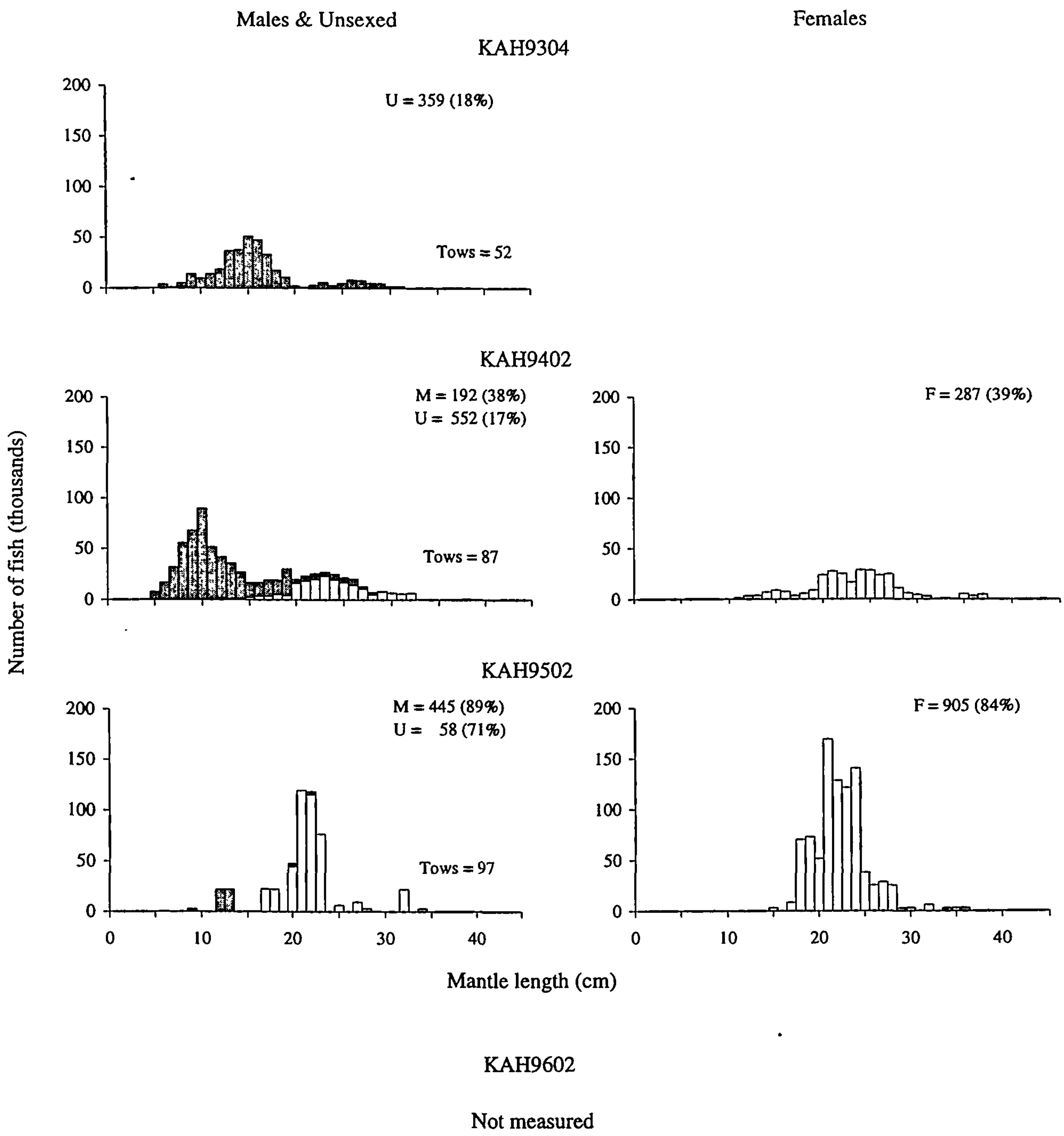


Figure 8 **: Scaled length frequency distributions of the major species, 1993–96, with the estimated total number of fish in the population (and percentage coefficient of variation). M, number of males; F, number of femal U, number of unsexed fish (shaded), Tows, number of stations at which the species was caught).**
a **. Arrow squid**