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Review of east coast South Island summer trawl survey time series 1996–97 to 1999–2000

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8. Executive Summary

A time series of four annual summer trawl surveys was conducted off the east coast South Island (ECSI) in December–January from 1996–97 to 1999–2000. The survey included the area between the Waiau River and Shag Point in the 10–400 m depth range using R. V. *Kaharoa*. This report reviews the time series and provides analyses of trends in relative abundance, catch distribution, population length frequency, and reproductive status of the major species. Target species were elephantfish, giant stargazer, red cod, and red gurnard.

The three most abundant species on all four surveys were spiny dogfish, barracouta, and red cod, in that order. The ranking of the target species, other than red cod, varied between surveys; elephant fish ranked 12th, 16th, 9th, and 7th; red gurnard 14th, 17th, 14th, and 19th; and giant stargazer 13th, 12th, 11th, and 11th. Red cod coefficients of variation (*c.v.s*) for total biomass were 23, 23, 17, and 30%, 0+ age class 35, 40, 38, and 27%, and 1+ age class 24, 27, 16, and 43%; elephantfish 31, 18, 28, and 25%; giant stargazer 12, 11, 10, and 14%; red gurnard 13, 16, 13, and 20%.

No statistically significant changes were found in total or recruited biomass for any of these species except for ling where total biomass has steadily decreased ($p<0.01$), and barracouta where pre-recruited biomass was found to be increasing ($p<0.05$). Biomass has fluctuated synchronously between most species on the ECSI, a result of catchability changes between years which may be correlated with water temperature, i.e., total biomass for 16 of the 23 species, including the target species, decreased in 1997–98, increased in 1998–99 and decreased again in 1999–2000 (down-up-down).

The current survey boundaries are adequate to include the main distributions of the target species. The surveys appear to be providing biomass indices that are consistent with other abundance indices for target species elephantfish, red cod and red gurnard, and for giant stargazer it is uncertain, although *c.v.s* were low. Other key non-target species that the surveys are useful for include dark ghost shark, juvenile school shark, juvenile dogfish, barracouta, and juvenile tarakihi.

A survey using the commercial vessel *Compass Rose*, in conjunction with *Kaharoa* in 1999–00, indicated that substantial biomass of elephantfish lies inside 10 m. An ongoing survey in this depth range would be useful to complement the *Kaharoa* survey. However, improved survey design and a

smaller codend mesh size should be considered to improve precision and increase the length frequency size range of elephantfish taken by the *Compass Rose*.

It is recommended that the four target species be retained and that surveys be carried out annually for elephantfish, red cod and red gurnard to index pre-recruit fish and every 2 to 3 years for giant stargazer to index recruited fish. There are only four surveys in the ECSI summer series and catchability variation makes judgment of the performance of the surveys difficult. More surveys are required to assess the effects of environmental factors on catchability. Giant stargazer, red gurnard and red cod otoliths (optional for RCO 0+ and 1+) should be collected and aged after each survey to provide information on growth and catch at age. Elephantfish spines should be collected and stored until an ageing procedure is developed.

9. Objectives:

Programme Objective:

1. To analyse and document the results of the trawl survey time series using RV *Kaharoa* completed off the ECSI in summer in 1996–97, 1997–98, 1998–99 and 1999–2000.

Specific Objectives

1. To determine for all QMS and other important species caught, trends in the following factors over the trawl survey time series:
   - relative abundance
   - distribution
   - length frequency distribution
   - reproductive condition
   - other relevant biological parameters

2 To make recommendations on the benefits of undertaking future trawl surveys off the east coast of the South Island based on the results of the review. This should include, as a minimum, information on the species for which the surveys are successfully monitoring biomass, and the appropriate frequency of future surveys for each of these species.

10. Methods:

See attached report.

11. Results:

See attached report.

12. Conclusions:

See attached report.

13. Publications:

Report attached.

14. Data storage:

No new data were generated by this project

INTRODUCTION

Background

Bottom trawl surveys are a useful tool for monitoring relative abundance and population dynamics of demersal fish species. The results of individual surveys in isolation, however, are of limited value because to identify trends in biomass, distribution, and year class strength, it is necessary to compare the results of all surveys in a time series. This has been carried out for inshore trawl survey time series on the west coast South Island (Stevenson & Hanchet 2000b), east coast South Island (winter surveys) (Beentjes & Stevenson 2000), and east coast North Island (Stevenson & Hanchet 2000a).

This report reviews the time series of four annual summer trawl surveys conducted off the east coast South Island (ECSI) in December–January from 1996–97 to 1999–2000. The key objectives of the surveys were to provide estimates of relative biomass, distribution, and population length frequency for the target species elephantfish (*Callorhynchus milii*), giant stargazer (*Kathetostoma giganteum*), juvenile red cod (*Pseudophycis bachus*), and red gurnard (*Chelidonichthys kumu*) The 1999–2000 objectives are shown below:

1. To determine the relative abundance and distribution of elephantfish, red gurnard, stargazer, and juvenile red cod along the east coast of the South Island from Kaikoura to Shag Point by carrying out a trawl survey. The target coefficients of variation (*c.v.*s) of the biomass estimates for these species are as follows: elephantfish (20–30%); juvenile red cod: 0+ (30%), 1+ (30%); red gurnard (25–30%); stargazer (15–20%).

   1996–97, red cod < 41 cm, target *c.v.* 50%; elephantfish, target *c.v.* 50%: 1997–98, red cod < 41 cm, target *c.v.* 30–35%; elephantfish target *c.v.* 30–35%: 1998–99, red cod under 2 years, target *c.v.* 20–30%.

2. To collect the data and determine the population length frequency, length-weight relationship, and reproductive condition of elephantfish, red cod, red gurnard, and stargazer.

3. To collect otoliths from red cod, red gurnard, and stargazer and spines from elephantfish.

4. To collect the data to determine relative biomass, distribution and length frequencies of all other Quota Management System (QMS) species, and, rough skate (*Raja nasuta*), smooth skate (*R. innominata*), and spiny dogfish (*Squalus acanthias*).

Each of these surveys was documented with little comparison between surveys (Stevenson 1997, Stevenson & Hurst 1998, Stevenson & Beentjes 1999, Stevenson & Beentjes In Press), whereas this report provides analyses of trends in data of the major species. In addition, recommendations are given on the nature of future surveys including how effective the surveys have been at monitoring biomass, year class strength and the most appropriate frequency of surveys for the most important commercial species.

The ECSI summer surveys replaced a winter time series in the same area, but included an additional shallower 10–30 m depth range to improve sampling of elephantfish and red gurnard. The maximum depth of 400 m was chosen primarily on the basis of the known commercial depth distribution of the target species. The survey area extended from Shag Point to the Waiau River; trawlable ground north and south of these points is scarce and the main ECSI trawl fishery lies within this area. As well as the target species, the surveys provided information on distribution, relative abundance, and length frequency for a range of commercial inshore and middle depth species such as barracouta (*Thyrsites atun*), dark ghost shark (*Hydrolagus novaezealandiae*), ling (*Genypterus blacodes*), rig (*Mustelus lenticulatus*), rough skate (*Raja nasuta*), sea perch (*Helicolenus* spp.), smooth skate (*R. inominata*), spiny dogfish (*Squalus acanthias*), and tarakihi (*Nemadactylus macropterus*).

The Quota Management System (QMS) was introduced in 1986 and some Total Allowable Commercial Catches (TACCs) were set substantially below annual catches at that time to allow stocks to rebuild. There was no way to determine the sustainability of these TACCs and trawl surveys were initiated as a monitoring tool, providing stock assessment data such as relative biomass, population age, year class strength, and length frequency, that could be used to assess the sustainability of some key fisheries. For example, for the recruitment driven red cod fishery, the winter and summer ECSI surveys have provided indices of pre-recruited and recruited red cod biomass. Future management of this fishery may lie in the ability to predict future biomass based on the strength of 0+ and/or 1+ year classes from trawl surveys (Beentjes 2000). Giant stargazer (STA 3), and red gurnard (GUR 3) are two important species caught off the east coast of the South Island that have had TACC increases under the Adaptive Management Programme (AMP) while it was proposed that elephantfish be introduced into the AMP in 2000–20001 to increase the current TACC in ELE 3 (SeaFIC 2000c). TACCs have been increased on the basis that these species were overcaught for several years indicating recovery of the stocks. The Ministry of Fisheries (MFish) requires data to be collected to monitor these stocks to determine if the increases to TACCs are sustainable, and these surveys play an integral part in the provision of these data (Annala *et al.* 2000).

Canterbury Bight and Pegasus Bay fishery

Canterbury Bight and Pegasus Bay have extensive continental shelf areas suitable for trawling, which tends to be the most common fishing method. The trawl fishery is described as multispecies (McGregor 1992) with catches usually comprising up to 25 quota and non-quota species. About 30 000 t of finfish are taken annually from the east coast of the South Island. The main inshore trawl target fisheries are red cod, barracouta, flatfish (*Pelotretis flavilatus, Peltorhamphus novaezelandiae, Rhombosolea plebeia, R. tapirina*), elephantfish, and tarakihi. Common bycatch species include arrow squid (*Nototodarus sloanii*), dark ghost shark, giant stargazer, hoki (*Macruronus novaezelandiae*), spiny dogfish, jack mackerel (*Trachurus declivus, T. novaezelandiae, T. murphyi*), ling, red gurnard, rough and smooth skate, sea perch, and warehou (*Seriolella punctata, S. brama*). Other less common fishing methods include set netting for elephantfish, rig, school shark (*Galeorhinus galeus*) and groper/hapuku (*Polyprion oxygeneios*), and lining for groper/hapuku. The estimated primary value of the 10 most common finfish species caught in Quota Management Area 3 in 1995 was about $20 million (based on The New Zealand Seafood Industry Economic Review 1994–96, and catch data from Annala *et al.* (1999).

The 12 n. mile exclusion zone, which applies to vessels over 43 m, has been extended seaward in Canterbury Bight and Pegasus Bay (The Fisheries South East Area Commercial Fishing Regulations 1986, Amendment No. 1) restricting larger vessels from fishing the shelf and upper-slope from Cape Saunders to the Clarence River. Domestic vessels, under 43 m, therefore land the bulk of the commercial catch within the survey area.

Previous east coast South Island trawl surveys

There have been five previous trawl survey series off the east coast of the South Island. The earliest of these was between 1978 and 1980 when 793 stations over 20 transects from Cape Campbell to Nugget Point were surveyed using *W. J. Scott.* The aim was to provide information on the main commercial inshore finfish species off southeast South Island (Fenaughty & Bagley 1981). Between 1980 and 1982 a series of nine trawl surveys was carried out in the Canterbury Bight from *James Cook*, with barracouta as the target species (Hurst & Fenaughty 1985). Between 1982 and 1983 nine trawl surveys were undertaken to investigate groundfish species and squid between Kaikoura and Foveaux Strait on *James Cook* (Paul & Kucerans 1984). A further series of eight trawl surveys targeting rig was undertaken from 1982 to 1984 using *Kaharoa* and *James Cook* in Golden Bay and Pegasus Bay (NIWA unpublished data). More recently, a time series of five winter trawl surveys was conducted off the east coast of the South Island from 1991 to 1996. The first four surveys (1991–94) were consecutive, after which the series became biennial, with the last survey in 1996. The purpose of these surveys was to provide estimates of relative biomass and length frequency distributions for the red cod and other key commercial species (Beentjes & Stevenson 2000).

Hydrology and bathymetry of east coast South Island

The main water current flowing over the continental shelf and slope of the ECSI has its origin as warm saline waters from the western subtropical convergence in the Tasman Sea with a contribution from Australian subantarctic water. Known as the Tasman Current, it sweeps around southern New Zealand through Foveaux Strait and the northern Snares Islands. This current then moves northeastward up the east coast of the South Island, where it becomes known as the Southland Current (Heath 1975, Heath 1985, Chiswell 1996). The Southland Current continues northeastward until it meets the Subtropical Convergence on the Chatham Rise and is deflected eastward. Part of the Southland Current continues on its original path north-eastward through the deeper Mernoo Gap into Cook Strait, mixing with the D'Urville and the East Cape Currents. To the east, the Southland Current is bounded by cooler less-saline subantarctic waters of the Southland Front. (*see* Carter *et al.* (1998) for an illustration of water circulation in this region).

Canterbury Bight continental shelf is comparatively wide, extending about 64 n. mile at its greatest distance from land. The large shelf areas of Canterbury Bight and Pegasus Bay are very productive, providing spawning and nursery grounds for fish species such as elephantfish and rig. Significant bathymetric features of the South Island east coast from Otago Peninsula to Kaikoura include relict canyons off Otago Peninsula (Saunders, Papanui, Taiaroa and Karitane Canyons) (Carter *et al.* 1985), Oamaru (Waitaki Canyon), Pegasus Bay (Pegasus Canyon) and the active Kaikoura Canyon south of Kaikoura (Lewis 1998).

METHODS

Survey area and design

The survey area covered depths of 10–400 m off the east coast of the South Island from the Waiau River to Shag Point, except at the northern end from the Kowai River to Waiau River, the southern end from Cape Wanbrow to Shag Point, and around Banks Peninsula where the minimum depth was 30 m. These areas have extensive areas of foul ground in the form of inshore rocky reefs and were likely to have different species composition from other parts of the survey area. Strata were digitised from bathymetric charts using depth contours as borders, i.e., 10–30, 30–100, 100–200, and 200–400 m. These four depth ranges represent inshore, inner shelf, shelf edge, and upper slope. The bathymetry of the survey area was updated with each survey and recorded on the survey charts, providing an aid to avoiding foul ground and ensuring that tows were in the assigned depth range. In 1996–97, 21 strata were used and this was increased to 22 in 1997–98, and 23 in 1998–99 and 1999–2000 by sub-dividing larger strata (Figure 1). The survey area of 26 938 km^2, including untrawlable (foul) ground, was the same for all surveys.

All four surveys were carried out between early/mid December and early/mid January (Table 1). The surveys used a two-phase stratified random trawl design (*after* Francis (1984). Before each survey, sufficient trawl stations to cover both first and second phase stations separated by at least 5 km were randomly generated using the computer program 'Rand_stn v2.1' (Vignaux 1994). For the 1996–97 survey, allocation of phase 1 stations was based on stratum area, with a minimum of three stations per stratum. Thereafter, a minimum of three stations per stratum was retained but in order to achieve the required coefficients of variation for the target species, an analysis of precision versus allocation of stratified random stations was run using catch rate data from previous surveys to allocate stations. Phase 2 stations were allocated on the basis of catch rates of target species.

Vessel and gear specifications

All surveys were undertaken on *R.V. Kaharoa*, a 28 m stern trawler with a beam of 8.2 m, displacement of 302 t, engine power of 522 kW, capable of trawling to depths of 600 m.

A two-panel trawl net based on an 'Alfredo' design, was constructed in 1991 specifically for South Island inshore trawl surveys and was used on all surveys with identical gear specifications. The codend mesh size was 28 mm. Rectangular V trawl doors fitted with Scanmar were used (*see* Stevenson (1997), Appendix 1, for details).

Trawling procedure

Trawling procedure was standardised for all surveys. Tows were conducted in daylight between 0500 and 1700 h (NZST). At each station it was planned to tow 2 n. miles (measured by GPS from when the gear reached the bottom to the start of hauling) at 3.0 knots (speed over the ground). If the station was in an area of foul or the depth was out of range, an area within 5 km of the station in the same stratum was searched; sometimes this resulted in tows being closer than the specified minimum of 5 km distance between tows. If suitable ground was not found, the station was abandoned and the next station on the list was selected as a replacement. Tow direction was dependent on weather conditions, but usually followed the bottom contour or was in the direction of the next station to reduce steaming time. For depths less than 70 m, a constant warp length of 200 m was used and greater than 70 m, a variable warp to depth ratio was used starting at about 3.5:1 and decreasing to about 2.2:1 at greater depths. Doorspread and headline height were recorded using Scanmar monitoring equipment with an average of five readings at 10 min intervals per tow. Sea bottom temperature was recorded from Scanmar sensors for all four surveys. Sea surface temperature was recorded from hull-mounted sensors only for 1996–97 and 1999–2000 surveys. Missing years' data are due to gear malfunction.

Catch and biological sampling

The catch from each tow was sorted into species, boxed, and weighed on motion-compensating 100 kg Seaway scales to the nearest 0.1 kg. Length, to the nearest centimetre below actual length, and sex were recorded for Individually Transferable Quota (ITQ) and selected non-ITQ species, either for the whole catch or, for larger catches, on a subsample of up to 200 randomly selected fish. For the target species (giant stargazer, elephantfish, red cod, and red gurnard), biological information was obtained from a random sample of up to 20 fish, during which the following records or samples were taken: length to the nearest centimetre below actual length; individual fish weight to the nearest 10 g (using motion-compensating 5 kg Seaway scales); otoliths/vertebral spines; and gonad stage. Individual weight, length, sex, and maturity were also recorded for rough and smooth skate. Up to four otoliths (or spines) per sex, per centimetre size class were collected. Reproductive maturity stages for elephantfish, rough skate, and smooth skate were recorded using a three stage classification, and for teleosts using a five stage classification (*see* Stevenson & Beentjes (In Press) for staging).

Individual fish weights were also collected for barracouta, dark ghost shark, spiny dogfish, tarakihi, and as many other ITQ species as possible on each survey. Samples were selected non-randomly from the random length frequency sample to ensure a wide range was obtained for each species.

Analysis of data

Doorspread biomass estimates were based on the area-swept method described by Francis (1981, 1989) using the Trawlsurvey Analysis Program (Vignaux 1994). All tows for which the gear performance was satisfactory (code 1 or 2) were used for biomass estimations. Biomass estimates assume that: the area swept on each tow equals the distance between the doors multiplied by the distance towed; all fish within the volume swept are caught and there is no escapement; all fish in the water column are below the headline height and available to the net; there are no fish from the ECSI stocks outside the survey area; fish distribution over foul ground is the same as that over trawlable ground.

Species were chosen for analysis if a minimum total of 200 kg was caught on at least half of all surveys and at least 100 kg caught on other surveys in the series. Silver warehou (*Seriolella punctata*) was also included because although total catch weight did not meet the above criteria, sufficient numbers of small fish were caught. All length frequencies were scaled by the percentage of catch sampled, area swept, and stratum area using the Trawlsurvey Analysis Program.

Length-weight coefficients for selected species where individual fish weights were recorded were determined by regressing natural log weight against natural log length ($W=aL^b$) on each survey. Length weight coefficients were used to scale length frequencies and to calculate recruited and year class biomass.

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 $P < 0.05$.

RESULTS AND DISCUSSION

Stations surveyed and catches

The number of stations was about 120 for 1996–97, 1998–99 and 1999–2000 surveys and 138 for the 1997–98 survey (Table 1). Phase 2 represented 12–14 % of stations. Between 97 and 130 t of predominantly fish and squid were caught on the surveys and mean catch rates per tow varied between 2 630 and 4 551 kg/km^2.

Biomass and precision

Biomass and *c.v.*s for the 23 main commercial species are given in Table 2. The three most abundant species on all four surveys were spiny dogfish, barracouta, and red cod, in that order. The percentage of total biomass (all species) accounted for by these three species ranged from 22 to 51% for spiny dogfish, 15 to 24% for barracouta, and 7 to 12% for red cod. Together these three species accounted for 56–79% of the total biomass of all species caught on each of the surveys. Dark ghost shark, hoki, sea perch and tarakihi, were consistently the next most abundant, the ranking changing between years. The ranking of the target species, other than red cod, varied between surveys; elephant fish ranked 12th, 16th, 9th, and 7th; red gurnard 14th, 17th, 14th, and 19th; and giant stargazer 13th, 12th, 11th, and 11th for the 1996–97, 1997–98, 1998–99 and 1999–2000 surveys, respectively.

The *c.v.* is an indication of the precision of the biomass estimate. For target species elephantfish, giant stargazer, and red gurnard, *c.v.*s were within, or close to, the specified target range of the 1999–2000 objectives (*see* objectives) for all surveys. Red cod target *c.v.*s and required length range changed between each survey and therefore it is not useful to compare actual and target *c.v.*s across all surveys. However, based on the 1999–2000 survey requirement to provide biomass indices for 0+ and 1+ year classes with *c.v.*s less than 30%, actual *c.v.*s for 0+ year class were greater than 30% for 3 out of four surveys and 1+ year class only for the 1999–2000 survey. Red cod *c.v.s* for total biomass were 23, 23, 17, and 30% (*see* Table 2), 0+ year class 35, 40, 38, and 27%, and 1+ year class 24, 27, 16, and 43% (Table 3). The high variability in red cod *c.v.*s is probably a reflection of the aggregated and highly mobile nature of red cod schools within the survey area together with variable recruitment. Other target species *c.v.s* for total biomass were: elephantfish 31, 18, 28, and 25%; giant stargazer 12, 11, 10, and 14%; red gurnard 13, 16, 13, and 20%.

Biomass trends

Total biomass for 16 of the 23 species, including the target species elephantfish, giant stargazer, red cod, and red gurnard, decreased in 1997–98, increased in 1998–99 and decreased again in 1999–2000 (*see* Table 2, Figure 5), i.e., down-up-down. Indeed, 17 of 25 species had their two highest biomass estimates in 1996–97 and 1998–99, and the probability of this occurring by chance alone is 9.8 x 10^{-8} (Francis *et al.* In prep). This pattern did not however, occur for the key species spiny dogfish and dark ghost shark although for the latter species biomass was highest in 1998–99 and total biomass for all species combined, adhered to the down-up-down pattern. In summary, biomass appears to be fluctuating synchronously between the bulk of the species on the ECSI indicating a strong between species correlation.

Trends in total biomass for the 23 major commercial species are shown in Figure 2. No statistically significant changes were found in total biomass for any of these species except for ling where the biomass has steadily decreased ($p<0.01$). The power of any statistical test to find trends in biomass is limited by the small sample size, here the number of surveys in the time series. There may be statistical differences in biomass between years, but the statistical analysis used would only detect significant upward or downward trends.

Total biomass and recruited biomass of nine commercial species where recruited size (i.e., recruited to the commercial fishery) is known, are shown in Figure 3. Where total and recruited biomass are the same, most of the catch was of commercial size, e.g., barracouta, elephantfish, giant stargazer. There were no statistically significant trends in increasing or declining recruited biomass for any of these species but the same synchronous pattern in biomass fluctuations was observed. Pre-recruited biomass of barracouta was found to be increasing ($p<0.05$).

Biomass by year class of eight species, where age class size is known, are shown in Figure 4. The synchronous pattern in total and recruited biomass fluctuations was less evident for these young year classes.

Water temperature and biomass

Isotherms estimated from bottom and surface temperatures are shown separately for December and January (Figure 6) because January water temperatures were often considerably warmer than in December. Mean satellite derived sea surface temperatures (SST) for the period December to January of each survey were extracted for a single location just south of Banks Peninsula (44 15 °S, 171 30 °E) (NIWA SST Archive). Mean *Kaharoa* surface and bottom water temperatures, and satellite SSTs are shown in Figure 7. Bottom temperatures appear to be slightly warmer in 1997–98 and 1999–2000, although the difference is only of the order of half a degree celsius. The trend is bottom temperature is not consistent with satellite SST. *Kaharoa* surface temperatures were collected on only two surveys (1996–97 and 1999–2000), and are similar to satellite SST for those years. Mean satellite SST declined by about 1°C in 1997–98, increased by about 2.5 °C in 1998–99, and then declined again by about 1°C in 1999–2000.

Total biomass of all species combined, are compared with *Kaharoa* surface and bottom temperatures, and mean satellite SST in Figure 7. To more closely examine the relationship between SST and total biomass of key individual species, including the target species, these variables were plotted together (Figure 8). The lowest and highest total biomass estimates of all species combined, and for most species independently, correspond with the satellite SST extremes, and the trends are similar, i.e., SST appears to be positively correlated with biomass estimates of most species. This relationship, albeit less marked, was also observed for the ECSI winter surveys where total biomass of all species combined was highest in warm years (Beentjes & Stevenson 2000).

The effect of catchability on biomass estimates

On the ECSI summer surveys, biomass of most species fluctuated widely, including the target species, which have fluctuated two to four-fold between years. Distribution, and recruitment strength of year classes were examined for all species, to determine whether these variables were a contributing factor in the biomass fluctuations. Apart from red cod, where there is some evidence for a strong 1996 year class contributing to the high biomass estimate of 1998–99, for all other species, there were no pulses of recruitment that could account for the large scale changes in biomass. However for 6 out of 23 species, density (as shown by catch rates) in 1997–98 was higher in the shallow 10–30 m strata, particularly south of Banks Peninsula. Species included in this group were barracouta, blue warehou, elephantfish, rig, school shark, and spiny dogfish (Figure 9).

Extreme changes in trawl survey estimates of biomass between surveys, that seem implausible and unrelated to productivity are not uncommon. For example, pale and dark ghost shark biomass estimates from Southland/sub-Antarctic and Chatham Rise surveys (data from Hurst & Schofield 1990, 1995) have varied substantially and Horn (1997a) suggested that the observed indices are probably related to changes in availability of ghost sharks to trawl gear rather than to real changes in abundance. Similarly, a high biomass estimate for spiny dogfish in the 1996 ECSI winter survey (Beentjes & Stevenson 2000) was also mirrored by unusually high spiny dogfish biomass estimates for the 1996 Southland/Snares Shelf trawl survey (Hurst & Bagley 1997) and the 1996 Chatham Rise hoki survey (*see* Hanchet & Ingerson (1997) for review). Hanchet & Ingerson (1997) suggested that the increase was due to changes in areal and vertical availability of spiny dogfish to the trawl gear, possibly as a result of environmental conditions.

Studies of commercial fisheries off southern Namibia indicate that sea surface water temperature can have a significant effect on catchability of many commercial species which have been shown to be more available to bottom trawl in summer than winter, and also in warm summers when water temperature is higher than normal (Macpherson *et al.* 1991, MacPherson & Gordoa 1992). Cape hake (*Merluccias capensis*), for example, are thought to concentrate closer to the bottom when water temperature is warm, making them more available to capture by trawl (Macpherson *et al.* 1991). Our observation that satellite SST appears positively correlated with biomass is consistent with this theory. Mean bottom water temperatures recorded during the ECSI summer surveys do not, however, appear to track the biomass fluctuations observed (*see* Figure 6), but temperatures do not vary a great deal between surveys, are potentially biased by the depth of the tow, and the calibration of the sensor is questionable. The advantage of using satellite SST taken from a single location each year is that it is directly comparable between years and can be used as a proxy for bottom water temperature.

Francis *et al.* (In prep) concluded that for many trawl survey time series, catchability differences between annual surveys exist, and that these differences can be extreme (either very high or very low). Out of 17 time series examined, catchability was found to be extreme in one out of five years. Three of the four ECSI summer surveys were found to be extreme, i.e., 1996–97 and 1998–99 had extremely high catchability, and 1999–2000 had extremely low catchability. No ECSI winter surveys were found to be extreme, but three of four ECNI late-summer surveys also had extreme catchability, although there is no overlap between the latter time series and ECSI summer surveys. It therefore appears that fishstocks on the east coast of both the North and South Islands are prone to substantially more frequent changes in catchability between years. Francis *et al.* (In prep) also tried to determine whether extreme catchability years were correlated with environmental variables (SST, westerly and southerly winds, SOI). Of the 17 extreme years, only 7 were identified as such from the environmental data (less than the expected number if extreme years were chosen at random). For the ECSI summer surveys only 1996–97 was correctly identified as having extreme high catchability, while 1999–2000 was incorrectly identified as being high and 1998–99 as being low. The results were therefore not consistent with the observation above that catchability is positively correlated with sea surface temperature (*see* Figures 7 & 8).

Changes in catchability can only be due to either the vessel fishing differently between surveys, or to changes in species availability (areal or vertical) or vulnerability (ability to avoid capture) to trawl. There were no apparent differences in the gear parameters between surveys so the only conclusion that can be drawn is that fish availability or vulnerability to trawl has varied between surveys. Because this contradicts one of the assumptions of trawl survey design, that catchability between surveys remains constant, any trends in biomass estimates are likely to be masked by the "noise" inherent in catchability variability. Further, because there are only 4 surveys in the time series, the notion that surface water temperature is correlated with catchability is at this stage, an hypothesis, and more surveys would be needed to corroborate or refute this idea. Until such time, conclusions on how well the surveys are estimating biomass need to be qualified by the issue of catchability.

Distribution and length frequency

The distribution and size of catches (kg.km^{-2}) of the major species are shown in Figure 9 and length frequency distributions in Figure 10.

Arrow squid

Arrow squid (*N. sloanii*) were distributed throughout the survey area and were caught at 55–82% of stations (Figure 9a). Catch rates were lowest in 1997–98 and this is reflected in the low biomass (*see* Table 2). Catch rates were generally highest between 100 and 400 m and in the south off Oamaru. Length frequency data are shown in Figure 10a. In each of these four surveys there is strong mode that varies between 10 and 13 cm with two additional weaker modes of larger squid. Female modes appear to be marginally larger than male modes. *N. sloanii* live for one year, spawn in June and July, and then die although it has been suggested that they may also spawn at other times of the year (Uozumi 1998, Annala *et al.* 1999). This would explain why there are multiple modes present and mode size is variable between years in a species that lives for only one year.

Barracouta

Barracouta were distributed throughout the survey area with highest catch rates generally on the continental shelf in less than 200 m, except for 1997–98 where highest catches tended to be in shallow water in the 10–30 m depth range. They were caught at 75–93% of stations (Figure 10b) and ranked second behind spiny dogfish in terms of station occurrence. Modes are apparent for 0+ (10–20 cm), 1+ (20–35 cm), 2 + (40–55 cm), and 3+ (55–65 cm) fish although these are sometimes obscured by the effect of variable growth and the ability of barracouta to spawn twice in one year. For example, in 1999–2000, and to a lesser extent 1998–99, there are small secondary 1+ modes, probably a result of separate spawning. It is possible to track year classes through the fishery but the strength of these year classes is not always apparent in successive years (Figure 10b). The biomass for 1997–1998 was half that of other surveys but the pre-recruit length frequency data for the previous year (1996–97) are not consistent with the decline in biomass, and similarly the 1997–98 data are inconsistent with an increase in biomass in 1998–99. Biomass follows the "down-up-down" pattern characteristic of species affected by changes in catchability, although the 1999–2000 biomass estimate is only marginally less than in 1998–99 (*see* Figure 8). The survey may be useful for monitoring barracouta pre-recruit abundance.

Blue warehou

Blue warehou were distributed throughout the survey area, and were caught at 24–40% of stations (Figure 9c). Highest catch rates were generally on the continental shelf in less than 100 m except for 1997–98 where catches tended to be confined to the shallow waters less than 30 m. Modes are apparent for 0+ (7–13 cm), and 1+ (14–18 cm) fish although in 1996–97, an additional mode is present that is too small to be 2+ (19–25 cm) fish and suggests more than one spawning event (Figure 10c). Biomass follows the "down-up-down" pattern characteristic of species affected by changes in catchability. The survey may be useful for monitoring blue warehou pre-recruit abundance.

Chilean jack mackerel

Chilean jack mackerel were distributed throughout the survey area, and were caught at 9–35% of stations (Figure 10d). Highest catch rates were generally on the continental shelf between 30 and 200 m with a tendency for catch rates to be higher south of Banks Peninsula. Catch rates were exceptionally low in 1997–98 and this was reflected in the very low biomass estimate for this survey (*see* Table 2). Only one length frequency mode is evident with a peak at about 50 cm, representing mature recruited fish (Figure 10d). Jack mackerel species are semi-pelagic undertaking vertical migrations (Annala *et al.* 1999) and mid water trawl or purse seine may be more appropriate methods to target this species. The biomass of Chilean jack mackerel is generally considered to be strongly tied to migration from South America with older fish arriving in New Zealand waters and oceanic fry returning to South America (Elizarov *et al.* 1993). Despite the effects of migration, jack mackerel biomass follows the "down-up-down" pattern characteristic of species affected by changes in catchability. The surveys are unlikely to be useful for monitoring Chilean jack mackerel abundance.

Dark ghost shark

Dark ghost shark were confined to the continental slope between 200 and 400 m, generally south of Banks Peninsula, and were caught at 20–27% of stations (Figure 9e). There are no consistently clear length frequency modes for smaller fish but a mode with a peak about 55 cm for males and 63 for females is apparent (Figure 10e), indicating that females grow faster and larger than males. Nothing is known of ghost shark age and growth making interpretation of age classes difficult. The 1998–99 length frequency data are distinct from the other surveys with large numbers of smaller fish (less than 45 cm), which are not present again in these numbers in the 1999–2000 survey, and could not have been predicted from the 1997–98 survey length frequency data. While ghost shark biomass did not follow the characteristic "down-up-down" pattern, the highest biomass occurred in 1998–99, the year when biomass for most species was highest, suggesting a catchability effect (*see* Figure 8). The surveys may be useful for monitoring adult abundance, although an understanding of age and growth is required to interpret the length frequency data.

Elephantfish

Elephantfish were caught at 36–43% of stations and confined to the inner continental shelf in less than 100 m, with highest catch rates generally in less than 30 m, especially 1997–98 where elephantfish were caught almost exclusively in 10–30 m (Figure 9f). Clear 0+ (12–21 cm) and 1+ length frequency modes are apparent in all surveys although the latter vary greatly in length (26–35 cm in 1996–97 and 1997–98; 22–31 cm in 1998–99 and 1999–2000) (Figure 10f). Elephantfish growth rates of juveniles have been shown to be variable (Francis 1997). No clear modes are evident for larger fish, but fish over the full length range are represented including mature males and females. Modal progression is evident with 0+ and 1+ year classes tracking between years. The strong 0+ mode in 1997–98 translates into a strong 1+ mode in 1998–99 and similarly the relatively weak 0+ mode in 1998–99 into a weak 1+ mode in 1999–2000. Biomass follows the "down-up-down" pattern characteristic of species affected by changes in catchability. The surveys monitor abundance of pre-recruit and adult juvenile elephant fish reasonably well.

Giant stargazer

Giant stargazer were distributed throughout the survey area with highest catch rates on the continental shelf in less than 200 m. They were caught at 44–75% of stations (Figure 9g). While modes are not clear, it is possible to identify 0+ (5–11 cm), 1+ (12–22 cm), 2+ (23–32 cm), and 3+ (31–41 cm) fish from the length frequency distributions with an understanding of length at age (Sutton 1999) (Figure 10g). The 0+ mode is absent on the 1999–2000 survey and weak on all other surveys. The 1+ year class is most easily identifiable, while the 2+ and 3+ modes tend to merge into each other. Individual modes for older year classes are not clearly distinguishable and have merged together. Biomass follows the "down-up-down" pattern characteristic of species affected by changes in catchability and the highest biomass was in 1998–99 when numbers of large fish caught are higher than on other surveys. The surveys monitor abundance of pre-recruit and adult giant stargazer reasonably well.

Hapuku

Hapuku (groper) were distributed throughout the survey area, mainly in the 30–200 m depth range and were caught at 17–32% of stations (Figure 9h). Too few fish were caught on each survey to show any clear modes in the length frequency distributions and nearly all hapuku caught were juveniles less than 80 cm (Figure 10h). Hapuku undertake annual spawning migrations between the ECSI and Cook Strait (Beentjes & Francis 1999), prefer foul ground, are targeted commercially using longline or set net, and are only a by-catch species of trawling. The surveys are unlikely to be useful for monitoring hapuku abundance.

Hoki

Hoki were mainly caught on the continental slope between 200 and 400 m and were caught in 11–19% of stations (Figure 9i). Hoki are most commonly caught between 500 and 800 m (Anderson *et al.* 1998) and large adults are generally found deeper than 400 m (Annala *et al.* 2000). Therefore, this survey is probably not deep enough to sample hoki effectively. The length frequency data are patchy, comprising mainly immature 1+ (30–40 cm) and 2+ fish (47–58). In 1998–99, the 1+ mode (1997 year class) was very strong, but this did not translate into a strong 2+ mode in 1999–2000. Length frequency data collected from trawl surveys in the Chatham Rise also showed the 1997 year class to be relatively strong (Ballara *et al.* 2000). Biomass follows the "down-up-down" pattern characteristic of species affected by changes in catchability. The surveys are unlikely to be useful for monitoring hoki.

Leather jacket

Leatherjacket were caught at 19–31% of stations and confined to the inner continental shelf in less than 30 m with highest catch rates between Timaru and Banks Peninsula, and off Oamaru (Figure 9j). Length frequency was not recorded for leatherjacket. It is not possible to determine if the surveys are monitoring abundance of leatherjacket.

Lemon sole

Lemon sole were distributed throughout the survey area, mainly on the continental shelf in the 10–200 m depth range and were caught at 31–64% of stations (Figure 9k). In 1999–2000, lemon sole were mainly concentrated in the south, off Oamaru and Shag Point and biomass was also very low, possibly a result of the change in distribution from the earlier surveys. Flatfish are fast growing, generally surviving for only 2 to 3 years, and maturity is reached at about 25 cm (Annala *et al.* 2000). There are no clear length frequency modes and distributions probably represent several year classes that have merged, and about half of the fish were mature (Figure 10j). Biomass follows the "down-up-down" pattern characteristic of species affected by changes in catchability. The trawl gear used is not optimal for targeting flatfish and therefore the surveys are unlikely to be useful for monitoring pre-recruited or adult lemon sole abundance.

Ling

Ling were distributed throughout the survey area with highest catch rates in the depth range 100–200 m and in the south off Oamaru. They were caught at 45–62% of stations (Figure 9l). The length frequency distributions are similar between years with only one distinguishable length frequency mode apparent with a peak at about 50 cm which represents the merged year classes of 2 to 7 year old fish (Horn 1993) (Figure 10k). The ling caught on these surveys were generally pre-recruits and considerably smaller than ling sampled from the Chatham Rise on *Tangaroa* surveys (Horn 1997b). Biomass declined in each survey, although no obvious change in distribution is evident. The high biomass estimate for the 1996–97 survey is due mainly to the presence of larger adult fish which are less common on subsequent surveys. Contrary to the biomass trend on these surveys, *Tangaroa* Chatham Rise surveys in 1999 and 2000, reported strong 3+, 4+ and 5+ modes (Horn *et al.* In prep). These survey do not monitor abundance of adults and biomass estimates of juvenile ling are inconsistent with other surveys.

New Zealand sole

New Zealand sole were generally concentrated on the inner continental shelf in less than 30 m and were caught at 17–41% of stations (Figure 9m). Length frequency modes are distinguishable at about 15–21 cm and 22–32 cm probably representing 1+ and 2+ fish, with indications of at least two older year classes that have merged. About half of the fish were mature (Figure 10j). In 1999–2000, biomass was very low with a reduction in the catch of both mature and immature fish. The fluctuations in biomass are similar to that of lemon sole and follows the "down-up-down" pattern characteristic of species affected by changes in catchability. The trawl gear used is not optimal for targeting flatfish and therefore the surveys are not useful for monitoring abundance of New Zealand sole.

Red cod

Red cod were distributed throughout the survey area and were caught at 56–86% of stations. The distribution of red cod tends to be patchy and unpredictable between years, although highest catch rates tended to be around 100 m and in the south off Oamaru (Figure 9n). Length frequency modes of pre-recruit 0+ (7–15 cm) and 1+ (16–30 cm) fish are clear in each survey (Figure 10l). The bulk of the larger recruited fish are predominantly 2+, and to a lesser extent 3+ fish (Horn 1996a, Beentjes 2000) and modes have merged. This 0+ year class varied in strength from year to year with exceptionally good recruitment in 1996–97 which translated into a strong 1+ mode in 1997–98, and a strong 2+ mode in 1998–99. Because there are few year classes present in the length frequency data, it is possible to track pre-recruit cohorts between surveys. Female year classes appear to be marginally larger than those of males. The strength of the 0+ and 1+ cohorts is a useful index of recruitment and has been used to model red cod stocks and predict future commercial catches (Beentjes 2000, Beentjes & Renwick In prep). For example, commercial catches in RCO 3 in 1998–99 were exceptionally high, indicating that the observed strong 1996 year class had progressed into good commercial catches. Biomass of the 0+ year class on the last three surveys has been low compared with 1996–97 indicating that catches in 1999–2000, 2000–2001, and 2001–2003 can be expected to be poor or at least less than 1998–99; early indications are that catches in the 1999–2000 season are poor. Biomass follows the "down-up-down" pattern characteristic of species affected by changes in catchability and the highest biomass estimate was in the 1998–99 when numbers of 1+ and 2+ fish caught are higher than on other surveys. The survey monitors abundance of pre-recruit and adult red cod reasonably well.

Red gurnard

Red gurnard were confined to the inner continental shelf with highest catch rates in about 30 m, north and south of Banks Peninsula. They were caught at 56–62% of stations (Figure 9o). Length frequency distributions changed substantially between years, and do not show a consistent pattern (Figure 10m). Spawning takes place in late spring and summer and the 'birthday' of 1 January was nominally assigned by Sutton (1997) indicating that red gurnard were sampled near or on their birthday (nominally referred to in this report as 1+ and 2+ etc). A 1+ mode (13–22 cm) is distinguishable in all but the 1996–97 survey, and is especially strong in 1998–99 though it did not progress to a strong 2+ mode. A 2+ mode is clearly present in 1998–99 (25–35 cm) but for other surveys it is difficult to identify 2+ fish which have largely merged with older fish. The large mode probably comprises fish in the age range 2 to about 13 years, based on the age and growth study for red gurnard (Sutton 1997). Females grow faster and larger than males. Red gurnard biomass follows the "down-up-down" pattern characteristic of species affected by changes in catchability and the highest biomass was in 1998–99 when numbers of mature fish caught are higher than on other surveys. The surveys monitored abundance only moderately well for red gurnard.

Rig

Rig were confined to the inner continental shelf with highest catch rates in about 30 m and in 1997–98 they were caught almost exclusively in 10–30 m. Rig were caught at 14–18% of stations (Figure 9p). Too few rig were caught on each survey to show any clear modes in the length frequency distributions and based on age at maturity (75–110 cm) (Annala *et al.* 2000), both mature and immature rig are present(Figure 10n). Rig are considered to have low vulnerability to trawl and are targeted by set net. Biomass follows the "down-up-down" pattern characteristic of species affected by changes in catchability. The surveys are not useful for monitoring abundance of rig.

Rough skate

Rough skate were distributed throughout the survey area with highest catch rates in less than 200 m. They were caught at 42–62% of stations (Figure 9q). Rough skate length frequency distributions are similar for all surveys and no clear modes are apparent (Figure 10o). Counts of growth bands from vertebral sections have been taken as indicative of age although this has not been validated (Francis *et al.* 1999). Males reach 50% maturity at about 53cm and 4 years, and females at 60 cm and 6 years, so the majority of rough skate caught were immature. Biomass follows the "down-up-down" pattern characteristic of species affected by changes in catchability. The surveys may be useful for monitoring abundance of rough skate.

School shark

School shark were confined to the inner continental shelf with highest catch rates in about 30 m and in 1997–98 they were caught almost exclusively in 10–30 m. School shark were caught at 28–40% of stations (Figure 9r). Length frequency distributions reveal at least four clear modes corresponding to , 0+ (newly born, 25–36 cm), 1+ (37–50 cm), 2+ (51–65 cm), and 3+ sharks (66–80 cm) (Figure 10p). The assignment of ages to these modes is consistent with Francis & Mulligan's (1998) study on age and growth of school shark. School shark were generally small compared with those caught commercially by set net and lining which range from 90 to 170 cm and can be as old as 25 years. Based on estimated age at maturity, school shark sampled were nearly all immature. The strong 1+ mode in 1997–98 progressed to strong 2+ and 3+ modes in 1998–99 and 1999–2000, respectively. The surveys have been successful in monitoring school shark pre-recruit abundance.

Sea perch

Sea perch were distributed throughout the survey area with highest catch rates in about 100m and were caught at 33–54% of stations (Figure 9s). Length frequency distributions are similar for all surveys and only one mode (7–17 cm) is distinguishable, with the remainder of the age classes merging into a single mode (Figure 10q). There are no juvenile modes and fish at 25 cm are about 8–10 years old (Paul 1998), although ageing has not been validated. Given the slow growth rate, the single larger mode is probably composed of multiple year classes. Two species of sea perch are found on the east coast of the South Island; *Helicolenus percoides* is generally found in depths of at least 50 m and *H. barathri* from 40 to 1200 m. The species sampled was probably *H. percoides,* but it is possible that some of the perch were *H. barathri.* Biomass follows the "down-up-down" pattern characteristic of species affected by changes in catchability. The surveys may be useful for monitoring abundance of sea perch when more is known about age, growth and taxonomy.

Silver warehou

Silver warehou were distributed throughout the survey area with high catch rates in all depths less than about 200 m. They were caught at 24–67% of stations (Figure 9t) but generally in low numbers. Two clear length frequency modes are distinguishable, in all surveys corresponding to 0+ (8–18 cm) and 1+ (20–30 cm), consistent with ageing validation studies by Horn & Sutton (1995) (Figure 10r). In 1997–98 these modes were relatively weak. Progression of this 0+ into the 1+ year class is apparent but the relatively weak modes in 1997–98 are not consistent with modes from the 1996–97 and 1998–99 surveys. The silver warehou sampled on these surveys were generally immature fish, known to inhabit the continental shelf, whereas adults tend to be found in deeper water on the slope (Annala *et al.* 2000). The surveys provide reasonable abundance indices for juvenile silver warehou.

Smooth skate

Smooth skate were distributed throughout the survey area with highest catch rates in less than 200 m. They were caught at 16–27% of stations (Figure 9u). Too few smooth skate were caught on each survey to show any clear modes in the length frequency distributions although a wide size range from about 21 to 140 cm was sampled (Figure 10s). Counts of growth bands from vertebral sections have been taken as indicative of age although this has not been validated (Francis *et al.* 1999). Males reach 50% maturity at about 94 cm and 8 years, and females at 109 cm and 13 years, so the majority of smooth skate caught were immature. The surveys may be useful for monitoring abundance of smooth skate, however small sample size is always likely to make interpretation difficult.

Spiny dogfish

Spiny dogfish were distributed throughout the survey area with highest catch rates generally between 50 and 200 m, and in the south. They were caught at 91–100% of stations, a greater proportion than any other species (Figure 9v). Length frequency distributions are similar for all surveys although numbers caught were greater in 1999–2000, and this is reflected in the high biomass estimate for this survey (Figure 10t). Only one mode is clearly distinguishable on all surveys at about 20–40 cm. Pups are born at a length of about 18–30 cm in April to September (Annala *et al.* 1998), so the small mode is probably 0+ sharks. The remaining lengths comprise multiple year classes and modes have merged together. Males were more common than females but not to the extent found on the ECSI winter surveys (Beentjes & Stevenson 2000). Males reach 50% maturity at about 58 cm at 6 years of age, and females at 73 cm and 10 years (Annala *et al.* 1998), so the majority of dogfish were immature. The increase in numbers of spiny dogfish caught in 1999–2000 is not consistent with the 1998–99 length frequency distribution, indicating that the doubling of biomass may be due to availability to the trawl gear. Spiny dogfish do not fit the pattern of many other species from this survey where biomass is higher when water temperature is warmer. The surveys may be useful for monitoring abundance of immature dogfish.

Tarakihi

Tarakihi were confined to the inner continental shelf in less than 100 m, although the strata yielding the highest catch rates were south of Banks Peninsula (Figure 9w). They were caught at 46–65% of stations. Three clear length frequency modes are distinguishable, particularly on the 1996–97 survey, and these correspond to 0+ (7–11 cm), 1+ (12–17 cm) and 3+ (18–23 cm) (Figure 10u). Tarakihi mature at about 25–35 cm (Annala *et al.* 2000), so the majority of fish caught were immature. The strong year classes in 1996–97 are not as evident in 1997–98. Biomass follows the "down-up-down" pattern characteristic of species affected by changes in catchability and the highest biomass was in 1998–99 when numbers of 2+ and older fish caught were higher than on other surveys. The surveys are useful for monitoring abundance of juvenile tarakihi.

Reproductive condition

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

Giant stargazer male gonads were mainly in the resting and maturing phase. In 1999–2000 a few male gonads were maturing (19%), or running ripe (9%). Females were similar. This is consistent with the view that stargazer spawn in winter (Annala *et al.* 2000).

Red cod male gonads ranged from resting to running ripe with a small proportion of gonads that were spent. Female gonads in contrast were mostly resting and maturing. The high percentage of maturing and running ripe males is not consistent with the view that red cod spawn in early spring (Beentjes 1992).

Red gurnard male gonads were predominantly in the resting phase with 2–8% mature and less running ripe or spent. In contrast, female gonads showed a much greater spread of gonad conditions with a greater proportion of mature (23–46%) and running ripe (6–18%) fish. Red gurnard are thought to have a long spawning period that peaks in early summer (Annala *et al.* 1999). Trawl survey observations are consistent with a summer spawning period.

SURVEY PERFORMANCE AND RECOMMENDATIONS ON FUTURE SURVEYS

In this section the performance of the four ECSI summer surveys to monitor the target species is examined and recommendations are made on future trawl surveys off ECSI including the frequency. The performance of the surveys in monitoring other key non-target species is also briefly discussed. To help determine which species are being successfully monitored, ECSI summer trawl survey biomass estimates are compared with available estimates of abundance (i.e., CPUE data, biomass estimates from other trawl surveys, commercial catch data, environmental indices) and to catch-at-age and length frequency data.

The usefulness of a trawl survey time series depends on the length of the time series, the variance of the biomass indices, the availability (vertical and areal) and vulnerability of the stock to the survey technique, and the availability of appropriate stock assessment models to utilise the data. For example, red cod abundance indices and year class strengths for the ECSI winter and summer surveys have been used in a stock reduction analysis (Beentjes 2000). Similarly, an assessment of ELE 3 has been carried out using biomass indices from both the ECSI winter and summer surveys (Starr In prep). For all AMP species (GUR 3, STA 3, and ELE 3 proposed for 2000–2001) it was recommended that ECSI trawl surveys be retained to monitor abundance, age composition, recruitment, and biological information (Annala *et al.* 2000). It is therefore important to determine if the trawl survey abundance indices used to monitor these stocks are meaningful.

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

1. Does the survey design adequately cover the known distribution of the fish?
2. Does species distribution change between surveys?
3. Are the levels of precision adequate to monitor trends in biomass?
4. Are there any significant trends in biomass and how might they be interpreted?
5. How do changes in abundance indices from the trawl surveys compare with other available estimates of abundance?
6. Are there trends detectable in the fish size frequency and age composition data?
7. What frequency of surveys would be required to monitor the biomass of the key species through time?
8. What are the benefits of developing time series of age data for any of the key species?

Target Species

Elephantfish

The ELE 3 stock includes Fishery Management Area 3 (FMA 3), and FMA 4. The survey boundaries includes only part of FMA 3 and covers the about two thirds of the ECSI, leaving roughly equal distances north and south of the survey boundary (Figure 11). On average, about 82% of elephantfish landings are from ELE 3. Most of the catch from ELE 3 comes from statistical area 022, and to a lesser extent 020 and 024, all of which are within the survey area (Raj & Voller 1999). Elephantfish are most commonly caught between 10 and 100 m (Anderson *et al.* 1998) and nearly all catches of elephantfish in the four summer surveys were in less than 100 m (Figure 9f). The 400 m maximum depth of the surveys is therefore adequate. The 10 m minimum depth may be too deep because elephantfish are known to congregate in less than 10 m to lay eggs in summer, though the timing and depth of these spawning aggregations can vary. The 1999–2000 *Kaharoa* survey was supplemented with a survey in 5–10 m using the commercial vessel F. V. *Compass Rose* (Stevenson & Beentjes In Press). This survey provided evidence that there is substantial biomass of elephantfish inside 10 m depth. Therefore the main part of ELE 3 stock is adequately covered by the survey but depends on the extent to which elephantfish congregate in waters less than 10 m to spawn. Elephantfish are caught predominantly as a by-catch of bottom trawl fisheries for red cod, barracouta, tarakihi and flatfish (Raj & Voller 1999), so trawl surveys are probably a suitable method to sample elephantfish.

Elephantfish were most abundant between Oamaru and Banks Peninsula between 10 and 50 m depth but in 1997–98 elephantfish were predominantly in the 10 to 30 m depth range indicating a shallower distribution in that year. Commercial fishers also reported higher catches of elephantfish in shallow water in 1997–98 (Raj & Voller 1999). Elephantfish biomass estimates have fluctuated more than four-fold over the four surveys with *c.v.*s between 18 and 31% (*see* Table 2). Therefore, although the precision of biomass estimates is satisfactory, the large annual changes in biomass are not plausible and are likely to be a result of changes in catchability.

CPUE abundance indices were determined for ELE 3 for the years 1989–90 to 1998–99 (Langley In prep) and overlap with the first three ECSI summer trawl survey biomass estimates (Figure 12). The trawl survey biomass estimates tend to mirror the CPUE indices for the matching years and suggest that catchability affects both commercial and research trawling. ELE 3 stock was were assessed using CPUE indices, ECSI (winter and summer) trawl survey biomass estimates, and a range of length frequency data sets as model inputs (Starr In prep). The model indicated that biomass increased in the 1990s and is consistent with the trends in CPUE trawl survey biomass. Therefore, despite the fluctuations in biomass due to catchability, the surveys appear to be tracking biomass.

Tracking the growth of juvenile elephantfish age classes between years is feasible using length frequency distributions from the trawl surveys. For example, the length frequency distribution from the 1996–97 summer survey is consistent with that of the 1996 winter survey (Beentjes 1998) with a large sub-adult mode (35–60 cm) progressing to 40–65 cm 6 months later. In addition, 0+ and 1+ age classes can be tracked between surveys although the relative strength of weak and strong cohorts is not always maintained between surveys. The length frequency distributions from *Kaharoa* and *Compass Rose*, surveys in 1999–200, even within the same depth ranges (10–30 m), were distinctly different; *Kaharoa* caught a wide range of length frequency classes from 0+ through to mature adults while *Compass Rose* caught mainly sub-adult elephantfish in the size range 30–40 cm. The reason for the absence of large mature fish on the *Compass Rose* is not clear. Length frequency distributions from the *Kaharoa* summer surveys are broadly similar to those from 1960 and 1980s ((Francis 1997) with the presence of 0+ and 1+ juvenile age classes. It is not surprising that identification of juvenile 0+ and 1+ cohorts between some surveys is difficult as some length frequency modes are likely to be blurred because Pegasus Bay and Canterbury Bight elephantfish have different growth rates (Francis 1997). Comparison with length frequency data from SeaFIC voluntary logbook programme indicates that the largest fish caught commercially are similar in size to the largest fish caught by *Kaharoa,* suggesting that *Kaharoa* samples all size classes of the elephantfish fishery.

Elasmobranchs are not considered to have high recruitment variability and are thought to produce similar numbers of eggs each year. Survival and recruitment are probably most effected by environmental variables. It is not known if the variability in juvenile year class strength is due to problems in the sampling design of the survey, or the aggregated distributions of the fish. Of the 6 to 8 age classes about four comprise the recruited biomass (greater than 50 cm). To monitor the pre-recruit biomass and year class strength of juvenile 0+ and 1+ fish, it is recommended that survey frequency be annual, and for recruited biomass, every 2–3 years. However, given that biomass fluctuations are known to be due in part to catchability, it may be necessary to conduct surveys annually until the environmental variables affecting catchability are better understood.

Elephantfish dorsal spines have been collected on all surveys but a validated ageing procedure has not been determined. We recommend that spines continue to be collected and stored until a suitable ageing method is available. Our current understanding of age and growth comes from MULTIFAN length frequency analysis and tagging (Francis 1997). These data will be useful for validating ages determined from spines. Sampson (2000) supports these recommendations on frequency of surveys and collection of spines.

Giant Stargazer

The STA 3 stock boundary is equal to FMA 3. The trawl survey area includes only part of FMA3 and covers the about two thirds of ECSI, leaving roughly equal distances north and south of the survey boundary (Figure 11). Giant stargazer is caught throughout New Zealand but mostly off both coasts of the South Island and particularly Southland. About 21% (1998–99) of giant stargazer landings are from STA 3, (Annala *et al.* 2000), taken mainly as bycatch of inshore bottom trawl fisheries for red cod, and to a lesser extent from hoki fisheries on the western Chatham Rise. Analysis of effort in STA 3 indicates that the number of commercial tows where giant stargazer was caught was highest in stat area 022, followed by 020, 024, and 018 (Vignaux 1997). Analysis of all NIWA research trawl surveys indicate that the most common depth for giant stargazer is about 350 m (range 10–700 m) (Anderson *et al.* 1998). The geographical distribution of giant stargazer was similar in all ECSI summer surveys and they were equally abundant in 30 to 200 m (*see* Figure 9g). The geographical area of the ECSI summer surveys, are therefore probably adequate to sample giant stargazer in STA 3, with the exception of the western Chatham Rise. The latter area however, is covered by Chatham Rise 1992–2000 *Tangaroa* trawl surveys (SeaFIC 2000b). Apart from a small percentage of landings taken by set net, giant stargazer are caught predominantly in bottom trawl fisheries, so trawl surveys can be regarded as a suitable method to sample giant stargazer.

Giant stargazer *c.v.*s were low (10–14%) but biomass estimates have fluctuated two-fold over the four surveys (*see* Table 2). Therefore, while the precision of the stargazer biomass estimates is good, the large annual changes in biomass are not plausible and may be a result of changes in catchability.

STA 3 CPUE indices for 1992–96 do not overlap with the summer surveys (Vignaux 1997). Further, there are concerns that CPUE for STA 3 does not properly reflect abundance because of the low proportion of the catch represented in the analysis, and because it is mainly caught as by-catch of other species. CPUE analysis is not considered to provide a meaningful index of abundance for giant stargazer (Annala *et al.* 2000, SeaFIC 2000b). Giant stargazer biomass estimates from the western Chatham Rise *Tangaroa* surveys show considerable fluctuation, of a similar order to that of the ECSI summer surveys, suggesting that these surveys may also be affected by annual changes in catchability (SeaFIC 2000b). However for the four surveys that overlap, the trends in biomass estimates are dissimilar (Figure 13). Commercial landings of STA 3 do not reflect the fluctuations shown in the summer survey biomass estimates (Annala *et al.* 2000) although the magnitude of landings are very dependent on the annual fishing practices of the various target species. Therefore there are no abundance indices that corroborate the trends in *Kaharoa* biomass estimates for stargazer.

Tracking juvenile age classes (0+, 1+) between years from length frequency data is difficult and open to interpretation. Older age class modes overlap and cannot be tracked. The consistently weak 0+ mode indicates this age class may not be fully vulnerable to the trawl gear. The length frequency distributions are broadly similar between surveys and there are no obvious trends in strong or weak year classes tracking through the fishery.

Because the surveys give little information on pre-recruit age classes, there is little point in attempting to index juvenile recruitment with annual surveys. The survey is probably more useful for monitoring recruited year classes, and a frequency of 2 to 3 years would be adequate. Because most age classes are merged otoliths should be collected and aged after each survey to provide information on growth and catch at age. Otoliths have been collected on a stratified size range for all surveys. Sampson (2000) supports these recommendations on frequency of surveys and collection of otoliths.

Red cod

The RCO 3 stock includes FMAs 3, 4, 5, and 6. The survey area includes only part of FMA 3 and cover about two thirds of the ECSI, leaving roughly equal distances north and south of the survey boundary (Figure 11). About 75% of red cod landings are from RCO 3, (Annala *et al.* 2000) and most comes from statistical areas 020 and 022 (Beentjes 2000). Red cod is one of the major bottom trawl target species on the ECSI. Analysis of all NIWA research trawl surveys, indicate that the most common depth for red cod is about 350 m (range 10–500 m) (Anderson *et al.* 1998). However, in ECSI summer surveys red cod were most abundant at about 100 m (*see* Figure 9n). Further, 127 m is the mean depth of commercial tows in RCO 3 where red cod is the target species (TCEPR forms 1991–92 to 1997–98, NIWA unpublished data); the depth range of the surveys (10–400 m) is therefore adequate. The geographical distribution of red cod was similar between surveys (higher densities to the south) indicating that there were no spatial shifts in range. The geographical area of the ECSI summer surveys, are probably adequate to sample most of the RCO 3 stock. Red cod are targeted exclusively by bottom trawl, so trawl surveys can be regarded as a suitable method.

Red cod biomass estimates were required for juvenile fish (less than 41 cm = 0+ & 1+) initially, and in the 1999–2000 survey for 0+ and 1+ fish individually. Therefore, we could expect *c.v.*s for 0+ and 1+ to be somewhat higher in the first three surveys since there was no optimisation of the survey design for these cohorts. Actual *c.v.*s for total biomass were 23, 23, 17, and 30% (*see* Table 2), 0+ biomass 35, 40, 38, and 27%, and 1+ biomass 24, 27, 16, and 43% (*see* Table 3). In general *c.v.*s greater than 35% are considered inadequate to monitor biomass. On this basis, the survey is performing well for estimates of total biomass, poor to average for 0+, and generally good for 1+. The variable *c.v.*s are a reflection of the way in which red cod aggregate in highly mobile schools comprised mainly of single cohorts (Beentjes 2000). Red cod biomass fluctuated nearly two-fold between surveys. The high biomass estimate in 1998–99 was predicted by the strong age class of 0+ fish (1996 year class) caught in the 1996–97 survey. Biomass did, however, fluctuate in the same manner as most other species and it seems likely that red cod is also subject to changes in catchability but strong recruitment and trends in abundance are discernible through this 'noise'.

RCO 3 CPUE abundance indices were determined for 1989–90 to 1997–98 (Beentjes 2000). Only 1996–97 and 97–98 years overlap with ECSI summer trawl survey biomass estimates but both indices show a decline, albeit only slight for the CPUE index (Figure 14). Commercial landings also tend to mirror the trawl survey biomass trends. Beentjes & Renwick (In prep) found that climatic environmental variables, (SST and south-westerly winds) are correlated with recruitment in RCO 3. This relationship was modeled and used to predict catches of red cod which also mirrored those of biomass estimates from the trawl surveys (*see* Figure 14). In summary, abundance indices derived from CPUE, commercial catch, and environmental predictors are all consistent with the trawl survey biomass estimates.

Tracking 0+ and 1+ age classes between years is possible from trawl survey length frequency data, but the 2+, 3+, and older age classes overlap and cannot generally be distinguished. The RCO 3 stock was assessed by the single stock method of Cordue (1998) using ECSI winter and summer trawl survey biomass estimates/catch at age data, and commercial fishery CPUE (Beentjes 2000). Model estimates of year class strength support the progression of the strong 1996 year class (0+ in 1996–97) through to 2+ in 1998–99, when commercial catches were also very high. This indicates that the 0+ age class is vulnerable to trawl gear to the extent that relative year class strength of 0+ fish is reflected by that of 1+ and 2+ cohorts.

Red cod abundance is highly recruitment driven, and the species is has fast growth, and high natural and fishing mortality. The commercial fishery is based predominantly on 2+, and to a lesser extent 3+ fish (Horn 1996b, Beentjes 2000). In order to monitor this fishery successfully it will be necessary to conduct annual surveys to index recruitment strength of 0+ and 1+ age classes. Otoliths have been collected on a stratified size range for all surveys and this should continue but for 0+ and 1+ age classes. Catch at age could alternatively be determined from the length frequency distributions. Sampson (2000) supports these recommendations on frequency of surveys and collection of otoliths.

Red Gurnard

GUR 3 stock includes FMAs 3, 4, 5, and 6. The survey area includes only part of FMA 3 and covers about two thirds of the ECSI, leaving roughly equal distances north and south of the survey boundary (Figure 11). On average (1989–90 to 1998–99), landings of GUR 3 account for about 20% of national landings (Annala *et al.* 2000), and most of this comes from statistical areas 020 and 022 (70%). The next most important statistical areas are 018 and 024 (10%); the survey area covers about half of the inshore area of 024 and a negligible portion of 018. Red gurnard supports a small target fishery but is predominantly caught as by-catch of red cod and flatfish target trawl fisheries. Analysis of all NIWA research trawl surveys, indicate that the most common depth for red gurnard is about 80 m (range 5–400) (Anderson *et al.* 1998). The preferred depth in the ECSI summer surveys was about 30 m (*see* Figure 9o). Sixteen metres was the minimum depth that red gurnard were caught on the 1999–2000 *Compass Rose* survey (Stevenson & Beentjes In Press), therefore the depth range of the surveys (10–400 m) is adequate for red gurnard. The geographical distribution of red gurnard was similar between surveys and there were no spatial shifts in range. The geographical area of the ECSI summer surveys is probably adequate to sample most of GUR 3. Red gurnard are targeted mainly by bottom trawl so trawl surveys can be regarded as a suitable method.

Red gurnard *c.v.*s were low, between 13 and 20%, but biomass estimates fluctuated nearly four-fold over the four surveys (*see* Table 2). Therefore, although the precision of the red gurnard biomass estimates is good, the large annual changes in biomass are not plausible and may be a result of changes in catchability.

GUR 3 CPUE abundance indices were determined for 1989–90 to 1998–99 (SeaFIC 2000a) and overlap with the first three ECSI summer trawl survey biomass estimates (Figure 15). Commercial catches in GUR 3 have declined steadily since 1993–94 and this is consistent with the trend in CPUE. Trawl survey biomass estimates, despite the influence of catchability, show an overall decline and are consistent with trends in CPUE and commercial catch.

Tracking pre-recruit 1+ and to lesser extent 2+ fish between years is possible from trawl survey length frequency data. Older age classes overlap and cannot be distinguished (*see* Figure 10m). A feature of the length frequency distributions is the strong 2+mode appearing in 1998–99. The relative strength of the 1997–98 1+ fish is not consistent with the strong 2+ mode in 1998–99 since an even stronger 1998–99 1+ mode did not track into a strong 2+ mode in 1999–2000. This may be a result of variation in catchability.

To index juvenile recruitment for red gurnard the surveys should be carried out annually. For recruited year classes, surveys could be every 2 years. Because most age classes are merged, otoliths should be collected and aged after each survey to provide information on growth and catch at age. Otoliths have been collected on a stratified size range for all surveys. Sampson (2000) supports these recommendations on frequency of surveys and collection of otoliths.

Non-target species

For the key non-target species, the performance of the surveys was assessed in less detail concentrating on the consistency and precision of biomass estimates and length frequency distributions.

<u>Elasmobranchs</u>

Elasmobranchs tend to be reasonably long lived with low recruitment variability so we would expect to find consistent biomass estimates between years. Biomass estimates of dark ghost shark fluctuated three-fold and precision was good to moderate (18–33%). The largest biomass estimate was in 1998–99 when most species experienced their highest biomass estimates suggesting that this species is affected by catchability. Dark ghost shark are most common in about 300 m (Anderson *et al.* 1998) so the survey depth range is probably adequate. Similar length frequency distributions between surveys indicate that the population was being sampled in a consistent manner (*see* Figure 10e). The surveys were therefore useful at monitoring dark ghost shark.

Biomass estimates of rig fluctuated six-fold and precision was moderate to poor (33–52%). Length frequency distributions provided little information on age classes as few rig were caught. Because of this and the low vulnerability to trawl, trawl surveys are not useful for monitoring rig.

School shark biomass estimates fluctuated less than two-fold and had moderate precision (23–27%). The characteristic catchability pattern was absent. Length frequency distributions comprised mainly juvenile sharks and had clear modes. The surveys are therefore considered useful for monitoring juvenile school shark.

Spiny dogfish biomass estimates fluctuated two-fold and precision was variable (16–37%). The characteristic catchability pattern was absent and the lowest biomass was recorded in 1998–99 when estimates for most species were maximum. Length frequency distributions were similar between surveys and comprised mainly juvenile sharks. The surveys may be useful for monitoring immature dogfish.

Barracouta

Barracouta biomass estimates were reasonably consistent except for 1997–98 when biomass was about half that of the other surveys. Precision of biomass estimates was good to moderate (14–34%). Length frequency distributions showed clear juvenile modes. Pre-recruited biomass (less than 50 cm) increased with each survey but no individual age classes for 0+, 1+, and 2+ increased consistently each year (*see* Figure). The survey may be useful for monitoring barracouta.

Ling

Ling biomass estimates declined with each survey and this trend was statistically significant. Precision of biomass estimates was highly variable however (18–64). No modes were present in the length frequency distributions and most fish were juvenile. The preferred depth of ling is about 500 m (Anderson *et al.* 1998) and the surveys are probably too shallow to monitor this species.

Tarakihi

Biomass estimates for tarakihi fluctuated two-fold and precision was good (15–24%). The characteristic catchability pattern of was present. The survey area is adequate as it covers the main distribution and depth range of tarakihi. The consistency in length frequency distributions between surveys suggests that the population was sampled in a consistent manner although most fish are juvenile. The surveys are considered useful for monitoring juvenile tarakihi. The ECSI is an important nursery ground for juvenile tarakihi and the surveys provide indices of pre-recruit strength (pers com Stuart Hanchet).

Conclusions and recommendations

Elephantfish

- The main part of the ELE 3 stock is covered by the *Kaharoa* survey boundaries with an unknown proportion of biomass inside 10 m.
- A commercial survey using *Compass Rose* in conjunction with *Kaharoa* in 1999–00 indicated that substantial biomass of elephantfish lies inside 10 m. Improved survey design and a smaller codend mesh size may improve precision and increase the length frequency size range on *Compass Rose.*
- Elephantfish biomass estimates are reasonably precise but are subject to catchability changes between surveys.
- Elephantfish CPUE abundance indices show similar trends to survey biomass indices.
- All age classes were represented on the surveys, and 0+ and 1+ age classes can be tracked between surveys from length frequency distributions, although growth rates are variable.
- It is recommended that surveys should be annual to monitor pre-recruit age classes and every 2–3 years for recruited biomass.
- We recommend that spines continue to be collected and stored until a suitable ageing method is available.
- Introduction of ELE 3 stock into the AMP (SeaFIC 2000c) was proposed at the 2000 Fishery Assessment Plenary. The plenary considered ECSI summer *Kaharoa* surveys necessary to support the 'Decision Rule' aspect of the programme.

Giant stargazer

- Most of STA 3 stock is covered by the survey boundaries (except the western Chatham Rise which is covered by *Tangaroa* surveys).
- Stargazer biomass estimates have good precision (10–14%) but are subject to catchability changes between surveys.
- There are no other abundance indices that corroborate the trends in *Kaharoa* biomass estimates for stargazer.
- Length frequency distributions are broadly similar between surveys and pre-recruit age classes are not well represented.
- The survey is probably more useful for monitoring recruited year classes, and a frequency of 2 to 3 years would be adequate.
- Because most age classes are merged, otoliths should be collected and aged after each survey to provide information on growth and catch at age.
- STA 3 is managed under the AMP and *Kaharoa* surveys are considered necessary to support the 'Decision Rule' aspect of the programme (Annala *et al.* 2000).

Red cod

- Most of RCO 3 stock is covered by the survey boundaries.
- Red cod estimates have variable precision: good for estimates of total biomass, poor to average for 0+, and good with one exception, for 1+. This is probably a reflection of schooling behaviour. Biomass estimates for red cod are subject to catchability changes between surveys.
- Abundance indices derived from CPUE, commercial catch, and environmental predictors are all consistent with the trawl survey biomass estimates.
- Single stock model estimates of red cod year class strength (Beentjes 2000) are consistent with the progression of the strong 1996 age class into the commercial fishery in 1998–99.
- Length frequency distributions are broadly similar between surveys and 0+, and 1+ age classes can be tracked between surveys.
- Trawl surveys should be conducted annually to index recruitment strength of pre-recruit 0+ and 1+ age classes.
- Collection of otoliths for recruited age classes should continue to provide information on catch at age and growth, but for 0+ and 1+ age classes collection is optional since this can be determined from length frequency distributions.

Red gurnard

- Most of the GUR 3 stock is covered by the survey boundaries.
- Red gurnard biomass estimates have good precision (13–20%) but are subject to catchability changes between surveys.
- Red gurnard CPUE abundance indices are consistent with trawl survey biomass estimates.
- 1 year old and 2 year old age classes can be tracked between surveys but relative strength is not consistent between surveys.
- To index juvenile recruitment for red gurnard the surveys should be carried out annually, but for recruited year classes, surveys could be every 2 years.
- Because the bulk of the age classes are merged, otoliths should be collected and aged to provide information on growth and catch at age.

Concluding remarks

There are only four surveys in the ECSI summer series and three of these were considered by Francis *et al.* (In prep.) to have extreme catchability variation. This makes judgment of the performance of the surveys difficult but trawl survey indices are nonetheless consistent with other abundance indices. More surveys are required to assess the effects of environmental factors on catchability.

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***Table 1*: Number of stations, total catch, and mean catch rate per tow for the core strata, 1996–99**

Trip code	KAH9618	KAH9704	KAH9809	KAH9917
Dates	12/12/1996–18/1/1997	3/12/1997–6/1/1998	7/12/1998–12/1/1999	16/12/1999–14/1/2000
Phase 1 stations	103	119	103	104
Phase 2 stations	15	19	15	16
Total stations	118	138	118	120
Total catch (t)	129.8	97.0	123.2	103.8
Mean catch rate per tow ($kg.km^{-2}$)	4 551	2 630	3 746	3 228

Table 2: **Estimated biomass (t), coefficient of variation (*c.v.*), for the 23 major commercial species, and total biomass for all species combined, 1996–97 to 99–2000**

	KAH9618		KAH9704		KAH9809		KAH9917	
Common name	Biomass	*c.v.* %	Biomass	*c.v.* %	Biomass	*c.v.* %	Biomass	*c.v.* %
Arrow squid	1 522	17	629	34	970	12	838	12
Barracouta	21 513	34	11 843	25	21 877	14	21 476	14
Blue warehou	2 101	54	619	51	4 030	95	608	39
Chilean jack mackerel	180	24	33	49	275	36	282	29
Dark ghost shark	3 066	18	5 870	33	7 416	27	2 512	19
Elephantfish	1 127	31	404	18	1 718	28	1 097	25
Giant stargazer	897	12	543	11	999	10	472	14
Hapuku	207	17	133	26	242	19	283	22
Hoki	3 106	24	2 189	41	4 812	29	773	23
Leatherjacket	212	31	122	18	111	25	150	24
Lemon sole	246	15	228	18	269	35	36	27
Ling	1 202	26	919	64	705	18	450	18
New Zealand sole	226	22	128	27	148	21	21	39
Red cod	10 634	23	7 536	23	12 823	17	6 690	30
Red gurnard	765	13	317	16	493	13	202	20
Rig	139	40	35	33	214	52	86	38
Rough skate	1 336	15	1 082	13	1 175	10	329	23
School shark	256	23	476	24	343	23	389	27
Sea perch	4 041	47	1 638	25	3 889	41	2 203	27
Silver warehou	307	35	474	90	269	19	444	23
Smooth skate	721	32	485	21	450	26	369	30
Spiny dogfish	35 776	28	29 765	25	22 842	16	49 832	37
Tarakihi	3 818	21	2 036	21	4 277	24	2 606	15
All species combined	90 424	11	78 195	12	102 543	7	98 129	19

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)**

	Size range (cm)	Age	KAH9618 Biomass	KAH9618 *c.v.* (%)	KAH9704 Biomass	KAH9704 *c.v.* (%)	KAH9809 Biomass	KAH9809 *c.v.* (%)	KAH9917 Biomass	KAH9917 *c.v.* (%)
Barracouta	>20	0+	3	52	*	86	24	41	1	47
	28–43	1+	1 108	35	699	53	1 531	20	2 004	17
	39–54	2+	1 562	29	2 290	48	4 965	20	2 437	21
Blue warehou	<13	0+	1	47	*	55	*	68	2	55
	12–22	1+	32	33	25	36	37	30	208	31
Elephantfish	>23	0+	1	78	23	58	3	40	29	65
	21–39	1+	11	66	95	45	147	52	148	38
Giant stargazer	>12	0+	*	48	*	54	*	84	–	
	12–25	1+	7	27	7	20	11	15	5	27
Hoki	29–47	1+	323	82	31	97	2 631	50	17	36
	44–60	2+	1 399	29	1 035	68	758	43	540	30
Red cod	<16	0+	195	35	12	40	51	38	8	27
	15–34	1+	2 149	24	3 155	27	3 050	16	2 204	43
Red gurnard	<19	1+	*	51	2	31	4	72	*	45
	19–30	2+	41	26	1	36	5	41	3	38
School shark	<37	0+	2	39	8	42	2	39	2	42
	37–60	1+	16	27	87	21	24	31	13	27
Silver warehou	<21	0+	5	39	1	29	24	34	29	33
	21–32	1+	154	48	26	53	201	46	225	29
	33–39	2+	35	61	3	73	10	39	15	39
Tarakihi	<13	0+	13	53	3	78	1	29	*	51
	12–19	1+	577	30	159	30	208	27	105	24
	18–23	2+	827	27	599	27	1 580	27	799	18

– 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 (red cod > 50 cm, red gurnard > 23 cm, and giant stargazer > 45 cm, Annala *et al*. 1999)**

	Males						Females					
	Gonad stage						Gonad stage					
	1	2	3	4	5	*n*	1	2	3	4	5	*n*
Giant stargazer												
KAH9618	61	39	0	0	0	38	82	17	1	0	0	84
KAH9704	35	58	8	0	0	26	60	32	6	1	0	82
KAH9809	79	20	0	0	2	61	82	14	1	0	3	158
KAH9917	56	16	19	9	0	32	51	39	3	6	1	71
Red cod												
KAH9618	31	39	25	6	0	88	90	8	1	0	0	250
KAH9704	13	50	20	17	0	30	51	46	3	1	0	158
KAH9809	42	12	22	19	4	73	90	9	1	0	< 0.5	365
KAH9917	29	40	12	17	2	124	54	30	9	5	2	520
Red gurnard												
KAH9618	18	80	2	0	0	343	20	50	23	6	0	403
KAH9704	15	77	7	< 0.5	< 0.5	221	4	35	46	14	1	304
KAH9809	31	62	5	1	1	401	33	24	32	10	1	375
KAH9917	39	49	8	3	0	189	16	20	44	18	1	176

Gonad stages: 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. (*see* Beentjes & Waas (1994) for detailed gonad stage descriptions).

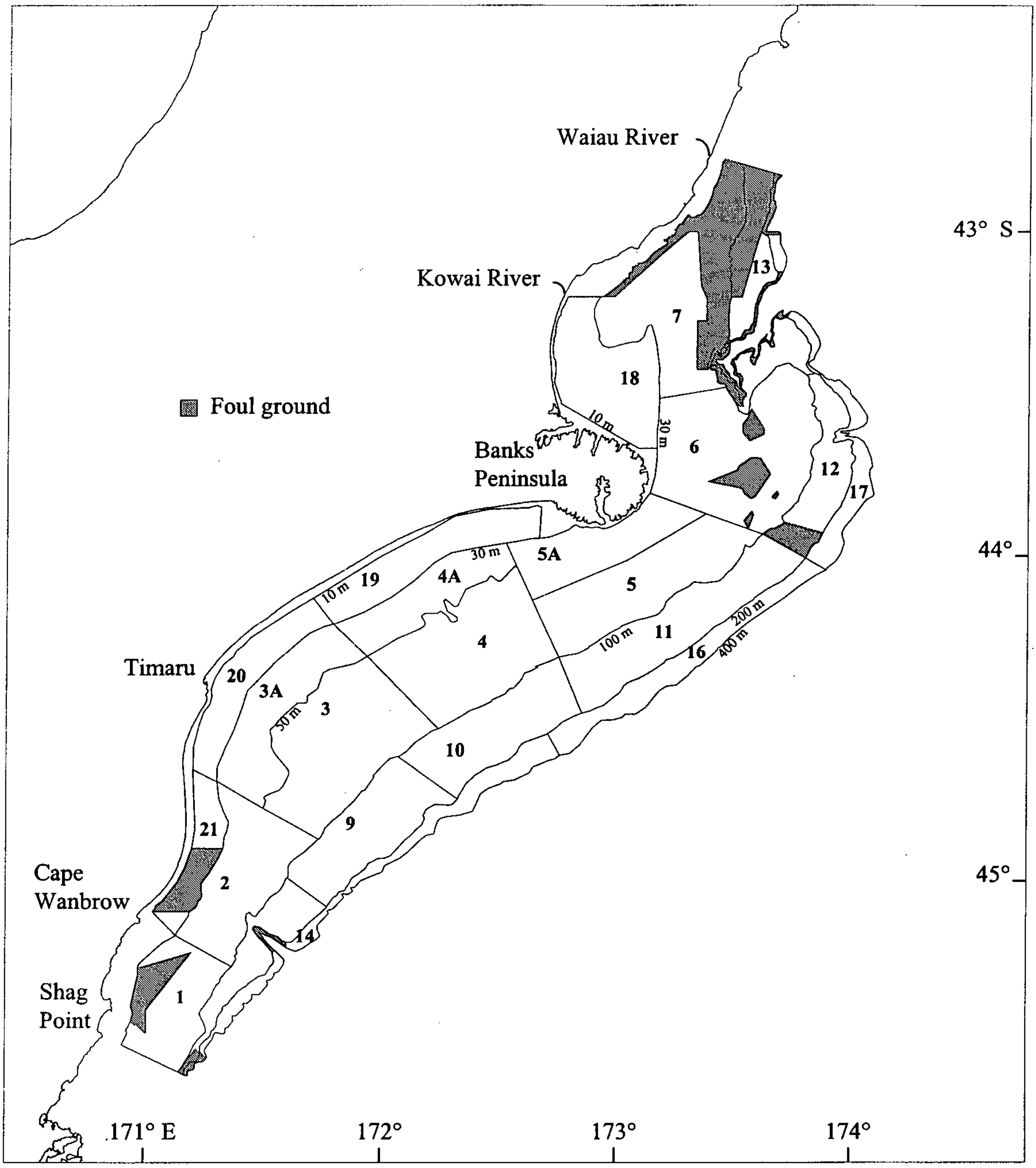


Figure 1: **Survey area (KAH9917) showing stratum boundaries and numbers (bold type), areas of untrawlable (foul) ground.**

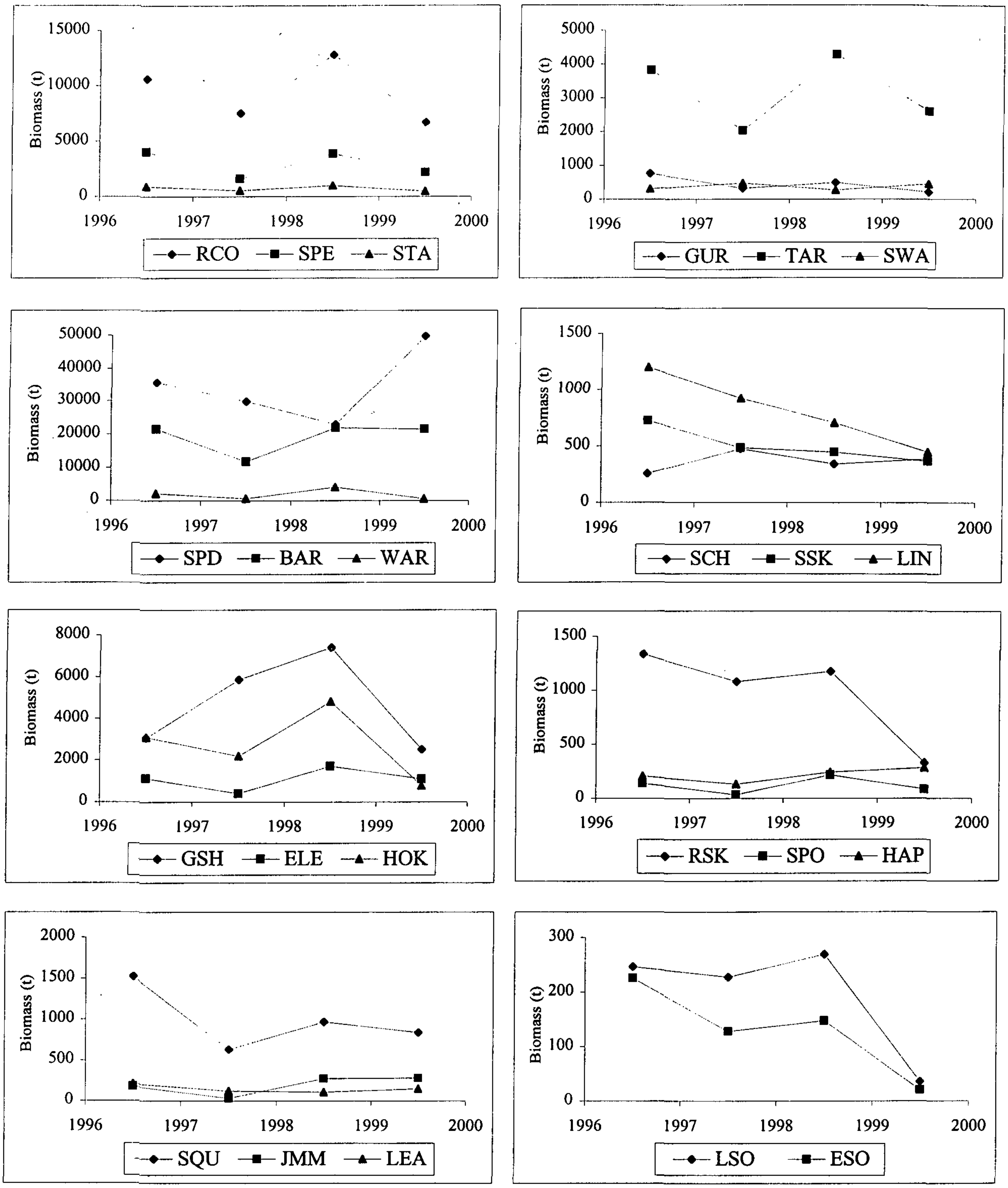


Figure 2: **Estimated biomass of the 23 major species, 1996–97 to 1999–2000 (RCO, red cod; SPE, sea perch; STA, giant stargazer; GUR, red gurnard; TAR, tarakihi; SWA, silver warehou; SPD, spiny dogfish; BAR, barracouta; WAR, blue warehou; SCH, school shark; SSK, smooth skate; LIN, ling; GSH, dark ghost shark; ELE, elephantfish; HOK, hoki; RSK, rough skate; SPO, rig; HAP, hapuku; SQU, arrow squid; JMM, Chilean jack mackerel; LEA, leatherjacket; LSO, lemon sole; ESO, New Zealand sole.**

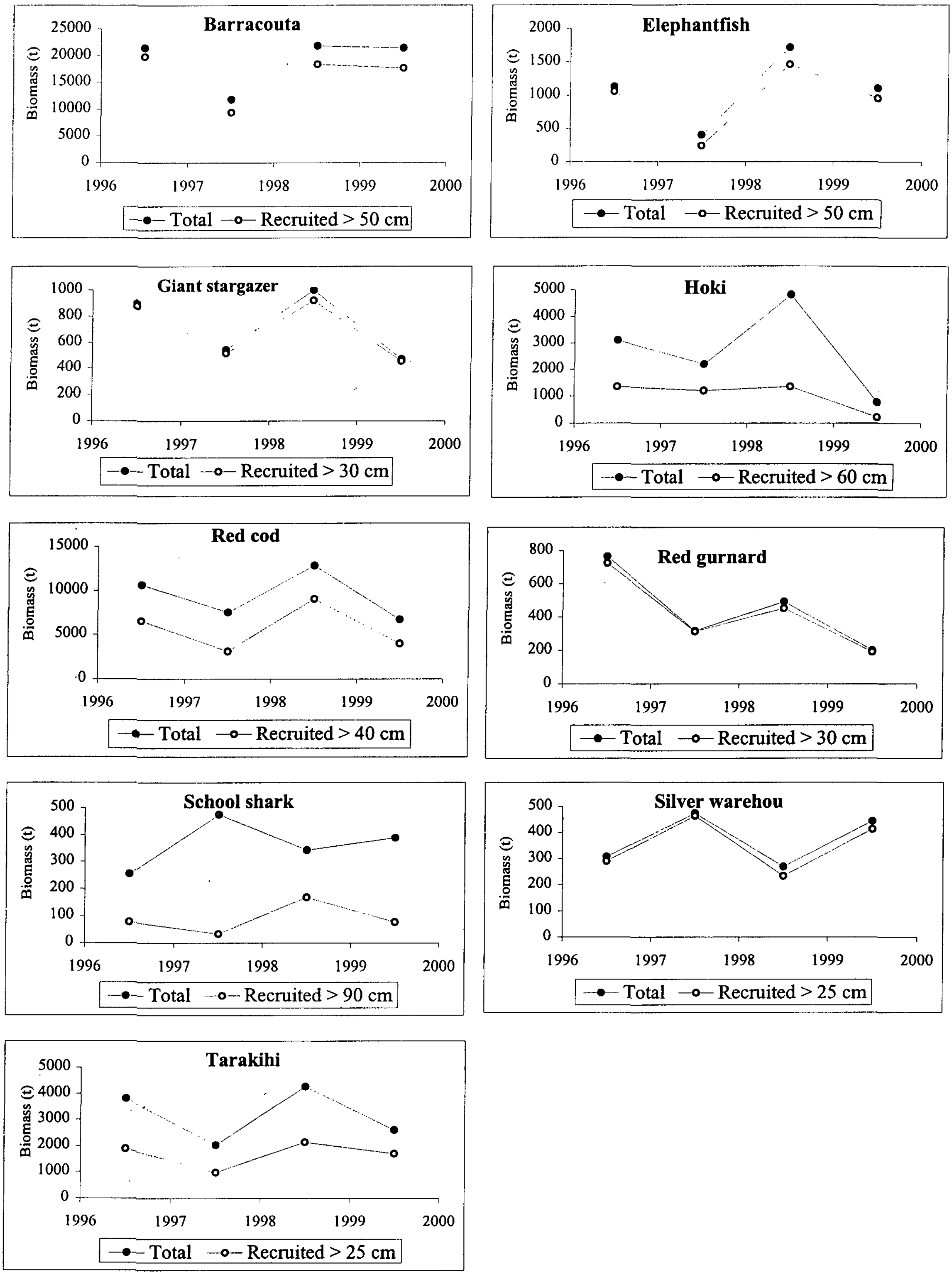


Figure 3 **: Total and recruited biomass of barracouta, elephantfish, giant stargazer, hoki, red cod, red gurnard school shark, silver warehou, and tarakihi.**

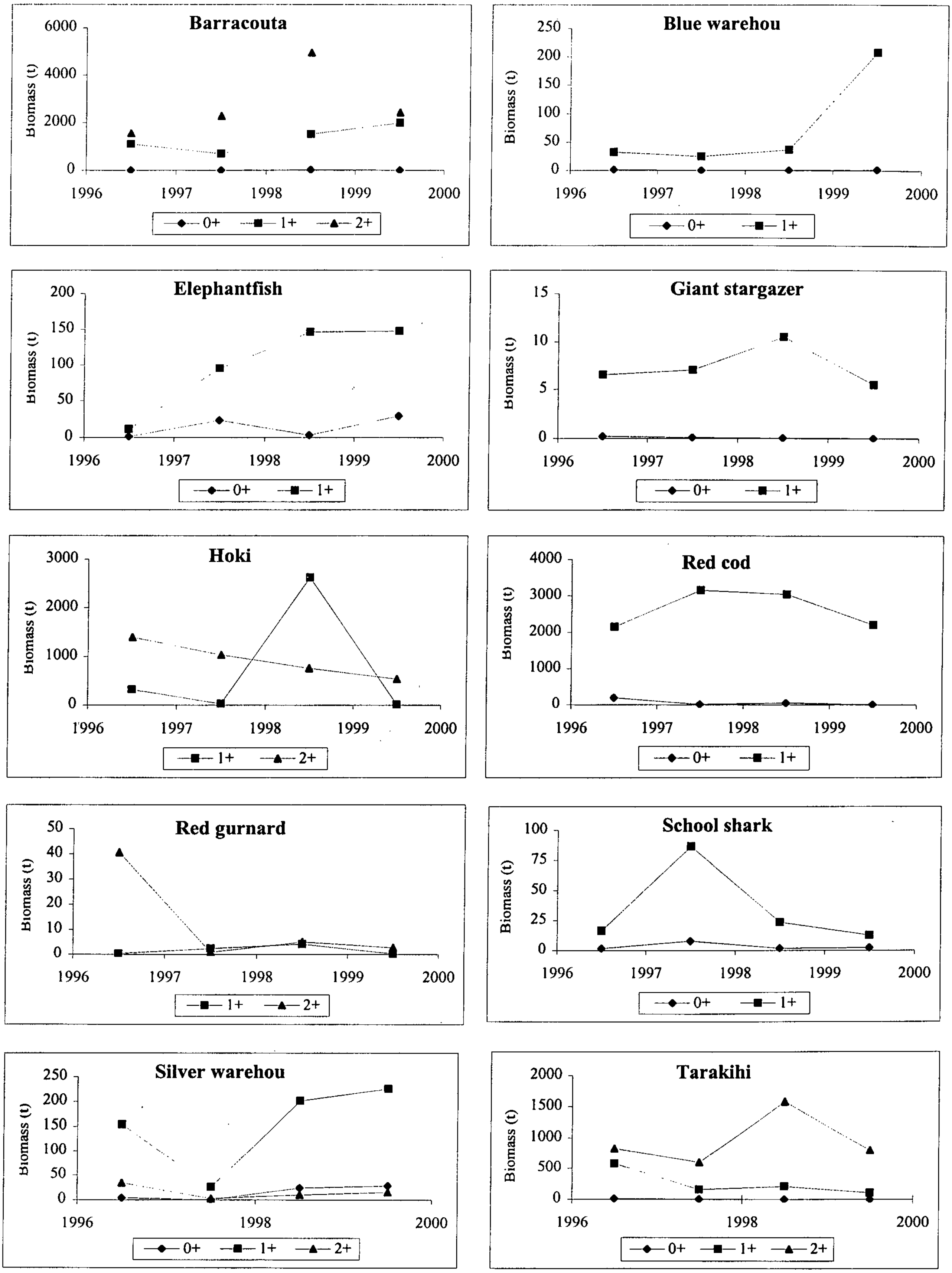


***Figure 4*: Biomass by year class for barracouta, blue warehou, elephantfish, giant stargazer, hoki, red cod, red gurnard, school shark, silver warehou, and tarakihi.**

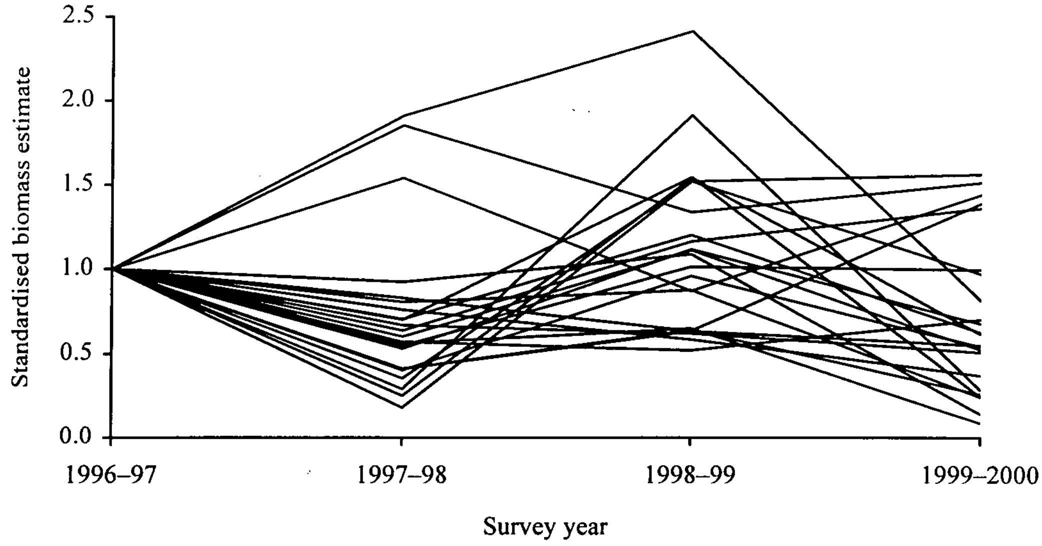


Figure 5: Standardised biomass estimates for 23 commercial species for each of the four trawl surveys. Biomass estimates have been standardised by dividing by the 1996–97 indices.

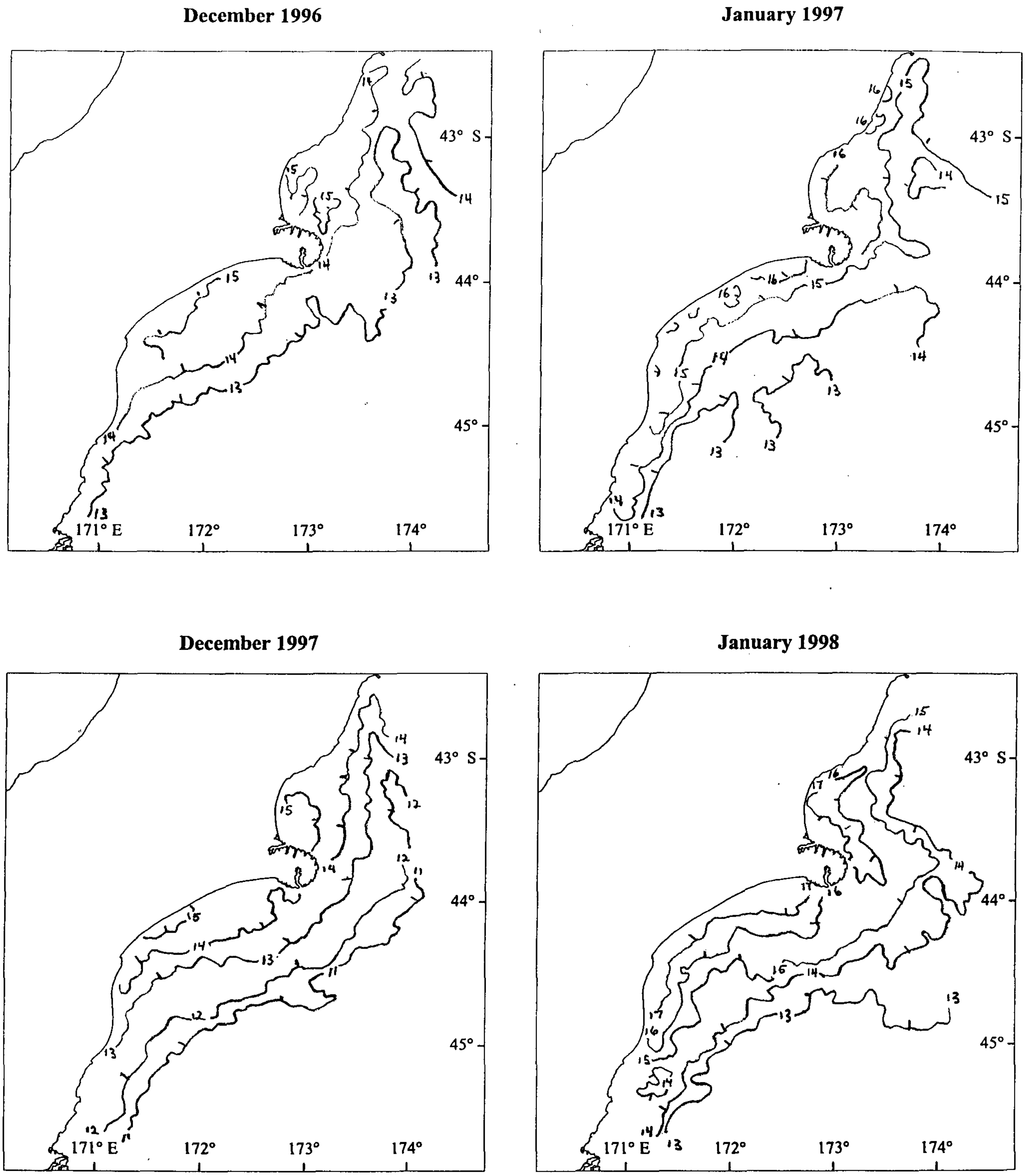
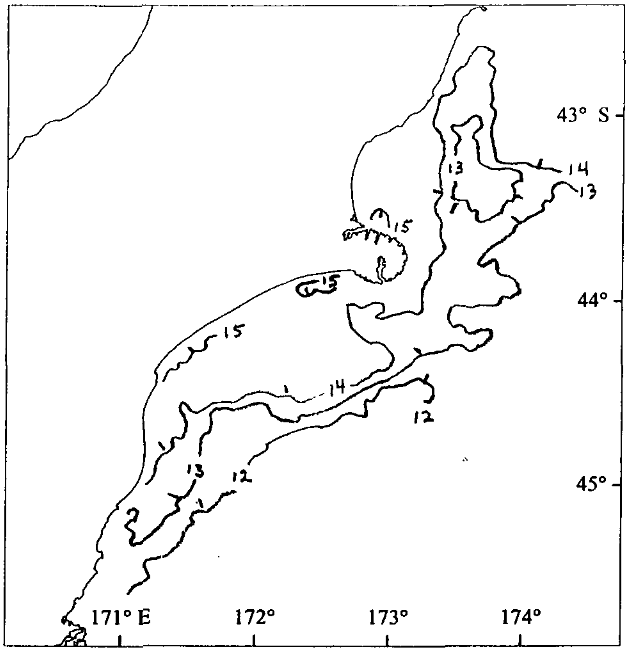
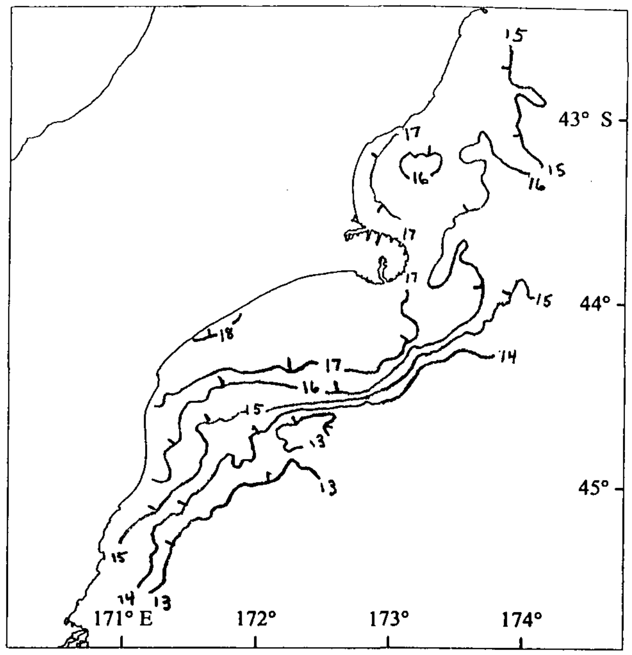


***Figure 6a*: Sea surface isotherms (1999–2000 isotherms estimated from station data, all others from NIWA SST Archive).**

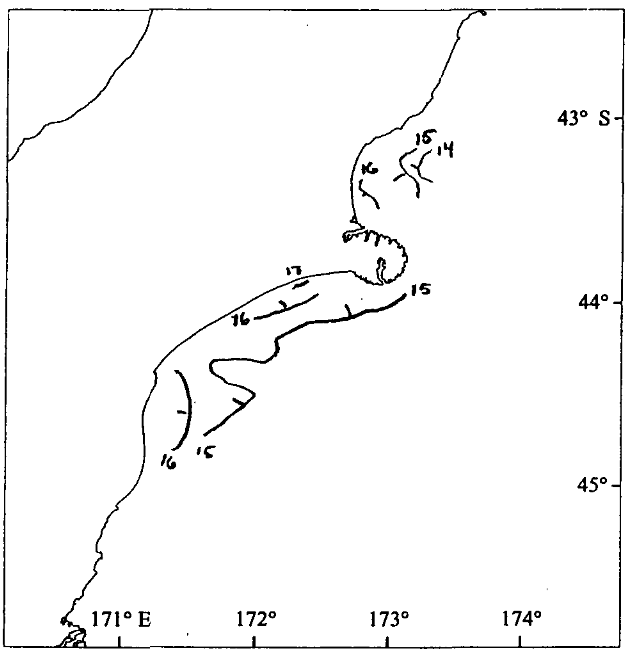
December 1998



January 1999



December 1999



January 2000

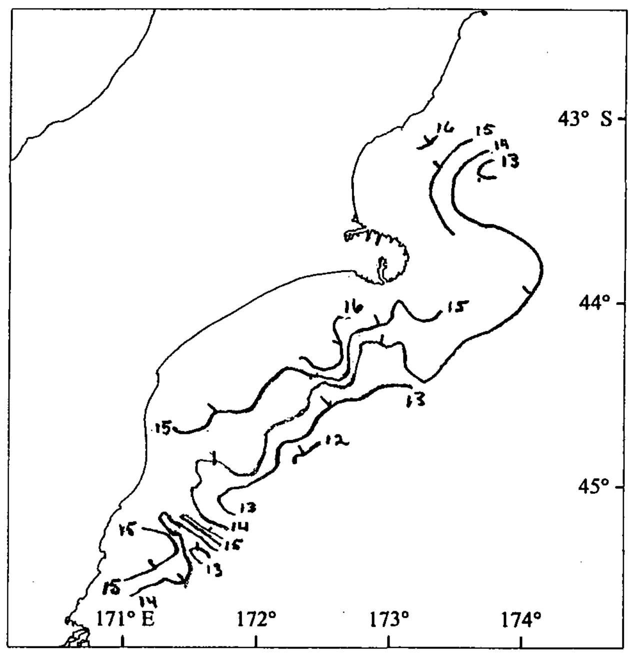


Figure 6a—continued

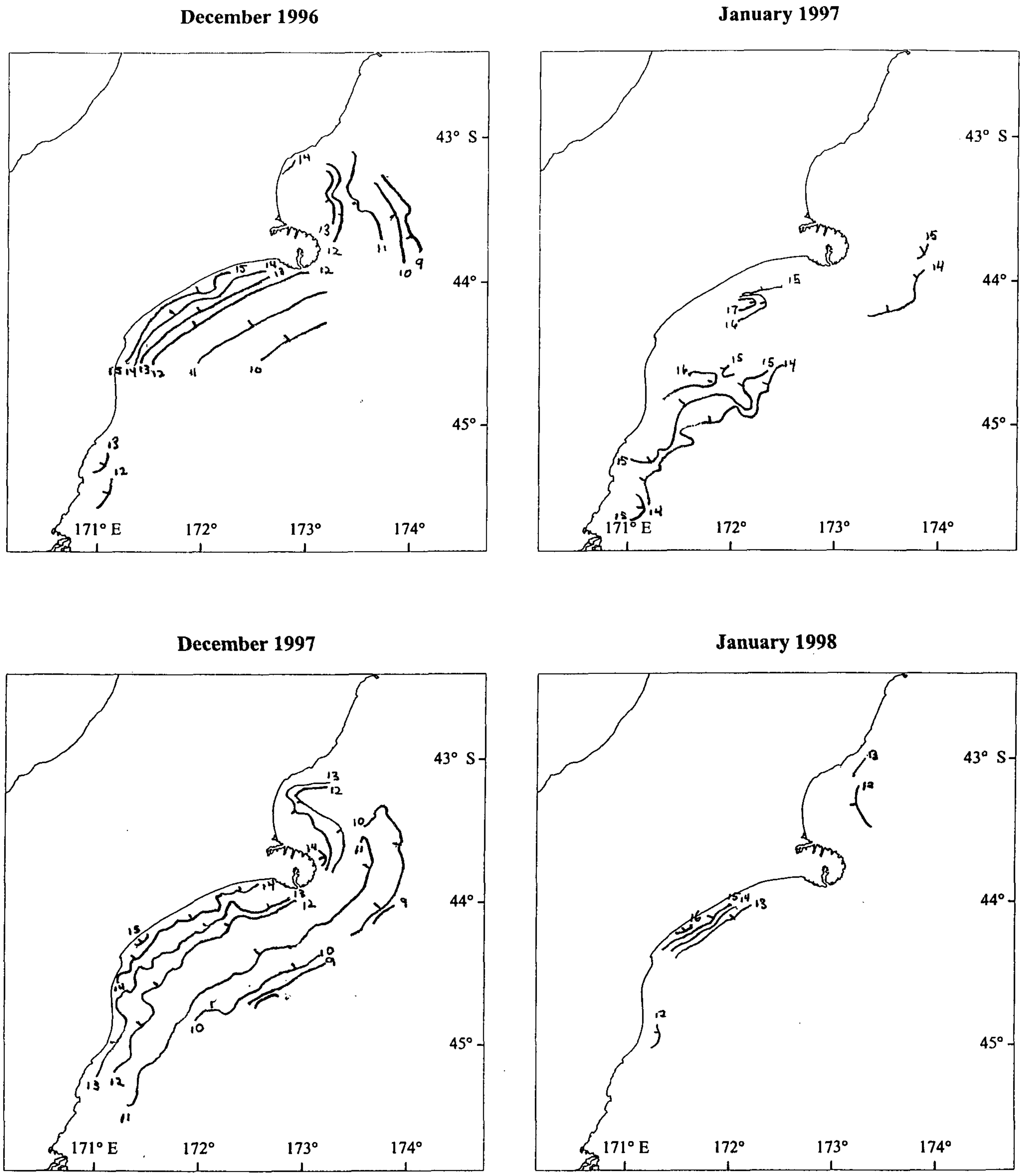


***Figure 6b*: Bottom temperature isotherms estimated from station data.**

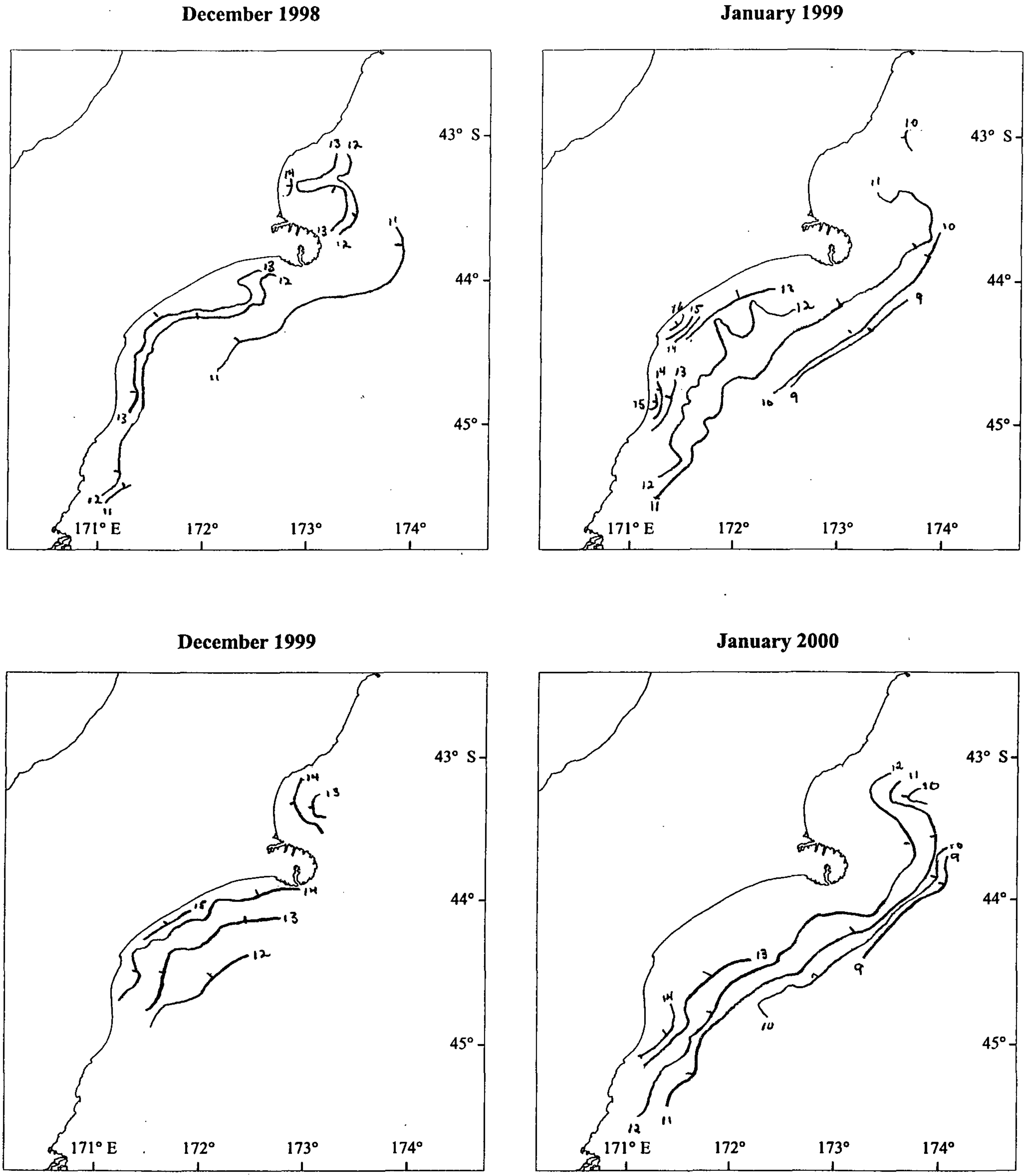


Figure 6b—continued

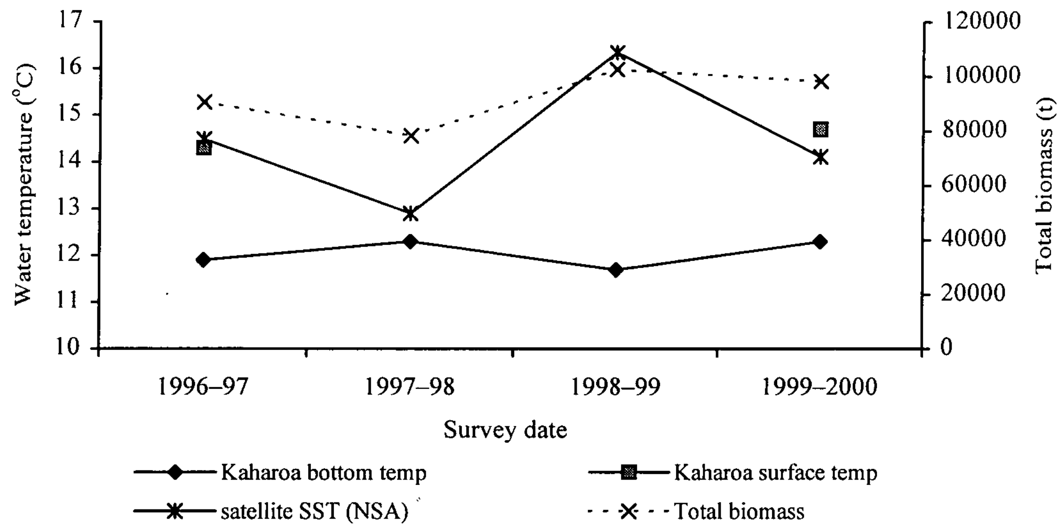


Figure 7: Mean satellite SST in the Canterbury Bight during the survey period, mean bottom and surface temperatures recorded during the surveys, and total biomass for each survey.

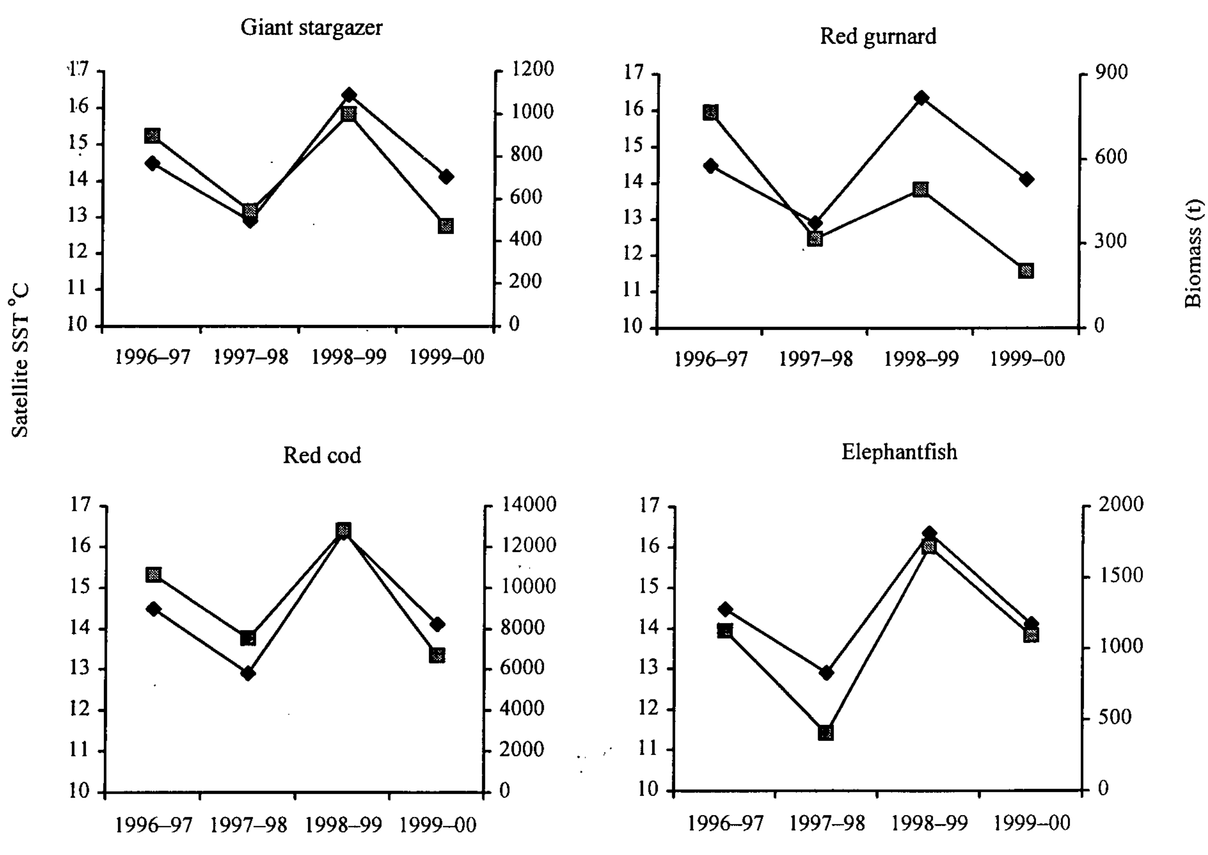


Figure 8: Mean satellite SST in the Canterbury Bight during the survey period and biomass of the most abundant species, including targets species. Diamonds represent SST and squares biomass.

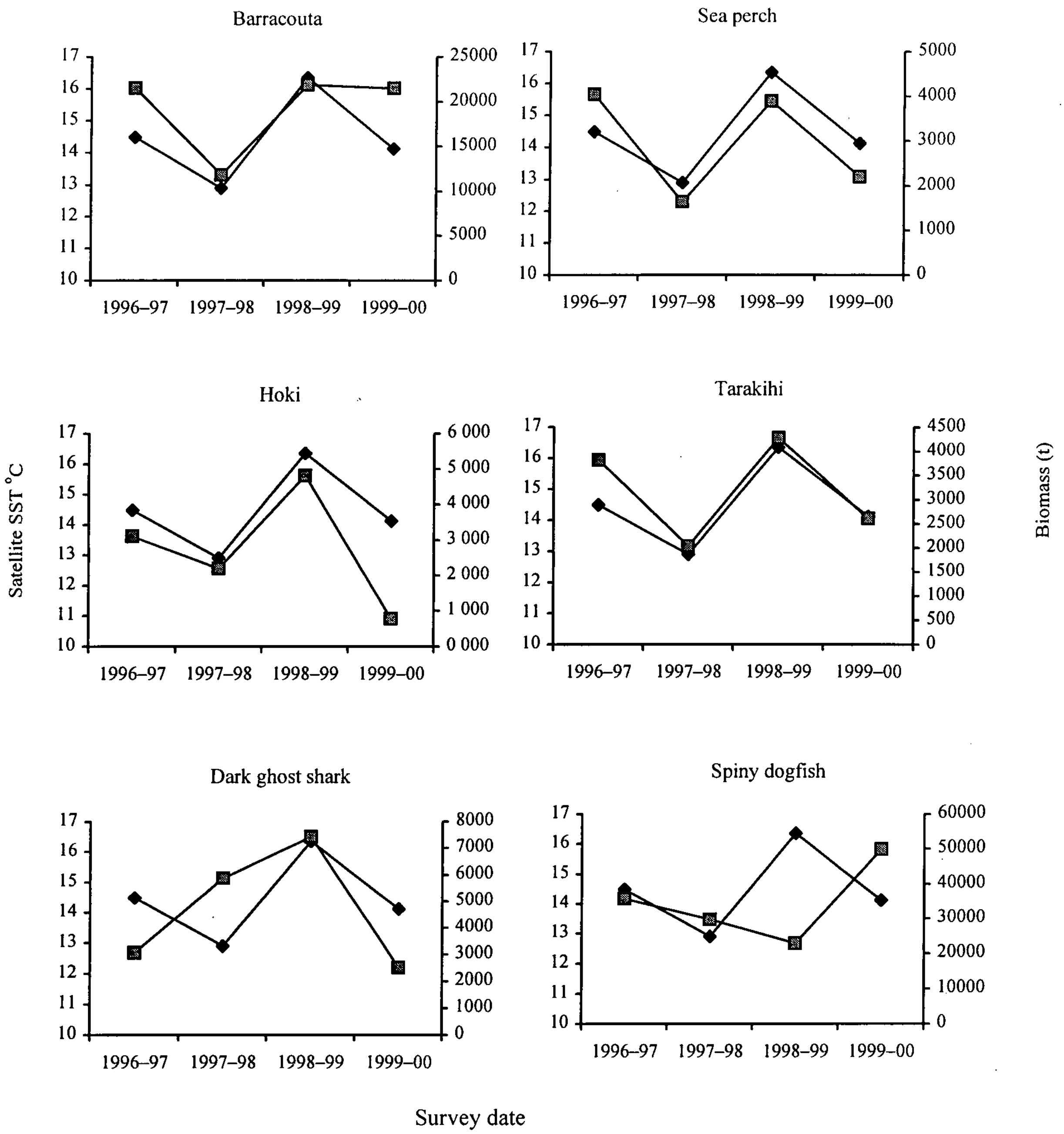


Figure 8–*continued.*

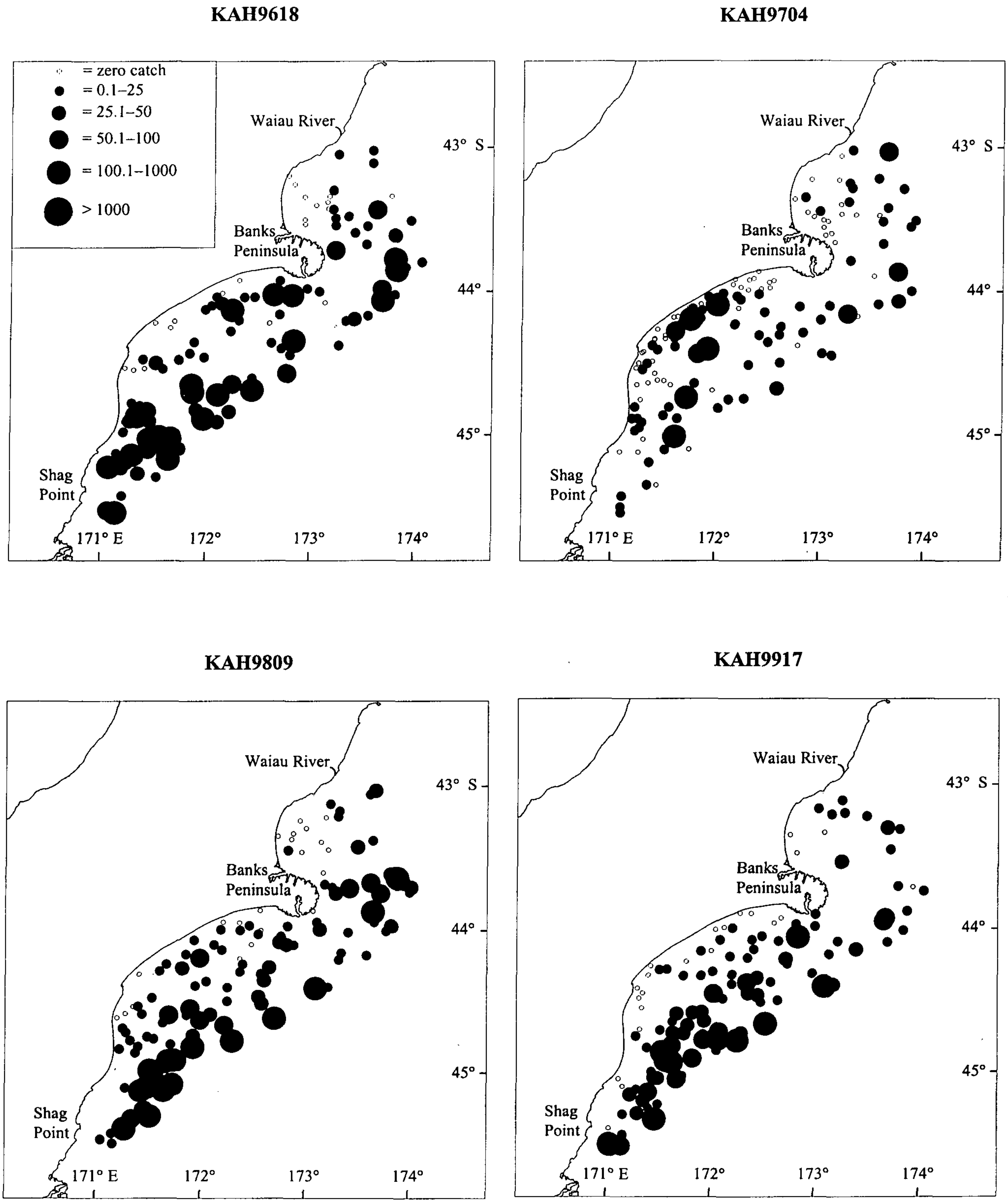


Figure 9: **Distribution and catch rates (kg.km^{-2}) of the major species (1996–1999).**
***a*: Arrow squid (maximum catch rate 1 068 kg.km^{-2}).**

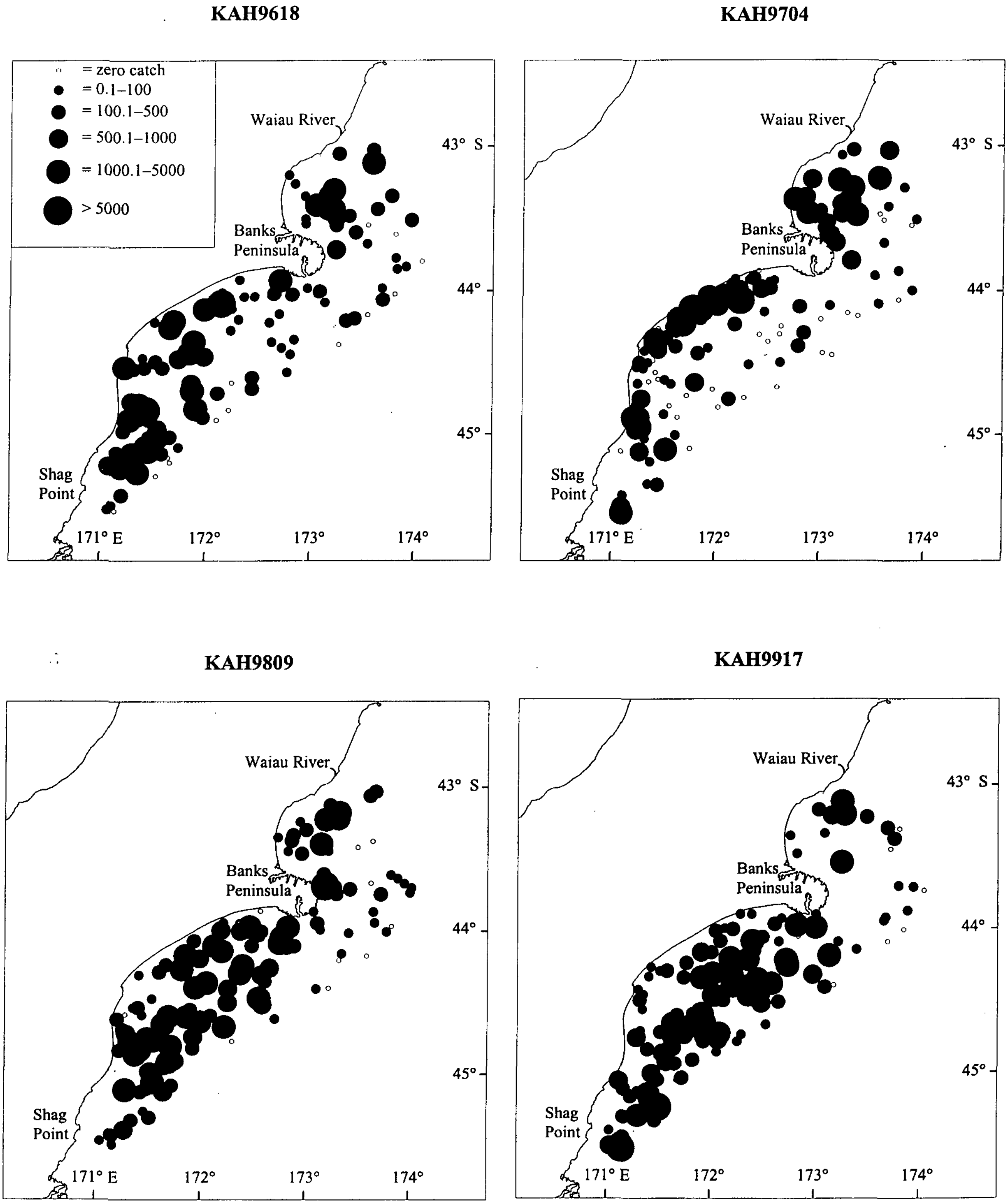


Figure 9b: **Barracouta (maximum catch rate 20 962 kg.km^{-2}).**

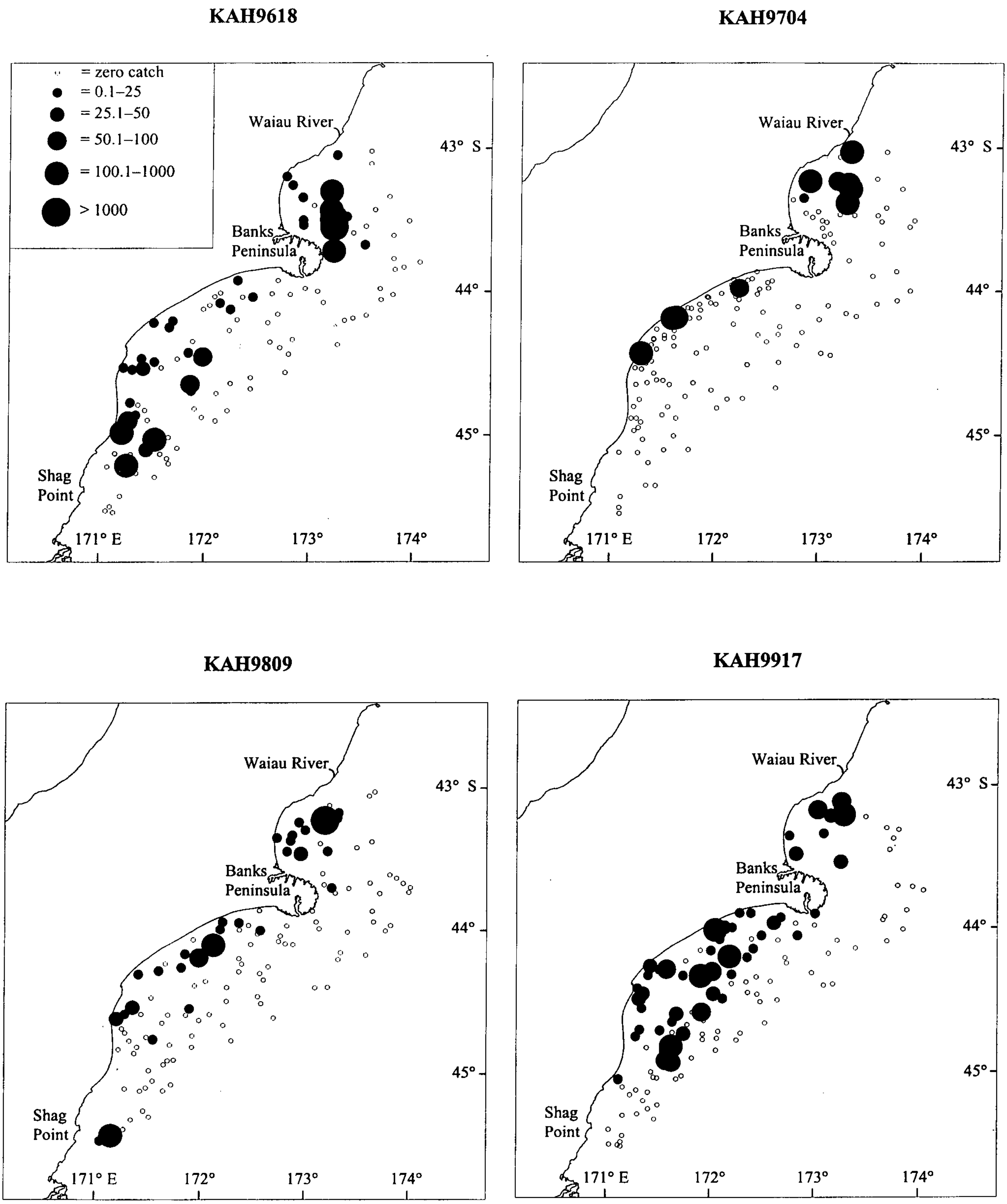


Figure 9c : **Blue warehou (maximum catch rate 12 829 kg.km** $^{-2}$ **).**

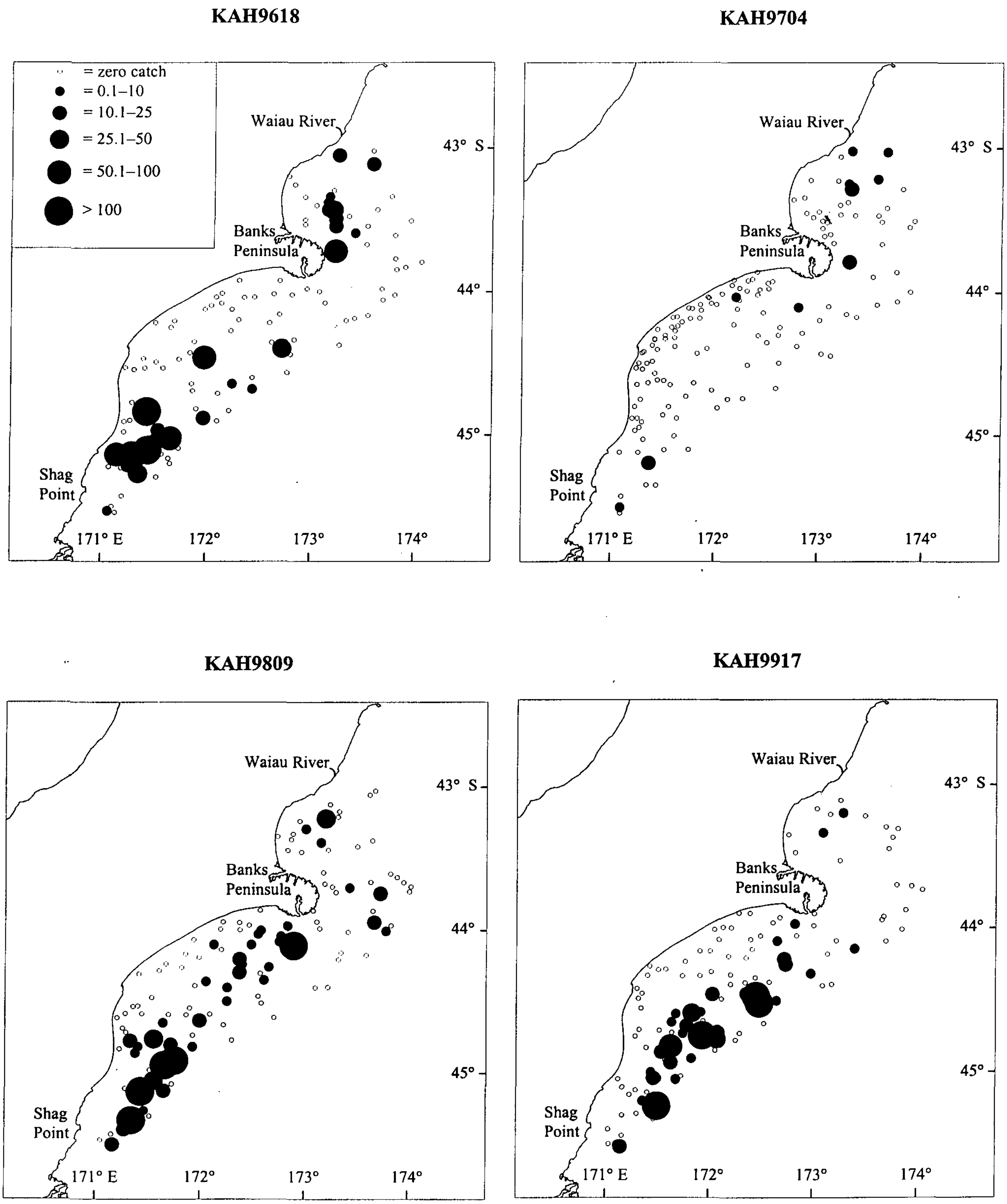


***Figure 9d*: Chilean jack mackerel (maximum catch rate 378 kg.km⁻²).**

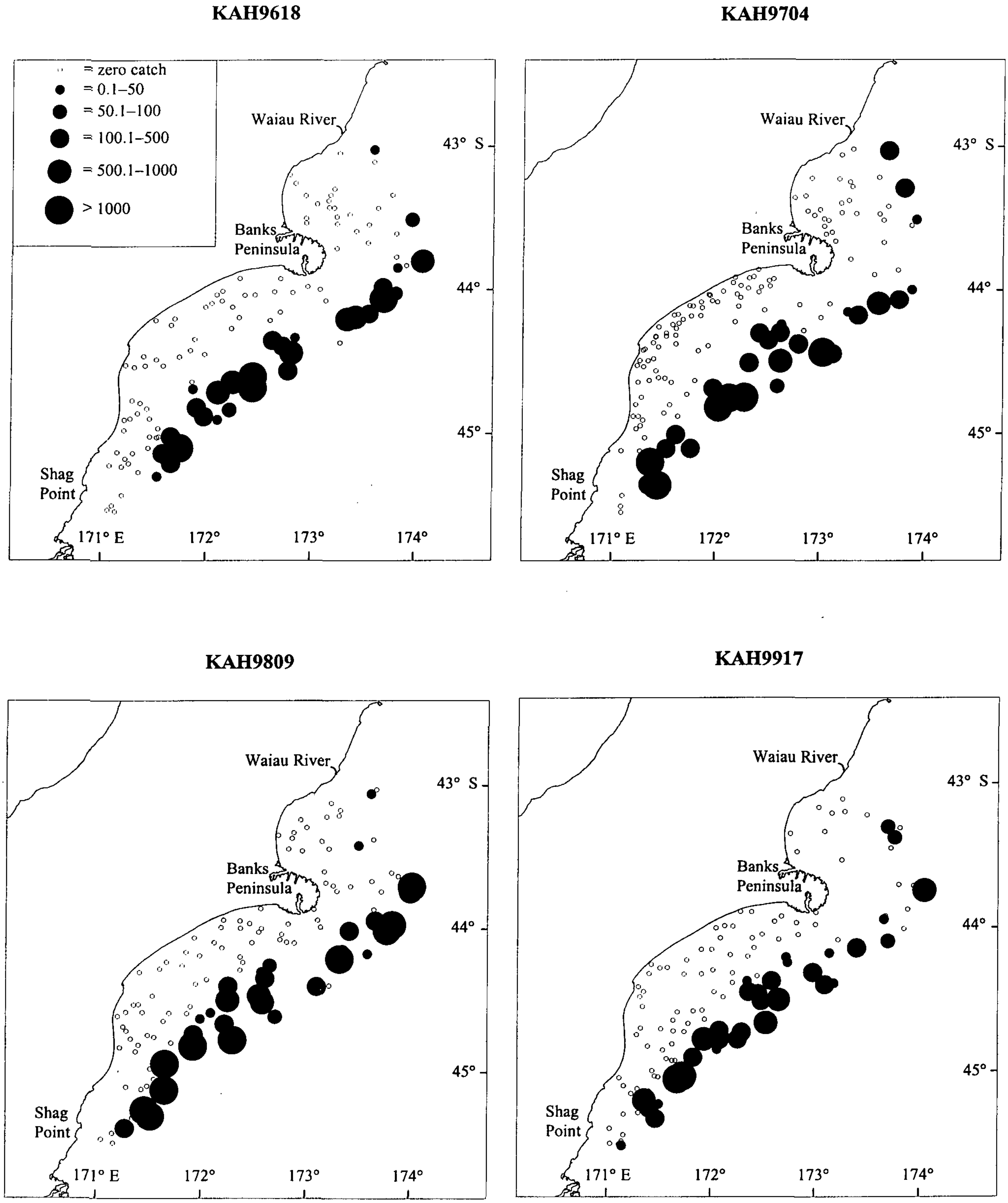


Figure 9e **: Dark ghost shark (maximum catch rate 7 322 kg.km⁻²).**

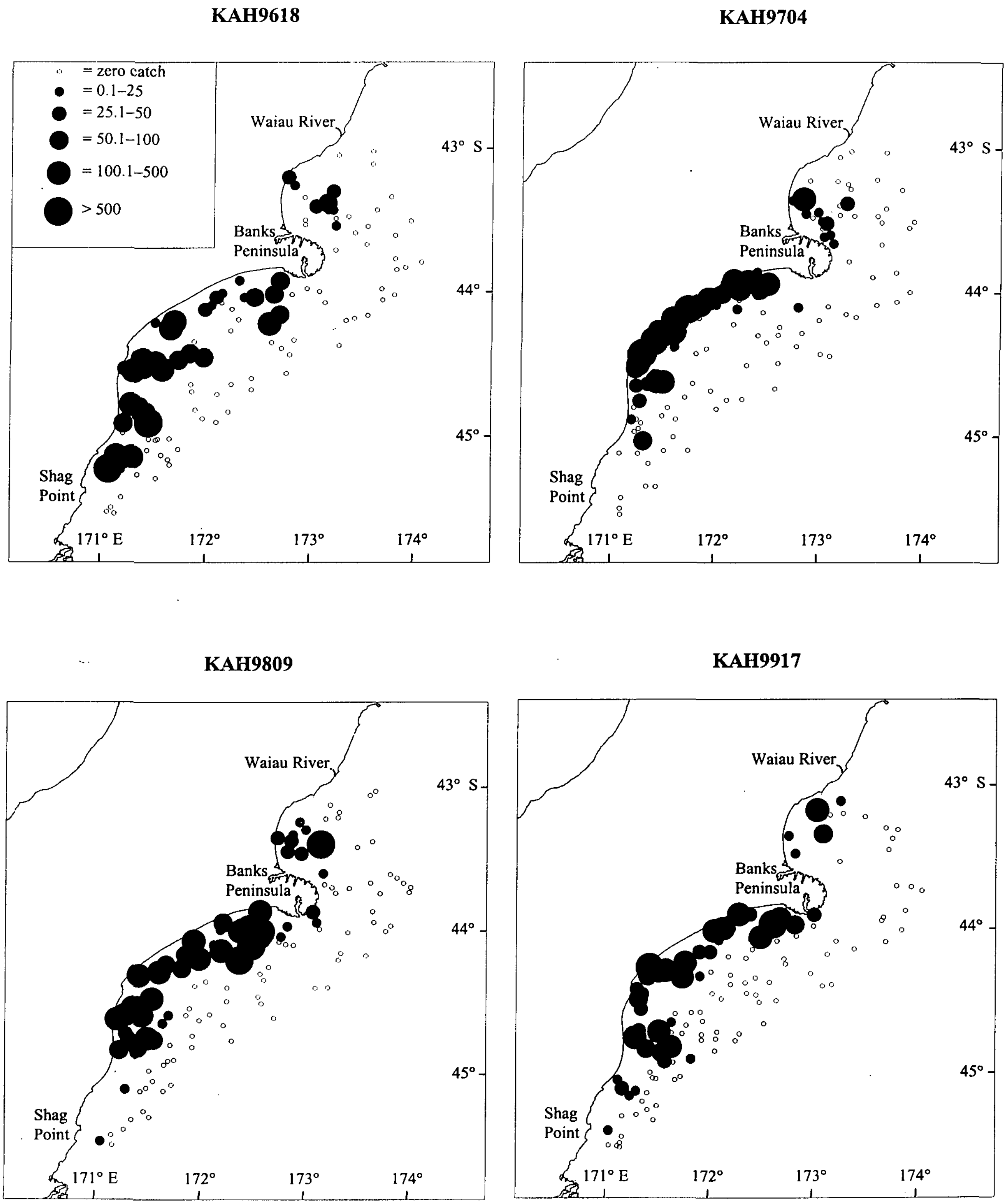


Figure 9f **: Elephantfish (maximum catch rate 2 347 kg.km^{-2}).**

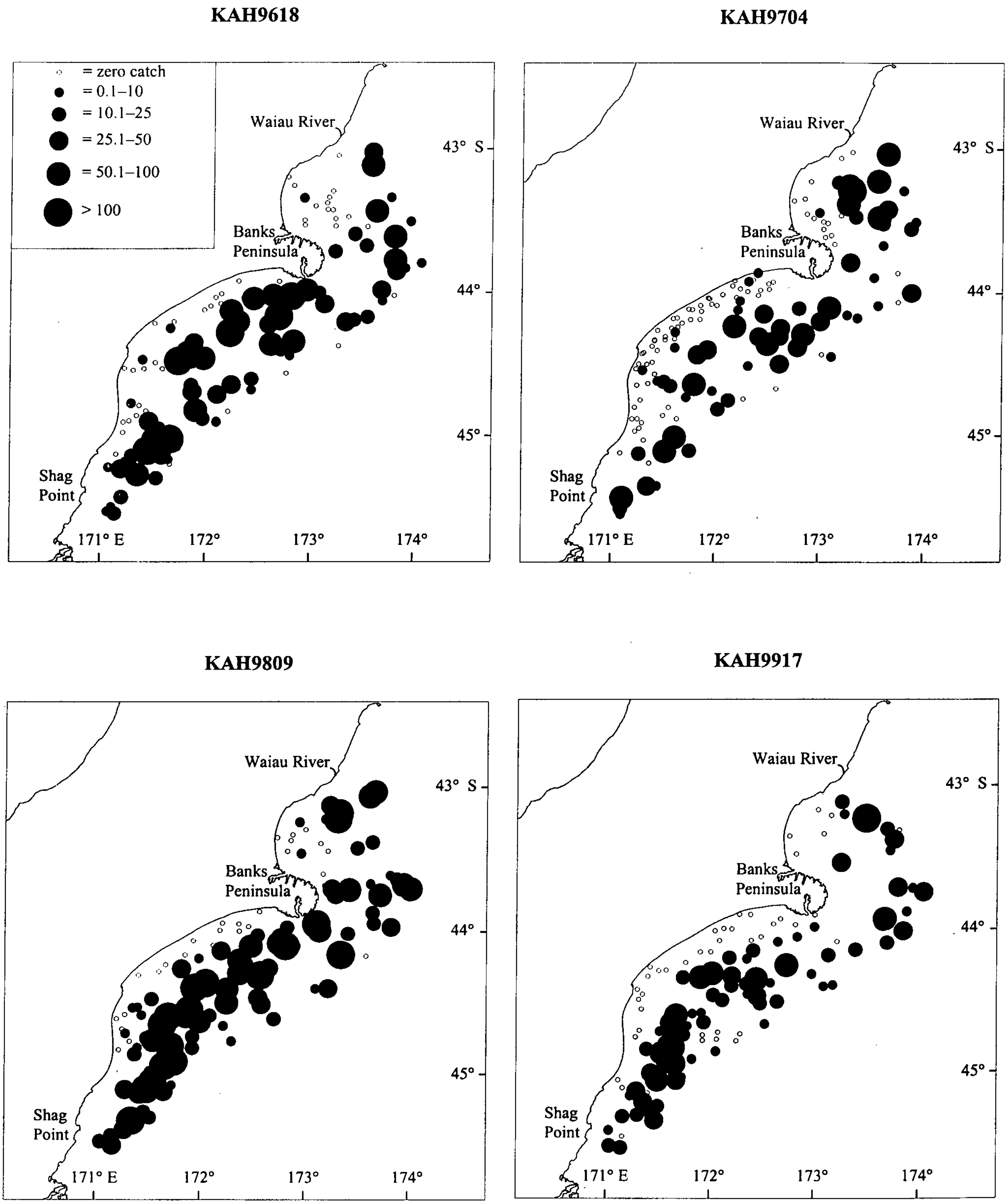


***Figure 9g*: Giant stargazer (maximum catch rate 344 kg.km^{-2}).**

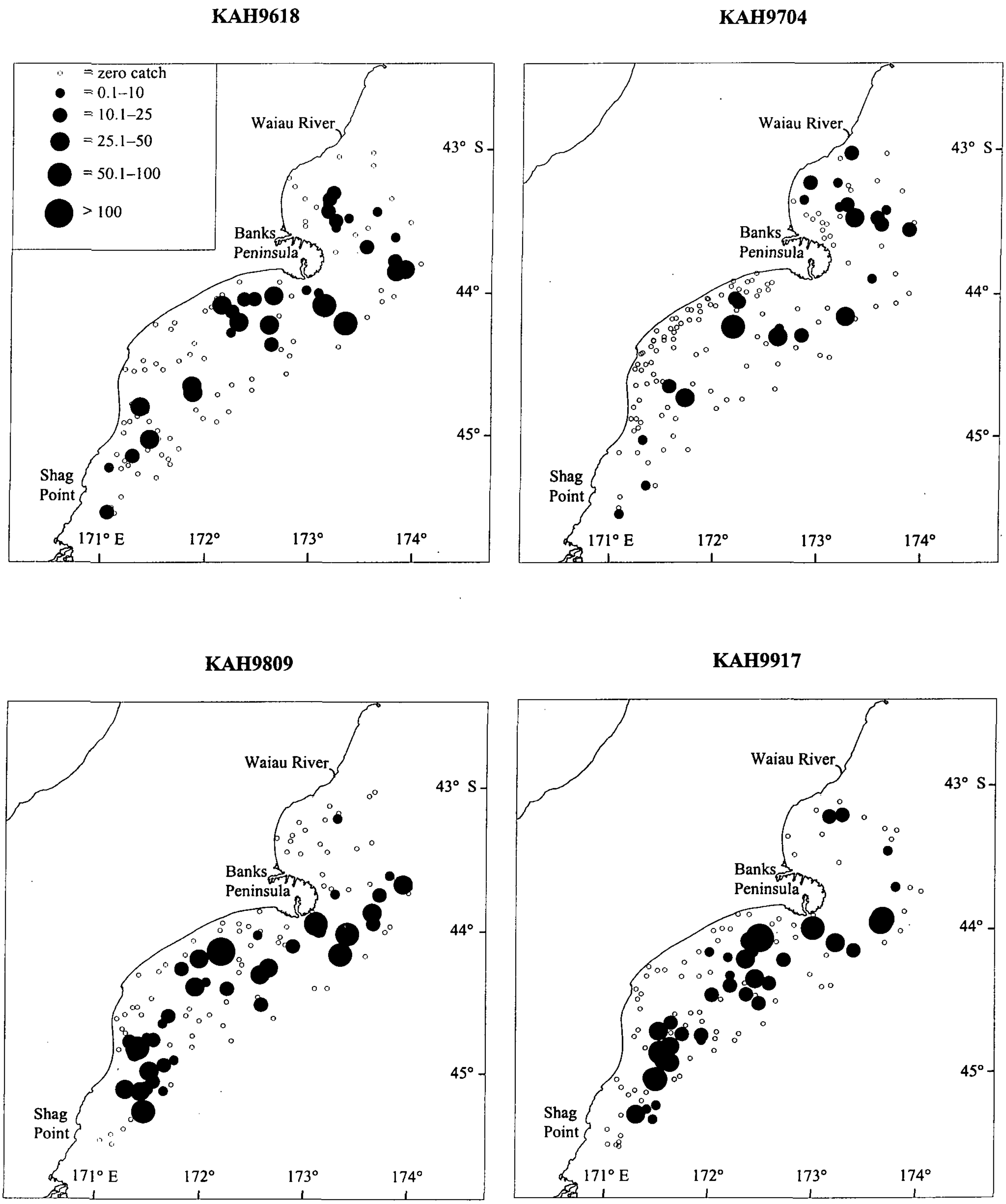


Figure 9h: **Hapuku (maximum catch rate 129 kg.km^{-2}).**

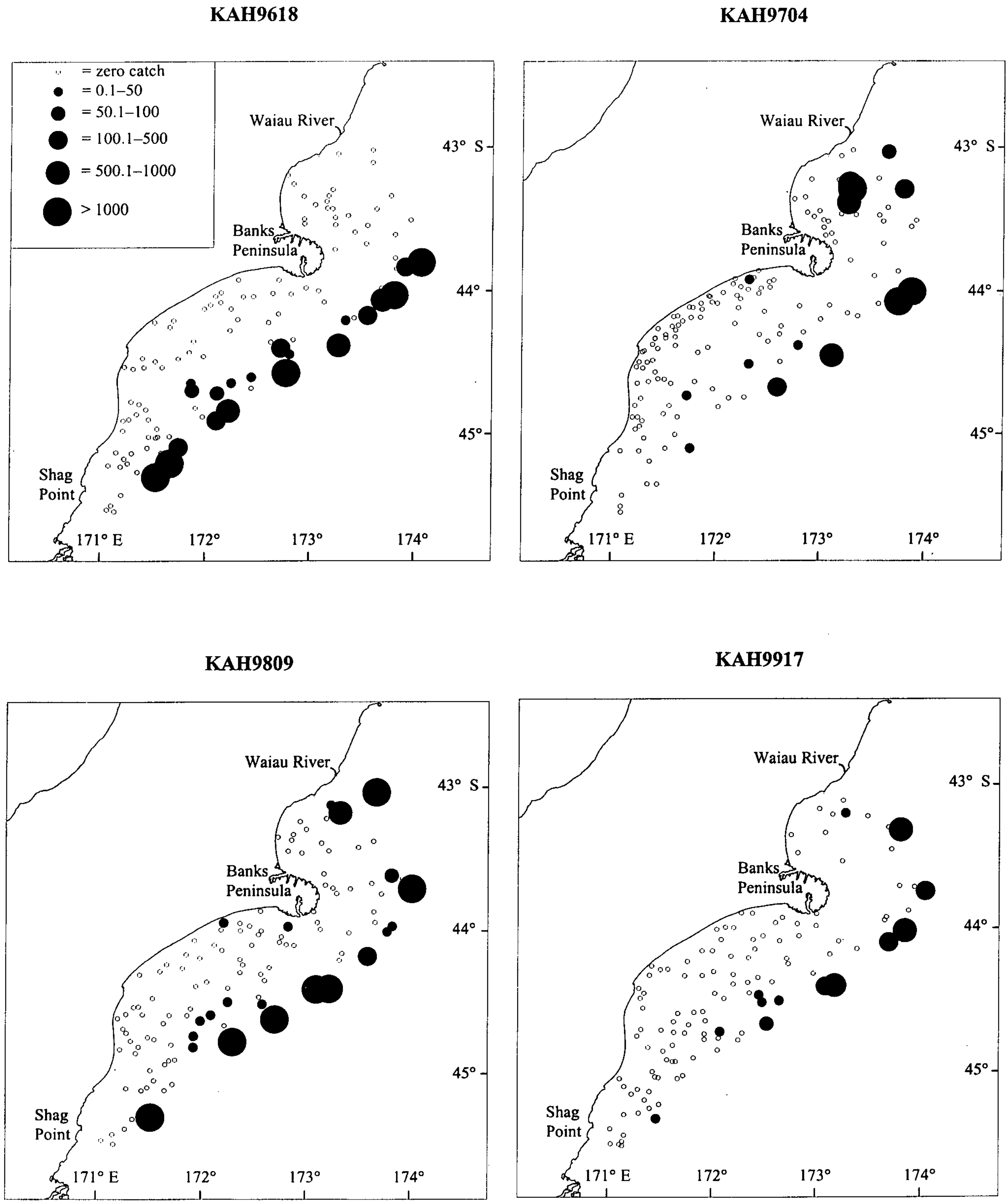


Figure 9i **: Hoki (maximum catch rate 5 040 kg.km⁻²).**

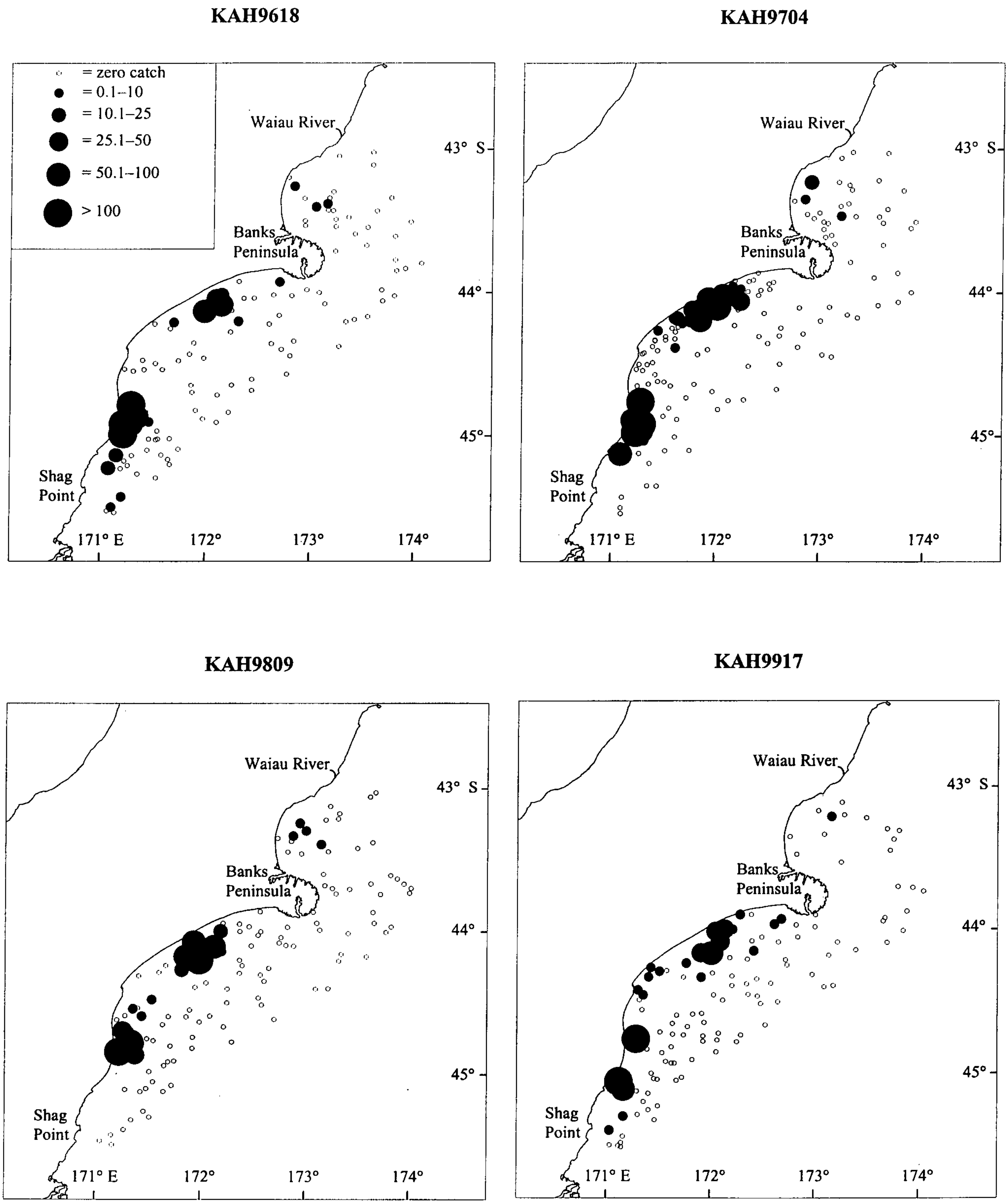


Figure 9j : **Leatherjacket (maximum catch rate 703 kg.km^{-2}).**

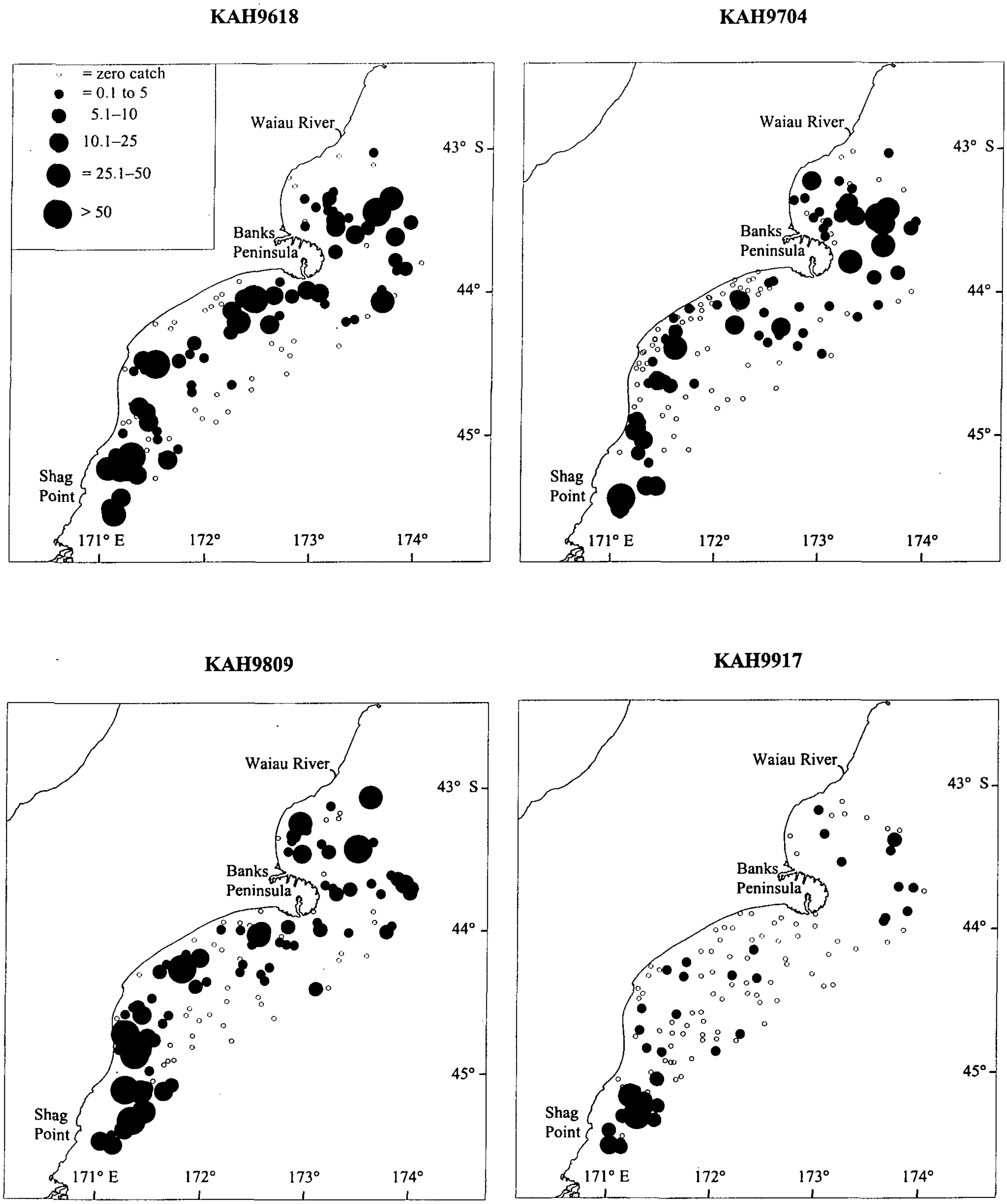


Figure 9k: **Lemon sole (maximum catch rate 134 kg.km^{-2}).**

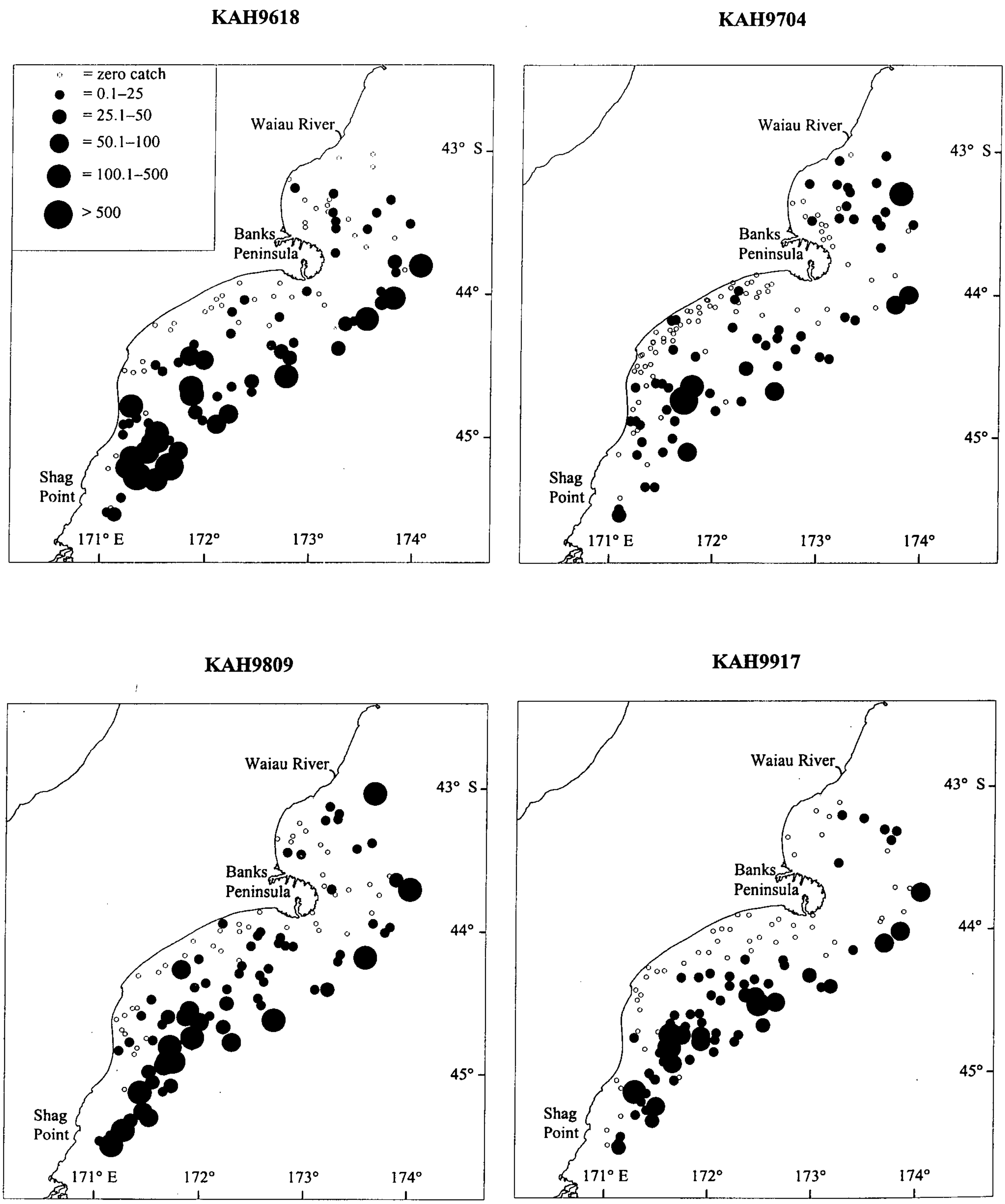


***Figure 9l*: Ling (maximum catch rate 2 076 kg.km⁻²).**

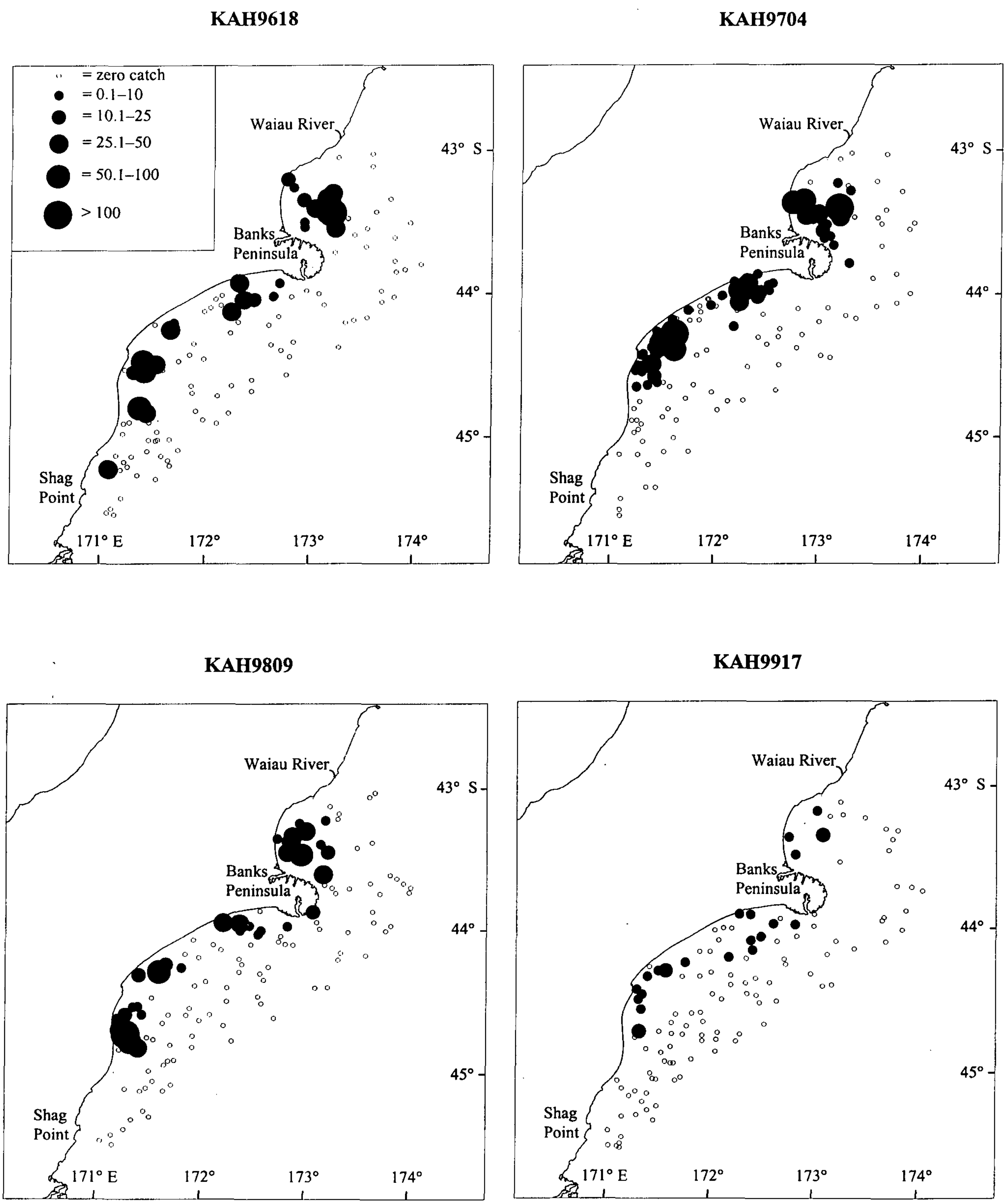


Figure 9m: **New Zealand sole (maximum catch rate 183 kg.km**$^{-2}$**).**

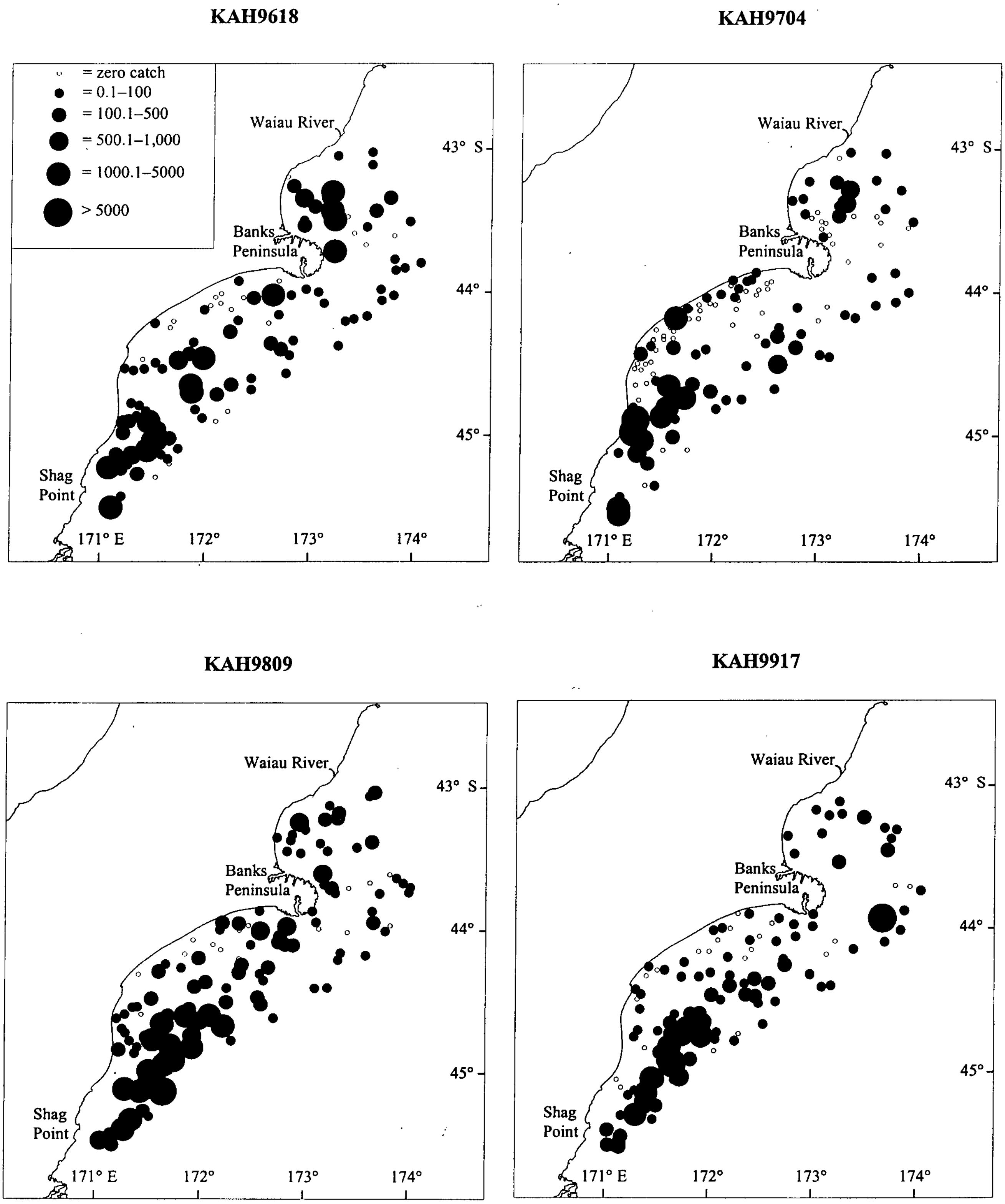


Figure 9n: **Red cod (maximum catch rate 19 755 kg.km⁻²).**

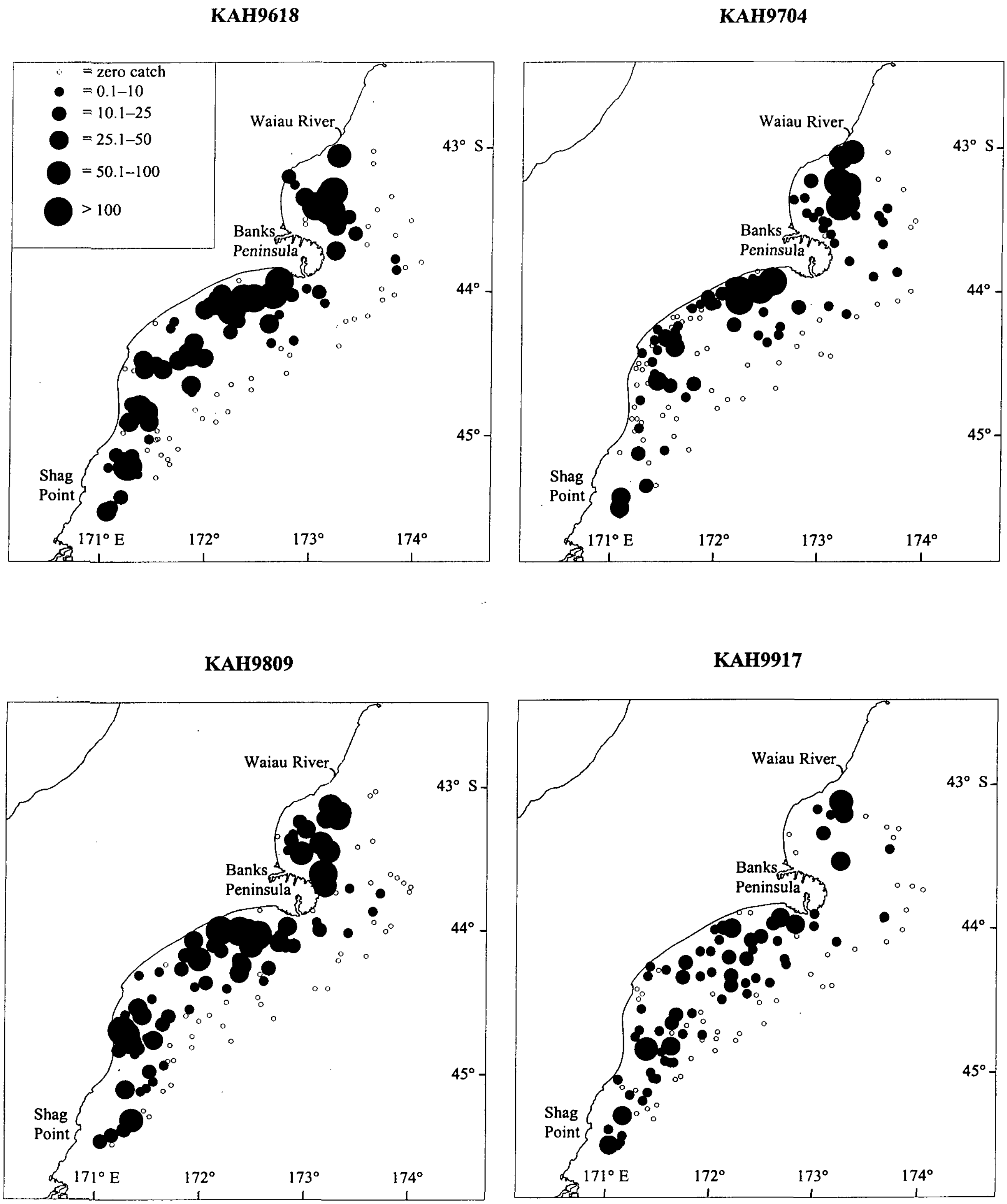


***Figure 9o*: Red gurnard (maximum catch rate 269 kg.km^{-2}).**

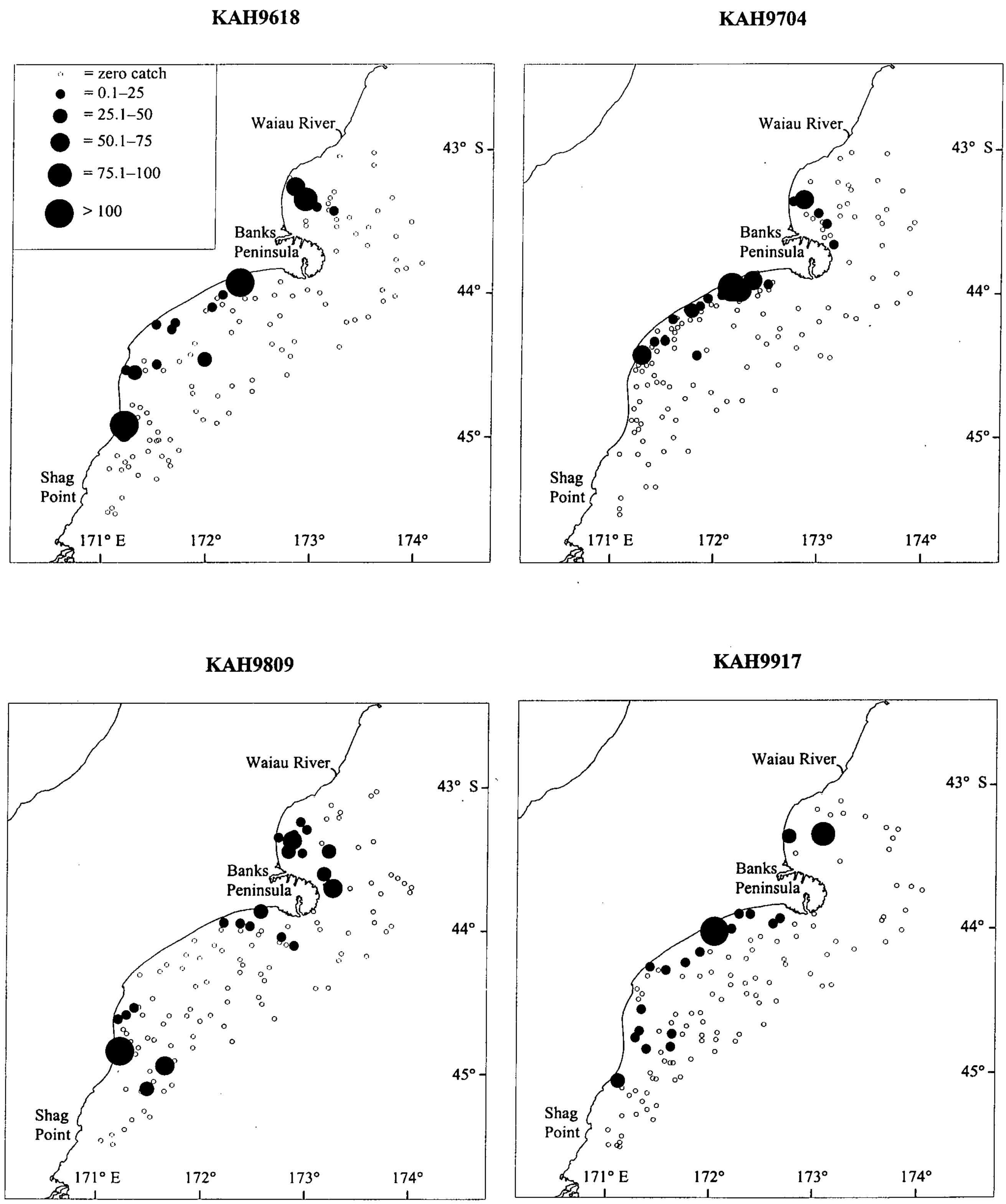


***Figure 9p*: Rig (maximum catch rate 442 kg.km^{-2}).**

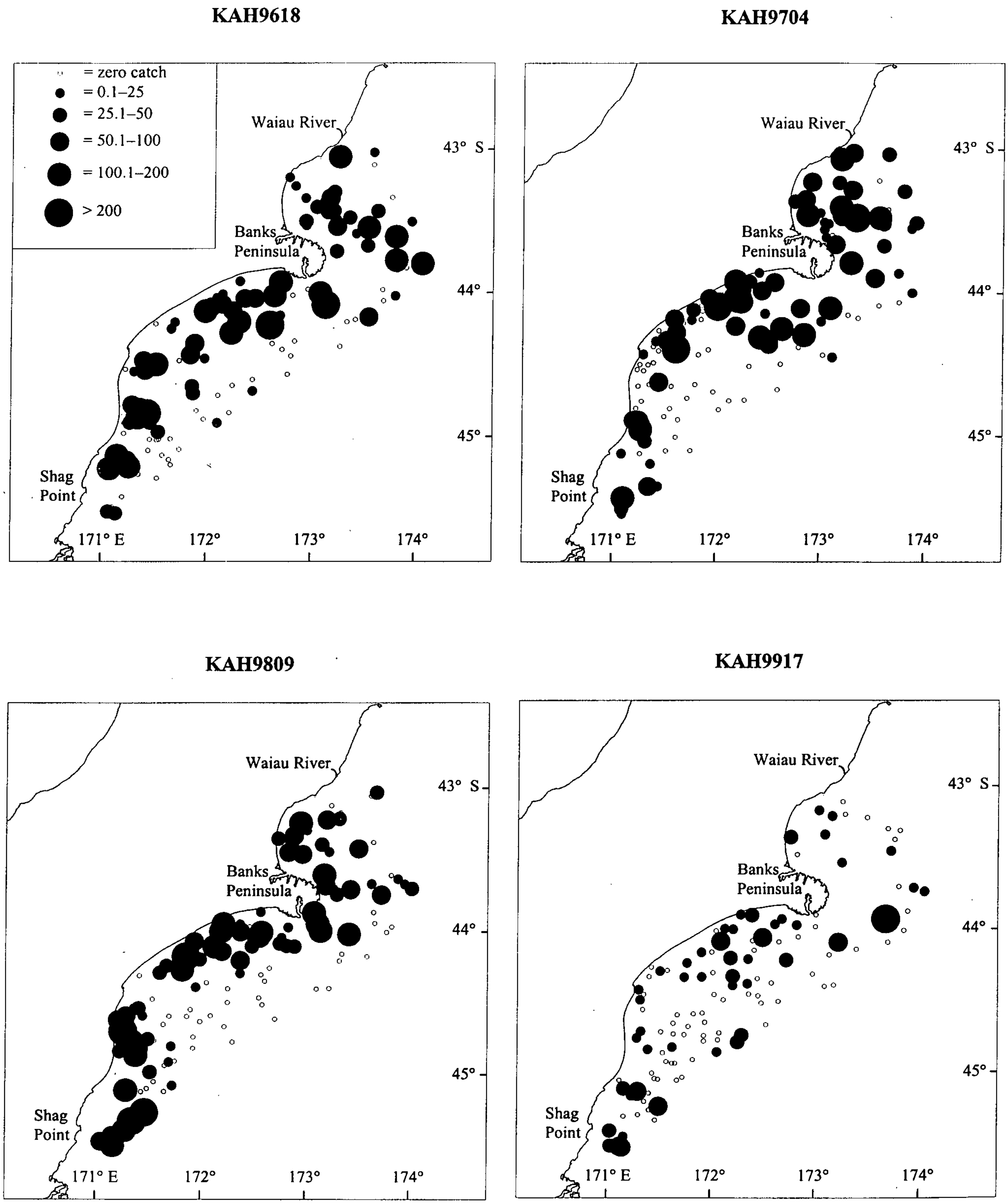


Figure 9q: **Rough skate (maximum catch rate 462 kg.km^{-2}).**

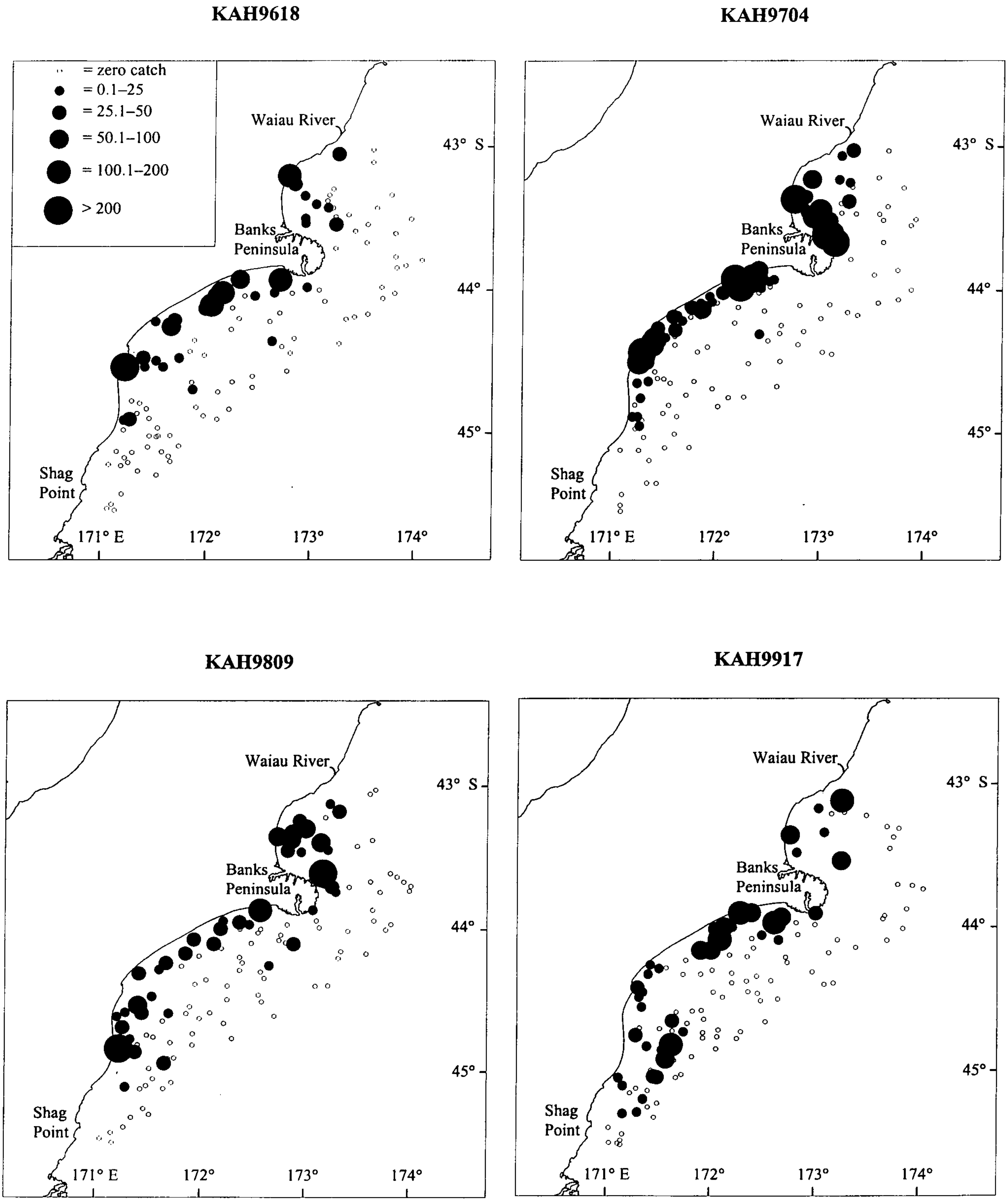


***Figure 9r*: School shark (maximum catch rate 1 050 kg.km^{-2}).**

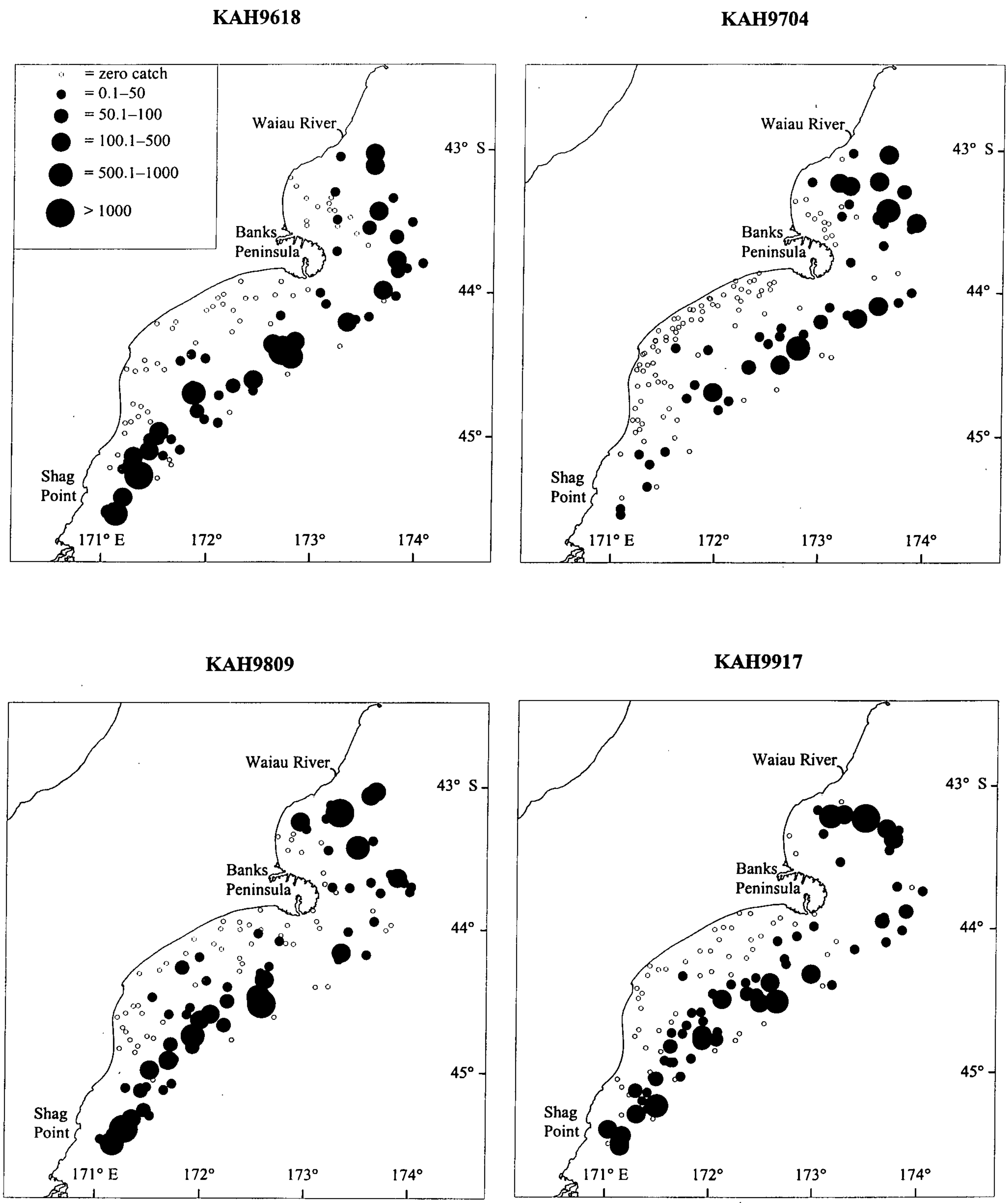


Figure 9s: **Sea perch (maximum catch rate 8 756 kg.km⁻²).**

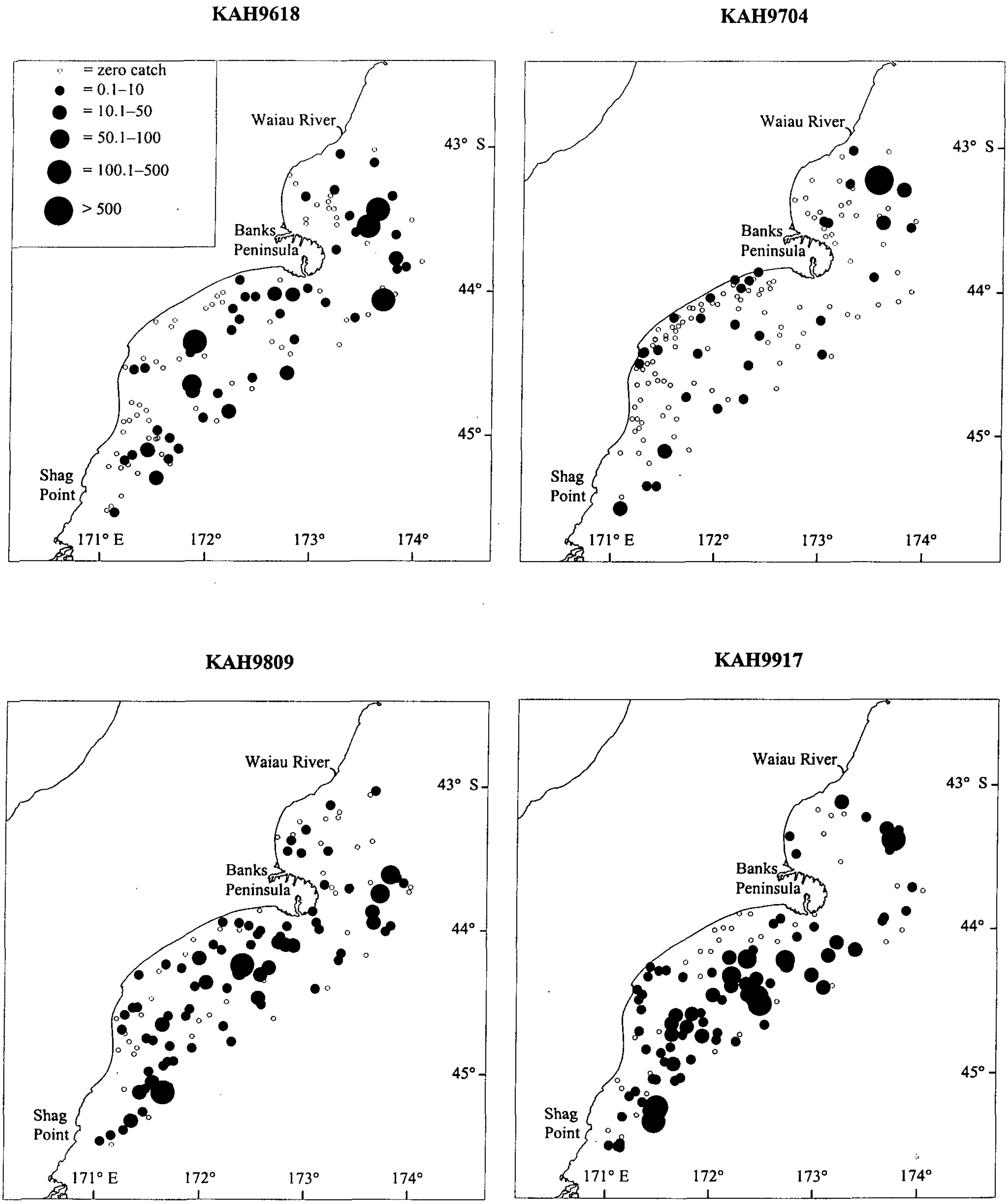


Figure 9t: **Silver warehou (maximum catch rate 1 279 kg.km^{-2}).**

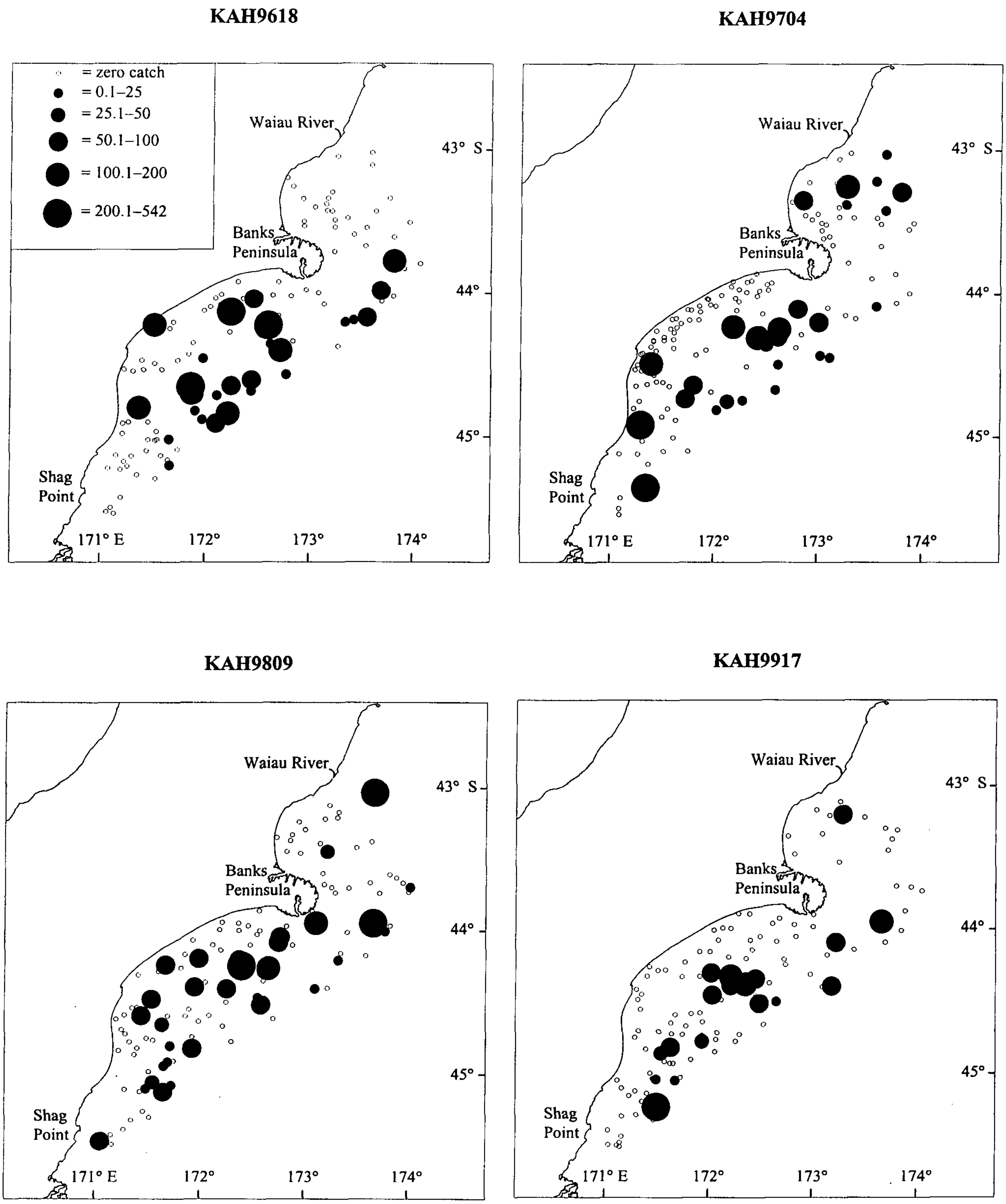


Figure 9u: **Smooth skate (maximum catch rate 542 kg.km^{-2}).**

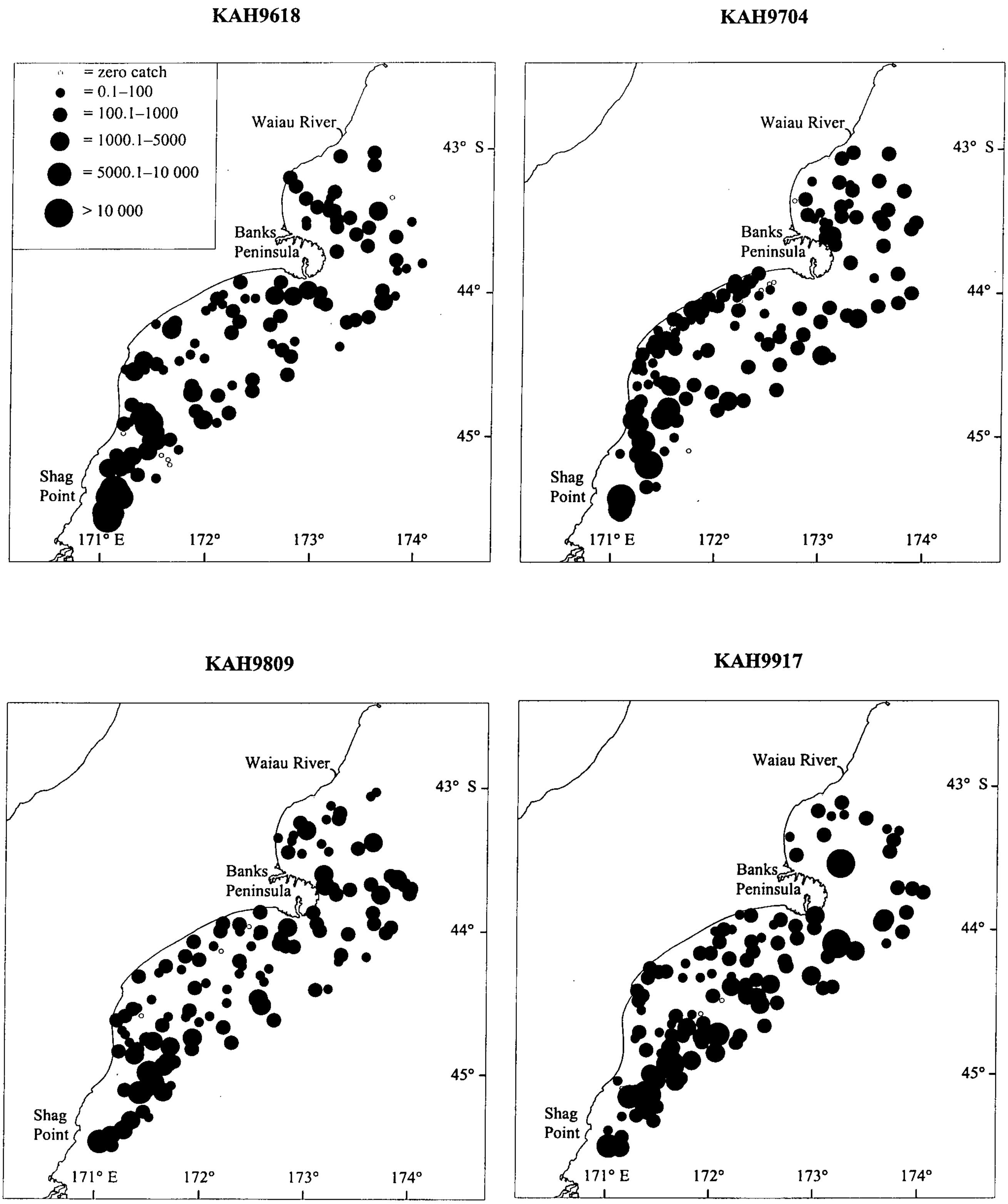


Figure 9v: **Spiny dogfish (maximum catch rate 88 037 kg.km^{-2}).**

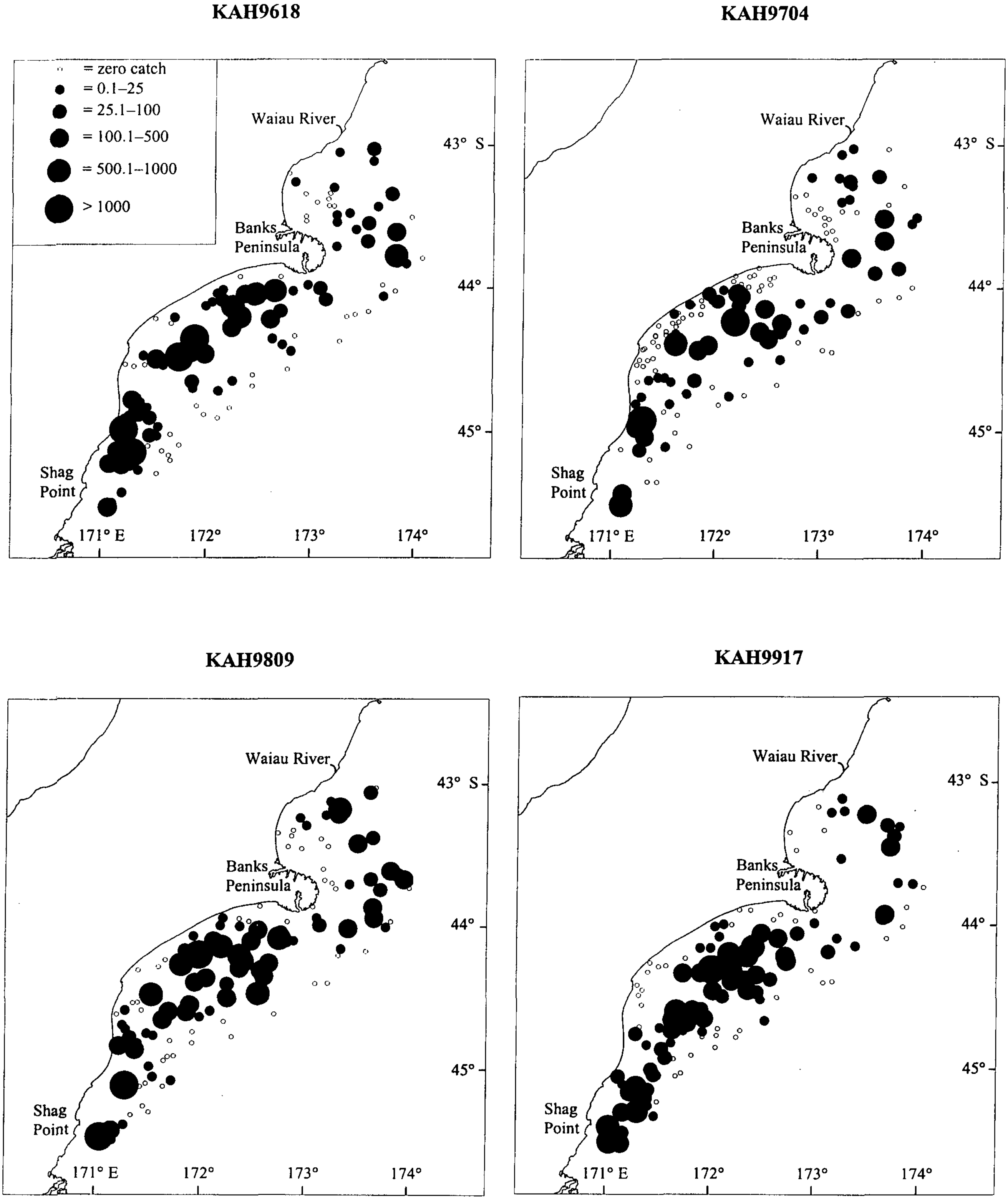


Figure 9w: **Tarakihi (maximum catch rate 3 188 kg.km^{-2}).**

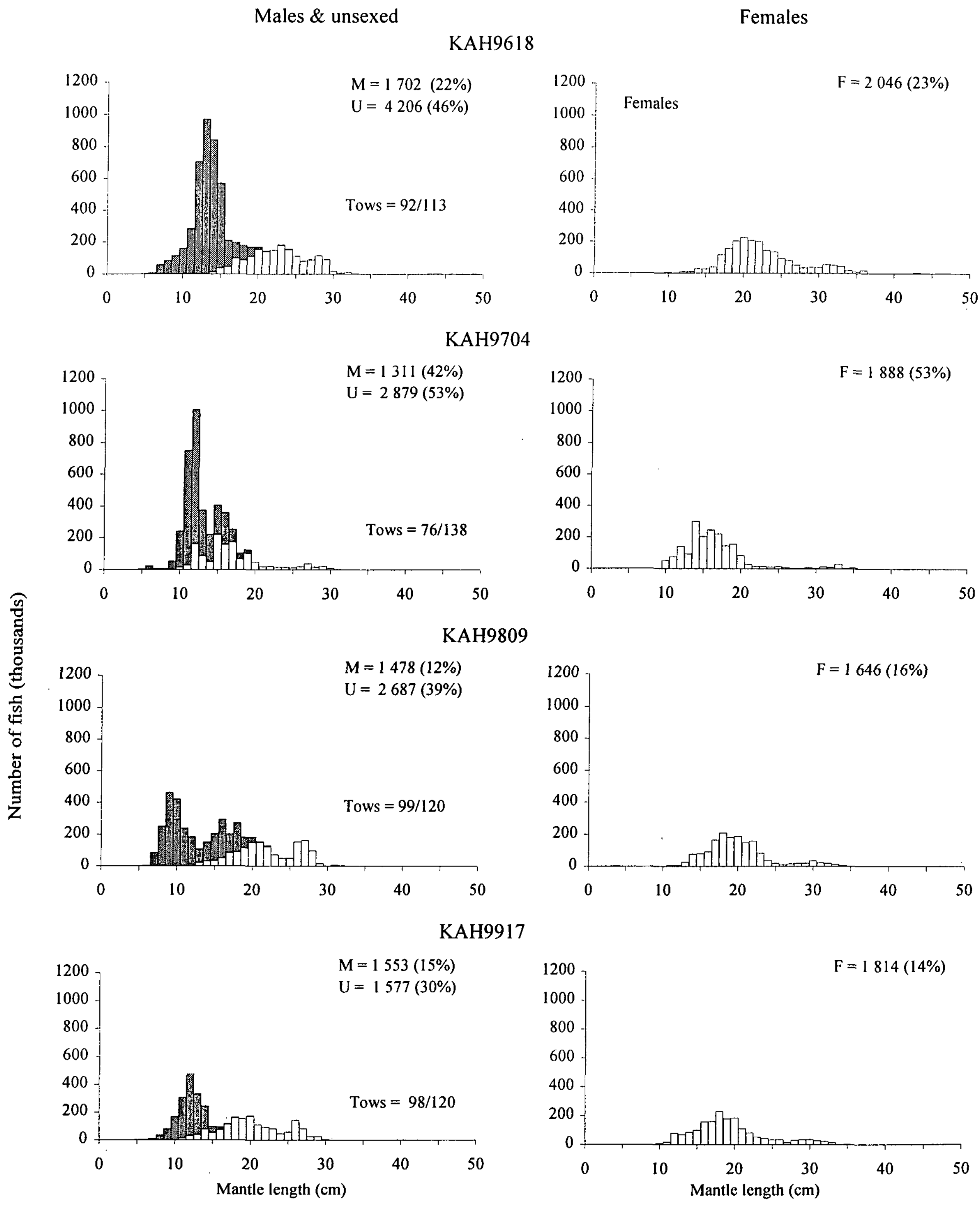


Figure 10: **Scaled length frequency distributions of the major species, 1996–97 to 1999–2000, with the estimated total number of fish in the population (thousands) and percentage coefficient of variation. M, number of males; F, number of females; U, number of unsexed fish; Tows, number of stations at which species was caught/total number of stations used for biomass estimate.**
a: Arrow squid.

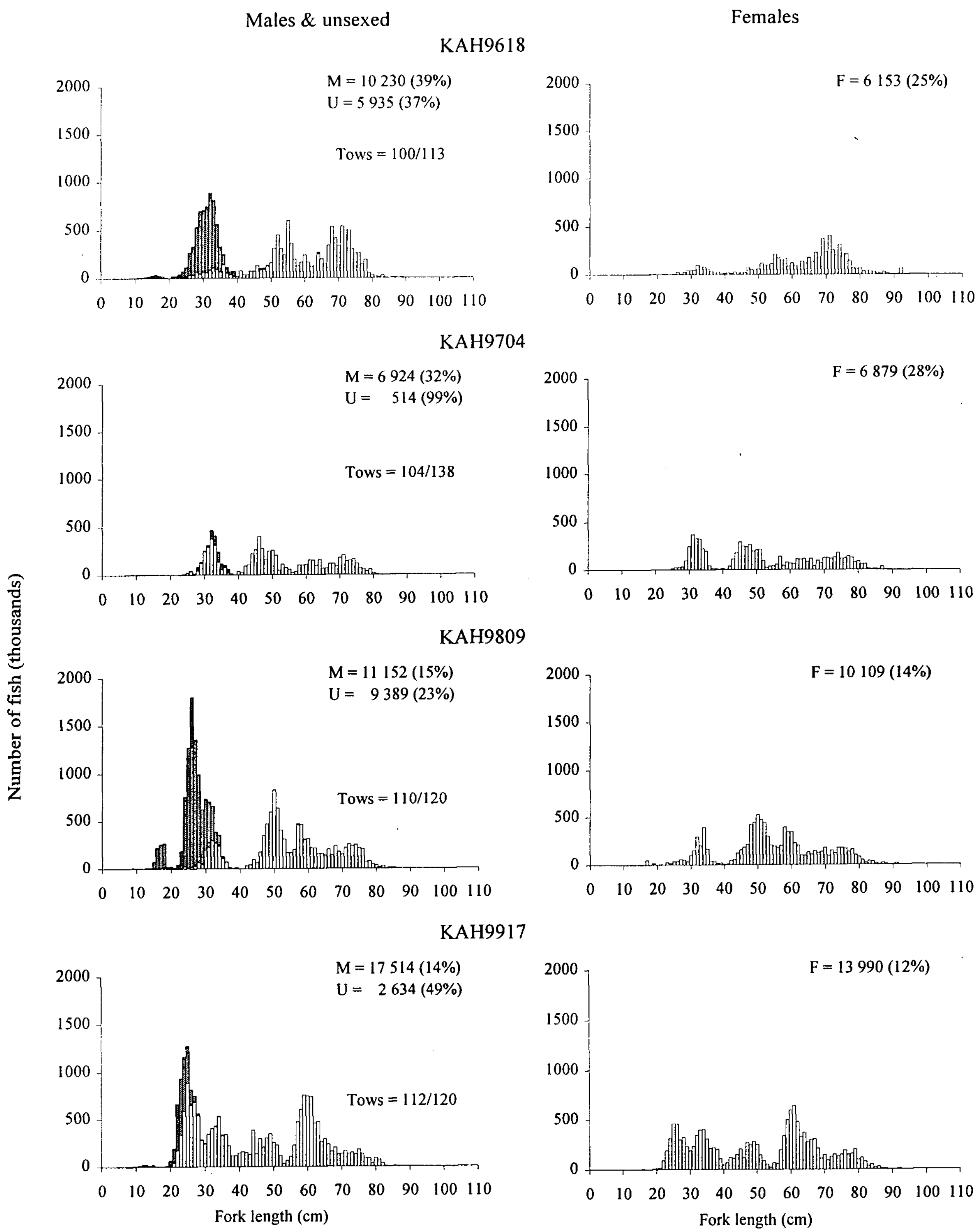


Figure 10b **: Barracouta.**

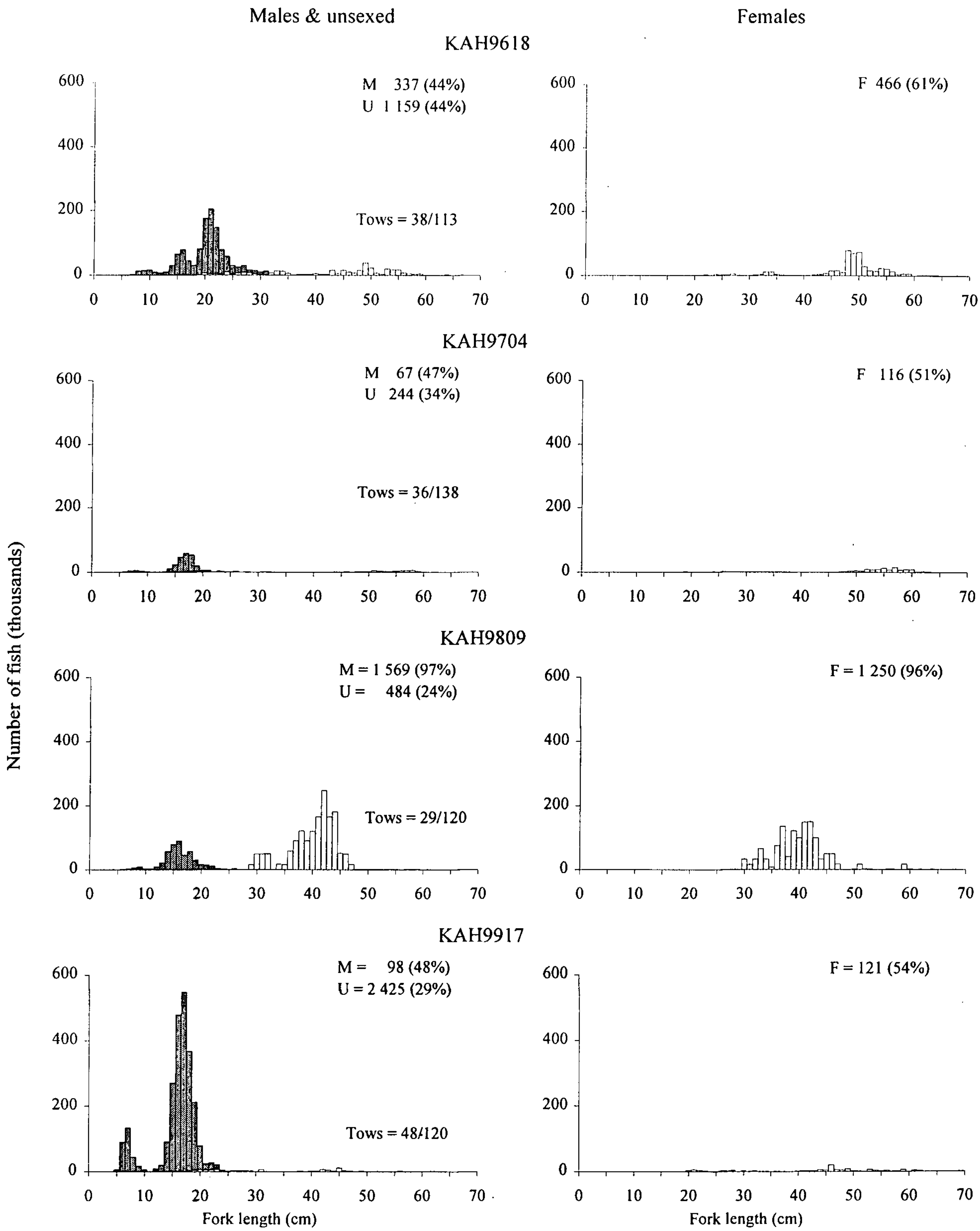


***Figure 10c*:** **Blue warehou.**

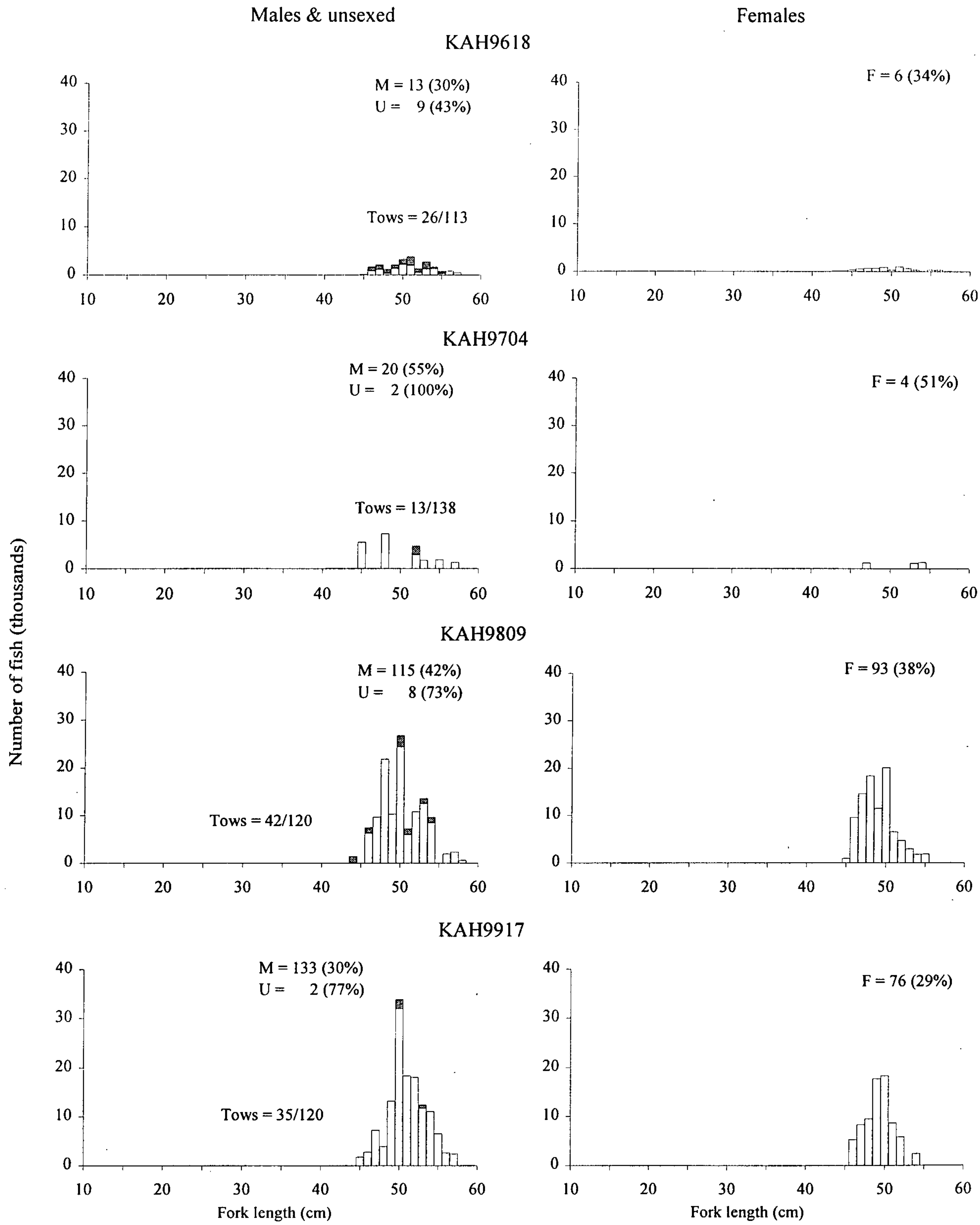


***Figure 10d*: Chilean jack mackerel.**

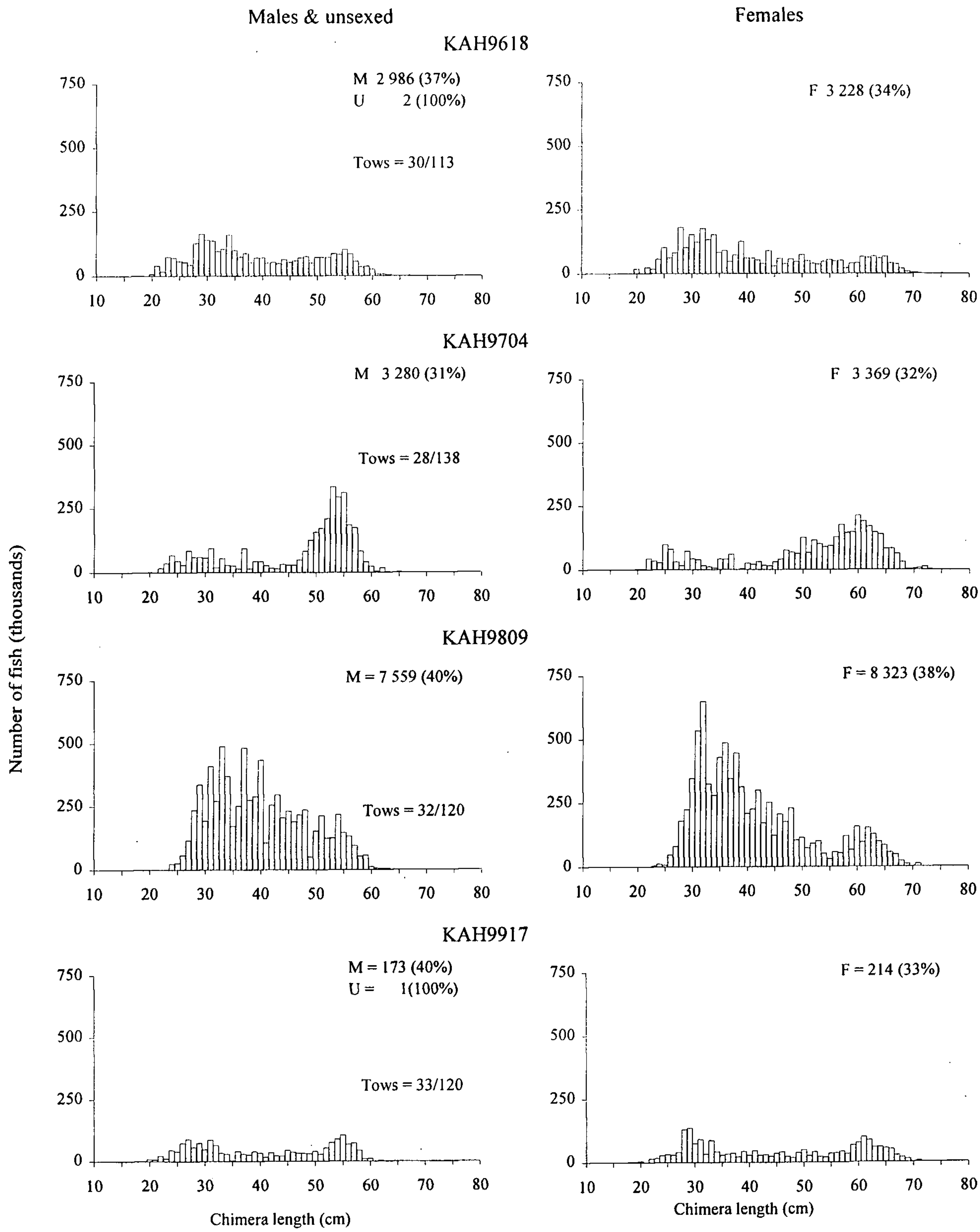


***Figure 10e*: Dark ghost shark.**

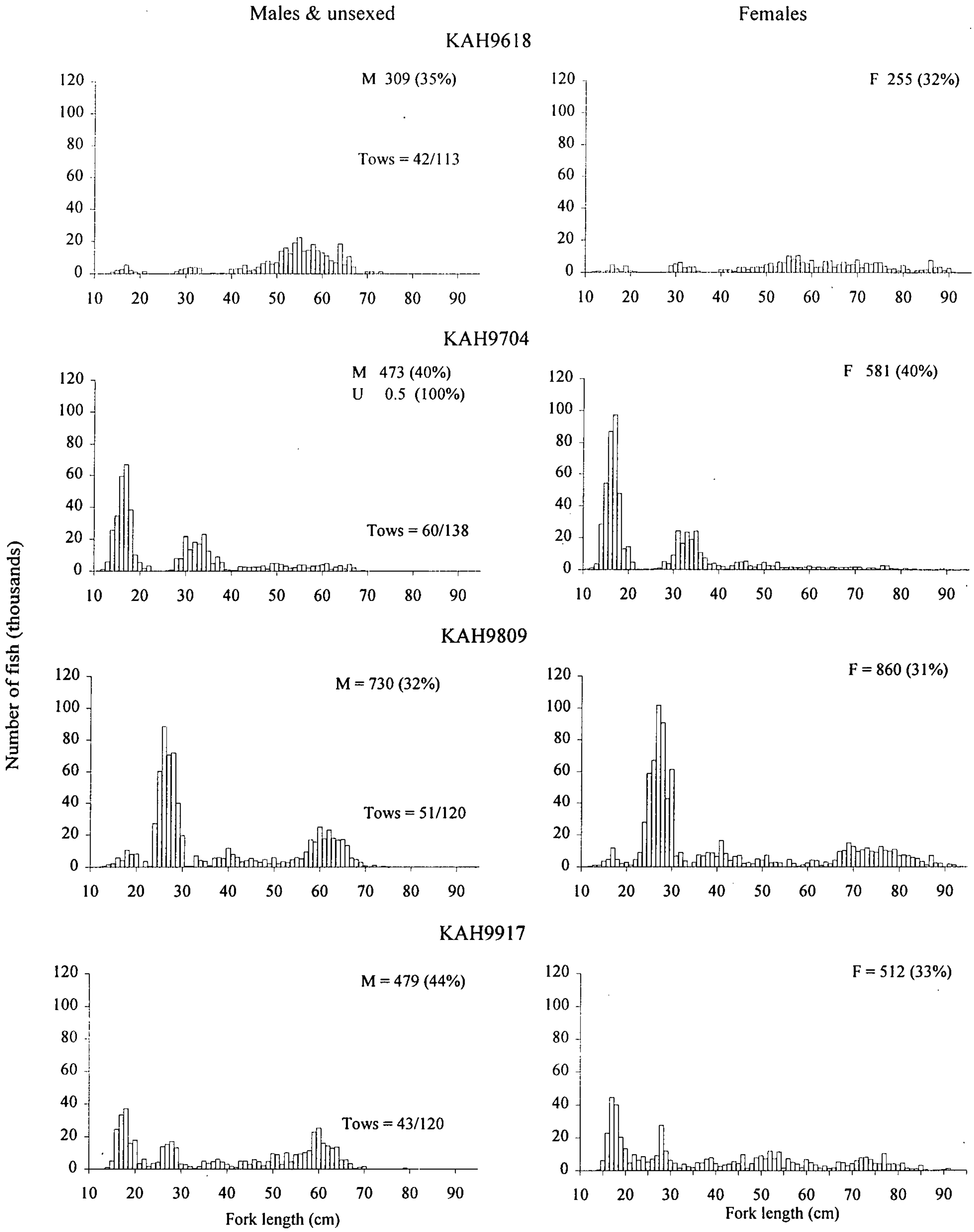


***Figure 10f*: Elephantfish.**

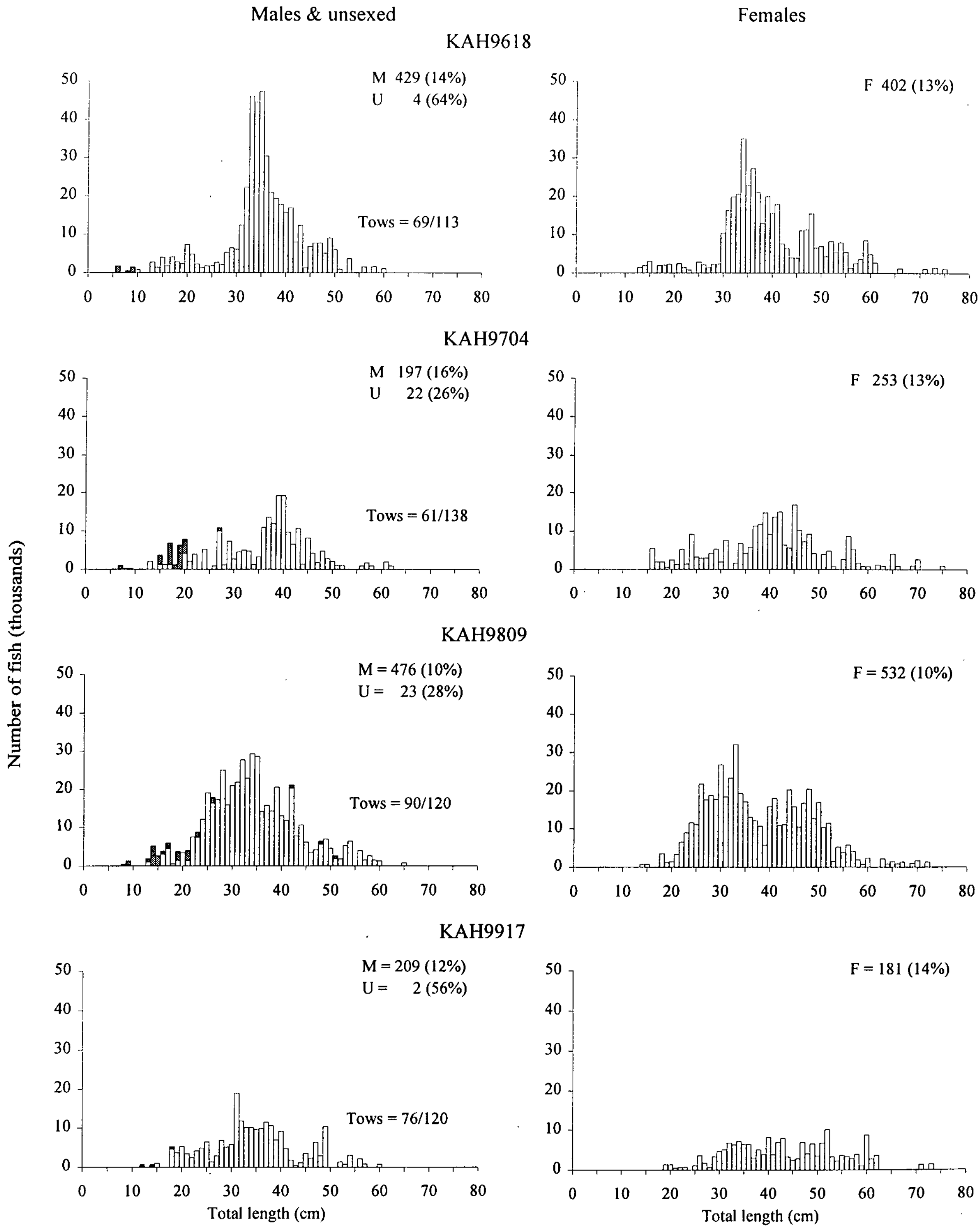


***Figure 10g*: Giant stargazer.**

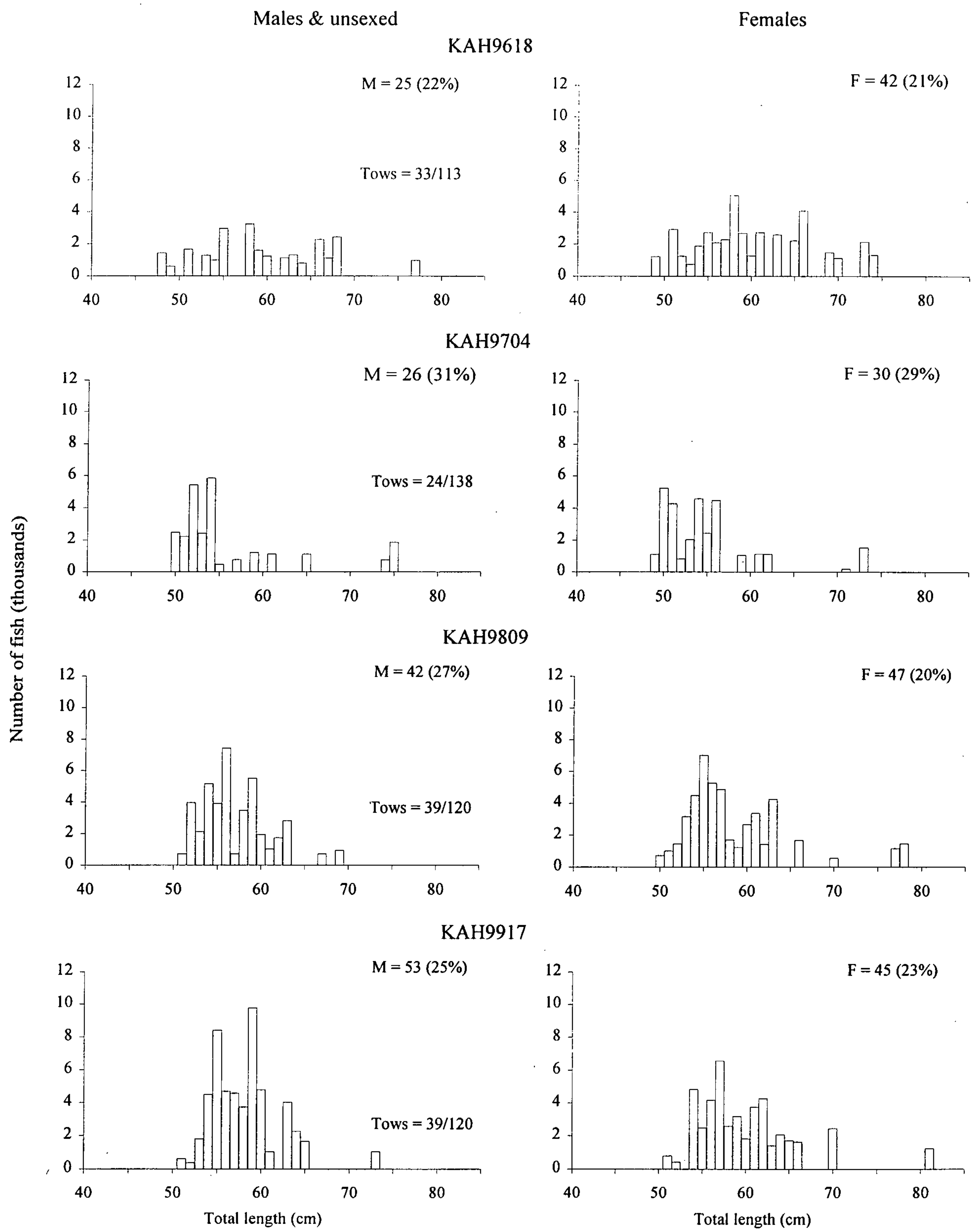


Figure 10h **: Hapuku.**

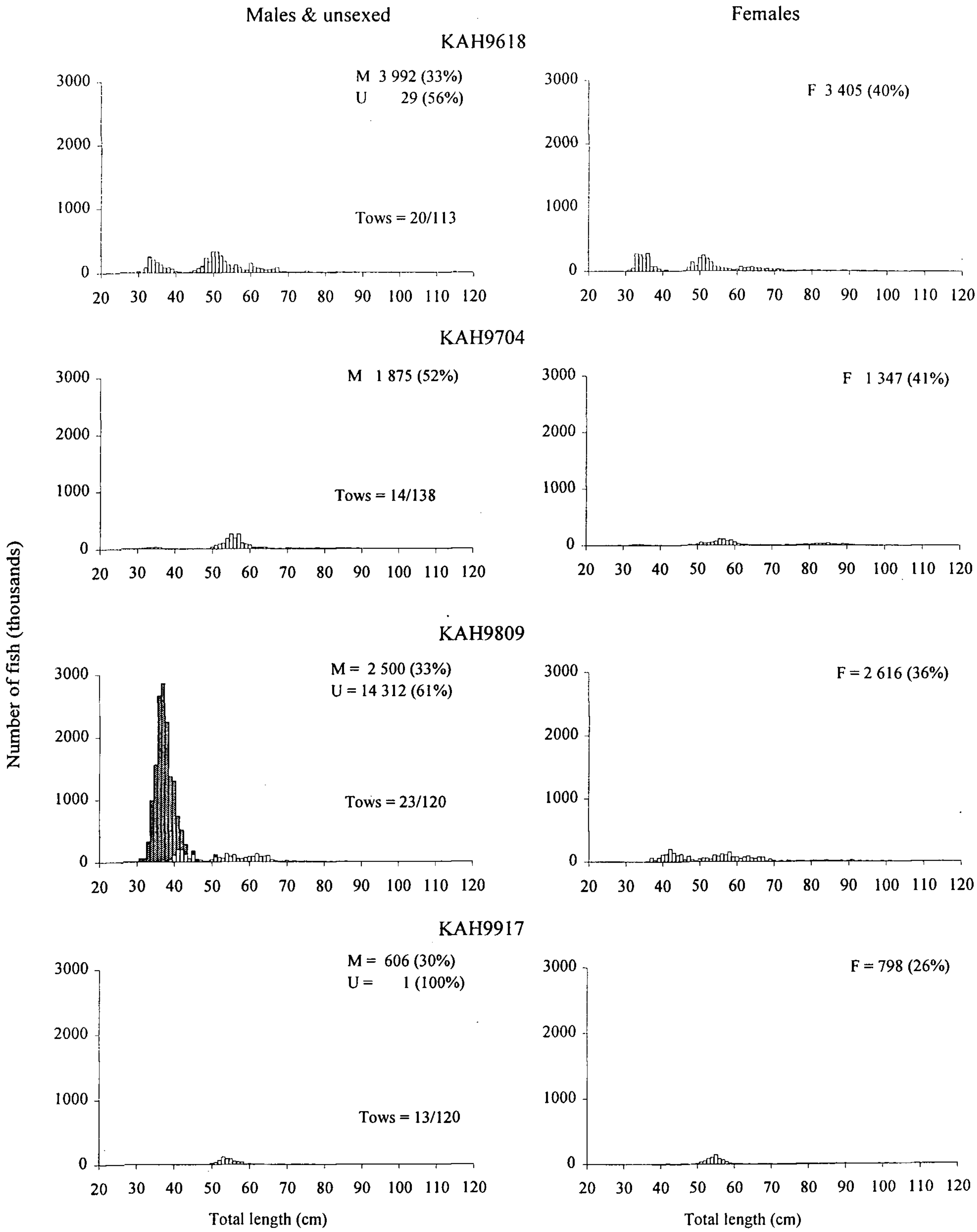


***Figure 10i*: Hoki.**

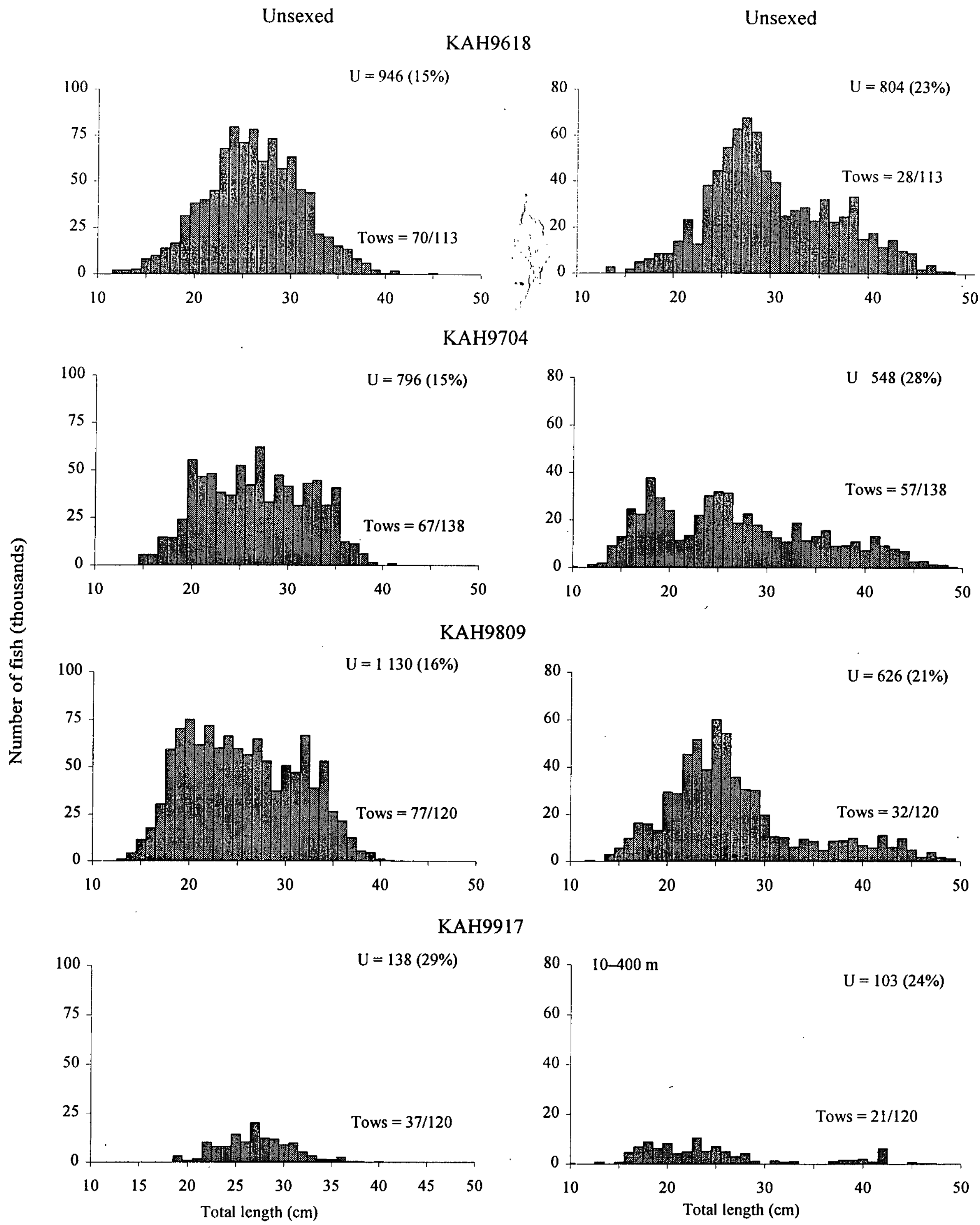


Figure 10j**: Lemon sole (left) and New Zealand sole (right).**

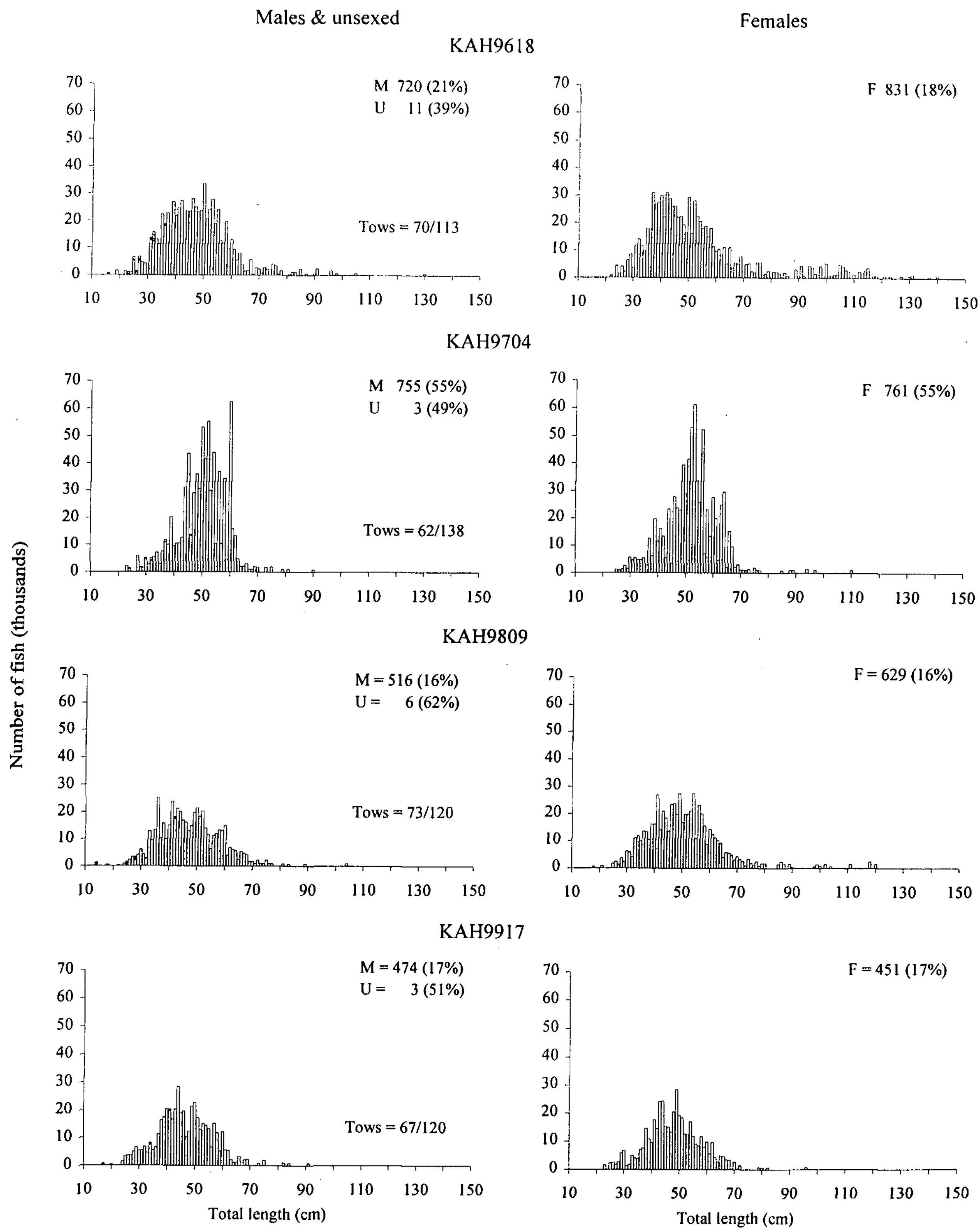


***Figure 10k*: Ling.**

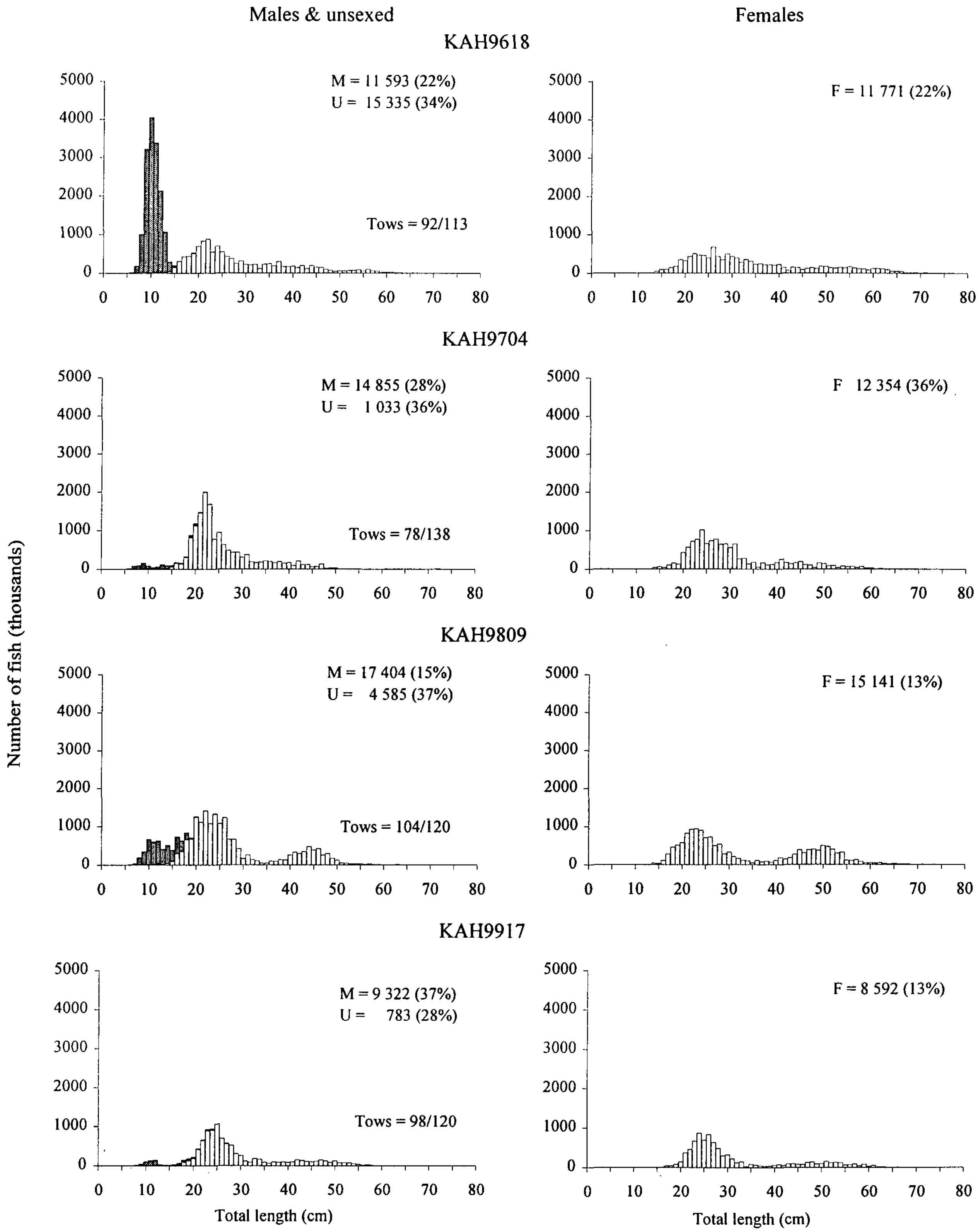


***Figure 10l*:Red cod.**

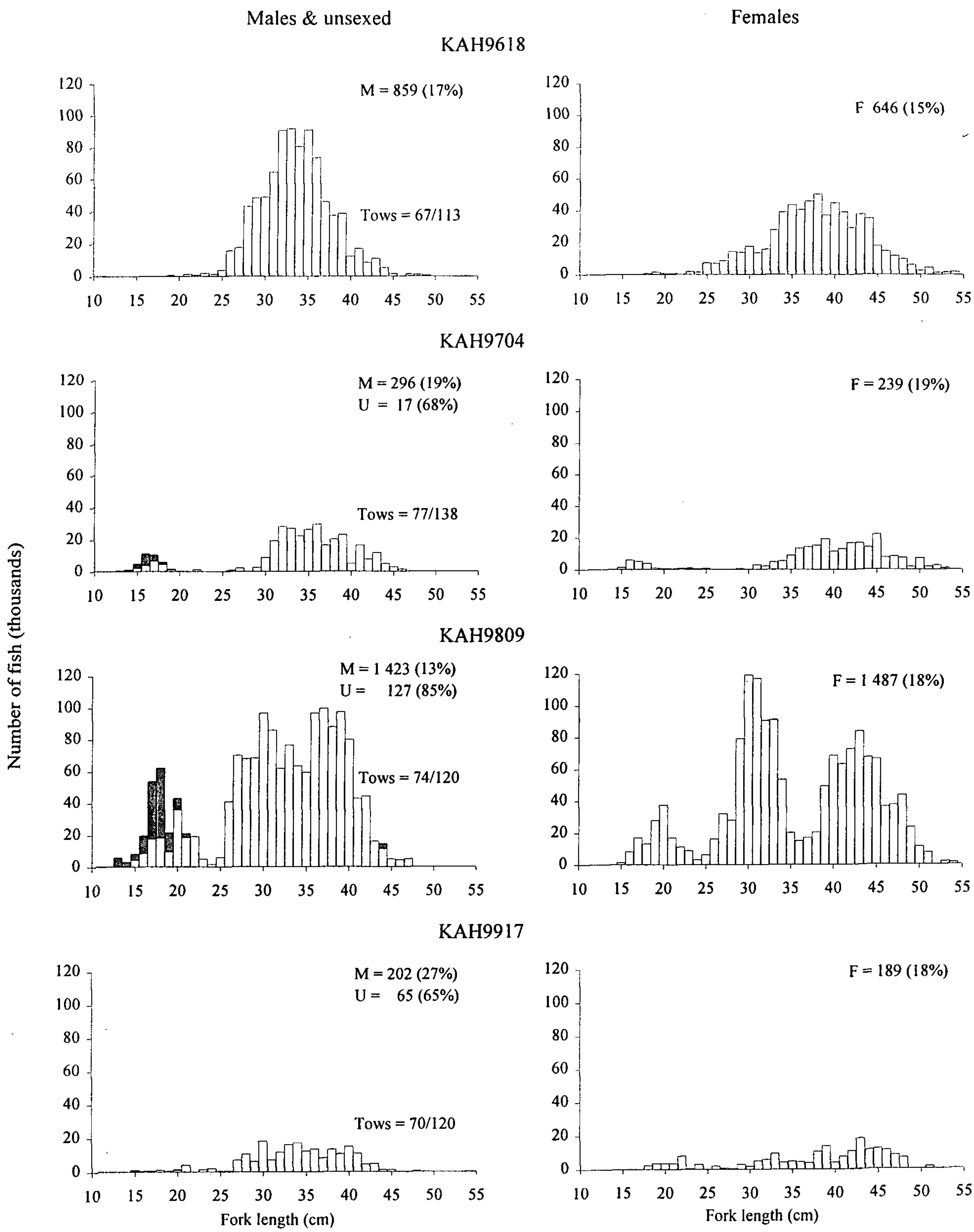


***Figure 10m*: Red gurnard.**

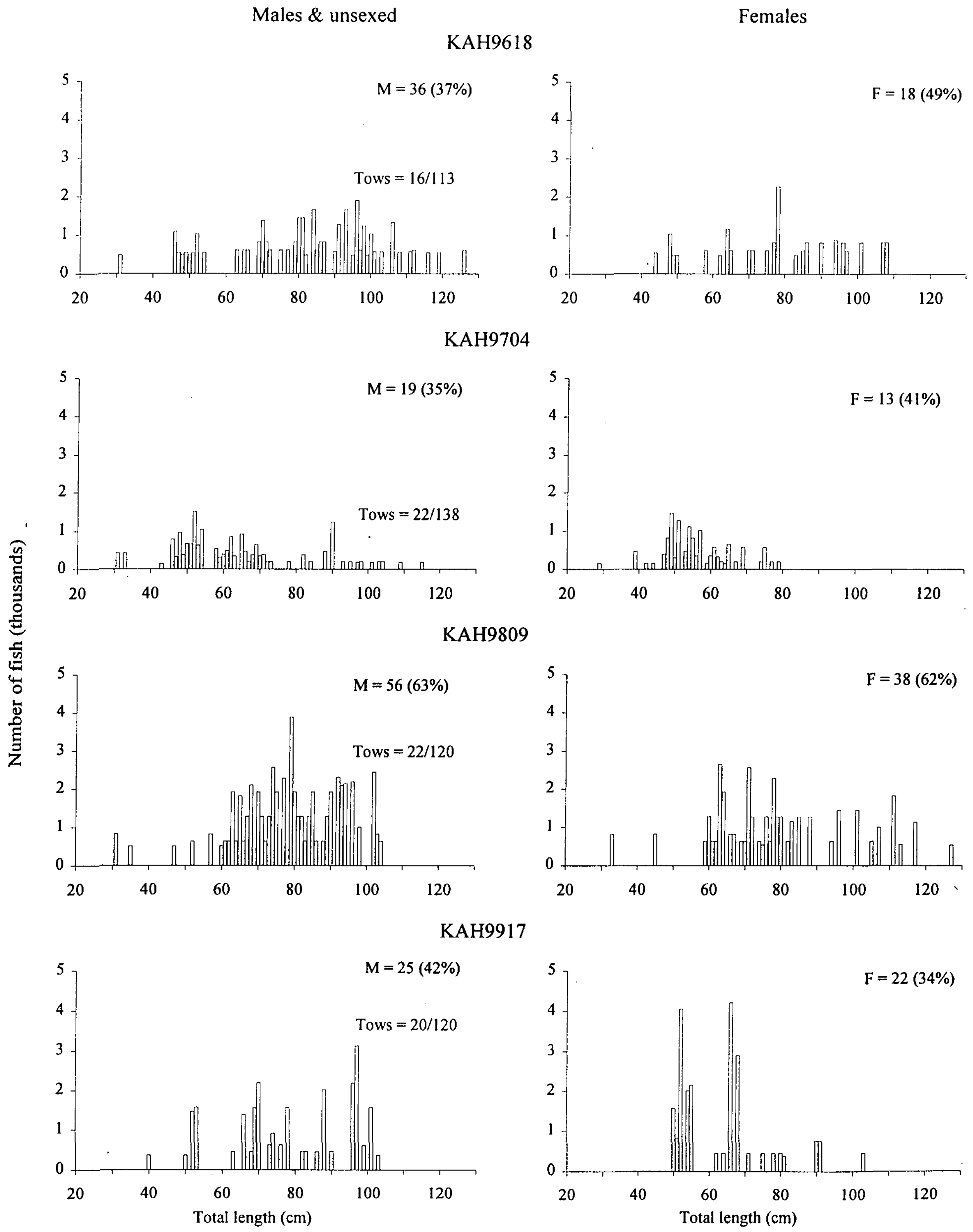


Figure 10n **: Rig.**

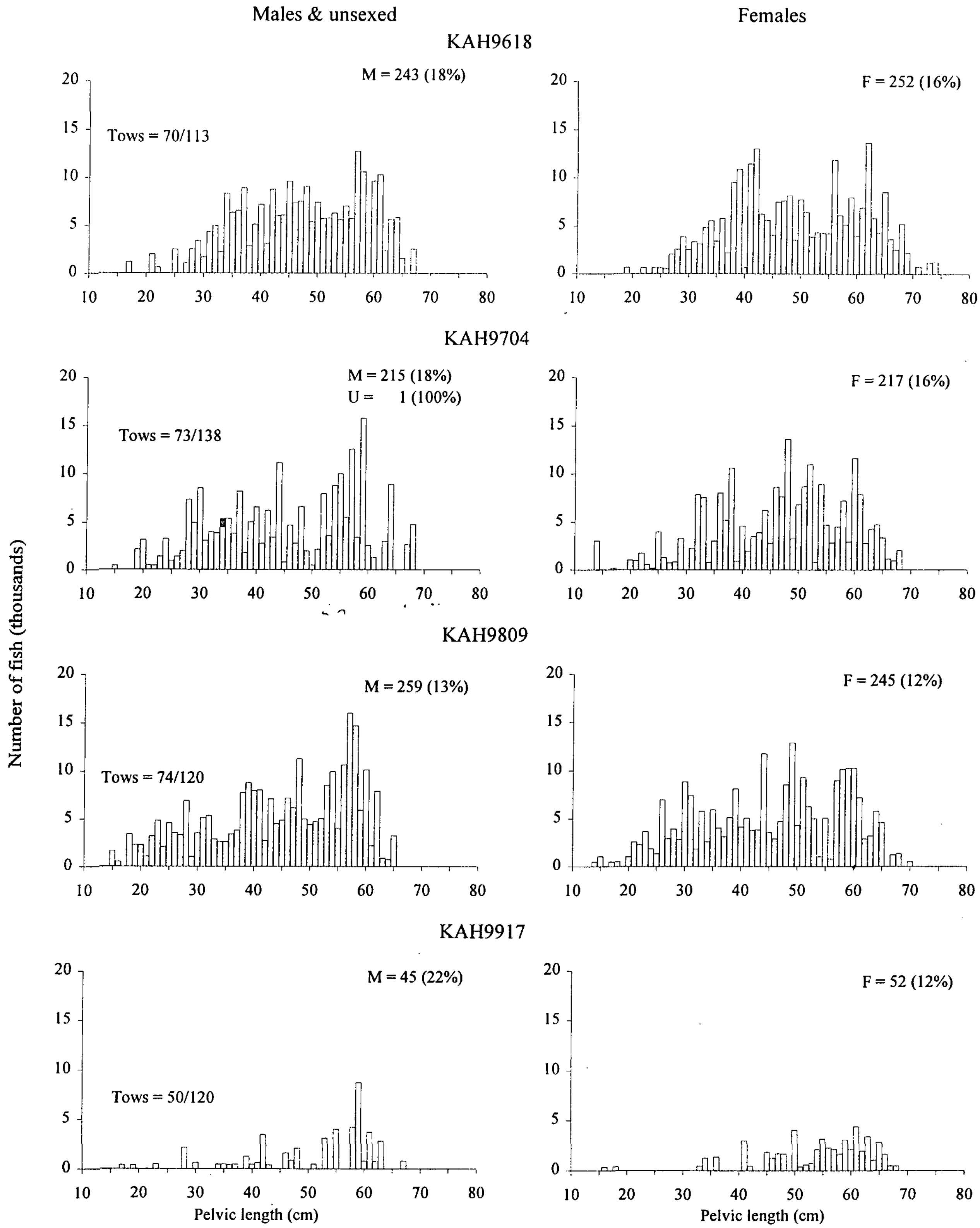


Figure 10o **: Rough skate.**

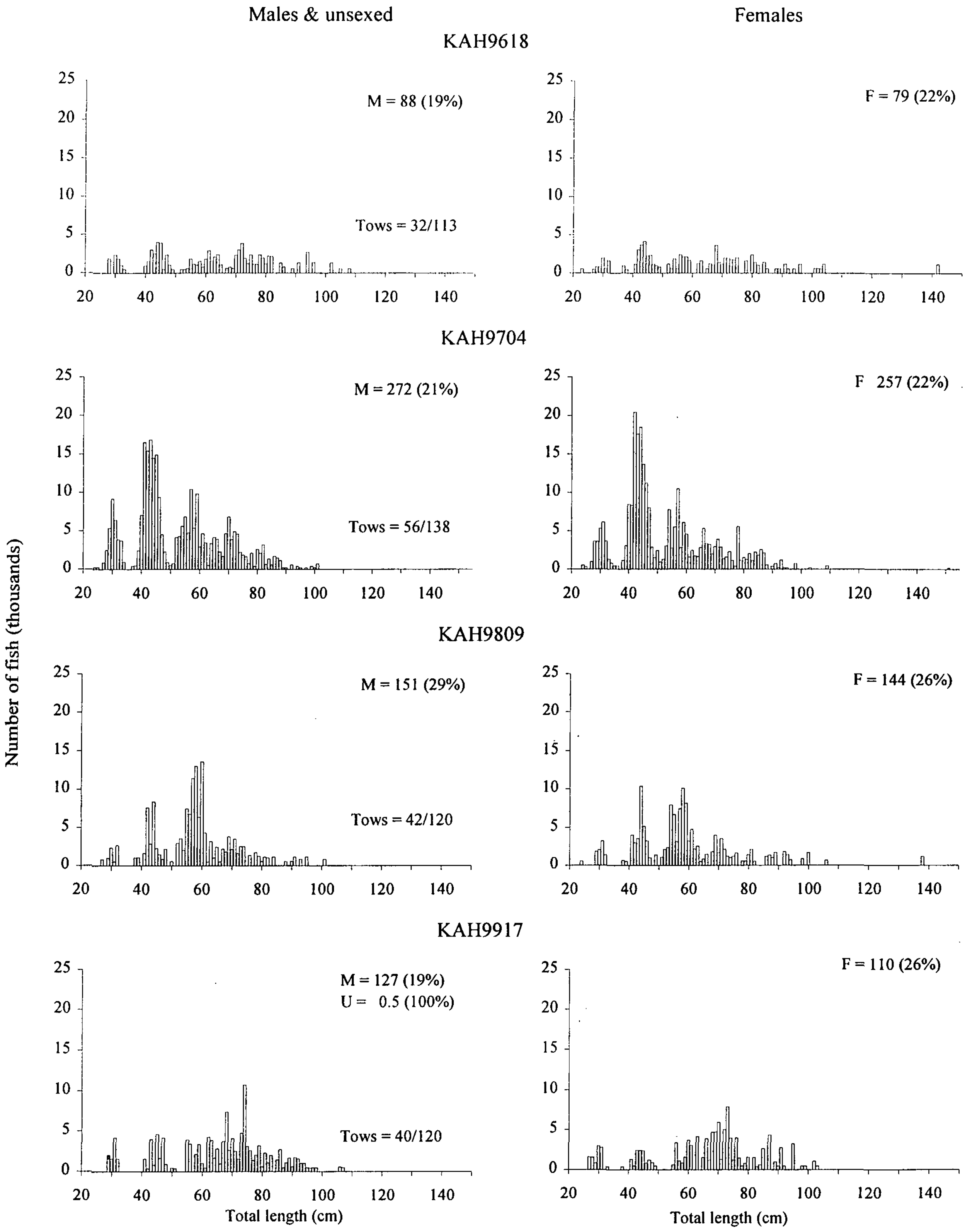


Figure 10p **: School shark.**

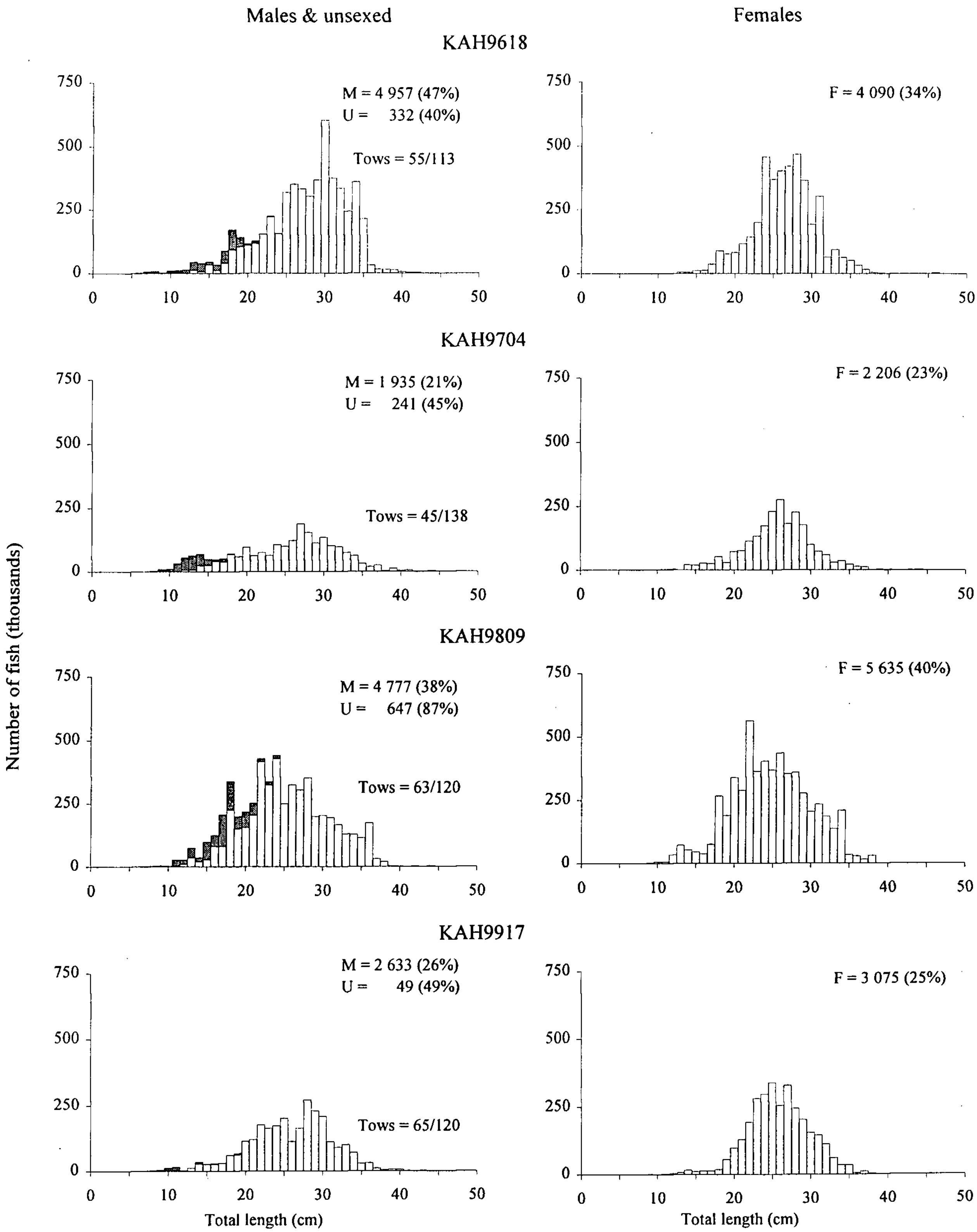


Figure 10q **: Sea perch.**

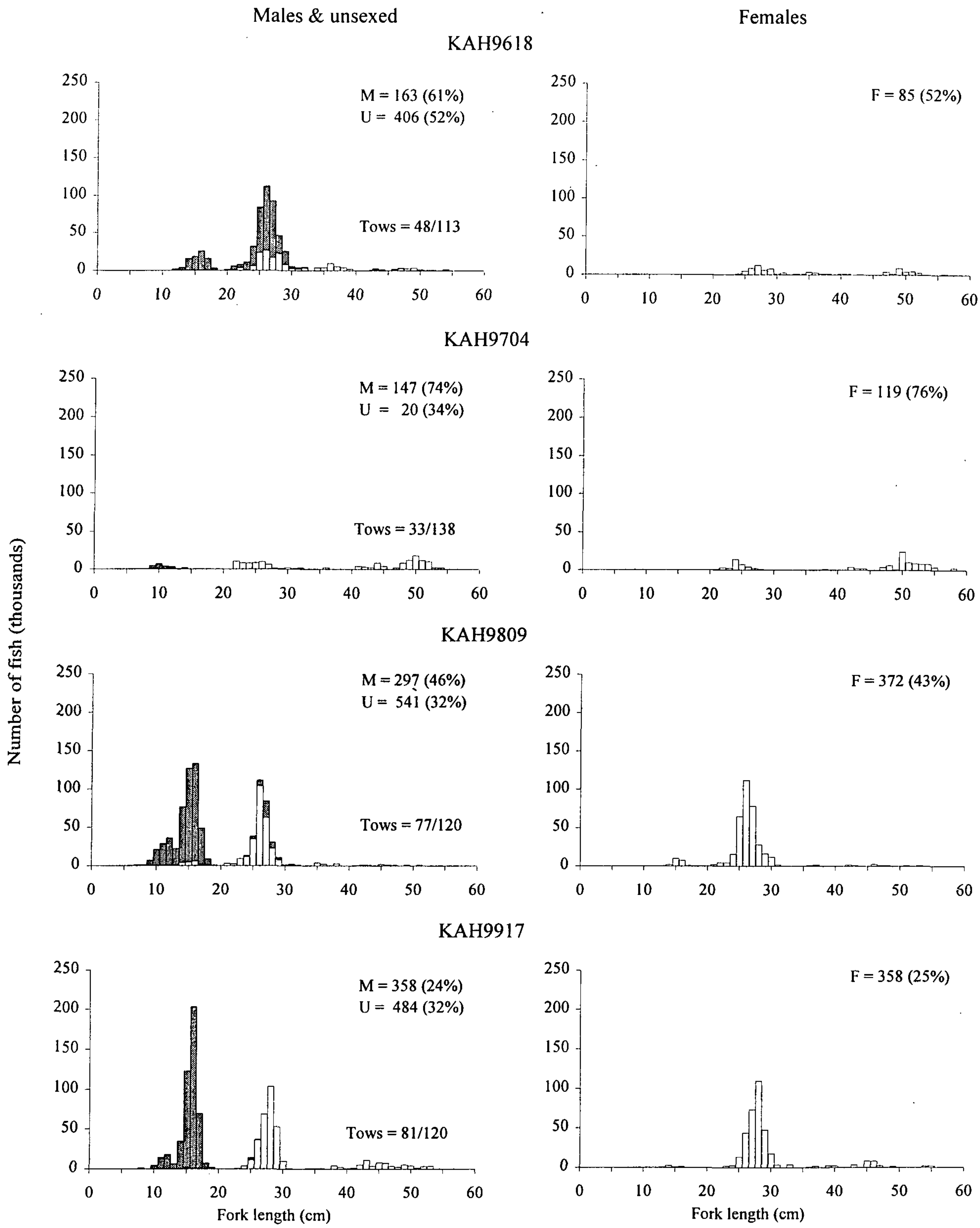


Figure 10r**: Silver warehou.**

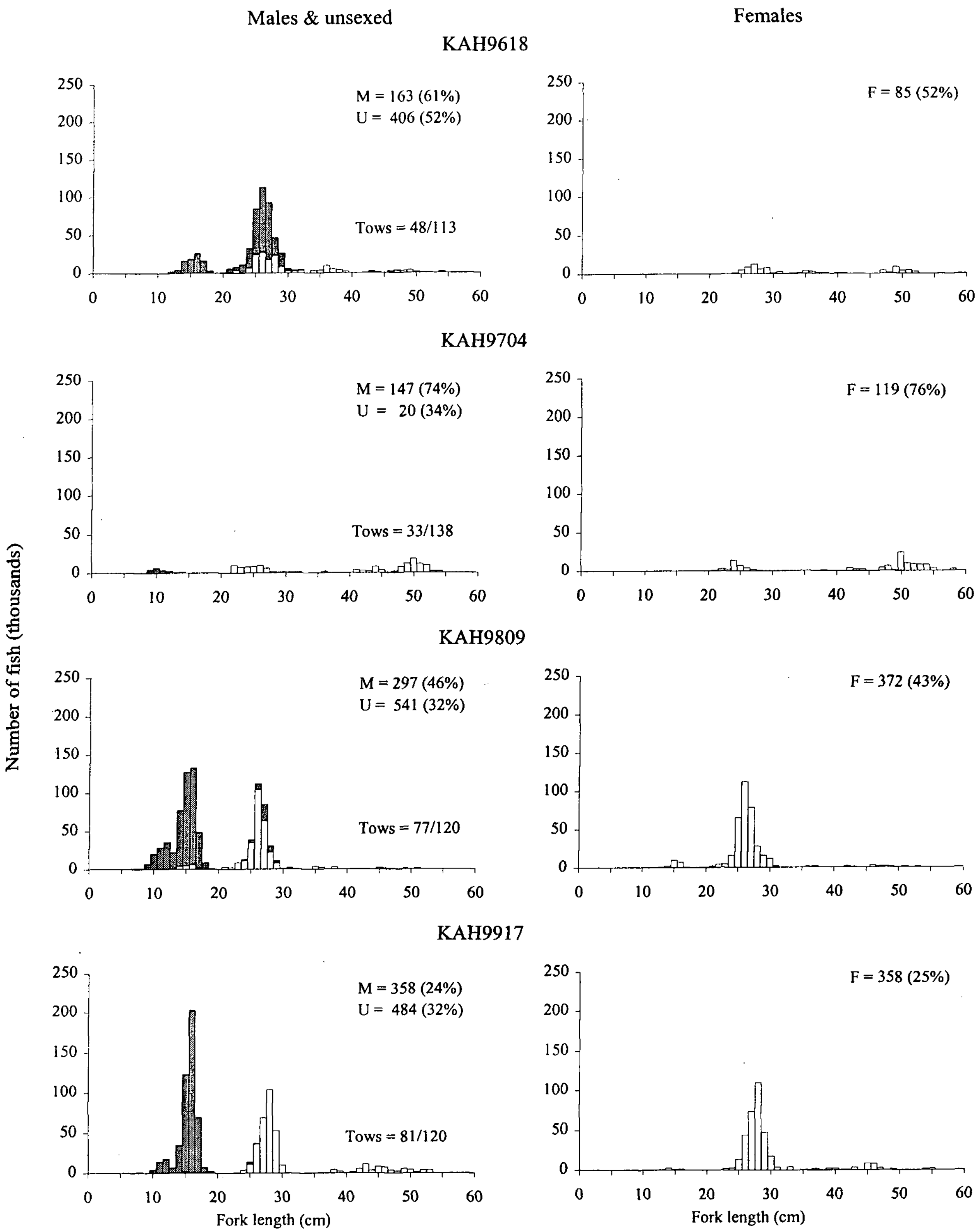


***Figure 10r*: Silver warehou.**

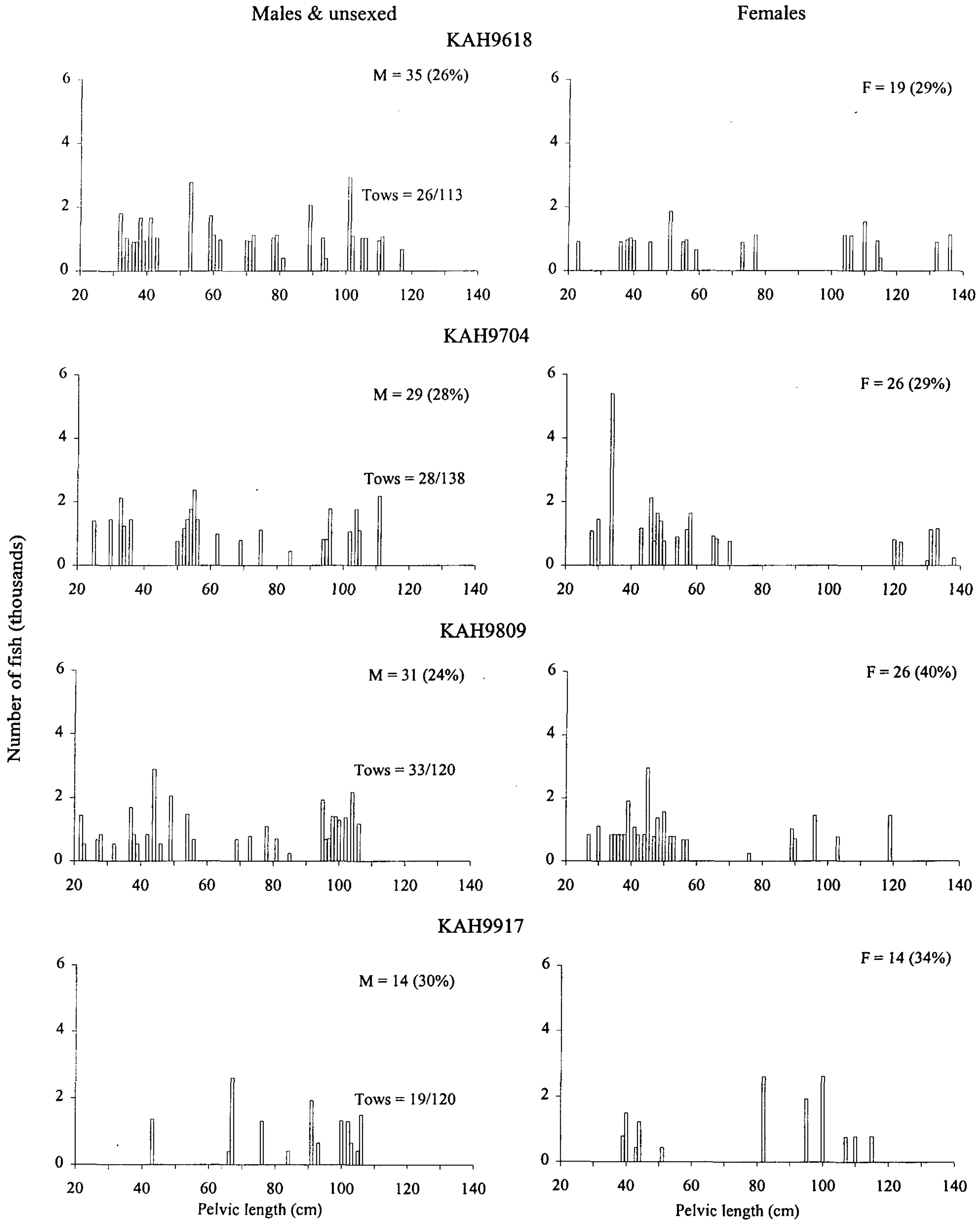


***Figure 10s*: Smooth skate**

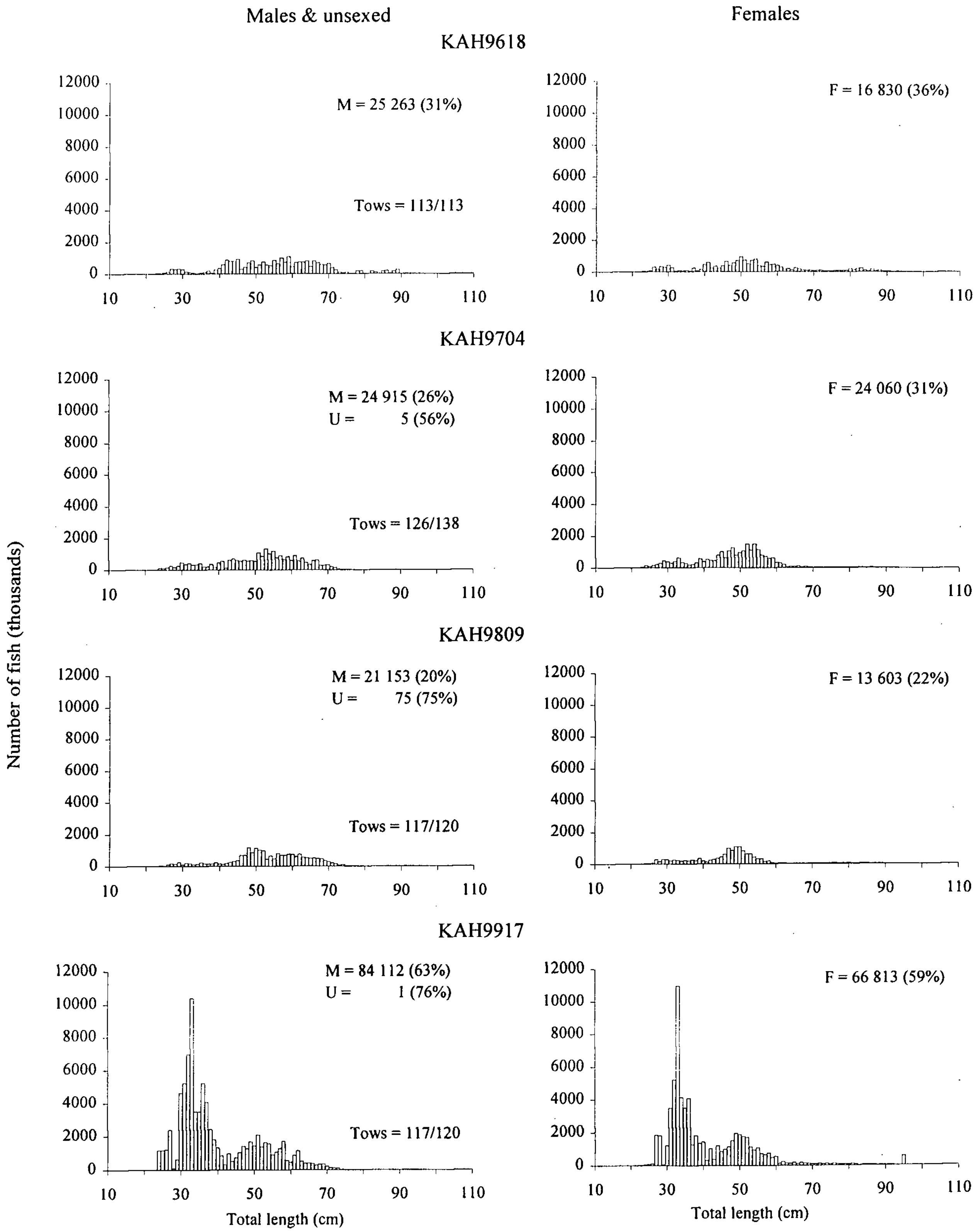


***Figure 10t*: Spiny dogfish.**

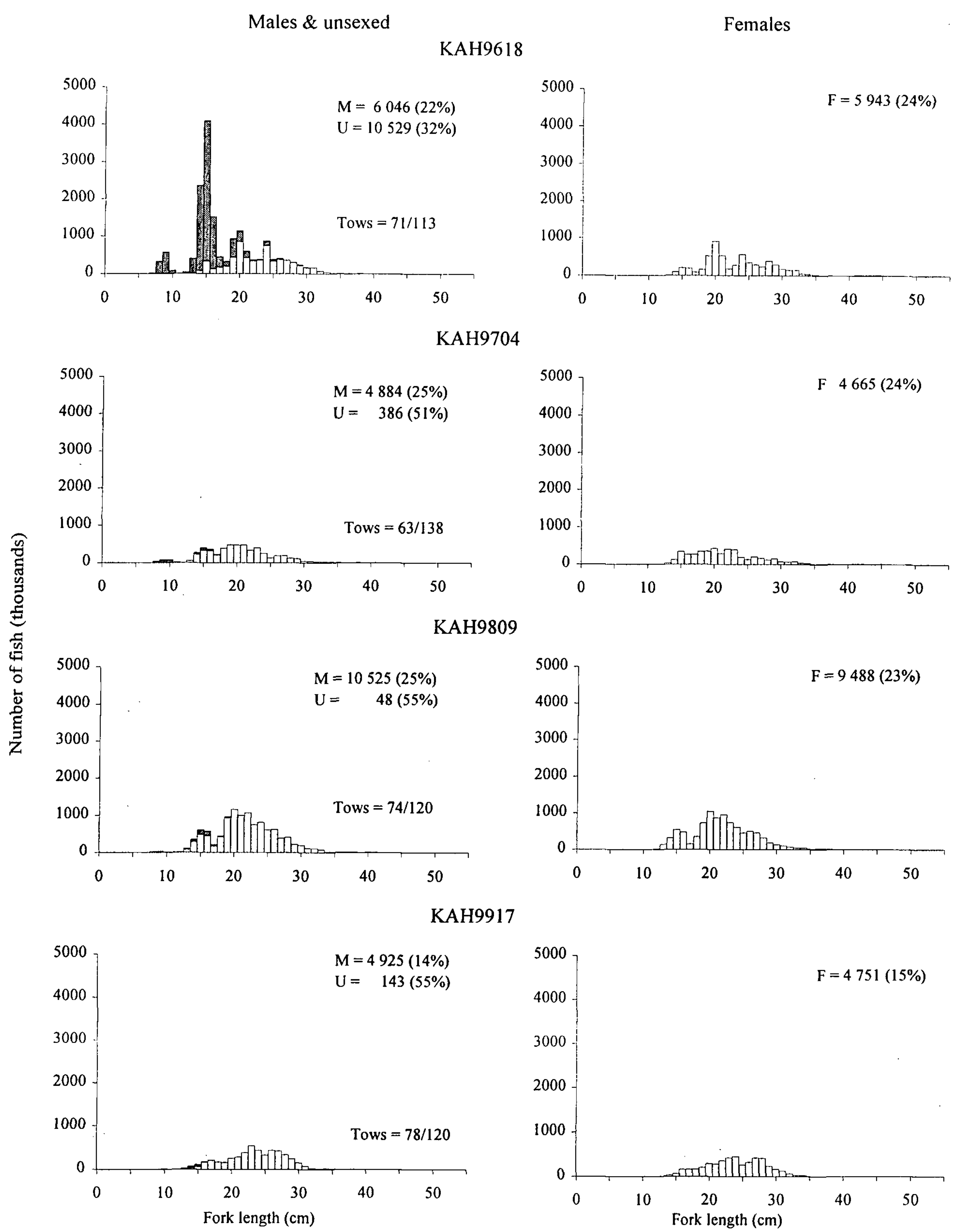


Figure 10u **: Tarakihi.**

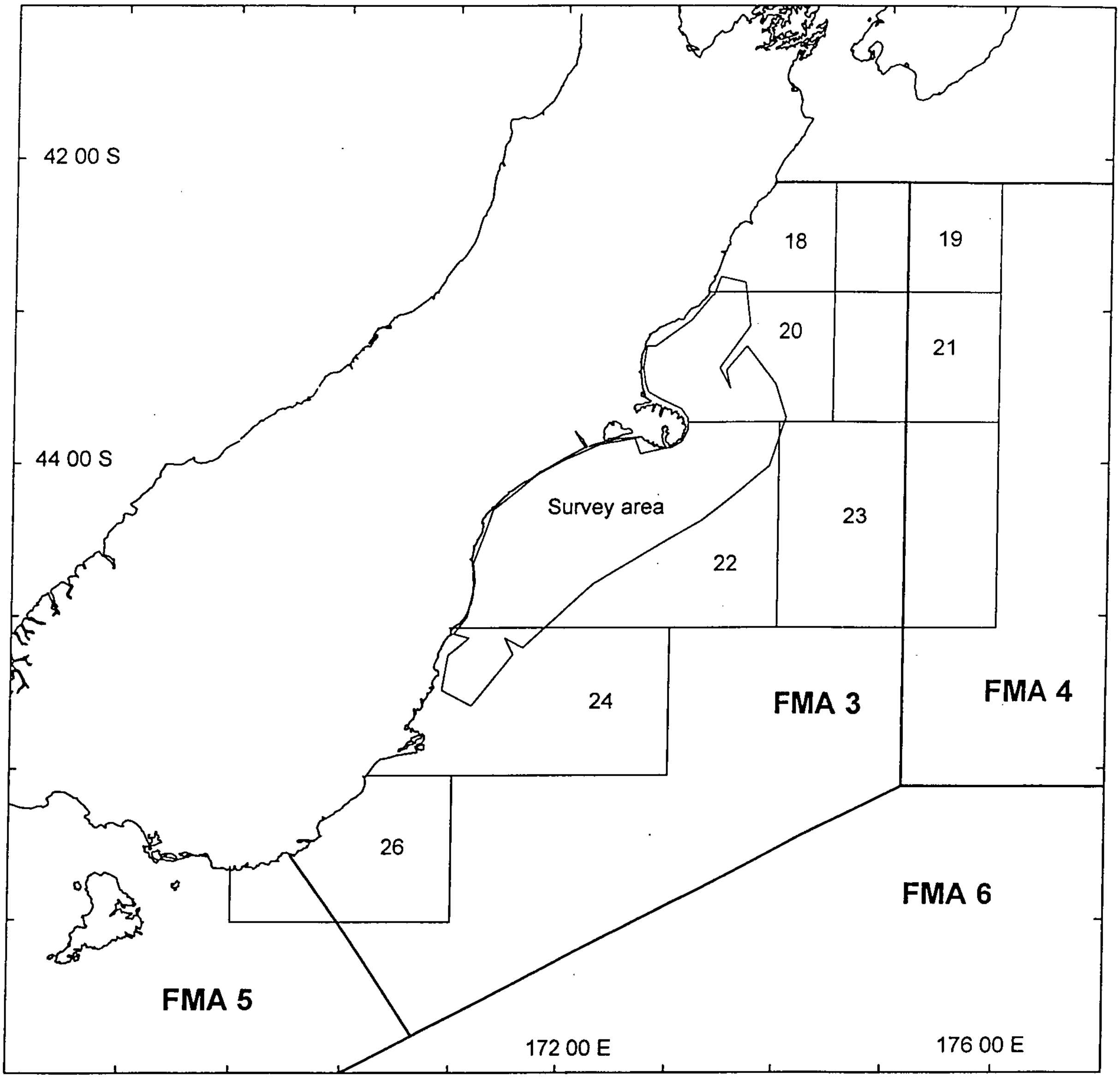


Figure 11: East coast South Island showing statistical areas, Fishery Management Areas (FMA and the survey area.

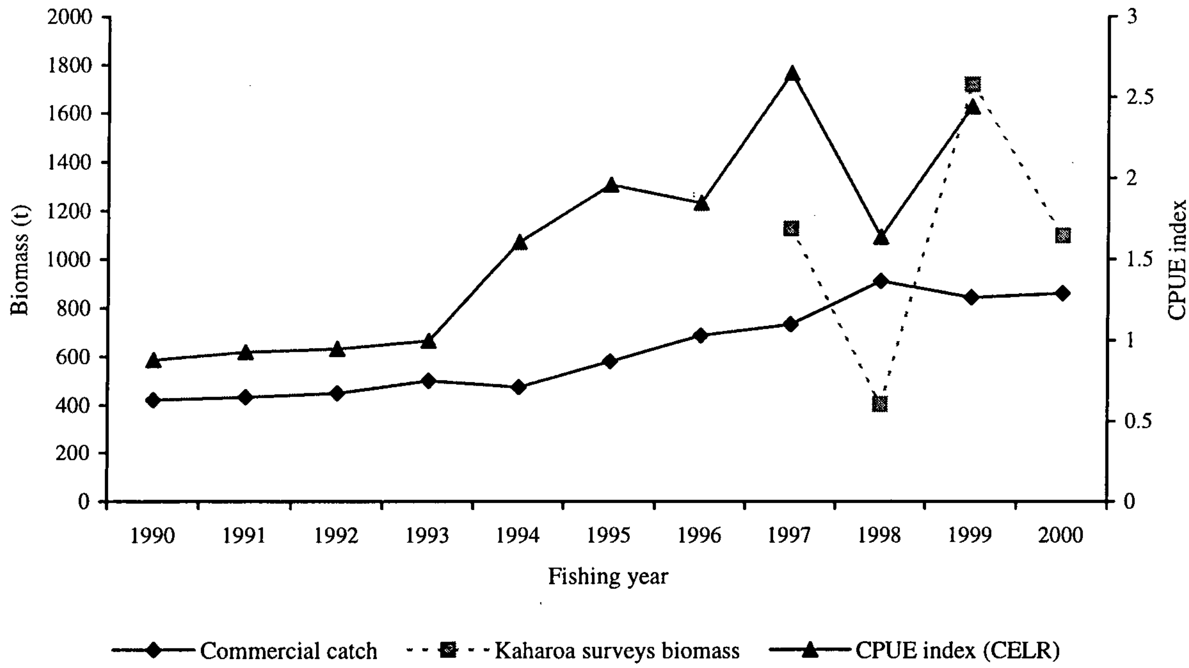


Figure 12: Comparison of elephantfish trawl survey biomass estimates, CPUE indices, and commercial catch in ELE 3. 2000 commercial catch was for period up until 31 May 2000. 1989–90 coded as 1990.

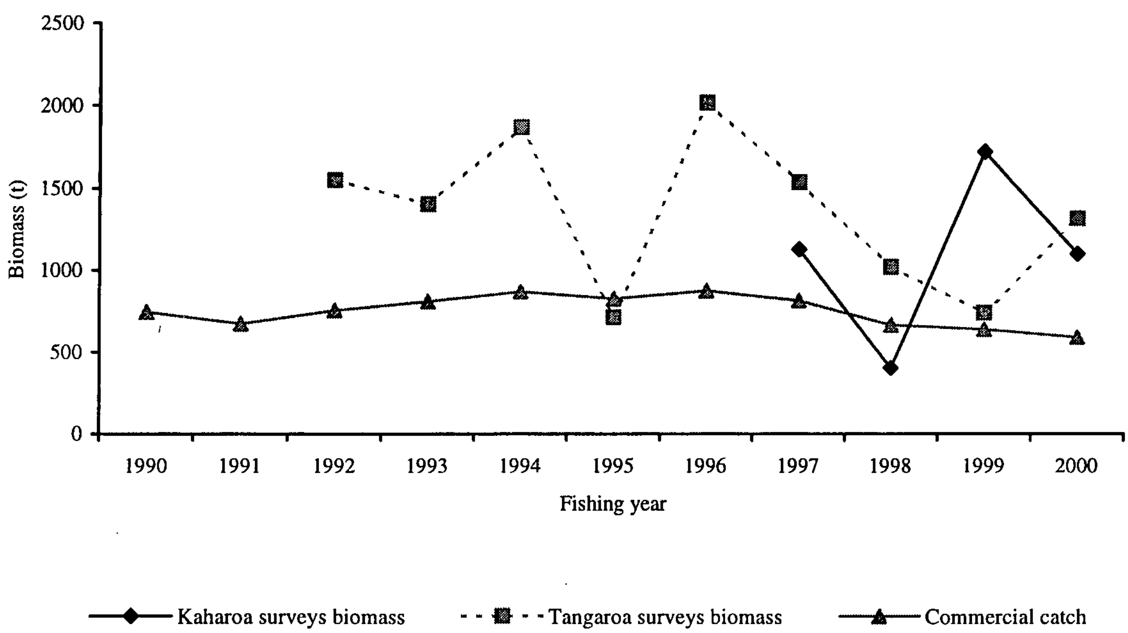


Figure 13: Comparison of giant stargazer *Kaharoa* and *Tangaroa* (western Chatham Rise) trawl survey biomass estimates, and commercial catch in STA 3. 2000 commercial catch was for period up until 31 May 2000. 1989–90 coded as 1990.

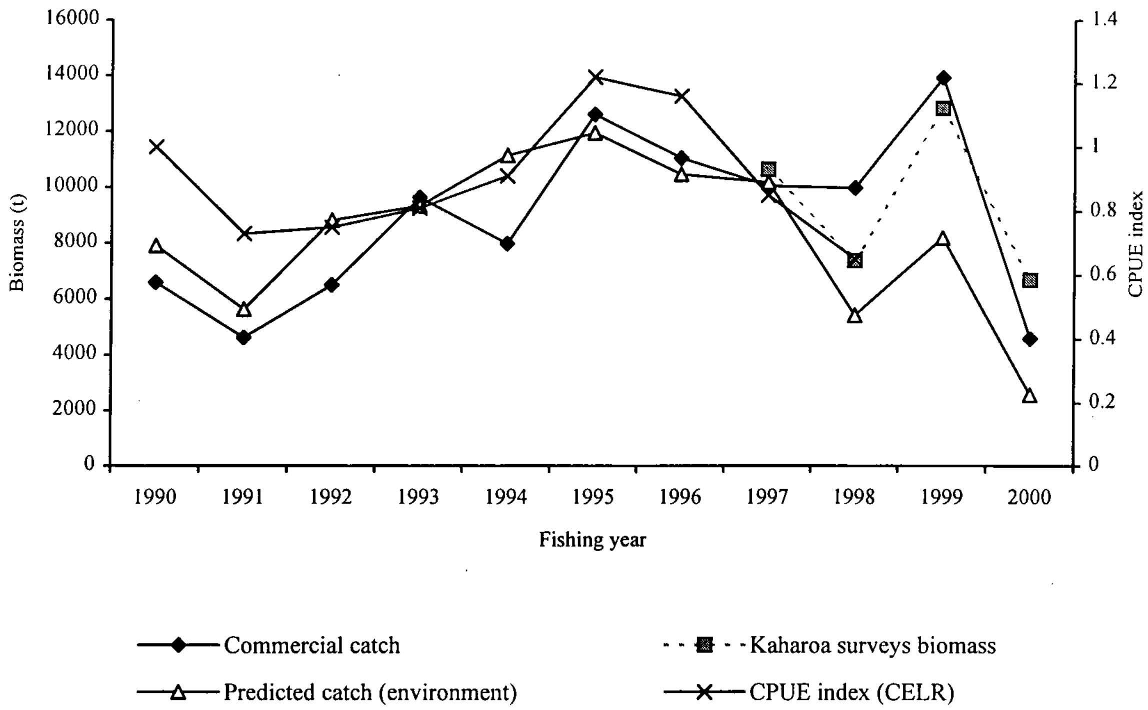


Figure 14: Comparison of red cod trawl survey biomass estimates, CPUE, commercial catch in RCO 3, and environmental index. 2000 commercial catch was for period up until 31 May 2000. 1989–90 coded as 1990.

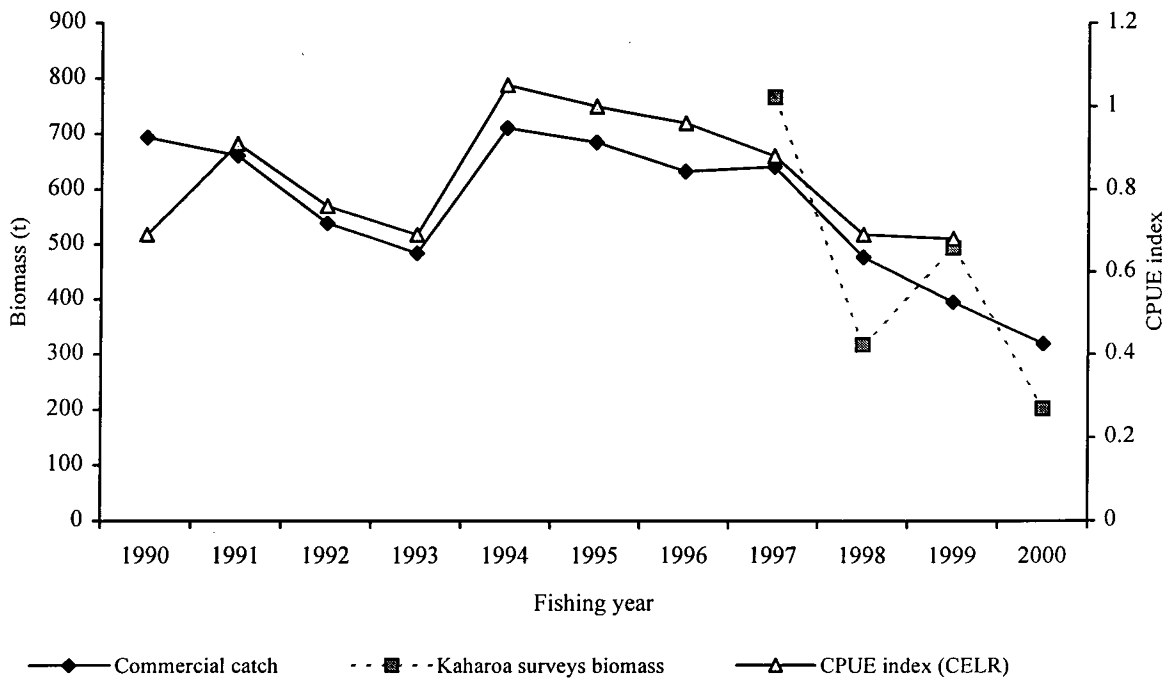


Figure 15: Comparison of red gurnard trawl survey biomass estimates, CPUE indices, and commercial catch in GUR 3. 2000 commercial catch was for period up until 31 May 2000. 1989–90 coded as 1990.

Appendix 1 : **Length-weight relationship parameters used to scale length frequencies and calculate length class biomass estimates. Source of data was NIWA *trawl* database**

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

Species	Survey year	*a*	*b*	n	Range (cm)	Raw data source
Barracouta	1996/97	0.0055	2.9800	429	22.8–87.2	KAH9704
	1997/98	0.0055	2.9800	429	22.8–87.2	KAH9704
	1998/99	0.0055	2.9800	429	22.8–87.3	KAH9704
	1999/2000	0.0158	2.6871	350	21.8–92.8	KAH9917
Blue warehou	All	0.0144	3.1000	338	27.4–69.6	TAN9604
Chilean jack mackerel	All	0.0104	2.9966	184	43.7–61.6	TAN9604
Dark ghost shark	1996/97	0.0018	3.3000	525	30–74	TAN9604
	1997/98	0.0015	3.3611	332	21.2–67.9	KAH9704
	1998/99	0.0014	3.3733	296	26–71.2	KAH9809
	1999/2000	0.0014	3.3733	296	26–71.3	KAH9809
Elephantfish	1996/97	0.0049	3.1654	378	13.4–91	KAH9618
	1997/98	0.0056	3.1284	774	13.7–87.6	KAH9704
	1998/99	0.0050	3.1587	931	13.8–92.5	KAH9809
	1999/2000	0.0058	3.1271	702	14.7–91.4	KAH9917
Giant stargazer	1996/97	0.0284	2.8680	504	6–75	KAH9618
	1997/98	0.0288	2.8561	353	7.6–75	KAH9704
	1998/99	0.0213	2.9353	917	8.6–72.4	KAH9809
	1999/2000	0.0159	3.0130	45	15.8–73.9	KAH9917
Hapuku	All	0.0025	3.4155	98	50.2–78.6	KAH9809
Hoki	All	0.0036	2.9490	1 511	34–102	TAN9601
Ling	All	0.0011	3.3411	482	32–162	TAN9501
Lemon sole	All	0.0080	3.1278	524	14.6–41.2	KAH9809
New Zealand sole	All	0.0098	3.0014	363	12.7–49.7	KAH9809
Red cod	1996/97	0.0124	2.9297	1 308	8–77	KAH9618
	1997/98	0.0126	2.9236	987	7.5–71.9	KAH9704
	1998/99	0.0100	2.9787	1 652	9.1–75.5	KAH9809
	1999/2000	0.0159	2.8580	1 656	8.4–74.3	KAH9917
Red gurnard	1996/97	0.0049	3.2154	748	18–54	KAH9618
	1997/98	0.0054	3.1897	656	14.2–52.6	KAH9704
	1998/99	0.0016	3.2237	846	13.2–54.6	KAH9809
	1999/2000	0.0048	3.2031	398	15.4–51.5	KAH9917
Rig	1996/97	0.0038	3.0152	32	31–108	KAH9618
	1997/98	0.0031	3.0593	123	29.1–115.7	KAH9704
	1998/99	0.0031	3.0593	123	29.1–115.7	KAH9704
	1999/2000	0.0031	3.0593	123	29.1–115.7	KAH9704
Rough skate	1996/97	0.0038	2.8864	366	17–74	KAH9618
	1997/98	0.0277	2.9325	509	14.1–68	KAH9704
	1998/99	0.0340	2.8767	336	14.6–70.4	KAH9809
	1999/2000	0.0190	3.0227	115	16.1–68	KAH9917
School shark	1996/97	0.0070	2.9100	804	30–166	Seabrook-Davidson (Unpub.)
	1997/98	0.0070	2.9100	804	30–167	Seabrook-Davidson (Unpub.)
	1998/99	0.0042	3.0303	523	32–154	KAH9701
	1999/2000	0.0042	3.0303	523	32–155	KAH9702
Sea perch	All	0.0262	2.9210	210	7–42	KAH9618
Silver warehou	All	0.0047	3.3800	262	16.6–57.8	TAN9502

Appendix 1—continued

Species	Survey year	*a*	*b*	n	Range (cm)	Raw data source
Smooth skate	1996/97	0.0240	2.9968	43	23–136	KAH9618
	1997/98	0.0220	2.9750	50	25–138	KAH9704
	1998/99	0.0317	2.8954	81	22–119	KAH9809
	1999/2000	0.0317	2.8954	81	22–120	KAH9809
Spiny dogfish	All	0.0038	3.0108	441	26.6–93.1	KAH9917
Tarakihi	1996/97	0.0146	3.0500	1 396	11–50	KAH9504
	1997/98	0.0146	3.0500	1 396	11–51	KAH9505
	1998/99	0.0111	3.1467	398	9.4–54.2	KAH9809
	1999/2000	0.0084	3.2382	326	14.4–43.9	KAH9917

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

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