Review of the inshore trawl survey series of the west coast South Island and Tasman and Golden Bays, 1992–97

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Abstract

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A series of four stratified random trawl surveys was carried out along the west coast of the South Island from Farewell Spit to the Haast River mouth and in Tasman and Golden Bays at depths from 20 to 400 m by RV *Kaharoa* in March-April, 1992–97. Time series trends in the estimated biomass, catch distribution, and population length frequency for the 16 major species are described.

Over the 1992–97 period no species has shown a significant decline in biomass, but dark ghost shark and school shark showed significant increases in biomass. The time series appears to be adequately monitoring the biomass of the four key target species (giant stargazer, red cod, red gurnard, and tarakihi) as well as the recruited biomass of jack mackerel (*Trachurus declivis*) and smooth skate, and is possibly useful for sub-adult rig and school shark. For most other species the adult biomass indices are too variable or too imprecise to be considered reliably monitored by the survey.

The surveys appear to be providing reliable indices of juvenile tarakihi, red cod, and hoki. A number of other species have variable indices of juveniles, but we are not currently able to determine whether these are indicative of year class strength.

It is recommended that the four key species be retained as target species and that surveys be carried out at least every two years to monitor the red cod and red gurnard stocks. It is also recommended that an ageing study be carried out to determine the biological parameters of each of the west coast stocks of the target species and the proportion at age from each of the surveys.

Introduction

Background

A time series of four trawl surveys was conducted along the west coast of the South Island from Farewell Spit to the Haast River mouth and in Tasman and Golden Bays during March-April in 1992, 1994, 1995, and 1997. Each of the surveys has been reported in standalone reports with little comparison of results (Drummond & Stevenson, 1995a, 1995b, 1996, Stevenson 1998). This report compares the estimated biomass, catch distribution, and population length frequency of the 29 major species from the four surveys.

Trawl surveys began after the introduction of the Quota Management System (QMS) in 1986 to provide data on relative biomass, population age, and length frequency to assess the sustainability of Total Allowable Commercial Catch (TACC) for certain key species. The survey area supports a number of important inshore fisheries and this series was initiated to estimate the relative abundance of species important to the inshore commercial fishery and vulnerable to bottom trawling. The main species that met these criteria, giant stargazer (*Kathetostoma giganteum*), red cod (*Pseudophycis bachus*), red gurnard (*Chelidonichthys kumu*), and tarakihi (*Nemadactylus macropterus*), were chosen as key target species for the series for optimisation of station allocation. In addition, TACCs for giant stargazer and red gurnard were increased when they were introduced into the Adaptive Management Programme (AMP) in 1991 and the surveys were seen as an appropriate technique to monitor any changes in abundance.

The survey was designed to cover a depth range of 20–400 m on the basis of the known depth distribution of the key species. The survey area included 3 strata in Tasman and Golden Bays and 16 along the west coast of the South Island from Cape Farewell (northern boundary) to Awarua Point (southern boundary). As a result of a pilot survey in 1990 (Drummond & Ryan 1992) the boundaries of the survey area were modified to exclude areas that historically had low catch rates (*see* Fenaughty *et al.* 1983, Drummond & Ryan 1992), amalgamating strata that had a high proportion of non-trawlable ground and moving the southern boundary north to the Haast River mouth. This reduced the number of strata on the west coast to 13. The results of the pilot survey are not included in this report because a different net with cut away lower wings and different rigging was used, making it not comparable with the subsequent surveys.

The series was also considered to be possibly useful for monitoring other inshore and middle depth species, including barracouta (*Thyrsites atun*), dark ghost shark (*Hydrolagus novaezelandiae*), rig (*Mustelus lenticulatus*), school shark (*Galeorhinus galeus*), and spiny dogfish (*Squalus acanthias*).

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 giant stargazer, red cod, red gurnard, and tarakihi in the inshore waters of the west coast of the South Island and Tasman and Golden Bays.
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.

The aim of this work was (i) to determine, for the major commercial species, trends in the relative abundance, distribution, length frequency distribution, reproductive condition, and other relevant biological parameters over the trawl survey time series, and (ii) to make recommendations on the benefits of undertaking future trawl surveys off the west coast of the South Island and in Tasman and Golden Bays.

West coast South Island fisheries

The west coast of the South Island has extensive shelf areas (especially north of Greymouth) suitable for trawling, which is the most common fishing method. Inshore fisheries are multi-species and are primarily based on flatfish (several species), red gurnard, red cod, giant stargazer, tarakihi, and blue warehou (*Seriolella brama*) (*see* Drummond & Ryan 1992). Other species taken as bycatch include arrow squid (*Nototodarus sloanii* and *N. gouldi*), dark ghost shark, ling, barracouta, jack mackerel (*Trachurus* spp.), spiny dogfish, rig, school shark, sea perch (*Helicolenus* spp.), rough skate (*Raja nasuta*), and smooth skate (*Raja innominata*).

Giant stargazer (STA 7) and red gurnard (GUR 7) are important inshore fisheries along the west coast of the South Island that have had TACC increases under the AMP. TACCs were increased because it was believed that stocks could provide larger sustainable yields (existing TACCs were over-caught for several years and fishers had problems avoiding them). For giant stargazer, the STA 7 TACC was increased to 702 t in 1992–93 but was still over-caught, peaking at 983 t in 1996–97. For red gurnard, the GUR 7 TACC was increased to 815 t in 1991–92, but was never fully caught and catches steadily declined from a high of 761 t in 1992–93 to 378 t in 1996–97. The TACC was reduced to the pre-AMP levels in 1997–98, but catches have continued to decline.

For red cod (RCO 7) the TACC of 3125 t has been exceeded in four of the last seven years, but the fishery is dependent on only one or two year classes and is heavily recruitment driven. For tarakihi (TAR 7), catches have fluctuated between 629 and 1013 t since 1990–91 against a TACC of 1087 t (Annala *et al.* 1999).

The 25 n. mile exclusion zone, which applies to vessels over 43 m length, restricts larger vessels from fishing the slope and shelf. Domestic vessels less than 43 m length therefore take most of the commercial catch within the survey area.

Hydrology and bathymetry of the west coast South Island

Surface currents along the west coast of the South Island are mainly subtropical in origin and are closely connected with currents off the east coast of Australia (Heath 1974). The Westland Current, which originates as a northward deflection of the Tasman Current off the Fiordland coast, carries this saline subtropical water along the west coast. A branch of the Westland Current turns into Cook Strait to form the D'Urville Current which provides the flow into Tasman and Golden Bays.

The continental shelf along the west coast is wide north of Cape Foulwind, gradually narrowing to about 30 n. mile wide at Greymouth. South of Greymouth the shelf is interrupted by the Hokitika and Cook Canyons, and is narrow and irregular (Figure 1).

Methods

Survey area and design

The survey area included Tasman and Golden Bays and the west coast of the South Island from Farewell Spit to the Haast River mouth (south of Greymouth) (*see* Figure 1). The surveys used a two-phase stratified random design (*after* Francis 1984). The two-phase methodology was applied separately to the west coast and the Tasman and Golden Bays areas because of the geographic separation of the two areas.

The same 16 strata were used for all four surveys with only minor adjustments to the depth contours based on bathymetric information from the surveys. For the two-phase methodology, red cod, red gurnard, giant stargazer, and tarakihi were designated as the target species. A total of 80 phase 1 stations were planned for each survey, with a minimum of 3 stations per stratum. The balance of 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 previous survey (for 1992, the catch rates from the pilot survey were used). Phase 2 station allocation was aimed at improving the precision of the biomass indices for the target species and was done after phase 1 had been completed. 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 program rand_stn v2.1 (*see* Vignaux 1994). Stations were required to be a minimum of 3 n. mile (5.6 km) apart.

The three depth ranges (20–100, 100–200, and 200–400 m) represent inshore, shelf edge, and continental slope respectively. 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 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 two-panel net used during the surveys was designed and constructed specifically for South Island inshore trawl surveys. The net was based on an 'Alfredo' design and fitted with an 74 mm (inside measurement) knotless codend.

Before the 1995 survey *Kaharoa* was equipped with new, heavier trawl doors based on the design of the old doors. For 1992 and 1994, doorspread was estimated using the method of Koyama (1974), but for 1995 and 1997 Scanmar sensors fitted to the new doors enabled doorspread to be measured directly. Gear trials in March 1995 provided comparisons between the performance of the old and new doors and more accurate estimates of doorspread using the old doors (*see* Drummond & Stevenson 1996, appendix 5a).

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 1992 and 1994 and by the Scanmar sensor in 1995 and 1997 and averaged over the tow. Sea surface temperature was recorded from a hull mounted sensor from 1992 to 1995 but failed to function in 1997 and a hand-held Checktemp 1 microprocessor thermometer was used instead. Bottom temperatures were recorded in 1995 and 1997, but not in 1992 or 1994 because of failure of the netsonde sensor.

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 identified to species level because of the difficulty of identifying species and the limited sorting time available between tows.

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, gonad stage, and otoliths were collected from a sample of up to 20 fish per tow for the target species. Additional biological data for blue warehou, school shark, rig, rough skate, smooth skate, and elephantfish (*Callorhinchus milii*) 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 and in 1992 giant stargazer were also tagged. Each fish was measured, sexed (if possible), tagged, and released within minutes of being removed from the codend.

Data analysis

Relative biomass indices and *c.v.*s were based on the area-swept method described by Francis (1981, 1989) using the Trawlsurvey Analysis Program (Vignaux 1994). Doorspread values for the 1992 and 1994 surveys were based on the doorspread:depth relationship calculated from the 1995 gear trials (*see* Drummond & Stevenson 1996), whereas values for 1995 and 1997 were measured directly. Only tows with acceptable performance (gear codes 1 and 2) were used for biomass indices. Strata areas were the same for all surveys and foul ground was included in strata areas.

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.

These were standard assumptions for the surveys (Stevenson & Hanchet 1999), were used for the original analyses, and have been retained for this analysis.

The *c.v.* associated with indices of biomass was calculated by the method of Vignaux (1994).

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. Where data were available from a survey the coefficients were calculated using the geometric mean functional relationship. For other species, coefficients were chosen from those available on the *trawl* database and a selection made to best match 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 greater than zero if P was less than 0.05.

The proportion of mature fish at specific gonad stages was determined by plotting all staged fish on a length frequency distribution and selecting a length at which at least 50% were mature.

Results

Stations surveyed and catches

The number of completed stations and station density for each survey are given in Table 1. From 1992 to 1995 the number of phase 2 stations depended on the time remaining after the completion of phase 1. In 1997, interim *c.v.*s were available and the number of phase 2 stations was reduced to only those necessary to meet the target *c.v.*s.

Mean catch per station increased from a low of 606 kg in 1992 to a high of 1047 kg in 1995, then decreased again to 694 kg per tow in 1997 (*see* Table 1).

Biomass and precision

Indices of biomass and *c.v.*s for the 16 major commercial teleost species and all species combined are given in Table 2a. Spiny dogfish was the most abundant species in all years. Red cod and barracouta were the only other species with biomass indices over 2000 t in every survey. Indices of biomass for tarakihi and giant stargazer remained fairly constant, fluctuating in the range of about 1000 to 1500 t. Hake (*Merluccius australis*) and hoki (*Macruronus novaezelandiae*) showed large increases in biomass in 1995.

For 1992 and 1994, the six most abundant species, in descending order, were spiny dogfish, arrow squid, red cod, barracouta, tarakihi, and giant stargazer. These species made up 59% in 1992 and 63% in 1994 of the total biomass of all species (*see* Table 2a). In 1995 the six most abundant species were spiny dogfish, hake, barracouta, hoki, arrow squid, and red cod (65% of total). For 1997, the six most abundant species were spiny dogfish, barracouta, red cod, dark ghost shark, giant stargazer, and school shark (44% of total).

Biomass indices for the west coast and Tasman and Golden Bays are given separately in Tables 2b and 2c. Dark ghost shark were caught only on the west coast. Red gurnard was the only species for which the total biomass was evenly divided between the two areas.

The ranges of the *c.v.*s for the target species were giant stargazer 12–17%, red cod 13–23%, red gurnard 13–19%, and tarakihi 10–14%. The mean *c.v.* for the top 16 species remained virtually unchanged across all years (21, 22, 20, and 22%) as did the *c.v.* for all species combined (9, 6, 6, and 6%). Non-target species with *c.v.*s less than 20% for all years were barracouta (13–19%), rig (10–18%), and spiny dogfish (7–15%). Other species with *c.v.*s of 30% or less each year were dark ghost shark, N.Z. jack mackerel (*T. declivis*), rough skate, and smooth skate.

Biomass trends

Changes in biomass indices are shown in Figures 2a–c. Only the biomass indices for dark ghost shark and school shark showed significant increases (P = 0.05 and 0.004 respectively). For dark ghost shark, the increase in biomass, especially in 1997, is mostly the result of a higher catch of smaller fish. This may be due to a change in catchability rather than an actual increase in abundance. No species showed a statistically significant decrease. The strongest non-significant trends were for the biomass indices for smooth skate (P = 0.10 downward), N.Z. jack mackerel (*T. declivis*) (P = 0.11 upward), and tarakihi (P = 0.16 downward). The reliability of these trends is limited by the small sample size of only four surveys.

Total biomass and recruited biomass are shown for 16 species in Figures 3a–c. Where total and recruited biomass are the same, 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 in Tasman and Golden Bays compared to the west coast for barracouta, blue warehou, giant stargazer, hoki, lemon sole, N.Z. sole (*Peltorhamphus novaezelandiae*), red gurnard, rig, sand flounder, school shark, silver warehou (*Seriolella punctata*), and tarakihi for all years. Pre-recruit biomass was a large proportion of total biomass in Tasman and Golden Bays for blue cod, hake, and red cod.

Biomass by year classes by area of nine species are shown in Figures 4a–c. Recruitment appears variable between years for a number of species. Only two surveys were in consecutive years, so we were unable to track most year classes between years from length frequency data alone. The youngest year classes for all species probably have low vulnerability to capture by the codend mesh size used.

Water temperature and catch rates

Surface temperatures were collected for all surveys and indicate that 1992 was cooler than other years by 2–3 °C (Figure 5a). Bottom temperatures were recorded only in 1995 and 1997 and are not shown.

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.

Barracouta

Barracouta were caught throughout the survey area with the highest catch rates in the 100–200 m depth range. They were caught at between 89 and 96% of all stations. Few adults were caught in Tasman and Golden Bays (Figure 6a). Despite moderate *c.v.*s (13–31%), the adult biomass indices varied two-fold between years and the survey is probably not monitoring adult abundance. Indices of pre-recruit barracouta (less than age 4) were obtained from both the west coast and Tasman and Golden Bays (Figure 6a). There were problems associated with tracking strong year classes using length frequency data because of variable growth rates, extra modes caused by fish spawning twice in one year (R. Hurst, NIWA Wellington, pers. comm.), and merging of modes after age 2. If these were to be used for monitoring abundance and estimating year class strength, otoliths would need to be collected and aged.

Blue warehou

Blue warehou were caught in Tasman and Golden Bays (small fish less than 30 cm fork length) and along the west coast mostly south of Cape Foulwind in depths less than 100 m. They were caught at 33 to 53% of all stations (Figure 6b). Biomass indices of adult blue warehou were highly variable between years and had high *c.v.*s. 0+ fish occurred in Tasman and Golden Bays in 1994 (13 cm), 1995 (15 cm), and 1997 (18 cm), and on the west coast in 1992 (15 cm). The 1+ year class was evident in Tasman and Golden Bays in 1994 and 1997 and on the west coast in 1997 with modal peaks at 24 cm (Figure 7a, b). However, indices by year class from both areas were low, and generally had high *c.v.*s (usually greater than 30%) (Table 3). Because of the poor precision in biomass estimates the surveys are probably not suitable to monitor adult or pre-recruit biomass.

Dark ghost shark

Dark ghost shark were confined to the west coast, mostly at depths between 200 and 400 m north of Greymouth, and were caught at between 30% and 44% of west coast stations (Figure 6c). There were consistent length frequency modes at about 55 cm for males and 61 cm for females from 1994 to 1997. In 1997, there was a large increase in smaller fish between 35 and 50 cm (Figure 7c). Despite moderate *c.v.*s (14–24%) the adult biomass indices varied five-fold between years and the survey is probably not monitoring the adult abundance.

Giant stargazer

Giant stargazer were caught throughout the survey area with the highest catch rates at 100–200 m on the continental slope south of Cape Foulwind (Figure 6d). They were caught at between 61 and 79% of all stations. Few giant stargazer were caught in Tasman and Golden Bays and almost all of these were less than 50 cm total length (Figure 7d). Biomass indices have been consistent between surveys and the *c.v.*s have been low (12–17%). The size structure of the recruited part of the population has been similar between years and probably comprises a number of age classes. The proportion of smaller fish (less than 35 cm) was greater in the 1995 and 1997 surveys and this indicates some variability in year class strength. No ageing has been carried out on stargazer from west coast South Island. The size distribution is superficially similar to that from the Chatham Rise (Paul *et al.* 1999) and the Southland area (Sutton 1999). Fish from the latter area were aged and found to be 5 to 15 years old (Sutton 1999). Sutton (1999) found evidence for moderate variation in year class strength from the east coast South Island but not from the Southland area.

Commercial catch and effort data for STA 7 were examined by Vignaux (1997). Commercial catches from 1992 to 1997 mirrored the CPUE indices with an initial decline followed by a gradual increase. In contrast, the west coast recruited trawl survey estimates showed no trend over a similar period. The reason for the inconsistency between the indices is not known, but could be related to spatio-temporal patterns in abundance.

If the data are to be fitted in a population model an ageing study should be carried out using otoliths collected during the series. The aims of the study would be to determine biological parameters such as growth, maximum age (and hence M), and trawl survey selectivity, and at least qualitatively, recruitment variability. If recruitment is found to vary considerably between years, then all otoliths should be aged so that year class strength can be estimated in the model.

The age structure and recruitment variability of this stock is unknown. However, assuming low to moderate recruitment variability, and a relatively large number of age classes (*ca* 15) in the recruited population, it is recommended that trawl surveys be carried out every 2–3 years to monitor this stock.

Hake

Pre-recruit hake were caught throughout the survey area, but were far more abundant along the west coast south of Cape Foulwind at depths less than 200 m (Figure 6e). The highest catch rates occurred south of Greymouth in 1995 giving a high biomass estimate for that year. Hake were caught at between 40 and 81% of all stations. Few hake were caught in Tasman and Golden Bays in 1992 and 1994, but in 1995 there was a mode in the length frequency distribution at 11 cm for 0+ fish and in 1997 at 36 cm for 1+ fish. Along the west coast, the length frequency distributions were dominated by a strong 1+ age group in 1995 with a mode at about 35 cm. A weaker 1+ mode was apparent at 28 cm in 1997 (Figure 7e). Given the magnitude of the differences between years it would be surprising if the surveys were not monitoring year class strength, but, at present there are no modelled estimates of year class strength from this stock.

Hoki

Pre-recruit hoki were most common along the west coast south of Greymouth at depths greater than 100 m in all years (Figure 6f). The highest catch rates were in 1995 when the highest biomass estimate occurred. Hoki were caught at between 47 and 73% of all stations. Indices of 0+ hoki abundance on the west coast varied 10-fold between years and had reasonably low *c.v.*s (19–30%). The 1994 year class was the strongest observed, being 10 times higher than the 1991 and 1993 year classes and five times higher than the 1996 year class. However, recent modelling results suggest that the 1994 year class is about twice as strong as the 1991 and 1993 year classes (Annala *et al.* 1999). The reason for this discrepancy is unclear. Relatively small numbers of 0+ hoki are caught in Tasman and Golden Bays and they are smaller than those caught on the west coast. It is unclear whether the series is reliably monitoring year class strengths.

Jack mackerel (*Trachurus declivis*)

This species of jack mackerel was caught mainly along the west coast in depths of 100–200 m (Figure 6g). Indices of *T. declivis* abundance were very consistent on the west coast with moderate *c.v.*s (20–27%), and the adult size distribution was also consistent between years (Figure 7g). There was some evidence of recruitment variability on the west coast, but the *c.v.*s for pre-recruits were high, the numbers were low, and the year classes could not be tracked through the population. Biomass of pre-recruits in Tasman and Golden Bays was at a similarly low level for three of the surveys, but in 1997 there was a 100-fold increase in recruitment of 1+ fish to this area. The reason for this increase and the relationship of Tasman and Golden Bays fish to the west coast fish is unknown.

Red cod

Red cod were caught throughout the survey area with the highest catch rates usually from south of Cape Foulwind at depths less than 200 m (Figure 7s). Red cod were caught at between 79 and 94% of all stations. Total biomass estimates were consistent between surveys, and the *c.v.*s were low to moderate (13–23%). In most years, most of the biomass was on the west coast, but, in 1997 almost half the biomass came from Tasman and Golden Bays. Although the fish have not been aged, the age structure of the population can be inferred by following peaks in the length frequency data (*see* Figure 7s). The west coast population was dominated by 1+ fish in most years except 1994 when there were more 2+ fish. The proportion of 3+ and older fish (greater than *ca* 45 cm) has tended to be low but variable between years. Estimates of 1+ fish were moderately precise (*c.v.*s 18–26%) and have varied only two-fold between years (*see* Table 3) suggesting low to moderate recruitment variability over this time period. In contrast, the biomass in Tasman and Golden Bays was highly variable. In most years there were low numbers of red cod, but in 1997 there was a large recruitment of 1+ fish to this area. The reason for this increase and the relationship of Tasman and Golden Bays fish to west coast fish is unknown. Because of the lack of continuity between surveys, the small number of ages, and the merging of modes after age 1, it was not possible to track year classes through the population. Ageing of otoliths from all four surveys should help in this regard. Red cod on the east coast South Island appear to show higher recruitment variability, with five-fold changes in pre-recruit biomass (*see* Annala *et al.* 1999).

Because of the few age classes, and hence high turnover of the population, and probable moderate to high recruitment variability, trawl surveys would need to be carried out at least every 2 years to monitor this stock.

Red gurnard

Red gurnard were caught at depths less than 100 m throughout the survey area, with the highest catch rates in Tasman and Golden Bays and along the west coast south of Cape Foulwind (Figure 6i). They were caught at all stations in Tasman and Golden Bays and at 32 to 48% of west coast stations. Total biomass indices were consistent between 1992 and 1995, before a 20% (non-significant) drop to 1997 (*see* Table 2). The *c.v.*s for all surveys have been low (13–19%). The size and age structure differs between Tasman and Golden Bays and the west coast (*see* Figure 7i). In Tasman and Golden Bays the fish are mainly 20–30 cm (comprising mainly 1+ fish, with low numbers of older fish in some years).

In contrast, the 20–30 cm fish are in low numbers on the west coast which is dominated by older fish (probably aged 2 to 6) (*see* Sutton 1997). This suggests that Tasman and Golden Bays may act as a nursery ground for the west coast fish. However, there is no evidence for movement of year classes from one area to another because indices of 1+ fish were similar for 1992 to 1995 and the survey with the highest number of 1+ fish was 1997 (*see* Table 3a). The length frequency data were examined for latitudinal trends along the west coast, but there was no evidence of a gradation by size from north to south. Although movement of fish from Tasman and Golden Bays to the west coast is the most likely hypothesis, the two areas could instead form separate populations. Hanchet *et al.* (unpublished results) found differences in the size and age structure of gurnard around the North Island. Fish from the west and north of the North Island were dominated by 20–30 cm long (mainly 2 year old) fish (similar to that found in Tasman and Golden Bays), whereas fish from the east coast North Island were 25–40 cm long (similar to that found on the west coast).

Because of the different age structures, the indices should be considered separately for each area. Biomass indices of 1+ fish from Tasman and Golden Bays varied four-fold between years and had moderate *c.v.*s of 16–29%. Biomass indices for red gurnard from the west coast have been less variable, ranging from 400 t in 1995 to 240 t in 1997. The 1997 estimate represented a decline of 30% from the average of the three previous surveys.

Commercial catch and effort data for GUR 7 were examined by Vignaux (1997). Gurnard were mainly caught in statistical areas 34 and 35 (Kahurangi Point to Abut Head), usually as bycatch of the target flatfish fishery. Standardised CPUE for gurnard in this fishery showed a steady decline of 50% between 1992 and 1996 (*see* Table 5). This decline is consistent with the trawl survey west coast recruited indices which showed a non-significant decline of about 30% from 1992 to 1997, and with the decline in catch since 1992–93 (Annala *et al.* 1999).

Sutton (1997) aged gurnard for the 1992 and 1994 surveys. If the data are to be fitted in a population model, it is recommended that proportion at age should be determined from each survey to allow estimation of year class strength within the model. This may also help to determine the relationship between fish from the two areas.

Because of the low to moderate recruitment variability and the relatively low number of age classes in the population (*ca* 6), it is recommended that trawl surveys should be carried out at least every 2 years to monitor this stock.

Rig

Rig were confined to the inner continental shelf in depths less than 100 m and were caught at 58 to 70% of all stations (Figure 6j). Variability in date of birth and length at age (Francis & Francis 1992) make it difficult to separate year classes in the length frequency distributions, but fish less than 40 cm are probably about 3 months old (Figure 7j). Large females (over 100 cm) were proportionally more abundant in Tasman and Golden Bays than on the west coast, but the proportion of large males was greater on the west coast. Sex ratios were dominated by males in both areas. The biomass indices were consistent between years, the *c.v.*s were reasonably low (11–21%), and the size distribution was consistent between years. It is likely that 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 undersampled. The surveys, therefore, are unlikely to be useful for monitoring adult rig abundance, but may be useful for monitoring pre-recruits.

Rough skate

Rough skate were caught throughout the survey area, with the highest catch rates being along the inner continental shelf at depths less than 200 m (Figure 6k). They were caught at 40 and 56% of all stations. Rough skate were measured only in 1997 and, therefore, length frequencies are not shown. Despite moderate *c.v.*s (19–34%) on the west coast, adult biomass indices varied two-fold between years and the survey is probably not monitoring abundance.

School shark

School shark were caught throughout the survey area, the highest catch rates being north of Cape Foulwind in depths of 100–200 m (Figure 6l). Length frequency distributions for Tasman and Golden Bays are polymodal and are mainly for immature fish less than 90 cm total length (Figure 7k). For the west coast, a much wider size range of fish was caught and the length frequency distributions are also polymodal, especially for fish shorter than 90 cm. Francis & Mulligan (1998) found considerable overlap in length at age for school shark aged from this series and, therefore, year class biomass indices were not calculated. There appeared to be a strong 0+ year class in 1992 which could be followed through the length frequency distributions for the following surveys to a modal peak at about 65 cm in 1994 and 75 cm in 1995 (and possibly 95 cm in 1997). The biomass indices were consistent between years, but the *c.v.*s were sometimes high (23–45%). It is likely that the larger fish in the population are under-represented when sampled with the bottom trawl gear. The surveys, therefore, are unlikely to be useful for monitoring adult school shark abundance, but may be useful for monitoring pre-recruits.

Silver warehou

Silver warehou were caught throughout the survey area at all depths, with the highest catch rates from Tasman Bay (Figure 6m). They were caught at 41 to 82% of all stations. The size distribution was very similar between the two areas, and was dominated by 0+ fish (15–25 cm) in each survey (Figure 7l). Biomass indices were highest in 1992 and 1997, but it is unknown if these reflect strong year classes because few older silver warehou were caught in any year. Biomass indices by age class generally had high *c.v.*s (17–65%), so the surveys are probably not useful for monitoring abundance.

Smooth skate

Smooth skate were caught along the west coast at all depths, with the highest catch rates from south of Greymouth, but were rarely caught in Tasman and Golden Bays (Figure 6n). They were caught at 44 to 55% of west coast stations. Smooth skate were measured only in 1997 and, therefore, length frequency distributions are not shown. Smooth skate had both consistent biomass estimates and reasonable *c.v.*s (18–27%). Its depth range is consistent with the range covered by the survey (Francis 1997), and its distribution showed no strong spatial pattern between years. The surveys, therefore, appear useful for monitoring smooth skate abundance

Spiny dogfish

Spiny dogfish were caught throughout the survey area, the highest catch rates being from south of Greymouth in depths of 100–200 m (Figure 6o). They were caught at 83 to 96% of all stations. Spiny dogfish were measured only in 1997 and, therefore, length frequency distributions are not shown. Despite moderate *c.v.*s (7–27%) on the west coast, the biomass indices varied two-fold between years and the survey is probably not monitoring abundance.

Tarakihi

Tarakihi were caught throughout the survey area, with the highest catch rates being from south of Greymouth at depths greater than 100 m and in Tasman Bay (Figure 7ac). They were caught at 78 and 86% of all stations. Tarakihi are summer-autumn serial spawners and a spawning ground has been identified on the west coast South Island near Jackson Bay (*see* Annala *et al.* 1999). It has been suggested that Tasman and Golden Bays are the nursery grounds for these fish (Annala 1987). It appears that the main part of the TAR 7 stock is adequately covered by the survey.

Biomass estimates were consistent between 1992 and 1995, before a non-significant 20% drop to 1997. The *c.v.*s for all surveys have been low (10–14%) (*see* Table 2a). The size and age structure differs between Tasman and Golden Bays and the west coast (*see* Figure 6w). In Tasman and Golden Bays most fish were less than 25 cm FL and comprised mainly 1+ (10–15 cm) and 2+ (17–22 cm) fish. On the west coast there was a higher proportion of larger fish (greater than 25 cm FL). Although the fish have not been aged, the age structure of the population can be inferred by following peaks in the length frequency data. A strong year class of 2 year old fish (15–20 cm) was caught on the west coast in 1992, and was seen in subsequent surveys with modes at 27 cm in 1994, 31 cm in 1995, and 33–35 cm in 1997. The larger adult mode at about 35 cm in males and 37 cm in females can also be tracked through the survey series. The population appears to comprise a number of age classes which is consistent with the population age structure of tarakihi elsewhere (*see* Annala 1987)

The survey also appears to be monitoring pre-recruit tarakihi in Tasman and Golden Bays, although the *c.v.*s are high (all greater than 35%) (*see* Table 3c). The highest estimate of 2+ fish in Tasman and Golden Bays was in 1992 (the 1990 year class). This was the strongest year class visible in the west coast population. Although 2+ fish were caught on the west coast in 1992, the numbers were small compared to those found in Tasman and Golden Bays, which supports the suggestion that the latter may act as a nursery ground for west coast tarakihi (Annala 1987). Further evidence for this comes from the gradation in size of tarakihi from north to south along the west coast. In 1994 and 1997 (years when all juvenile fish ages were present) 1+, 2+, and 3+ fish were found in Tasman and Golden Bays, 2+ and 3+ fish (and older) were found north of Cape Foulwind, and only 2+ fish and older were found south of Cape Foulwind (*see* Figure 8). However, in 1992, when a strong year class was present, some 2+ fish were caught throughout the survey area. The length data provide evidence of moderate (three-fold) recruitment variability, although this is poorly estimated.

If the data are to be fitted in a population model it is recommended that an ageing study be carried out 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.

Because of the low to moderate recruitment variability, and the relatively low number of age classes in the population (*ca* 6), it is recommended that trawl surveys should be carried out at least every 2 years to monitor this stock.

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 giant stargazer gonads were mainly in the maturing or ripening phase with 2–8% running ripe or spent. Development of female gonads was similar, except in 1992 when there was a higher proportion of spent fish than in other years. Development is consistent with giant stargazer spawning in winter (*see* Annala *et al.* 1999).

There was considerable variation in red cod male gonad development between surveys. Although most males were in the resting, developing, or ripening stages, in 1994 and 1997, 25% were running ripe and in 1997 13% were spent. Female gonad development was more consistent, with most fish with resting gonads, 11–26% developing, 3–10% ripening, and 1–6% spent. Red cod are thought to spawn in spring (*see* Annala *et al.* 1999) and female development appears to fit this assumption.

Red gurnard male gonads were mostly resting or developing with a few fish in later stages of development. Females showed more variation in gonad development with a much higher percentage of fish running ripe or spent in 1994 and 1995. Gurnard have a prolonged spawning period with a peak in early summer and ripe adults may be found throughout the year (*see* Annala *et al.* 1999).

Tarakihi male gonads were mostly ripening or running ripe (51–68%) with 7–16% spent. Female development was not as advanced, with most being in the resting or developing stage. This is consistent with tarakihi spawning in autumn (Annala 1987) although there was a high proportion of spent fish in 1992.

Conclusions and Recommendations

- Stargazer – The survey appears to cover most of the range of the STA 7 stock, and the biomass indices are consistent between years and precise. Although no ageing study has been carried out, it appears that recruitment is low to moderate and the population probably consists of a relatively large (*ca* 15) number of age classes. It is recommended that trawl surveys need to be carried out every 2–3 years to monitor this stock.

- Red cod – The survey appears to cover most of the range of the RCO 7 stock, and apart from the strong recruitment of 1+ fish to Tasman and Golden Bays in 1997, there is no strong evidence of spatial variation between years. The survey is monitoring both pre-recruit (1+) and recruited biomass with moderate *c.v.*s. The fish have not been aged, but from the length frequency data it appears there are only a few age classes in the population. Because of the few age classes, and hence high turnover of the population, and probably moderate to high recruitment variability, trawl surveys would need to be carried out at least every 2 years to monitor this stock.

- Red gurnard – The survey appears to cover most of the range of the GUR 7 stock and there is no evidence of spatial variation between years. The surveys appear to be monitoring both pre-recruit (Tasman and Golden Bays) and recruited (west coast) parts of the stock, though movement of fish between the two areas has yet to be confirmed. The moderate variability in the pre-recruit indices, and the absence of strong year classes found by Sutton (1997), indicate low to moderate recruitment variability. Because of this, and the relatively low number of age classes in the population (*ca* 6), it is recommended that trawl surveys should be carried out at least every 2 years to monitor this stock.

- Tarakihi – The survey appears to cover most of the range of the TAR 7 stock, and the biomass indices are consistent between years and precise. Although no ageing study has been carried out, it appears that recruitment variability is moderate and that the population consists of a number of age classes (*see also* Annala *et al.* 1987). It is therefore recommended that trawl surveys need to be carried out every 2–3 years to monitor this stock.

- The survey appears to be useful for monitoring recruited biomass of jack mackerel (*T. declivis*), smooth skate, and leatherjacket, and possibly useful for sub-adult rig and school shark. For most other species the adult biomass indices are too variable or too imprecise to consider that they are being reliably monitored by the surveys.

- The survey also catches large numbers of pre-recruits from a wide range of commercial species, but it is difficult to determine the reliability of the indices. The surveys currently appear to be providing reliable indices for juvenile tarakihi, red cod, and hoki. A number of other species including stargazer, gurnard, blue and silver warehou, jack mackerel (particularly *T. declivis*), barracouta, hake, and ling all have variable indices of juveniles, but at this stage we are unable to determine whether these are indicative of year class strength. Furthermore, stock relationships between Tasman and Golden Bays and the west coast are not known.

- The frequency of the surveys depends on the target species which require monitoring and on the strategies used to manage them. The current survey appears to reliably monitor the four key target species (giant stargazer, red gurnard, red cod, and tarakihi) and it is recommended that these species be retained as target species. Assuming that the surveys will continue to focus on the four key target species, and that the current constant catch policy approach will continue, then the biology of the species becomes important. Giant stargazer and tarakihi appear to have low to moderate recruitment variability and several age classes in the commercial fishery, and could be monitored by carrying out surveys every 2–3 years. Monitoring of red cod and red gurnard, which have fewer adult age classes, would require a frequency of at least every 2 years.

- Otoliths collected from the four target species should be routinely 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 age structures determined. From the length frequency data, there is evidence of moderate recruitment variability for red cod, red gurnard, and tarakihi. It is therefore, recommended that an ageing study be carried out with two objectives: to determine biological parameters for each of the west coast stocks, and to determine proportion at age from each of the surveys so that year class strength can be estimated.

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Table 1 : **Number of stations, total catch, and mean catch rate per tow, 1992–97**

	KAH9204	KAH9404	KAH9504	KAH9701
	22/3–28/4	19/3–20/4	22/3–24/4	21/3–13/4
Phase 1 stations	79	78	80	80
Phase 2 stations	34	38	22	8
Total stations	113	116	102	88
Total catch (t)	68.5	86.2	106.8	61.1
Mean catch rate per tow (kg.km^{-2})	1 203	1 500	2 300	1 619

Table 2 : **Estimated biomass (t) and coefficient of variation (*c.v.* %) for the 16 major commercial species 1992–97**
a **: All areas combined**

	KAH9204		KAH9404		KAH9504		KAH9701	
	Biomass	*c.v.* (%)	Biomass	*c.v.* (%)	Biomass	*c.v.* (%)	Biomass	*c.v.* (%)
Barracouta	2 478	14	5 298	16	4 480	13	2 993	19
Blue warehou	123	40	80	22	115	29	842	31
Dark ghost shark	375	20	722	14	767	24	1 591	21
Giant stargazer	1 302	12	1 350	17	1 551	16	1 450	15
Hake	391	25	99	31	5 244	27	1 019	46
Hoki	405	17	826	49	3 616	21	1 100	25
Jack mackerel (*Trachurus declivis*)	92	24	99	26	106	20	162	19
Red cod	2 719	13	3 169	18	3 123	15	2 546	23
Red gurnard	573	16	559	15	584	19	471	13
Rig	288	14	380	10	490	10	308	18
Rough skate	173	27	196	23	251	22	185	30
School shark	933	22	1 151	41	1 204	35	1 432	25
Silver warehou	292	38	66	35	38	20	204	20
Smooth skate	339	19	341	18	315	20	302	26
Spiny dogfish	3 919	15	7 145	7	8 370	10	5 275	13
Tarakihi	1 409	14	1 394	13	1 389	10	1 087	12
All species combined	25 234	9	31 078	6	43 626	6	34 429	6
		21	1430	22	1978	20	1310	22

Table 2b: **West coast**

	KAH9204		KAH9404		KAH9504		KAH9701	
	Biomass	*c.v.* (%)	Biomass	*c.v.* (%)	Biomass	*c.v.* (%)	Biomass	*c.v.* (%)
Barracouta	2 178	16	4 106	18	4 125	13	2 530	22
Blue warehou	113	43	63	27	105	32	817	31
Dark ghost shark	375	20	722	14	767	24	1 591	21
Giant stargazer	1 291	12	1 344	17	1 541	16	1 433	15
Hake	385	26	99	31	5 240	27	1 004	47
Hoki	395	17	825	49	3 604	21	1 100	25
Jack mackerel (*Trachurus declivis*)	92	24	93	27	106	20	110	22
Red cod	2 583	13	2 959	19	2 858	16	1 456	15
Red gurnard	321	20	285	25	399	28	237	22
Rig	217	16	288	11	384	13	213	21
Rough skate	110	19	172	25	206	23	165	34
School shark	878	23	1 058	45	945	42	1 385	26
Silver warehou	270	40	39	40	21	19	127	27
Smooth skate	325	19	341	18	315	20	294	27
Spiny dogfish	3 390	17	6 656	7	7 662	11	5 080	13
Tarakihi	1 296	13	1 231	13	1 288	11	865	12

Table 2c: **Tasman & Golden Bays**

	KAH9204		KAH9404		KAH9504		KAH9701	
	Biomass	*c.v.* (%)	Biomass	*c.v.* (%)	Biomass	*c.v.* (%)	Biomass	*c.v.* (%)
Barracouta	472	28	1 192	33	355	32	463	15
Blue warehou	10	80	17	31	10	37	25	33
Dark ghost shark	0		0		0		0	
Giant stargazer	11	43	6	48	10	63	18	26
Hake	6	58	1	75	5	32	15	50
Hoki	10	96	1	93	13	44	*	79
Jack mackerel (*Trachurus declivis*)	*	100	6	69	3	100	52	38
Red cod	135	84	210	37	265	36	1 090	50
Red gurnard	252	24	274	16	185	14	233	12
Rig	71	26	92	25	105	16	95	34
Rough skate	63	68	24	48	45	64	20	28
School shark	56	26	93	32	259	52	47	41
Silver warehou	181	59	27	62	17	38	77	29
Smooth skate	14	70	0		0		8	100
Spiny dogfish	529	30	489	22	707	31	195	20
Tarakihi	113	86	163	58	101	34	222	34

* Less than 0.5 t

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

	Size range (cm)	Age	KAH9204 Biomass	KAH9204 *c.v.* (%)	KAH9404 Biomass	KAH9404 *c.v.* (%)	KAH9504 Biomass	KAH9504 *c.v.* (%)	KAH9701 Biomass	KAH9701 *c.v.* (%)
Barracouta	10–28	0+	87	26	36	35	16	19	197	19
	25–37	1+	174	17	944	38	190	20	129	27
	47–59	2+	65	31	536	16	310	18	76	37
Blue warehou	10–20	0+	23	35	4	31	13	33	9	27
	19–27	1+	8	86	9	36	3	37	22	30
Hake	8–27	0+	0		6	30	23	28	14	42
	22–46	1+	0		71	39	5 124	27	999	47
Hoki	8–34	0+	216	19	243	21	2 656	24	564	30
	33–51	1+	119	34	359	78	504	65	182	36
Jack mackerel										
(*T. declivis*)	10–19	1+	*	100	1	39	*	50	49	36
	16–25	2+	1	65	3	37	3	28	2	54
Red cod										
Males	5–22	0+	2	23	*	35	6	23	11	26
	23–43	1+	626	19	248	22	531	18	759	27
Females	5–22	0+	9	29	1	36	13	18	13	23
	23–49	1+	706	18	166	27	524	20	792	31
Red gurnard	19–29	1+	99	25	34	22	67	19	147	15
Silver warehou	12–26	1+	251	43	42	45	34	21	126	25
	24–35	2+	18	52	19	62	4	58	43	37
Tarakihi	9–15	1+	5	82	5	28	11	20	18	27
	16–22	2+	127	73	27	34	75	39	48	34
	21–26	3+	9	30	139	52	29	27	187	34

* Less than 0.5 t

Table 3b : **West coast**

	Size range (cm)	Age	KAH9204 Biomass	KAH9204 *c.v.* (%)	KAH9404 Biomass	KAH9404 *c.v.* (%)	KAH9504 Biomass	KAH9504 *c.v.* (%)	KAH9701 Biomass	KAH9701 *c.v.* (%)
Barracouta	10–28	0+	46	45	3	56	3	50	57	54
	35–49	1+	156	19	171	30	151	24	36	29
	47–59	2+	63	31	514	16	306	19	71	39
	33–49	1+	*	100	13	87	0		0	
Blue warehou	10–20	0+	21	39	*	49	5	51	1	75
	19–27	1+	1	33	*	100	2	54	6	37
Hake	8–27	0+	10	30	6	30	23	29	14	42
	22–46	1+	14	58	71	39	5 121	27	985	48
Hoki	8–34	0+	205	19	243	21	2 643	24	563	30
	33–51	1+	119	34	359	78	504	65	182	36
Jack mackerel (*T. declivis*)	10–19	1+	0		*	52	*	50	1	52
	16–25	2+	1	71	3	38	3.17	28	0.4	48
Red cod Males	5–24	0+	2	25	*	32	6	25	9	27
	23–40	1+	603	20	241	22	720	19	473	24
Females	5–28	0+	9	31	1	49	12	17	10	26
	23–45	1+	636	18	150	30	540	20	275	24
Red gurnard	19–29	1+	17	37	1	90	3	43	17	57
Silver warehou	12–26	1+	229	46	16	52	17	17	49	44
	24–35	2+	18	52	18	66	4	56	43	37
Tarakihi	9–15	1+	*	27	*	100	*	44	*	100
	16–21	2+	20	25	1	83	*	62	1	49
	22–26	3+	7	28	30	58	8	30	32	58

* Less than 0.5 t

Table 3c: **Tasman and Golden Bays**

	Size range (cm)	Age	KAH9204		KAH9404		KAH9504		KAH9701	
			Biomass	*c.v.* (%)	Biomass	*c.v.* (%)	Biomass	*c.v.* (%)	Biomass	*c.v.* (%)
Barracouta	10–28	0+	41	20	33	37	12	20	140	15
	27–48	1+	18	24	767	46	39	28	93	36
	47–59	2+	1	72	21	39	4	70	5	26
Blue warehou	10–20	0+	3	46	3	32	8	42	8	29
	19–27	1+	7	95	9	36	2	51	16	38
Hake	8–27	0+	10	30	0		*	40	0	59
	22–46	1+	14	58	*	64	3	40	14	51
Hoki	8–34	0+	10	96	1	93	13	44	0	79
	33–51	1+	–		–		–		–	
Jack mackerel										
(*T. declivis*)	10–19	1+	*	100	*	59.2	0		49	37
	16–25	2+	*	100	*	100	0		1	70
Red cod										
Males	5–24	0+	*	45	*	81	1	51	2	83
	23–43	1+	29	88	7	44	33	47	272	62
Females	5–28	0+	1	56	*	27	5	31	2	42
	23–49	1+	88	86	16	40	89	36	488	48
Red gurnard	19–29	1+	82	29	33	23	64	20	130	16
Silver warehou	12–26	1+	181	59	26	65	17	38	77	29
	24–35	2+	0		1	68	0		0	
Tarakihi	9–15	1+	4	88	5	28	11	20	18	27
	16–22	2+	106	86	26	36	75	39	45	36
	21–26	3+	2	85	108	65	12	42	151	39

– No catch

* Less than 0.5 t

Table 4: **Percentage of fish at various gonad stages. Only fish above a known size at maturity were selected (giant stargazer > 45 cm; red cod > 50 cm; red gurnard > 27 cm; and tarakihi > 33 cm)**

	Males						Females					
	Gonad stage						Gonad stage					
	1	2	3	4	5	*n*	1	2	3	4	5	*n*
Giant stargazer												
KAH9204	14	63	20	0	2	250	17	61	6	0	17	357
KAH9404	10	52	35	3	1	303	18	66	12	0	3	380
KAH9504	9	54	29	5	2	242	22	73	4	0	2	320
KAH9701	7	50	37	2	3	228	14	74	12	0	0	238
Red cod												
KAH9204	9	39	51	1	0	120	63	26	10	0	1	200
KAH9404	20	24	30	24	2	184	76	11	6	0	6	317
KAH9504	28	36	32	4	0	90	79	16	5	0	1	254
KAH9701	23	15	25	25	13	80	72	24	3	0	1	181
Red gurnard												
KAH9204	60	39	1	0	0	102	44	42	9	1	5	192
KAH9404	26	62	6	1	4	152	14	14	22	7	42	382
KAH9504	13	75	4	0	7	378	7	44	18	5	26	272
KAH9701	24	42	22	2	10	333	31	47	10	2	10	239
Tarakihi												
KAH9204	12	21	39	13	16	292	21	40	4	3	32	609
KAH9404	9	15	20	43	12	233	13	69	8	4	6	733
KAH9504	8	18	31	37	7	210	17	72	4	1	5	639
KAH9701	17	18	13	43	10	135	15	77	6	2	1	561

Gonad stages used were: 1, 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.

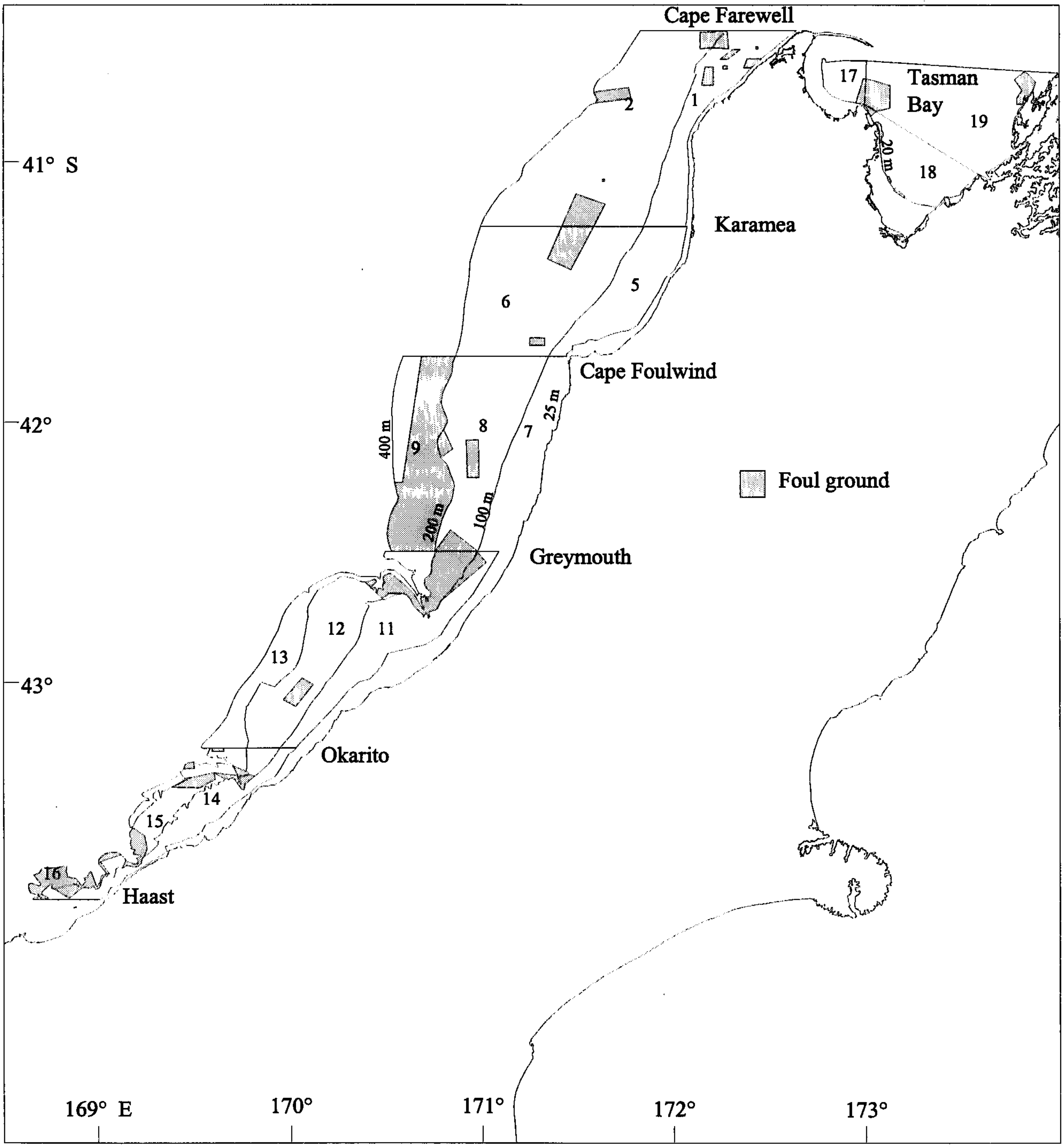


***Figure 1*: Survey area with stratum boundaries and numbers showing untrawlable (foul) ground.**

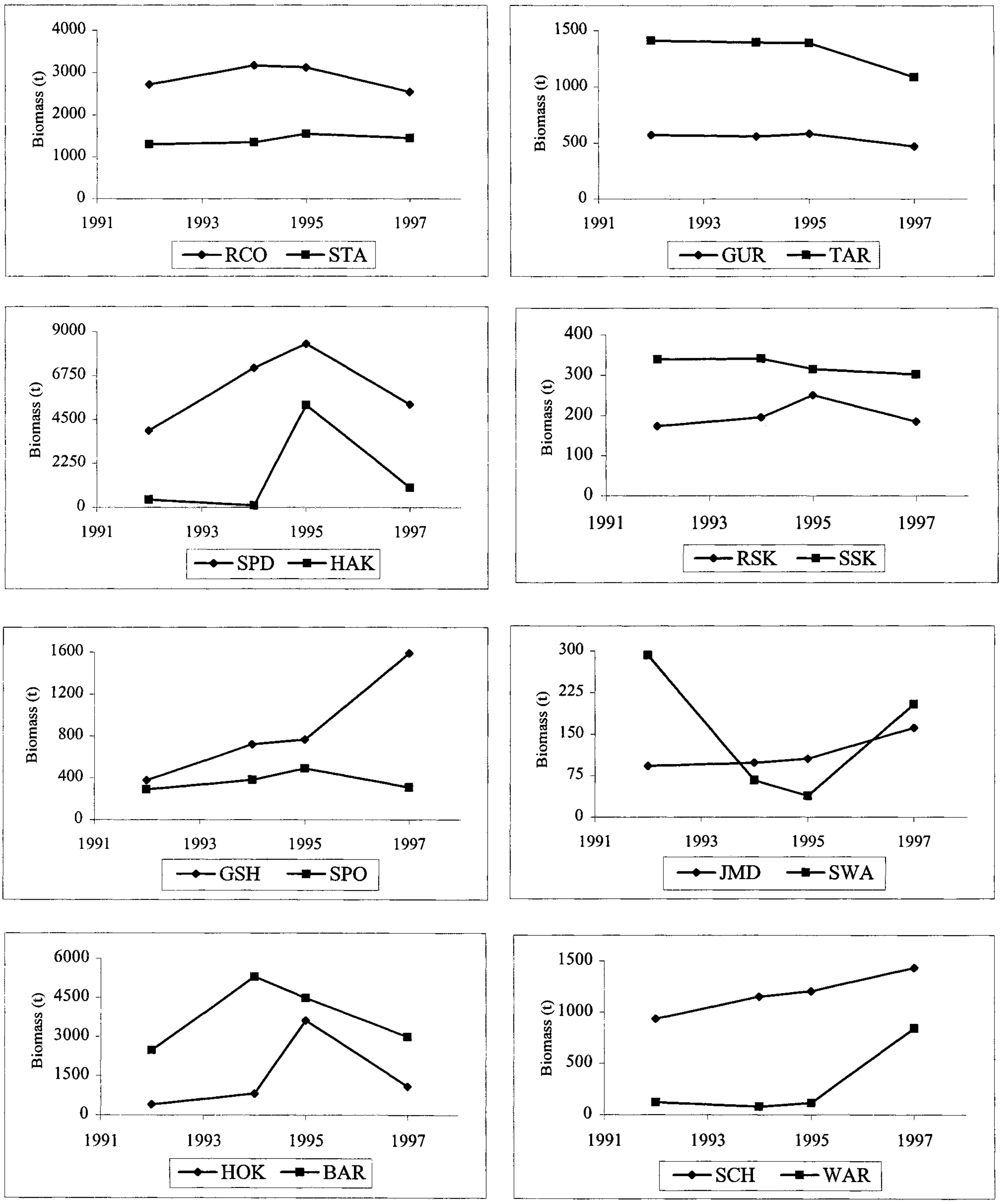


Figure 2a: **Estimated biomass of the 16 major species, 1992–97, all areas. (RCO, red cod; STA, giant stargazer; GUR, red gurnard; TAR, tarakihi; SPD, spiny dogfish; HAK, hake; RSK, rough skate; SSK, smooth skate; GSH, dark ghost shark; SPO, rig; JMD, jack mackerel *(T. declivis)*; SWA, silver warehou; HOK, hoki; BAR, barracouta; SCH, school shark; WAR, blue warehou).**

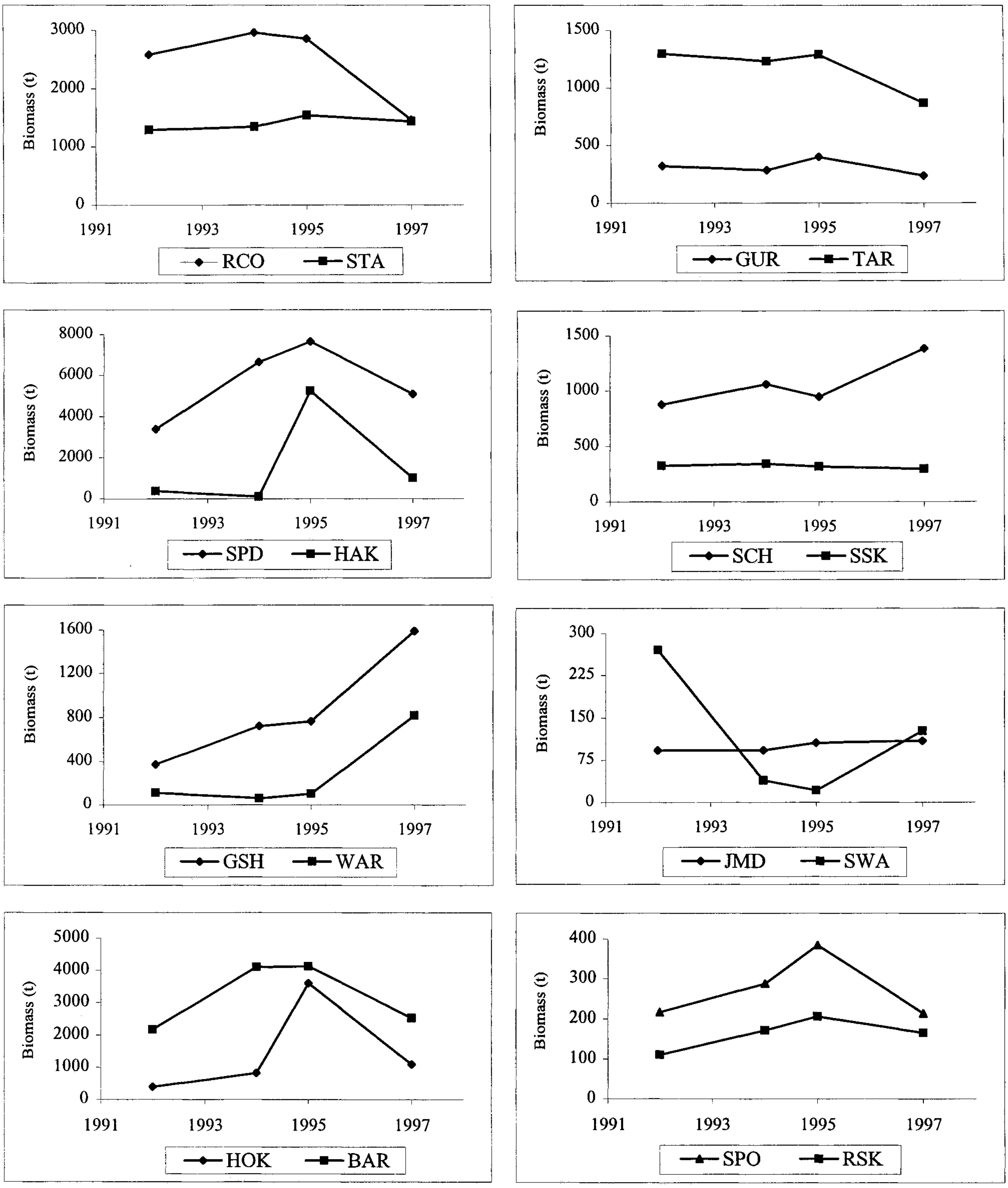


Figure 2b **: Estimated biomass of the 16 major species, 1992–97, west coast. (RCO, red cod; STA, giant stargazer; GUR, red gurnard; TAR, tarakihi; SPD, spiny dogfish; HAK, hake, SCH, school shark; SSK, smooth skate; GSH, dark ghost shark; WAR, blue warehou; JMD, jack mackerel *(T. declivis)*; SWA, silver warehou; HOK, hoki; BAR, barracouta; SPO, rig; RSK, rough skate).**

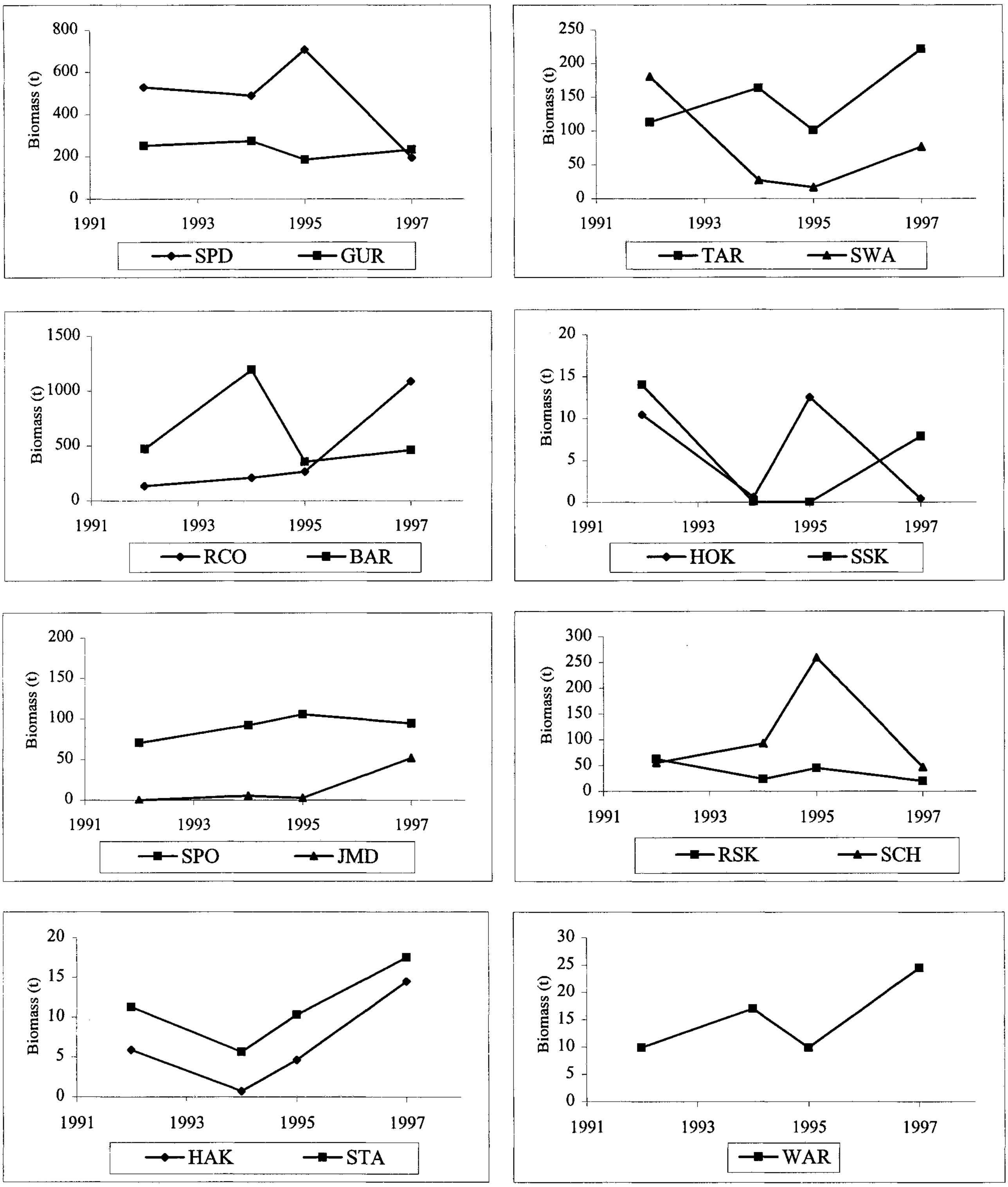


***Figure 2c*: Estimated biomass of the 16 major species, 1992–97, Tasman and Golden Bays. (SPD, spiny dogfish; GUR, red gurnard; TAR, tarakihi; SWA, silver warehou; RCO, red cod; BAR, barracouta; HOK, hoki; SSK, smooth skate; SPO, rig; JMD, jack mackerel (*T. declivis*); RSK, rough skate; SCH, school shark; HAK, hake; STA, giant stargazer; WAR, blue warehou (GSH, dark ghost shark had zero biomass).**

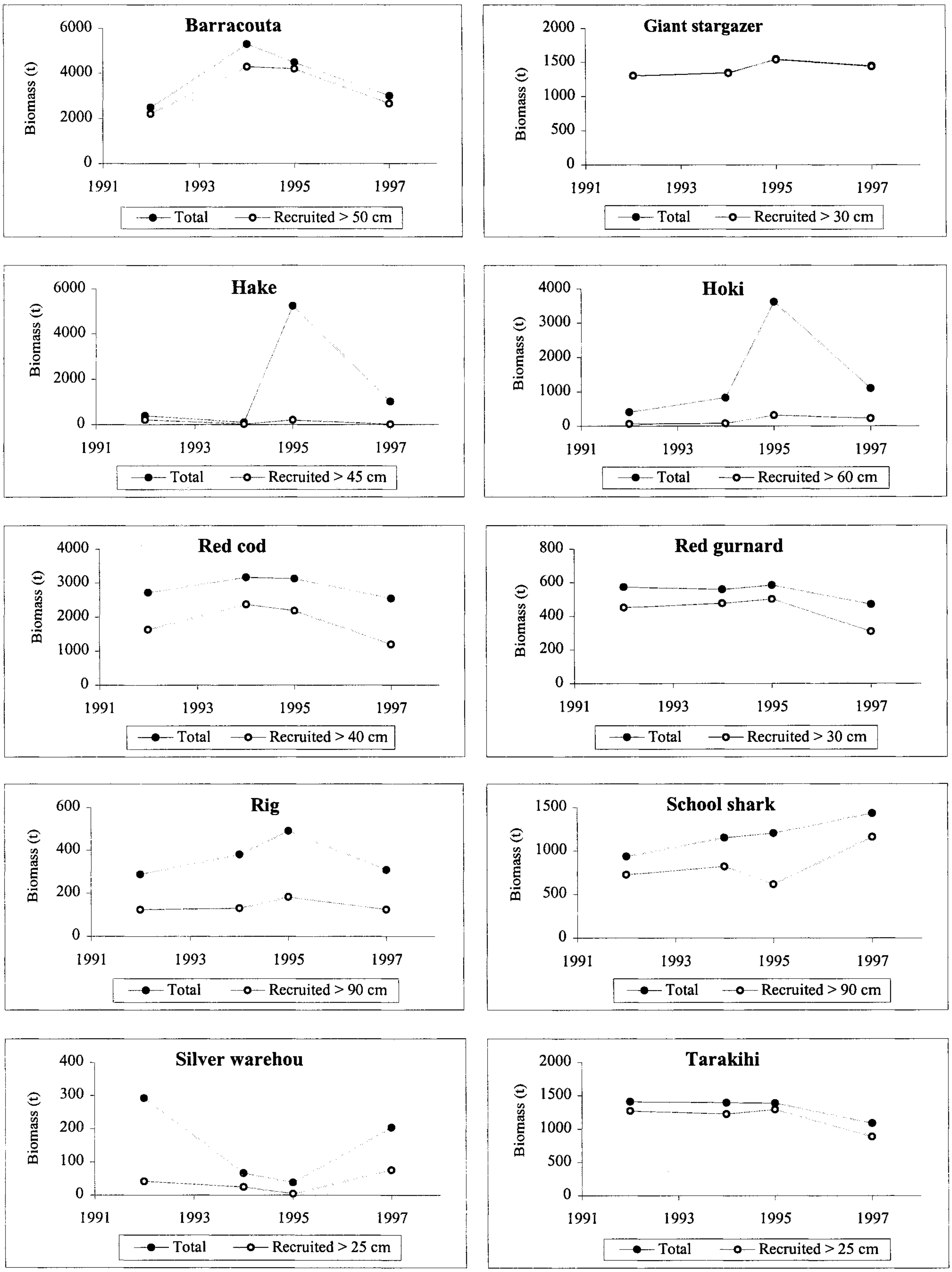


Figure 3a **: Estimates of total and recruited biomass, 1992–97, all areas, for barracouta, giant stargazer, hake, hoki, red cod, red gurnard, rig, school shark, silver warehou, and tarakihi.**

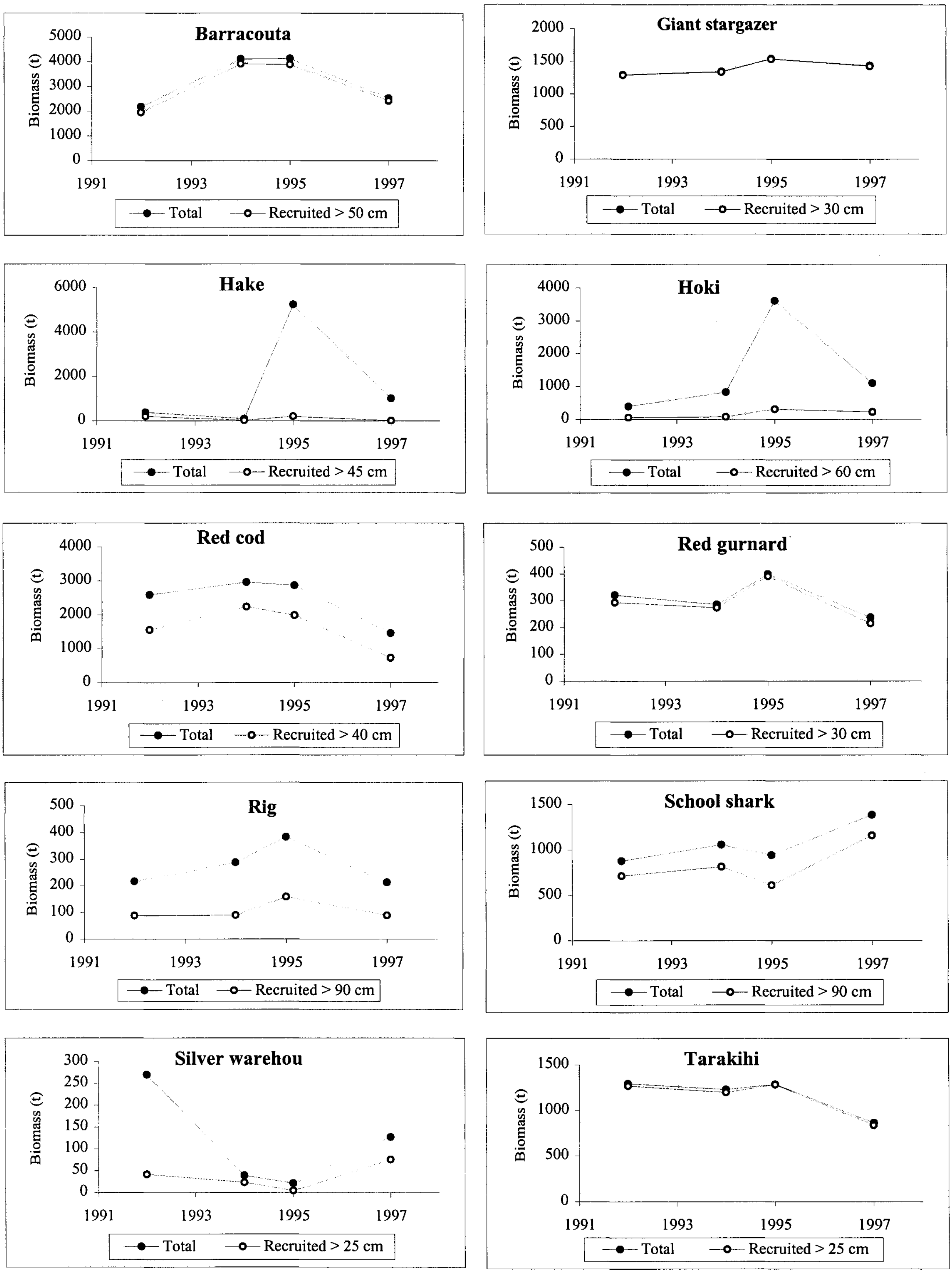


Figure 3b: **Total and recruited biomass, 1992–97, west coast, for barracouta, giant stargazer, hake, hoki, red cod, red gurnard, rig, school shark, silver warehou, and tarakihi.**

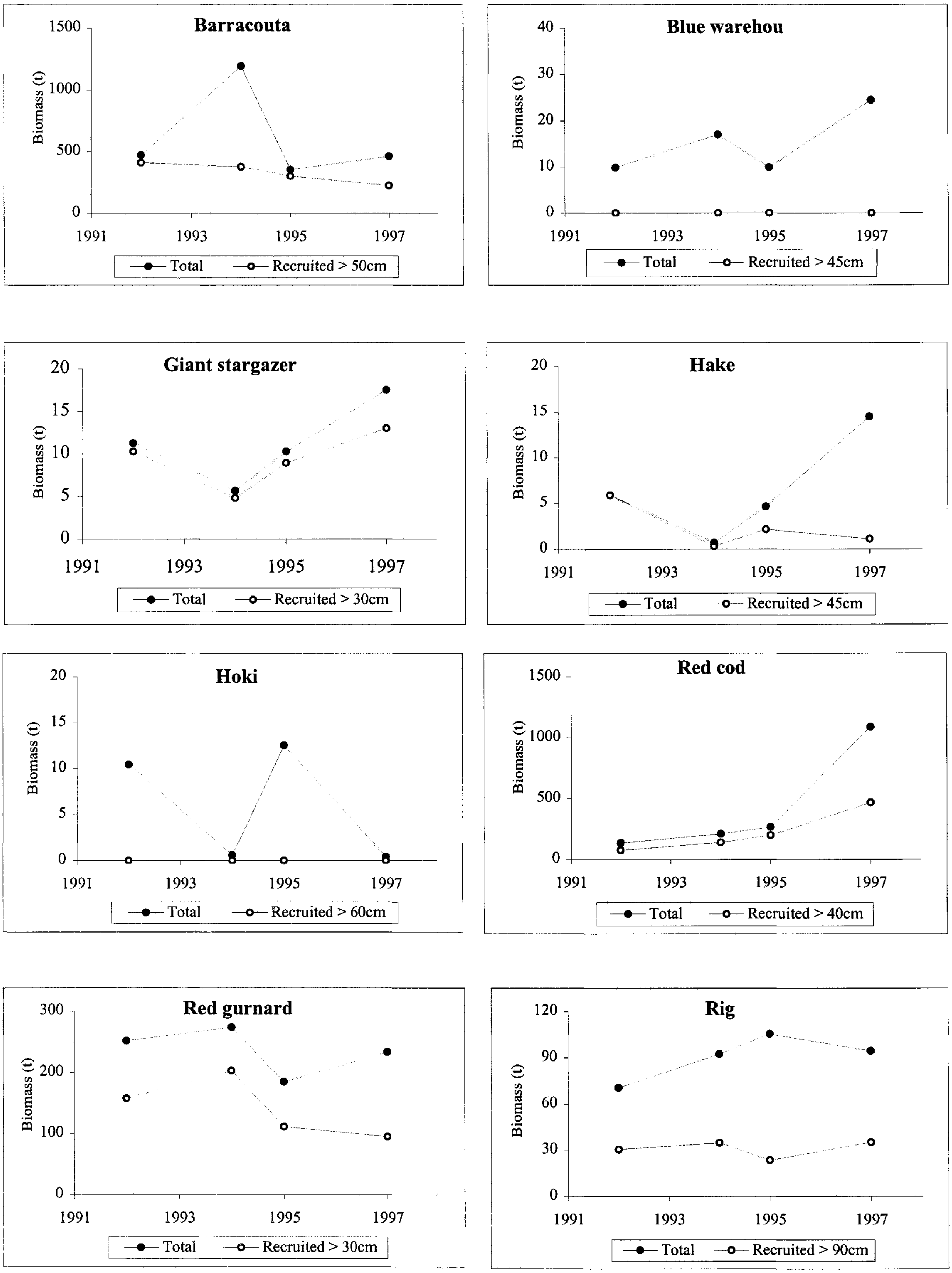
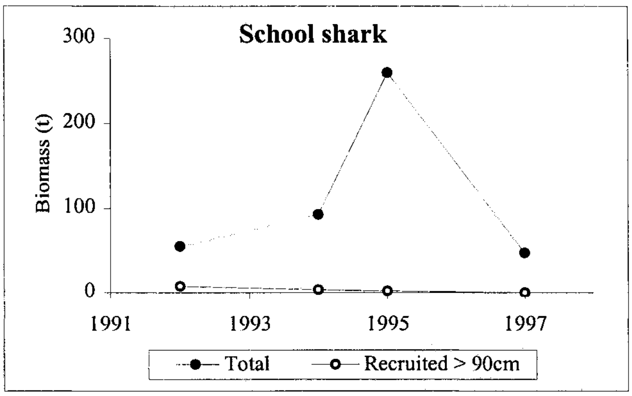
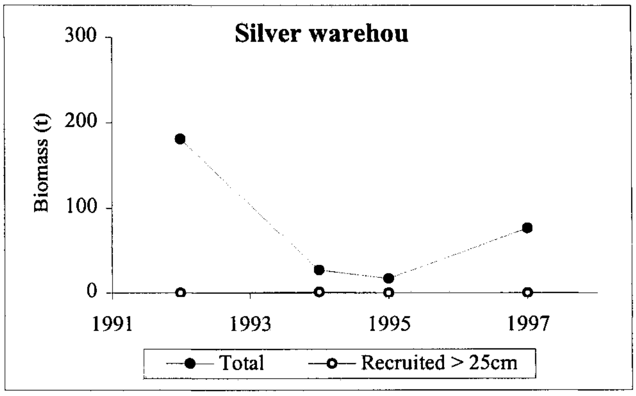


***Figure 3c*: Total and recruited biomass, 1992–97, Tasman and Golden Bays for barracouta, blue warehou, giant stargazer, hake, hoki, red cod, red gurnard, rig, school shark, silver warehou, and tarakihi.**





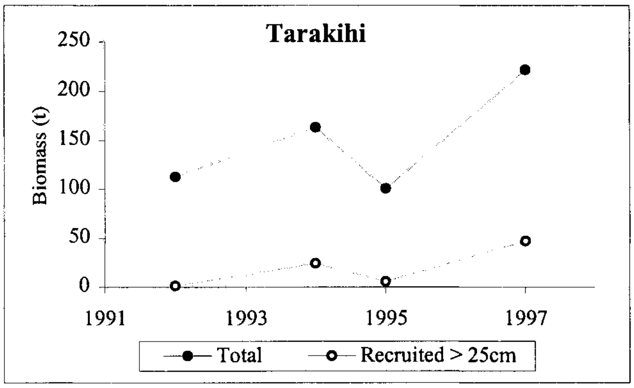


Figure 3c —contimued

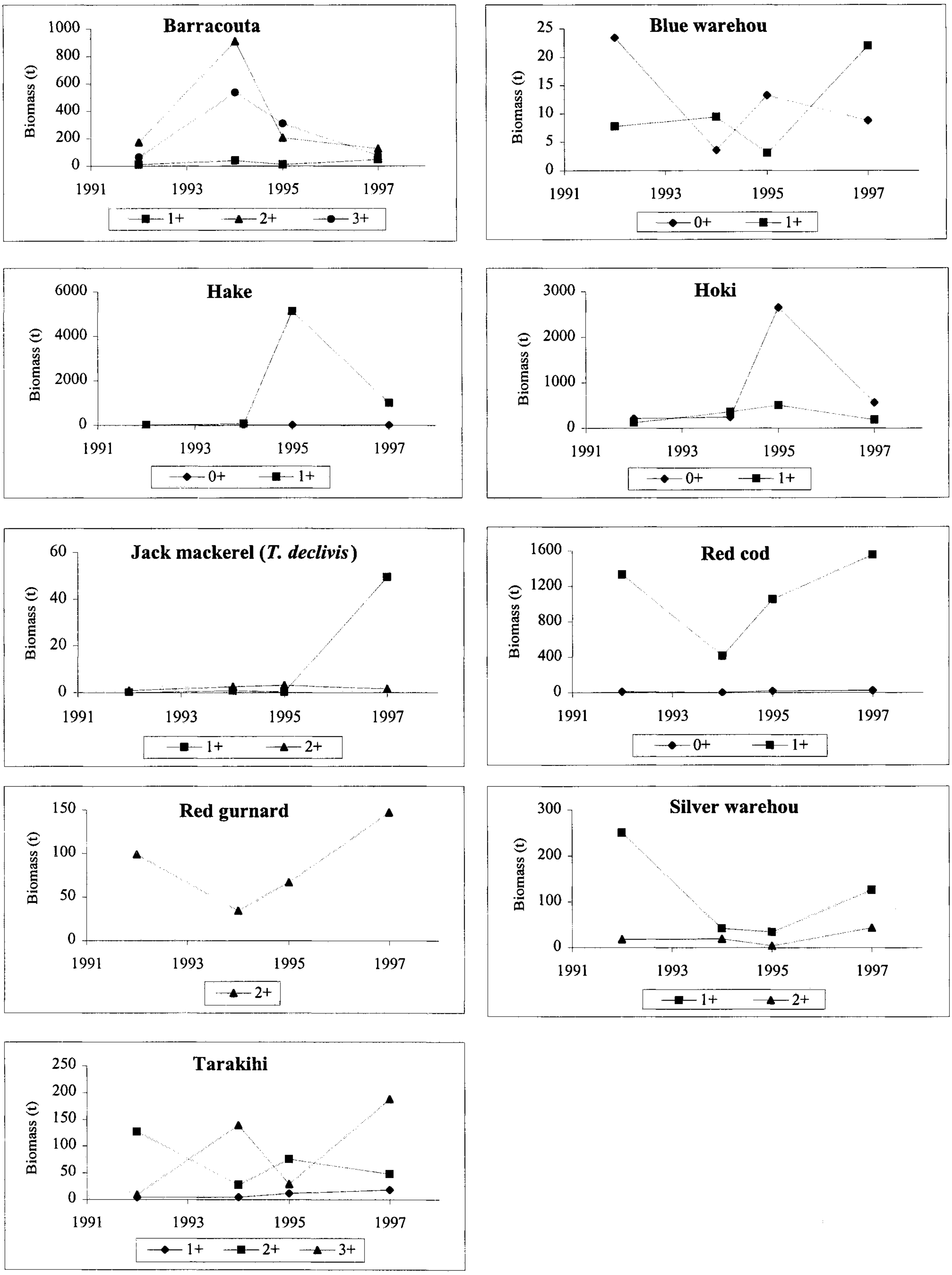


***Figure 4a*: Estimated biomass by year class, 1992–97, all areas, for barracouta, blue warehou, hake, hoki, jack mackerel (*T. declivis*), red cod, red gurnard, silver warehou, and tarakihi.**

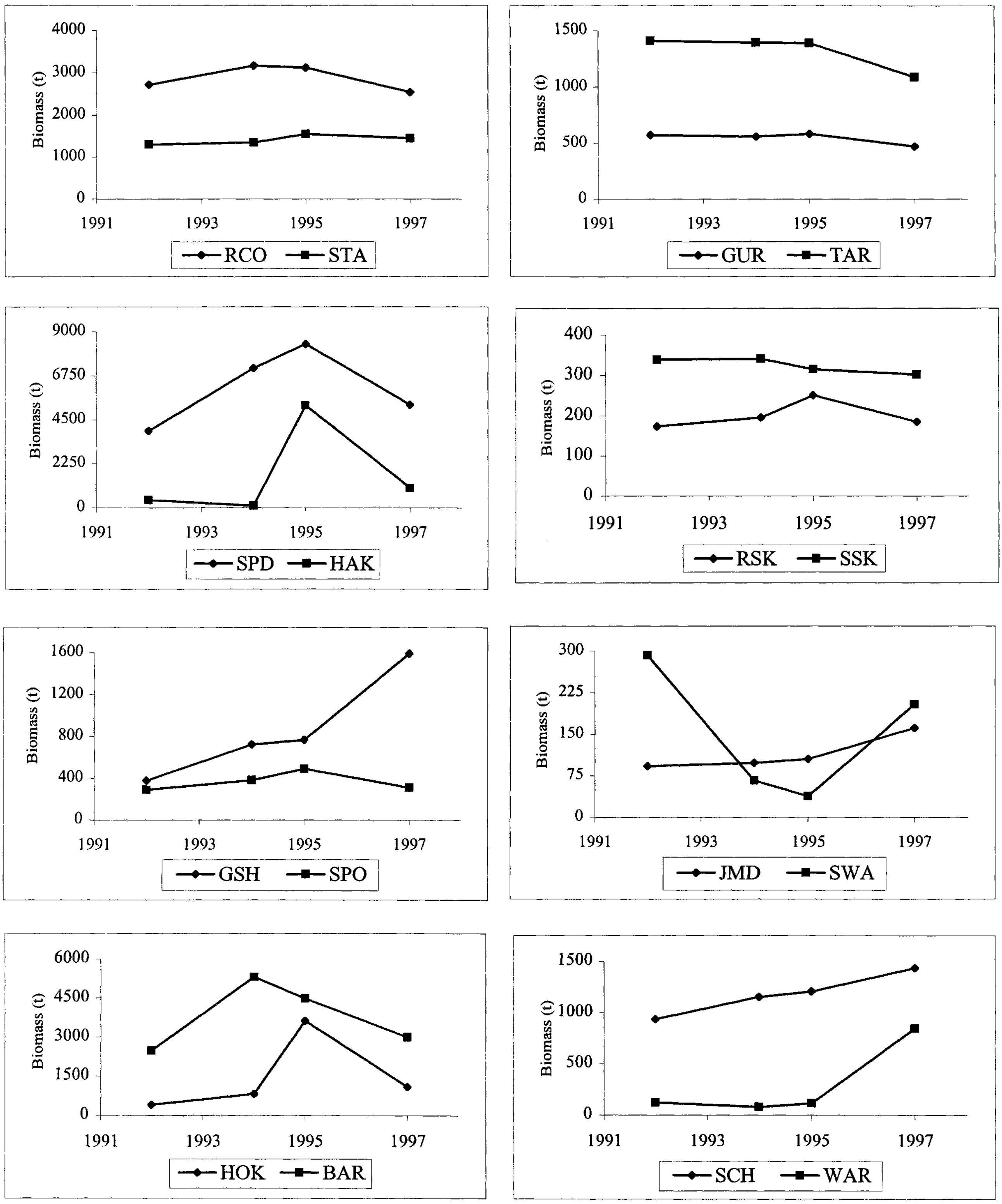


***Figure 2a*:** **Estimated biomass of the 16 major species, 1992–97, all areas. (RCO, red cod; STA, giant stargazer; GUR, red gurnard; TAR, tarakihi; SPD, spiny dogfish; HAK, hake; RSK, rough skate; SSK, smooth skate; GSH, dark ghost shark; SPO, rig; JMD, jack mackerel *(T. declivis)*; SWA, silver warehou; HOK, hoki; BAR, barracouta; SCH, school shark; WAR, blue warehou).**

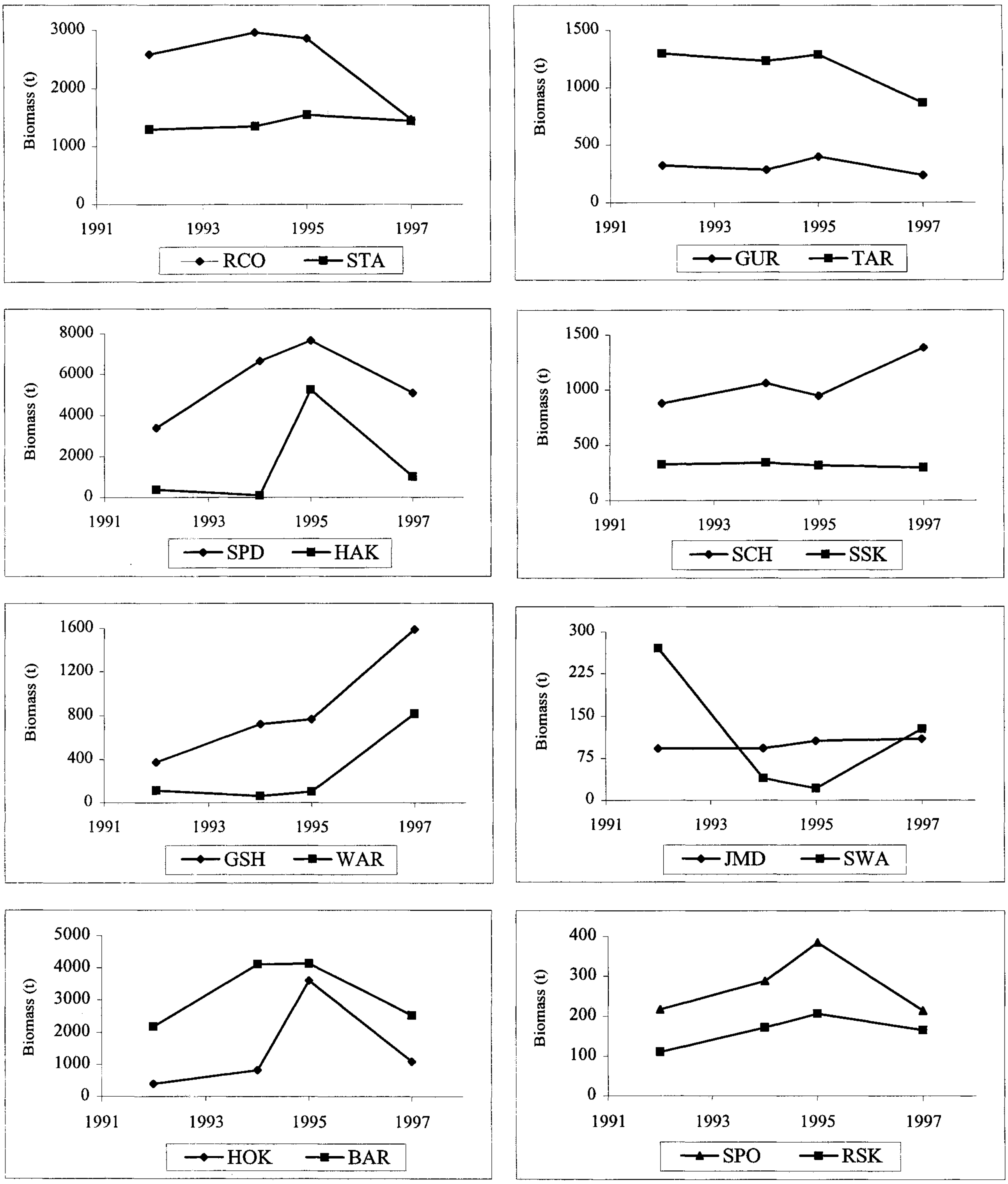


Figure 2b **: Estimated biomass of the 16 major species, 1992–97, west coast. (RCO, red cod; STA, giant stargazer; GUR, red gurnard; TAR, tarakihi; SPD, spiny dogfish; HAK, hake, SCH, school shark; SSK, smooth skate; GSH, dark ghost shark; WAR, blue warehou; JMD, jack mackerel *(T. declivis)*; SWA, silver warehou; HOK, hoki; BAR, barracouta; SPO, rig; RSK, rough skate).**

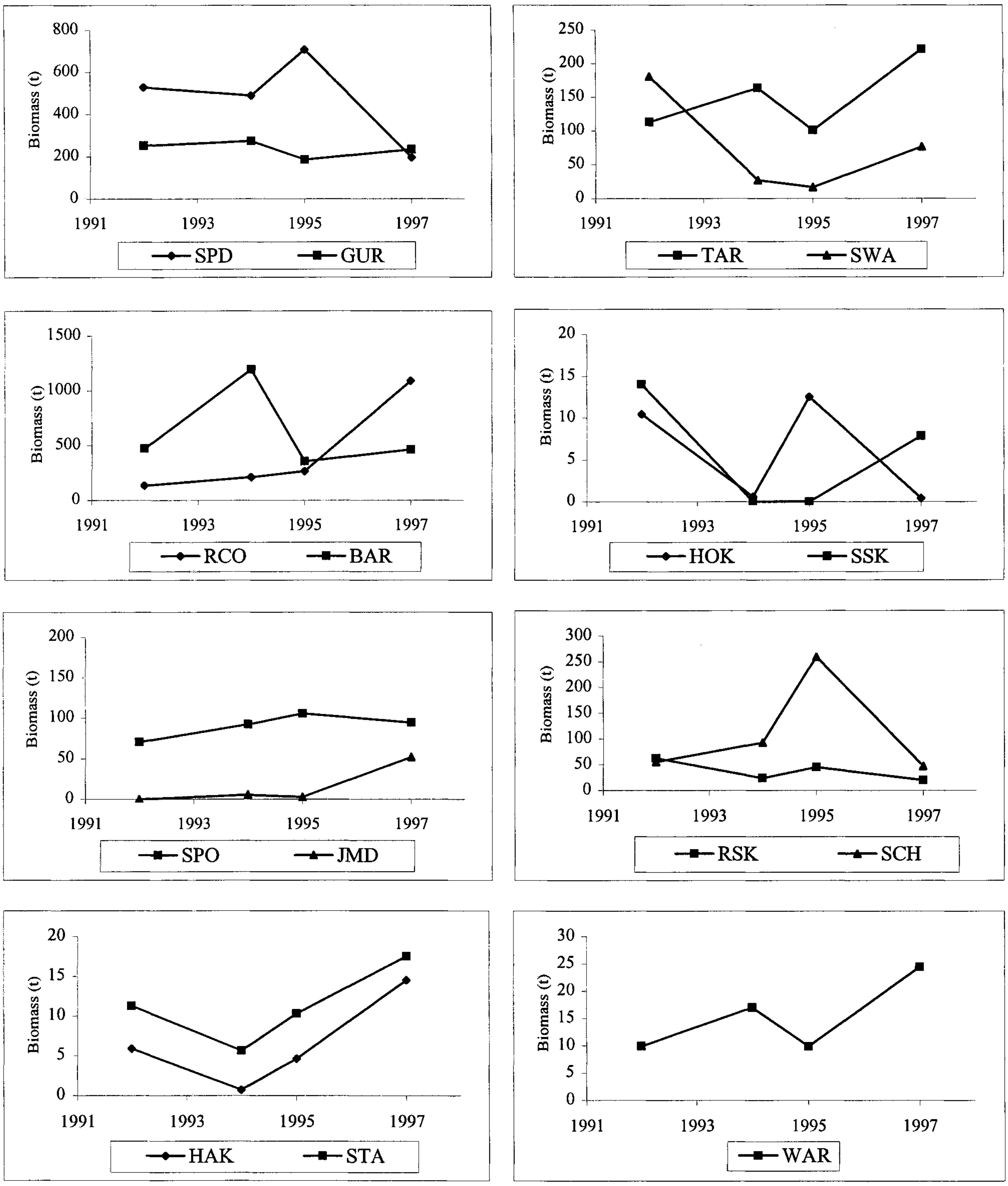


***Figure 2c*: Estimated biomass of the 16 major species, 1992–97, Tasman and Golden Bays. (SPD, spiny dogfish; GUR, red gurnard; TAR, tarakihi; SWA, silver warehou; RCO, red cod; BAR, barracouta; HOK, hoki; SSK, smooth skate; SPO, rig; JMD, jack mackerel (*T. declivis*); RSK, rough skate; SCH, school shark; HAK, hake; STA, giant stargazer; WAR, blue warehou (GSH, dark ghost shark had zero biomass).**

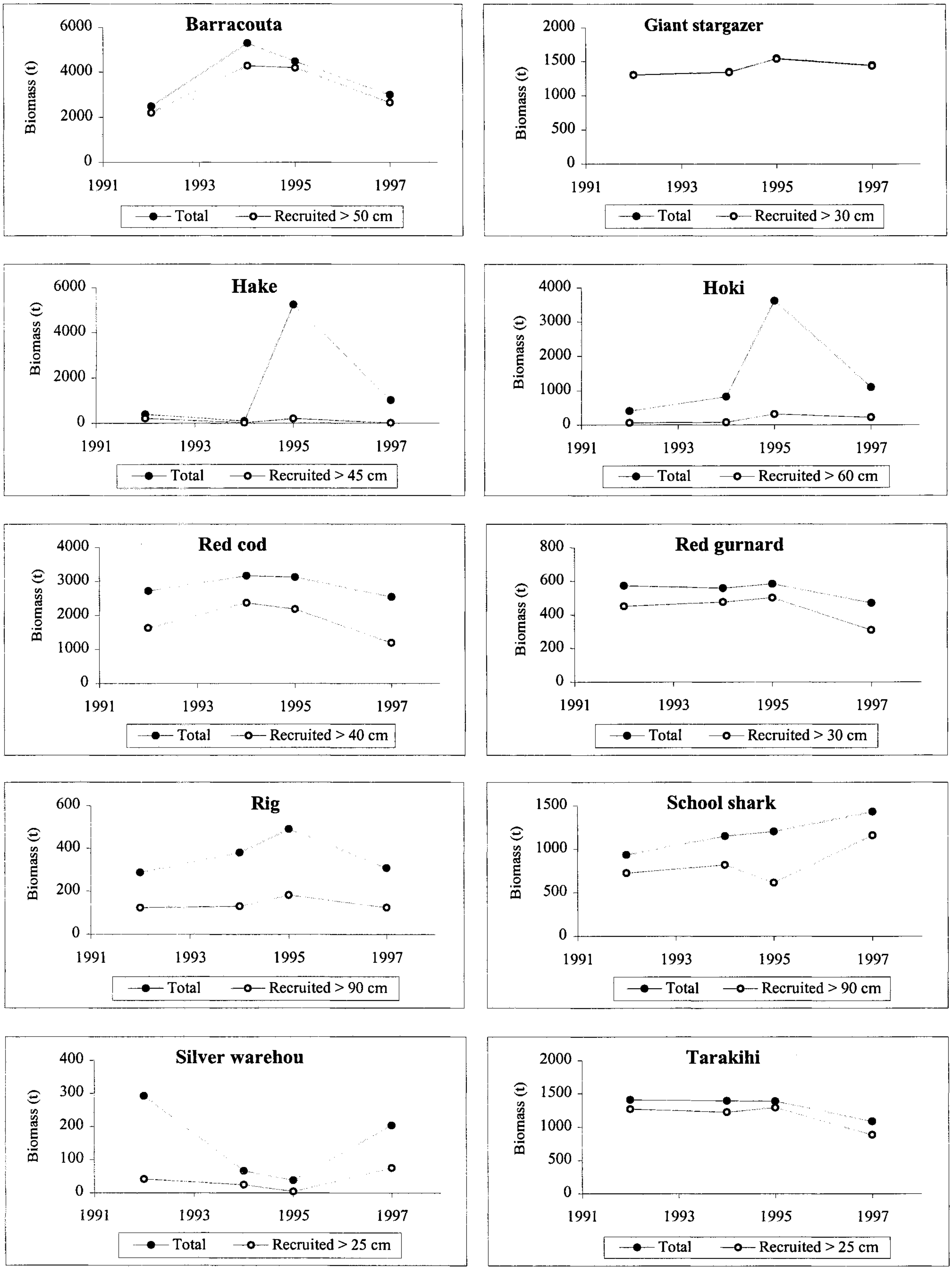


***Figure 3a*: Estimates of total and recruited biomass, 1992–97, all areas, for barracouta, giant stargazer, hake, hoki, red cod, red gurnard, rig, school shark, silver warehou, and tarakihi.**

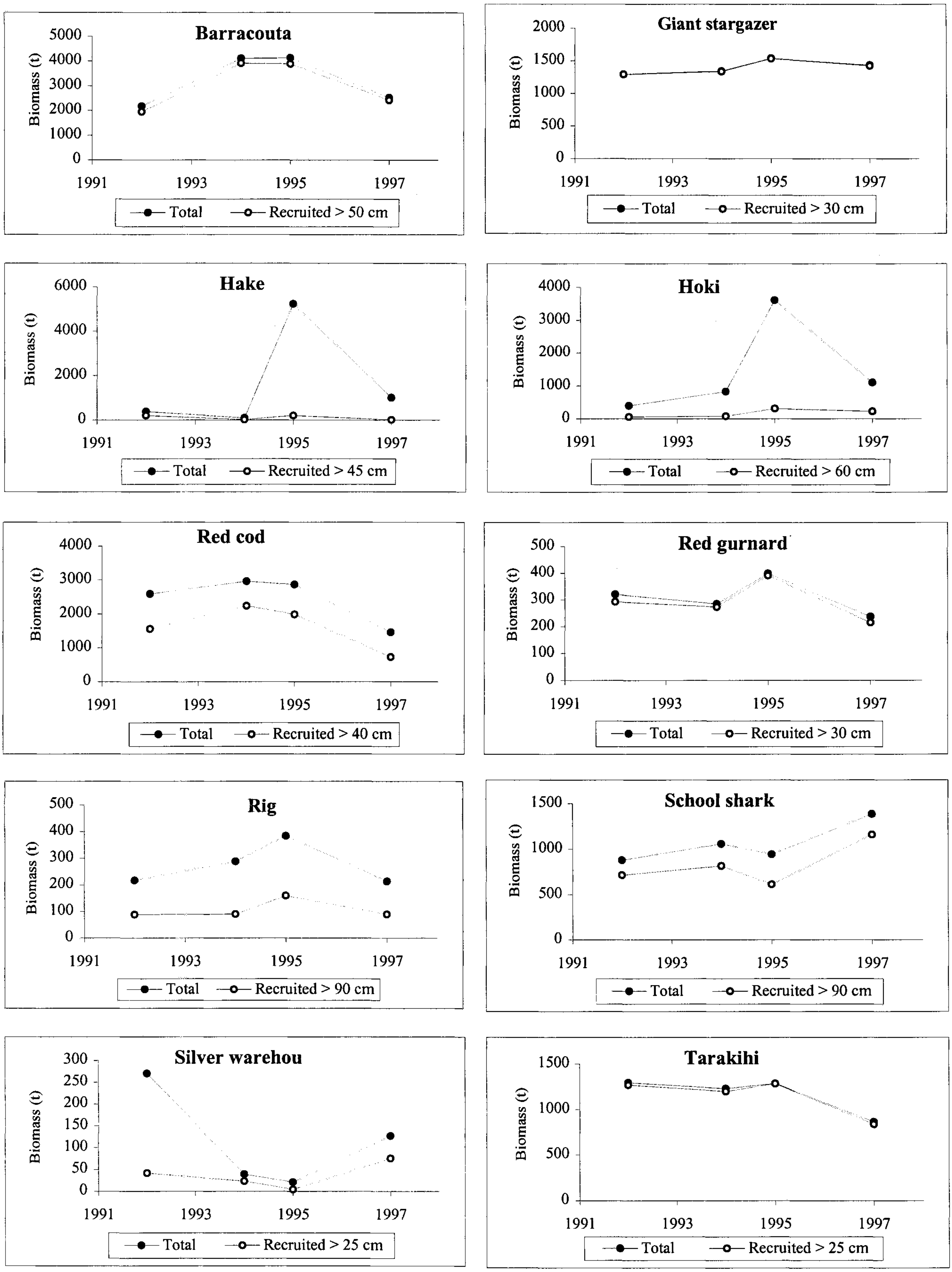


Figure 3b **: Total and recruited biomass, 1992–97, west coast, for barracouta, giant stargazer, hake, hoki, red cod, red gurnard, rig, school shark, silver warehou, and tarakihi.**

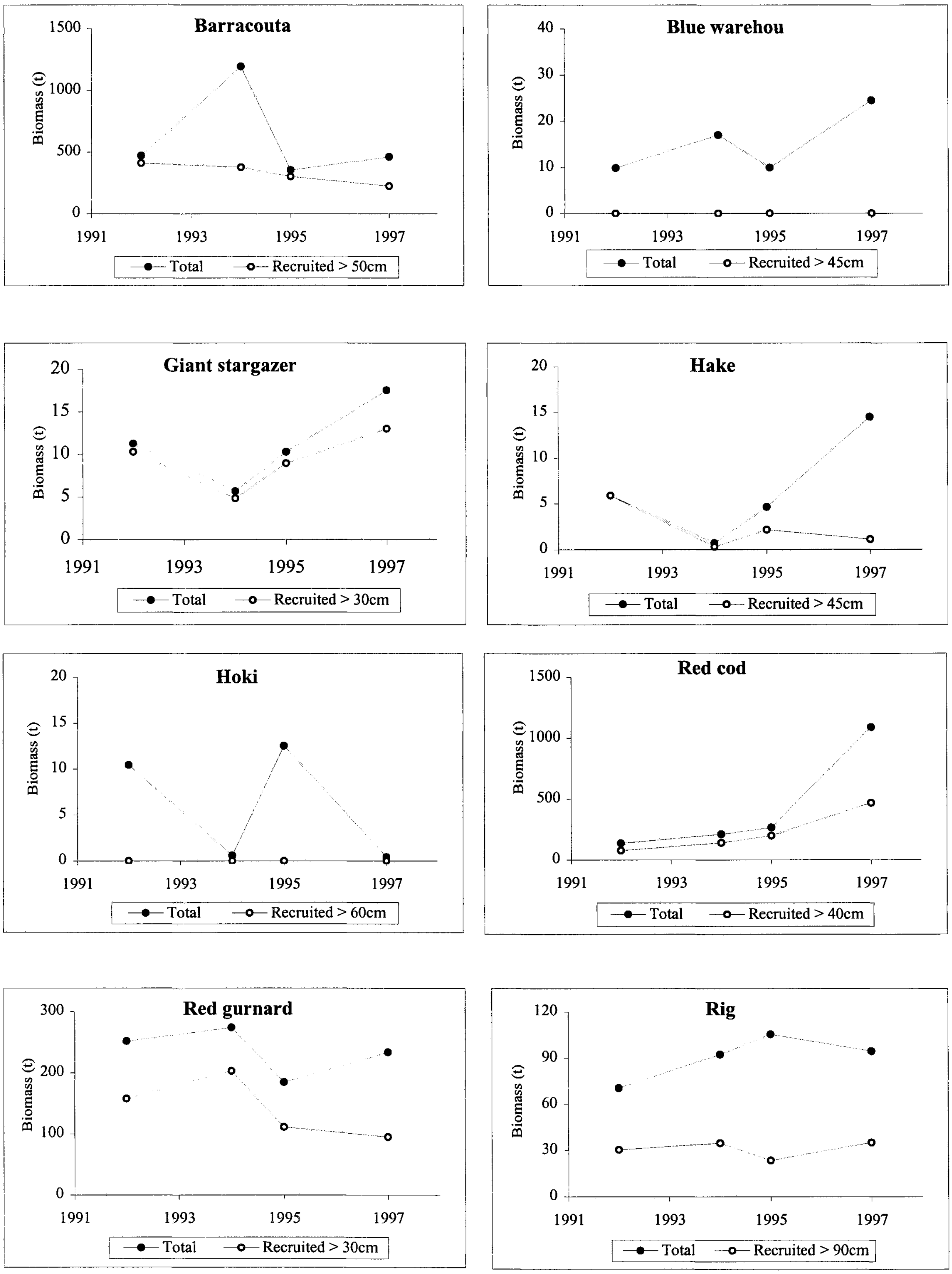
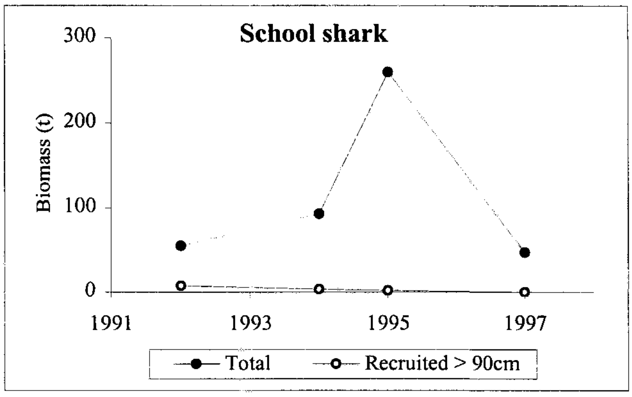
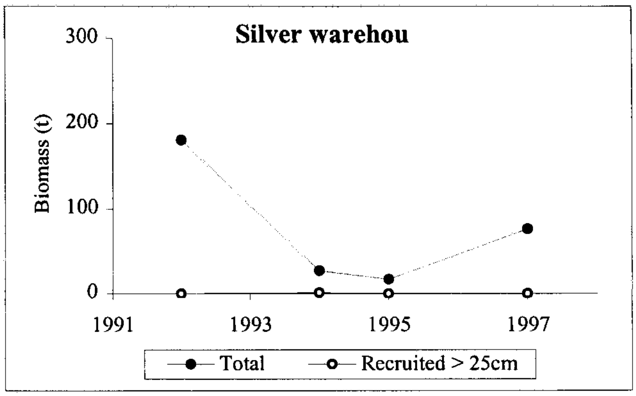


***Figure 3c*: Total and recruited biomass, 1992–97, Tasman and Golden Bays for barracouta, blue warehou, giant stargazer, hake, hoki, red cod, red gurnard, rig, school shark, silver warehou, and tarakihi.**





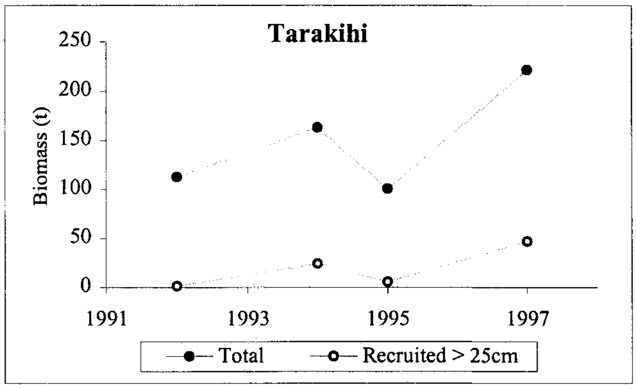


Figure 3c —contimued

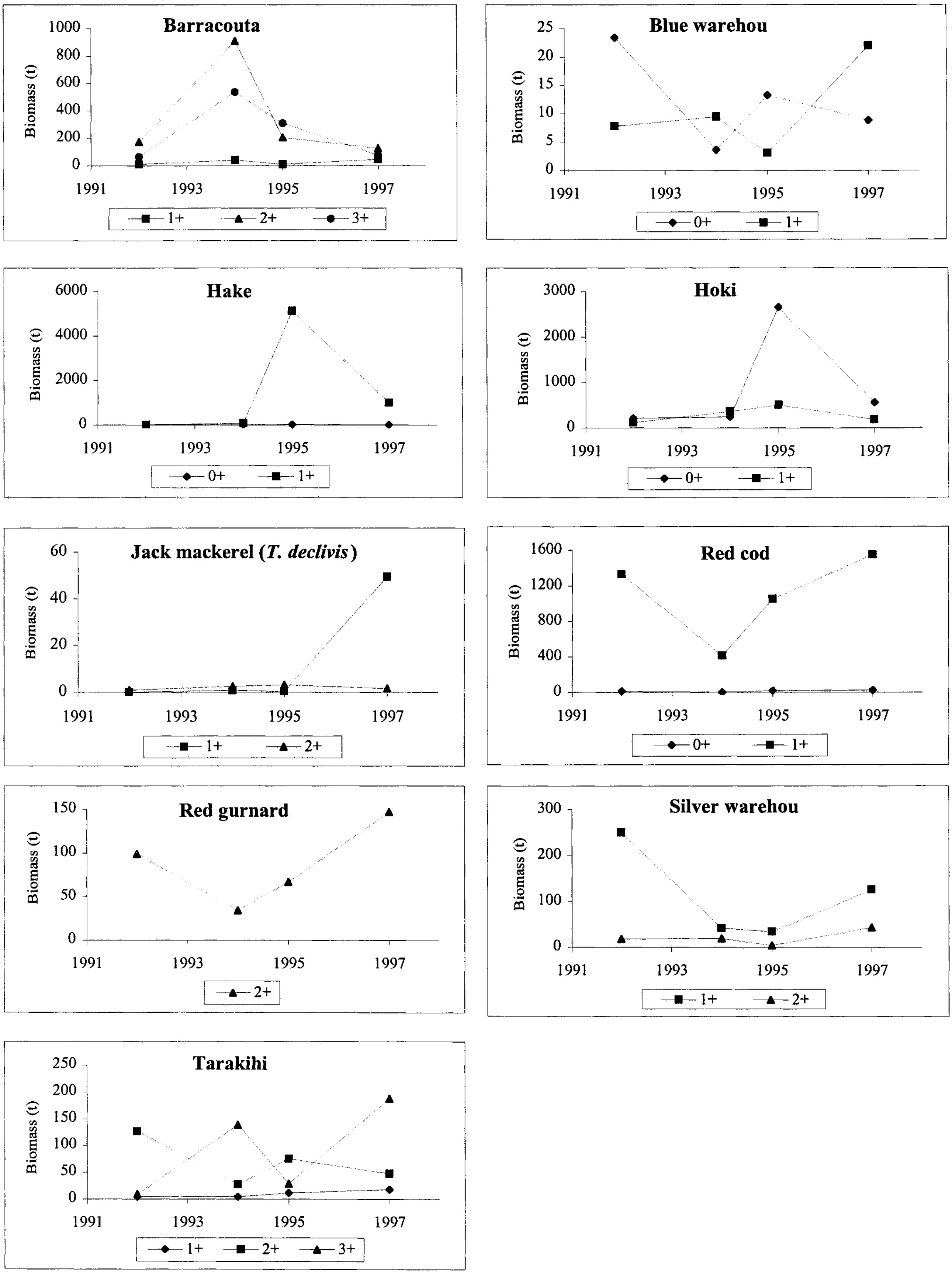


***Figure 4a*: Estimated biomass by year class, 1992–97, all areas, for barracouta, blue warehou, hake, hoki, jack mackerel (*T. declivis*), red cod, red gurnard, silver warehou, and tarakihi.**

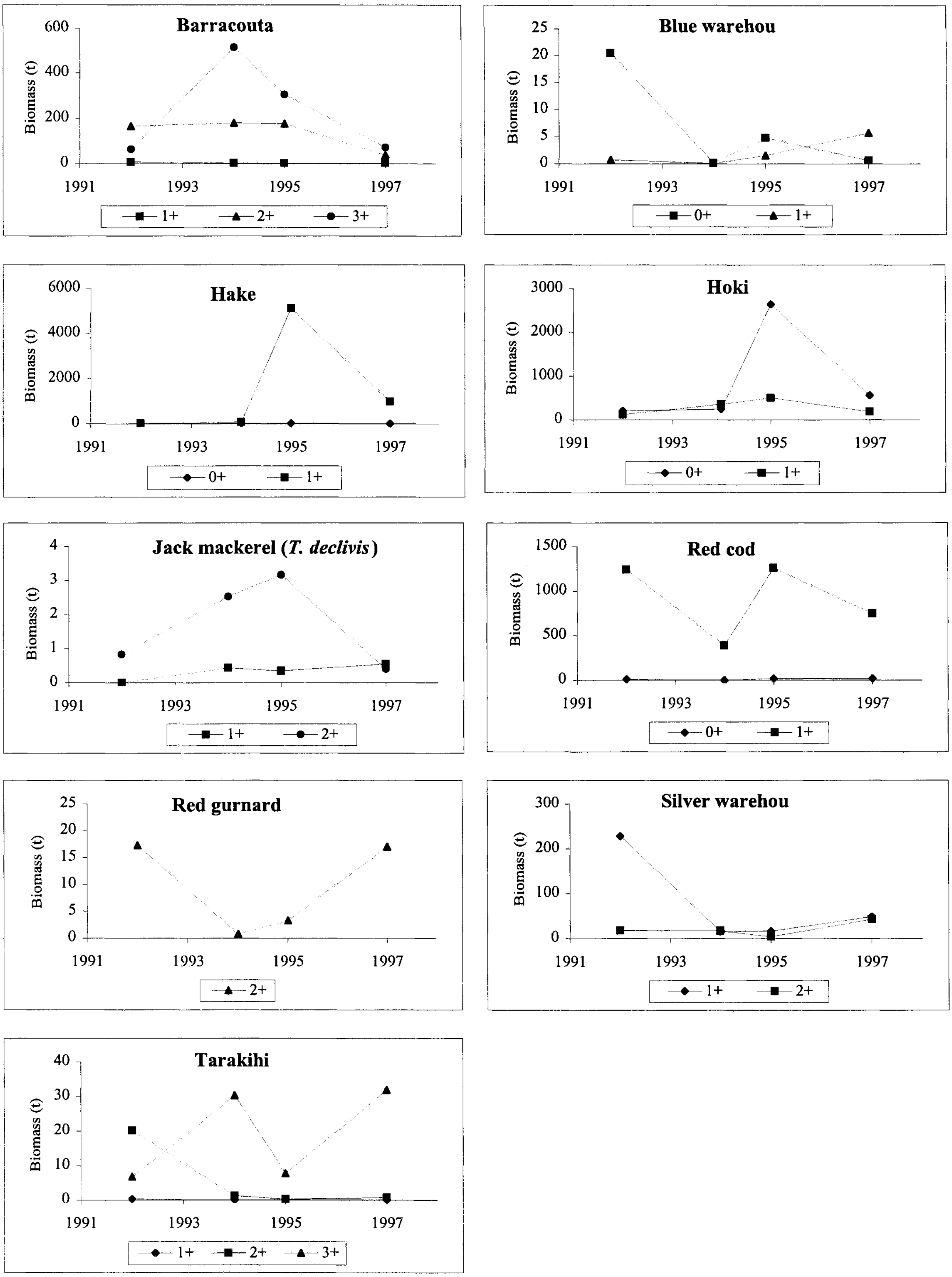


Figure 4b **: Estimated biomass by year class, 1992–97, west coast, for barracouta, blue warehou, hake, hoki, jack mackerel (*T. declivis*), red cod , red gurnard, silver warehou, and tarakihi.**

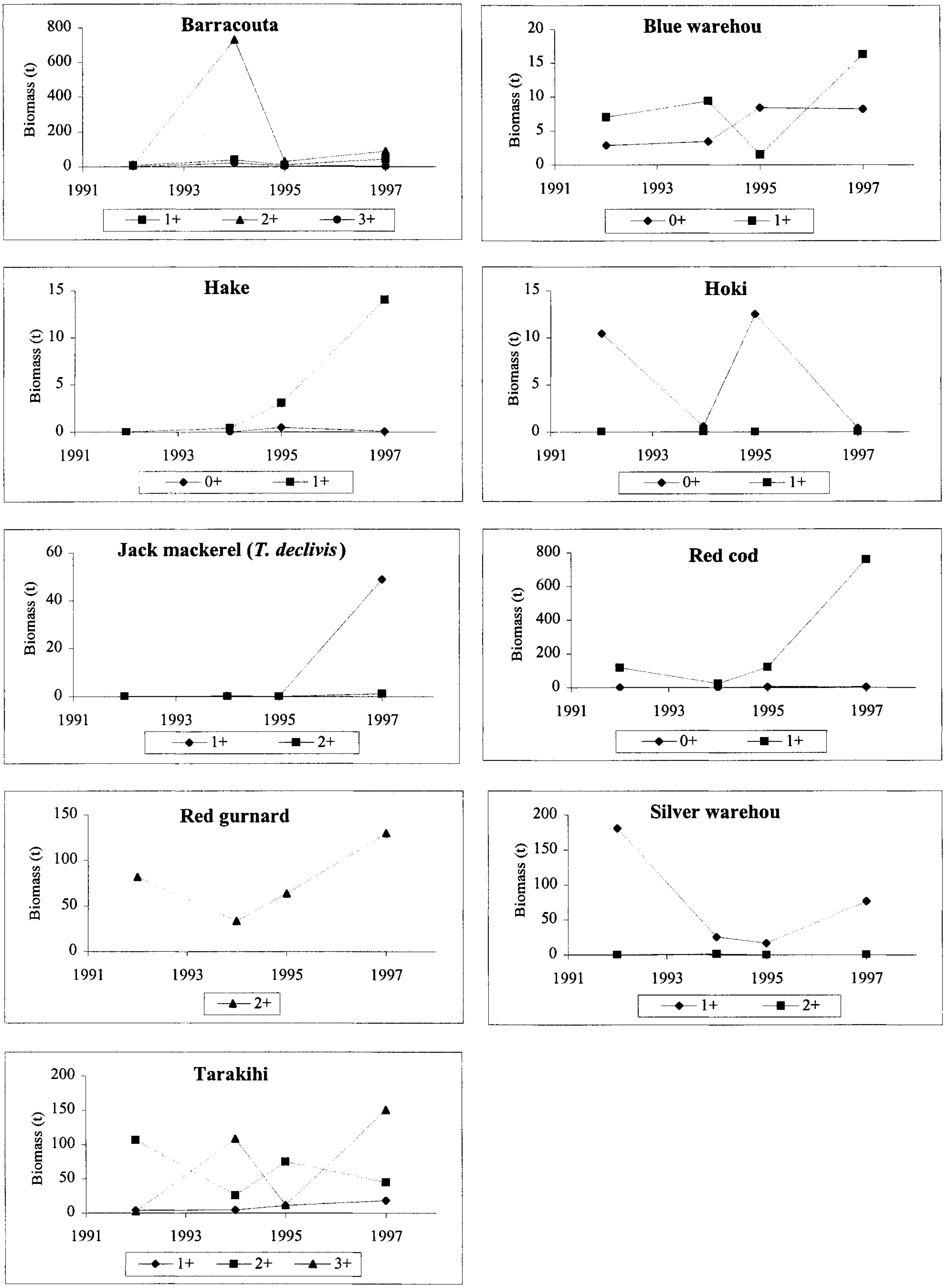


***Figure 4c*: Estimated biomass by year class, 1992–97, for Tasman and Golden Bays for barracouta, blue warehou, hake, hoki, jack mackerel (*T. declivis*), red cod, red gurnard, silver warehou, and tarakihi.**

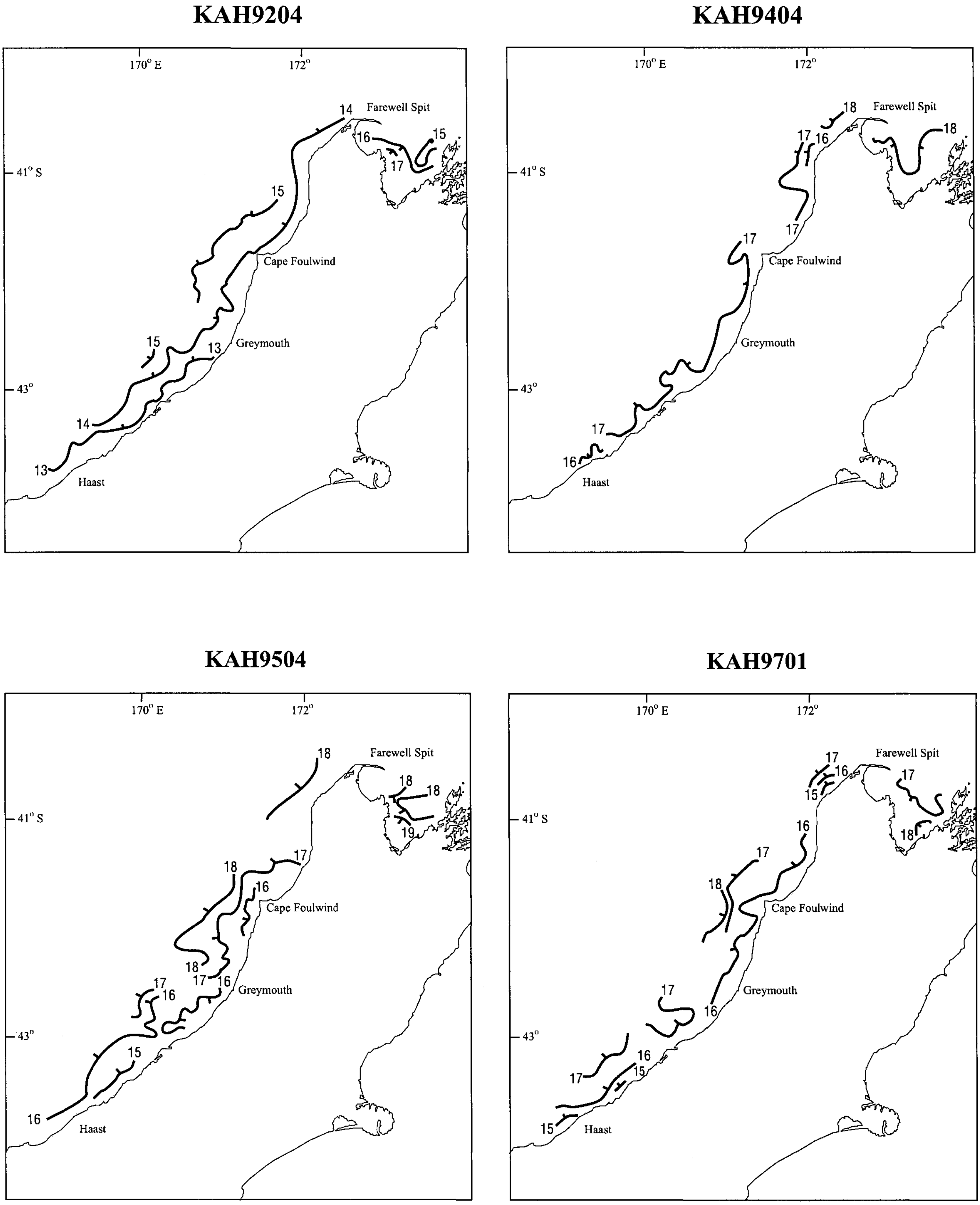


Figure 5 : **Sea surface isotherms estimated from station data.**

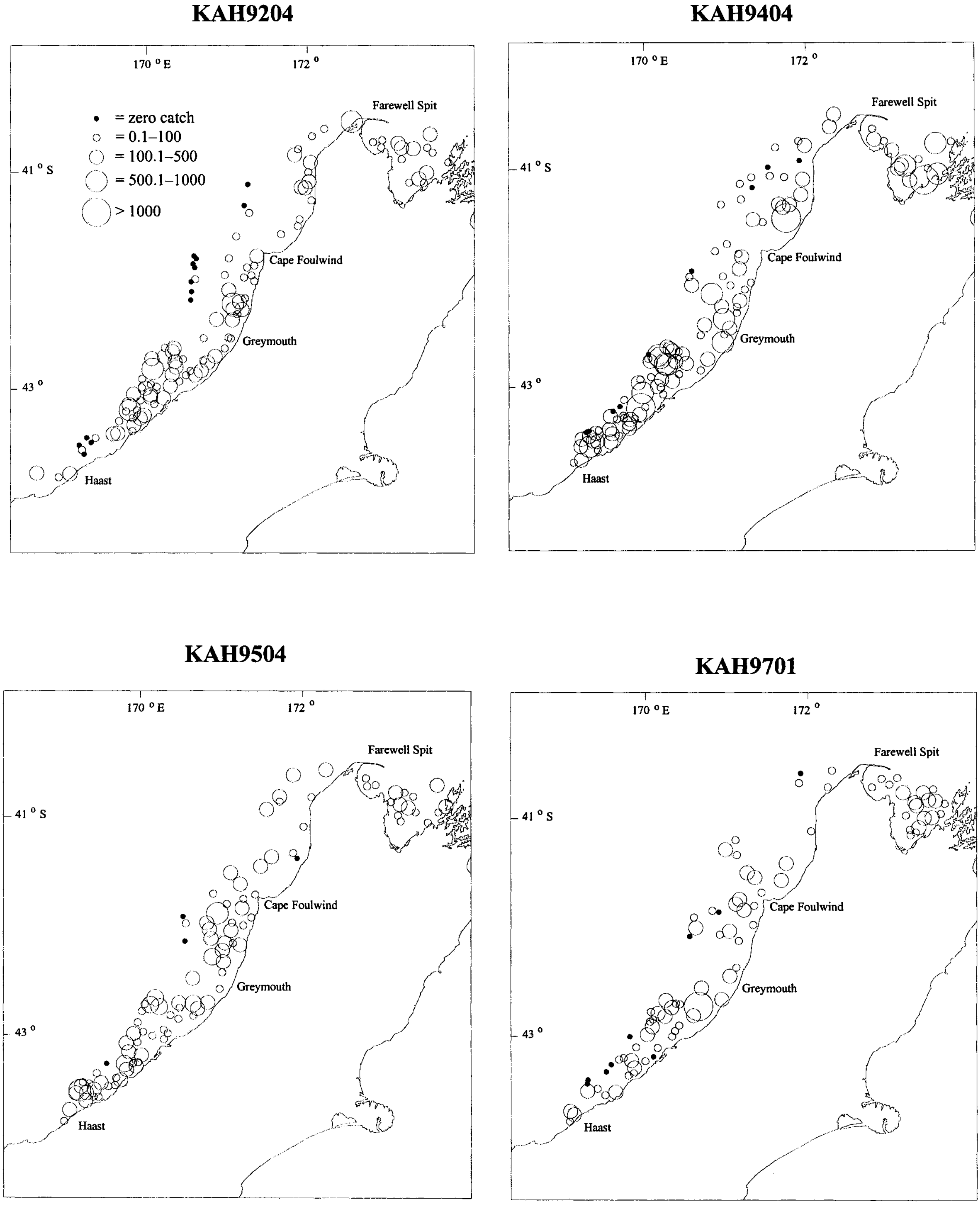


Figure 6 **: Distribution and catch rates (kg.km^{-2}) of the major species, 1992–97**
a **: Barracouta (maximum catch rate, 3336 kg.km^{-2}).**

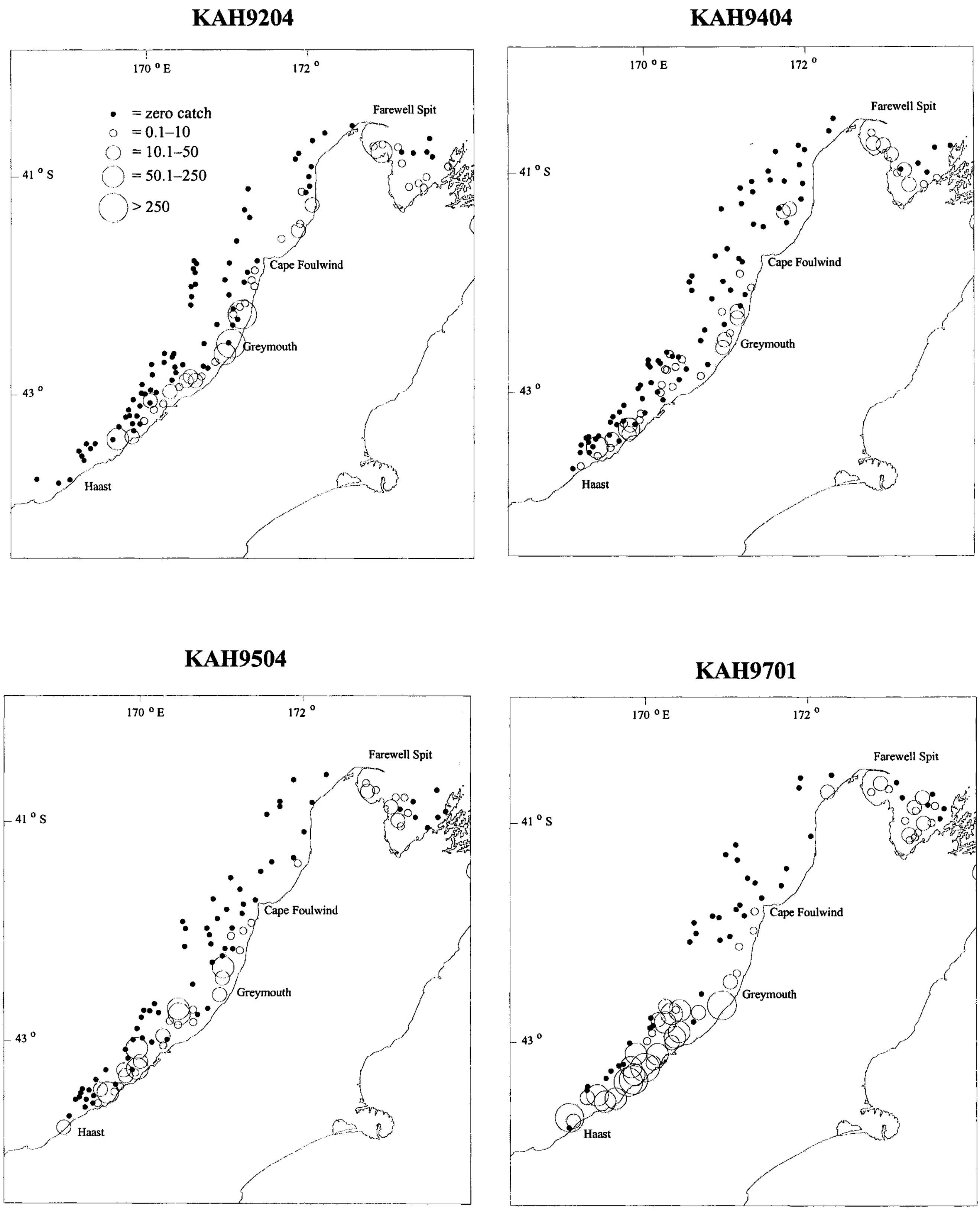


***Figure 6b*: Blue warehou (maximum catch rate, 1386 $kg.km^{-2}$).**

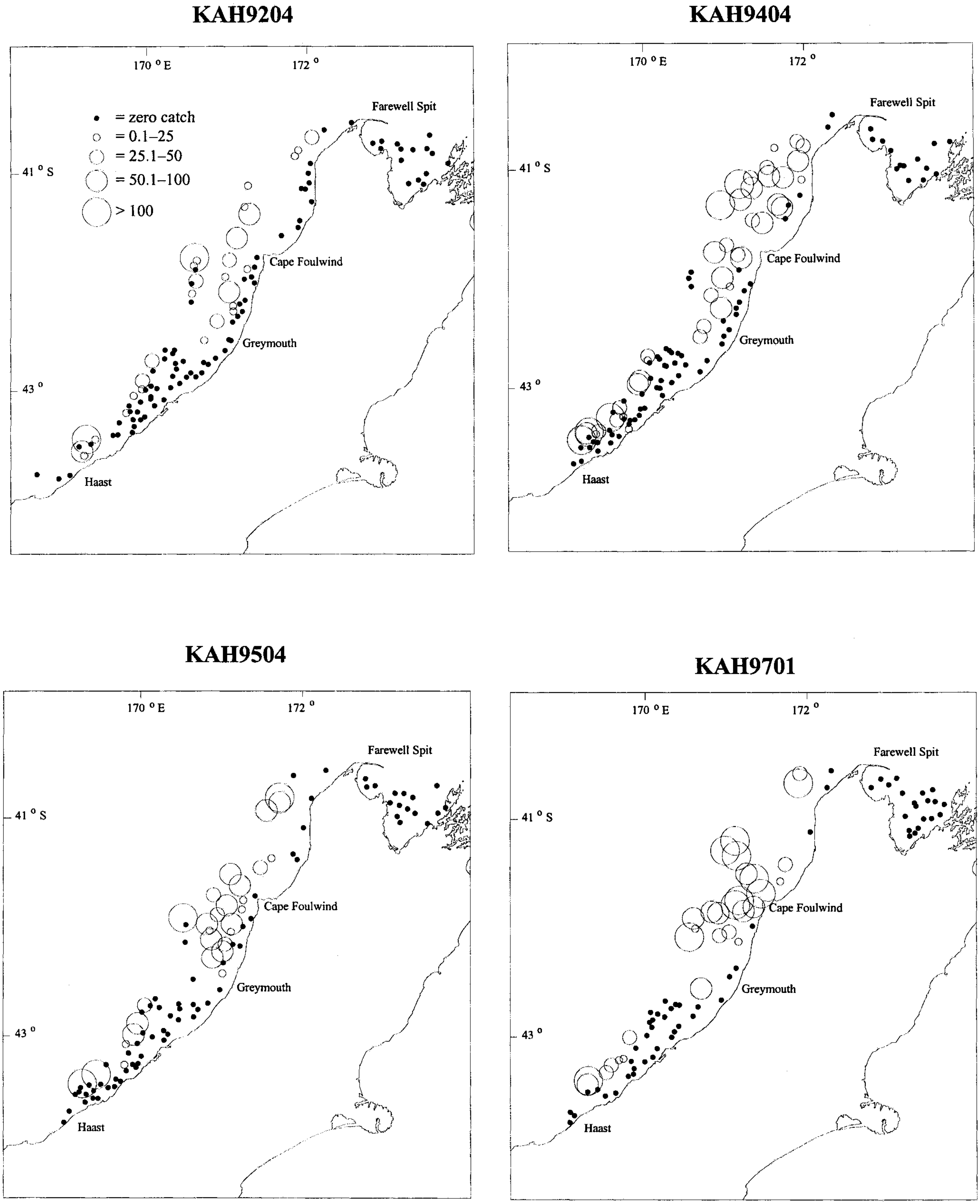


***Figure 6c*: Dark ghost shark (maximum catch rate, 324 kg.km^{-2}).**

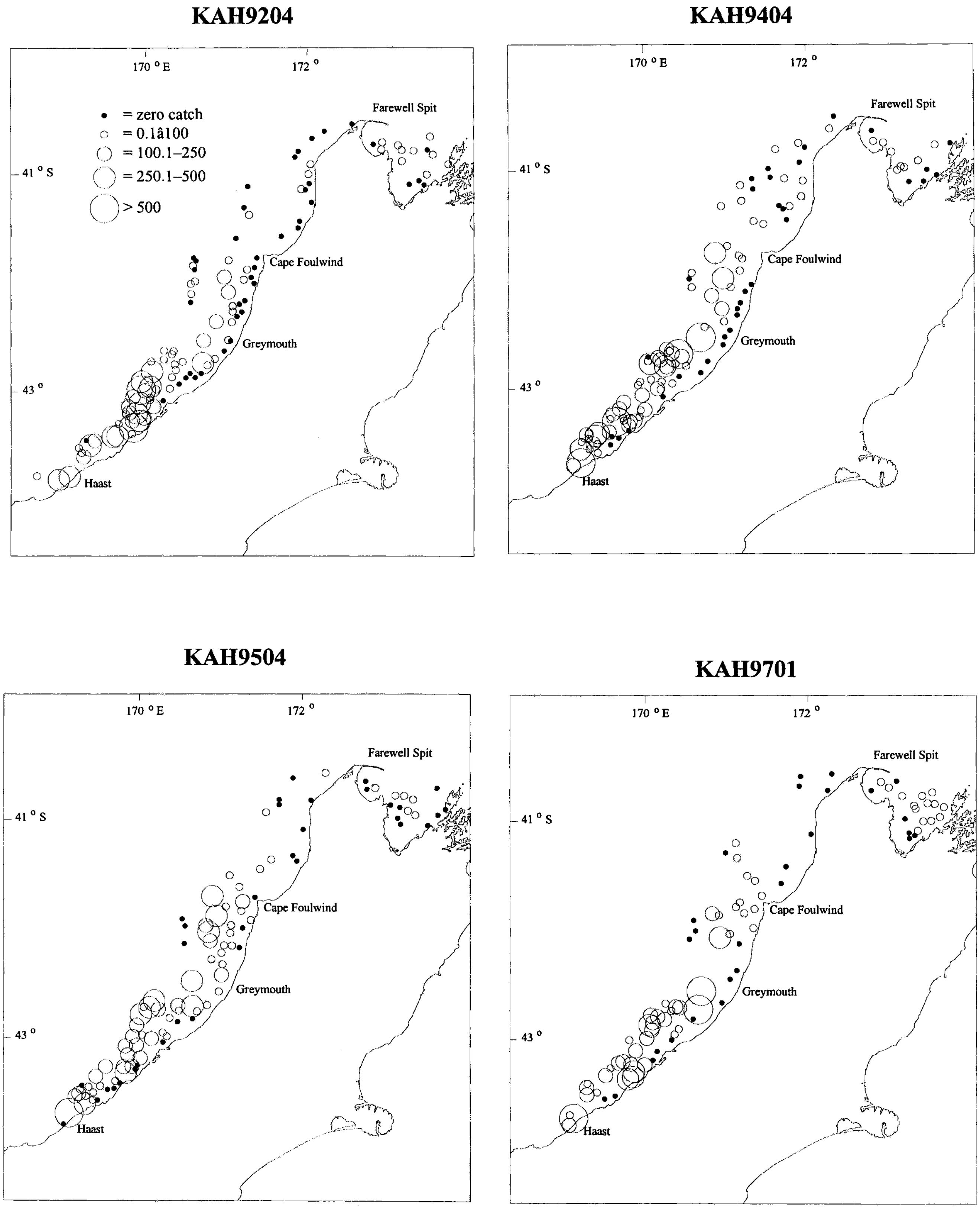


***Figure 6d*: Giant stargazer (maximum catch rate, 2365 kg.km^{-2}).**

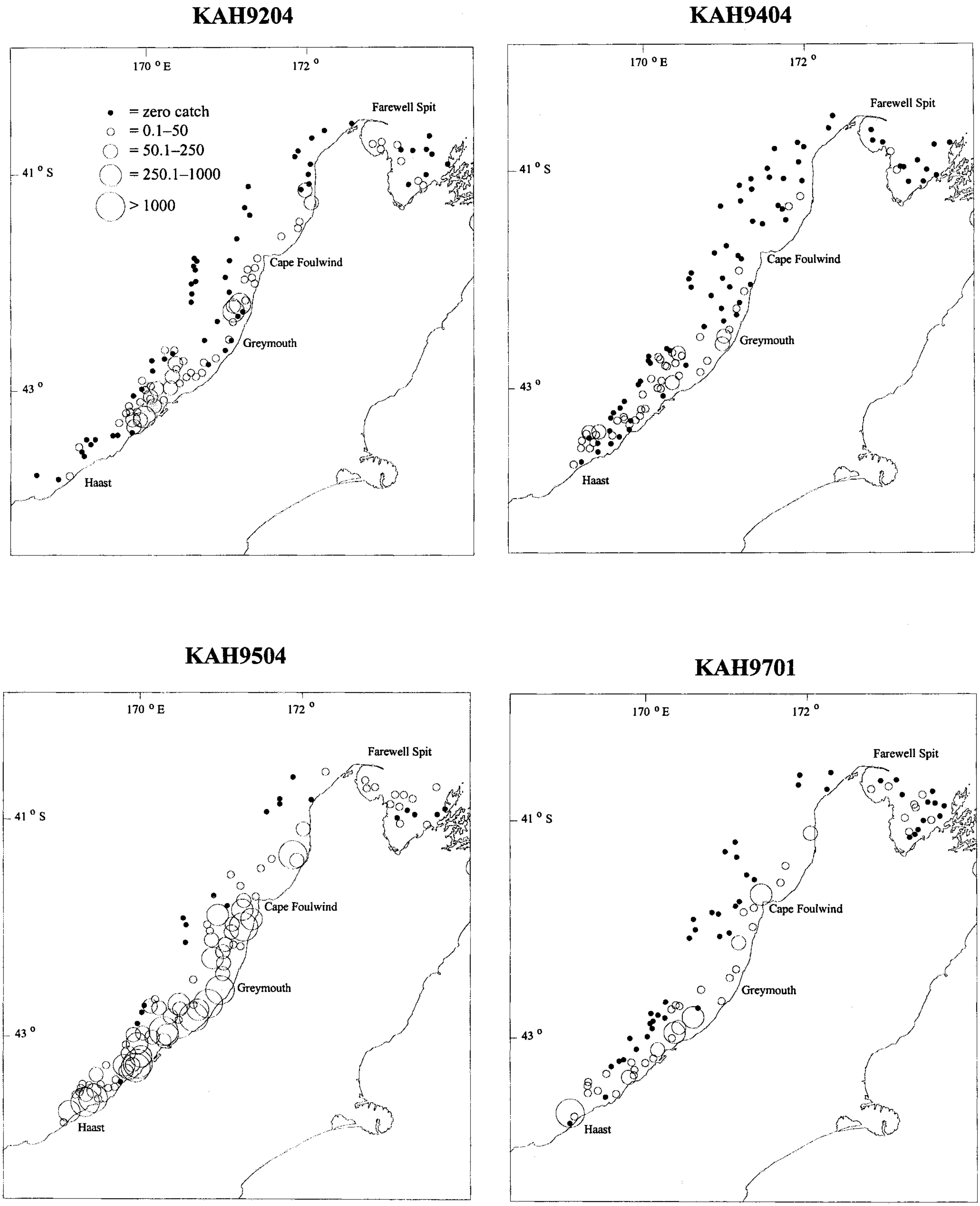


Figure 6e: **Hake (maximum catch rate, 8849 kg.km^{-2}).**

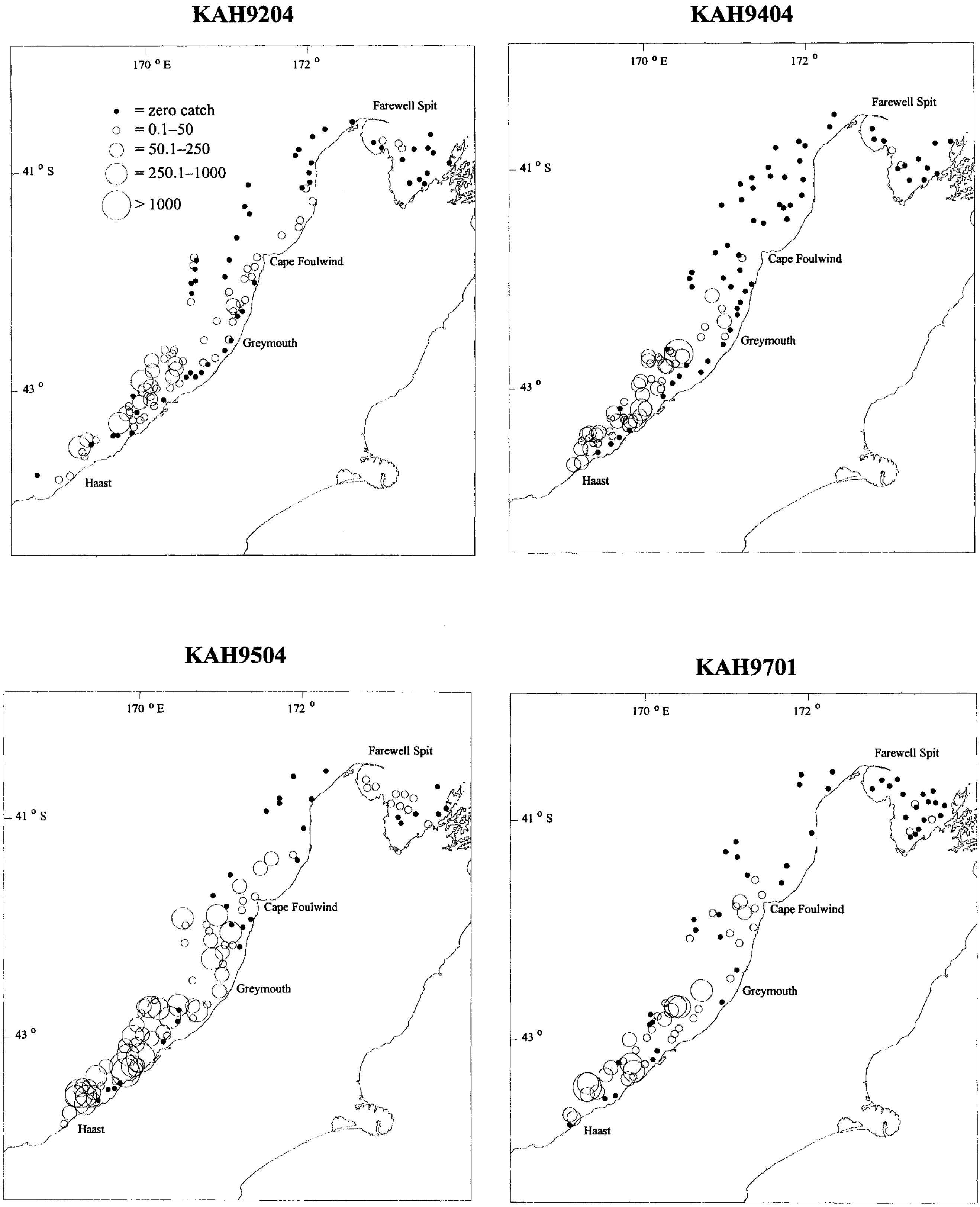


***Figure 6f*: Hoki (maximum catch rate, 4958 kg.km^{-2}).**

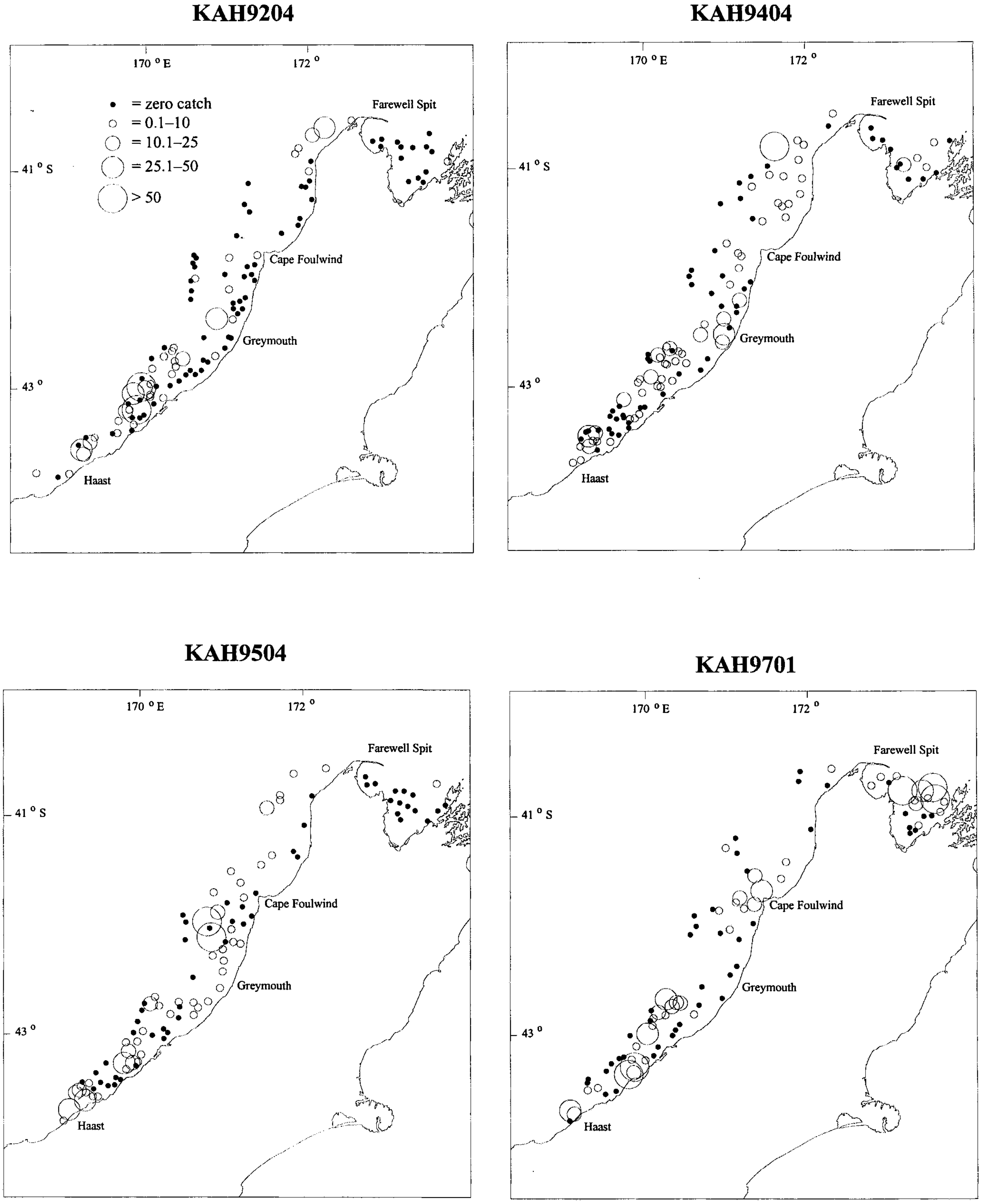


***Figure 6g*: Jack mackerel (*Trachurus declivis*) (maximum catch rate, 4958 kg.km $^{-2}$).**

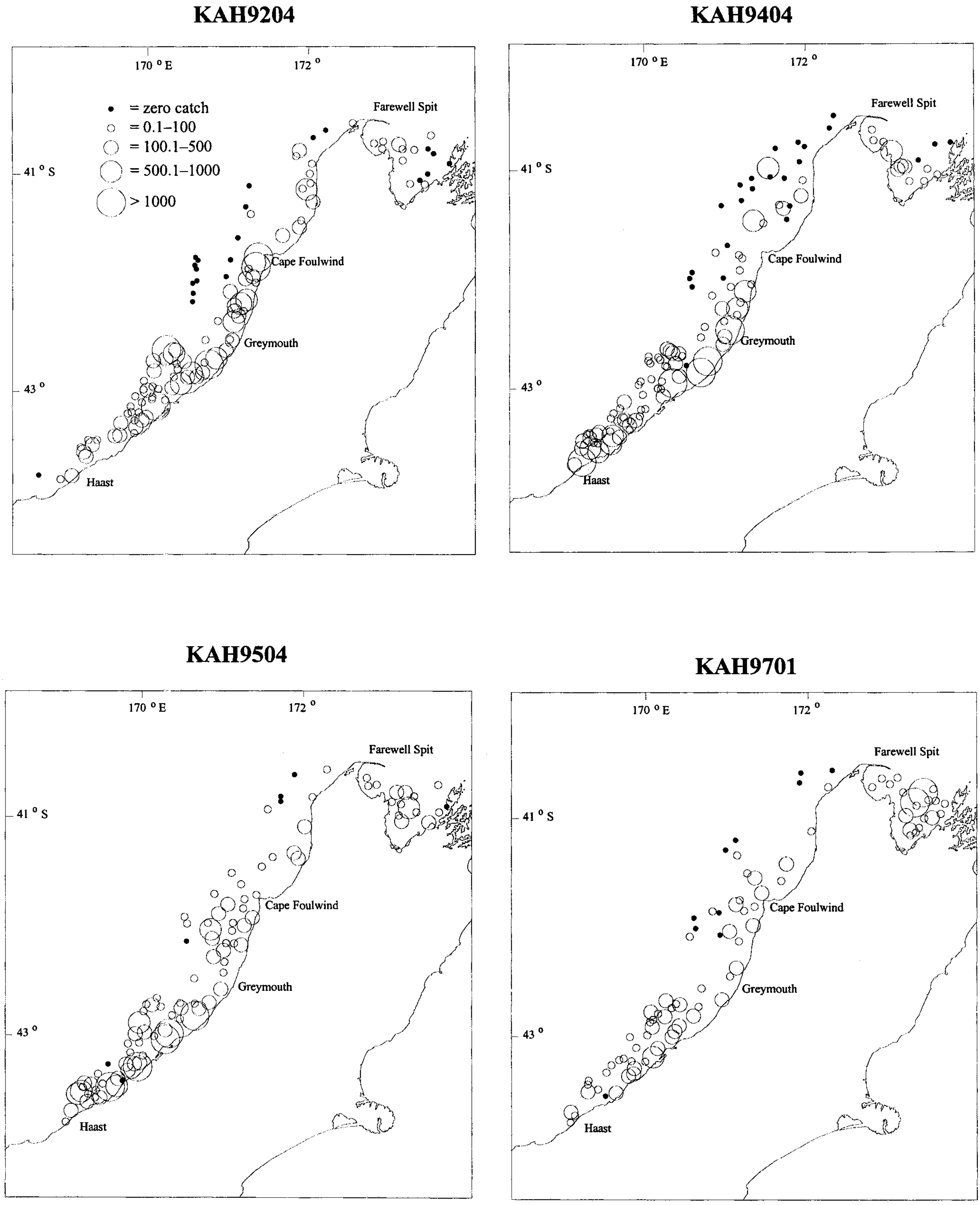


***Figure 6h*: Red cod (maximum catch rate, 3534 kg.km^{-2}).**

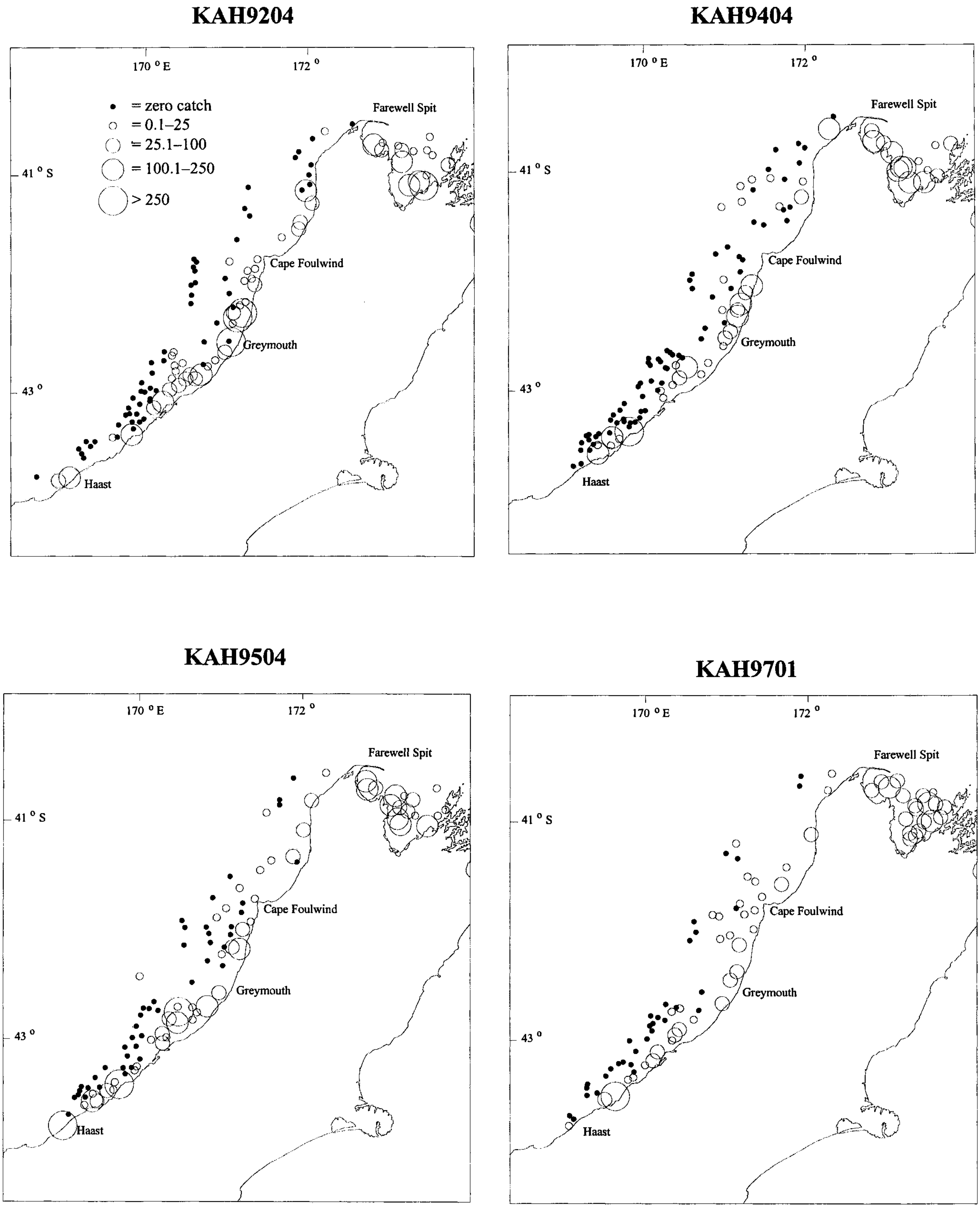


Figure 6i : **Red gurnard (maximum catch rate, 773 kg.km⁻²).**

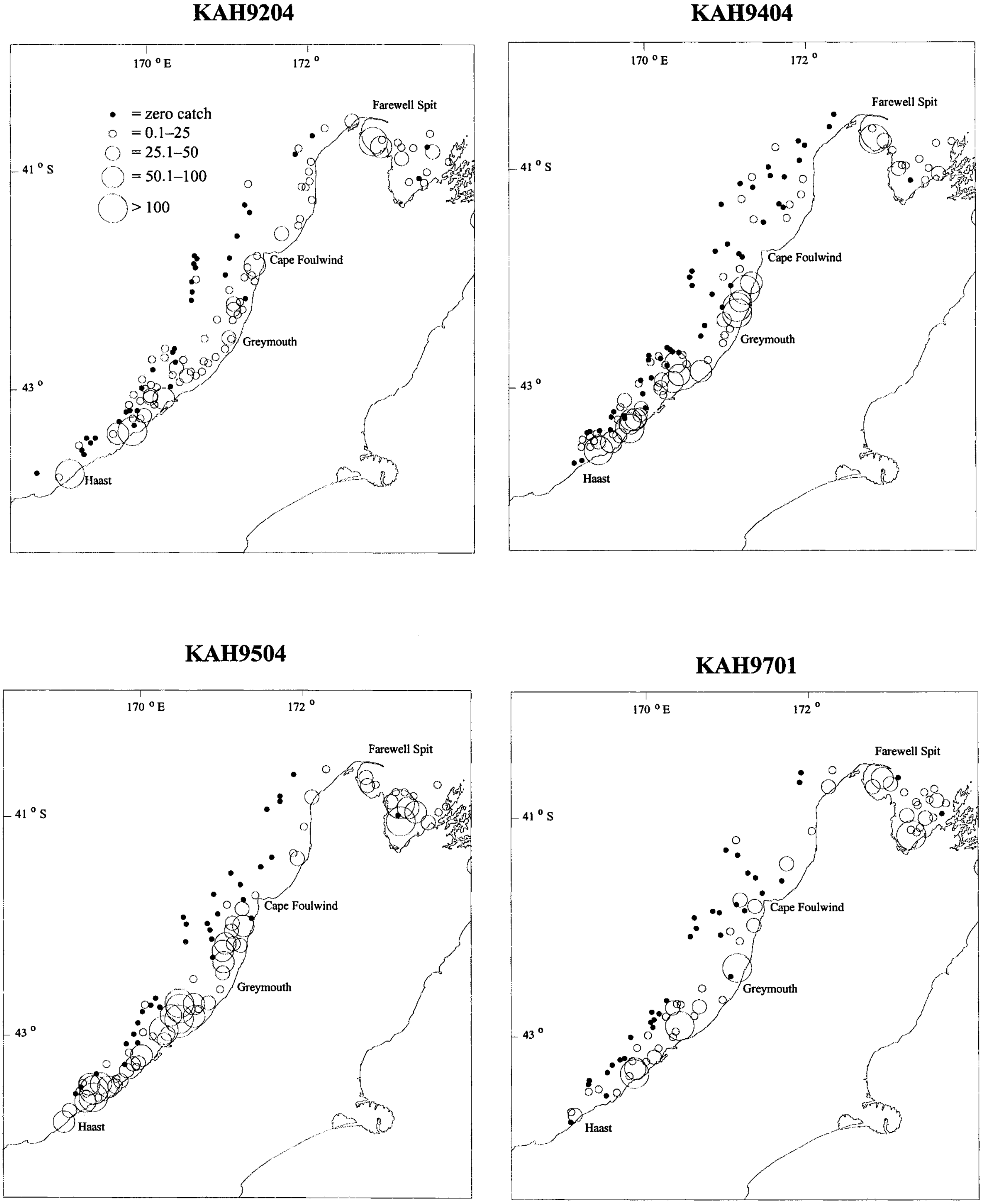


Figure 6j : **Rig (maximum catch rate, 369 kg.km^{-2}).**

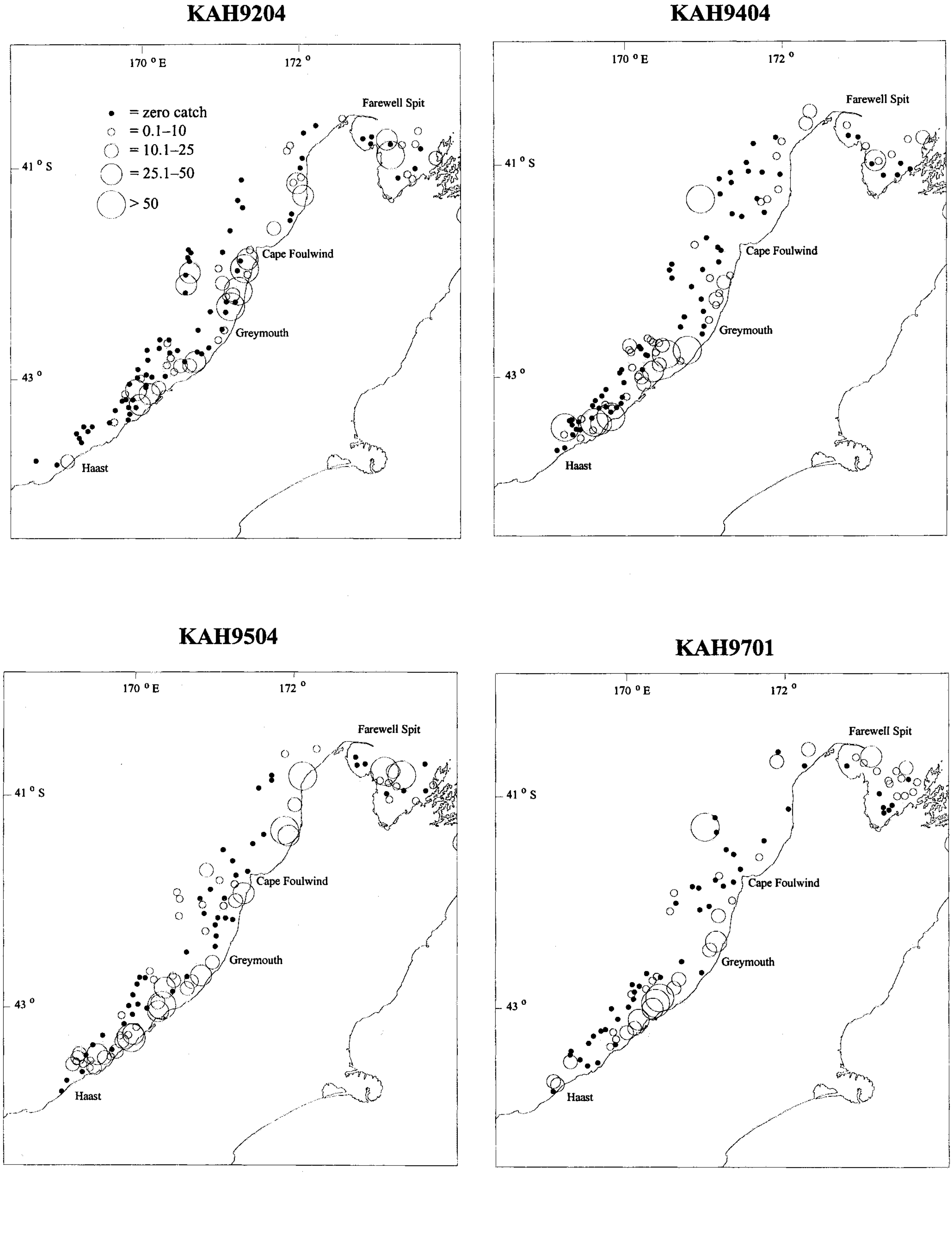


***Figure 6k*: Rough skate (maximum catch rate, 185 kg.km^{-2}).**

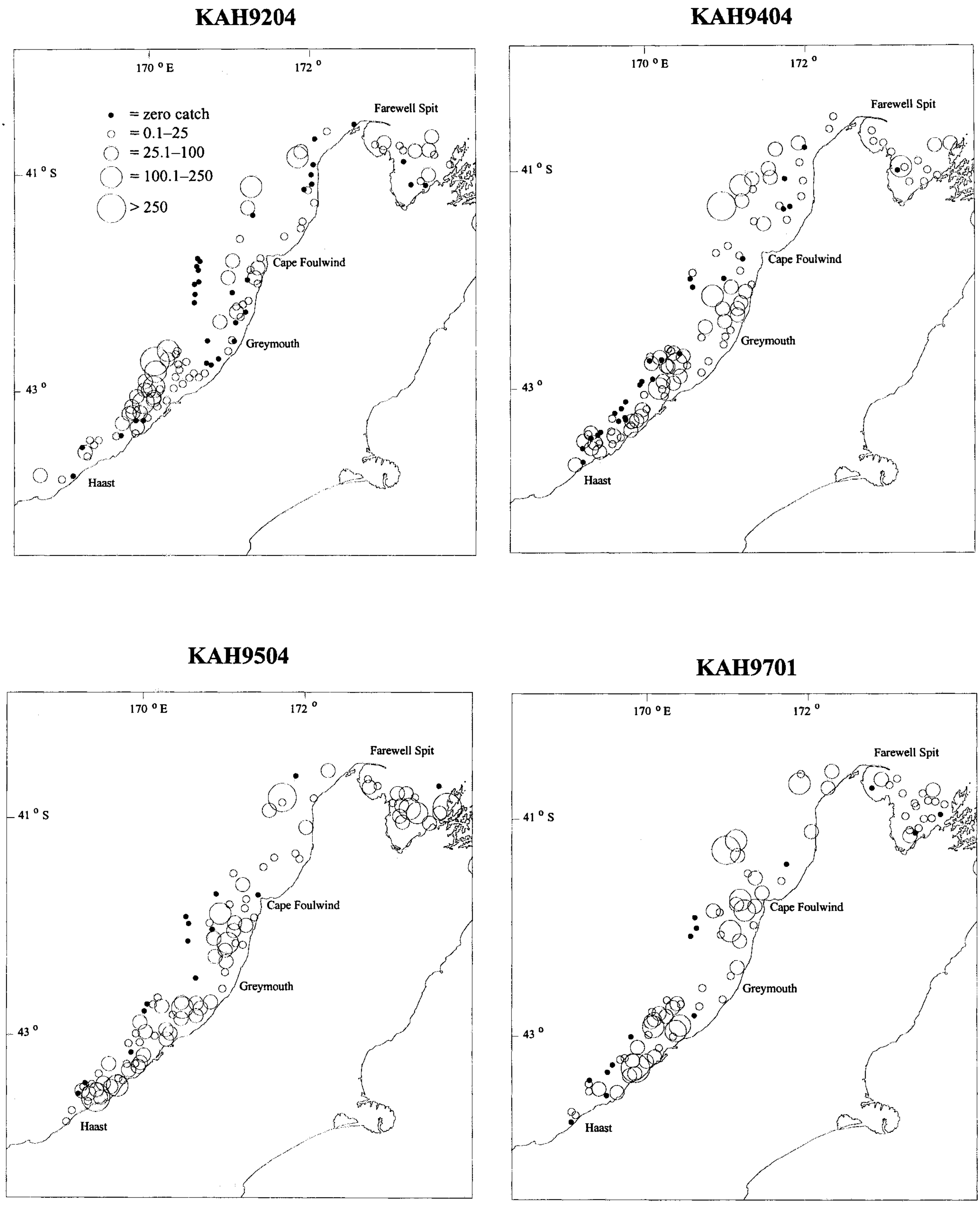


Figure 6l**: School shark (maximum catch rate, 1026 kg.km^{-2}).**

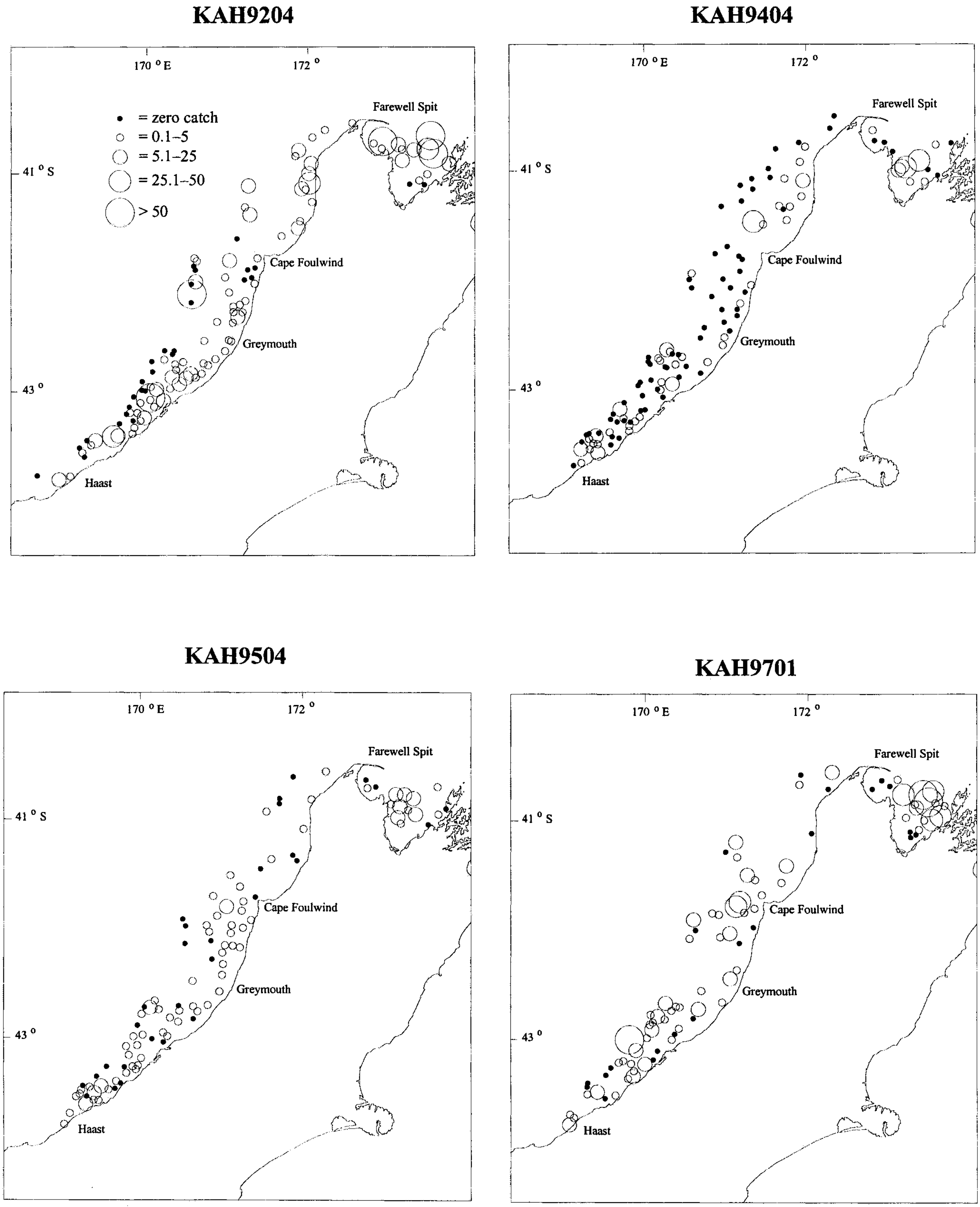
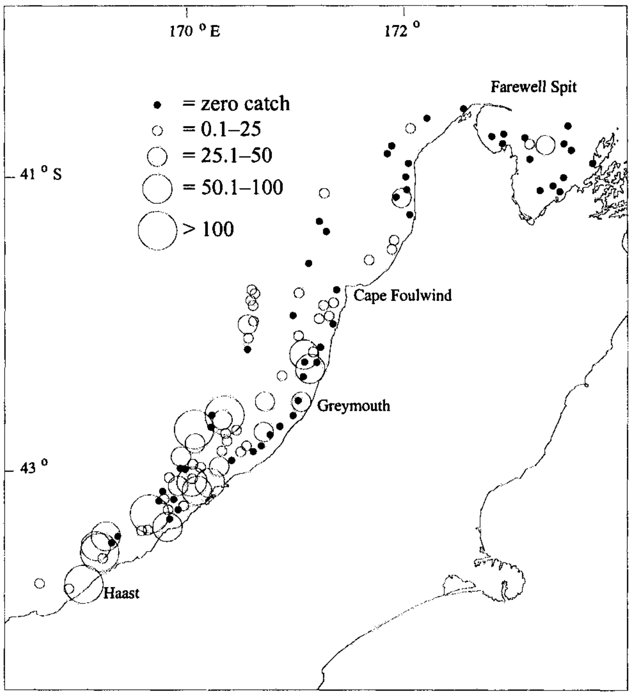


Figure 6m**: Silver warehou (maximum catch rate, 361 kg.km $^{-2}$).**

KAH9204



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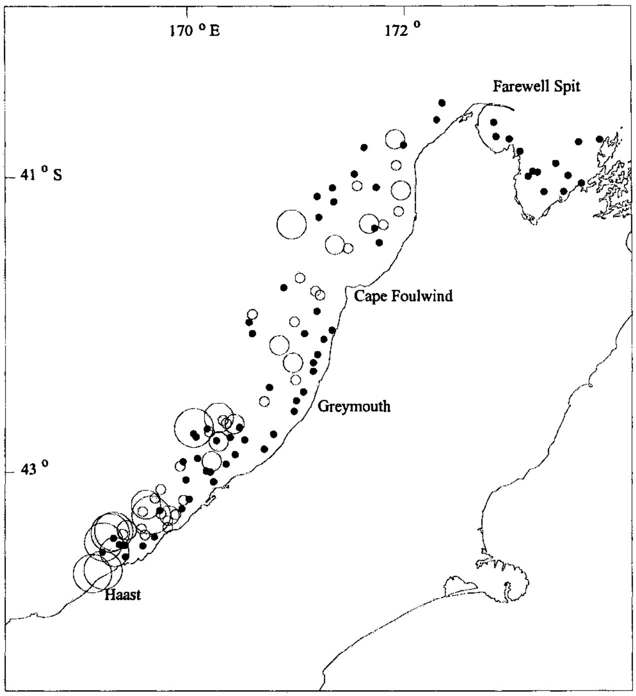

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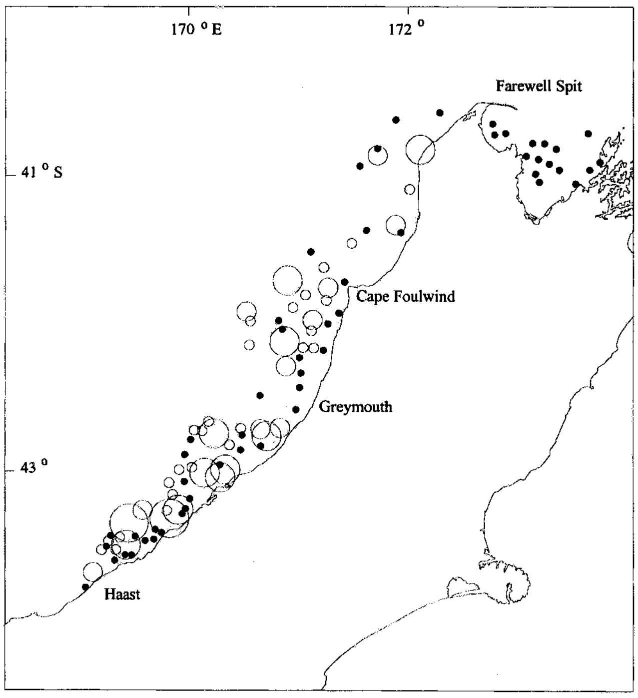

KAH9701

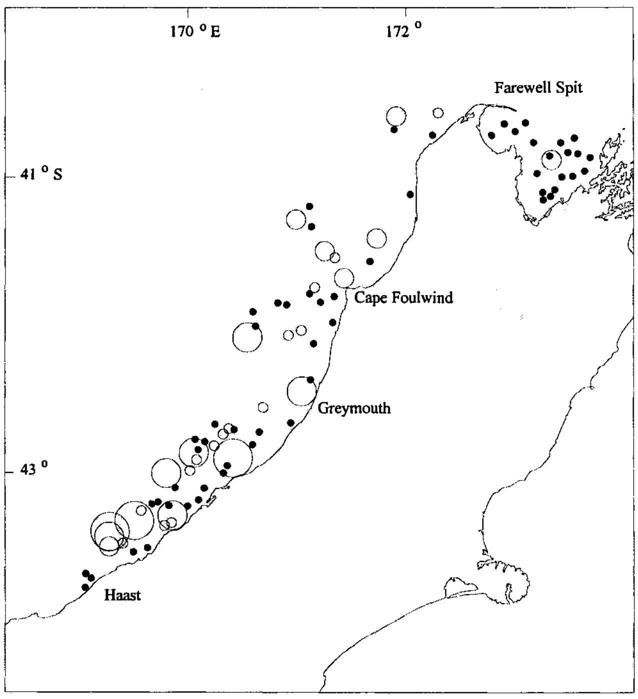

***Figure 6n*: Smooth skate (maximum catch rate, 289 kg.km^{-2}).**

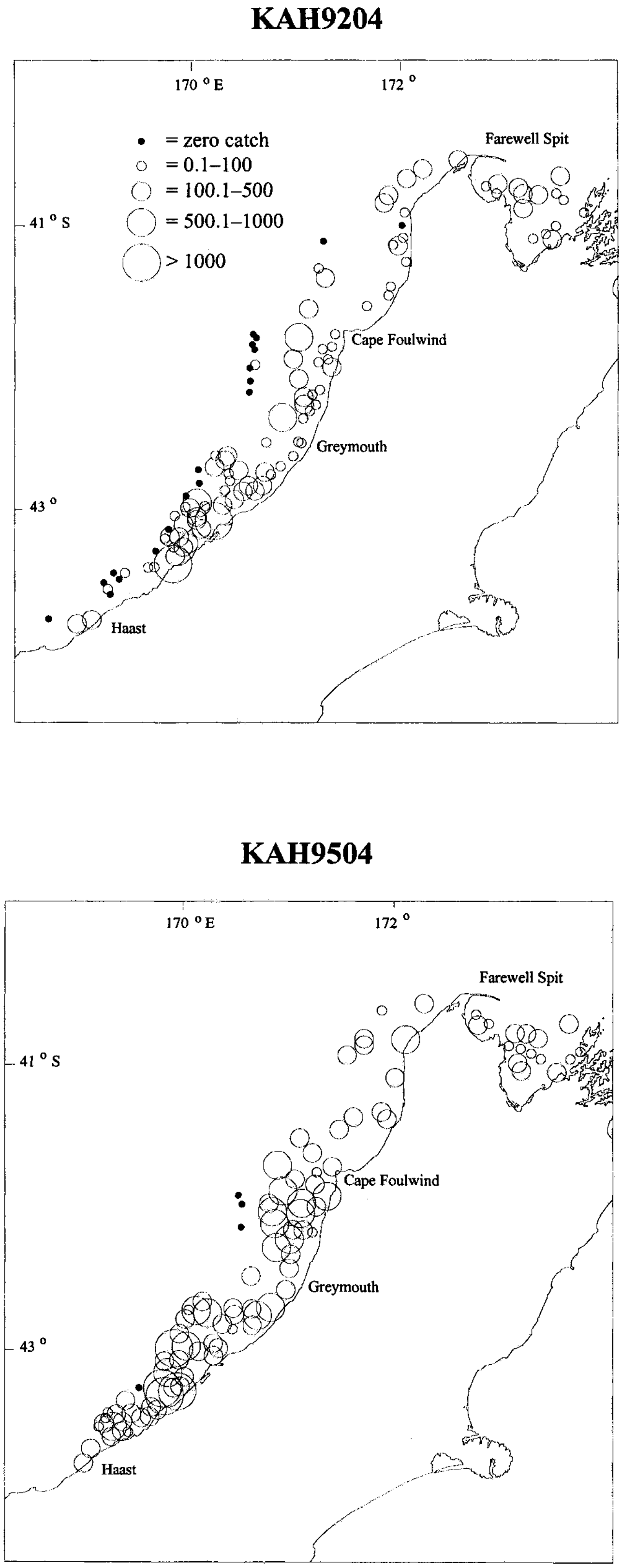

***Figure 6o*: Spiny dogfish (maximum catch rate, 2900 kg.km^{-2}).**

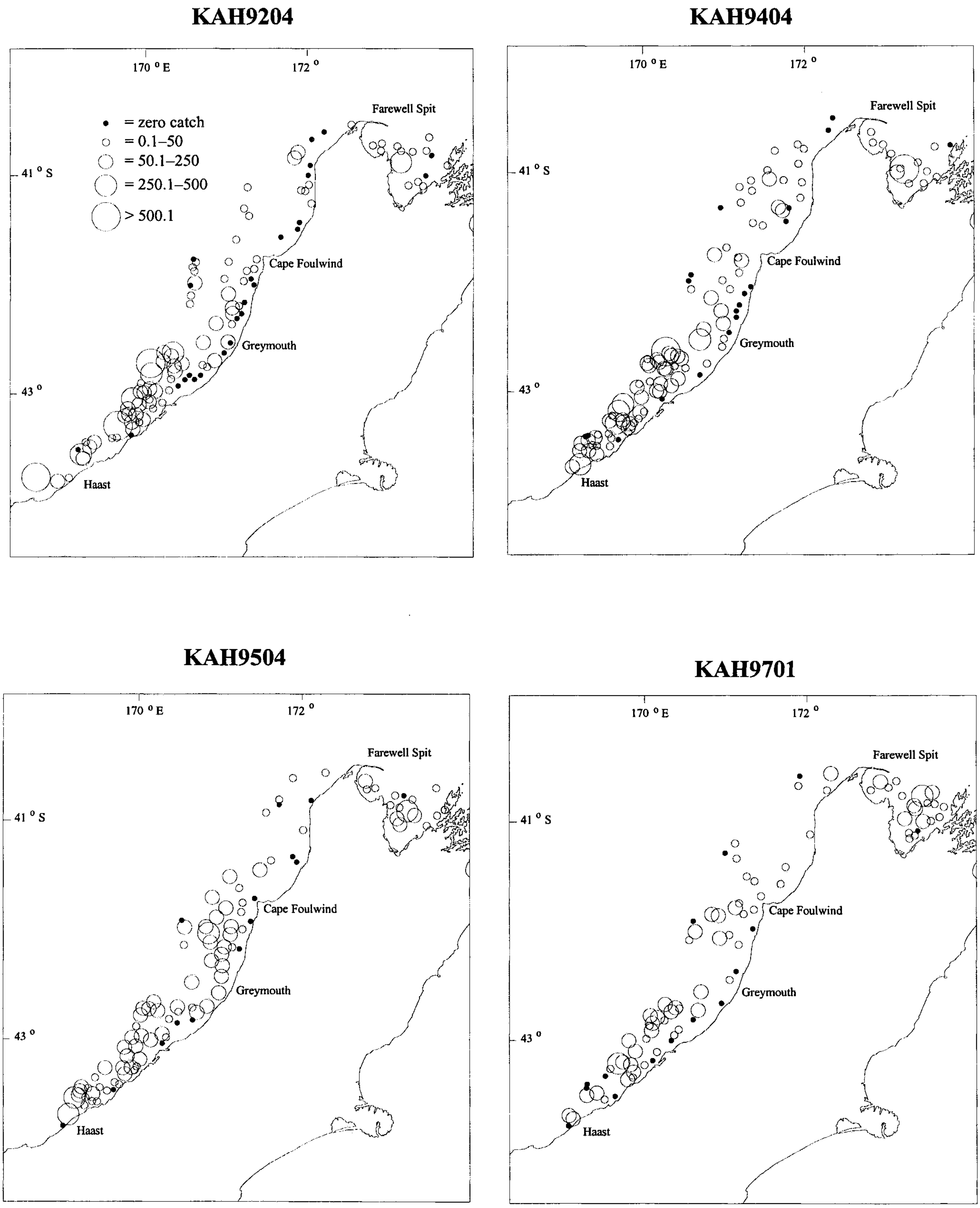

Figure 6p: **Tarakihi (maximum catch rate, 909 kg.km^{-2}).**

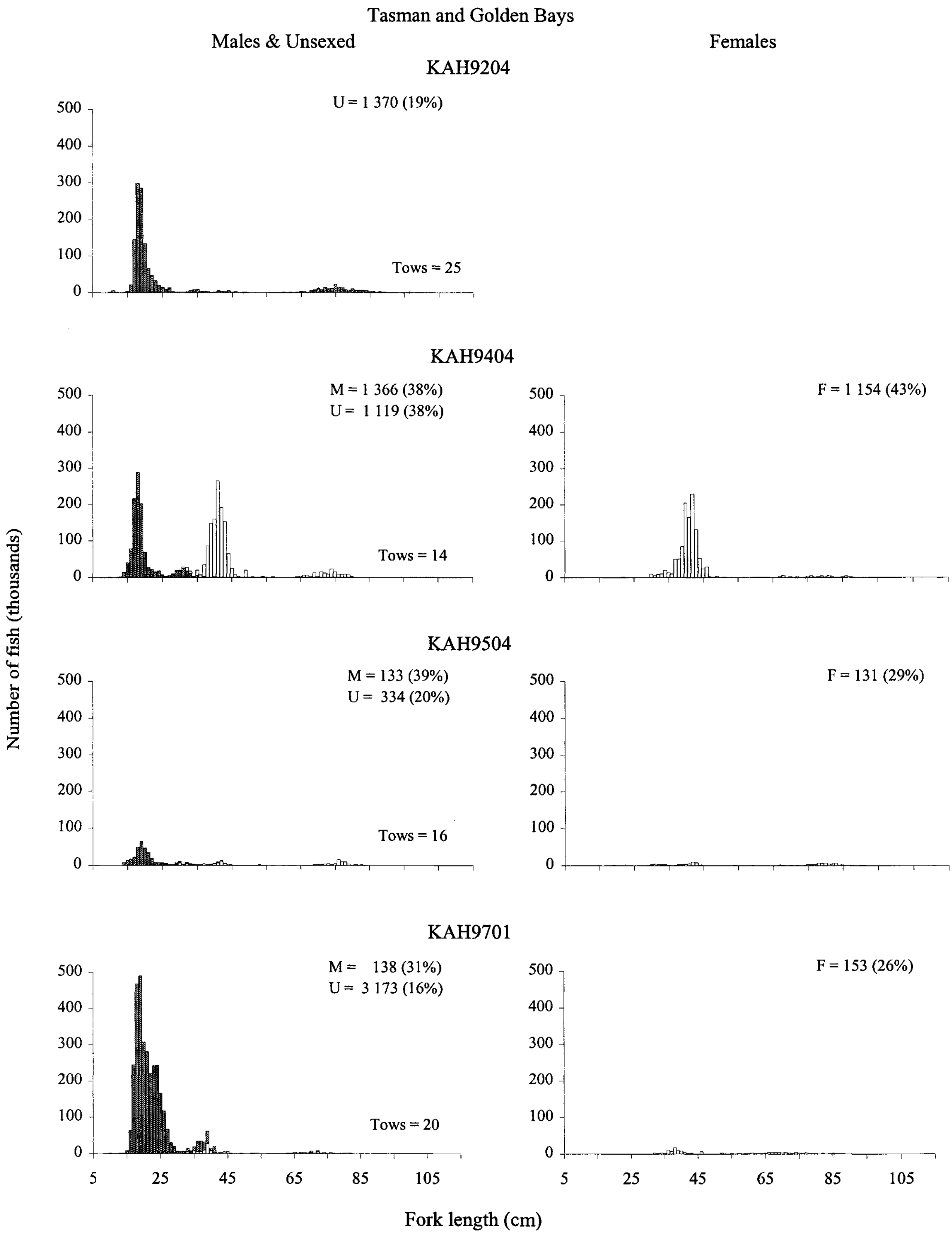

***Figure 7*: Scaled length frequency distributions of the major species, 1992–97, with the estimated total number of fish in the population (thousands) (and percentage coefficient of variation). M, number of males: F, number of females; U, number of unsexed fish; Tows, number of stations at which species was caught. *a*: Barracouta**

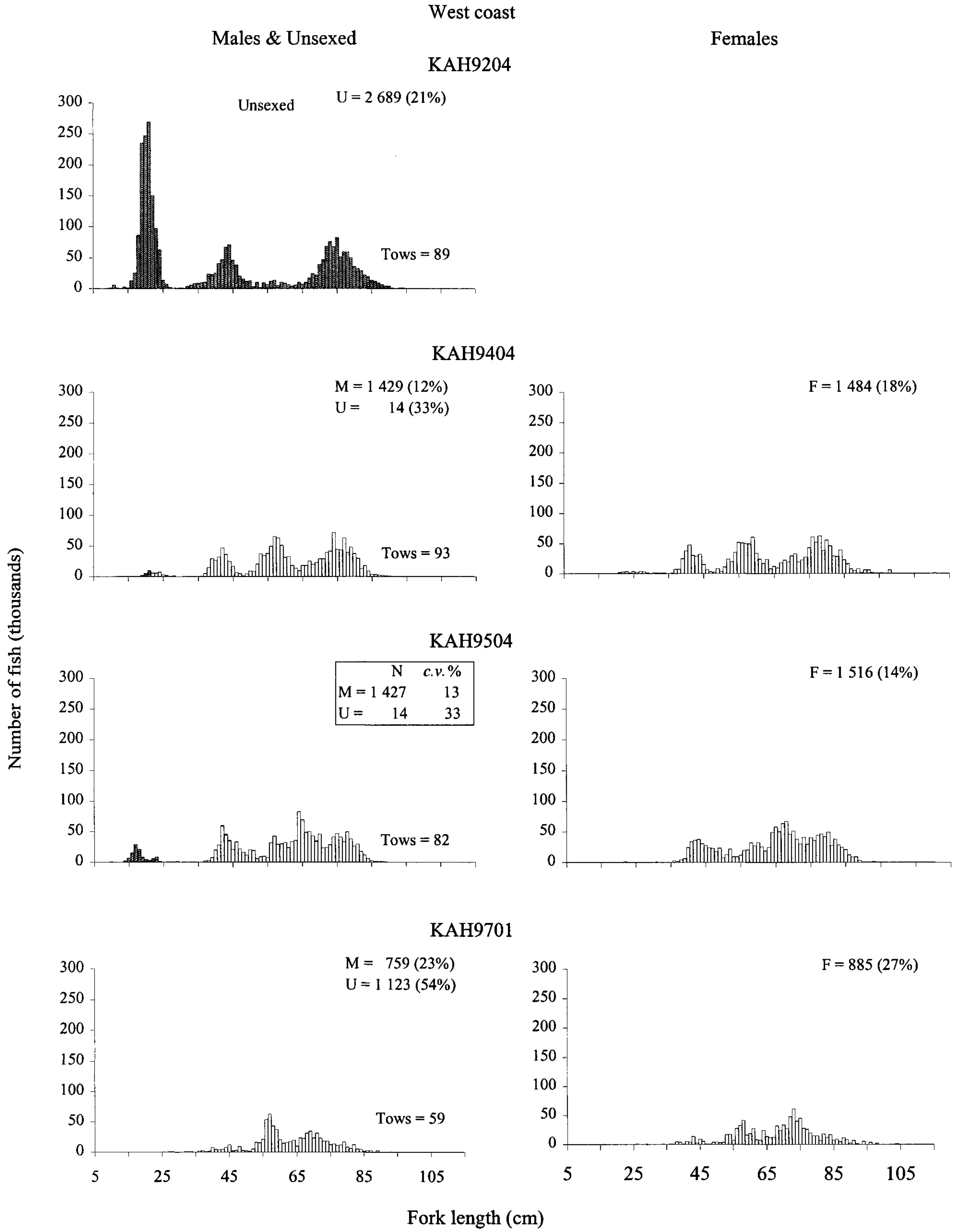

Figure 7a—continued

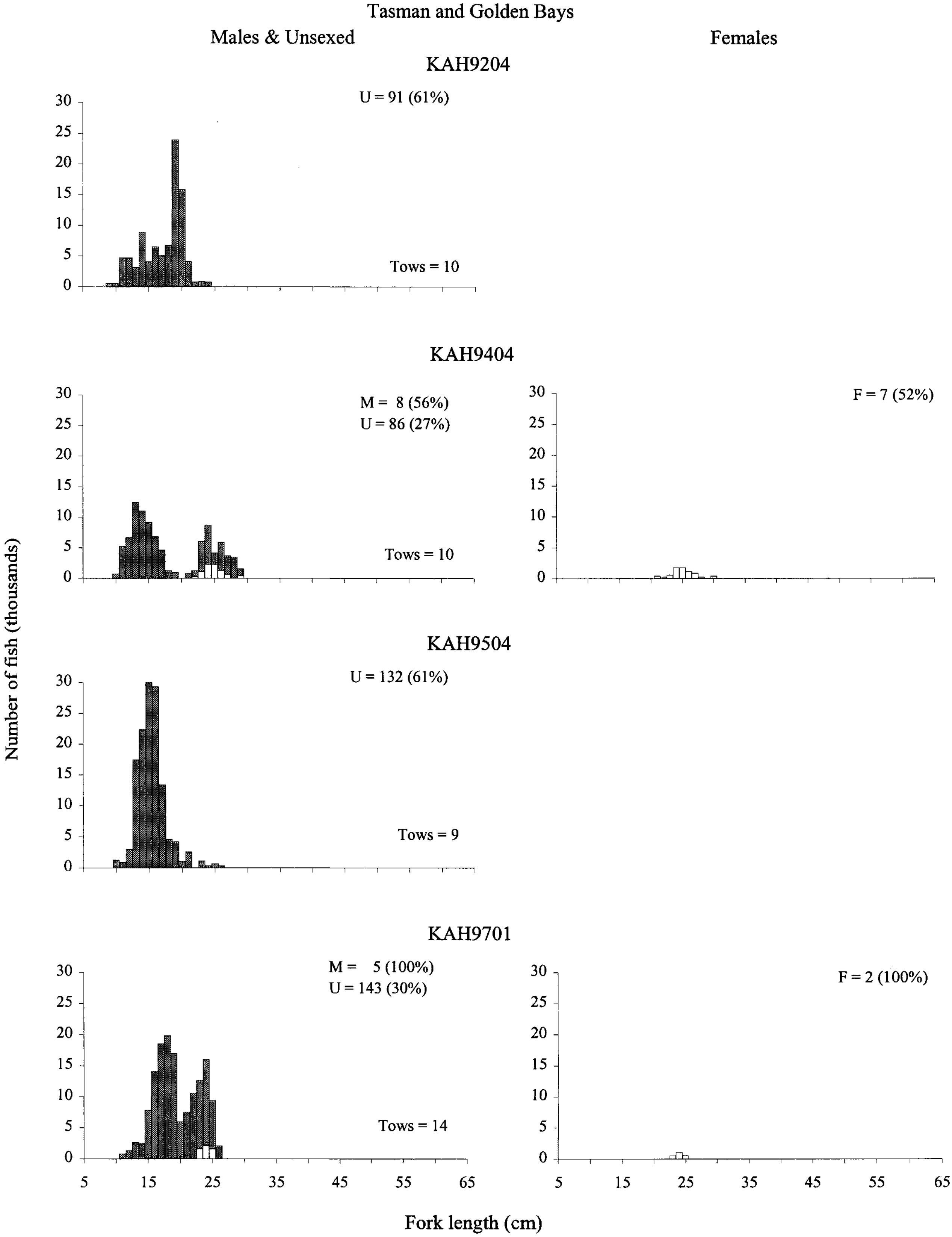

Figure 7b : **Blue warehou**

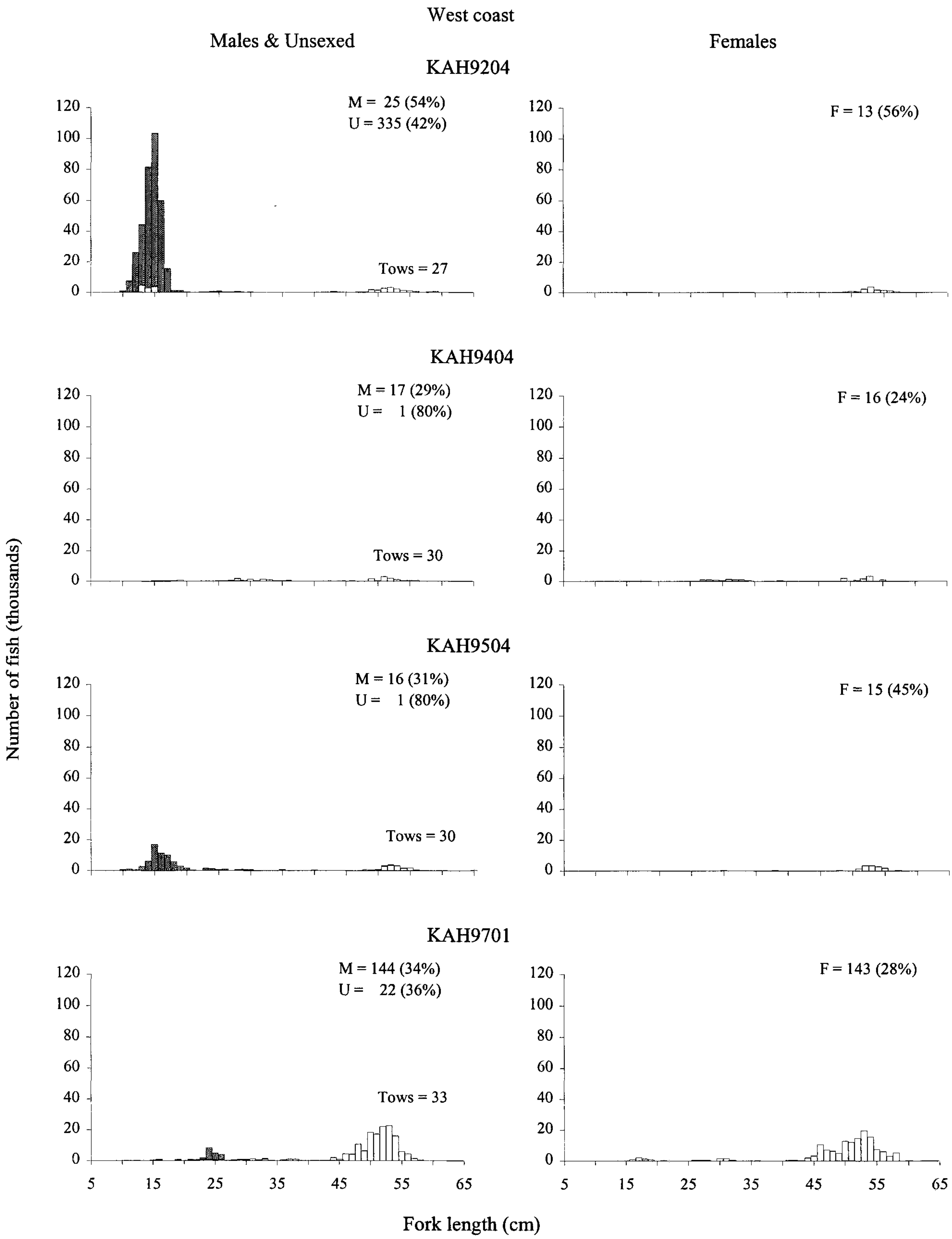

Figure 7b—continued

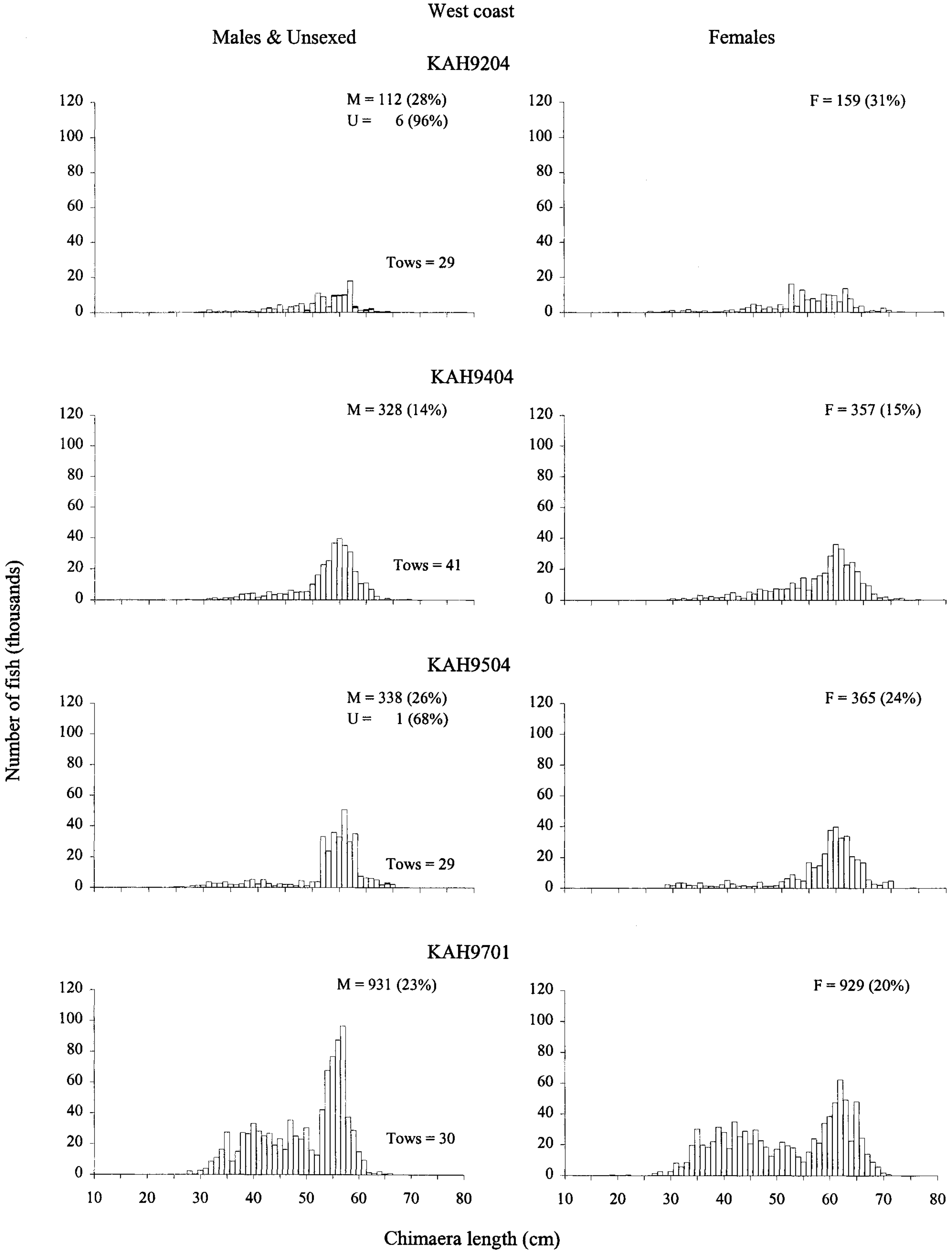

***Figure 7c*: Dark ghost shark**

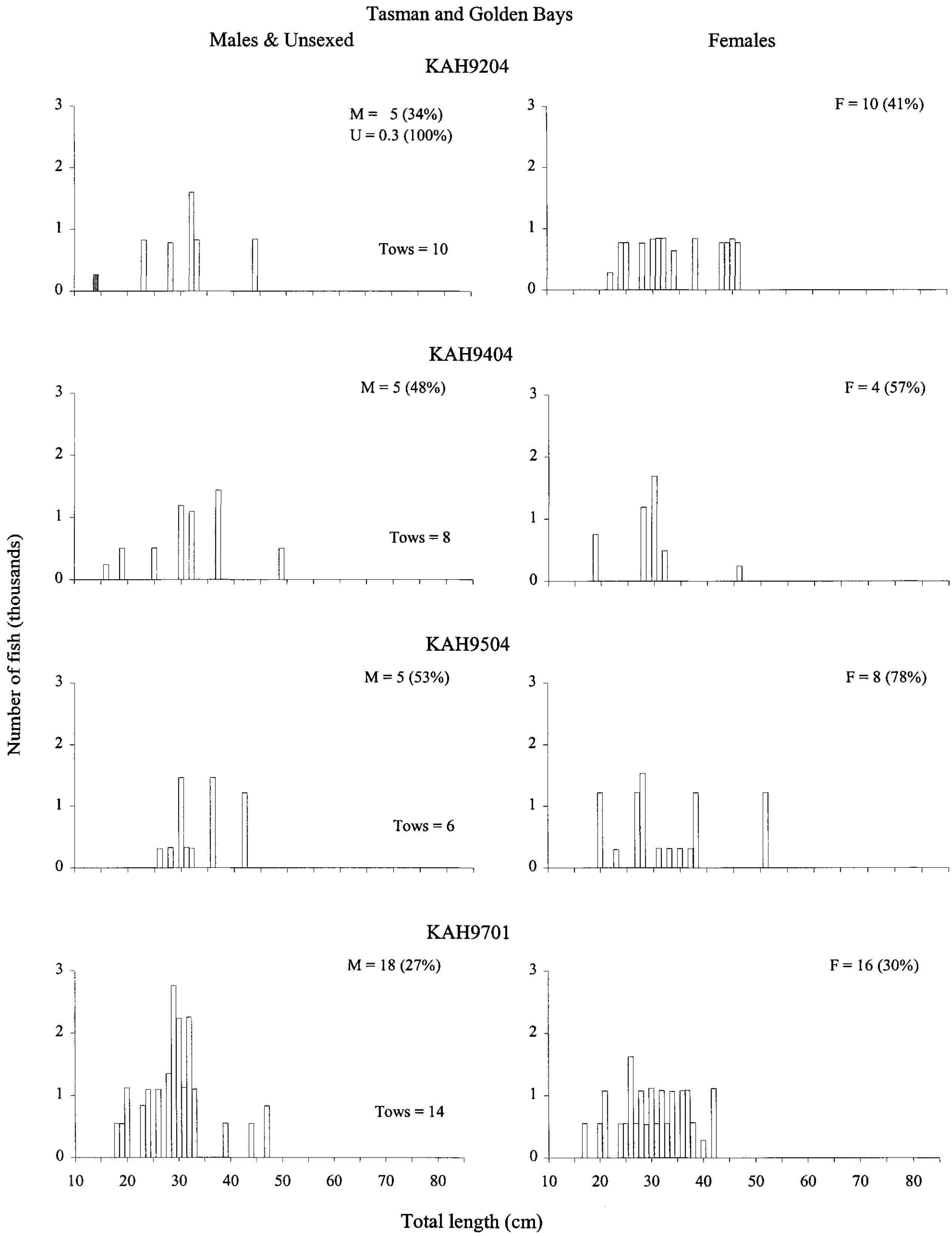

Figure 7d **: Giant stargazer**

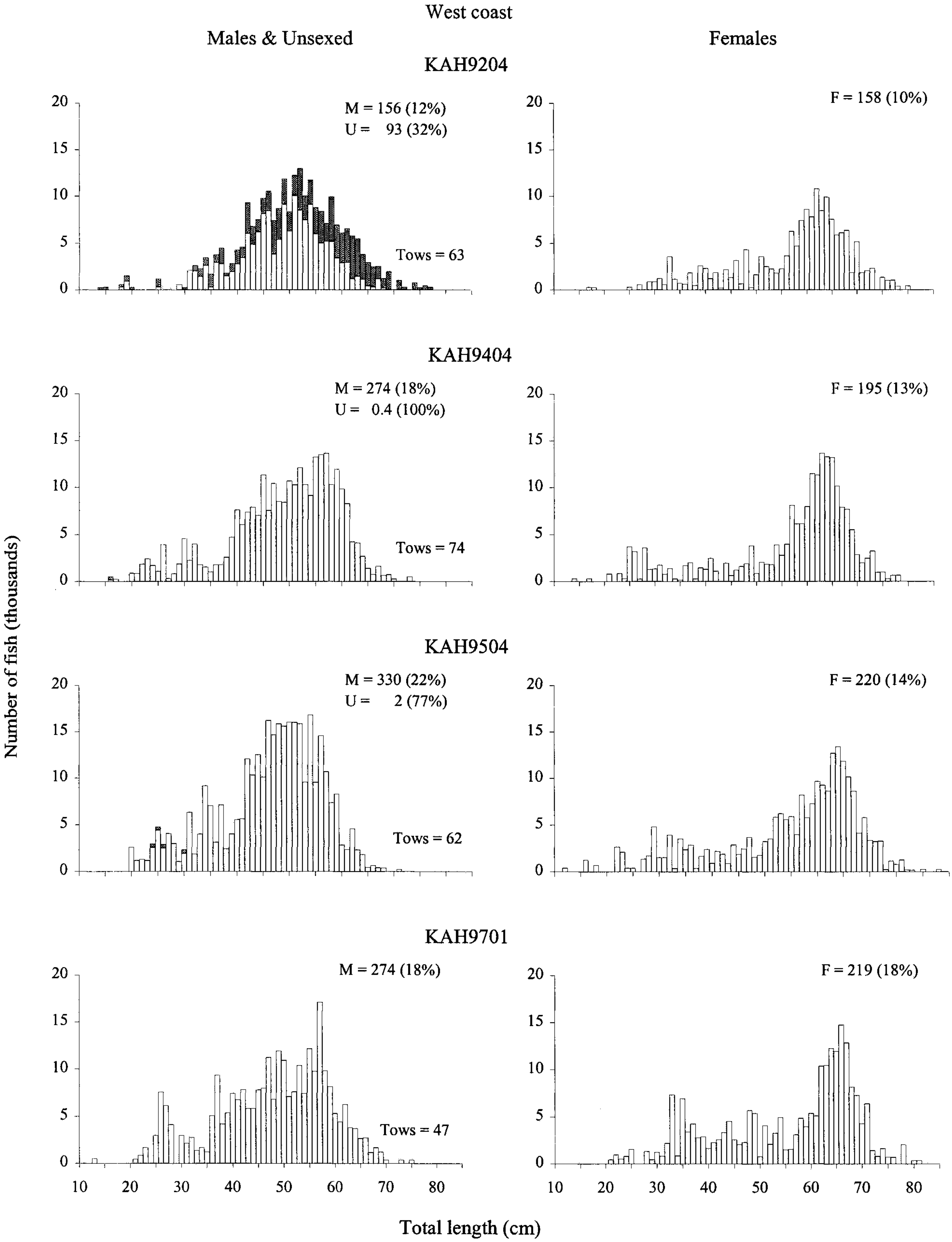

Figure 7d—continued

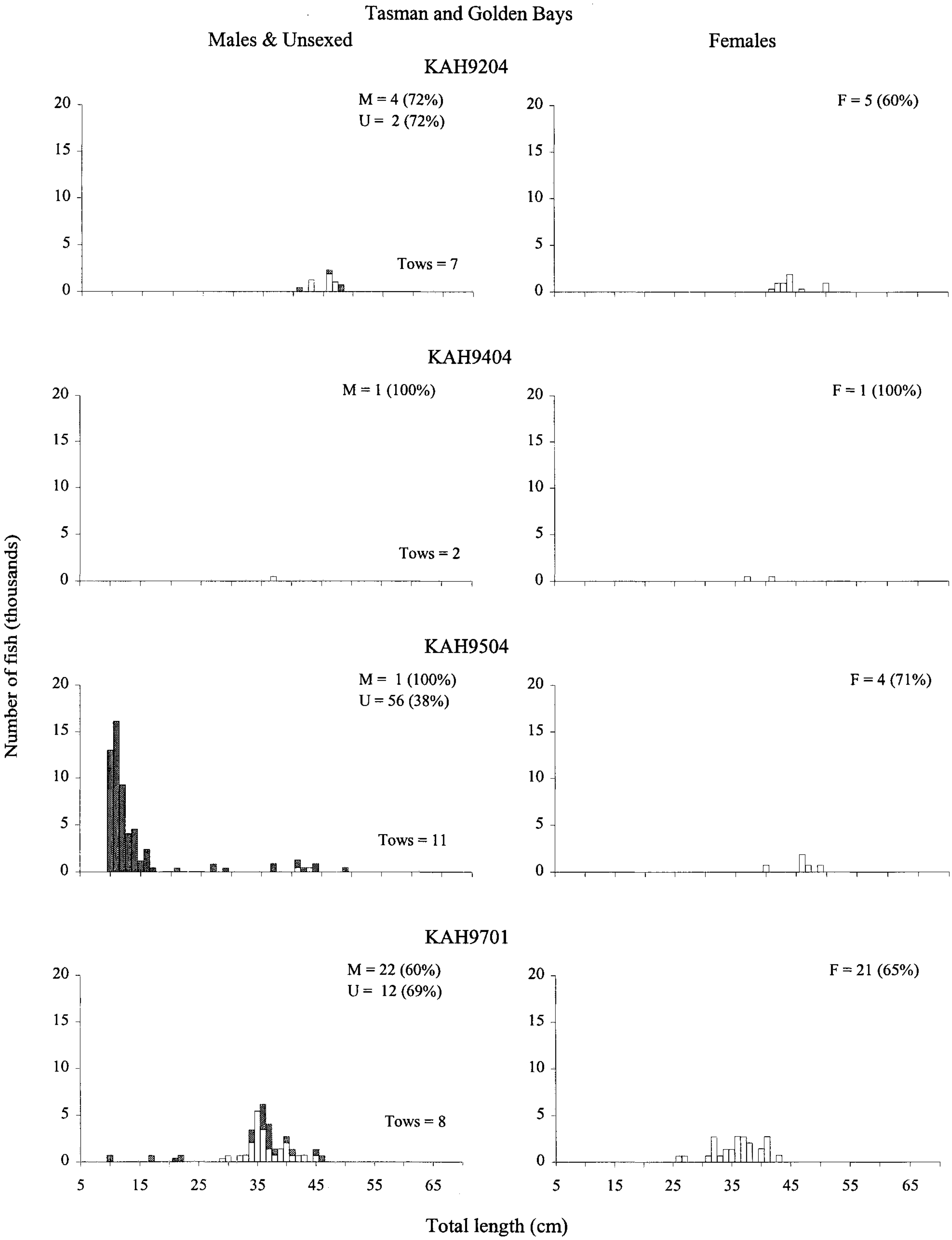

***Figure 7e*:** **Hake**

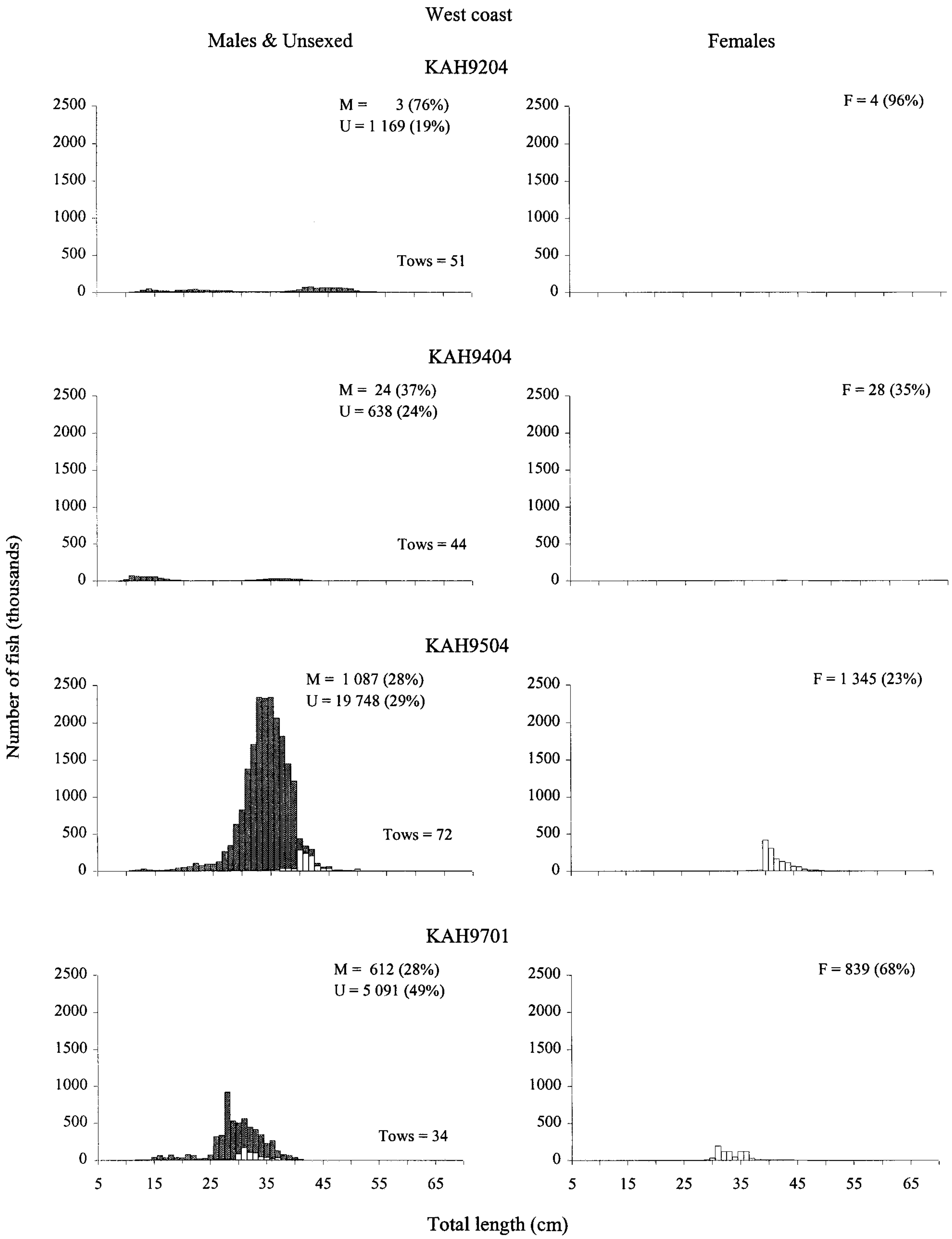

Figure 7e—continued

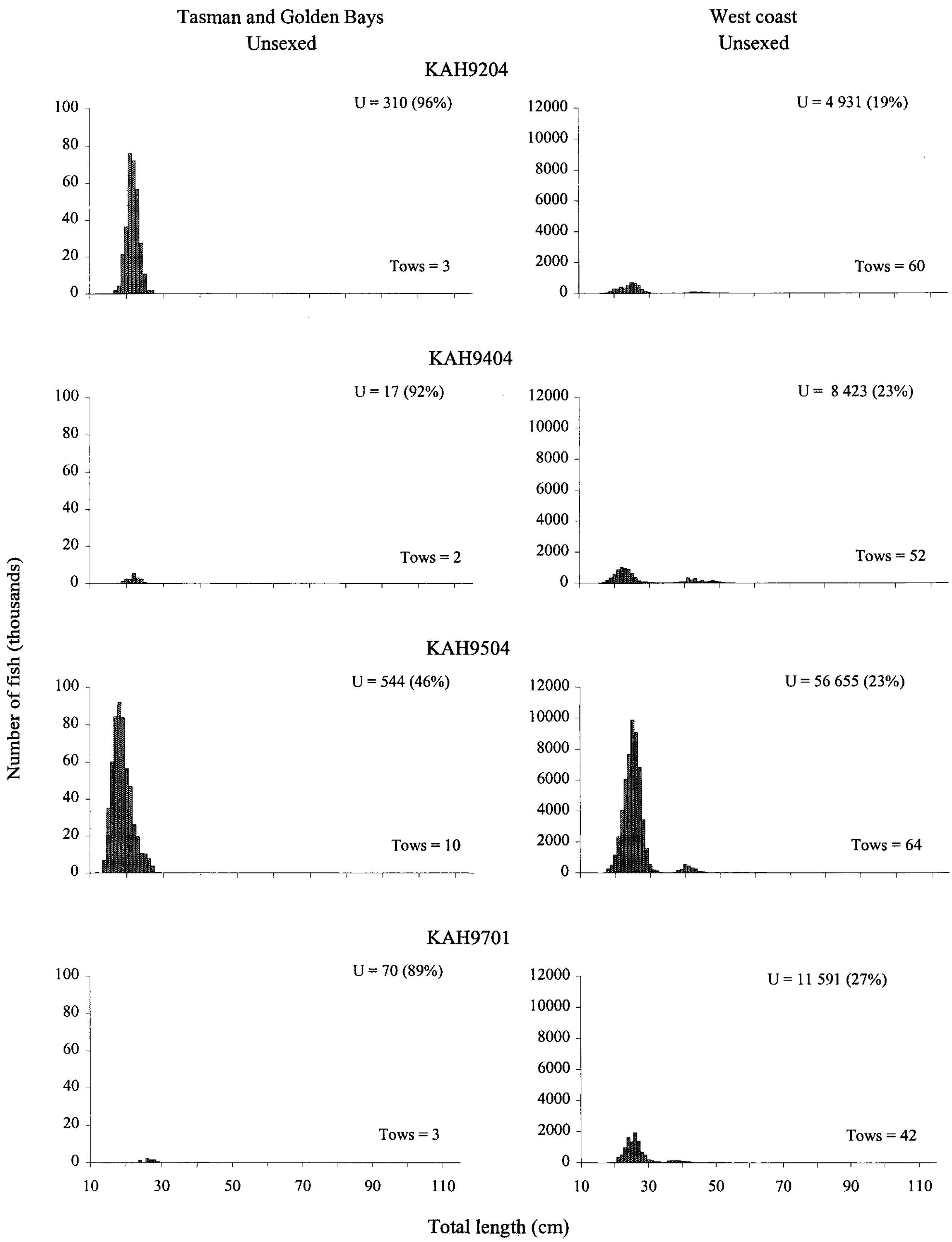

***Figure 7f*: Hoki**

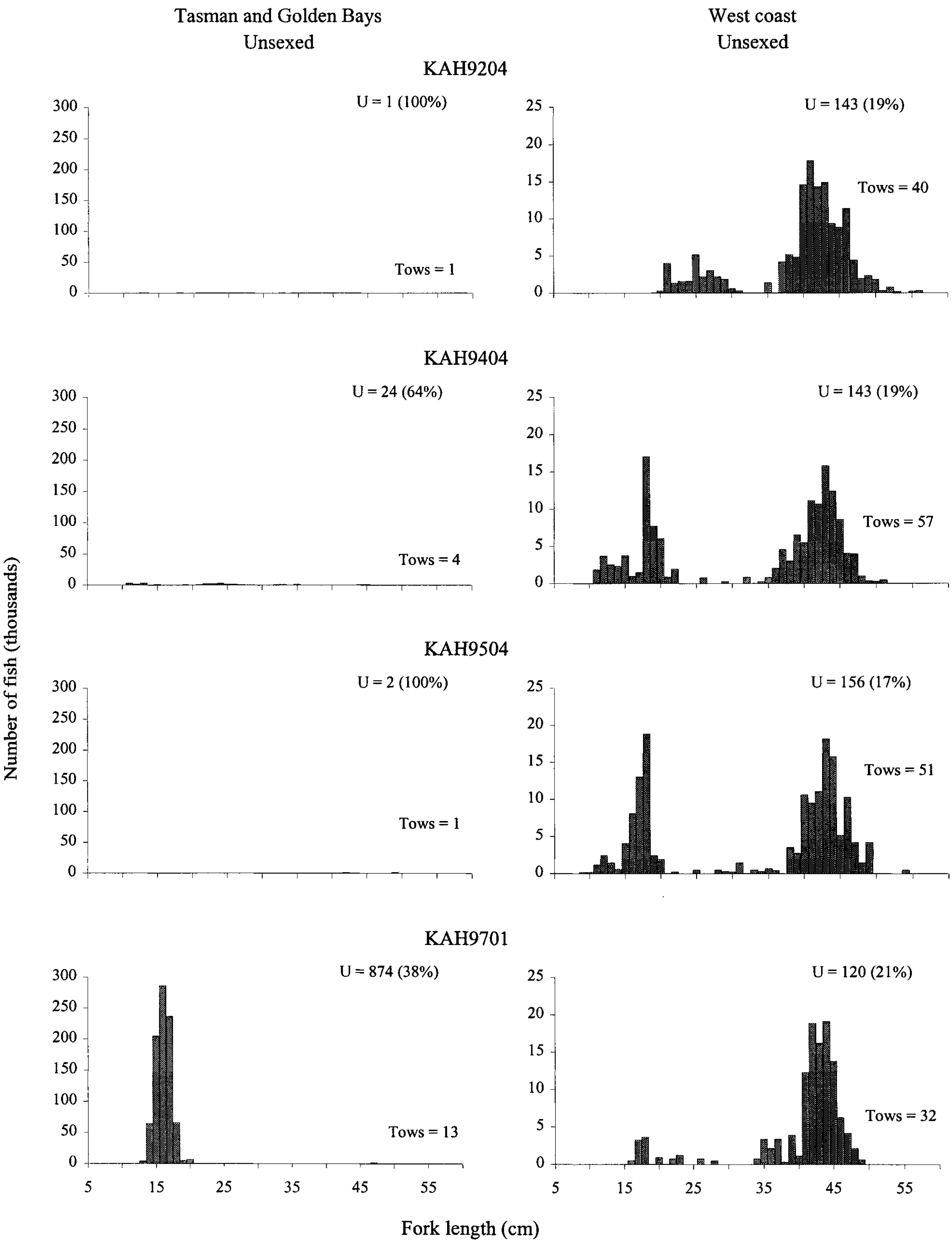

***Figure 7g*: Jack mackerel (*Trachurus declivis*).**

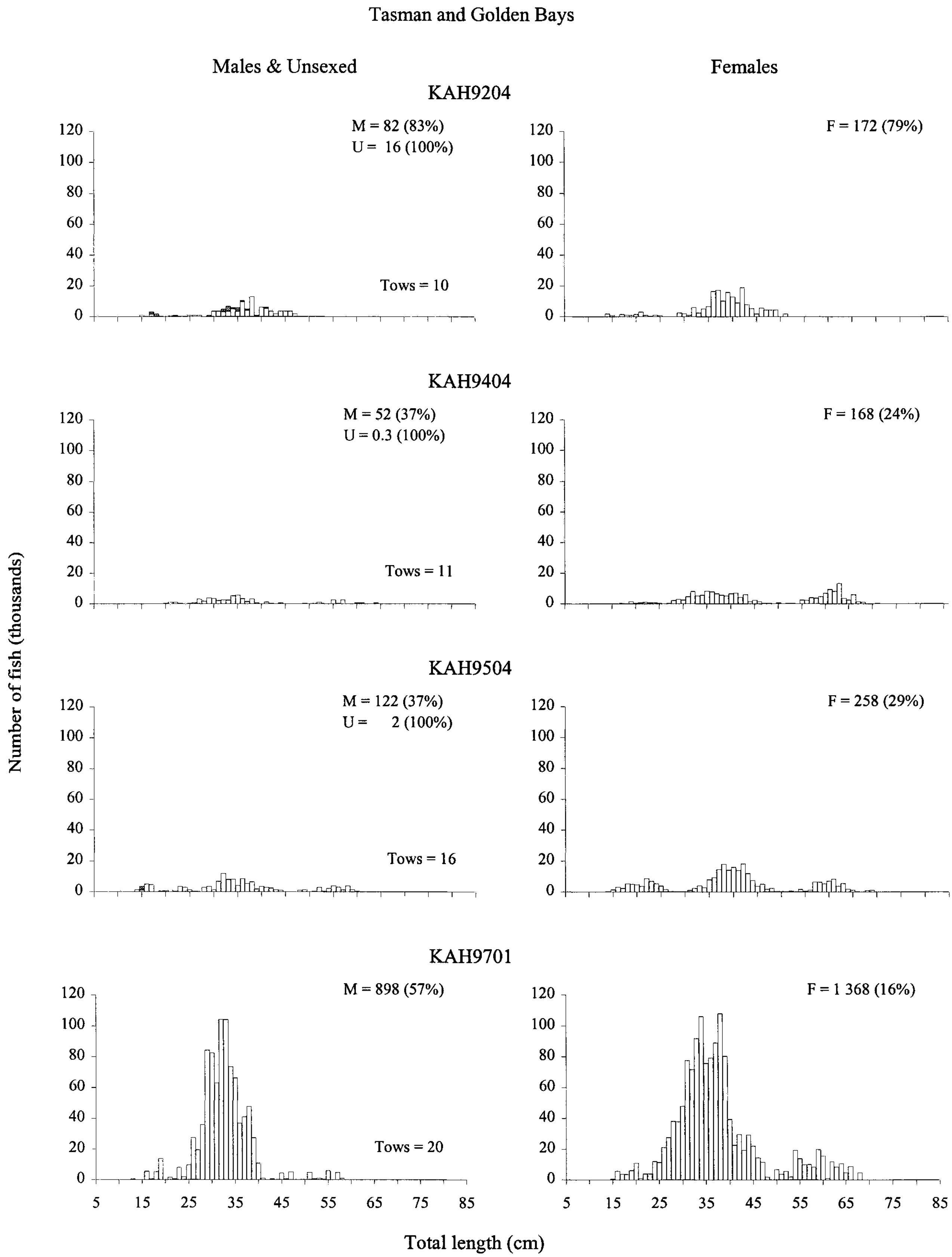

Figure 7h : **Red cod**

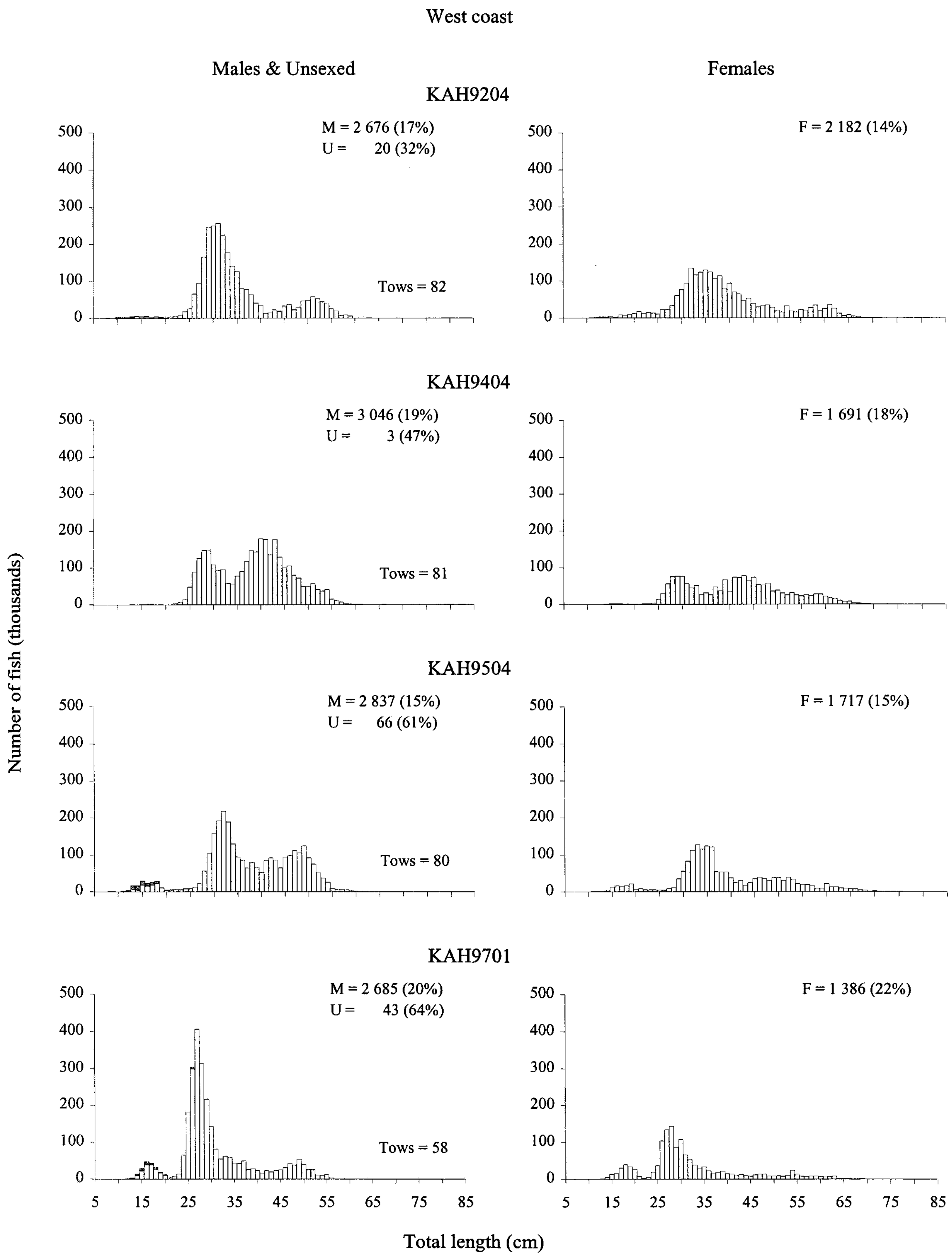

Figure 7h—continued

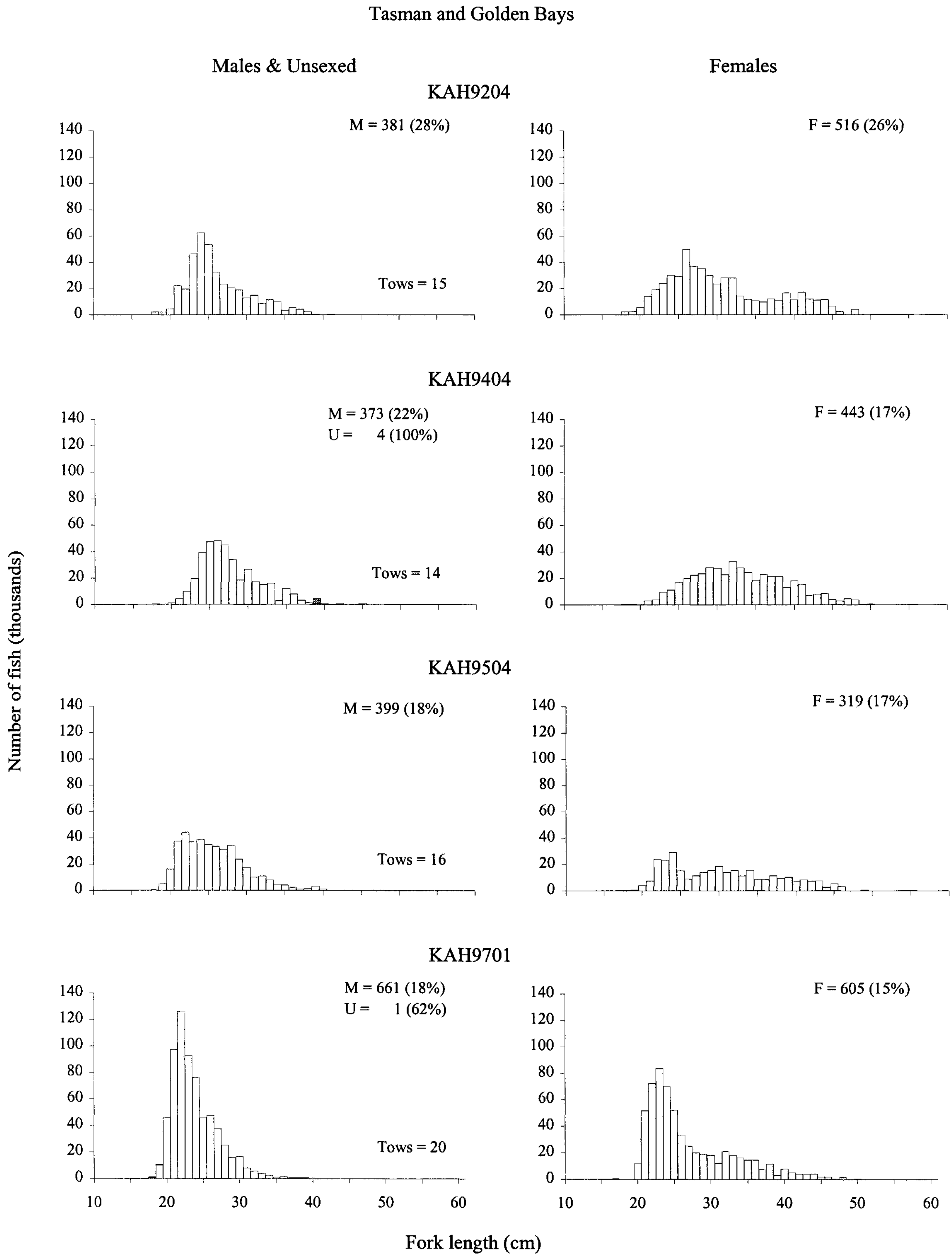

***Figure 7i*: Red gurnard**

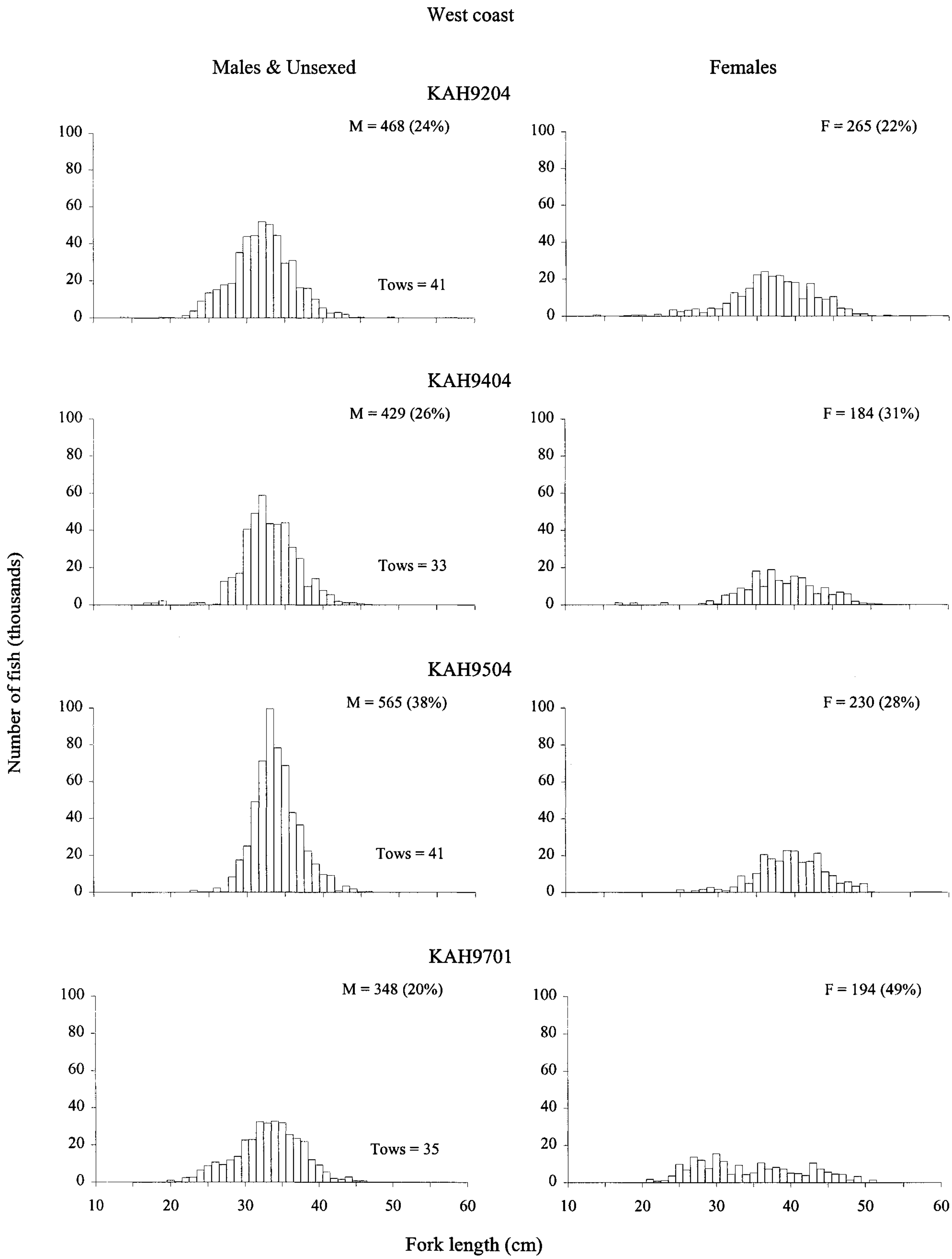

Figure 7i—continued

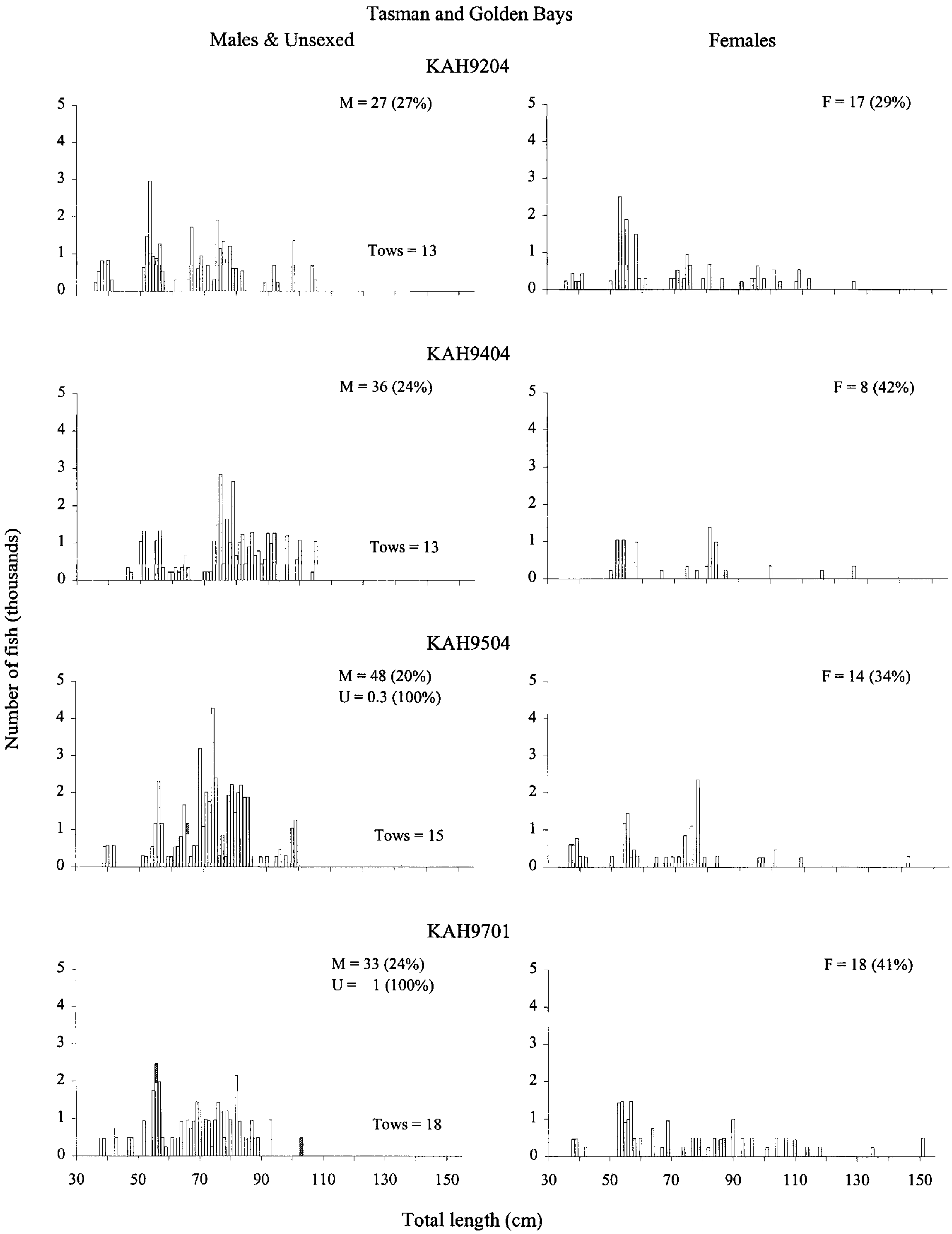

***Figure 7j*: Rig**

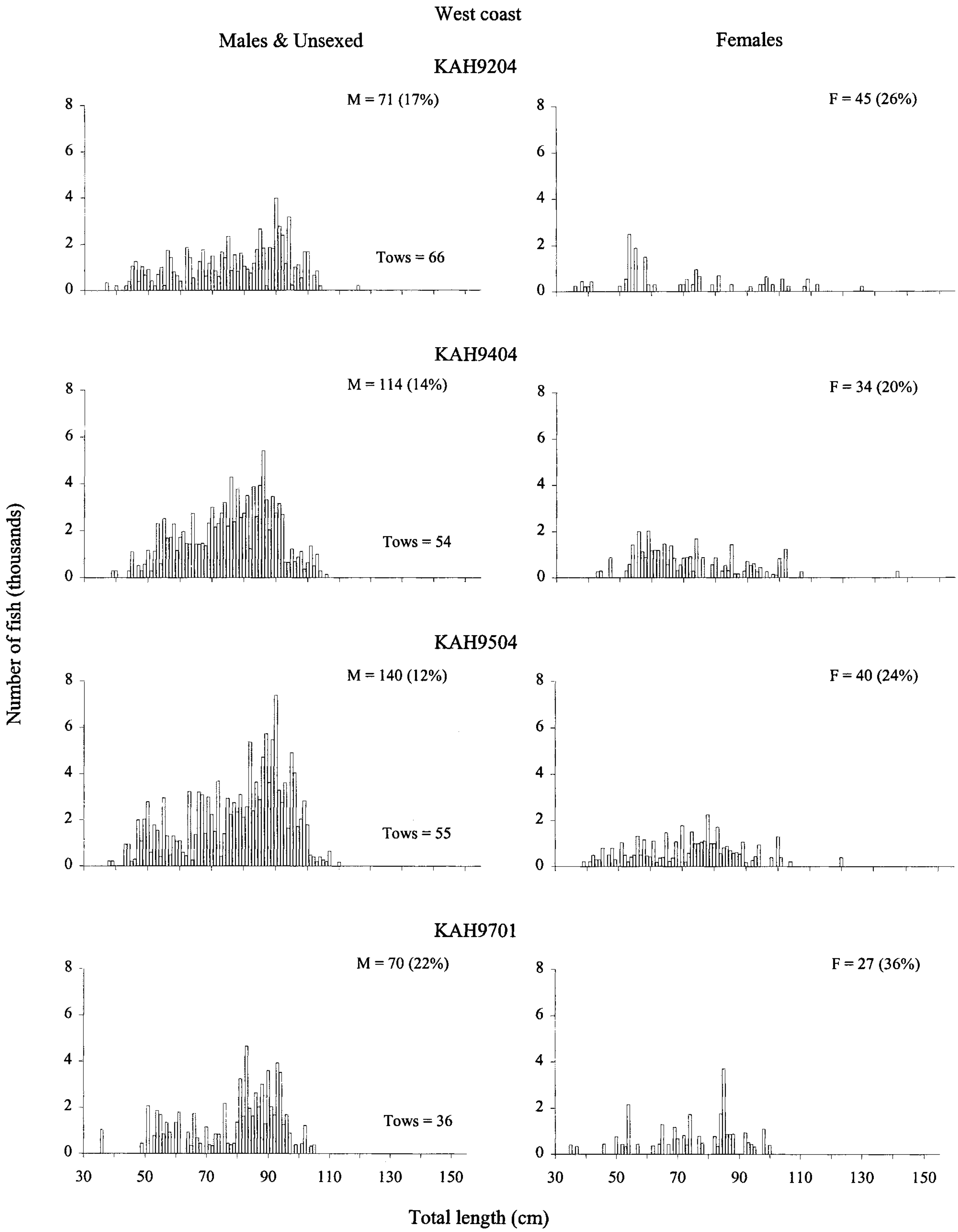

Figure 7j—continued

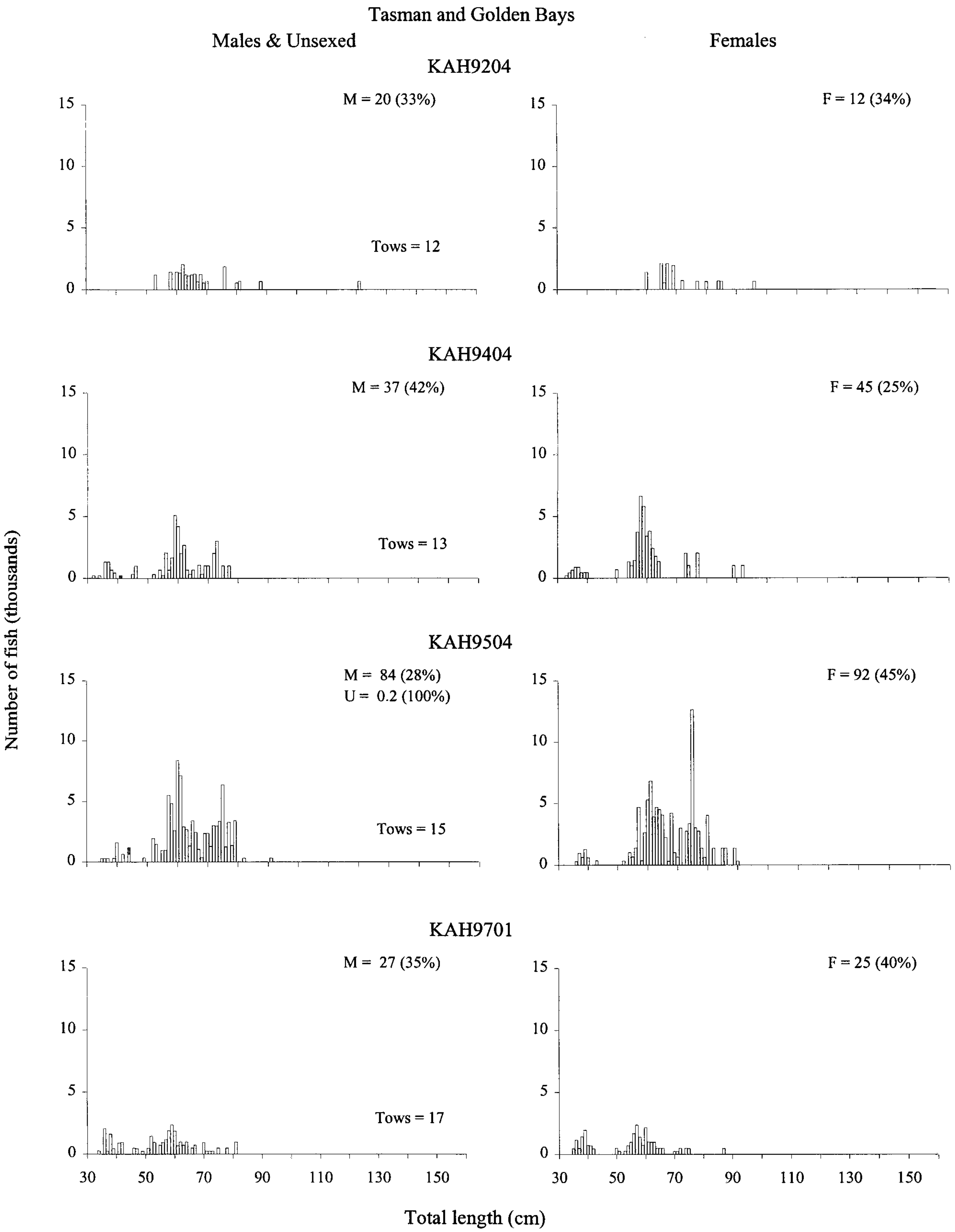

Figure 7k **: School shark**

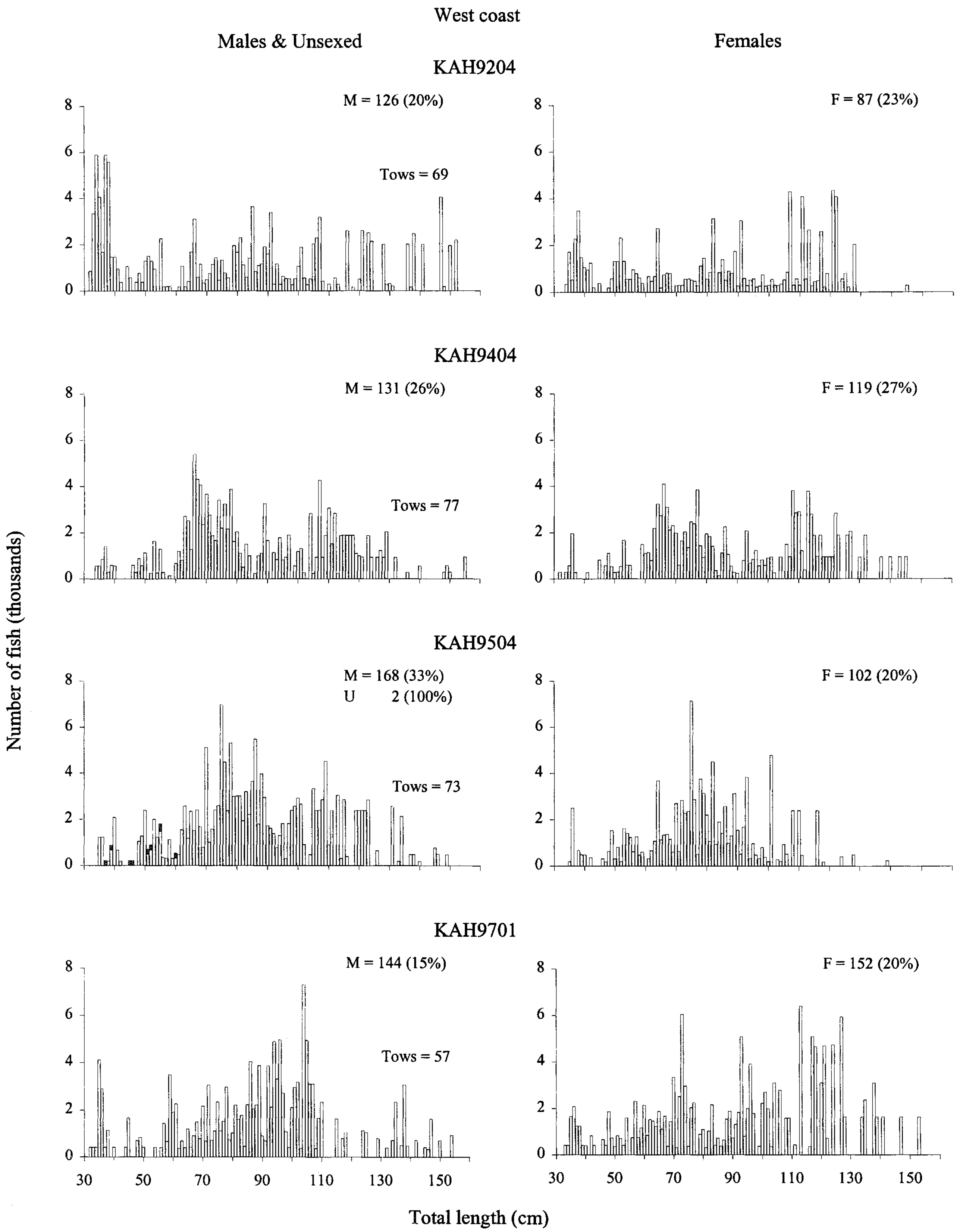

Figure 7k—continued

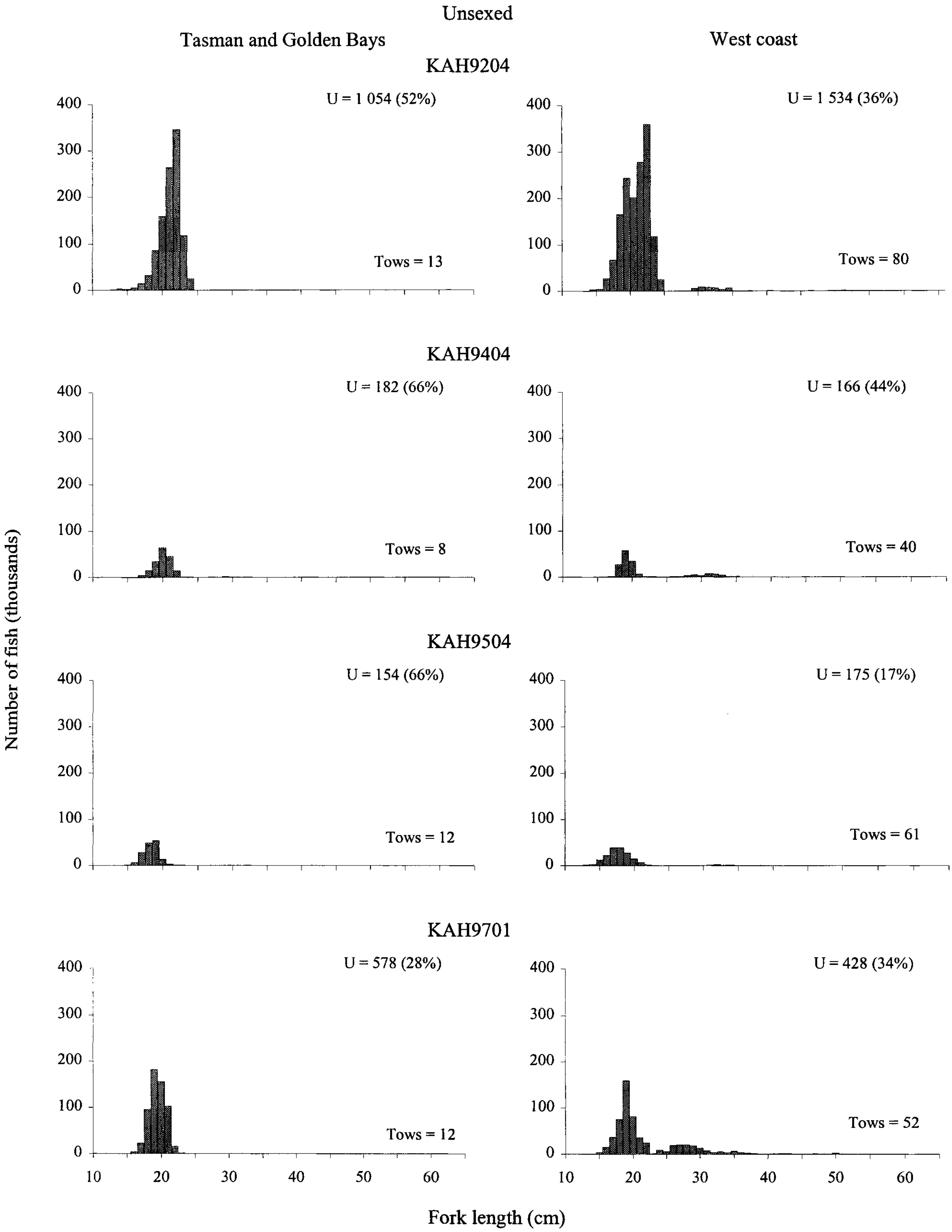

***Figure 7l*: Silver warehou**

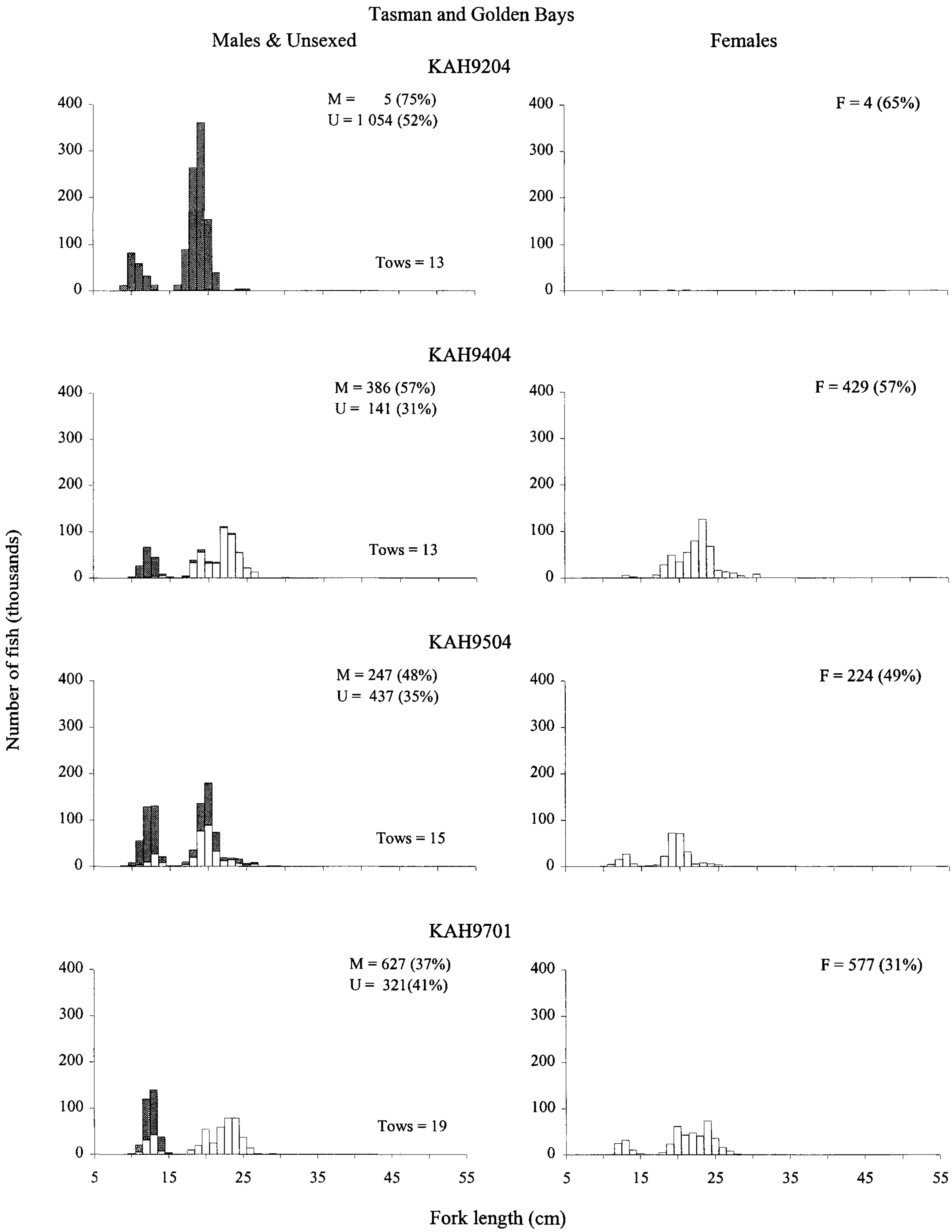

Figure 7m **: Tarakihi**

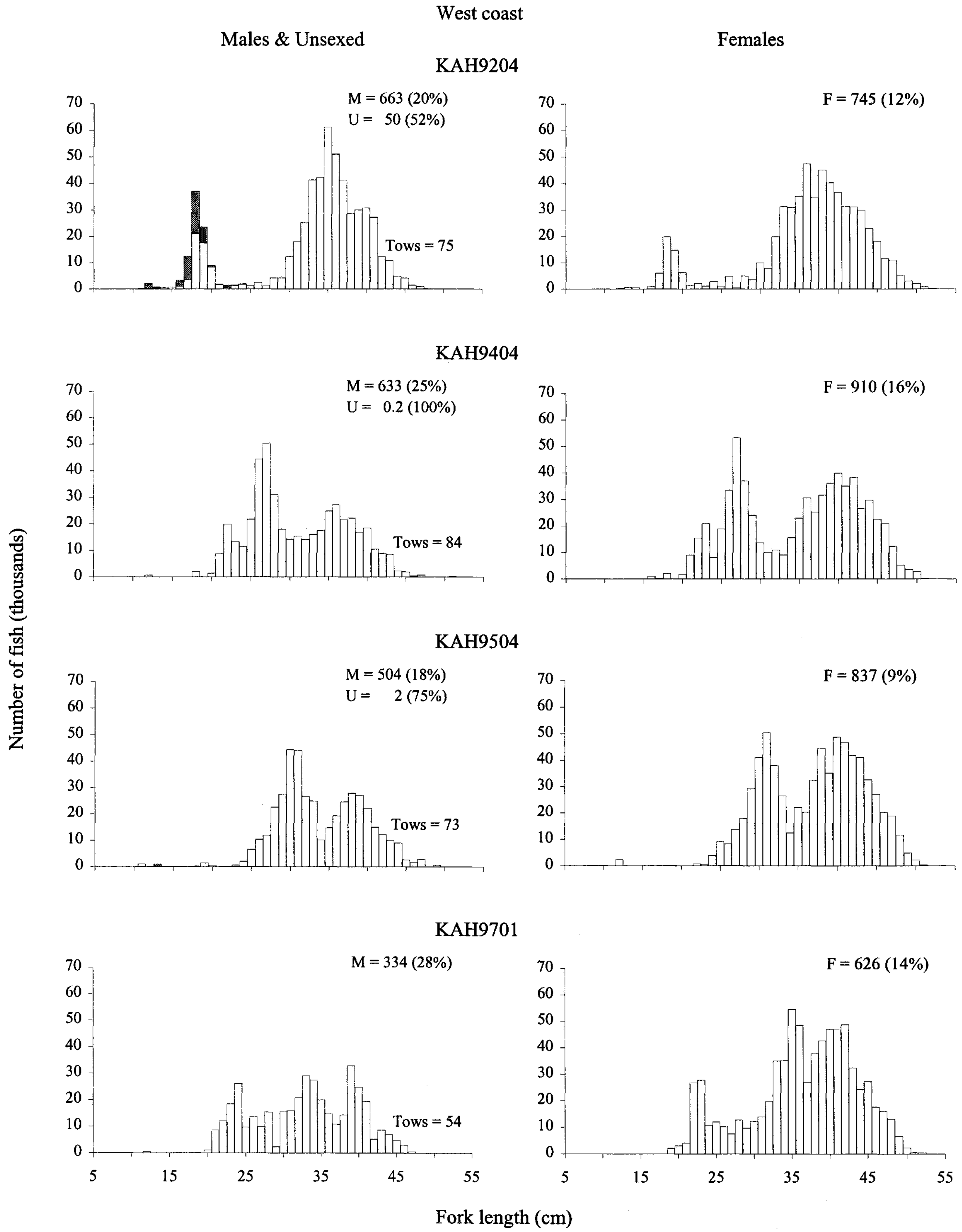

Figure 7m—continued

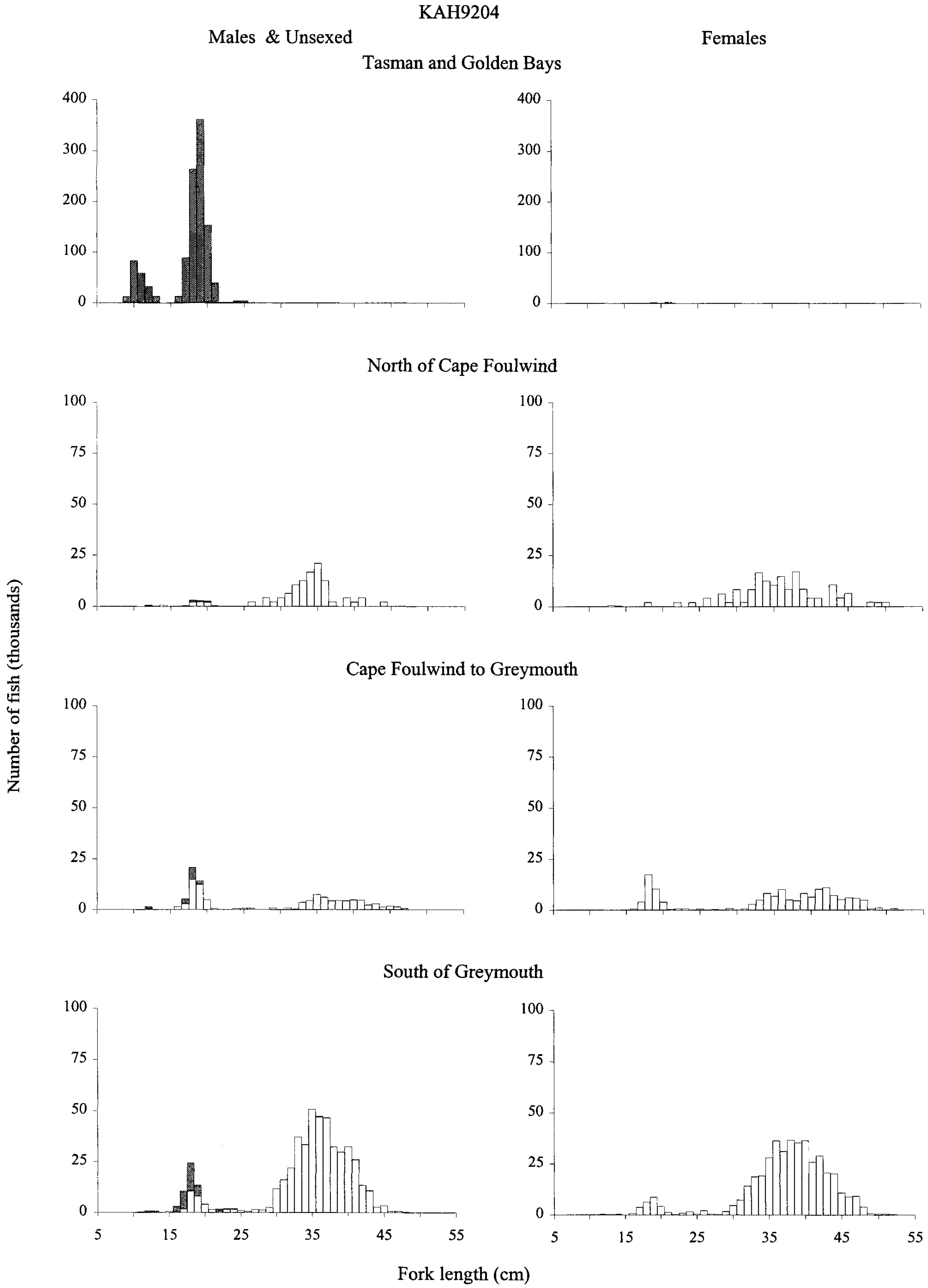

Figure 8 : **Length frequency distributions by geographic area for tarakihi, 1992–97. Note that y-axis values vary.**

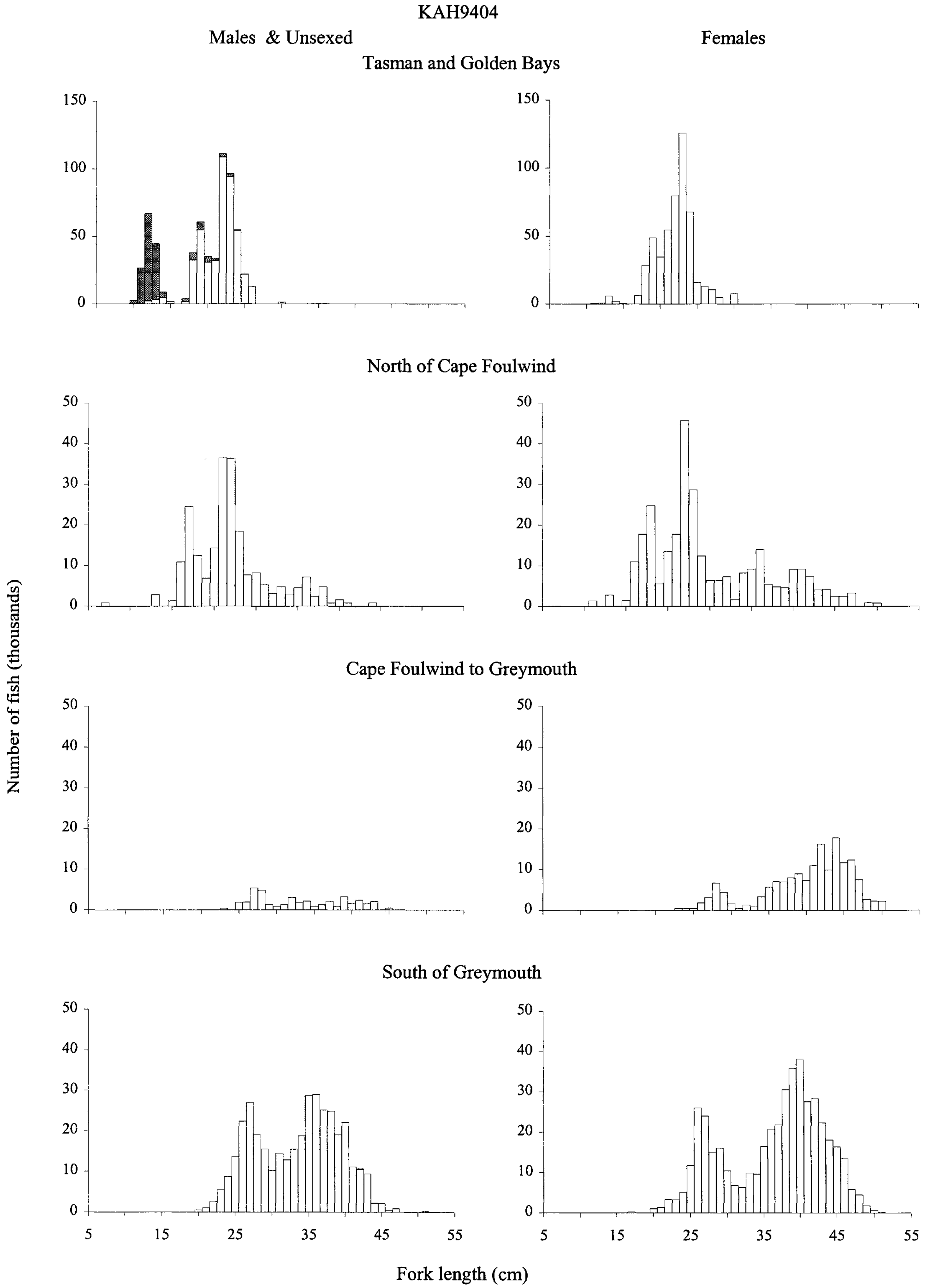

Figure 8—continued

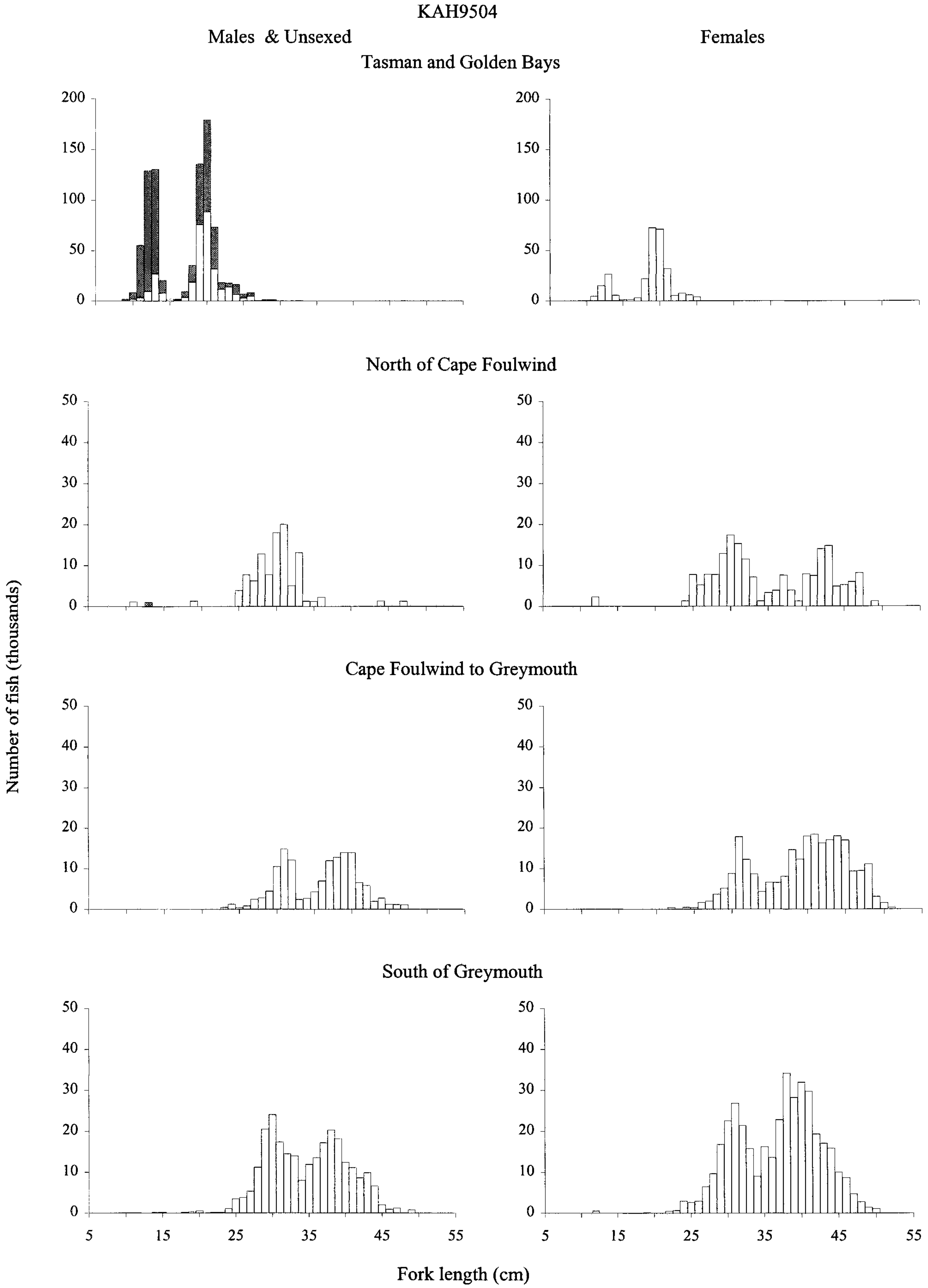

Figure 8—continued

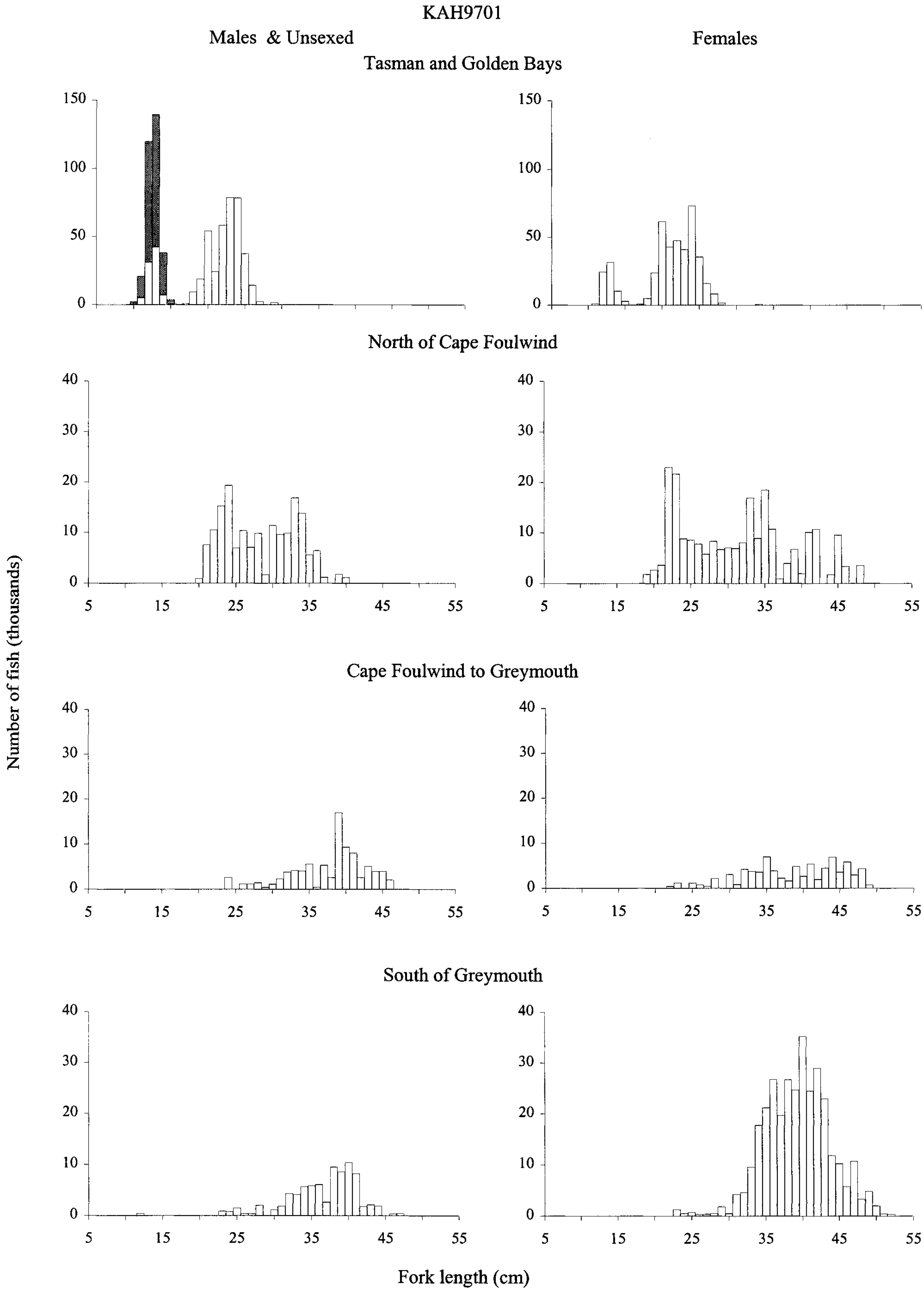

Figure 8—continued