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

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Contents

Abstract

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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* between 1993 and 1996. Time series trends in the estimated biomass, catch distribution, and population length frequency for the 16 major species are described.

Over the 1993–96 period no species showed a significant change in biomass. The time series 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 was 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 some of each stock may be over foul ground and that the proportions may vary between years. Trevally were not monitored successfully because of problems with catchability (highly variable biomass indices and inconsistent size distribution between years). Biomass indices for other species fluctuated widely and/or had unacceptably high *c.v.*s.

The 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 target and non-target species. Because of the variability between surveys, at least three surveys would be required.

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

Introduction

Background

A series of four annual trawl surveys was conducted along the east coast of the North Island at depths of 20–400 m from Cape Runaway to Turakirae Head from 1993 to 1996. Each of the surveys has been reported individually 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 16 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 optimisation of station allocation.

March-April was initially chosen as the most appropriate time of the year to carry out the series because this 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.

After the first survey, strata adjacent to the South Island were omitted because the rough bottom caused significant damage to the net. New longitudinal boundaries were established at Tolaga Bay, Cape Kidnappers, and Castle Point (Figure 1) after 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 its full depth range (50–600 m). Stevenson & Kirk (1996) discussed problems of availability of adult snapper and trevally to bottom trawl. In 1996, snapper and trevally were also dropped as target species, and 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.

The 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 *Wesermünde* 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.).

The aim of this work was (i) to determine, for the main commercial species, trends in the relative abundance, distribution, length frequency distribution, reproductive condition, and other relevant biological parameters and (ii) to make recommendations on the benefits of undertaking future trawl surveys off the east coast of the North Island.

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 TACCs 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 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. The commercial trevally catch is taken in mixed trawl fisheries, mostly in conjunction with snapper fishing, and some is taken by set net (*see* Annala *et al.* 1999).

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 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 (*see* 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, and 1996), 15 strata were used with new longitudinal boundaries at Tolaga Bay, Cape Kidnappers, and Castle Point (*see* Figure 1).

Up to 84 phase 1 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 2 stations were allocated to improve the precision of the biomass indices for the target species from phase 1. Before the 1993 survey began, sufficient stations to cover both phases within each stratum were randomly generated for each stratum separately using the computer program 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. Bathymetry 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.

Before the 1995 survey, *Kaharoa* was equipped with new trawl doors based on the design of the old doors but heavier. 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).

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 subsample 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, and 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 indices 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 and 2) were used for biomass indices.

For analysis of 1993 data, strata 1–6 were excluded to maintain comparability. In addition, areas for strata 14 and 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 indices were required, and for deriving population length frequencies. The length-weight coefficients used 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

Indices of biomass and *c.v.*s for the 16 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 (*Lepidopus caudatus*), and tarakihi, 65%; 1995, hoki, barracouta, tarakihi, spiny dogfish, and frostfish, 48%; 1996, barracouta, Chilean jack mackerel (*Trachurus murphyi*), N.Z. jack mackerel (*T. novaezelandiae*), red cod, and hoki, 42%.

Indices of gemfish biomass 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 between 700 t and 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 indices from 570 t to 4474 t. The biomass indices 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 16 major species remained virtually unchanged for all years (30–36%). However the *c.v.* for all species combined was more variable (11–24%). No species had *c.v.*s less than 20% for all years, and only rig, rough skate, and school shark had *c.v.*s of 30% or less each year.

Biomass trends

No species showed a statistically significant trend in biomass (Figure 2). The strongest trends were for declining biomass indices 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, it 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, but this did not lead to an increase in total biomass.

Biomass indices by year classes of eight 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. For silver warehou, the strong 0+ year class in 1994 can be followed to 1995. 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 year classes for all species probably have low vulnerability to capture because of 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 5). Bottom temperatures were recorded in 1995 and 1996 and showed a decreasing trend from north to south and decreased with depth.

Distribution and length frequency

The distribution and catch rates ($kg.km^{-2}$) for the major species are shown in Figure 6 and population length frequency distributions in Figure 7. Data presented for 1993 included only strata off the North Island.

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 6a). The large increase in barracouta biomass in 1994 came mainly from the south of the survey area and comprised fish of all sizes, but 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 7a).

Frostfish

Frostfish were caught throughout the survey area, mostly in depths greater than 50 m at between 65 and 75% of all stations (Figure 6b). Frostfish were not measured. Biomass varied twofold between years, was relatively imprecise, and may not be monitoring abundance.

Gemfish

Gemfish were caught all along the east coast North Island in depths greater than 100 m (Figure 6c). They were caught at between 12 and 45% of stations. The length frequency distributions show the progression of year classes between surveys (Figure 7b). 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. However, the precision of the biomass indices of this year class was poor with *c.v.*s ranging from 42 to 47% (*see* Table 3). Horn & Hurst (1999) showed that this mode represents the 1991 year class, and catch at age data have 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 indices of relative abundance of 3+ fish (*see* Table 3). However, indices 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, is not well estimated by the model, and may prove to be stronger than originally thought.

Otoliths from the commercial catch have been aged since 1989. However, otoliths from only 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 be aged because of overlap between modes as the fish become 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 which have both declined since 1993 (Hurst *et al.* 1999). 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.

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 6d). 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 7c).

There was a large decline in the biomass index 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), biomass indices from scampi surveys, and commercial landings (Annala *et al.* 1999). 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.

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 6e). They were caught at between 26 and 35% of stations. The length frequency distributions showed a strong 0+ age group in 1994 and 1995 (the 1993 and 1994 year classes) (Figure 7d). Modelling suggests the 1992 to 1994 year classes were all strong, with the 1994 year class being strongest (Annala *et al.* 1999). The surveys do not appear to be reliably monitoring hoki 0+ abundance and are too shallow to monitor adult abundance.

Jack mackerel (*Trachurus novaezelandiae*)

New Zealand jack mackerel were caught throughout the survey area in depths less than 200 m (Figure 6f). They were caught at between 61 and 78% of stations. There was a large increase in biomass in 1996 as a result of larger catches in most areas. Age group modes were most evident in 1996 with peaks at 5, 12, and 22 cm representing the 0+, 1+, and 2+ year classes (Figure 7e). 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. Biomass indices for jack mackerel were highly variable with at times high *c.v.*s (24–66%) and could not be monitored by the surveys.

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 6g). 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 7f). There was a broad mode from about 35 to 50 cm, but year classes can not be tracked through the surveys.

John dory biomass estimates declined from about 270 t in 1993 and 1994 to 170 t in 1995 and 1996, and *c.v.*s were variable (17–48%). 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 or model mis-specification.

Red cod

Red cod were caught throughout the survey area with the highest catch rates usually south of Tolaga Bay (Figure 6h). They were caught at between 61 and 68% of stations. The length frequency distributions for 1994 and 1996 were dominated by 1+ fish (25–40 cm) (Figure 7g). There is no evidence of younger or older fish of these year classes. Biomass indices were highly variable and had high *c.v.*s, and the survey is not useful for monitoring abundance.

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 6i). 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 7h). The biomass indices varied fivefold between surveys and do not appear to be monitoring abundance.

Rig

Rig were caught throughout the survey area at low rates mostly at depths less than 100 m (Figure 6j). 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 7i). Although the *c.v.*s for rig were reasonably low (13–26%), the size distribution varied between years. It is likely that the larger fish in the population are under-represented when sampled with the bottom trawl gear, and the highly skewed sex ratio suggests that females were also under-sampled. The surveys are probably not monitoring abundance.

School shark

School shark were caught throughout the survey area, most consistently north of Cape Kidnappers at depths greater than 50 m (Figure 6k). They were caught at between 26 and 64% of stations. The few fish caught make it difficult to identify modes or track year classes between surveys (Figure 7j). Despite the consistent biomass indices and moderate *c.v.*s (16–24%), the low numbers of fish caught make it unlikely that the survey was monitoring abundance.

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 6l). They were caught at between 9 and 24% of stations. Although few 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 (Figure 7k) (*see also* Horn & Sutton 1995). There appears to be a good correlation between indices of 0+ and 1+ fish, but the indices 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.

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 6m). 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.

The biomass indices 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 7l). 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). Catch sampling of the SNA 2 stock during the 1997–98 season showed that the current fishery is dominated by the 1985, 1988, and 1990 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 may allow a better estimate of pre-recruit snapper, but may also lead to a greater escapement of adult snapper. 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.

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 large snapper may not be vulnerable to the bottom trawl (Gilbert & Sullivan 1994), 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 many age classes in the fishery (*ca* 10–15), and variable biomass estimates, surveys would need to be carried out every 2 years to monitor abundance in SNA 2. Any uncertainty over the selectivity and abundance of large snapper would be reflected in uncertainty over any assessment of this stock.

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 6n). They were caught at 83–96% of stations. Spiny dogfish were not measured. Biomass indices were reasonably consistent between years, but the *c.v.*s were usually high (25–78%) and the series was probably not useful for monitoring abundance.

Tarakihi

Tarakihi were caught throughout the survey area with the highest catch rates north of Tolaga Bay: they were caught at between 56 and 77% of stations (Figure 6o). 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 indices 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 codend mesh used. A few fish 15–20 cm (possibly 2+ fish) were caught during each survey, so pre-recruit fish do occur in the survey area (*see* Figure 7m, Table 3).

Although no ageing study has been carried out on otoliths collected during the surveys, it appears from other stocks (e.g., *see* Stevenson & Hanchet 2000) 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 were to be fitted in a population model, it is strongly recommended that an ageing study be completed using otoliths collected from the surveys 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, but 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

Trevally were caught mostly north of Castlepoint with the highest catch rates north of Cape Kidnappers (Figure 6p). They were caught at between 32 and 50% of stations. The vulnerability of trevally 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 temperature 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%). 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 (Figure 7n). 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, but there are 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.

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% 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).

Male tarakihi 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, 35% of females were mature (stage 3). 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).

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 indices and higher *c.v.*s on the ECNI survey. Estimated *c.v.*s for all species combined ranged from 6 to 9% for the west coast South Island (Stevenson & Hanchet 2000), 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 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.

- Indices of recruited snapper biomass were reasonably consistent between years and had moderate *c.v.*s, but a proportion of the stock may be over foul ground and this proportion may vary between years. Although large snapper may not be 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 many age classes in the fishery (10–15), and the variable biomass indices, surveys would need to be carried out every 2 years to monitor abundance in SNA 2. Any uncertainty over the selectivity and abundance of large snapper would be reflected in uncertainty over any assessment of this stock.

- Indices of recruited tarakihi biomass were reasonably consistent between years and had moderate *c.v.*s, but 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 indices 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 indices were moderately precise. However, the size distribution was inconsistent between years. Because of uncertainties in trevally catchability and variability in biomass indices, recruit and pre-recruit abundance are unlikely to be adequately monitored using trawl surveys.

- The surveys do not appear to be useful for monitoring any other species because recruited biomass indices were too variable or too imprecise to consider that 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. Barracouta, hoki, jack mackerel (*T. novaezelandiae*), John dory, and silver warehou all have variable indices of juveniles, but we were unable to determine whether these are indicative of year class strength. The large 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 to determine biological parameters for each of the species and 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, at least three surveys would be required.

Acknowledgments

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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 16 major commercial species**

	KAH9304		KAH9402		KAH9502		KAH9602	
	Biomass	*c.v.* (%)	Biomass	*c.v.* (%)	Biomass	*c.v.* (%)	Biomass	*c.v.* (%)
Barracouta	2 153	15	7 081	33	2 103	29	2 487	23
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
Hoki	543	24	2 729	47	2 937	42	1 411	50
NZ jack mackerel								
T. novaezelandiae	243	24	461	32	366	30	1 845	66
John dory	265	17	268	31	170	18	172	48
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
School shark	315	16	235	23	148	24	229	23
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; tarakihi > 29 cm) (Annala *et al*. 1999)**

	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.

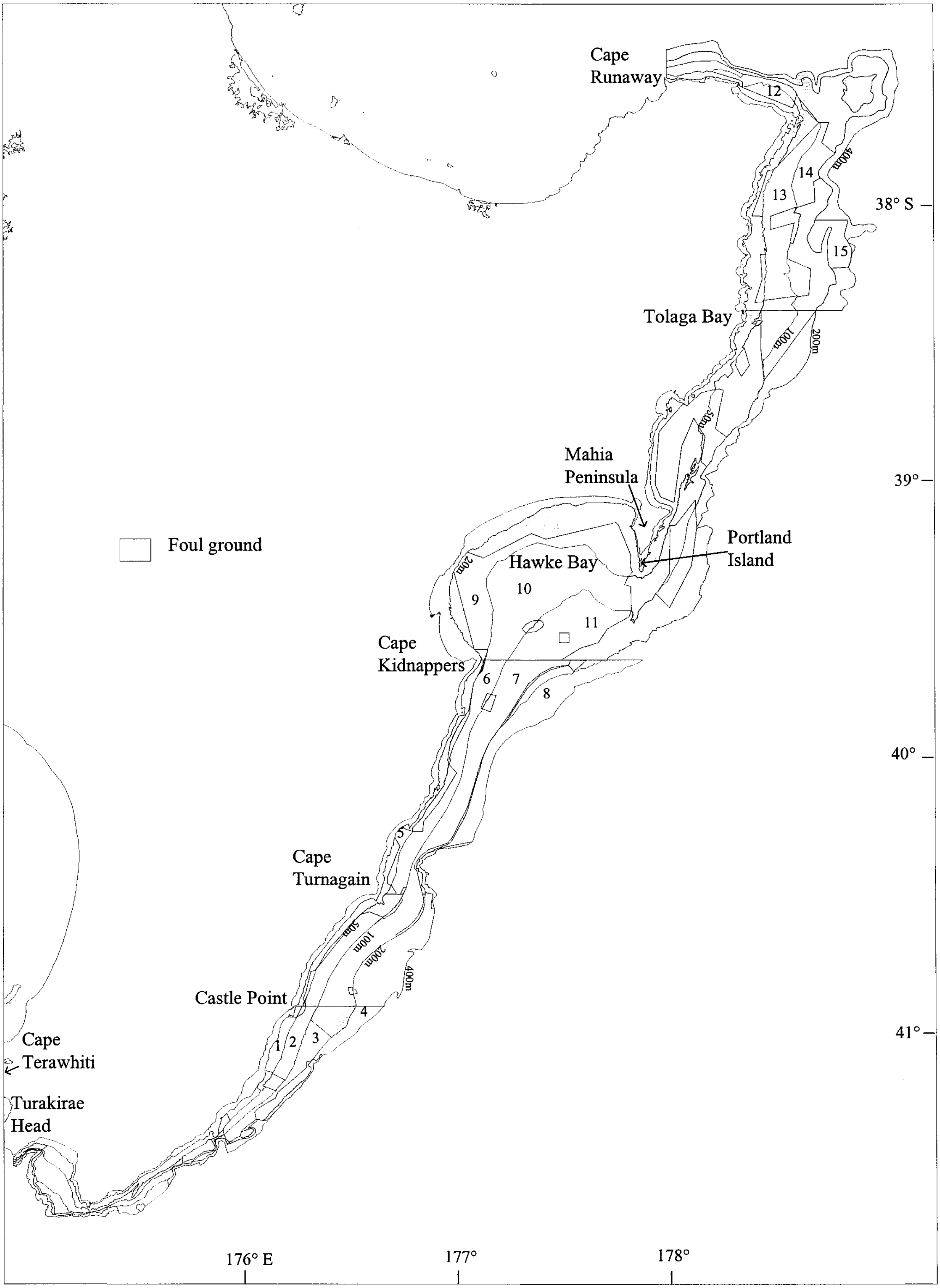


***Figure 1*: Stratum boundaries, 1994–96, with locations mentioned in the text.**

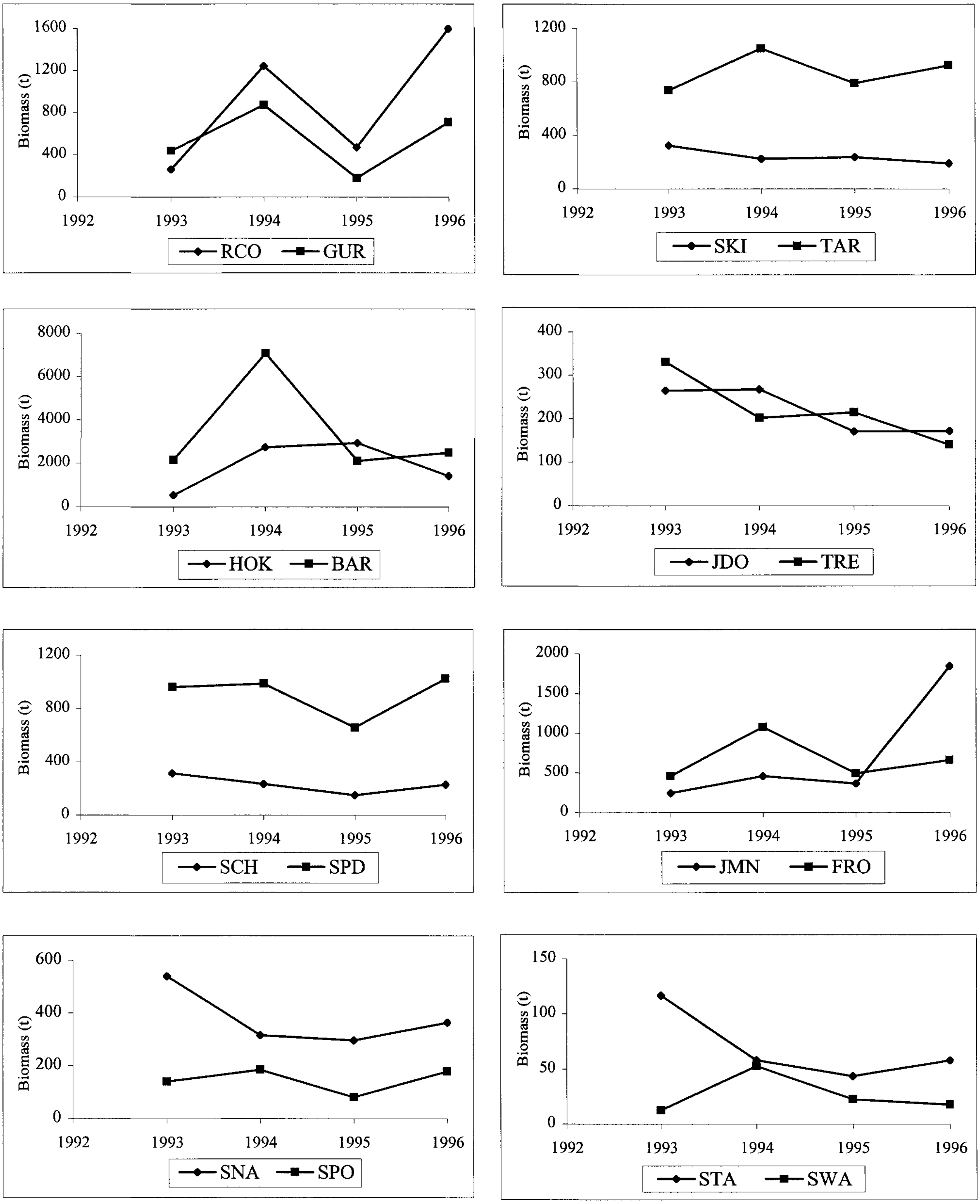


Figure 2 **: Estimated biomass of the 16 major species, 1993–96. (RCO, red cod; GUR, red gurnard; SKI, gemfish TAR, tarakihi; HOK, hoki; BAR, barracouta; JDO, John dory; TRE, trevally; SCH, school shark; SPD, spiny dogfish; JMN, jack mackerel (*T. novaezelandiae)* ; FRO, frostfish; SNA, snapper; SPO, rig; STA, giant stargazer; SWA, silver warehou).**

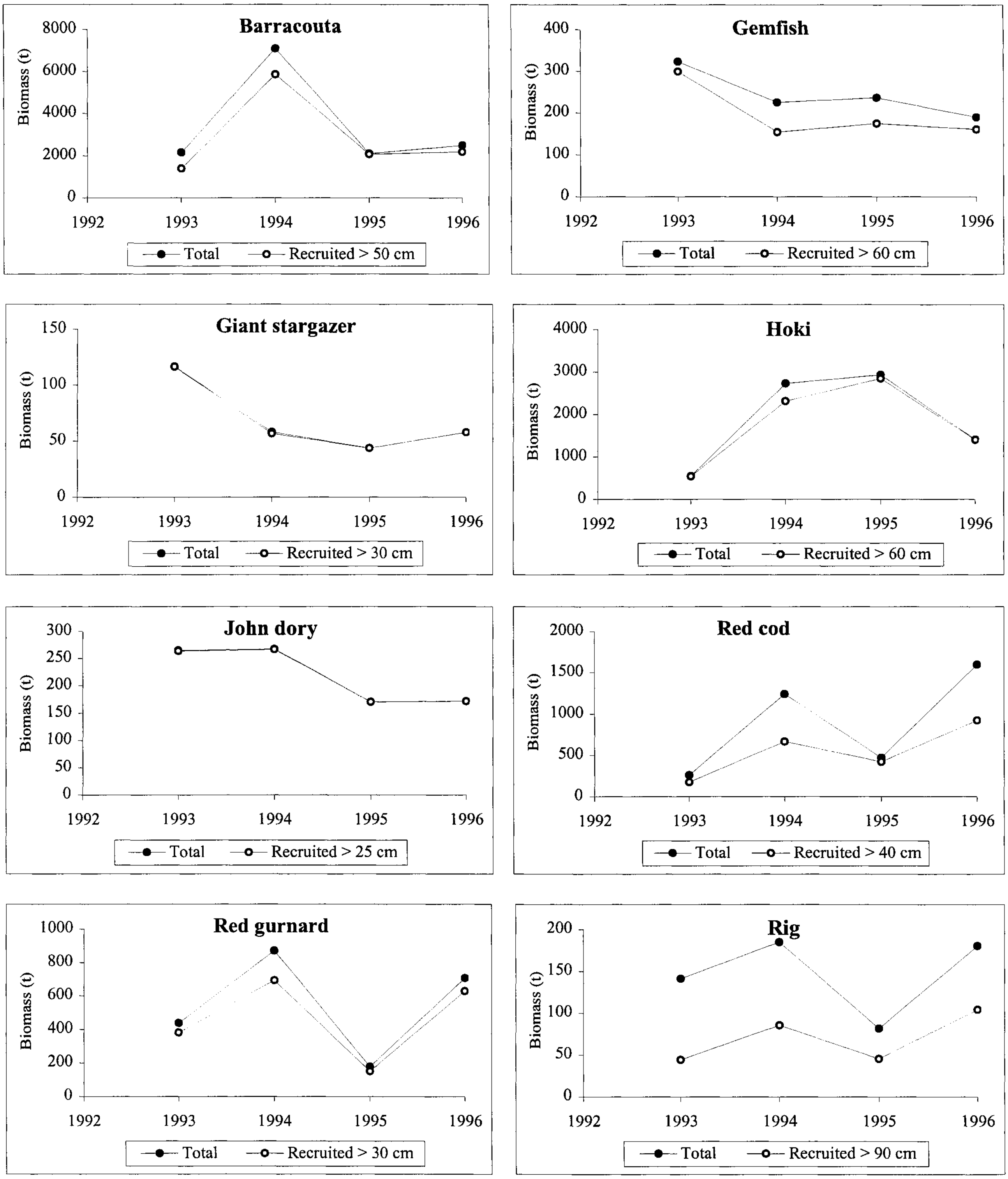


Figure 3 **: Estimates of total and recruited biomass (t), 1993–96, all areas, for barracouta, gemfish, giant stargazer, hoki, john dory, red cod, red gurnard, rig, school shark, silver warehou, and tarakihi.**

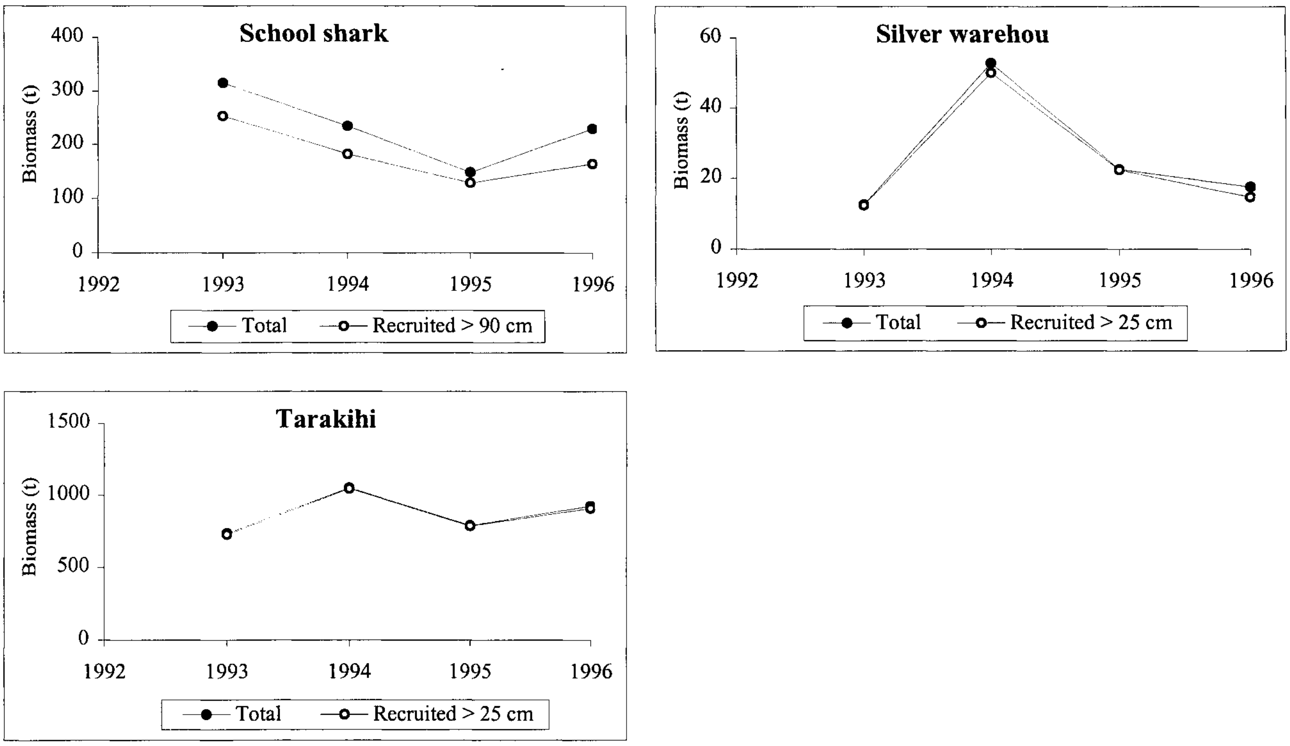


Figure 3—continued

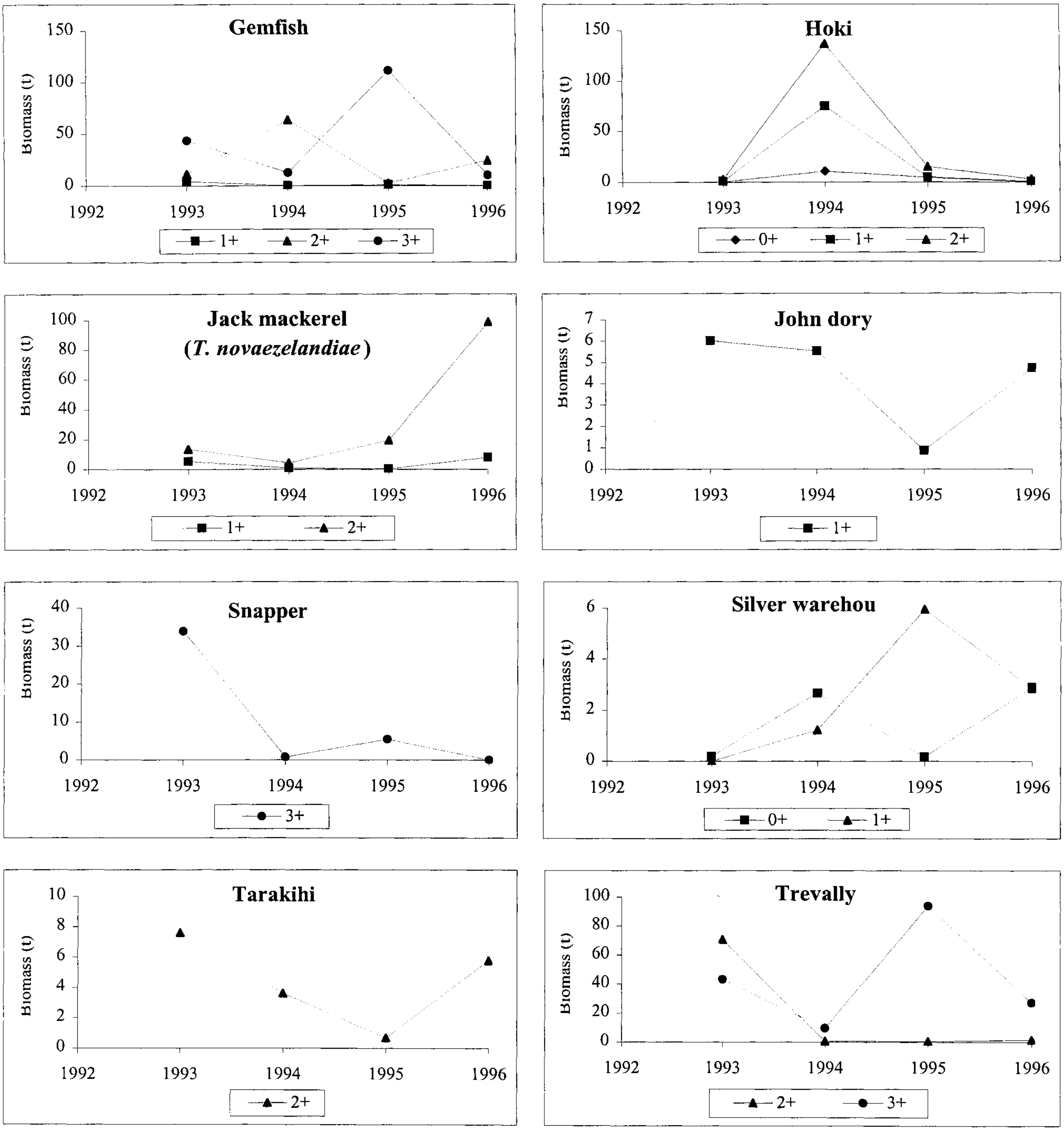


Figure 4: **Estimated biomass (t) by year class, 1993–96, all areas, for gemfish, hoki, jack mackerel (*Trachurus novaezelandiae*), John dory, snapper, silver warehou, tarakihi, and trevally.**

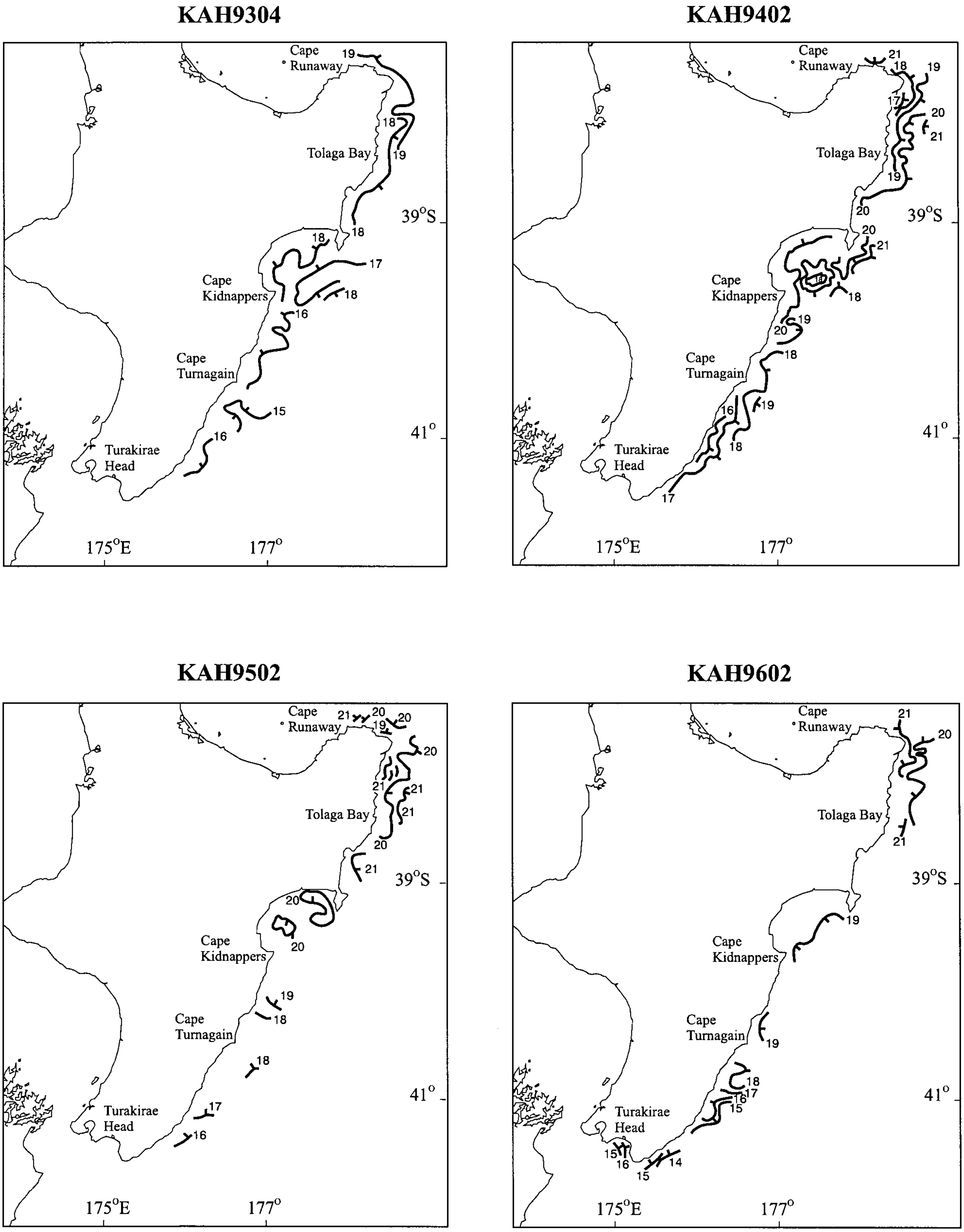


Figure 5 **: Sea surface isotherms estimated from station data.**

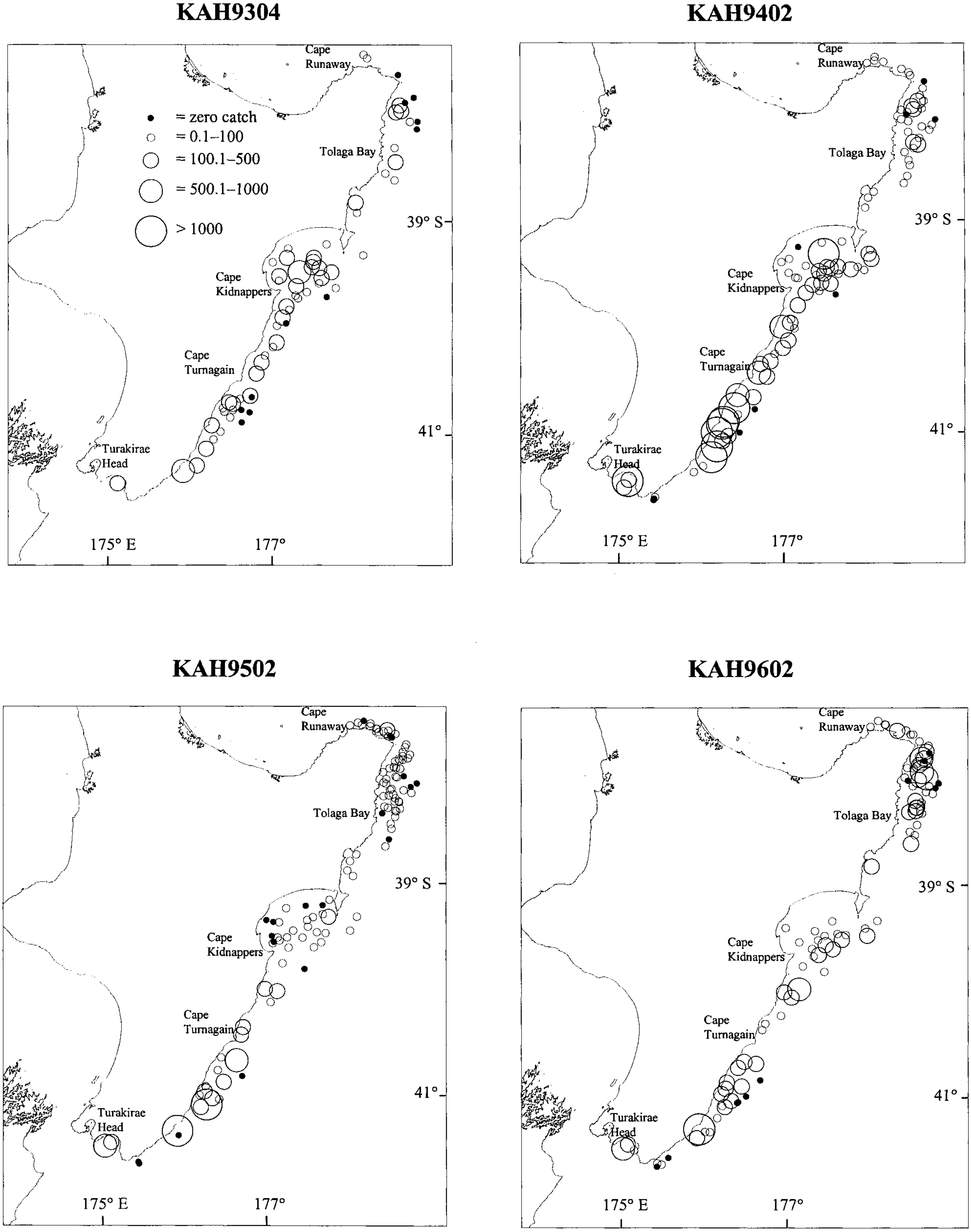


Figure 6: **Distribution and catch rates (kg.km^{-2}) of the major species 1993–96.**
a **: Barracouta (maximum catch rate 4812 kg.km^{-2})**

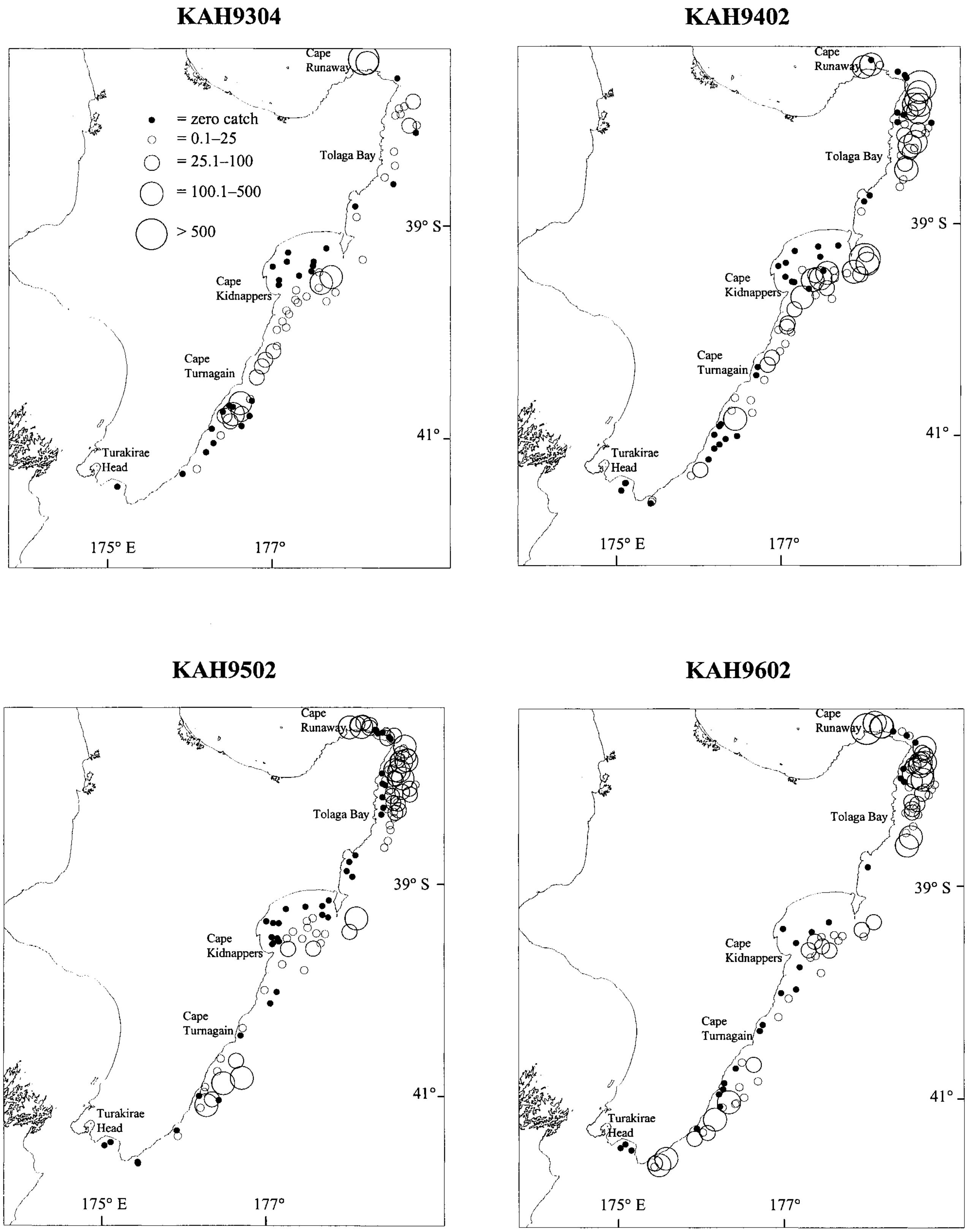


Figure 6b: **Frostfish (maximum catch rate 3618 kg.km^{-2})**

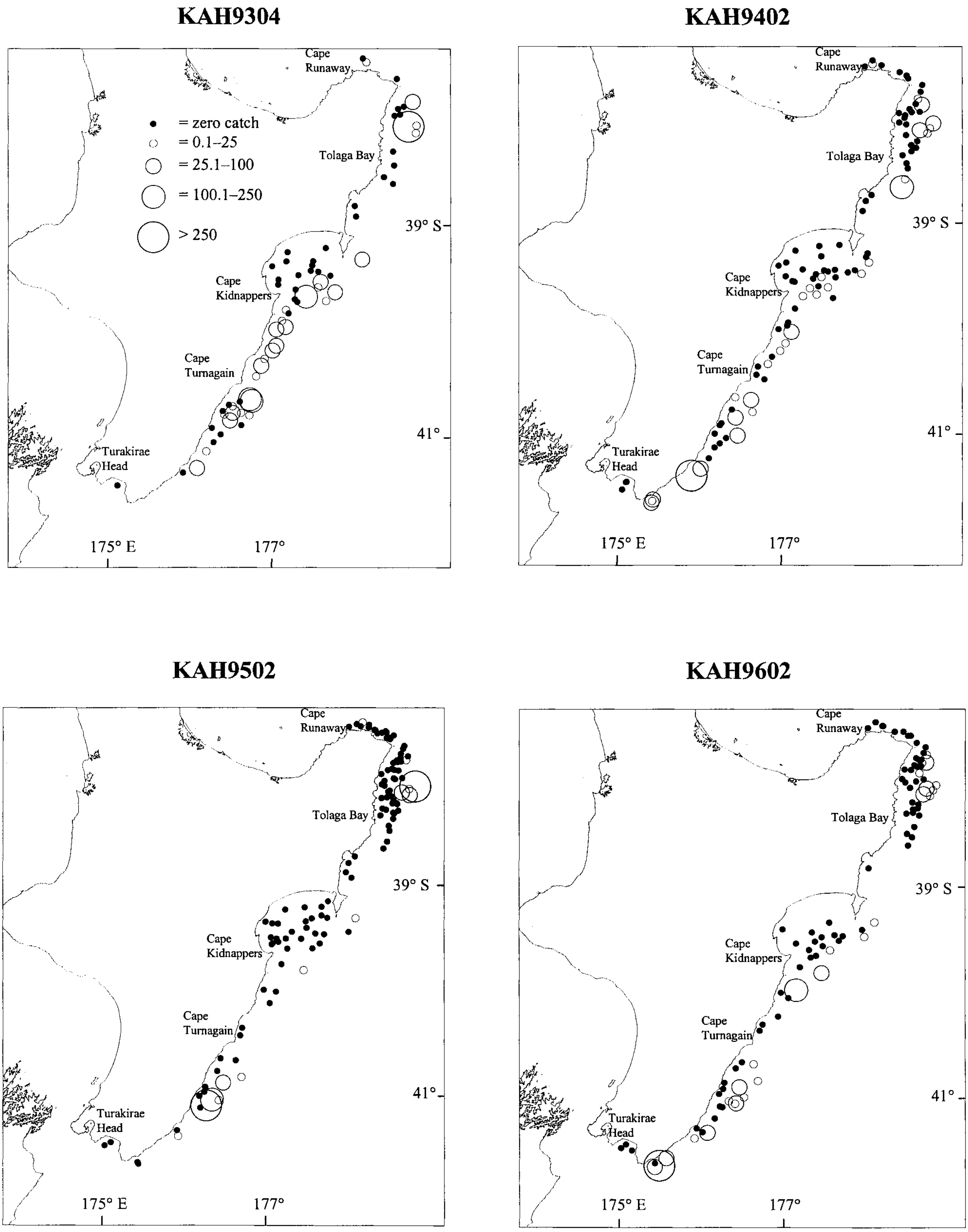


***Figure 6c*: Gemfish (maximum catch rate 591 kg.km^{-2})**

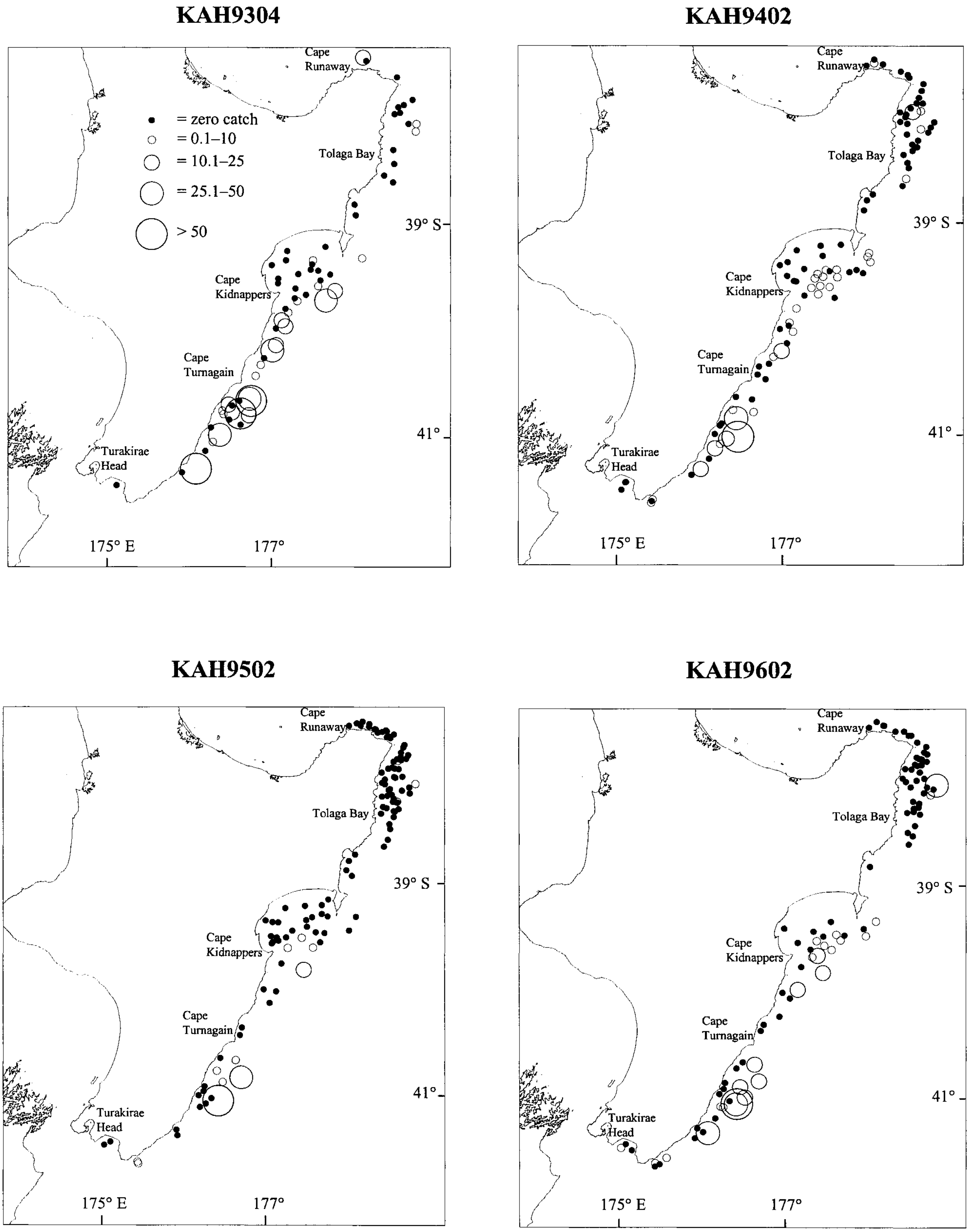


***Figure 6d*: Giant stargazer (maximum catch rate 104 kg.km^{-2})**

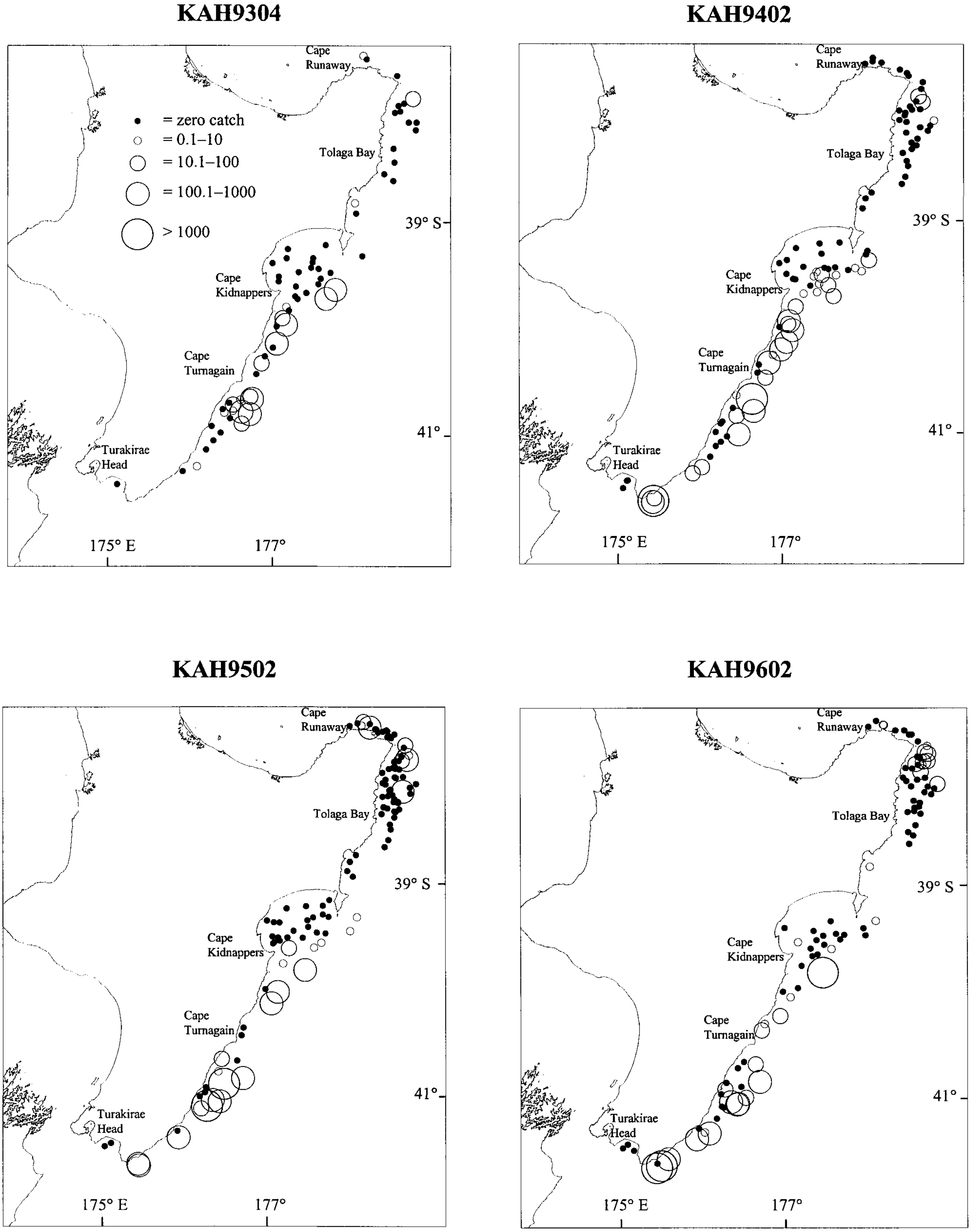
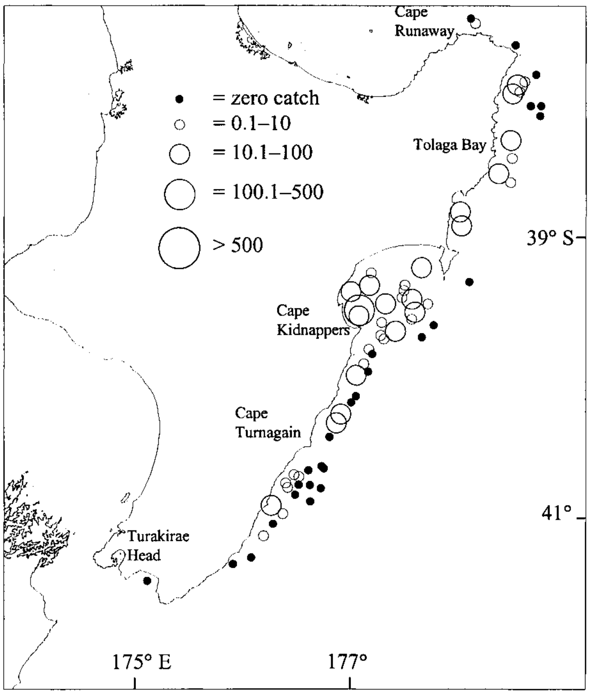
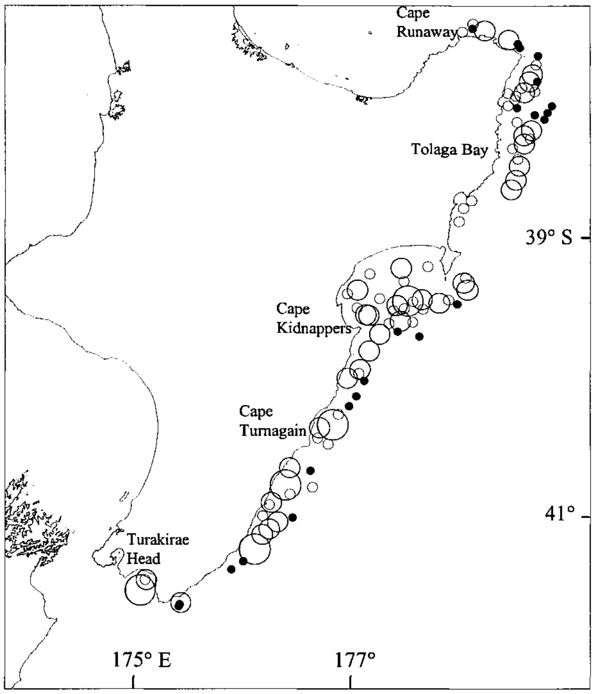


Figure 6e: **Hoki (maximum catch rate 4632 kg.km⁻²)**

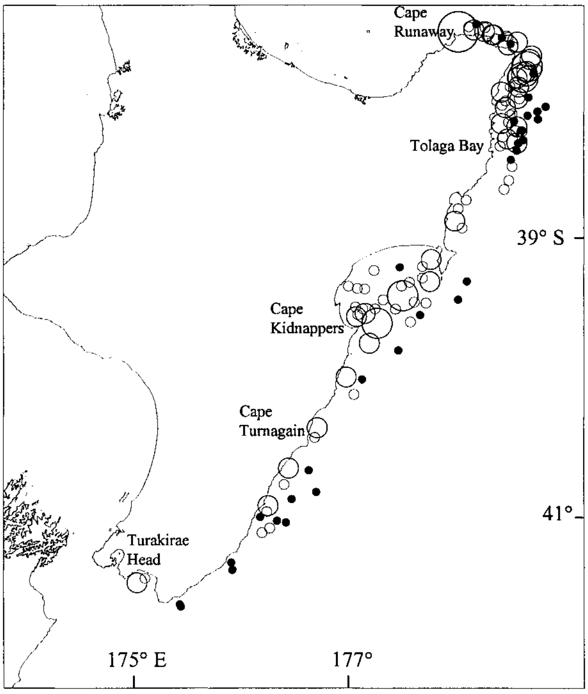
KAH9304



KAH9402



KAH9502



KAH9602

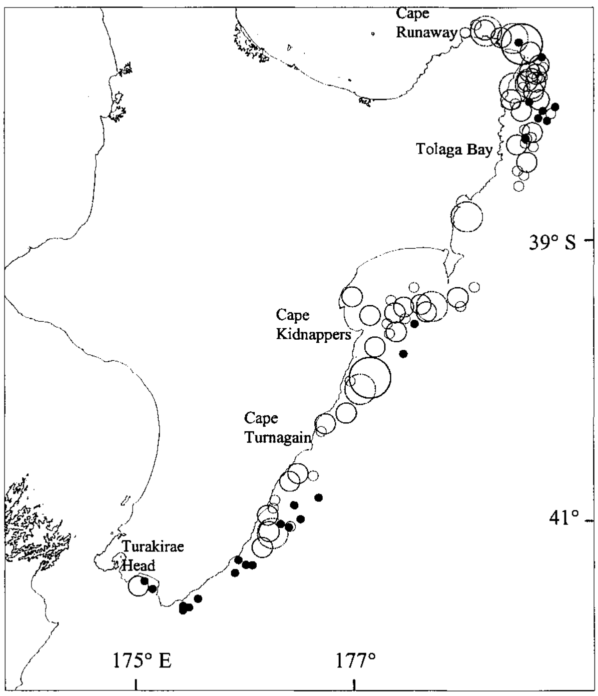


Figure 6f**: N.Z. jack mackerel (*****Trachurus novaezelandiae*****) (maximum catch rate 2658 kg.km^{-2})**

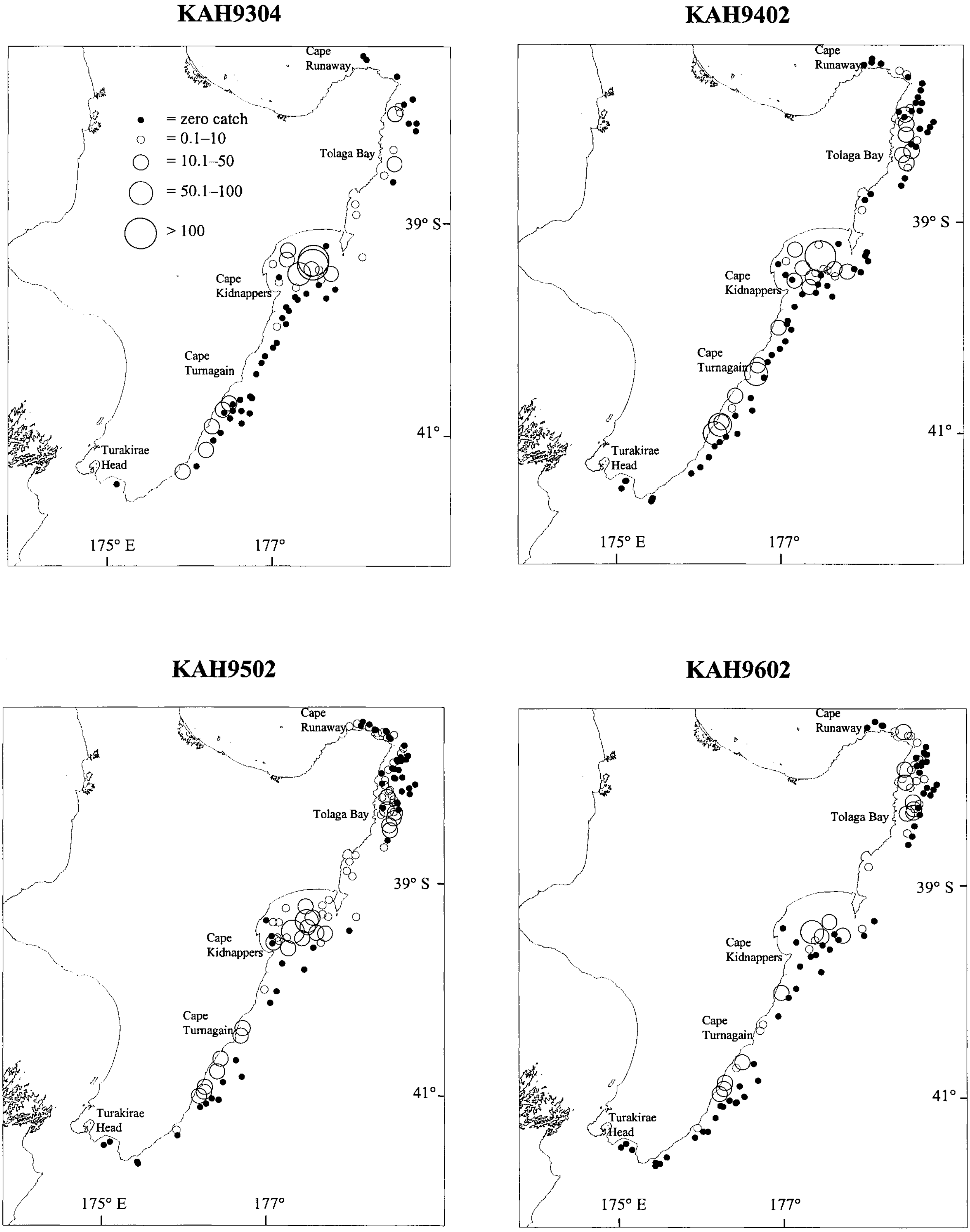


Figure 6g: **John dory (maximum catch rate 140 kg.km^{-2})**

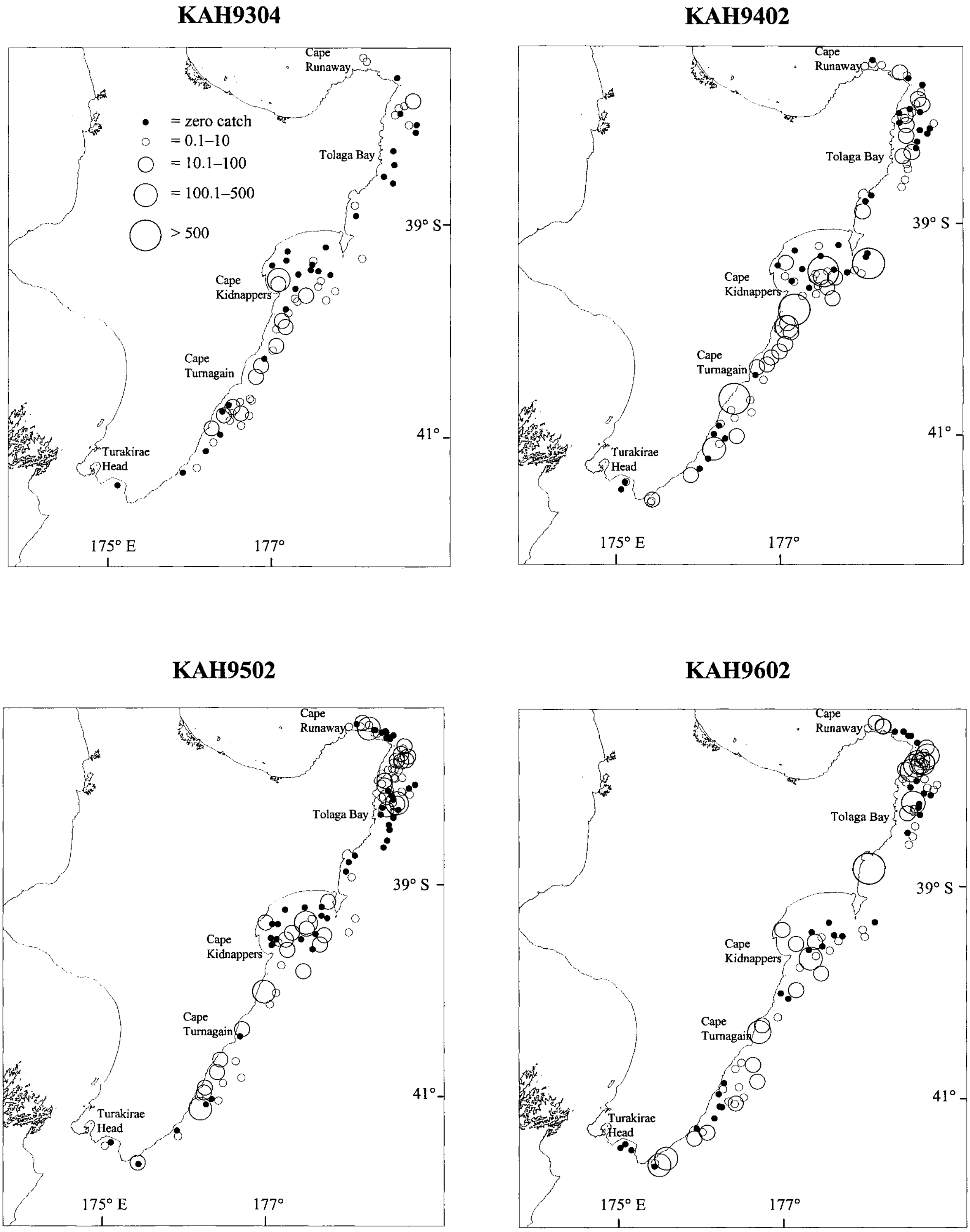


***Figure 6h*: Red cod (maximum catch rate 3485 kg.km^{-2})**

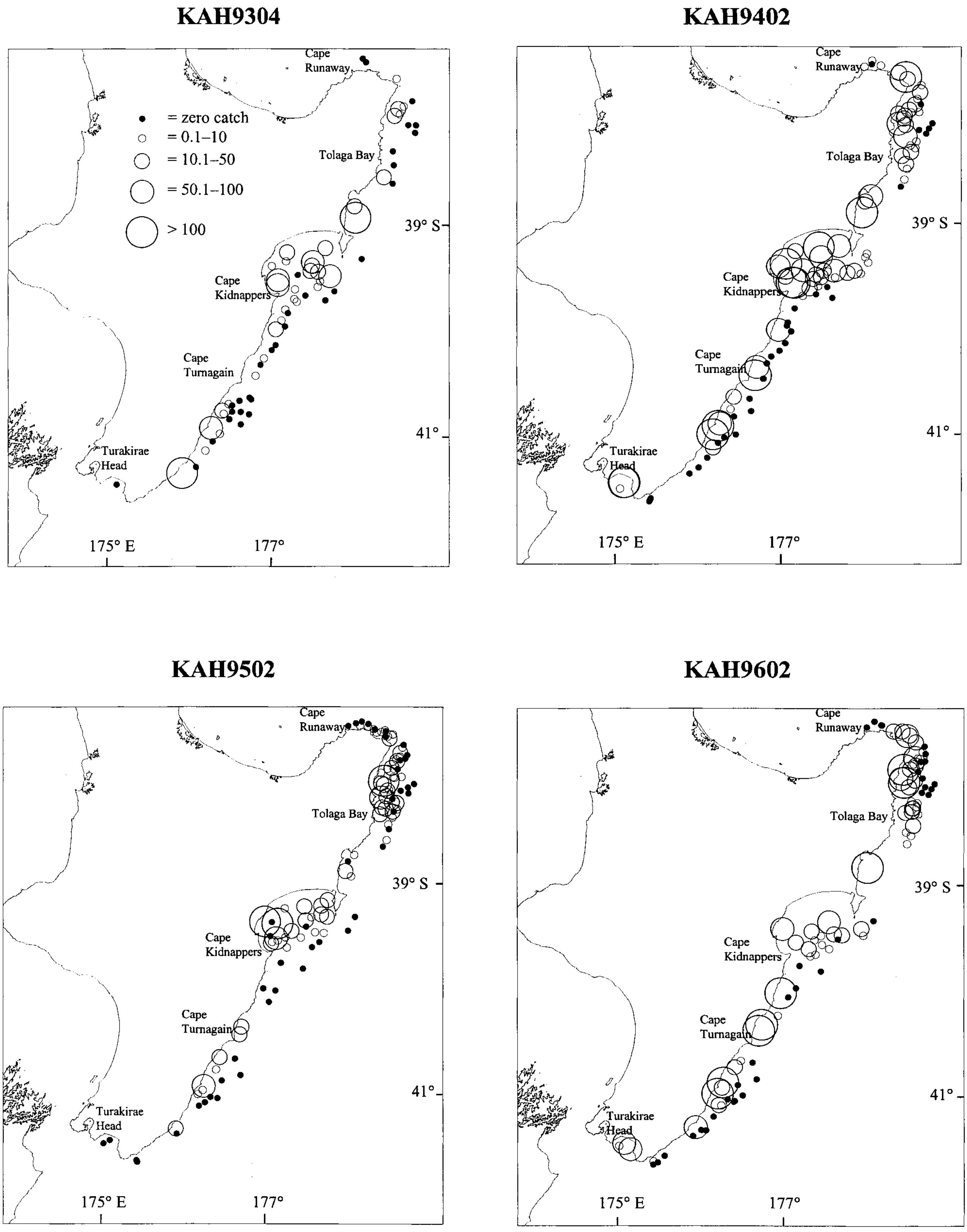
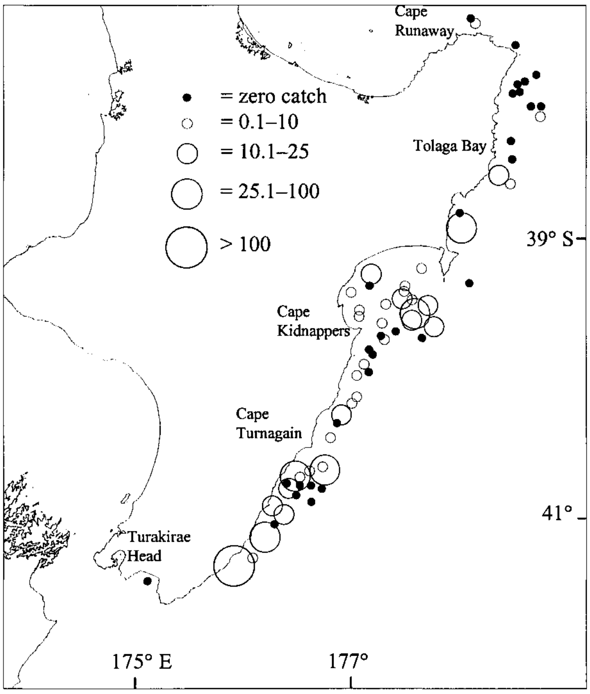


Figure 6i : **Red gurnard (maximum catch rate 460 kg.km^{-2})**

KAH9304



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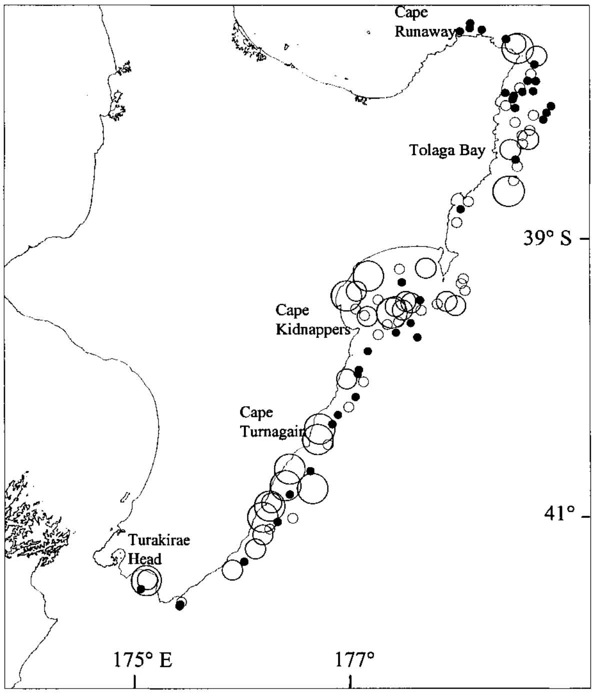

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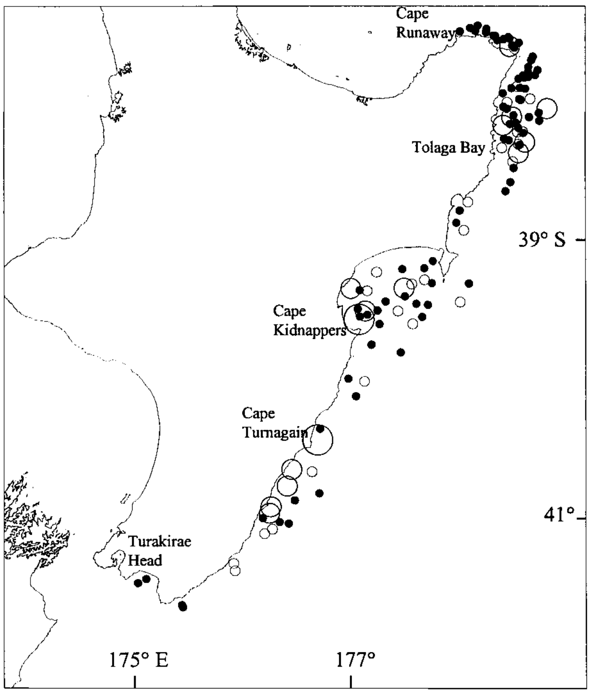

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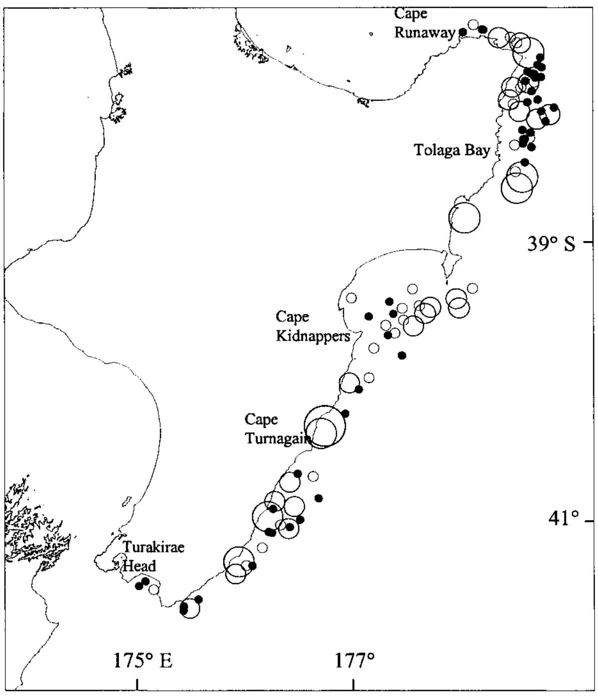

Figure 6j **: Rig (maximum catch rate 112 kg.km^{-2})**

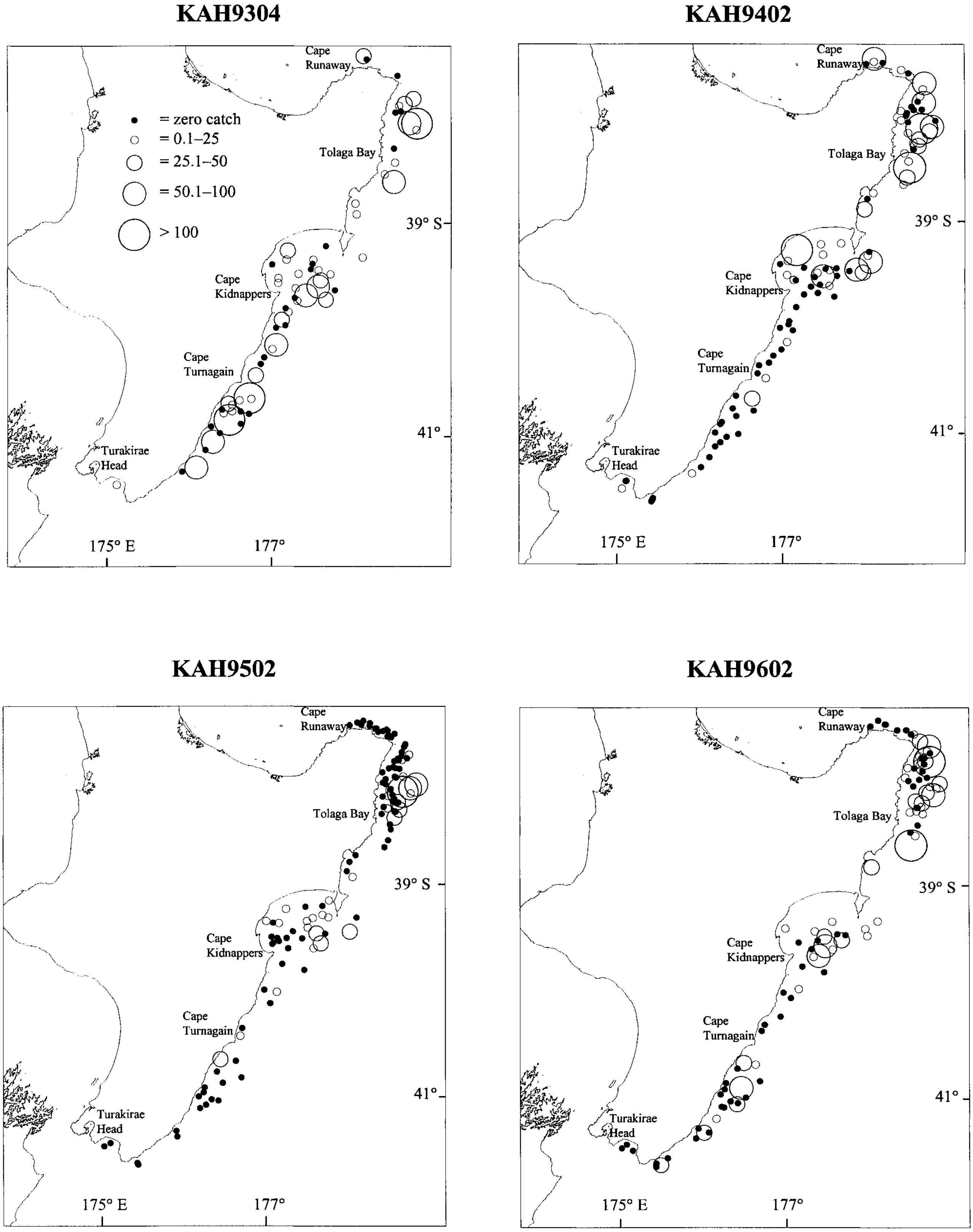

***Figure 6k*: School shark (maximum catch rate 208 kg.km^{-2})**

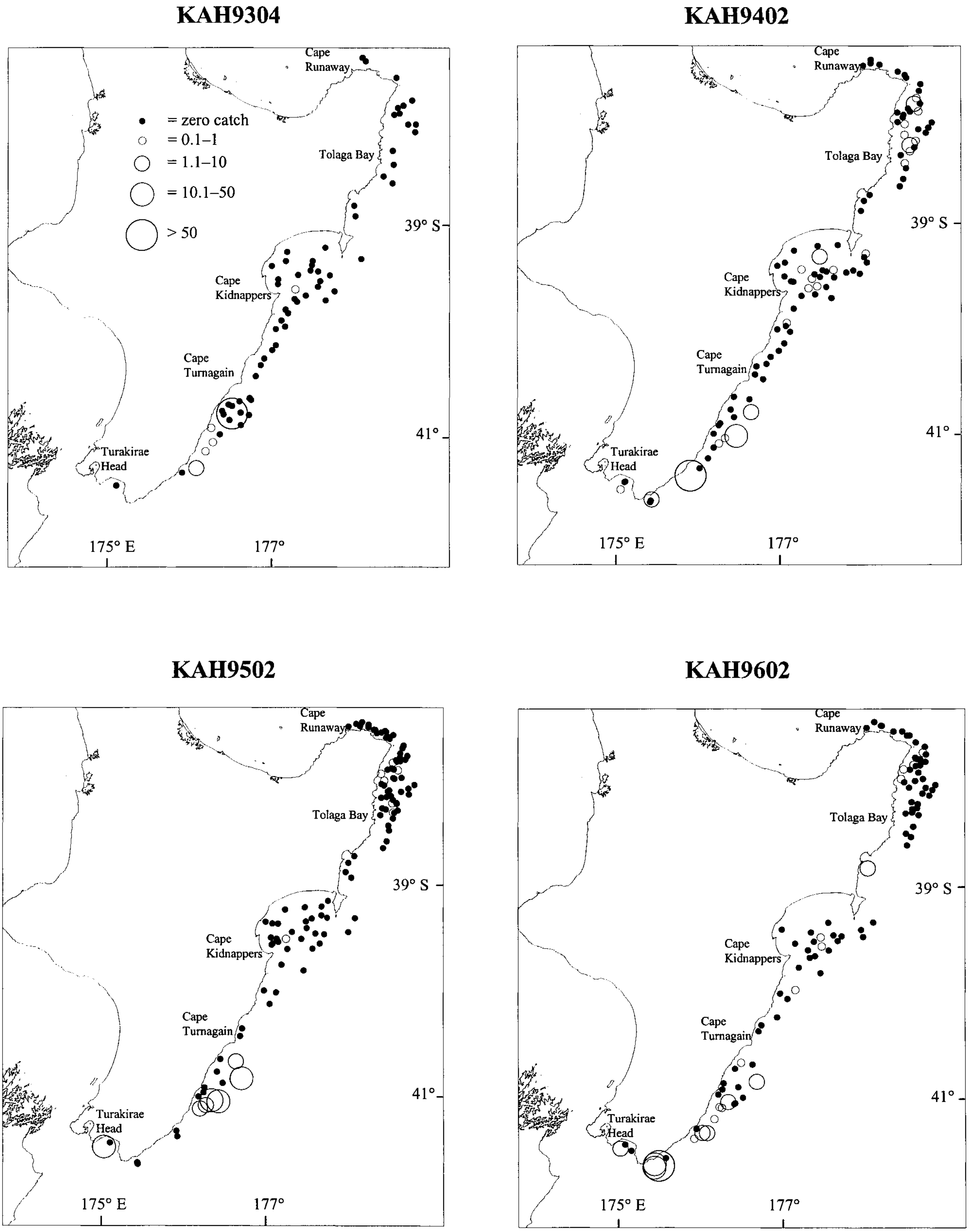

Figure 6l: **Silver warehou (maximum catch rate 321 kg.km^{-2})**

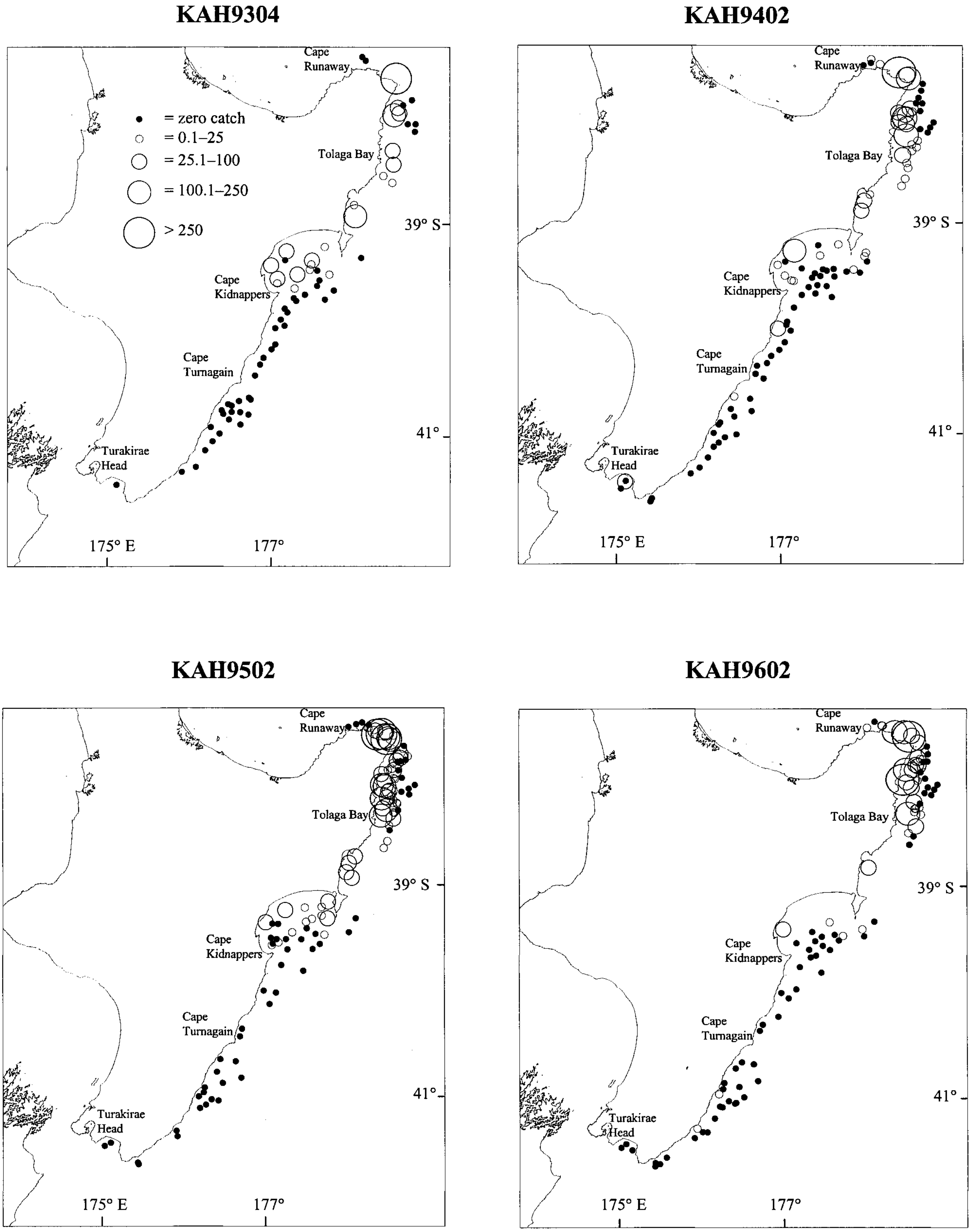

***Figure 6m*: Snapper (maximum catch rate 598 kg.km^{-2})**

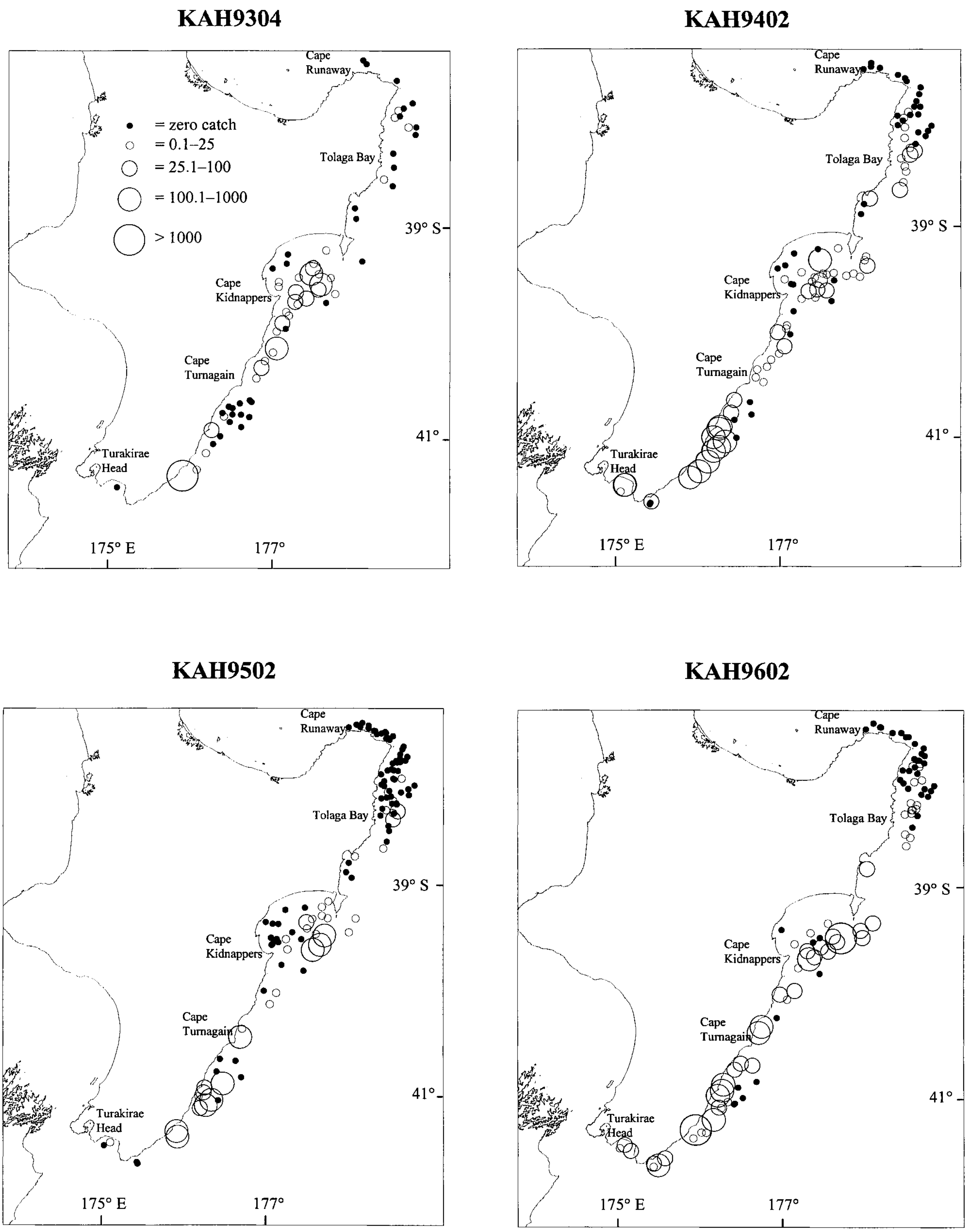

Figure 6n: **Spiny dogfish (maximum catch rate 26 001 kg.km^{-2})**

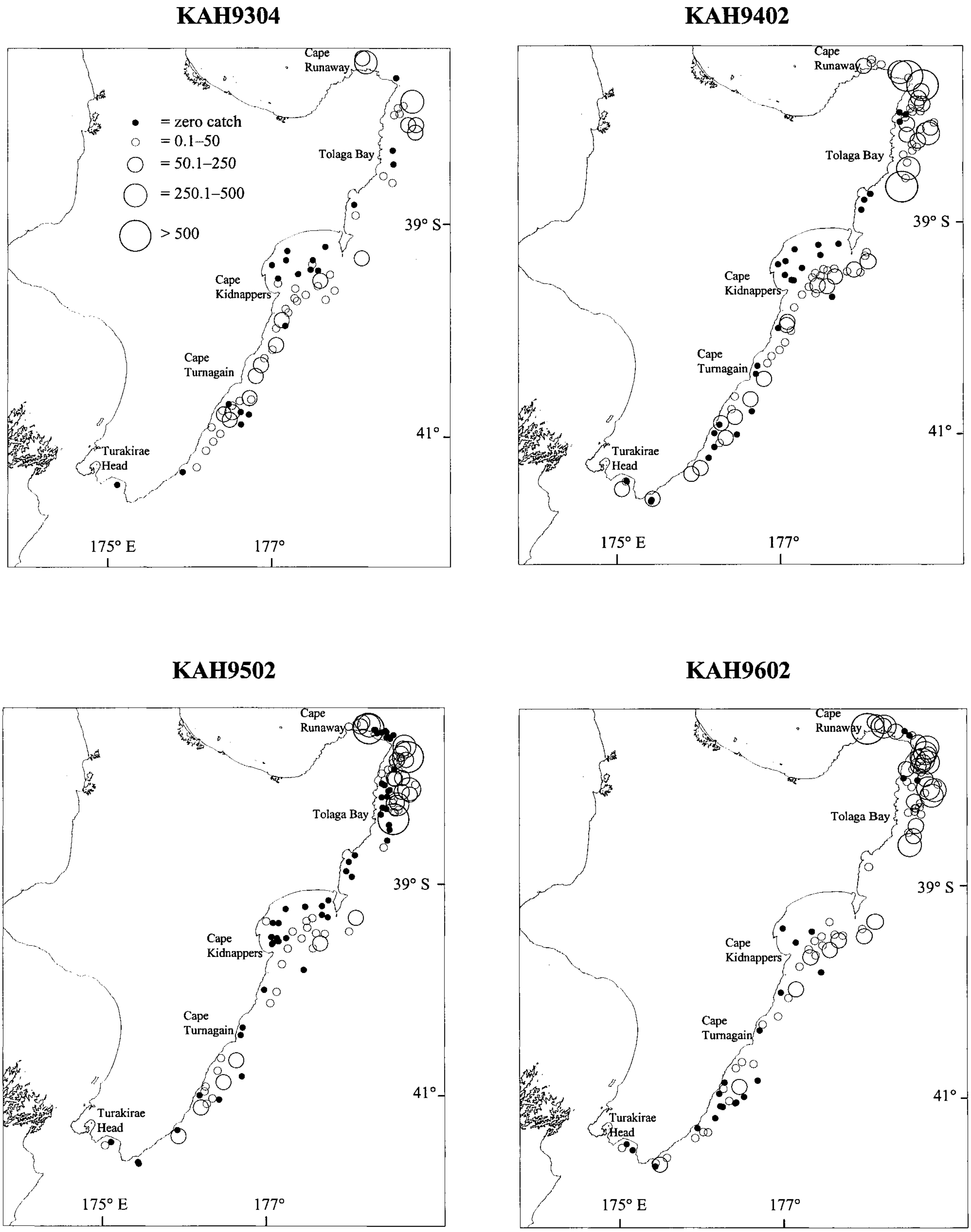

Figure 6o: **Tarakihi (maximum catch rate 2837 kg.km^{-2})**

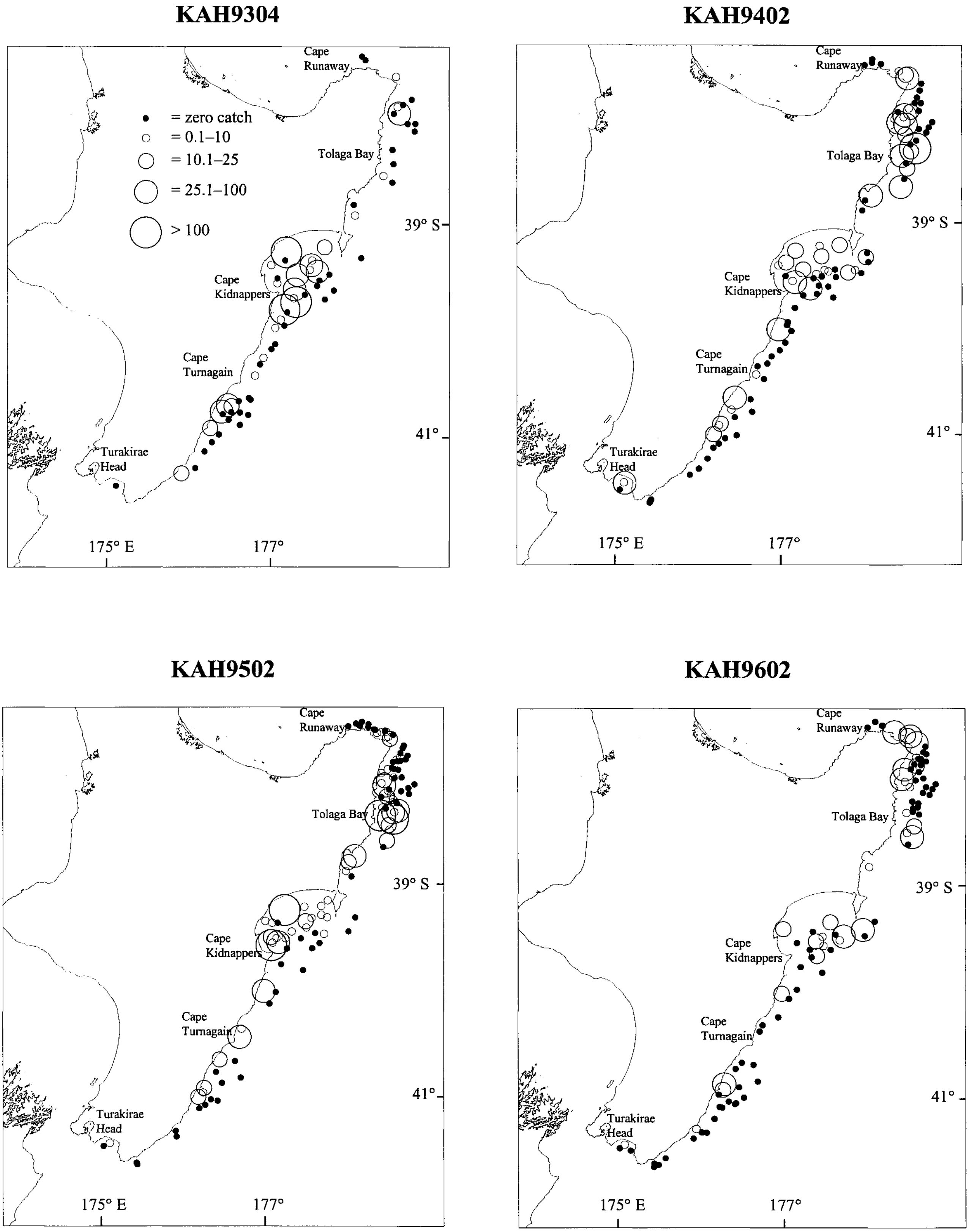

***Figure 6p*: Trevally (maximum catch rate 569 kg.km^{-2})**

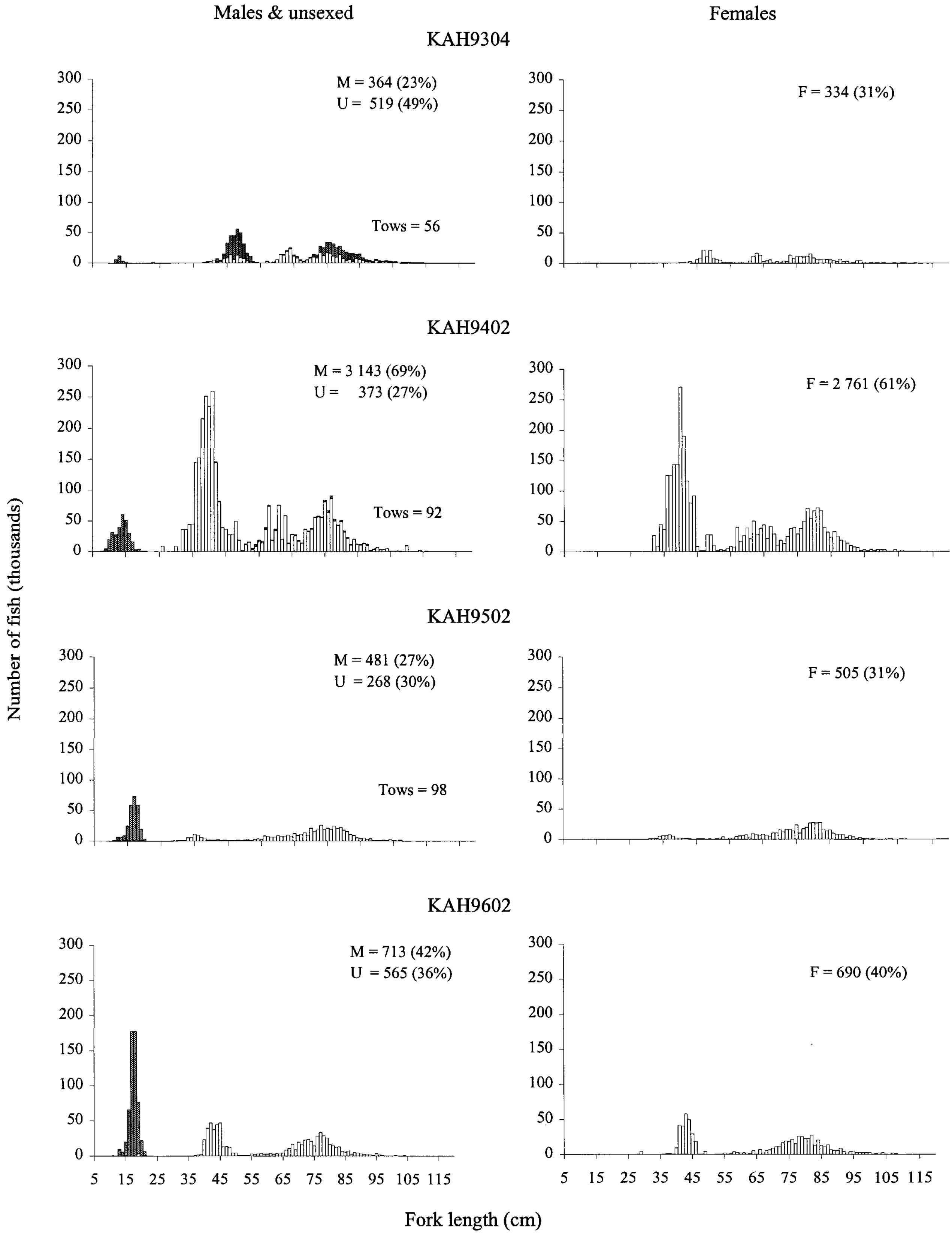

***Figure 7*: Scaled length frequency distributions of the major species, 1993–96, with the estimated total number of fish in the population (and percentage coefficient of variation). M, number of males; F, number of femal U, number of unsexed fish (shaded), Tows, number of stations at which the species was caught).**
***a*: Barracouta.**

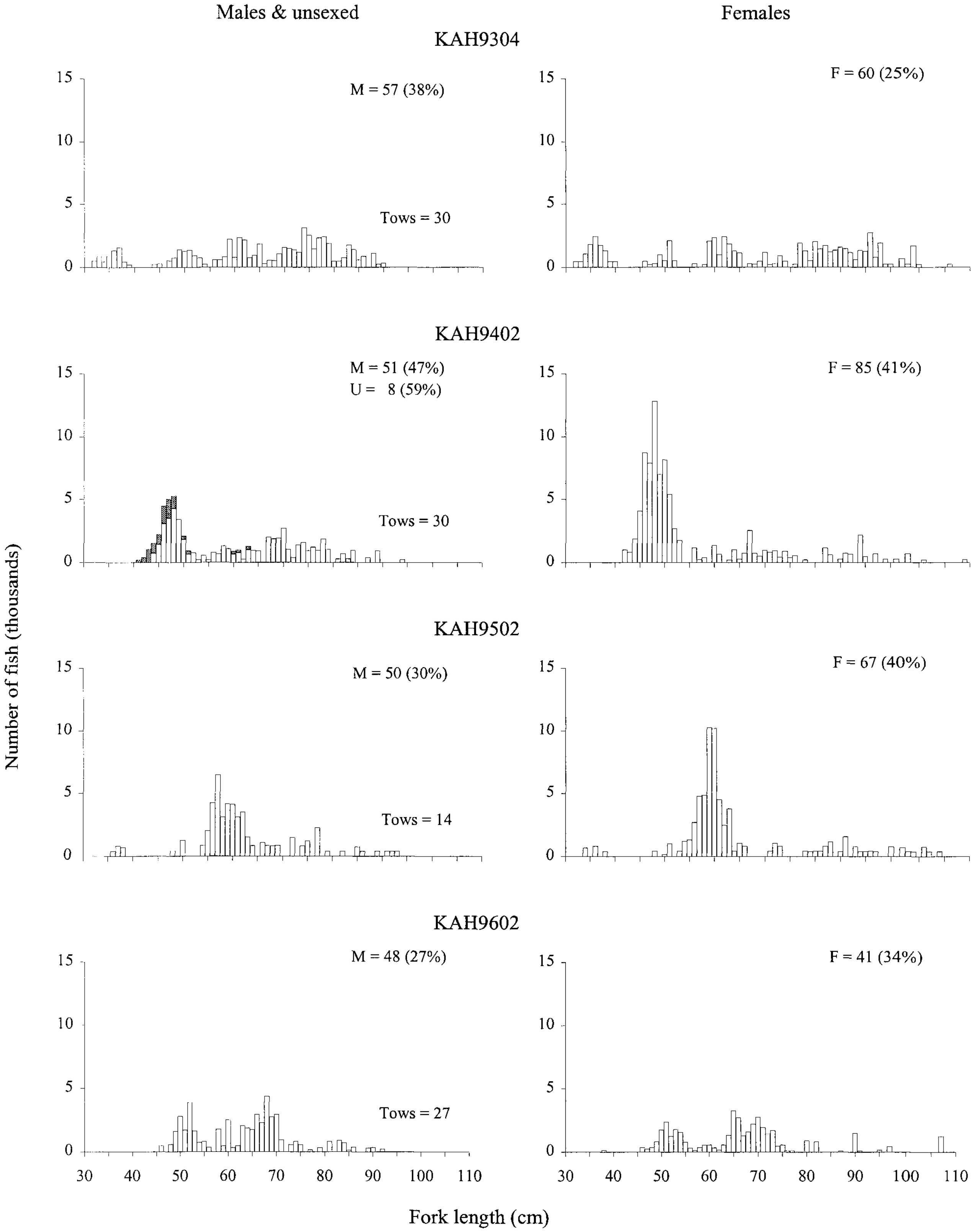

Figure 7b **: Gemfish.**

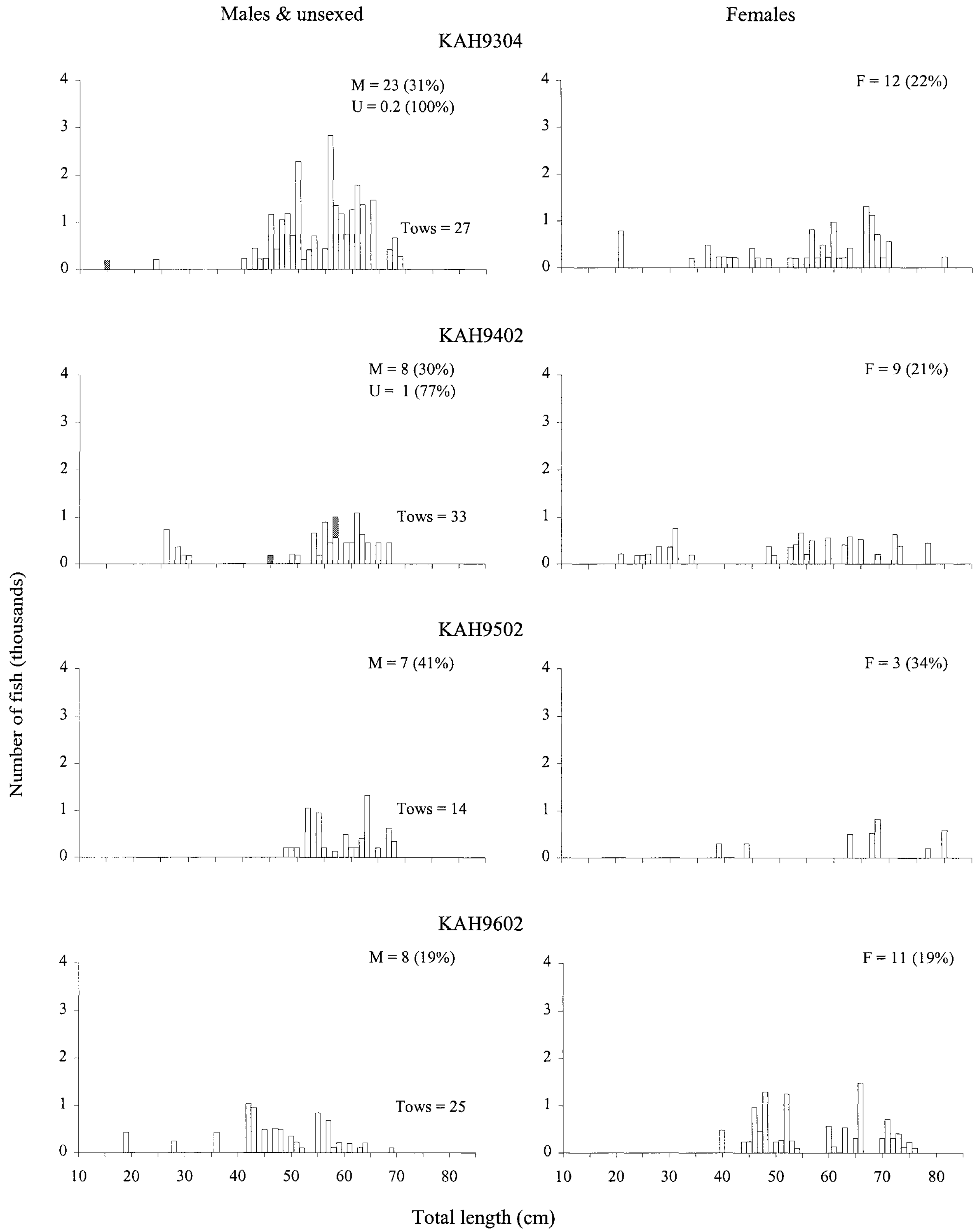

***Figure 7c*: Giant stargazer.**

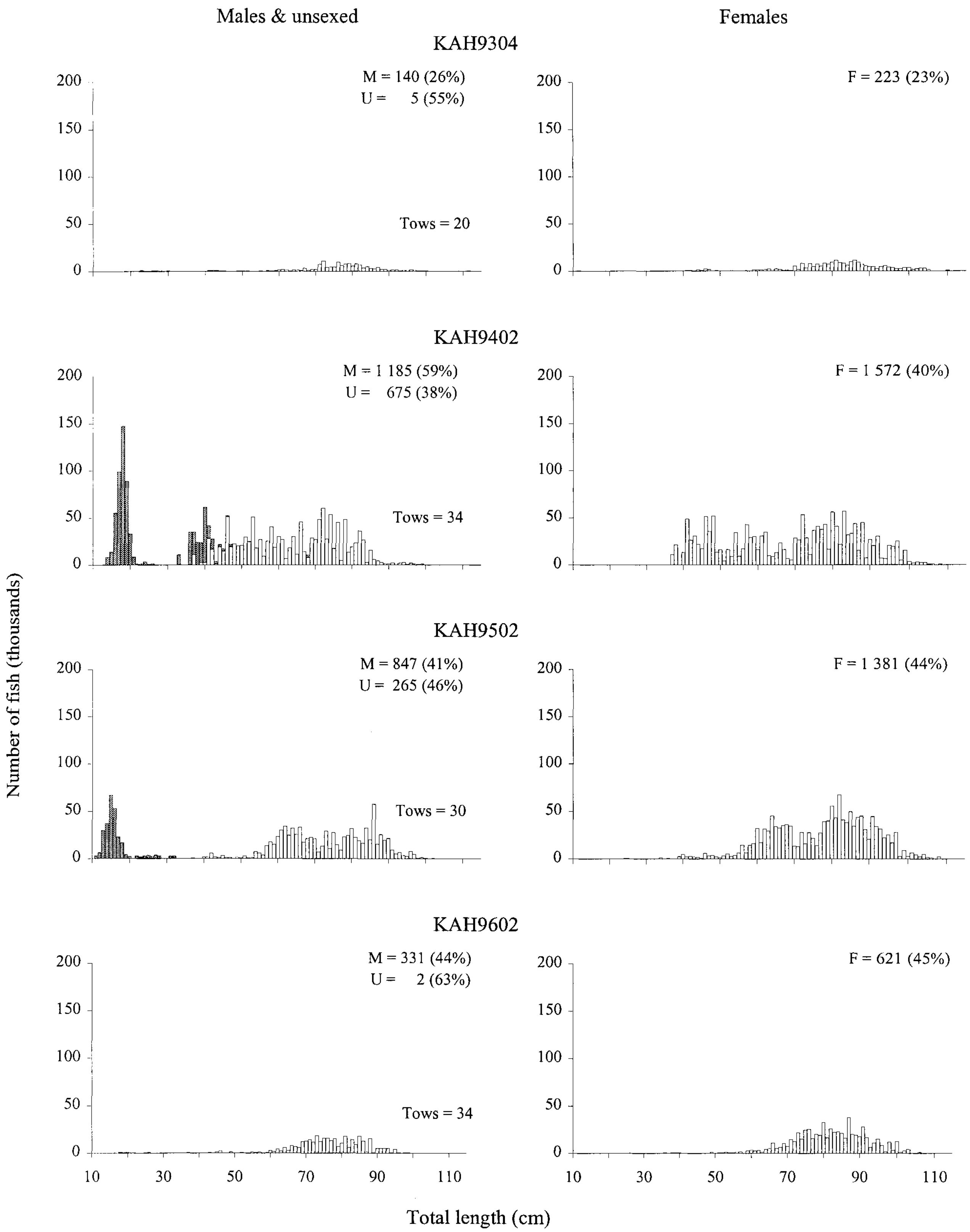

***Figure 7d*: Hoki.**

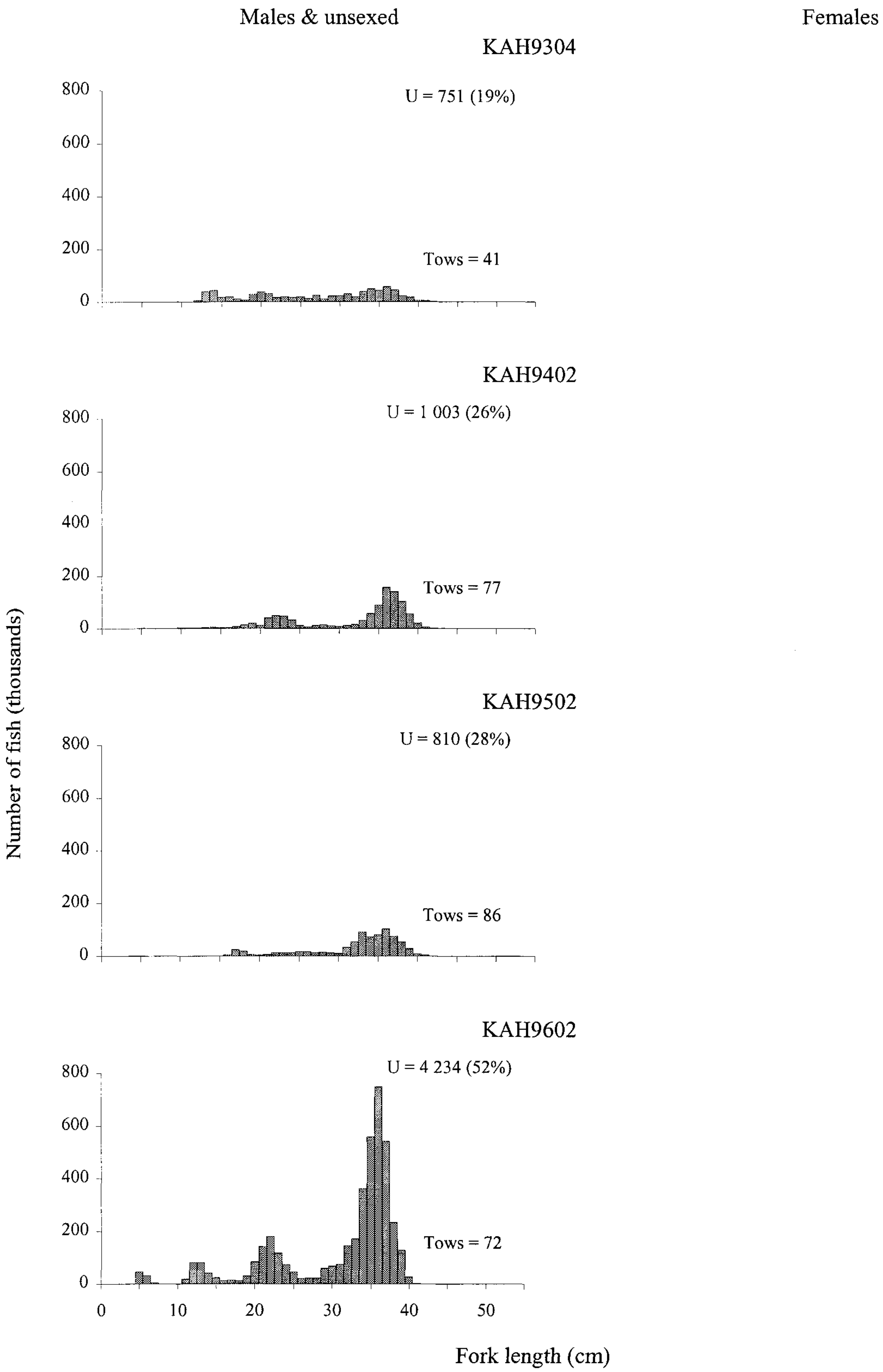

Figure 7e**: Jack mackerel (*****T. novaezelandiae*****).**

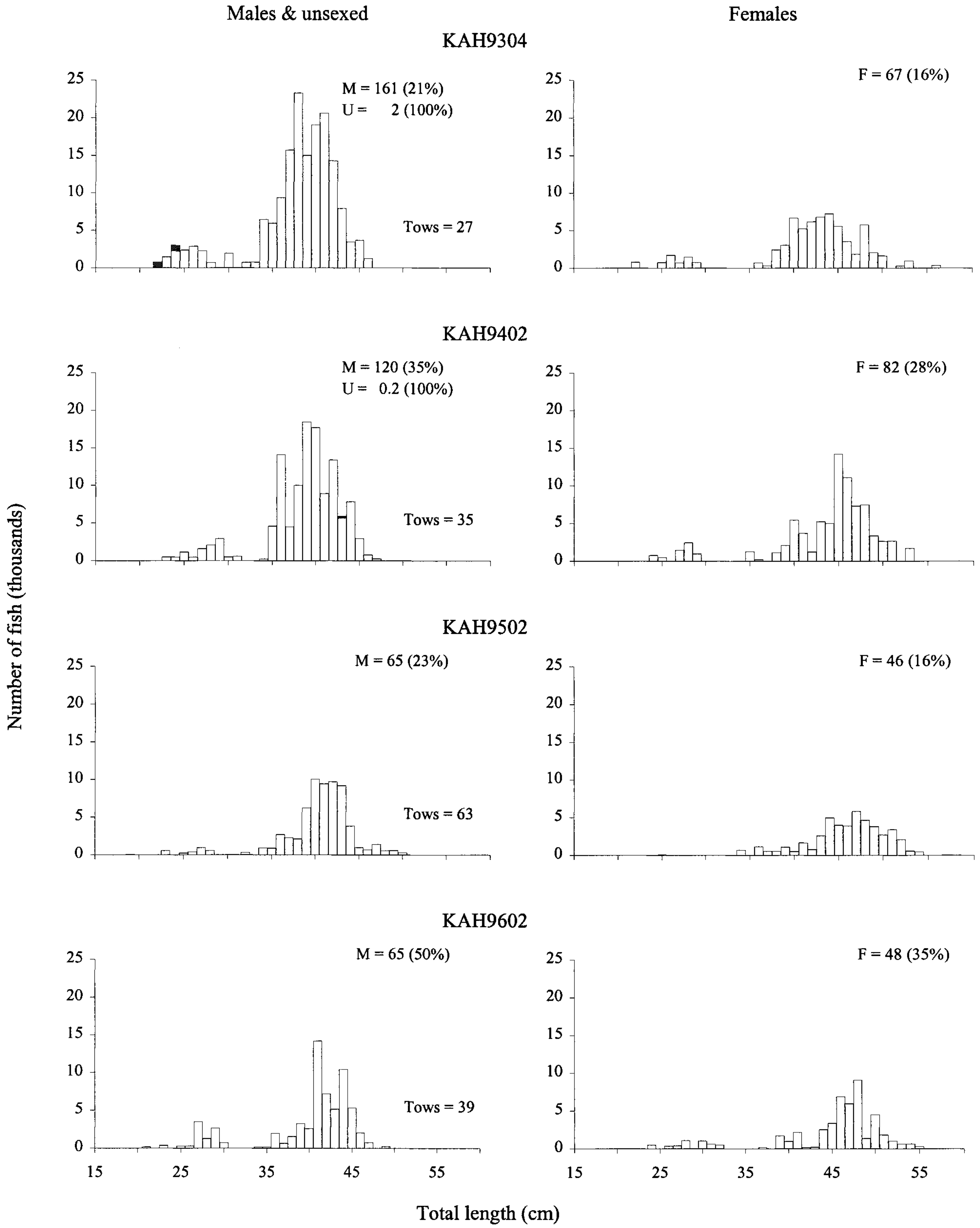

Figure 7f**: John dory.**

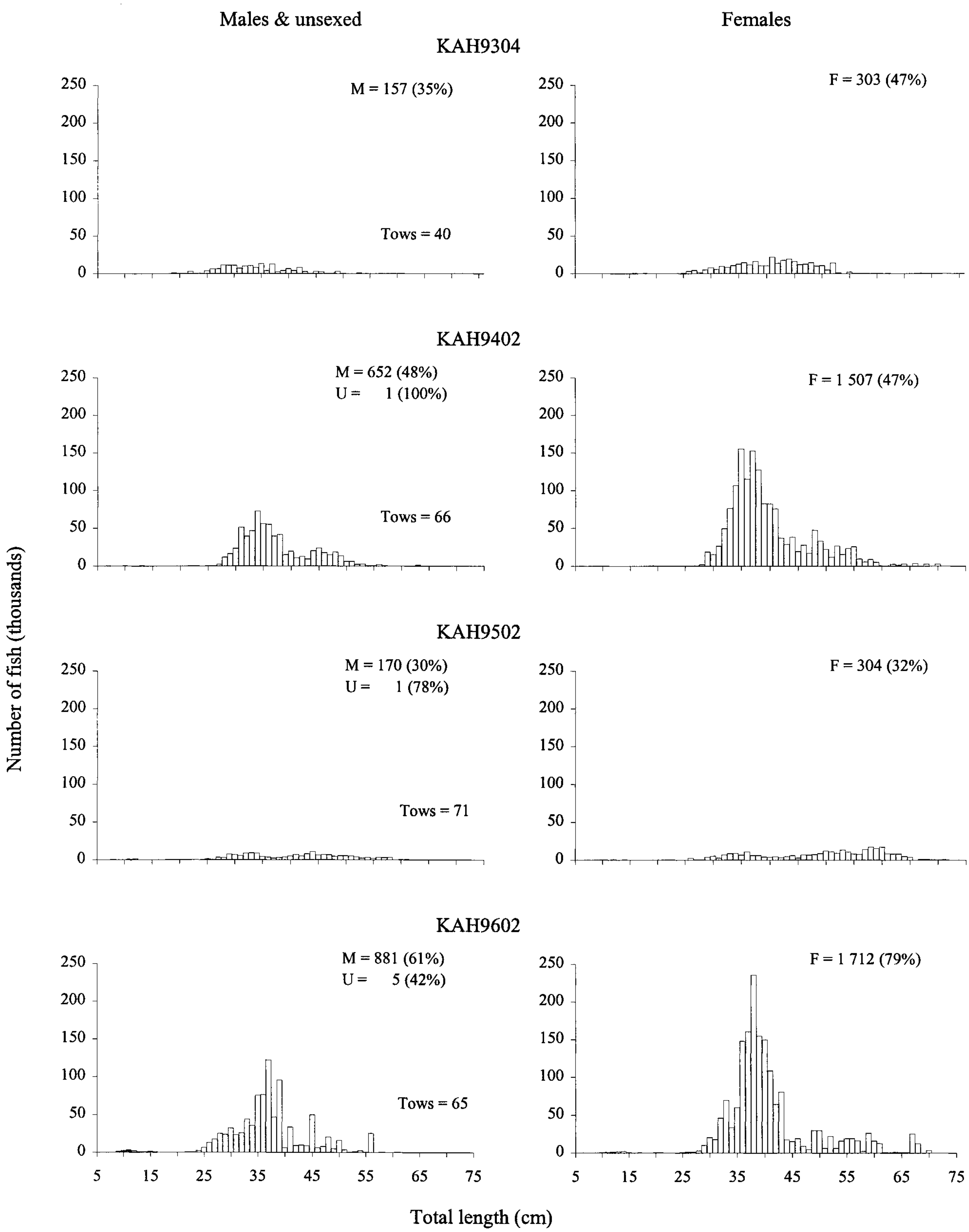

***Figure 7g*: Red cod.**

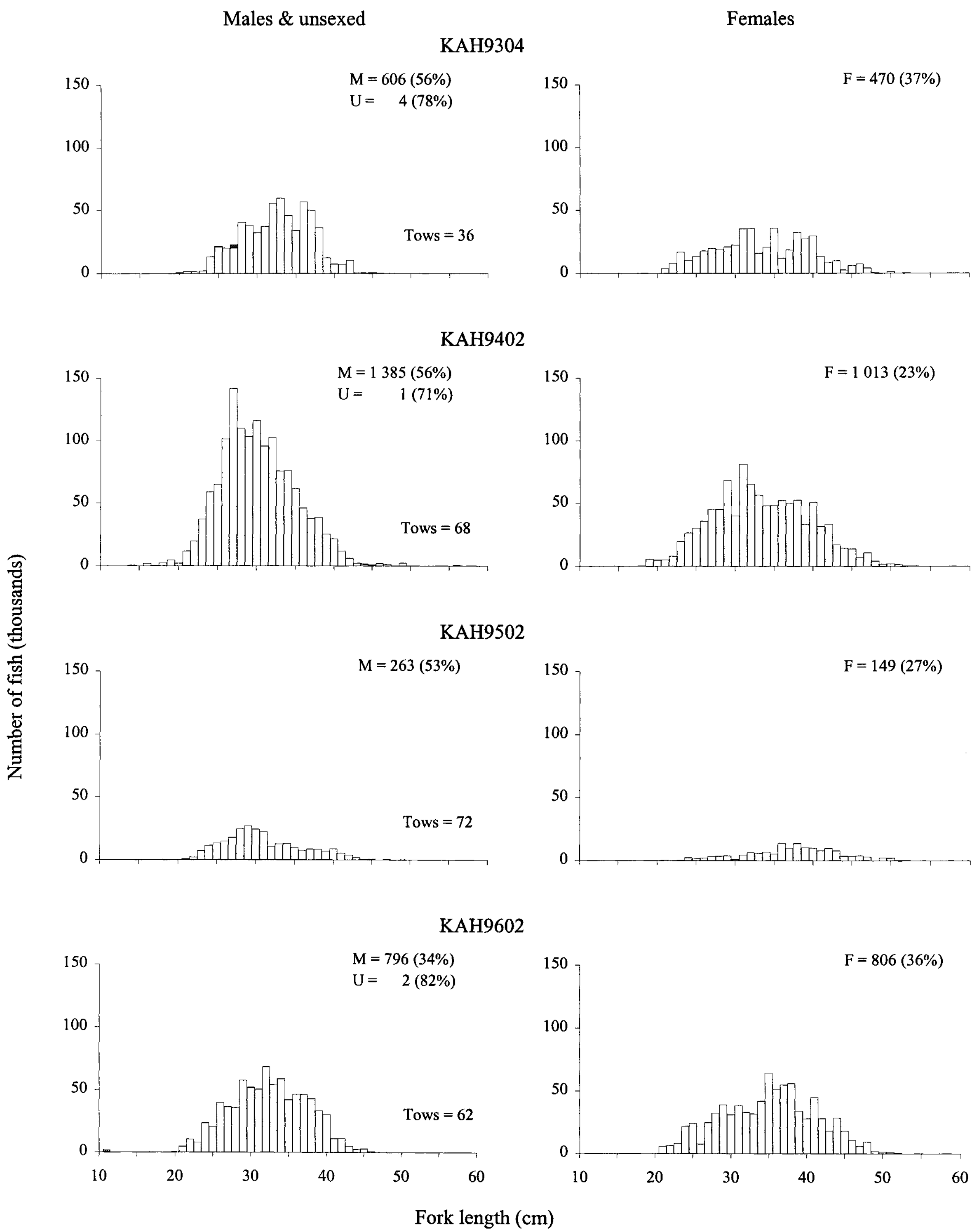

***Figure 7h*: Red gurnard.**

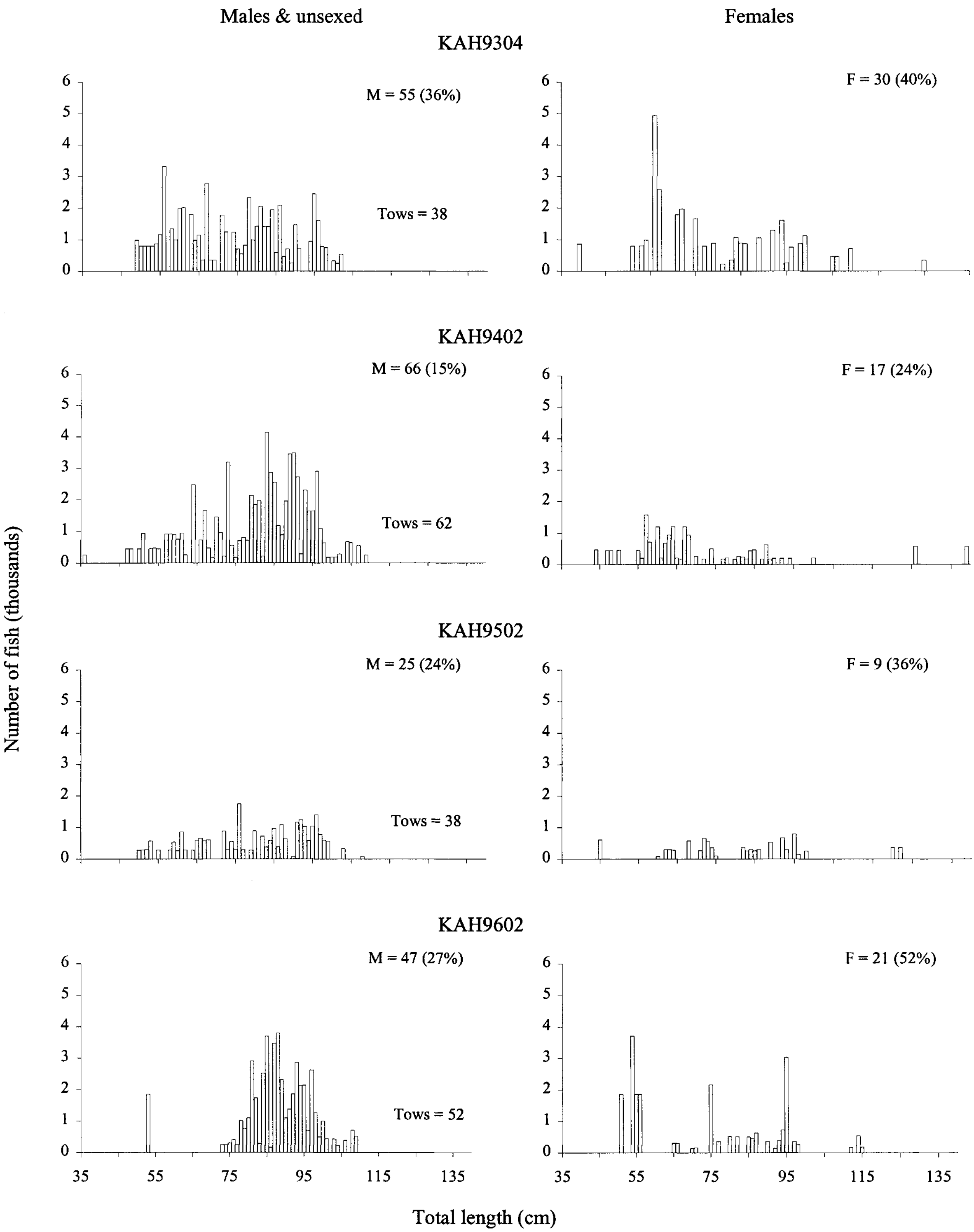

***Figure 7i*: Rig.**

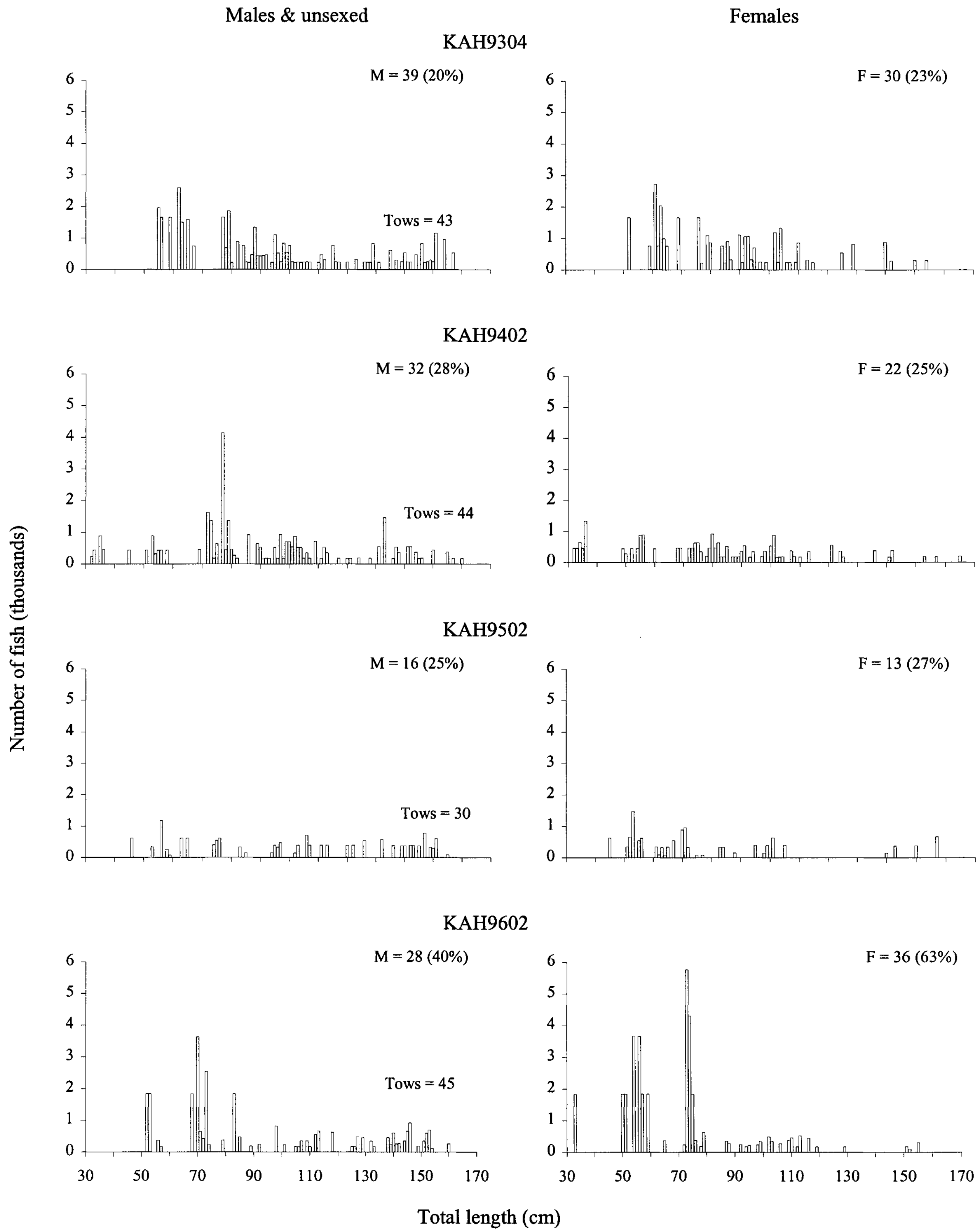

***Figure 7j*: School shark.**

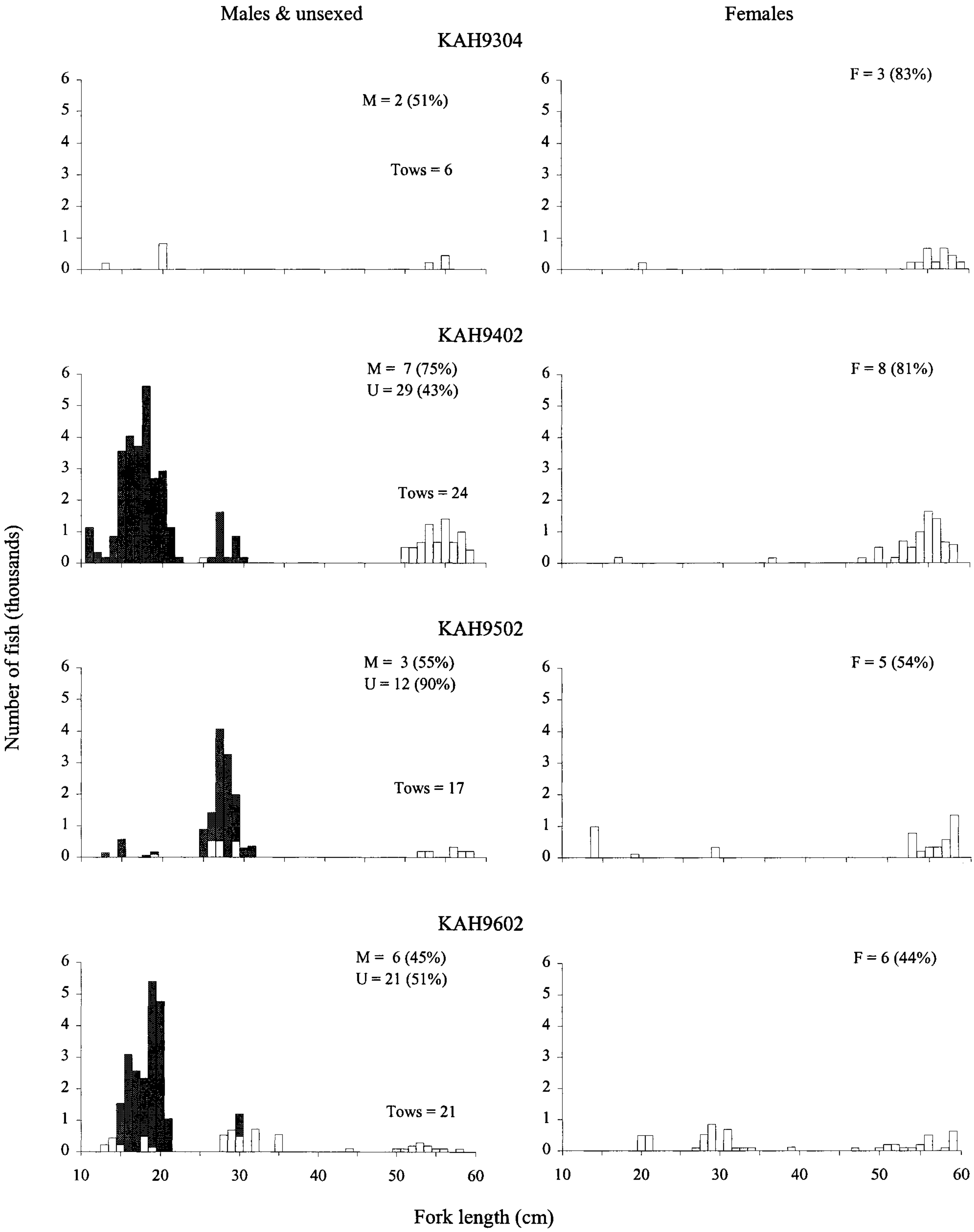

***Figure 7k*: Silver warehou.**

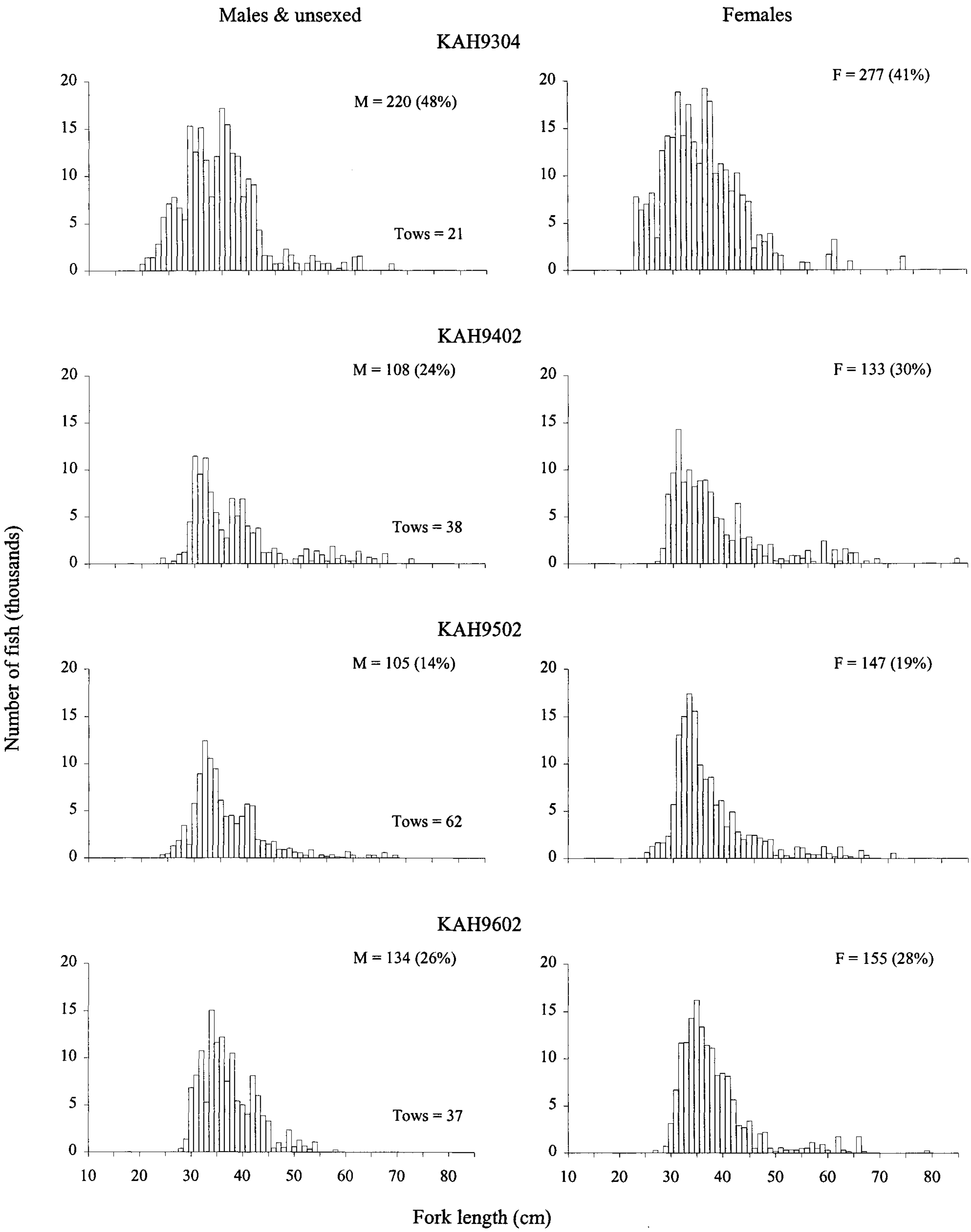

Figure 7l**: Snapper.**

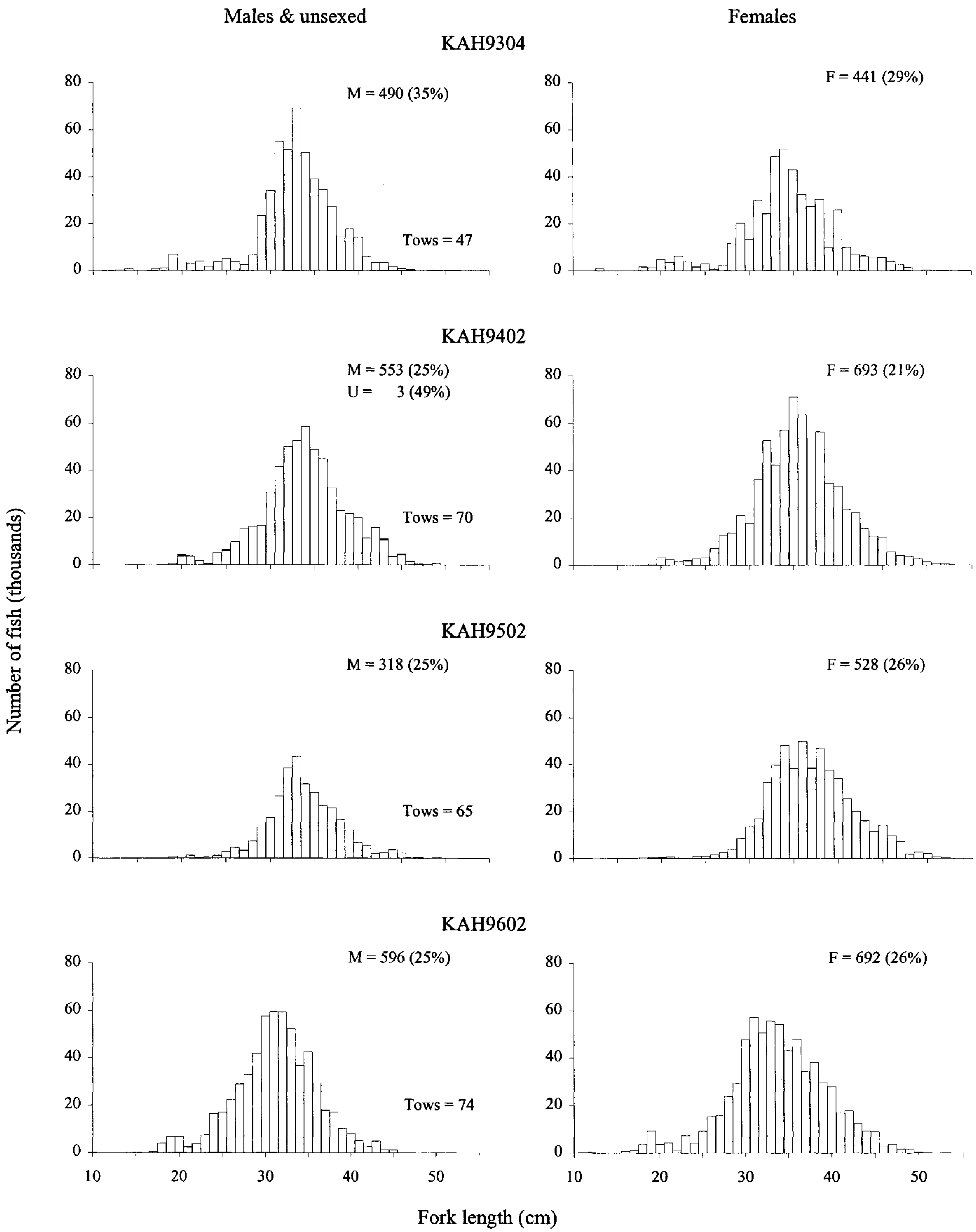

Figure 7m **: Tarakihi.**

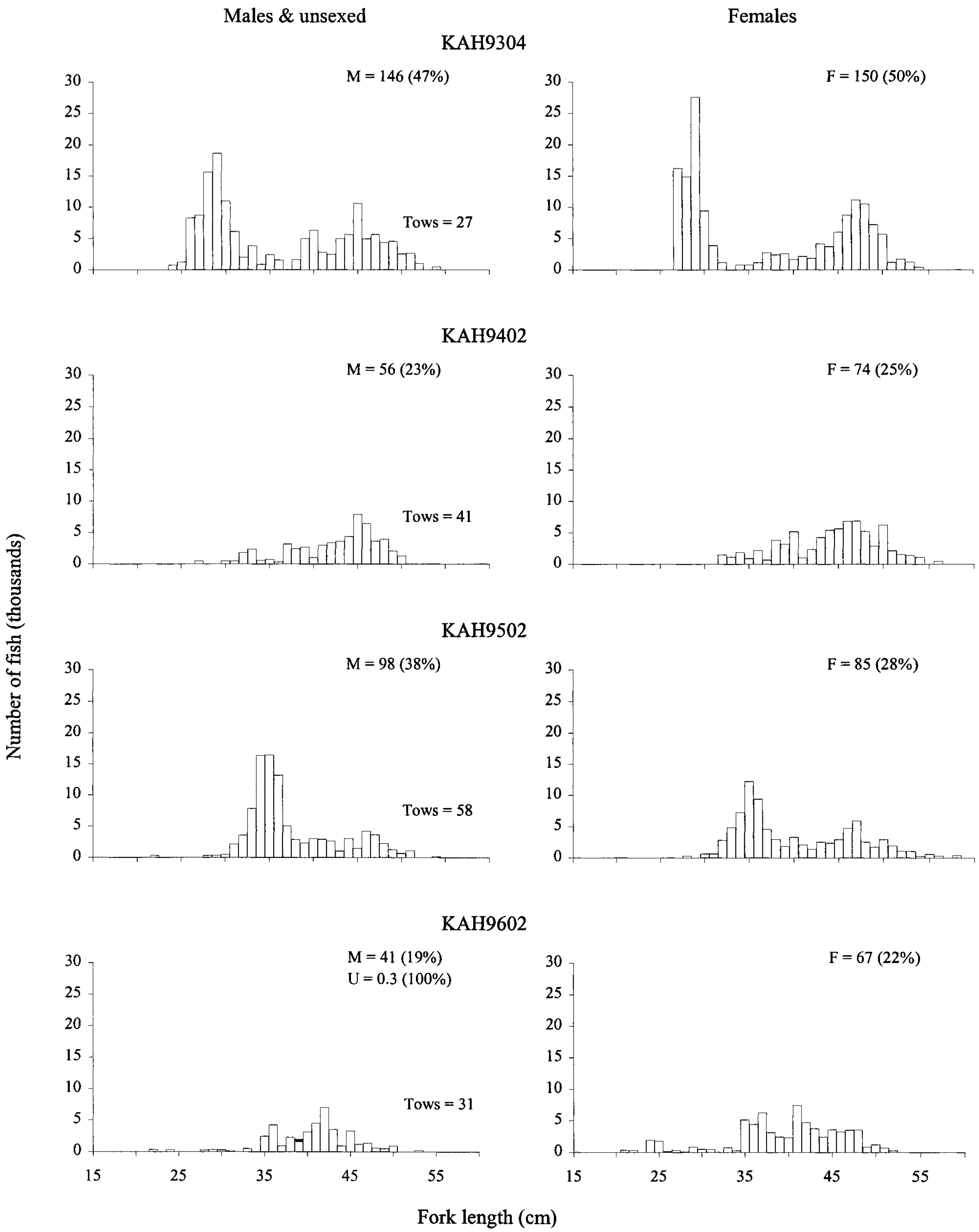

Figure 7n **: Trevally.**