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Review of east coast South Island winter inshore trawl survey time series (*Kaharoa*, 1991–1996)

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Final Research Report

Report Title:	Review of east coast South Island winter inshore trawl survey time series.(*Kaharoa*, 1991–96)
Authors:	Michael Beentjes & Michael Stevenson
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4. Project Code:	INT9801
5. Project Leader:	Stuart Hanchet

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Start Date:	1 October 1998
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7. Programme Objective:

To analyse and document the results of the trawl survey time series using RV *Kaharoa* completed off the east coast South Island in winter (1991, 1992, 1993, 1994, 1996).

Specific Objectives

To determine for all commercial species with a total catch greater than 200 kg in each survey in each survey of a series, trends in the following factors over the trawl survey time series:

- relative abundance
- distribution
- length frequency distribution
- reproductive condition
- other relevant biological parameters

8. Executive summary

A time series of five winter trawl surveys was conducted off east coast South Island from 1991 to 1996. This report reviews the time series of surveys and provides analyses of trends in relative abundance, catch distribution, population length frequency, and reproduction of the major species. Detailed methods are provided for the survey design, trawling procedure, processing of the catch and analysis of data. The nature of the fishery as well as bathymetry and hydrology of the Canterbury Bight and Pegasus Bay are described. Previous trawl survey time series within the region are detailed.

The three most abundant species on all five surveys were spiny dogfish, barracouta, and red cod. The ranking of barracouta and spiny dogfish, in terms of biomass, varied between years but red cod ranked consistently third. The percentage of total biomass (all species) accounted for by these three species ranged from 24 to 44% for spiny dogfish, 17 to 32% for barracouta, and 6 to 14% for red cod. Together these three species accounted for about 60 to 70% of the total biomass of all species caught on each of the surveys.

For the target species red cod, the *c.v.s* for total biomass were 33, 40, 30, 35, and 30% and pre-recruited (1+) biomass 44, 50, 46, 41, and 30%. Species with the lowest *c.v.s* were giant stargazer (11–17%), spiny dogfish (10–26%), smooth skate (18–25%), and rough skate (19–25%).

No statistically significant trends were found in pre-recruited, recruited or year class biomass for any species. Those species showing the strongest non-significant trends in biomass were spiny dogfish, dark ghost shark, and Chilean jack mackerel.

There was a two-fold increase in total biomass between 1994 and 1996 mainly a result of large catches of barracouta, spiny dogfish, rattails, and Chilean jack mackerel in 1996. Comparison of total biomass with water temperature (surface and bottom temperature and satellite SST) indicates that these variables may be correlated. The increase in barracouta biomass appears to be to some extent due to good recruitment in previous years but for other species it is unclear. Water temperature may be affecting a range of underlying variables such as cohort distribution, migration, and vertical movement, all of which can influence catch rates. Therefore water temperature may be an important environmental variable affecting the availability of many fish species to trawl gear, although the mechanism is unclear.

The survey performed well in terms of providing recruitment indices for red cod. For the first four surveys, there is a correlation between the 1+ red cod recruitment index and the following years commercial catch. However the weak 1+ year class of 1996 did not translate into poor commercial catches in 1996–97, although we know nothing of recruitment in 1995 since no survey was undertaken.

The surveys were successful in monitoring or tracking year classes between surveys for red cod and barracouta, and only moderately so for giant stargazer and red gurnard. For the remaining important species, year classes were not well monitored.

Red cod were distributed throughout the survey area but were patchy and unpredictable between surveys, although highest catch rates tended to be in depths around 200 m.

Gonad development was consistent with the accepted view that giant stargazer spawn in winter and red cod in spring. Red gurnard are thought to have a long spawning period that peaks in early summer however female gonad development appears to be too advanced to fit this picture and suggests that some spawning takes place in winter.

9. Introduction

See attached report.

10. Methods

See attached report.

11. Results

See attached report.

12. Conclusions

See attached report.

13. Publications

To be published as a NIWA Technical Report (see attached report).

14. Data Storage

No new raw data generated by this project.

Contents

Review of east coast South Island winter trawl survey time series (*Kaharoa* 1991–96)

Abstract

Beentjes, M. P. & Stevenson, M. L. 1999: Review of east coast South Island winter trawl survey time series (Kaharoa, 1991–96). ***NIWA Technical Report XX.*** **X p.**

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Introduction

Background

A time series of five winter trawl surveys was conducted off east coast South Island from 1991 to 1996. The first four surveys (1991–1994) in the time series were consecutive after which the series became biennial with the last survey in 1996. Each of these surveys have been documented in standalone reports with little comparison of the results between surveys (Beentjes & Wass 1994, Beentjes, 1995a b, 1998a b). This report reviews the time series of surveys and provides analyses of trends in relative abundance, catch distribution, population length frequency, and reproduction of the major species. A pilot survey in 1990 will not be considered in this report as it used a different net and trawl gear. The winter time series has been discontinued in favour of a summer time series which began in the summer of 1996–97 and includes the same area (Stevenson 1997).

The Quota Management System was introduced in 1986 and some TACCs were set substantially below annual catches at that time to allow stocks to rebuild. There was no method of determining the sustainability of these TACCs and trawl surveys were initiated as a monitoring tool, providing stock assessment data such as relative biomass, population age and length frequency, that could be used to assess the sustainability of some key fisheries. For the recruitment driven red cod fishery the surveys provided data on recruitment 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+ cohorts from trawl surveys.

Elephantfish (ELE3), giant stargazer (STA3) and red gurnard (GUR3) are three important species caught in east coast South Island that have had TACC increases under the Adaptive Management Programme (AMP). TACCs have been increased on the basis that these species were overcaught for several years indicating recovery of the stocks. The Ministry of Fisheries require data to be collected to monitor these adaptive management stocks to determine if the increases to TACCs are sustainable and therefore these surveys have played an integral part in the provision of this data.

In designing this trawl survey series the depth range of 30–400 m was chosen on the basis of the known commercial depth distribution range of red cod, shallow water species such as elephantfish, rig, red gurnard, and species that are found at greater depths such as dark ghost shark and ling. The survey area extended from Shag Point to the Waiau River; trawlable ground north and south of these points is relatively scarce and the main east coast South Island trawl fishery lies within this area. Red cod (*Pseudophycis bachus*) was the main target species, and catch rates of this species were used to optimize second phase design. The survey provided information on distribution, relative abundance and length frequency for red cod, and secondarily for a range of inshore and middle depth species such as barracouta (*Thyrsites atun*), dark ghost shark (*Hydrolagus novaezealandiae*), elephantfish (*Callorhynchus milii*), giant stargazer (*Kathetostoma giganteum*), ling (*Genypterus blacodes*), red gurnard (*Chelidonichthys kumu*), rig (*Mustelus lenticulatus*), sea perch (*Helicolenus* spp.), spiny dogfish (*Squalus acanthias*), and tarakihi (*Nemadactylus macropterus*).

The wording of Project Objectives varied slightly between surveys but can be summarised as follows:

1. To determine the distribution and develop a time series of relative abundance indices for red cod and other major commercial species using bottom trawl surveys along the east coast of the South Island between Kaikoura and Oamaru in the depth range 30 to 400 m. (Other important species include giant stargazer, barracouta, spiny dogfish, tarakihi, sea perch, ling, elephantfish, rig, dark ghost shark and red gurnard).

2. To determine the distribution and develop a time series of recruitment indices of red cod and other commercial species.

3. To determine the population age structure of red cod to monitor population dynamics.

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 comprised of an assemblage of 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, elephantfish, and tarakihi. Common by-catch species include arrow squid, dark ghost shark, giant stargazer, hoki, spiny dogfish, jack mackerel, ling, red gurnard, rough and smooth skate, sea perch, and warehou. Fishers need to have a diverse quota portfolio that includes the above quota species in quantities that reflect relative catches of each species. Other less common fishing methods include set netting for elephantfish, rig, school shark and groper, and lining for groper. The estimated primary value of the ten most common finfish species caught in Quota Management Area 3 in 1995 was about $20m (based on The New Zealand Seafood Industry Economic Review 1994–1996, and catch data from Annala *et al.* 1999). Red cod ranked 9th out of 38 commercial finfish species caught in New Zealand in 1995 with an estimated primary value of $7.7m, of which about 77% was caught in the east coast South Island. Since the introduction of the QMS in 1986 red cod catches from RCO3 have varied four fold between 3000 and 12000 t and this is believed to be due to variable recruitment between years.

The 12 n. mile exclusion zone which applies to vessels over 43 m, has been extended seaward in the 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 slope from Cape Saunders to the Clarence River. Domestic vessels, less than 43 m length, therefore land the bulk of the commercial catch within the survey area.

Previous east coast South Island trawl surveys

There have been four previous trawl survey series in the east coast 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 the *W. J. Scott.* The aim was to provide information on the main commercial inshore finfish species on the southeast South Island (Fenaughty & Bagley 1981). Between 1980 and 1982 a series of nine trawl surveys was carried out in the Canterbury Bight on the *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 the *James Cook* (Paul & Kucerans 1984). A further series of eight trawl surveys targeting rig was undertaken using *Kaharoa* and *James Cook* from 1982 to 1984 in Golden Bay and Pegasus Bay areas (unpublished).

Hydrology and bathymetry of east coast South Island

The main water current flowing over the continental shelf and slope of the South Island south east coast 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. This current then moves north eastward up the east coast of the South Island, where it becomes known as the Southland Current (Chiswell 1996, Heath 1975). The Southland Current continues north eastward 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 mixing with the D'Urville Current which travels eastward through Cook strait. To the east, the Southland Current is bounded by less saline cooler subantarctic waters forming 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 47 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 many fish species. Significant bathymetric features of the South Island east coast from Otago Peninsula to Kaikoura include relic canyons off Otago Peninsula (Saunders, Papanui, Taiaroa and Karitane Canyons), Oamaru (Waitaki Canyon), Pegasus Bay (Pegasus Canyon) and the active Kaikoura Canyon south of Kaikoura. Other features include the Conway Trough that links up with the Kaikoura Canyon and the stretch of deeper water between Banks Peninsula and the Chatham Rise known as the Mernoo Gap. Much of the area north of Waiau River is foul ground and untrawlable.

Methods

Survey area and design

The survey area extended from the Waiau River (south of Kaikoura) to Shag Point (north of Otago Peninsula). All five surveys were carried out from early to mid May through to early June. The timing varied slightly between years but tended to extend either side of the original dates of the 1991 survey. The surveys used a two-phase stratified random trawl design (*after* Francis 1984). The total survey area was 23 341 km^2. Before each survey sufficient trawl stations to cover both first and second phase stations, were randomly generated using the computer program 'Rand_stn v2.1' (Vignaux 1994) with a minimum distance of 5 km apart specified. Allocation of phase 1 stations was based on stratum area with a minimum of 3 stations per strata, and phase 2 stations on catch rates of red cod (Table 1).

Nine strata were used in 1991–93 however, in 1994 the stratification was changed by sub-dividing these nine strata into seventeen in an attempt to reduce coefficients of variation for relative biomass estimates for red cod and other key species. The new stratification with 17 strata was used again in 1996. Stratification used in the 1994 and 1996 surveys are shown in Figure 1. The depth range of 30–400 m was chosen on the basis of the known commercial depth distribution range of red cod, shallow water species such as elephantfish, rig, red gurnard, and species that are found at greater depths such as dark ghost shark and ling. The three depth ranges (30–100, 100–200, and 200–400 m) represent inshore, shelf edge, and continental slope. Strata were digitised from bathymetric charts using depth contours as borders. 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.

Vessel and gear specifications

GRV *Kaharoa,* a 28 m stern trawler with a power rating of 522 kW and a displacement of 302 t, is capable of trawling to depths of 500 m. A two-panel net was specially designed and built in 1991 for the South Island inshore *Kaharoa* trawl surveys. Based on the 'Alfredo' design, the net fishes hard down, and achieves a headline height of about 4–5 m. The codend inside measurement was 74 mm (knotless). New Rectangular 'V' trawl doors fitted with SCANMAR sensors were used on the 1996 survey (*see* Beentjes and Wass 1994 for net plan, and Drummond & Stevenson 1996 for details of new doors used in 1996).

Trawling procedure

Trawling procedure was standardised for all surveys. Tows were conducted in daylight between 0730 and 1700 hours (NZST). 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 – in some cases this may have 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. Standard tows were one hour at a speed over the ground of 3 kn.– a distance of 3 n. miles was generally achieved for one hour tows. In 1996 tow length was reduced to around 30 min in some areas when consistently large bags became unmanageable. Warp to depth ratio was maintained at around 3:1 except in shallow water where it was as high as 6:1.

Kaharoa was equipped with SCANMAR before the 1996 survey, and doorspread was recorded every 10-15 min and averaged over the tow. Headline height was recorded from the *net sonde* and averaged over the length of the tow: Sea bottom temperature was recorded from the net sonde in 1992 and 1994 and by the SCANMAR net monitor in 1996. Sea surface temperature was recorded with the hull sensor on the 1992, 1993, and 1994 surveys. Missing years data are due to gear failure.

Catch and biological sampling

The catch of each species from each tow was sorted, 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 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. Biological information was obtained from a random sample of up to 20 fish for red cod, red gurnard, and stargazer, 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 compensated 5 kg Seaway scales), otoliths, gonad stage, and stomach fullness, digestive state, and percentage composition of prey items. Individual weight, length, sex, and maturity were recorded for rough and smooth skate on the 1996 survey.

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). Biomass estimates for 1991 to 1994 surveys used doorspread values that were based on 1995 gear trials where SCANMAR was fitted to the old doors to determine the doorspread to depth relationship (Drummond & Stevenson 1996). Biomass estimates for 1996, used doorspread values measured directly with SCANMAR. All tows where 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 east coast South Island stocks outside the survey area; fish distribution over foul ground is the same as that over trawlable ground.

Species were chosen for analysis based on the criteria that 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. An exception was made for silver warehou because although total catch weight did not meet the above criteria, there were sufficient numbers of small fish 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 were determined for red cod, giant stargazer, and red gurnard on all surveys, as well as dark ghost shark, rough and smooth skate in 1996. Coefficients were determined by regressing natural log weight against natural log length ($W=aL^b$). Length weight coefficients were used to scale length frequencies and to calculate recruited and year class biomass (Appendix 1).

In 1991 strata 7 and 9 were not surveyed and therefore to make the 1991 total survey biomass comparable to other surveys, the mean proportion of biomass contributed by strata 7 and 9 in the 1992 to 1996 surveys was used to adjust the estimates for 1991 (note that strata 9 became strata 16 and 17 in 1994 and 1996). Overall this resulted in an increase to total biomass of around 5%. Of the important species listed in objective 1, dark ghost shark and ling were most affected in the deep stratum 9 (200–400 m). For example, for dark ghost shark we could expected on average, 25% (range 5–65%) of the biomass to have been caught in stratum 9, although there is considerable variability between years. For the following species the comparable figures were ling 20% (range = 12–39%), red cod 6% (range=1–17%), and giant stargazer 4% (range = 2–6%). Similarly, the species most affected by missing out the shallower stratum 7 (100–200 m) was sea perch, where on average we could have expected 10% (range = 3–17%) of the biomass to have been caught in stratum 7. For the following species the comparable figures were giant stargazer 8% (range = 4–11%), spiny dogfish 3% (range = 1–9%), tarakihi 3% (range = 1–7%), and red cod 2% (range = 1–4).

The length frequency distributions that are presented for 1991 have not been adjusted to account for the missing strata and therefore the scaled populations numbers were derived from the unadjusted biomass. However, in order to determine if there was a difference in the size of fish that might have been caught in strata 7 and 9, length frequency distributions were extracted for the missing strata for each survey and compared with the distributions for the remaining strata. For the key species there was generally no appreciable difference in the length frequency distributions between these areas for each of the surveys. The exceptions were dark ghost shark which were smaller in strata 7 & 9 in 1996 and tarakihi which were larger in these strata in 1993. The comparatively small numbers of fish involved however would not affect the shape of the length frequency distributions shown in Figure 8.

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

Considerably more stations were completed in the last two surveys of the time series (55 stations in 1991 compared to 121 in 1996) (Table 1). The increase in the number of stations on the last two surveys was mainly a result of the allocation of more days to the these surveys, less days lost to bad weather, and efficiency gains through experience and knowledge of foul ground locations. More phase 2 stations were also allocated in 1994 and 1996 as phase 1 stations were completed on or before schedule leaving extra time available to survey phase 2 stations.

Biomass and precision

Biomass and coefficients of variation (*c.v.*s) for the main 18 commercial species are given in Table 2. Total estimated biomass and *c.v.* for all species caught on the surveys are also shown. The three most abundant species on all five surveys were spiny dogfish, barracouta, and red cod. The ranking of barracouta and spiny dogfish, in terms of biomass, varied between years but red cod ranked consistently third. The percentage of total biomass (all species) accounted for by these three species ranged from 24 to 44% for spiny dogfish, 17 to 32% for barracouta, and 6 to 14% for red cod. Together these three species accounted for about 60 to 70% of the total biomass of all species caught on each of the surveys. Tarakihi, sea perch, dark ghost shark, and arrow squid were the next most abundant, the ranking changing between years. Chilean jack mackerel is notable in that biomass was reasonably stable between 1991 and 1994 and then increased 10 fold from155t in 1994 to 1585 t in 1996.

The coefficient of variation (*c.v.*) is an indication of the precision of the biomass estimate. For the target species red cod, the *c.v.s* for total biomass were 33, 40, 30, 35, and 30% (*see* Table 2) and pre-recruited (1+) biomass 44, 50, 46, 41, and 30% (Table 3). There was no clear improvement in *c.v.*s for either total or pre-recruit biomass as a result of lengthening the 1994 and 1996 surveys to accommodate more phase 2 stations, and/or by re-stratifying to more accurately reflect the distribution of red cod. This is probably a reflection of the aggregated and highly mobile nature of red cod schools within the survey area and variable recruitment. For most other species there was an improvement in the precision of biomass estimates (*see* Table 2). Species with the lowest *c.v.s* were giant stargazer (11–17%), spiny dogfish (10–26%), smooth skate (18–25%), and rough skate (19–25%).

Biomass trends

Trends in biomass for 18 major commercial species are shown in Figure 2. No statistically significant trends were found in increasing or declining biomass for any of these species. Those species showing the strongest non-significant trends were spiny dogfish, dark ghost shark, and Chilean jack mackerel with probabilities of 0.06, 0.06, and 0.07, respectively. The power of any statistical test to find trends in biomass is limited by the small sample size, in this case the number of surveys in the time series.

Total biomass and recruited biomass of 8 species are shown in Figure 3. Where total and recruited biomass (= recruited to the commercial fishery) are the same, this indicates that most of the catch was of commercial size. There were no statistically significant trends in increasing or declining recruited biomass for any of these species. It is noteworthy that with the exception of giant stargazer, recruited biomass increases in 1993, declines in 1994, and increases again in 1996. This trend is more pronounced for the total biomass for all species with a two fold increase in biomass between 1994 and 1996. This was mainly a result of large catches of spiny dogfish, barracouta, rattails, and to a lesser extent dark ghost shark and Chilean jack mackerel in 1996. Such extreme changes in biomass between surveys is not without precedence and has been observed for pale and dark ghost shark from Southland/sub-Antarctic and Chatham Rise surveys (data from Hurst & Schofield 1990, 1995). Horn (1997a) suggests that the indices are probably related to changes in availability of ghost sharks to trawl gear rather than to real changes in abundance. The very high biomass estimate for spiny dogfish in the 1996 survey was also mirrored by unusually high spiny dogfish biomass estimates for the 1996 Southland trawl survey (Hurst & Bagley 1997) and the 1996 Chatham Rise hoki survey (*see* Hanchet & Ingerson 1997 for review). Hanchet & Ingerson (1997) suggest that the increase is due to changes in spiny dogfish areal and vertical availability to the trawl gear, possibly a result of environmental conditions. The affect of water temperature on catch rates in this time series is discussed in the following section Water temperature and catch rates.

Biomass by year class of 8 species are shown in Figure 4. There were no statistically significant trends in increasing or declining biomass of any year class for any of these species. There may be statistical differences in biomass between years, however the statistical analysis used would only detect any significant upward or downward trend. For red cod the 1+ year class was strongest in 1994. Commercial catches of red cod in RCO3 in 1994–95 increased by 60% compared to the previous year, consistent with 1994 1+ fish entering the commercial fishery the following year as 2+ fish. For the first four surveys there is a high correlation between 1+ red cod recruitment index and the following years commercial catch (Annala *et al.* 1999). However the weak 1+ year class of 1996 did not translate into poor commercial catches in 1996–97, although we know nothing of recruitment in 1995 since no survey was undertaken. The abundance of recruited red cod appears correlated with commercial catches in the same year and this holds for all surveys. Predictions of the potential red cod fishery in following years is limited by the small number of surveys in this time series and the move to biennial survey frequency after 1994. The strength of the red cod 0+ year class does not appear to be related to the 1+ cohort, but probably has a low vulnerability to capture with the codend mesh used. The summer time series, which uses a 40 mm codend, has been more successful in catching 0+ red cod cohorts and if this time series continues it will provide both 0+ and 1+ cohort strength as predictor variables (Stevenson 1997).

Water temperature and catch rates

Surface temperatures were collected for three surveys and indicate that in 1992 the mean temperature was cooler than both 1993 and 1994 by about 1 °C (Figures 5a b). Similarly, of the three years for which bottom temperatures were recorded, 1992 was also cooler than 1994 and 1996 by about 3 °C.

In order to extend the water temperature data time series, satellite derived sea surface temperatures (SST) were extracted for locations in Canterbury Bight (44.5 S 171.5 E) and Pegasus Bay (43.5 S 173.5 E). Mean monthly SST for 1°x1° square grids (=resolution) that included the above locations were used to provide SST for the period 1991–1996. Mean SST for May 1991–1996 and mean surface and bottom temperatures recorded during the survey are shown in Figure 6 (top). The Kaharoa mean water temperature data will be affected by distance from land and depth but in broad terms interannual differences in water temperature should still be apparent if they are large enough. The trend in SST shows little difference between Canterbury Bight and Pegasus Bay except for the magnitude of the temperatures which are warmer in the north. Survey recorded surface and bottom water temperature displays the same trends as SST in temperature and confirms that 1992 was the coolest year, after which water temperature increased each year. The difference in SST between 1992 and 1996 was about 2 °C.

Total biomass of all species has been plotted against Canterbury Bight SST in Figure 6 (bottom). The lowest and highest total biomass estimates correspond with the temperature extremes, and the trends are remarkably similar. There appears to be a relationship between temperature and catch rate with high catches when water temperature is warm. The key species driving the increase in biomass in 1996 were barracouta, spiny dogfish, rattails and Chilean jack mackerel. With the of exception of rattails where no data exists for length and distribution has not been analysed, distribution, and recruitment were examined for these species to determine whether these variables were a contributing factor in the large biomass estimates of 1996. Distributions of each species were similar between years and therefore the increase cannot be attributed to changes in distribution. Barracouta biomass in 1996 is strongly influenced by a component of large fish which probably spawned in 1989 and 1990 and the 1989 cohort appears to be largely absent in the 1994 survey, appearing again in 1996. Spiny dogfish length frequencies in 1996 were similar in regard to the size classes caught to previous surveys except that more smaller fish were caught, although this would not have affected biomass greatly. The reproductive life history of Chilean jack mackerel is not well understood. The biomass of Chilean jack mackerel is strongly tied to migration from South America where a westward gradient of dominant age and size classes has been shown with older fish arriving in New Zealand waters and oceanic fry are thought to return to South America (Elizarov *et al.* 1993). The increase in biomass observed in 1996 may be tied in with this migration. In addition jack mackerel display a high degree of vertical movement in the water column which will influence vulnerability to trawling.

In summary, barracouta, spiny dogfish and Chilean jack mackerel biomass increased dramatically between 1994 and 1996 as did water temperature. The increase in barracouta biomass appears to be to some extent due to good recruitment in previous years but for other species it is unclear. Water temperature may be affecting a range of underlying variables such as cohort distribution, migration, and vertical movement all of which can influence catch rates. Therefore water temperature may be an important environmental variable affecting the availability of some fish species to trawl gear, although the mechanism is unclear.

Distribution and length frequency

The distribution and size of catches expressed by catch rates (kg.km^{-2}) for major species are shown in Figure 7 and length frequency distributions in Figure 8.

Arrow squid

Arrow squid (*Nototodarus sloanii*) were distributed throughout the survey area and were caught at between 89% and 96% of stations (Figure 7a). Catch rates were lowest in 1991 and this is reflected in the low biomass (*see* Table 2). Highest catch rates were generally on the continental slope in the depth range 200–400 m. Meaningful length frequency data were only collected for 1993–96 (Figure 8a). In each of these three surveys there appear to be three modes present, with peaks at about 10 cm, 21 cm and 30 cm, the latter mode being the strongest. Female modes appear to be marginally larger than males. *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 (Annala *et al.* 1999). This would explain why there are multiple modes within a single year class.

Barracouta

Barracouta were distributed throughout the survey area with highest catch rates generally on the continental shelf in less than 200 m. They were caught at between 82% to 94% of stations (Figure 7b);

only spiny dogfish was caught at more stations. Strong year classes can be identified in some years with modes for males and unsexed, and females at about 25, 35, 50, 58, and 70 cm (Figure 8b). Two strong year classes, 1989 (at 35 cm in 1991) and 1990 (at 35 cm in 1992) can be tracked through to 5+ and 6+ fish in 1996. The next strong year class to appear is the 1995 cohort in 1996 which is similar to the pattern found off Southland in 1996 (Hurst & Bagley 1997). The survey appears to have been successful in monitoring barracouta year class strength.

Chilean jack mackerel

Chilean jack mackerel (*Trachurus murphyi*) were distributed throughout the survey area and were caught at between 33% to 55% of stations (Figure 7c). The high catch rates in 1996 were reflected in the high biomass estimate for this survey (*see* Table 2). Highest catch rates were generally on the continental shelf in less than 200 m. Only two modes are evident with peaks at about 40 and 48 cm, the latter being the strongest, particularly in 1996 (Figure 8c).

Dark ghost shark

Dark ghost shark were confined to the continental slope between 200 to 400 m generally south of Banks Peninsula, and were caught at between 22% to 44% of stations (Figure 7d). The high catch rates in 1993, 1994, and 1996 were reflected in the high biomass estimates for these surveys (*see* Table 2). Consistent length frequency modes for males with peaks at about 35 cm and 55 cm are most distinct in 1993, 1994, and 1996 (Figure 8d). Females modes are less distinct and they grow larger than males. Growth is slow for ghost shark, at about 3.5 cm a year for females (Horn 1997a), and therefore the 35 cm mode could not have progressed to the 55 cm mode in one year. The length frequency distribution for 1993, 1994, and 1996 are similar with little evidence of strong year classes tracking through the surveys. .

Elephantfish

Elephantfish were confined to the inner continental shelf in less than 100 m, although the strata yielding highest catch rates varied between surveys. They were caught at between 30% to 34% of stations (Figure 7e). The high catch rates in 1996 were reflected in the high biomass estimate for this survey (*see* Table 2). Length frequency distributions change substantially between years with 1991 containing mostly mature fish (> 50 cm males and > 60 cm females, *see* Stevenson & Beentjes *1999*), while in 1992 and 1996 the bulk of the catch was immature. In 1993 and 1994 numbers of mature and immature were similar. Clear 1+ and 2+ year classes (22 cm and 34 cm) are present in 1992, and the 2+ year class progresses to 3+ in 1993. A 1+ and a strong 3+ year class (25 cm and 46 cm) are present in 1996 (Figure 8e). The year classes do not track well between surveys with some missing year classes. For example, there is a strong 3+ year class in 1996 but these fish were not caught as 1+ or 2+ fish on earlier surveys.

Giant stargazer

Giant stargazer were distributed throughout the survey area with highest catch rates generally on the continental shelf in less than 200 m. They were caught at between 70% and 92% of stations (Figure 7f). The 1+ year class is distinct in 1991 and 1994 with a peak at about 20 cm (Figure 8f). Individual modes for older year classes are not clearly distinguishable and appear to have merged together. However Sutton (1999) tracked the 1991 1+ (20 cm mode) and 3+ (35 cm mode) year classes to 4+ (36 cm) and 6+ (41 cm) in 1994, relying on an understanding of mean length at age. The surveys monitored year class strength only moderately well for giant stargazer.

Hapuku

Hapuku (*Polyprion oxygeneios*) were distributed throughout the survey area with highest catch rates generally in Pegasus Bay, and around Banks Peninsula. They were caught at between 25% and 69% of stations (Figure 7g). Too few fish were caught on each survey to show any clear modes in the length frequency distributions although a possible mode can be seen at 51 cm in all but the 1994 survey. This would correspond to fish around 2–3 years old (Francis *et al.* 1999). Generally the hapuku caught were juvenile immature fish less than 80 cm (Figure 8g). Hapuku mean growth rate is only around 4 cm/yr making it difficult to track year classes.

Hoki

Hoki were confined to the continental slope between 200 to 400 m and were caught at between 9% and 22% of stations (Figure 7h). The length frequency data are patchy indicating that the survey did not sample hoki well; given the preferred depth range of hoki of 400–700 m (Anderson *et al.* 1998), this survey was marginal for this species. However three clear modes with peaks at about 25, 45, and 65 cm are distinguishable in 1993 and 1996 and not all year classes are present on each survey (Figure 8h). The strong mode at 45 cm in 1993 are 1+ fish and correspond to a strong 1991 year class which is absent in 1994 appearing again in 1996 as 4+ fish (about 60 cm) Length frequency data collected from trawl surveys off the west coast, Cook Strait, and Chatham Rise also showed the 1991 year class to be relatively strong (Ballara *et al.* 1998). These surveys showed the 1992 and 1994 year class also to be strong but on the east coast South Island trawl winter surveys this was not the case. The latter surveys did however show a strong 1995 year class in 1996 as 0+ fish which was not found on the other surveys.

Ling

Ling were distributed throughout the survey area with highest catch rates in the depth range 100–200 m. They were caught at between 60% and 82% of stations (Figure 7i). The length frequency distributions are similar between years with only one distinguishable length frequency mode apparent with a peak at about 50 cm. There are no obvious strong year classes (Figure 8I). The ling caught on these surveys were generally pre-recruits and considerably smaller than ling sampled from the Chatham Rise Tangaroa surveys (Horn 1997b).

Red cod

Red cod were distributed throughout the survey area and were caught at between 75% and 89% of stations. . The distribution of red cod tends to be patchy and unpredictable between years although highest catch rates tended to be in around 200 m depth (Figure 7j). Length frequency distributions are generally dominated by a single strong 1+ year class with a peak at about 35 cm (Figure 8j). This 1+ year class varies in strength from year to year with good recruitment in 1991, 1992, 1994, and poor recruitment in 1993 and 1996. The 0+ cohort is evident in 1991 and 1993 but probably not fully vulnerable to capture on these surveys. The bulk of the larger fish are predominantly 2+ and to a lesser extent 3+ fish (Horn 1995). Female year classes appear to be marginally larger than males. Because there are only a few year classes present in the length frequency data it is possible to track cohorts between surveys. The strength of the 1+ cohort is a useful index of recruitment.

Red Gurnard

Red gurnard were confined to the inner continental shelf in less than 100 m, although the strata yielding highest catch rates varied between surveys. They were caught at between 24% and 49% of stations (Figure 7k). Length frequency distributions change substantially between years, and do not show a consistent pattern between years. A strong 1+ year class with a peak at about 25 cm is distinguishable in 1992. Although it is difficult to follow the progression of any one cohort, Sutton (1997) interpreted a progression of the 1+ year class (25 cm mode) in 1991 to 2+ (33 cm mode) in 1993 and 3 + (37 cm mode) in 1994 (Figure 8k). Female year classes, where they can be seen, appear to be larger than males and the largest fish are females The 1+ year classes were absent in 1991, 1994, and 1996 and may not be fully recruited to the survey. The surveys monitored year class strength only moderately well for red gurnard.

Rough skate

Rough skate were distributed throughout the survey area with highest catch rates in less than 200 m. They were caught at between 26 and 52% of stations (Figure 7l). Rough skate length was only measured in 1996 and are not shown here.

School shark

School shark were confined to the shelf with highest catch rates in about 100 m and were caught at between 23% and 42% of stations (Figure 7m). Too few fish were caught and measured on each survey to show clear modes in the length frequency distributions (Figure 8l). School shark caught on this survey were generally small compared to school shark caught in the Southland/Snares shelf Tangaroa surveys (Hurst & Bagley 1997).

Sea perch

Sea perch were distributed throughout the survey area with highest catch rates generally in about 100 m. They were caught at between 59% and 82% of stations (Figure 7n). Individual year classes are not distinguishable from the length frequency distributions and show one mode with a peak at about 25 cm. The length frequency distributions appear stable with no strong year classes obvious. There are no juvenile modes present and fish at 25 cm are around 8–10 years old (Paul 1998), although ageing has not been validated. Given the slow growth rate the single mode is probably composed of multiple year classes (Figure 8m). There are two species of sea perch found in the east coast South Island; *Helicolenus. percoides* is generally found in depths of at east 50 m and *H. barathri* from 40 to 1200 m. While it is considered that the species sampled are *H. percoides,* it is possible that some of the sea perch caught were *H. barathri.*

Silver warehou

Silver warehou were distributed throughout the survey area with highest catch rates generally in about 200 m on the shelf edge. They were caught at between 41% and 69% of stations (Figure 7o) although numbers caught were small (Figure 8n). High catch rates in 1993 and 1996 are consistent with high biomass estimates for these surveys. Two year classes are distinguishable particularly in 1993, 1994 and 1996. (Figure 8n). Modes have peaks at about 19 cm, and 31 cm (0+ and 1+, *see* Table 3). Only the 0+ year class appears in each year and is strongest in 1996. The 1+ year class is strongest in 1993. Progression of this 0+ into the 1+ year class is apparent from 1992 to 1996. The silver warehou sampled on these surveys were generally small pre-recruits.

Smooth skate

Smooth skate were distributed throughout the survey area with highest catch rates in less than 200 m. They were caught at between 27 and 59% of stations (Figure 7p). Smooth skate length was only measured in 1996 and are not shown here.

Spiny dogfish

Spiny dogfish were distributed throughout the survey area with highest catch rates generally between 50 and 200 m. They were caught at between 94% and 99% of stations, a greater proportion than any other species (Figure 7q). High catch rates in 1996 are consistent with high biomass estimates for this survey. Individual year classes are not clearly distinguishable from the length frequency distributions which show one strong mode with a peak at about 66 cm and indications of a smaller mode with a peak about 50 cm in both sexes (Figure 8o). These modes are probably made up of multiple year classes. Sex ratios strongly favour males and this is most obvious in 1996 when these modes were also strongest. Spiny dogfish from the Southland trawl survey time series were larger and not always dominated by males (*see* Hurst & Bagley 1997).

Tarakihi

Tarakihi were confined to the inner continental shelf in less than 200 m, although the strata yielding highest catch rates varied between surveys (Figure 7r). They were caught at between 61% and 75% of stations. Two modes are distinguishable (Figure 8p) with peaks at about 13 and 18 cm (0+, 1+, *see* Table

3). The 1+ year class is strongest in 1993. It is unlikely the 0+ year was fully vulnerable to capture on these surveys. The tarakihi sampled on these surveys were generally small pre-recruits.

Reproductive condition

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

Giant stargazer male gonads were mainly in the resting and maturing phase with 5–37% in the ripening phase. In 1994 and 1996 a small number of male gonads were running ripe (5–10%). Females were similar except there were a higher proportion of fish with resting and maturing gonads. Gonad development is consistent with the view that stargazer spawn in winter (Annala *et al.* 1999).

Red cod male gonads were mainly in the resting and maturing phase. In 1993 and 1996 nearly all fish (96% and 98%) were resting whereas in 1991, 1992 and 1994 there was a large proportion of fish that were maturing and a small proportion ripening, and in 1994 4% were running ripe. Female gonads were mostly resting with the exception of 1991 where 81% were maturing. The lack of gonad development is consistent with the view that red cod spawn in spring (Beentjes 1992).

Red gurnard male gonads were predominantly in the resting phase. In 1993 and 1996 nearly all fish (93% and 98%) were resting whereas in 1991, 1992 and 1994 there was a larger proportion of fish that were maturing and in 1993 3% were running ripe. Female gonads showed a much greater spread of gonad conditions with a greater proportion of fish with ripening and running ripe gonads. Red gurnard are thought to have a long spawning period that peaks in early summer (Annala *et al.* 1999). Female gonad development appears to be too advanced to fit this picture and suggests that some spawning takes place in winter.

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Table 1: Number of stations, total catch, and mean catch rate per tow, 1991–96

	KAH9105	KAH9205	KAH9306	KAH9406*	KAH9606*
Dates	15/5–1/6	13/5–7/6	7/5–6/6	7/5–11/6	7/5–11/6
Phase 1 stations	50	75	66	74	76
Phase 2 stations	5	5	8	31	45
Total statons	55	80	74	105	121
Total catch (t)	52.5	71.0	96.0	142.4	190.3
Mean catchrate per tow (kg.km^2)	2 049	1 708	2 537	2 521	3 455

Table 2: Estimated biomass (t), coefficient of variation (*c.v.* %), for the 18 major commercial species, and total biomass for all species combined 1991–96. Biomass estimates for KAH9105 have been adjusted to allow for non-sampled strata (7 & 9).

	KAH9105		KAH9205		KAH9306		KAH9406		KAH9606	
	Biomass	*c.v.* (%)	Biomass	*c.v.* (%)	Biomass	*c.v.* (%)	Biomass	*c.v.* (%)	Biomass	*c.v.* (%)
Arrow squid	443	22	1 303	32	1 062	17	1 421	25	1 204	30
Barracouta	8 361	29	11 672	23	18 197	22	6 965	34	16 848	19
Chilean jack mackerel	47	26	200	31	225	28	155	38	1 585	34
Dark ghost shark	962	42	934	44	2 911	42	2 702	25	3 176	23
Elephantfish	300	40	176	32	481	33	164	32	858	30
Giant stargazer	672	17	669	16	609	14	439	17	465	11
Hapuku	186	24	104	35	177	31	54	32	102	19
Hoki	61	93	108	75	413	32	125	49	460	32
Ling	1009	35	525	17	651	27	488	19	488	21
Red cod	3 760	33	4 527	40	5 601	30	5 637	35	4 619	30
Red gurnard	763	40	142	30	576	31	123	34	505	27
Rough skate	*	*	224	24	335	21	517	20	177	19
School shark	100	30	104	21	369	42	155	36	202	18
Sea perch	1 716	30	1 934	28	2 948	32	2 342	29	1 671	25
Silver warehou	29	21	32	22	256	44	35	28	231	32
Smooth skate	*	*	605	18	658	25	306	25	385	24
Spiny dogfish	12 873	22	10 787	26	13 949	17	14 530	10	35 169	15
Tarakihi	1 712	33	932	26	3 805	55	1 219	31	1 656	24
All species combined	43 137	#	38 965	11	56 913	10	41 397	10	79 889	12

* Rough and smooth skates not separated, combined biomass = 1 993 t (*c.v.* 25%)
# Unable to calculate because of adjustments to individual species

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). Biomass estimates for KAH9105 have been adjusted to allow for non-sampled strata (7 & 9)

	Size range (cm)	Age	KAH9105 Biomass	KAH9105 *c.v.* (%)	KAH9205 Biomass	KAH9205 *c.v.* (%)	KAH9306 Biomass	KAH9306 *c.v.* (%)	KAH9406 Biomass	KAH9406 *c.v.* (%)	KAH9606 Biomass	KAH9606 *c.v.* (%)
Barracouta	15–30	0+	28	41	6	43	9	27	5	40	161	20
	28–43	1+	1 015	24	1 643	27	141	33	291	18	191	37
	39–54	2+	191	38	2 523	27	4 304	23	377	26	1 113	24
	47–66	3+	2 382	37	1 547	34	8 174	30	4 302	52	1 563	18
Elephantfish	15–35	0+	1	100	5	93	1	68	1	49	4	66
	30–43	1+	1	100	38	88	66	55	26	57	23	63
	38–52	2+	3	62	17	53	58	56	21	51	344	43
Giant stargazer	10–25	1+	8	27	6	18	1	44	7	29	1	48
	23–32	2+	34	22	55	15	31	16	8	36	32	28
Hoki	15–31	0+	–		–		*	61	–		4	51
	33–44	1+	–		–		28	72	–		5	58
	41–54	2+	–		–		48	85	–		4	56
Red cod	11–27	0+	62	64	12	29	7	28	9	28	2	33
	24–46	1+	2 026	44	2 436	50	1 999	46	4 239	41	763	30
Red gurnard	19–28	1+	10	40	22	57	14	43	1	46	1	51
Silver warehou	8–25	0+	19	23	19	32	5	26	24	37	60	23
	24–35	1+	7	35	10	35	114	58	10	39	82	37
Tarakihi	10–16	0+	16	25	7	26	43	54	11	62	5	43
	15–23	1+	158	38	178	29	1 990	64	355	32	372	31

– 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												
KAH9105	25	63	13	0	0	8	19	76	5	0	0	21
KAH9205	56	33	11	0	0	9	63	11	16	11	0	19
KAH9306	53	35	12	0	0	17	86	0	14	0	0	29
KAH9406	22	36	37	5	0	59	82	16	1	0	0	91
KAH9606	57	29	5	10	0	42	91	3	6	0	0	78
Red cod												
KAH9105	23	74	3	0	0	35	16	81	0	0	0	83
KAH9205	60	40	0	0	0	20	92	8	0	0	0	64
KAH9306	96	2	2	0	0	45	100	0	0	0	0	133
KAH9406	45	49	3	4	0	200	99	1	0	0	0	151
KAH9606	98	2	0	0	0	297	99	< 0.5	< 0.5	0	0	398
Red gurnard												
KAH9105	61	39	0	0	0	51	20	52	28	0	0	60
KAH9205	82	18	0	0	0	49	70	17	6	6	0	64
KAH9306	93	3	1	3	0	74	59	23	15	2	1	83
KAH9406	52	48	0	0	0	71	44	54	2	0	0	57
KAH9606	98	1	>0.5	0	0	231	76	13	9.4	2	0	149

Gonad stages used were: 1, immature or resting; 2, maturing (oocytes visible in females); 3, mature (hyaline oocytes in females, milt expressible in males); 4, running ripe (eggs and milt free flowing); 5, spent. (*see* Beentjes & Waas 1994 for detailed gonad stage descriptions)

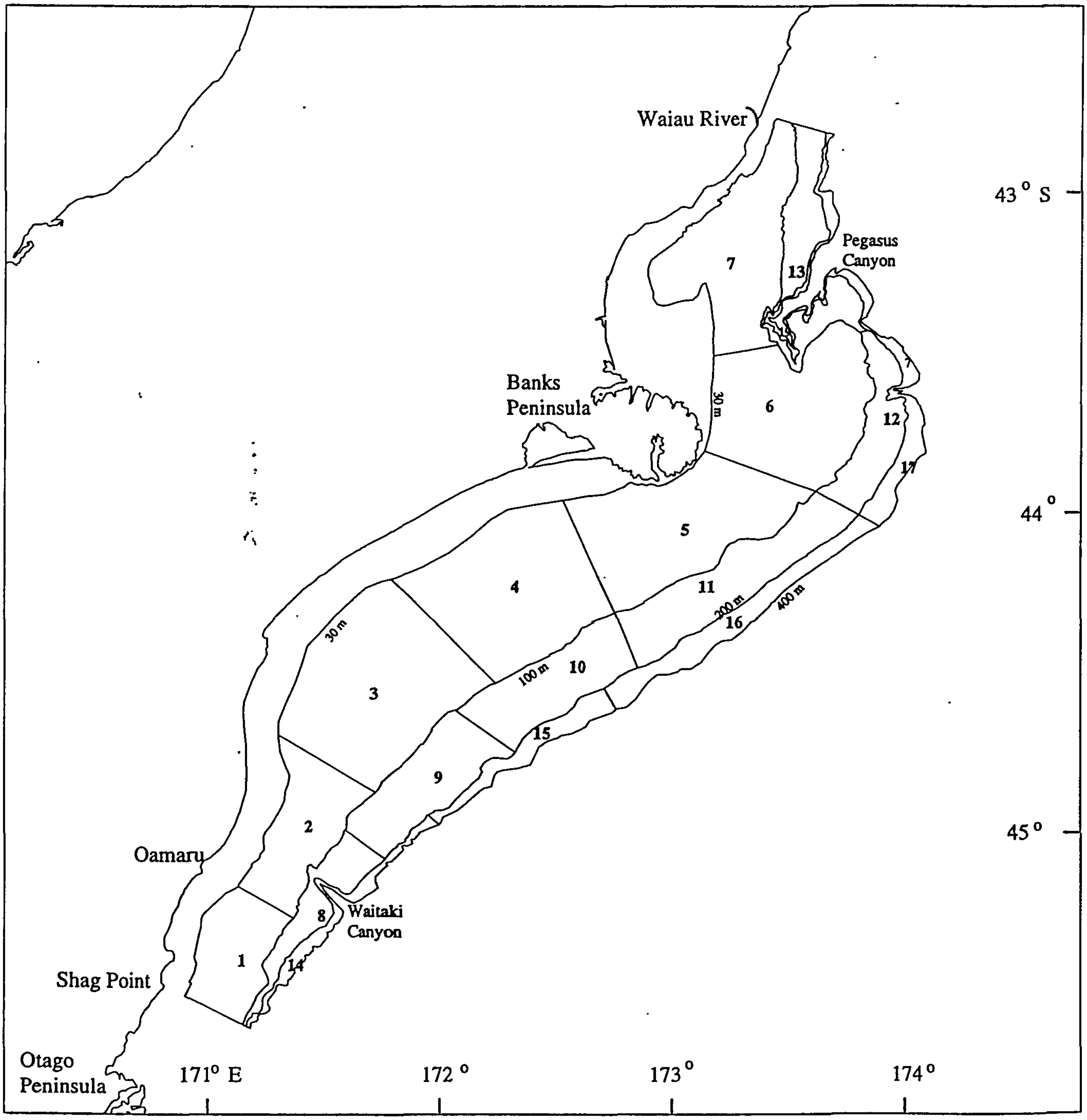


Figure 1: **Survey area and strata (as in 1994 & 1996).**

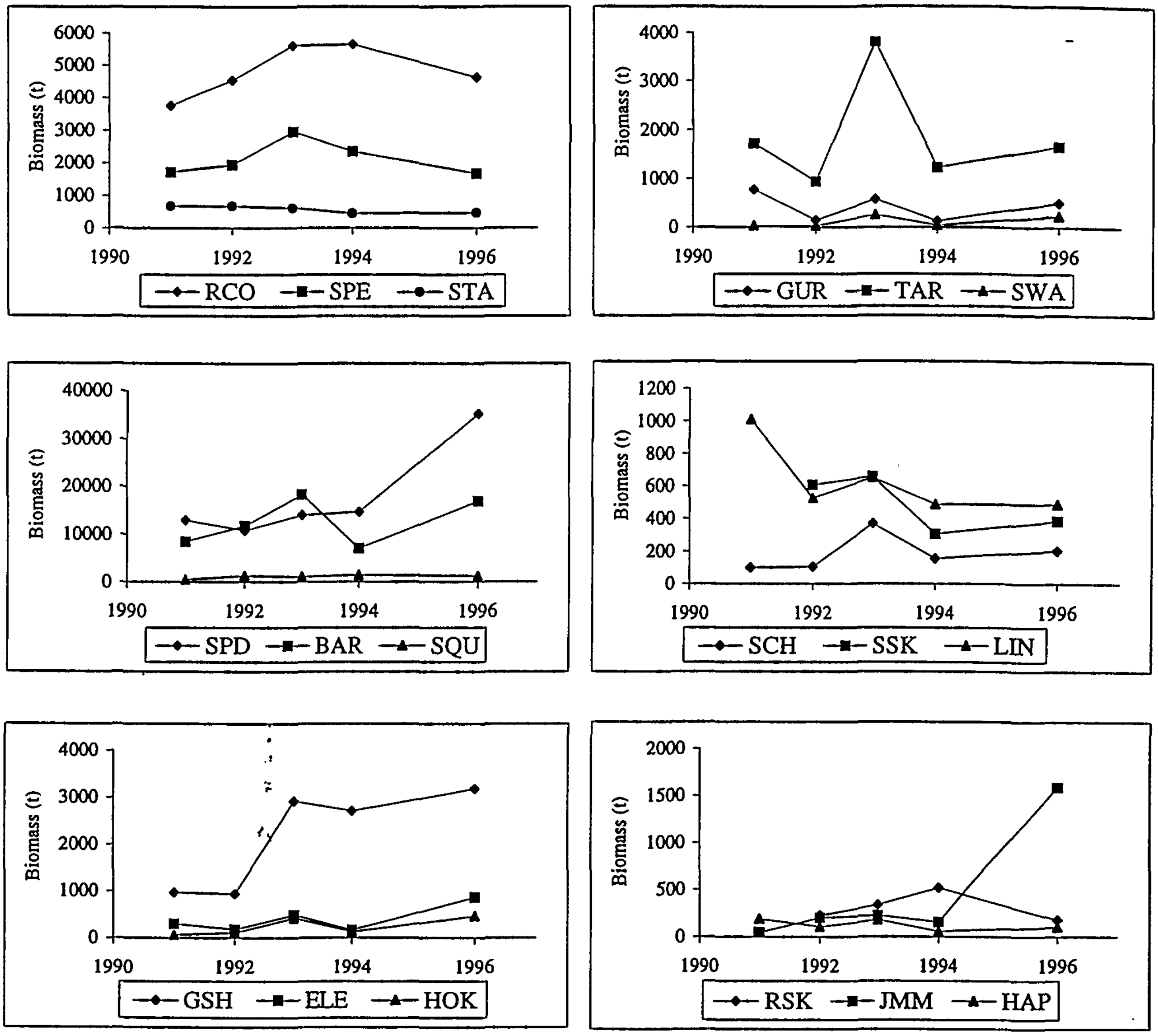


Figure 2 : **Estimated biomass of the 18 major species, 1991–96. (RCO, red cod; SPE, sea perch; STA giant stargazer; GUR, red gurnard; TAR, tarakihi; SWA, silver warehou; SPD, spiny dogfish; BAR, barracouta; SQU, arrow squid; SCH, school shark; SSK, smooth skate; LIN, ling; GSH, dark ghost shark; ELE, elephantfish; HOK, hoki; RSK, rough skate; JMM, Chilean jack mackerel; HAP, hapuku.)**

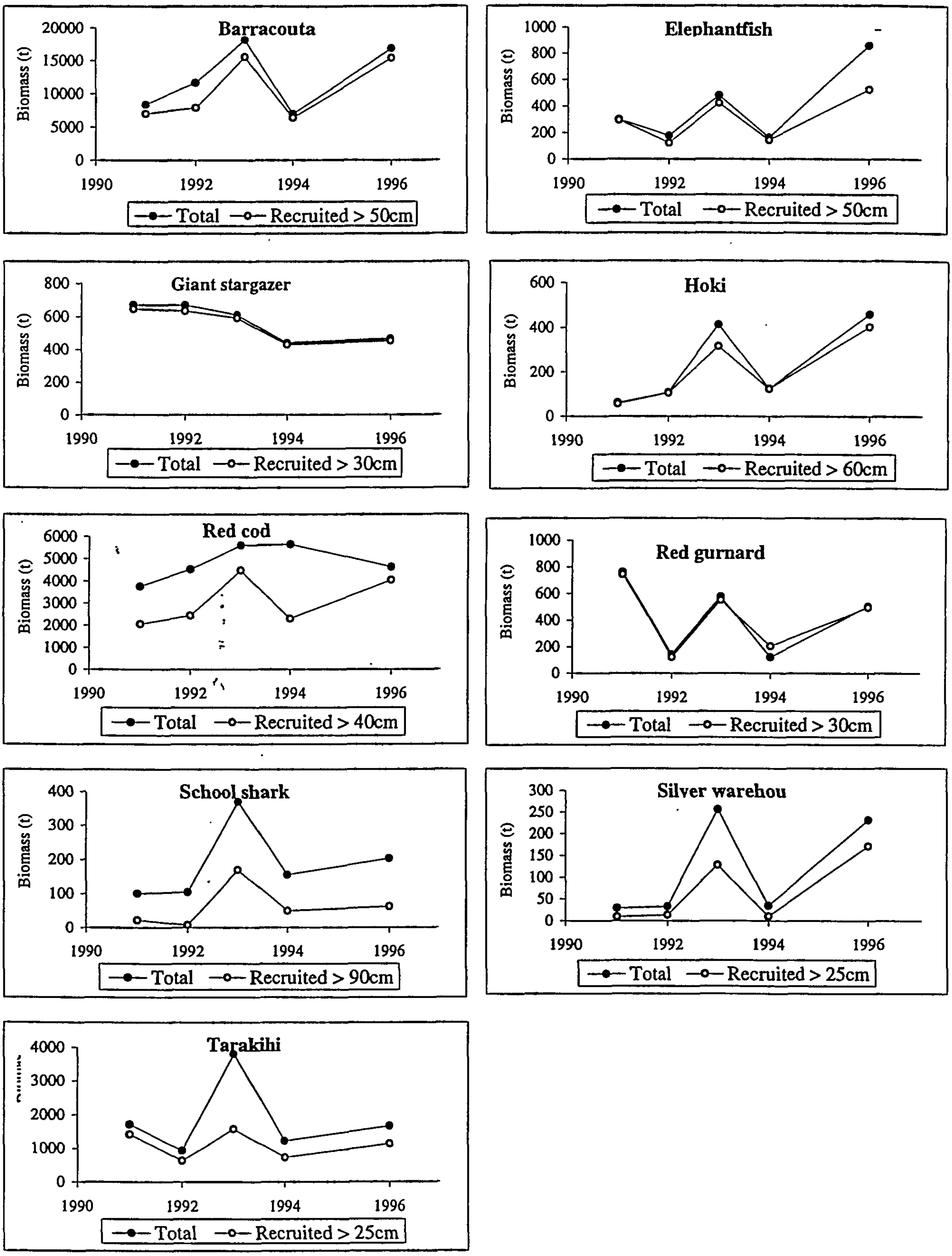


Figure 3 : **Total and recruited biomass of barracouta, elephantfish, hoki, red cod, red gurnard, school shark, silver warehou and tarakihi.**

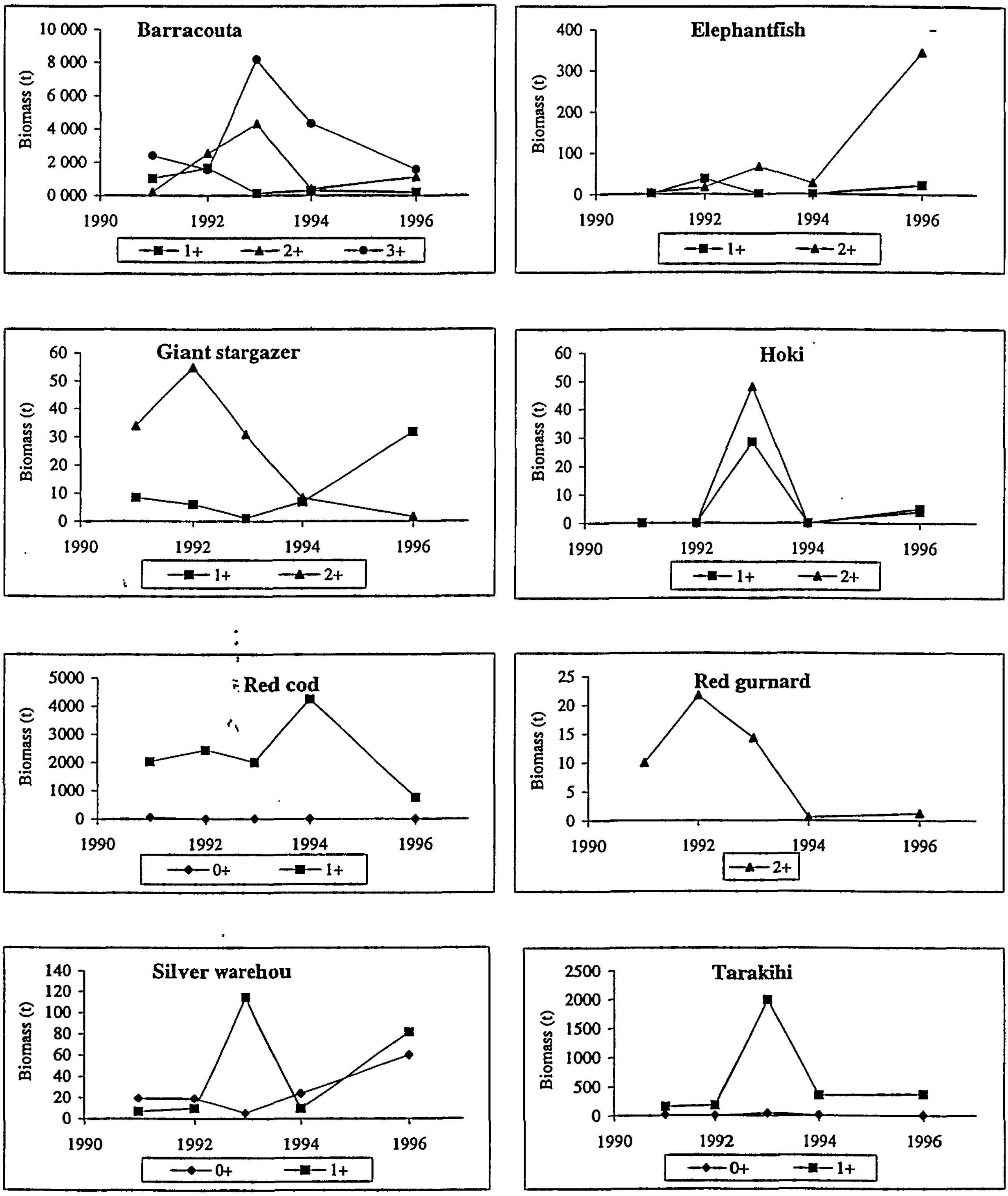
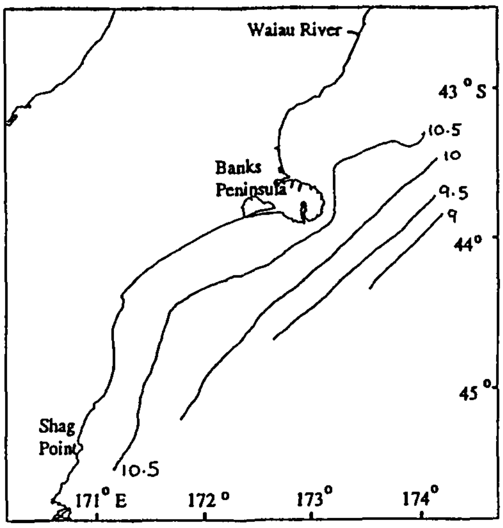
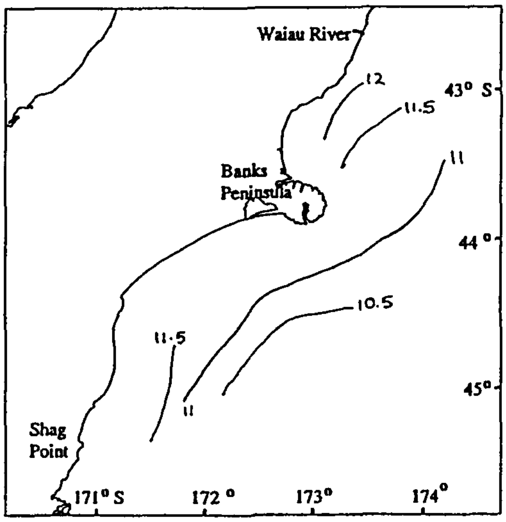


Figure 4 : **Biomass by year class for barracouta, elephantfish, giant stargazer, hoki, red cod, red gurnard, silver warehou, and tarakihi.**

KAH9205



KAH9306



KAH9406

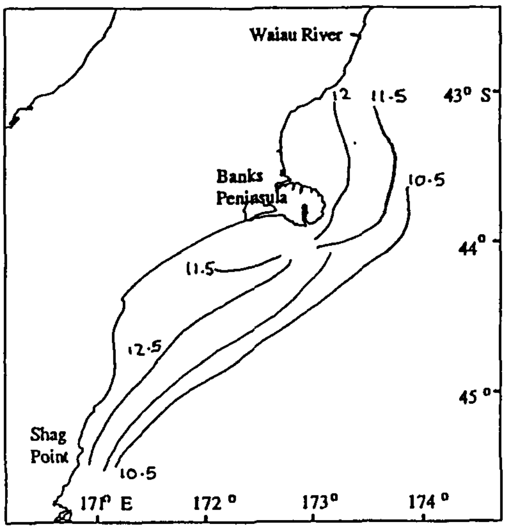


***Figure 5a*: Sea surface isotherms estimated from station data.**

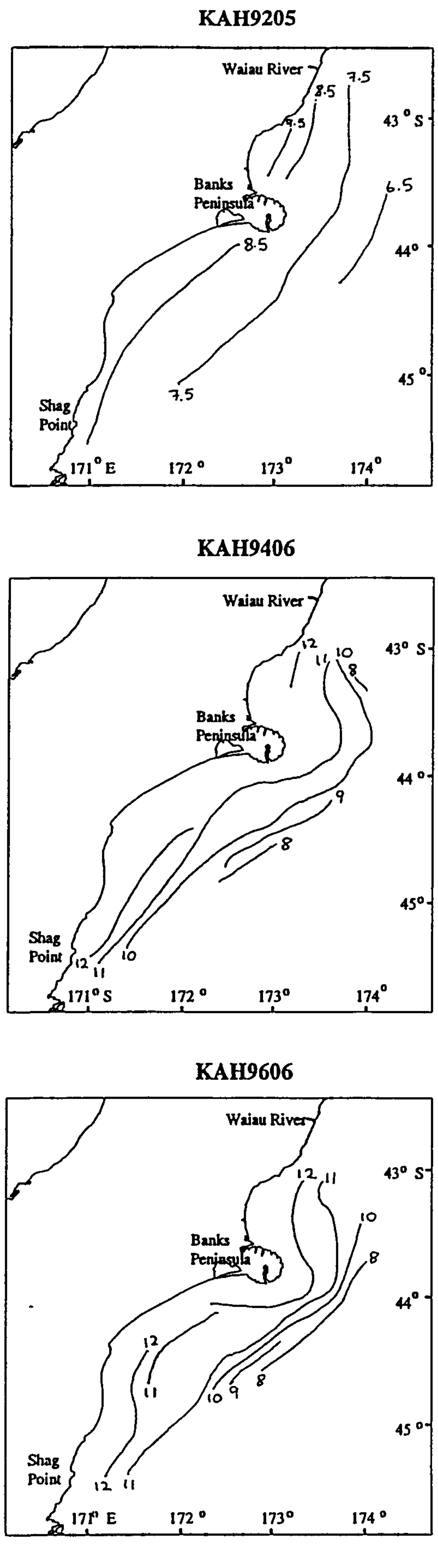
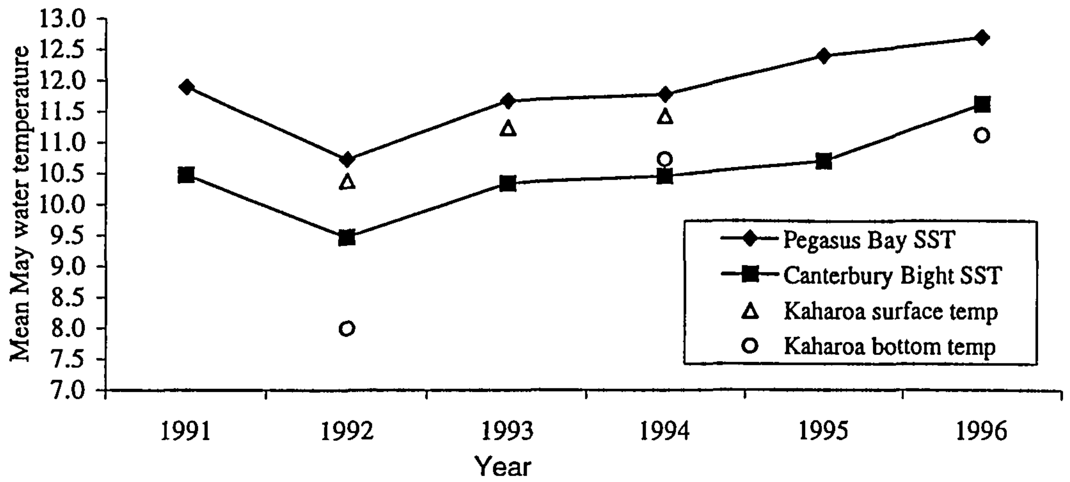


***Figure 5b*:** **Bottom isotherms estimated from station data.**



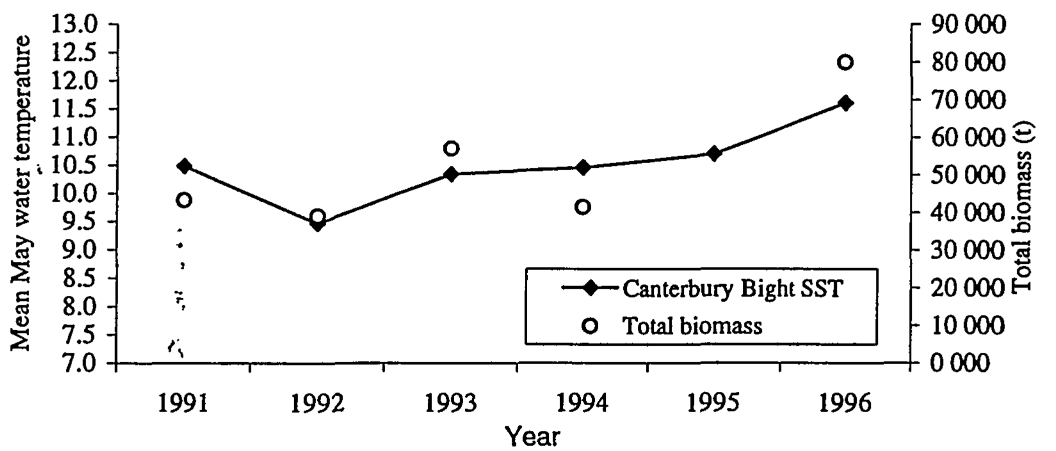


Figure 6 **: Top, Mean monthly sea surface temperature (SST) in May for Canterbury Bight, Pegasus Bay, and bottom and surface temperatures recorded during the surveys.**
Bottom, Mean monthly SST in May for Canterbury Bight and total biomass for each survey.

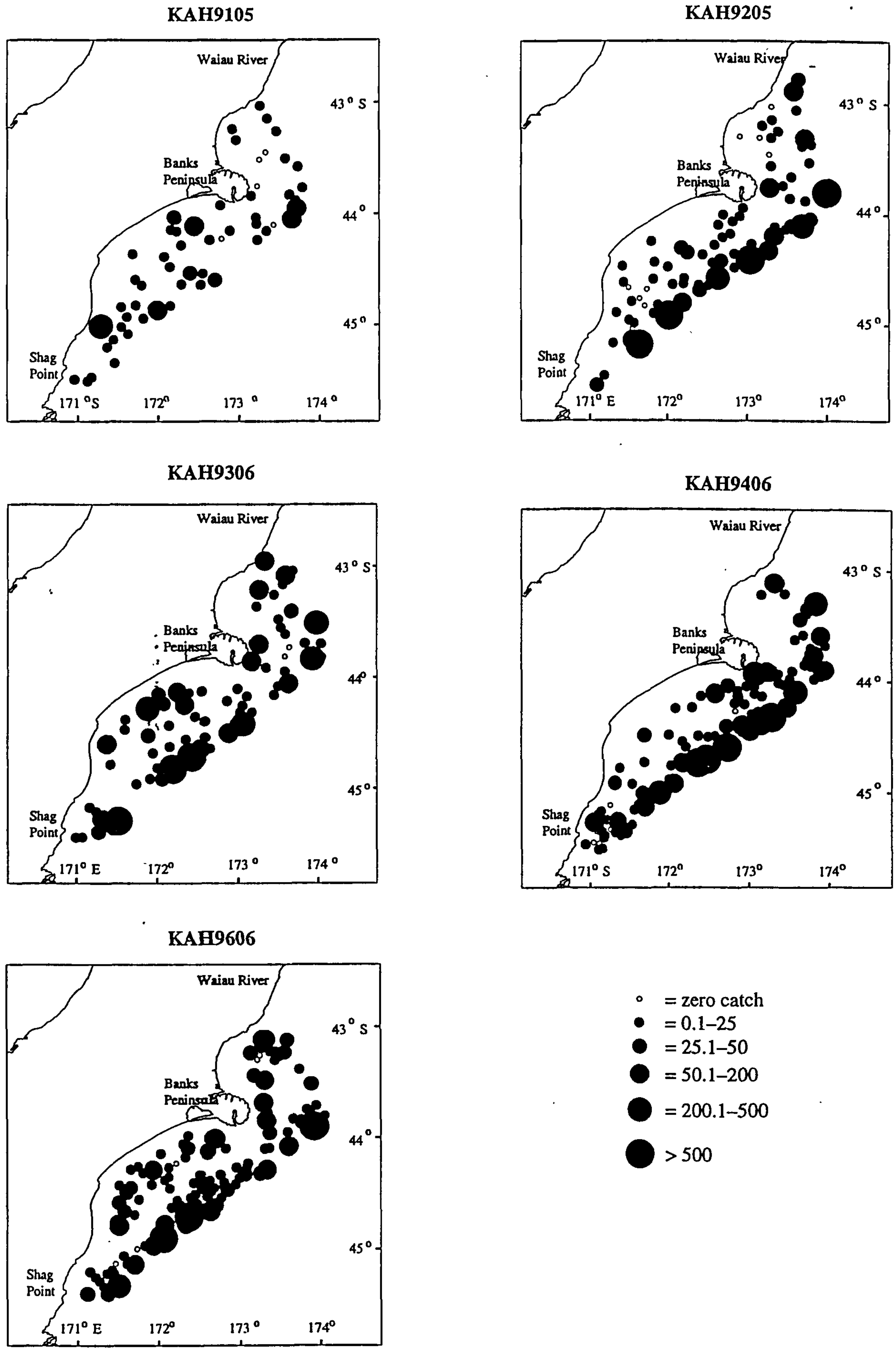


Figure 7 : **Distribution and catch rates (kg.km^{-2}) of the major species, 1991–96.**
a **: Arrow squid (maximum catch rate 3564 kg.km^{-2}).**

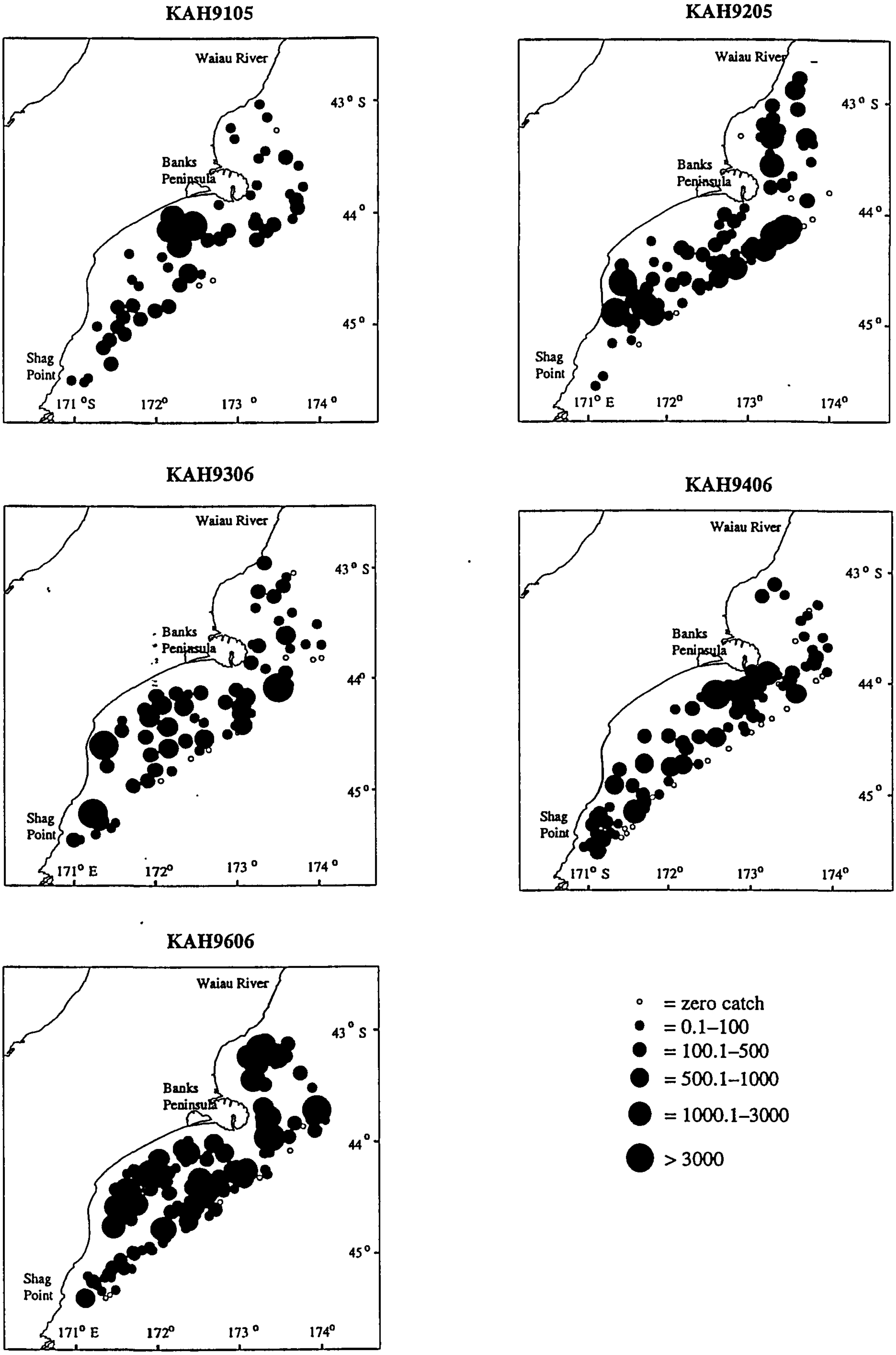


Figure 7b: **Barracouta (maximum catch rate 9071 kg.km^{-2}).**

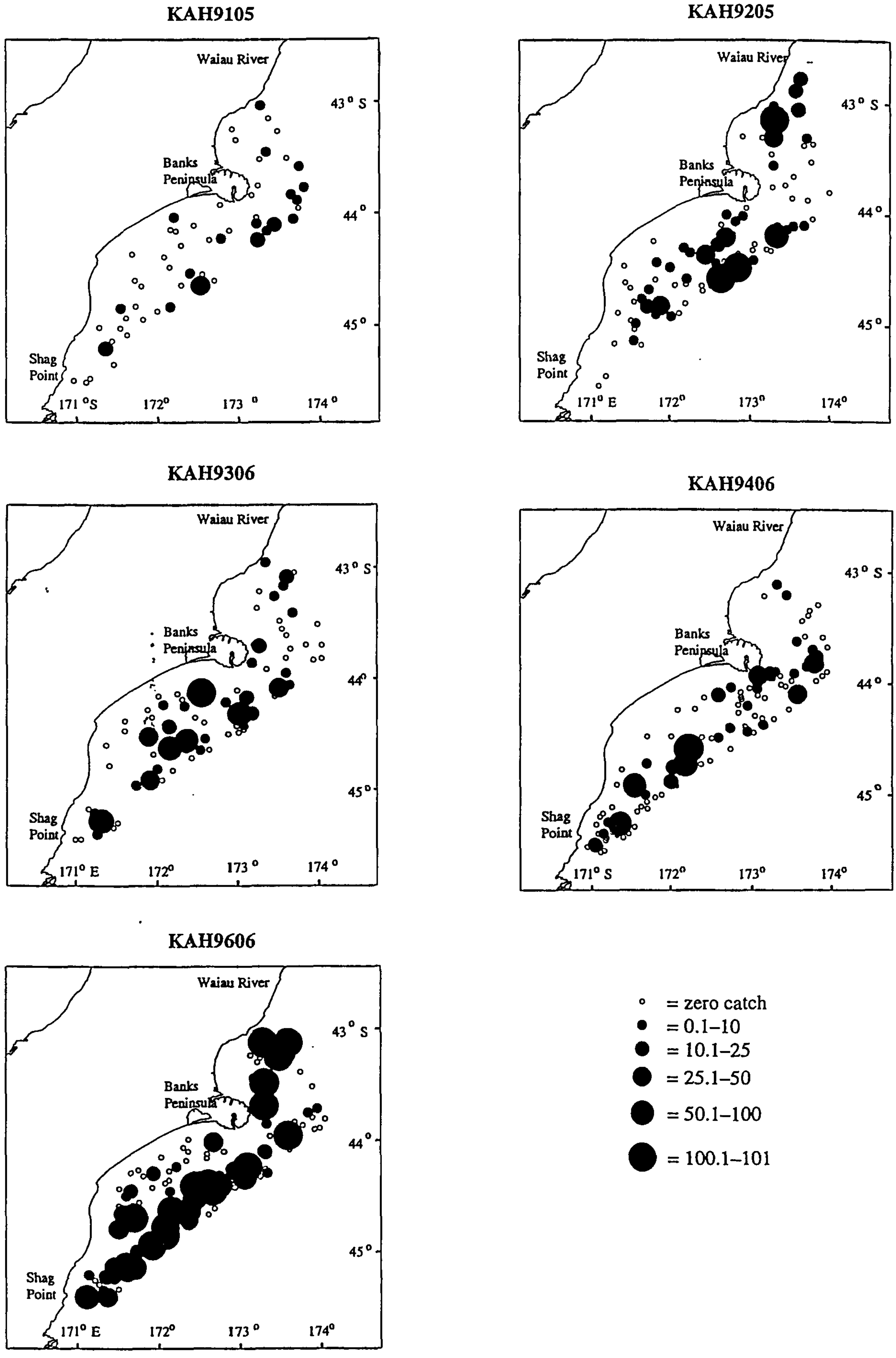


Figure 7c: **Chilean jack mackerel (maximum catch rate 2928 kg.km^{-2}).**

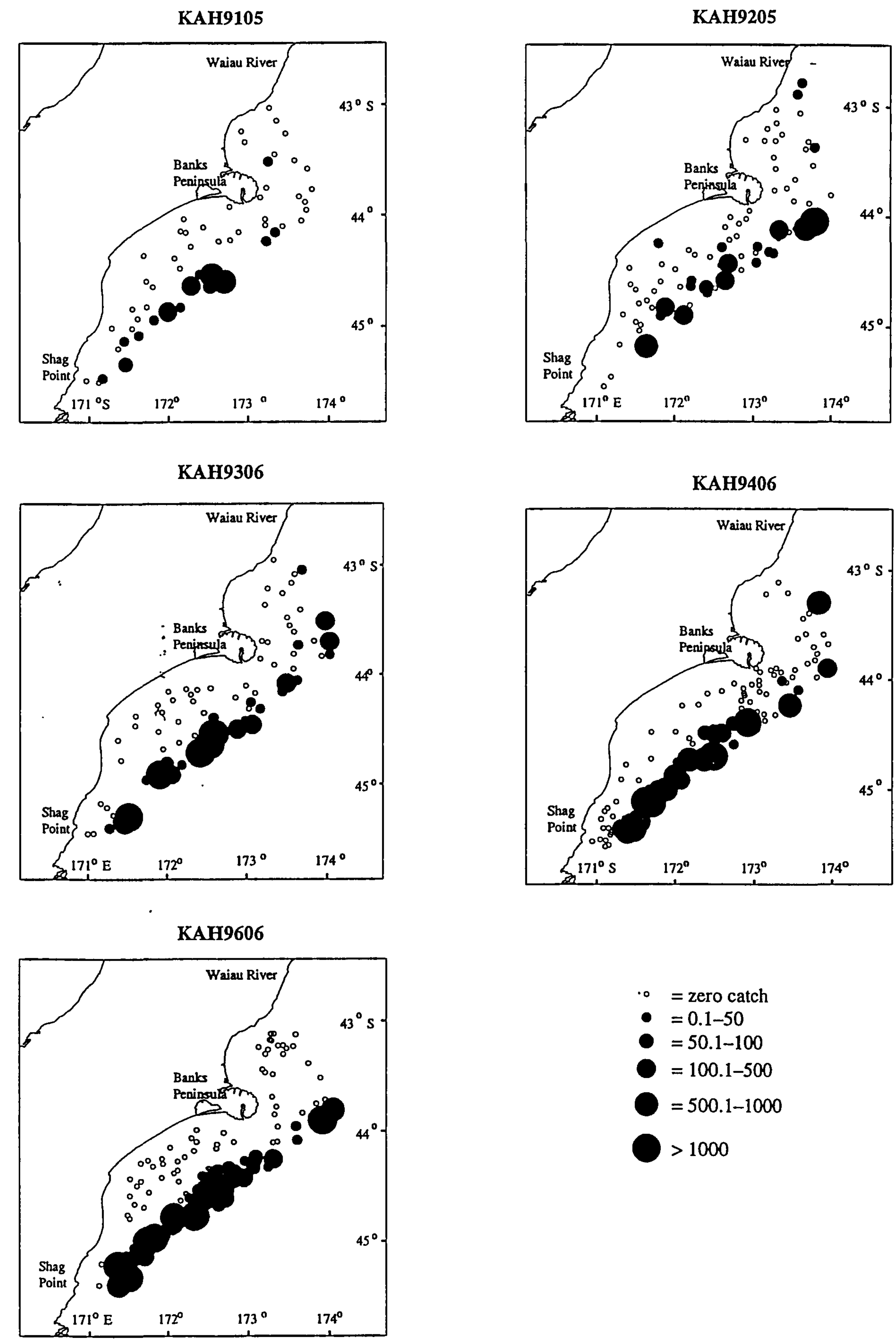


Figure 7d: **Dark ghost shark (maximum catch rate 4775 kg.km^{-2}).**

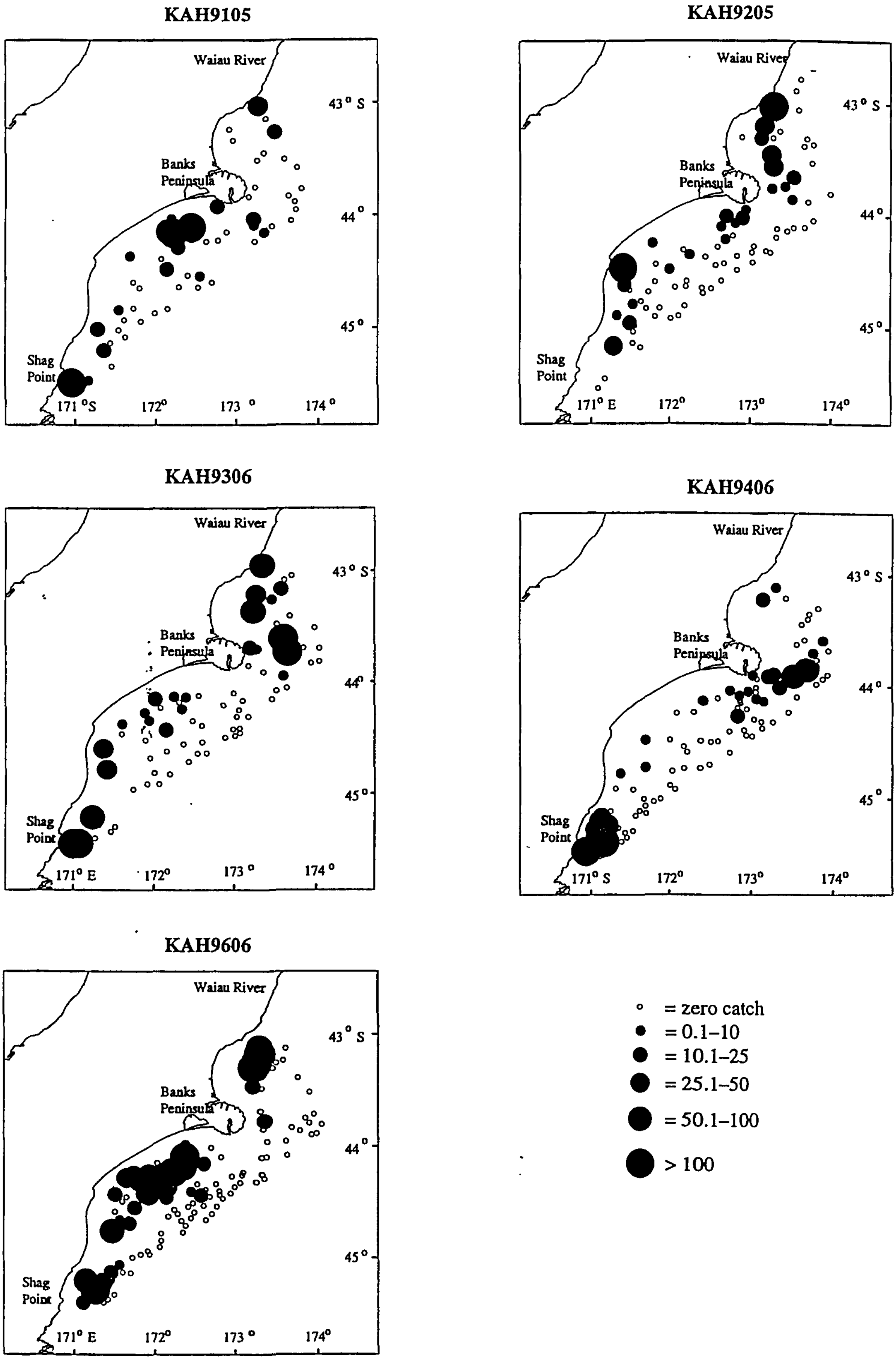


Figure 7e: **Elephantfish (maximum catch rate 994 kg.km $^{-2}$).**

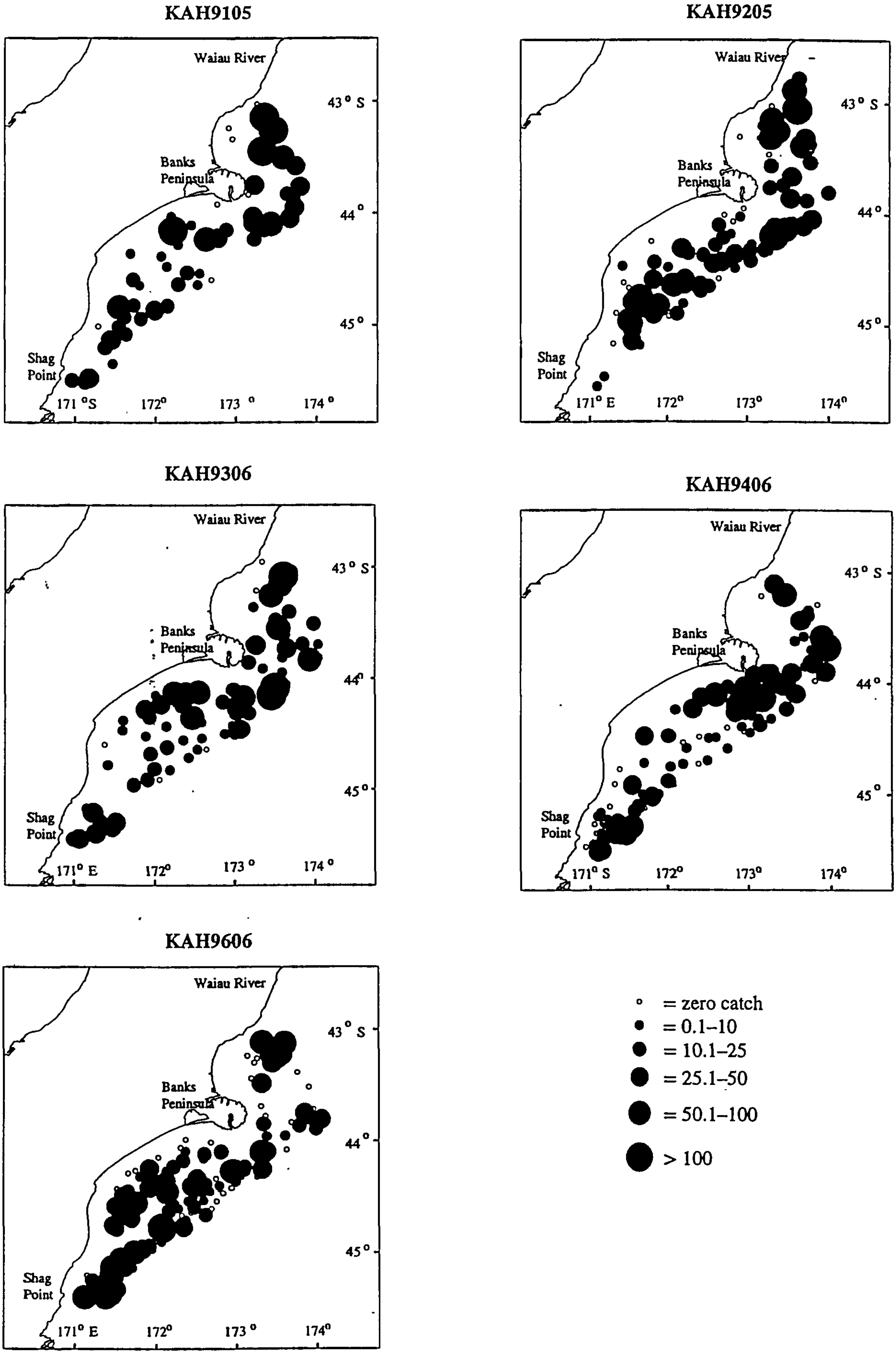


Figure 7f : **Giant stargazer (maximum catch rate 240 kg.km^{-2}).**

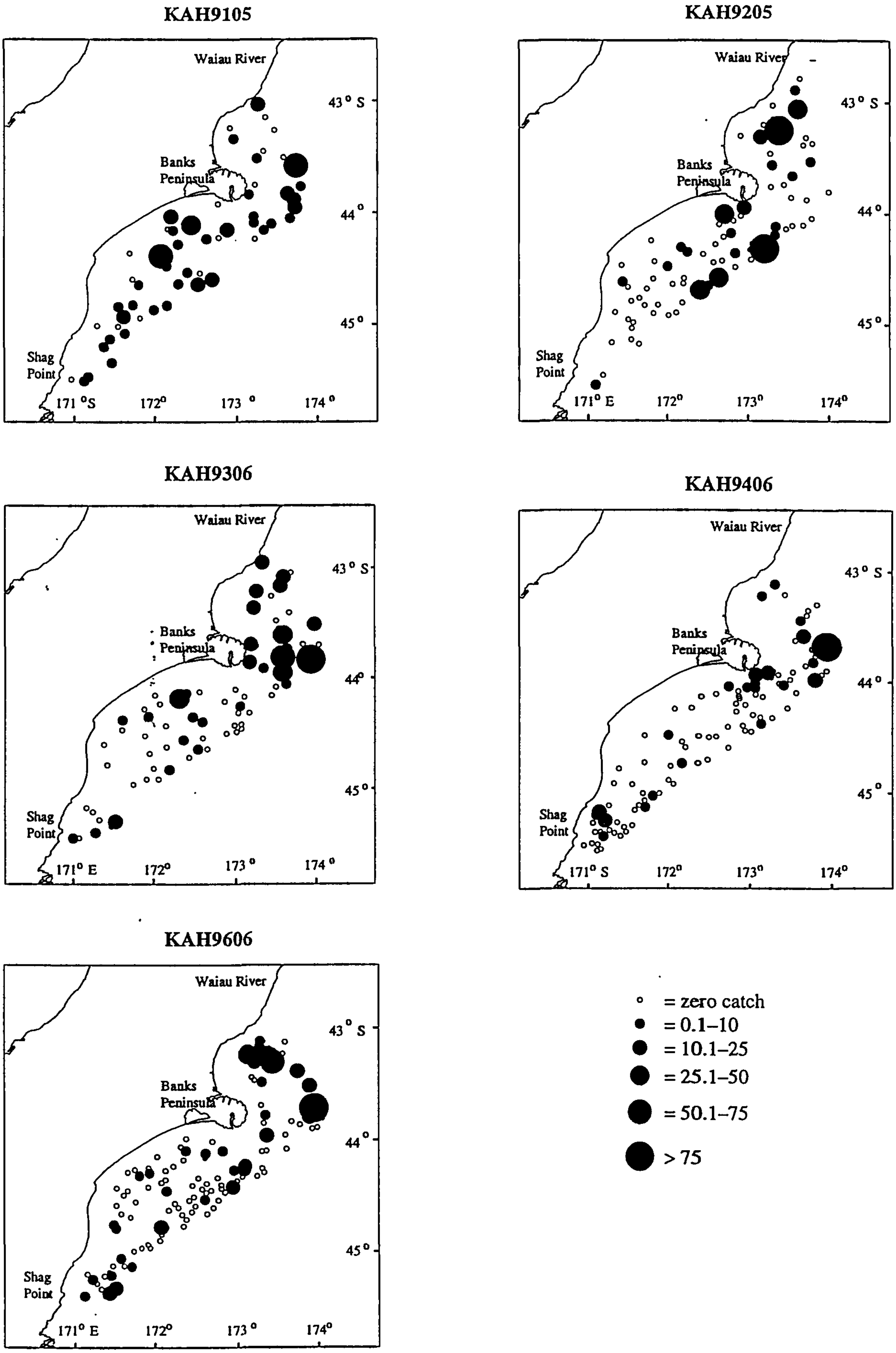


Figure 7g: **Hapuku (maximum catch rate 219 kg.km^{-2}).**

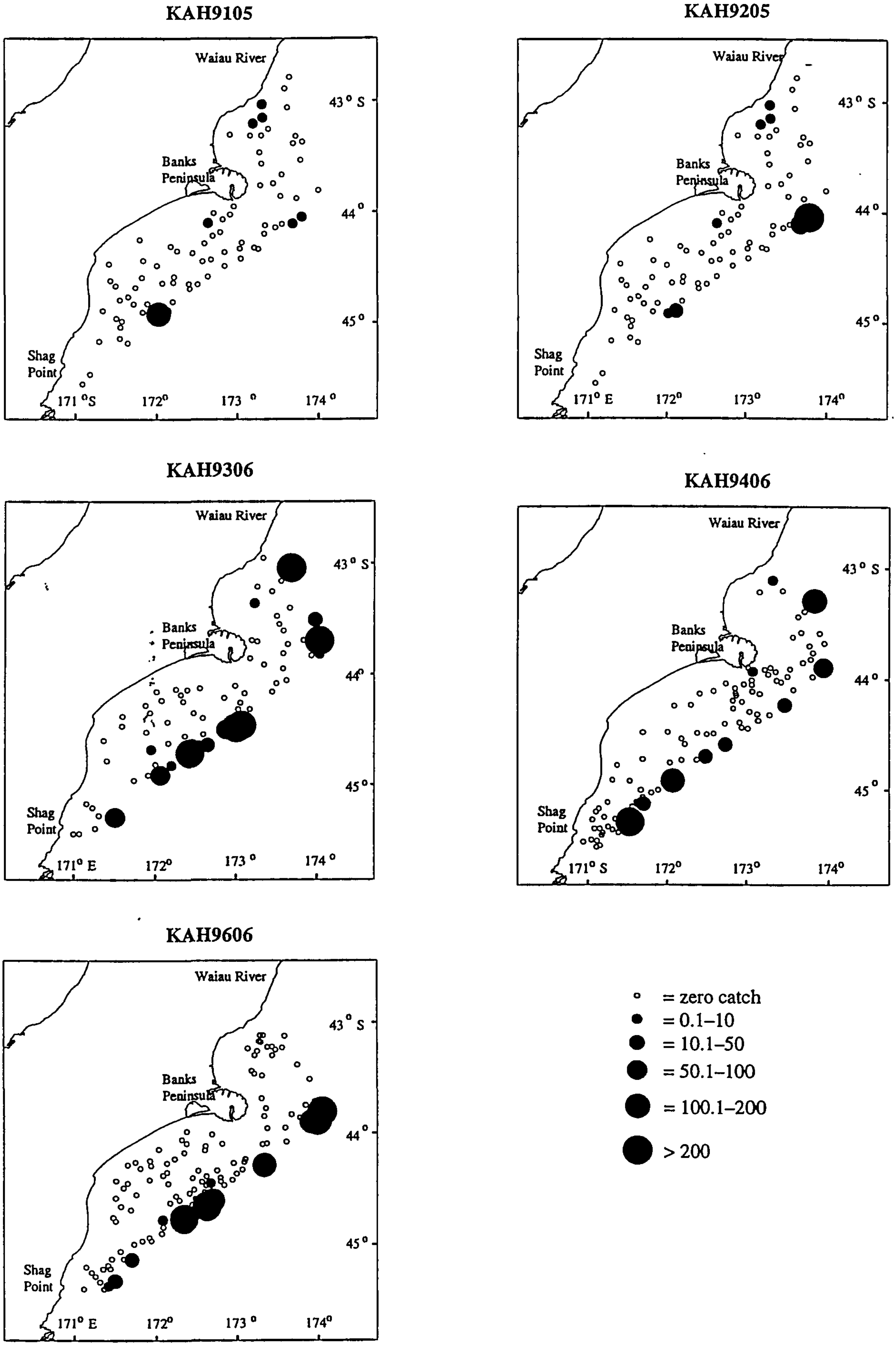


Figure 7h: **Hoki (maximum catch rate 788 kg.km^{-2}).**

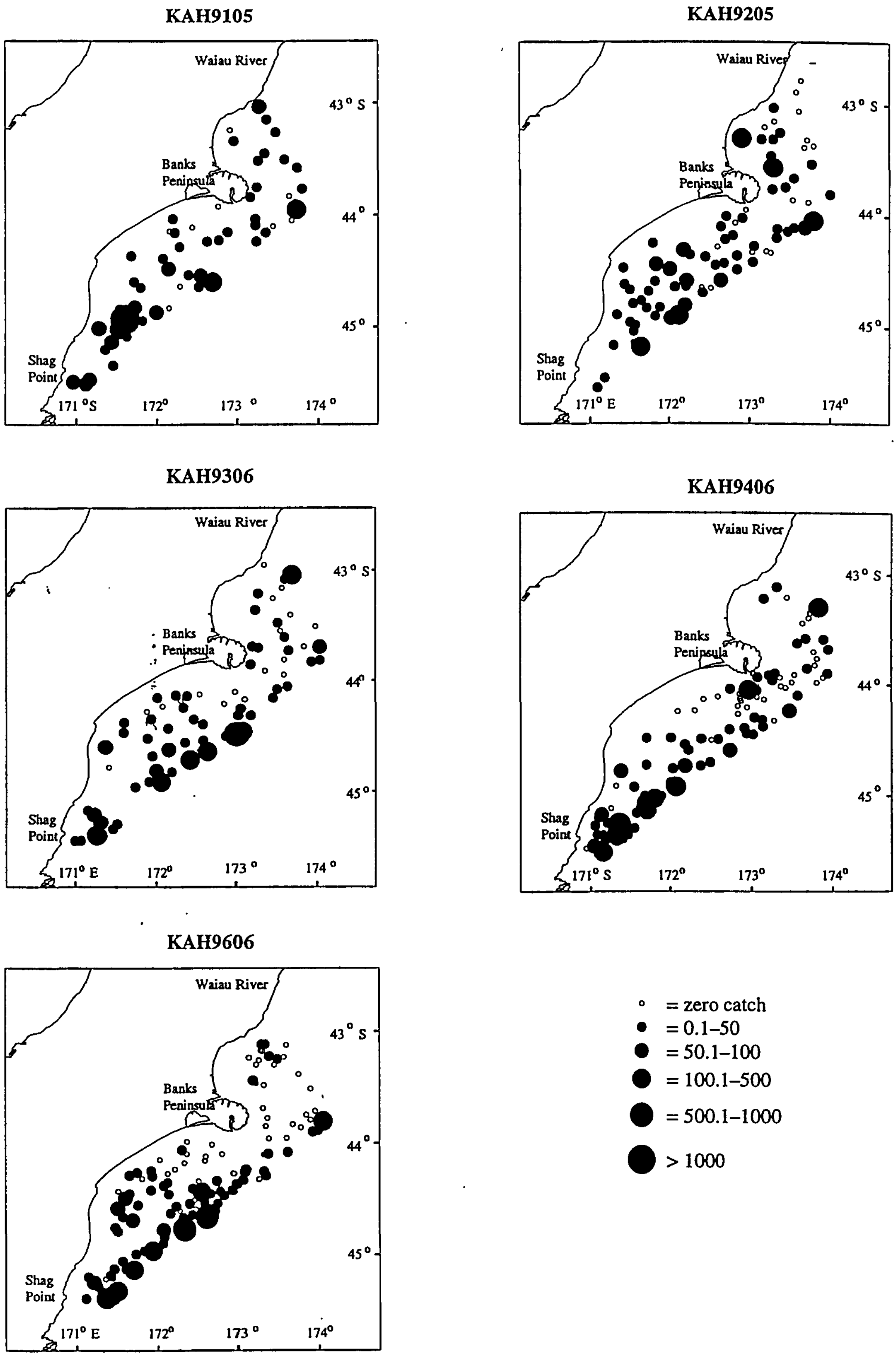


Figure 7i : **Ling (maximum catch rate 1084 kg.km^{-2}).**

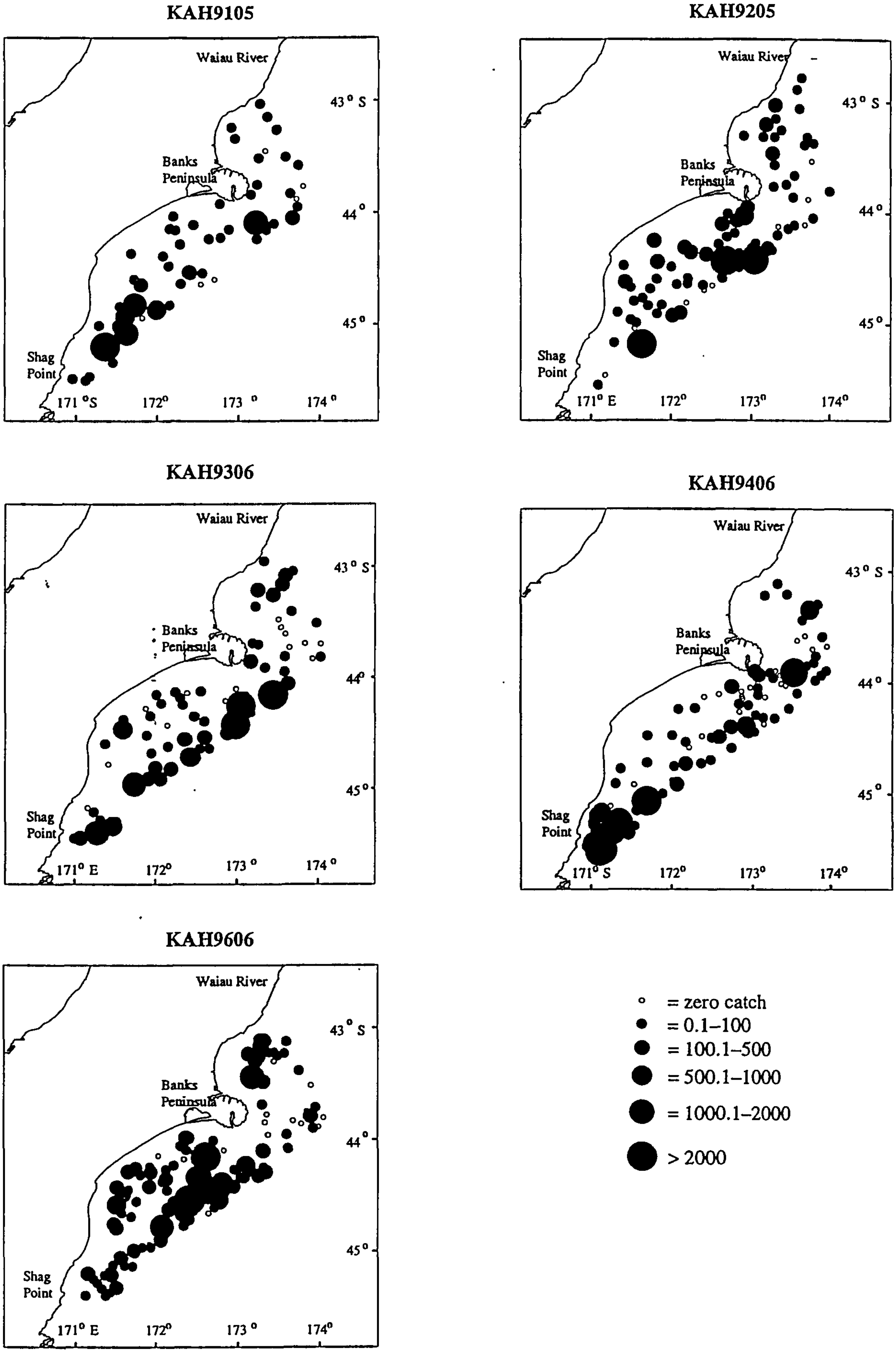


Figure 7j : **Red cod (maximum catch rate 7163 kg.km^{-2}).**

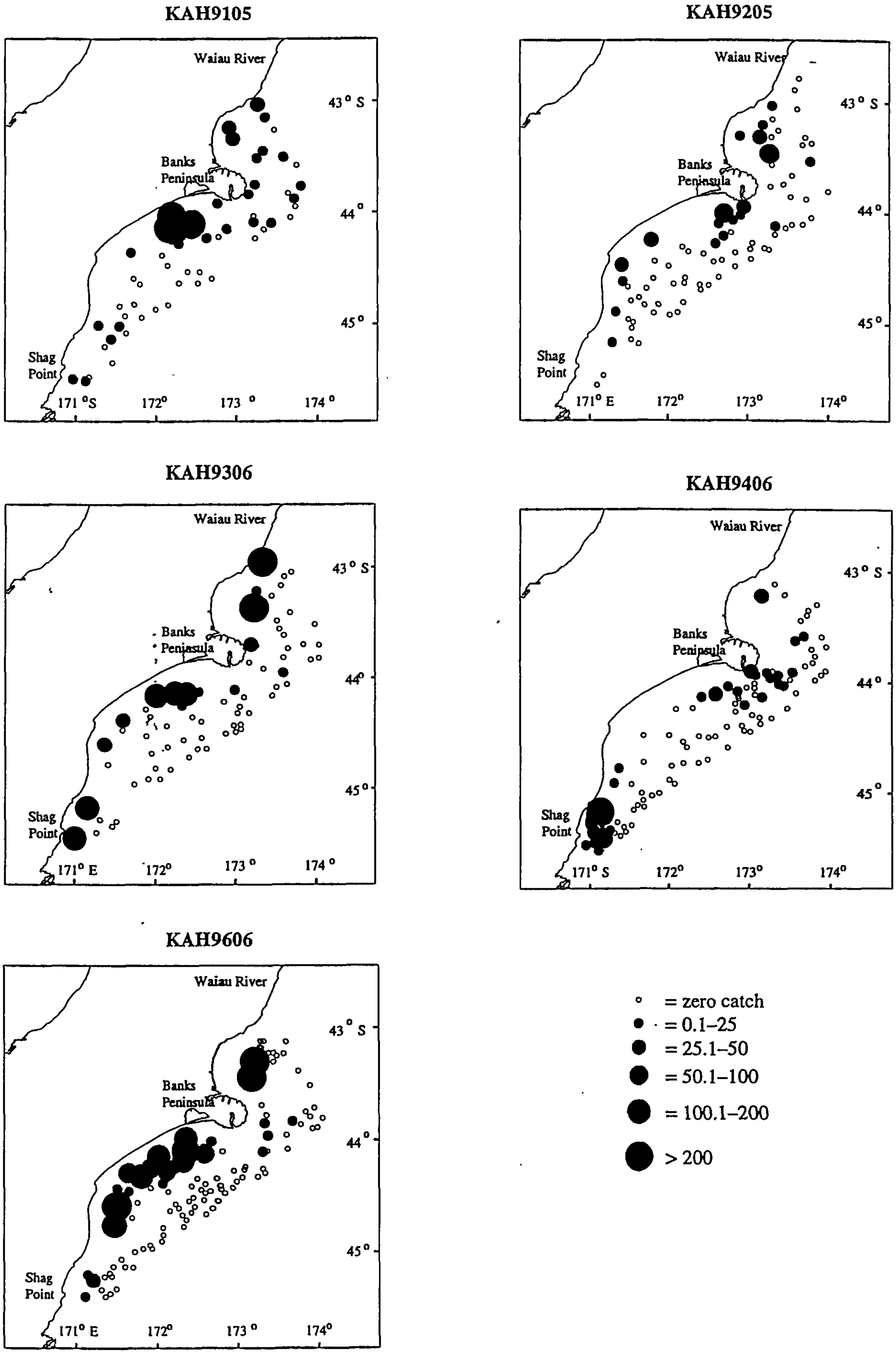


Figure 7k: **Red gurnard (maximum catch rate 475 kg.km^{-2}).**

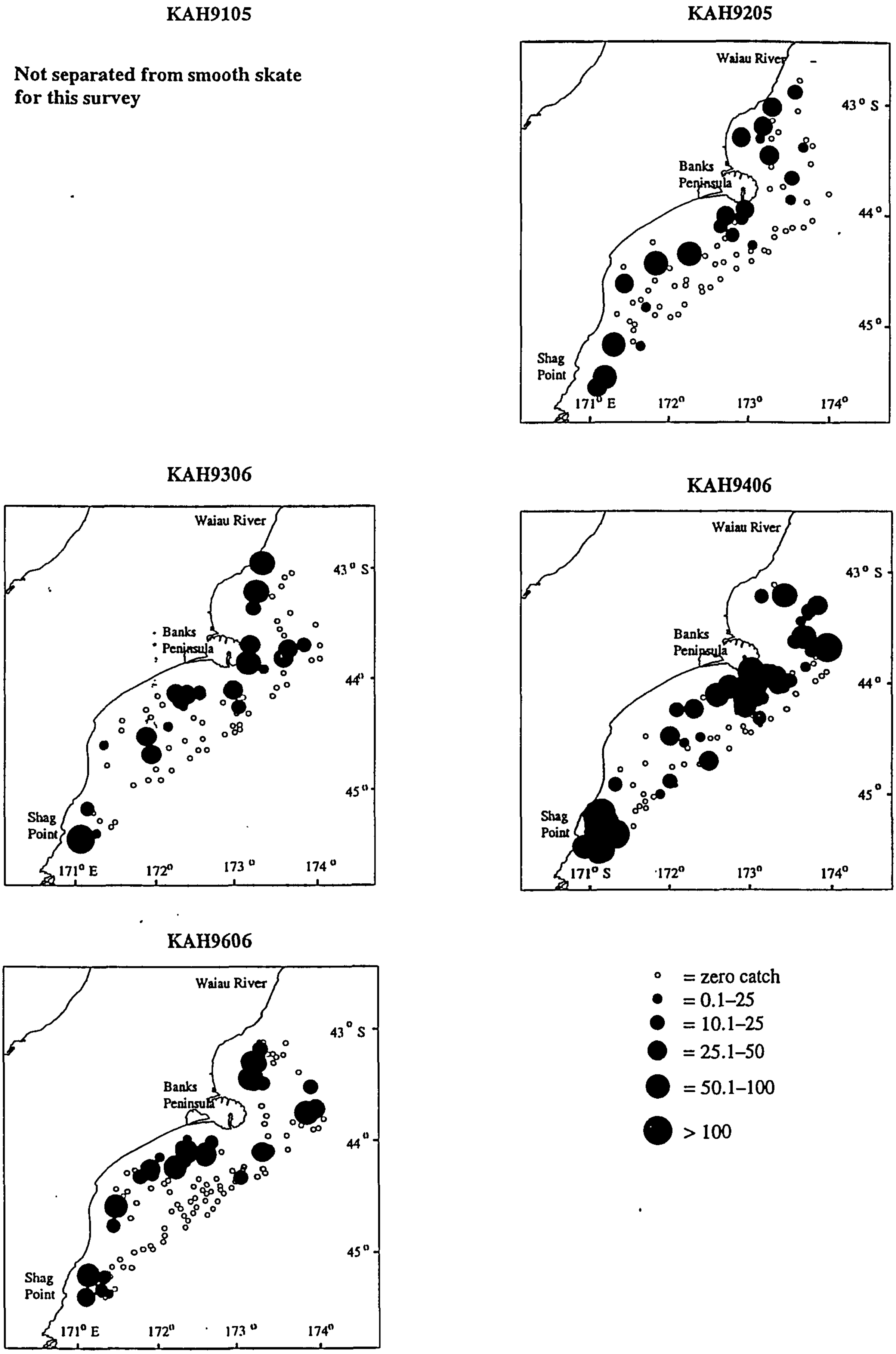


Figure 71 : Rough skate (maximum catch rate 217 kg.km^{-2}).

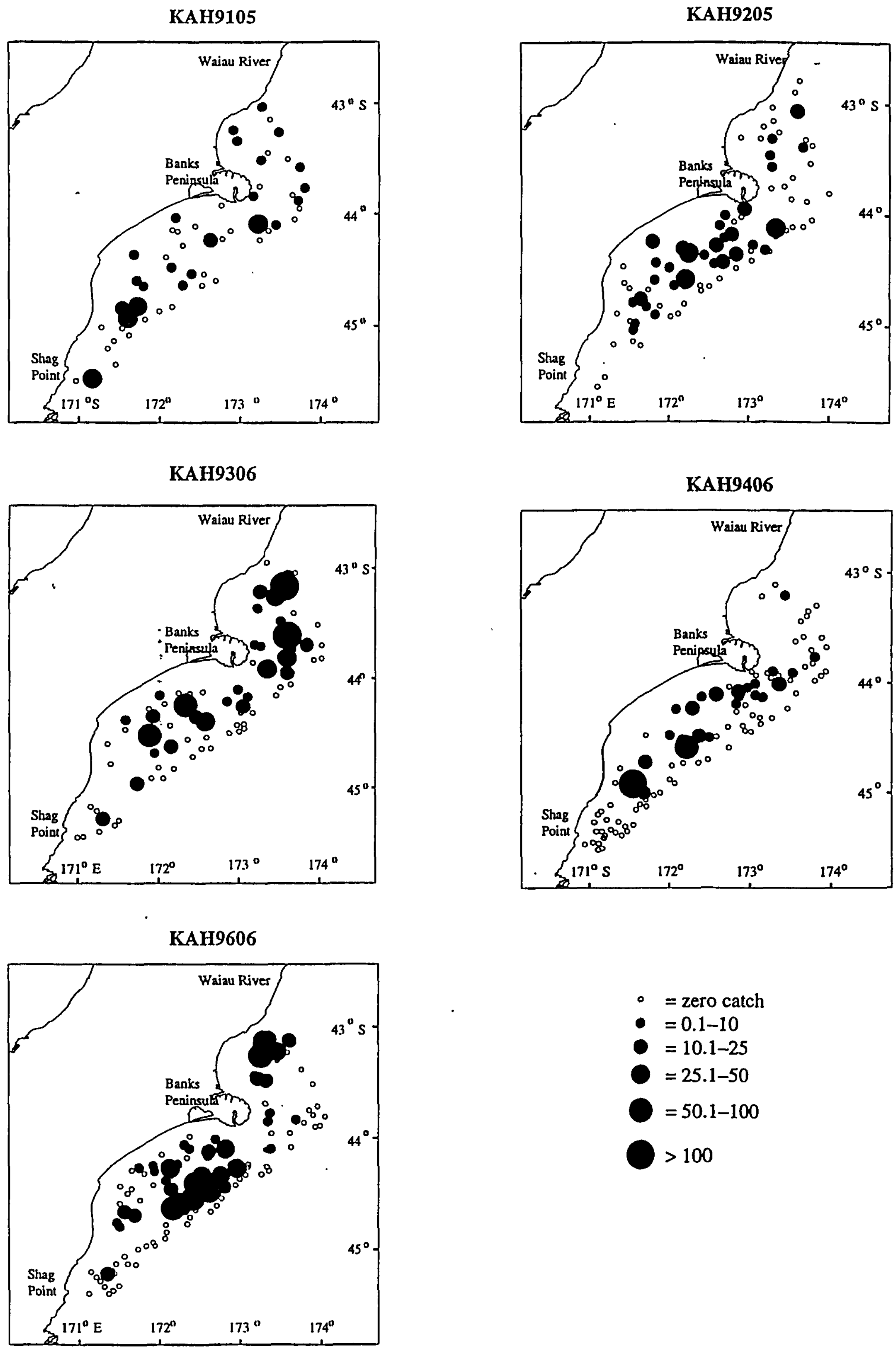


Figure 7m: School shark (maximum catch rate 307 kg.km^{-2}).

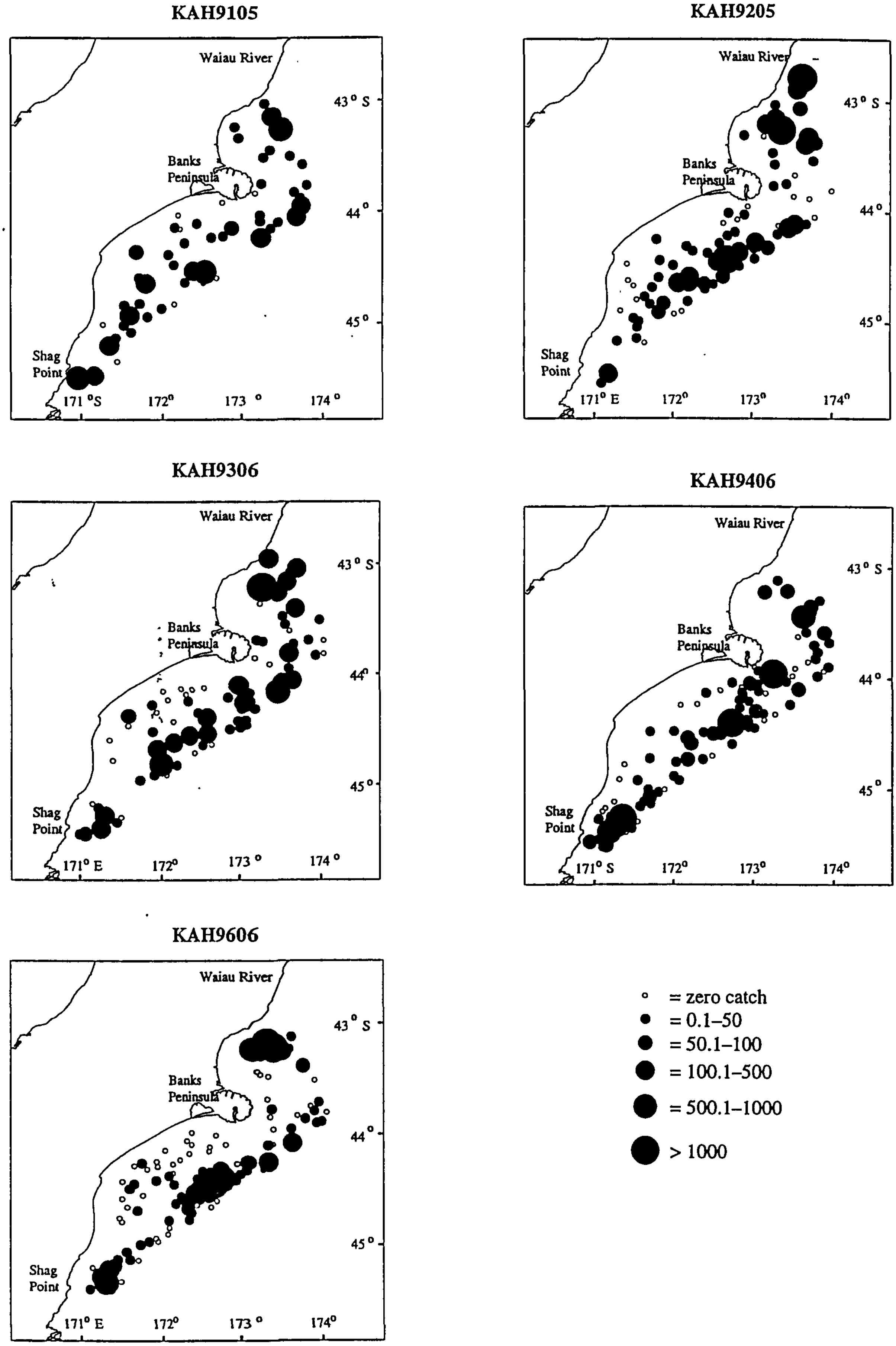


Figure 7n: **Sea perch (maximum catch rate 2683 kg.km^{-2}).**

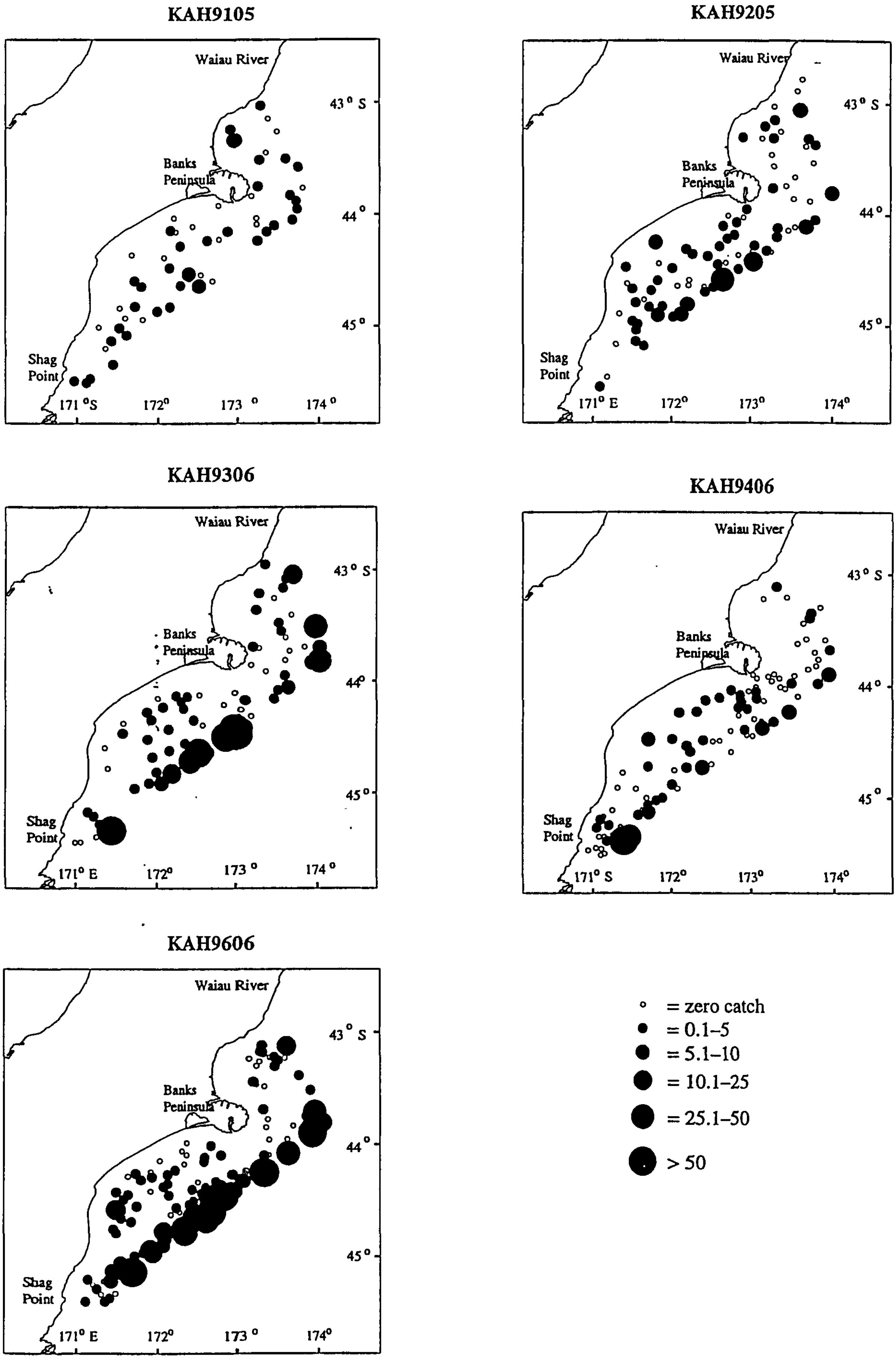


Figure 7o: **Silver warehou (maximum catch rate 825 kg.km^{-2}).**

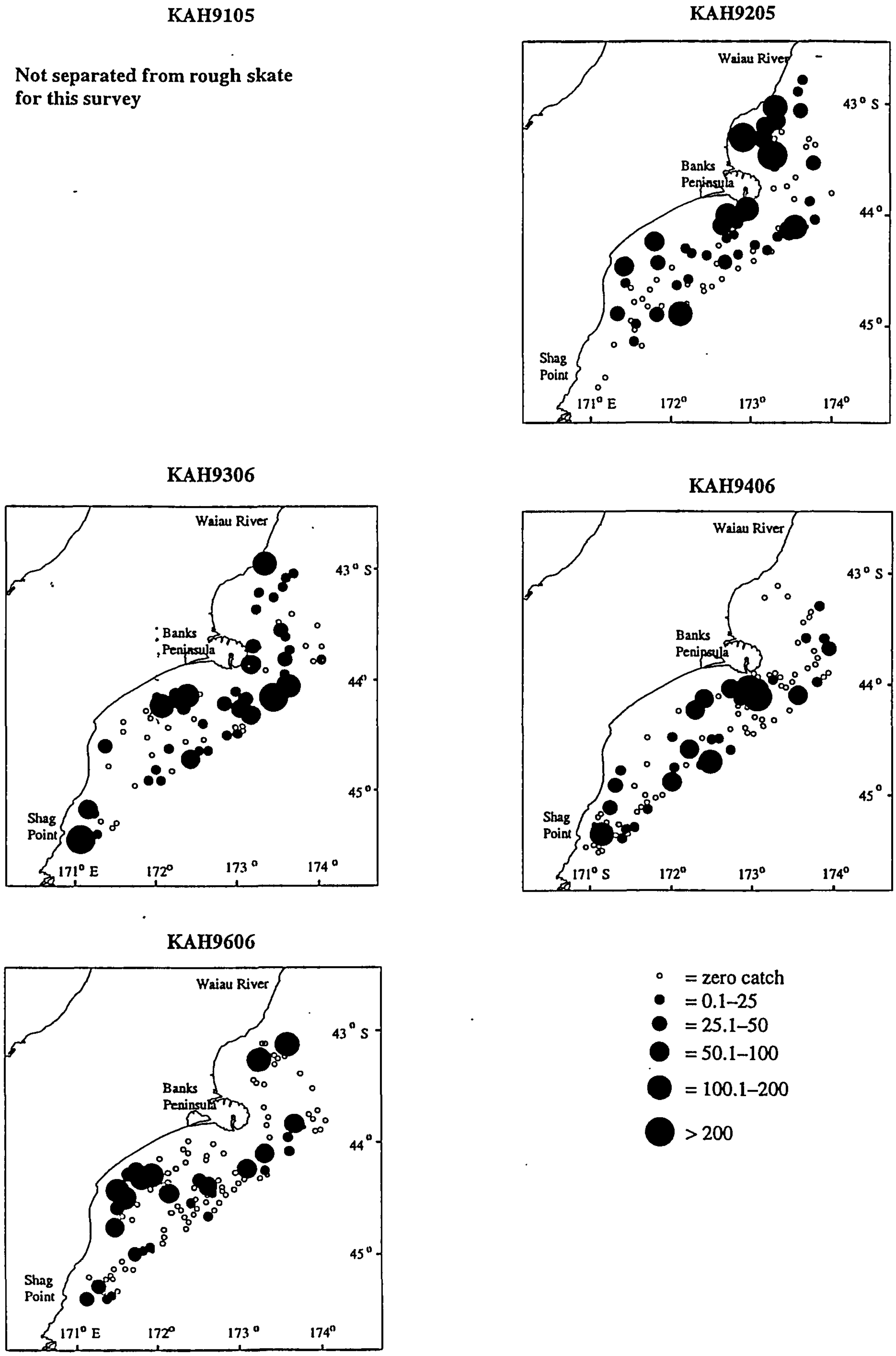


Figure 7p: Smooth skate (maximum catch rate 331 kg.km^{-2}).

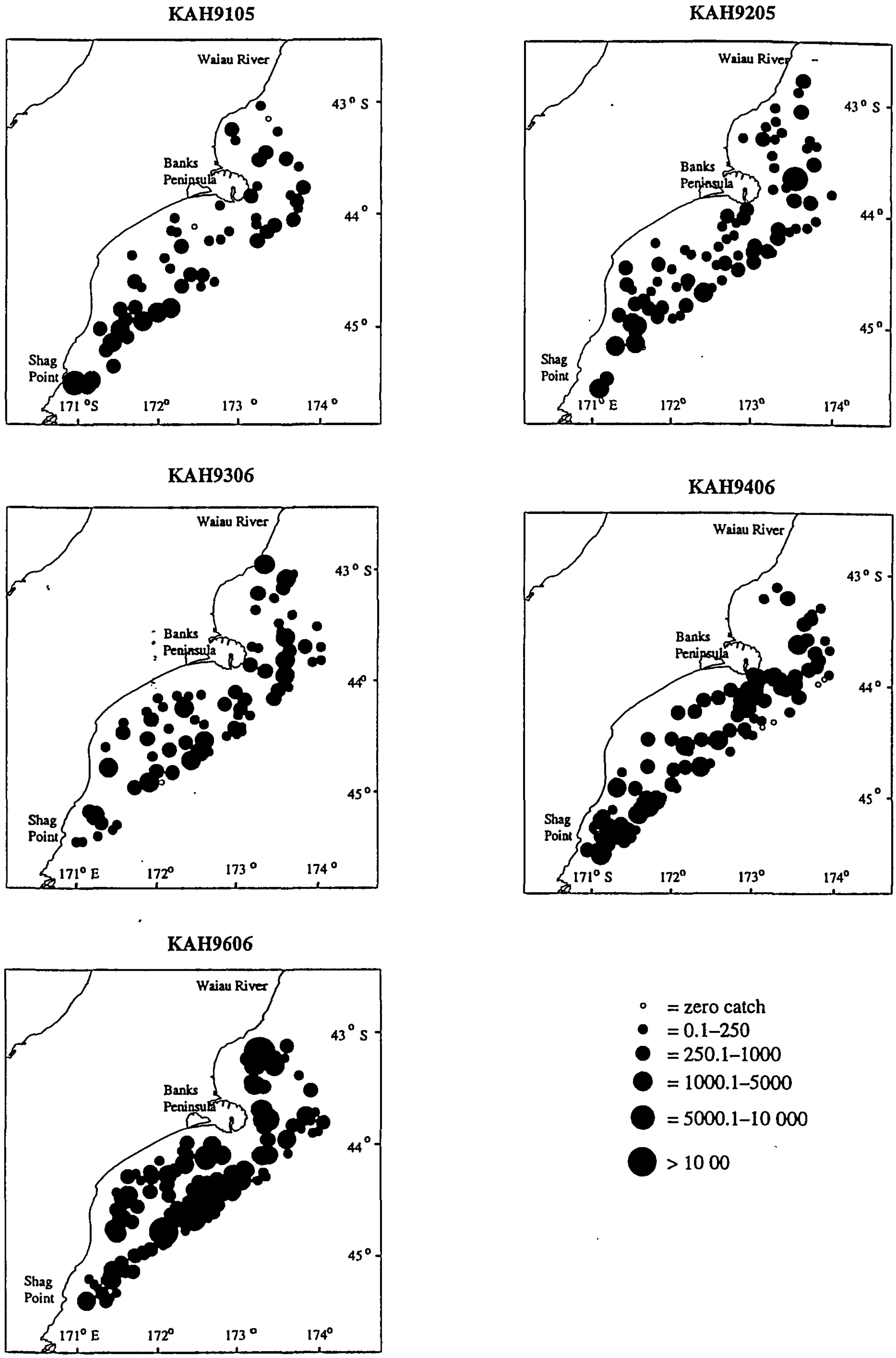


Figure 7q: **Spiny dogfish (maximum catch rate 13 311 kg.km^{-2}).**

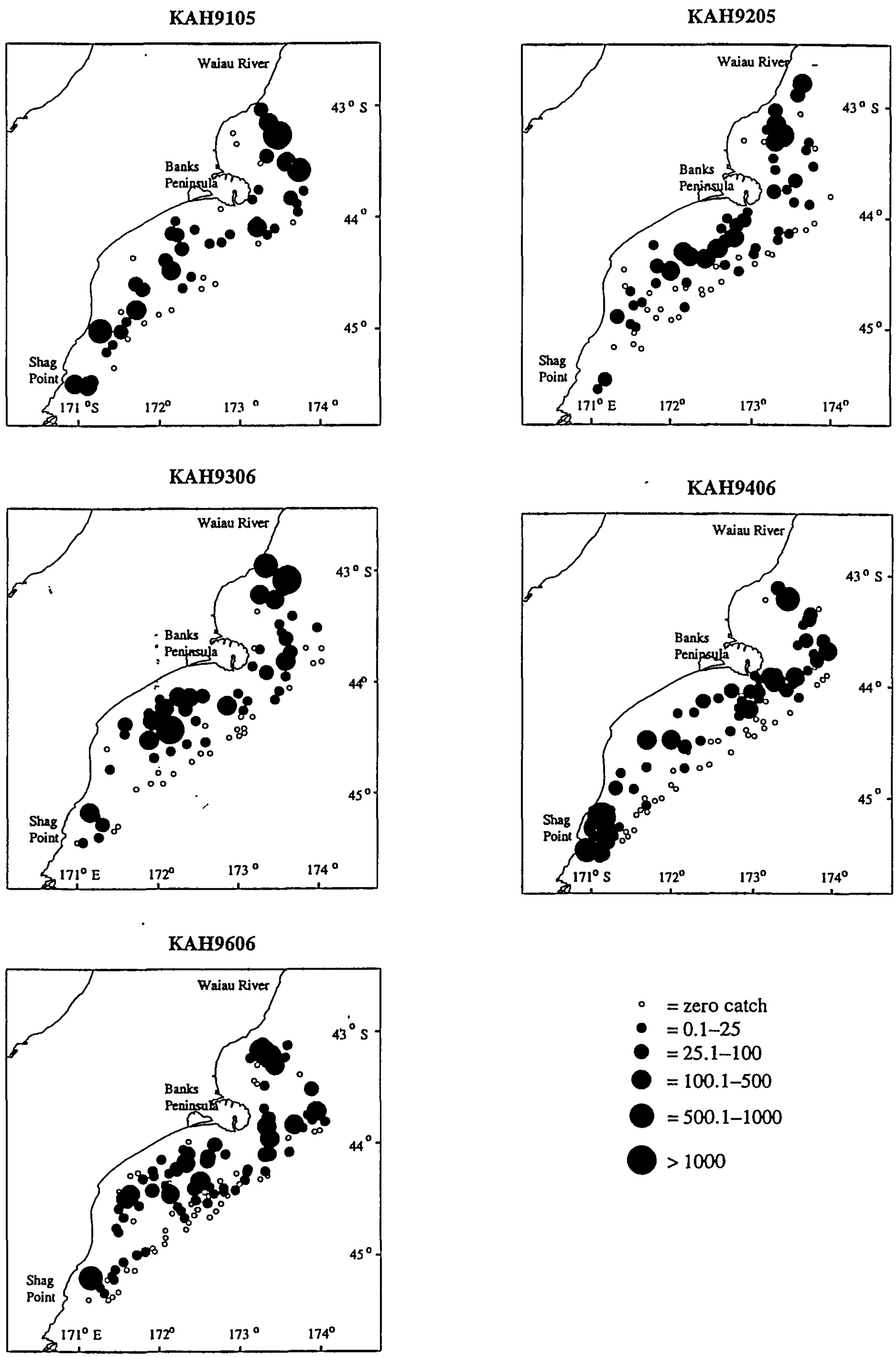


Figure 7r : **Tarakihi (maximum catch rate 5471 kg.km^{-2}).**

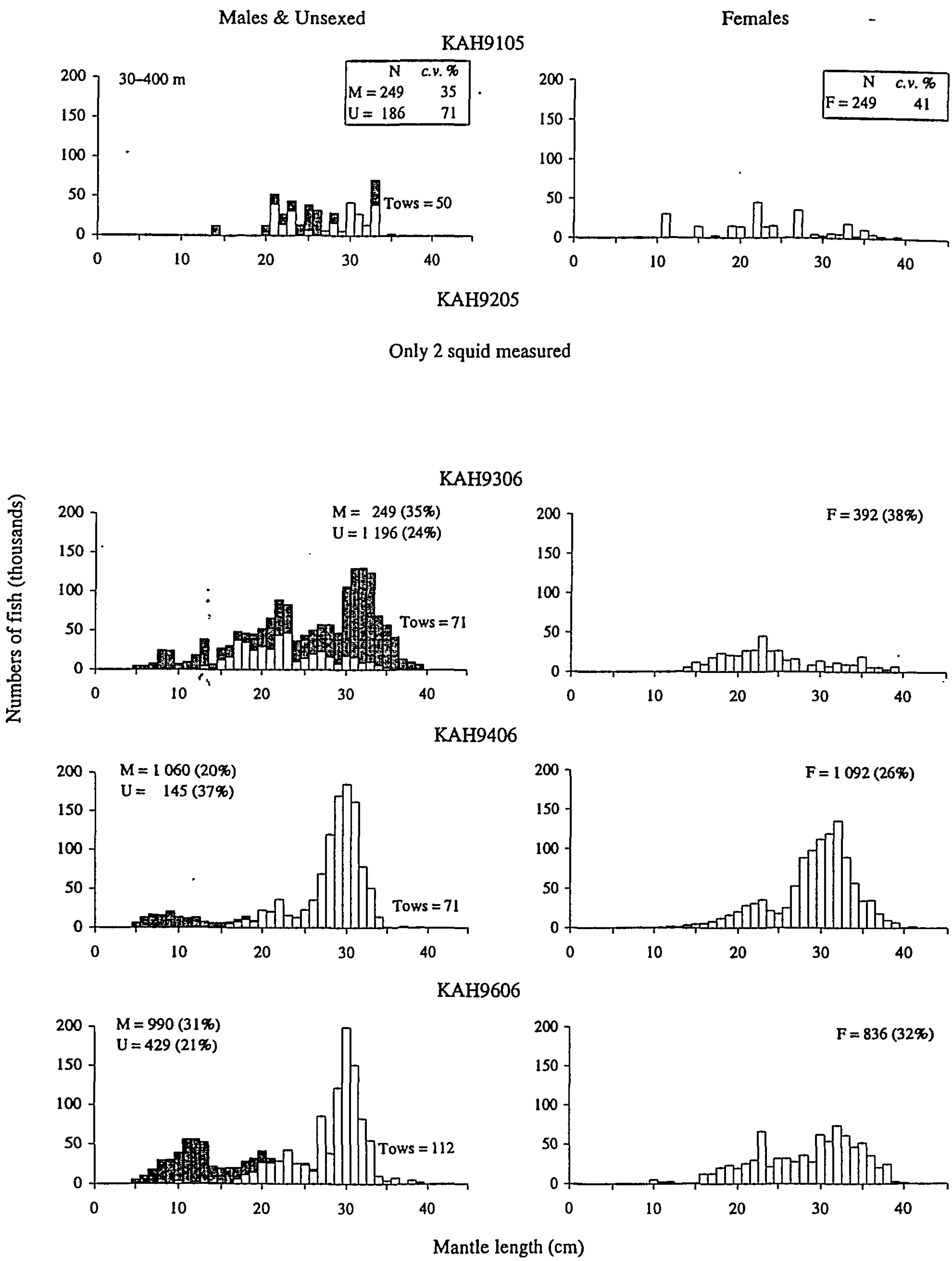


Figure 8 **: Scaled length frequency distributions of the major species, 1991–96, with the estimated total number of fish in the population (and percentage coefficient of variation). (M, number of males; F, number of females; U, number of unsexed fish (shaded) ; Tows, number of stations at which species was caught).**
a **: Arrow squid**

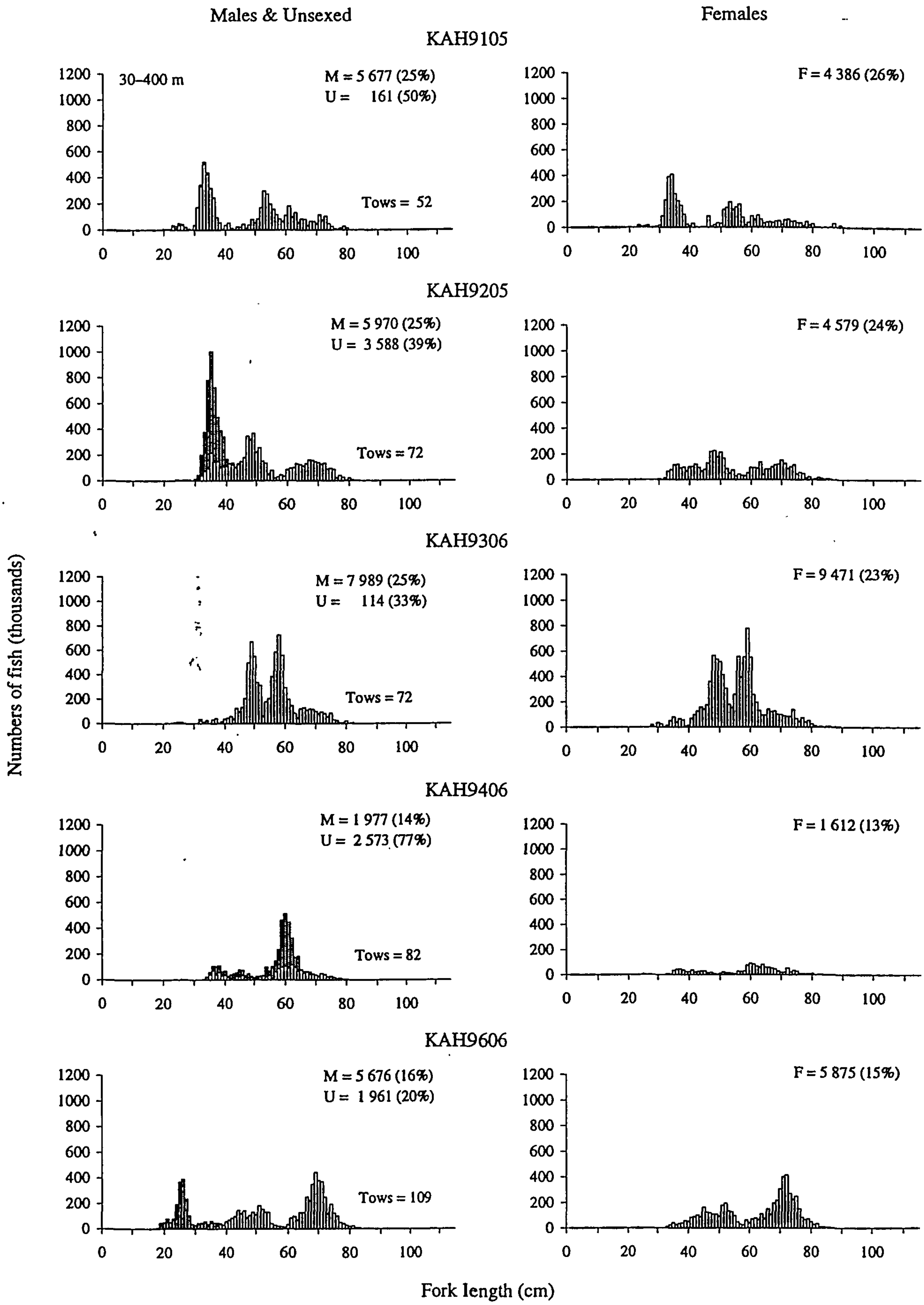


Figure 8b : **Barracouta**

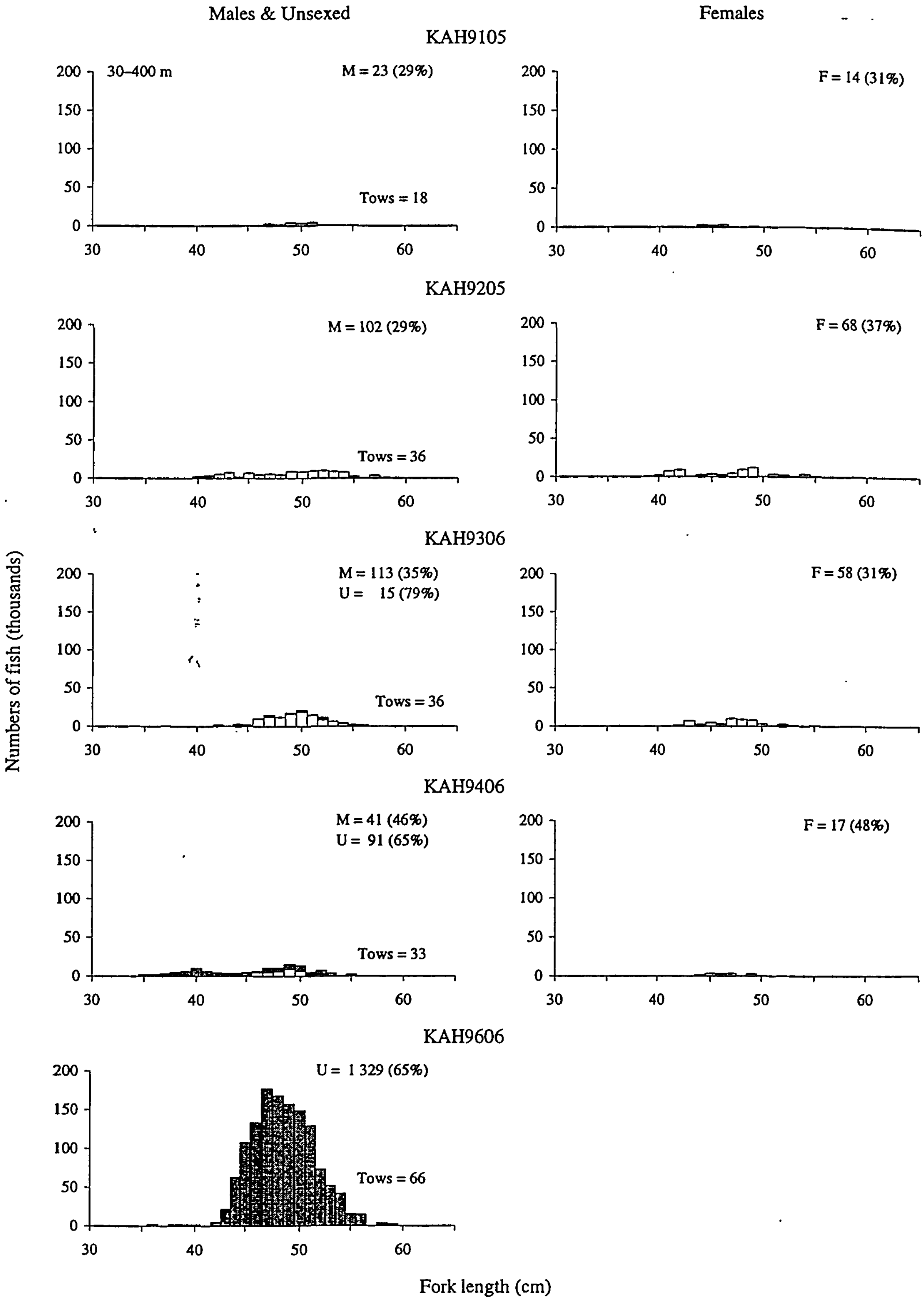


Figure 8c : **Chilean jack mackerel**

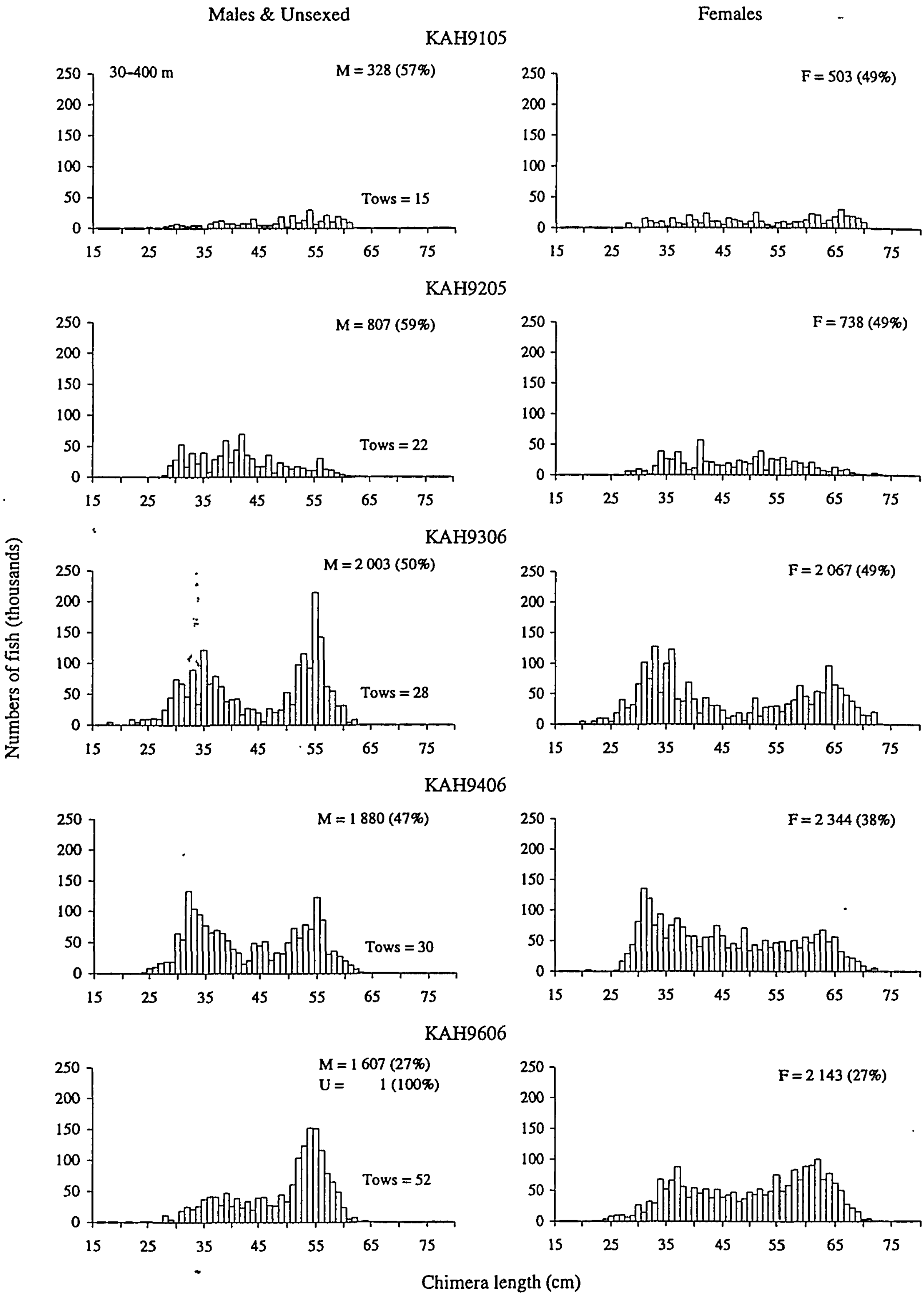


Figure 8d : **Dark ghost shark.**

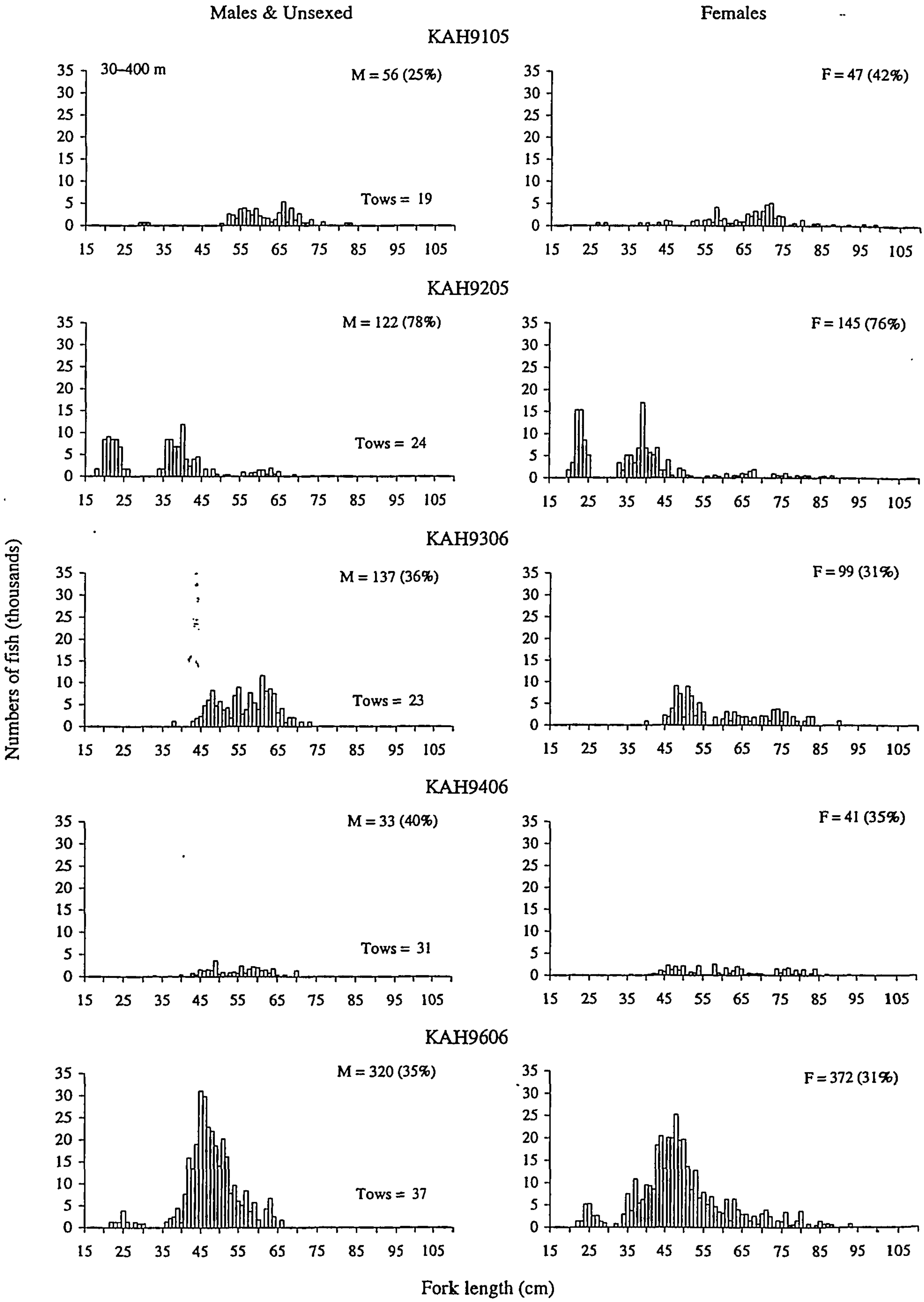


Figure 8e : **Elephantfish**

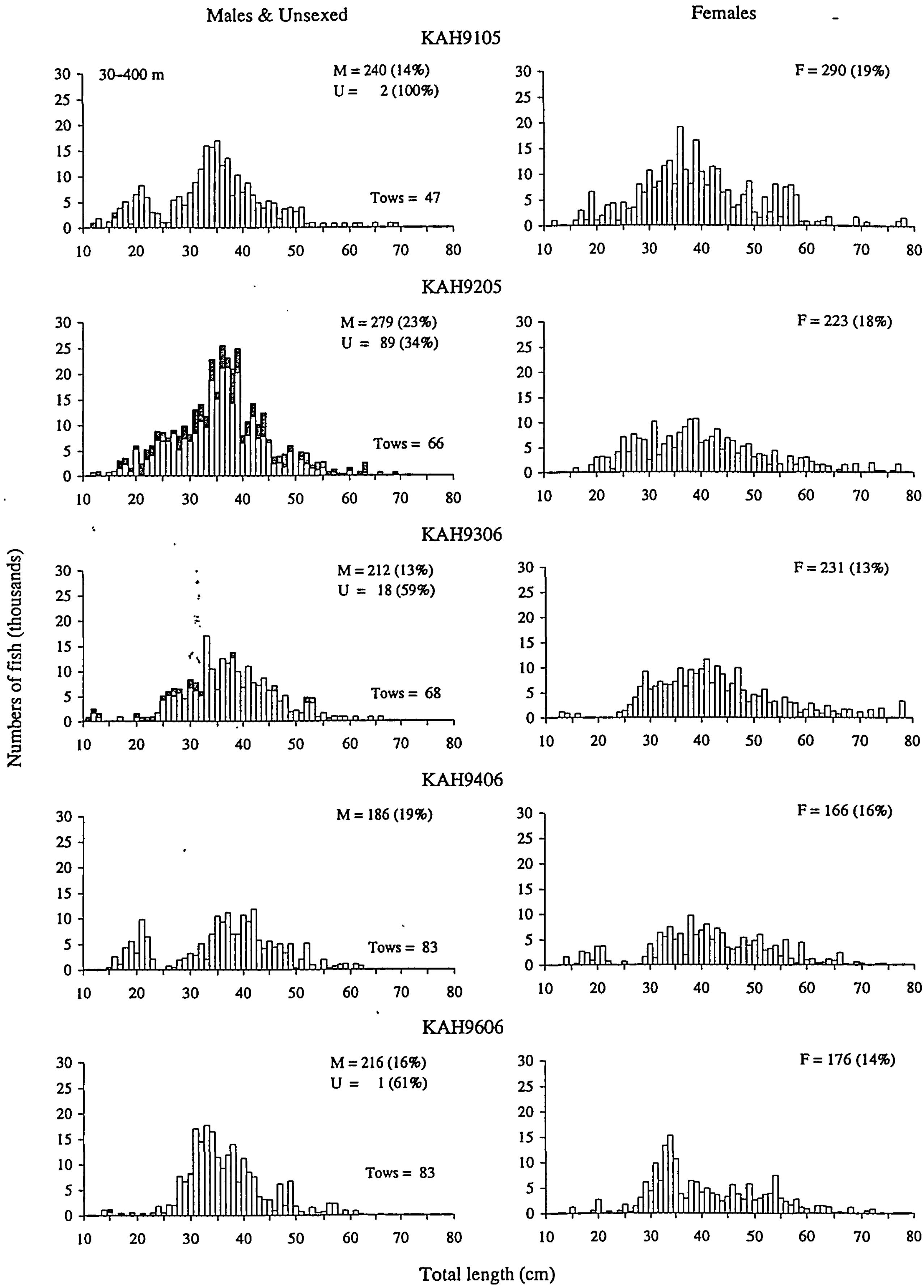


Figure 8f: **Giant stargazer**

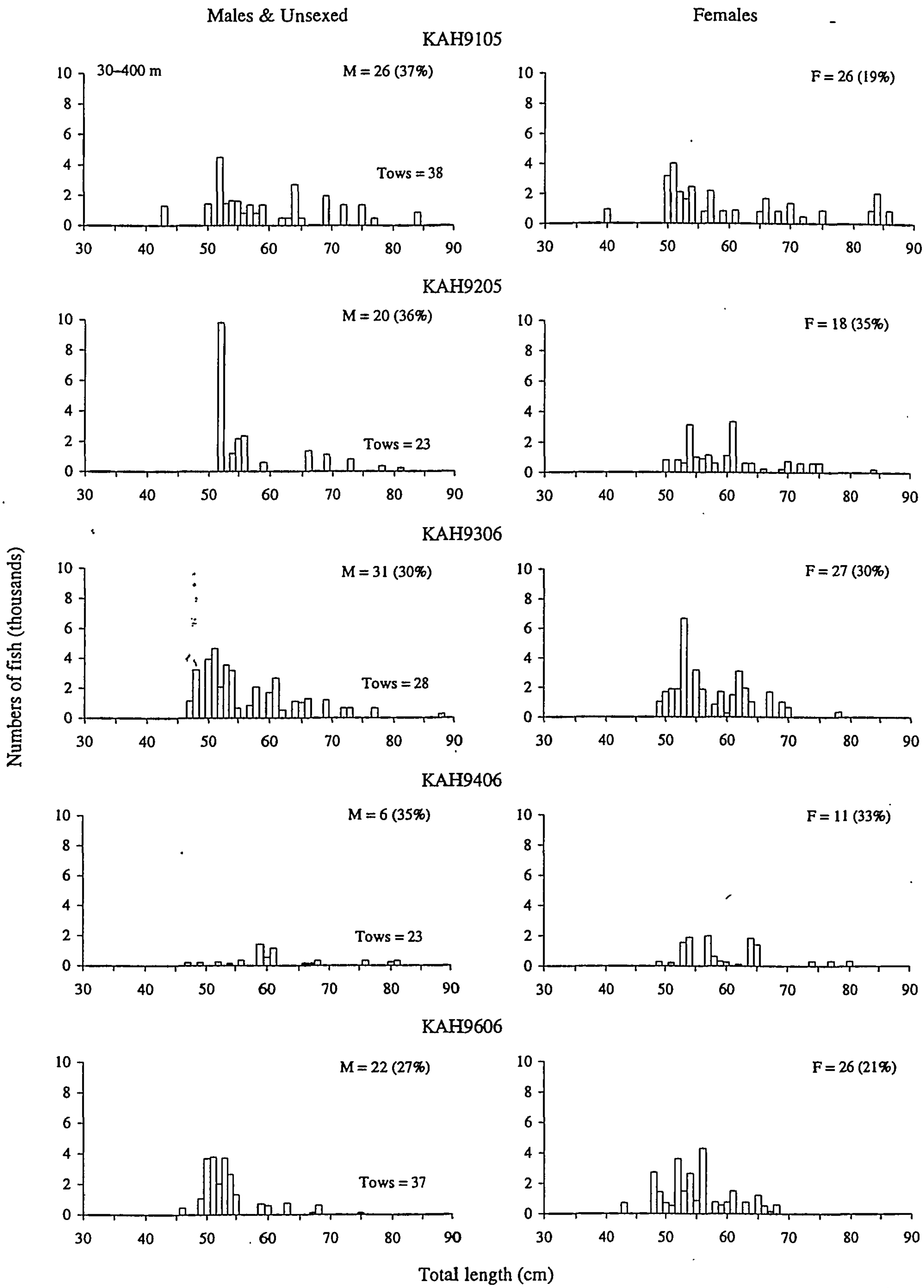


Figure 8g : **Hapuku**

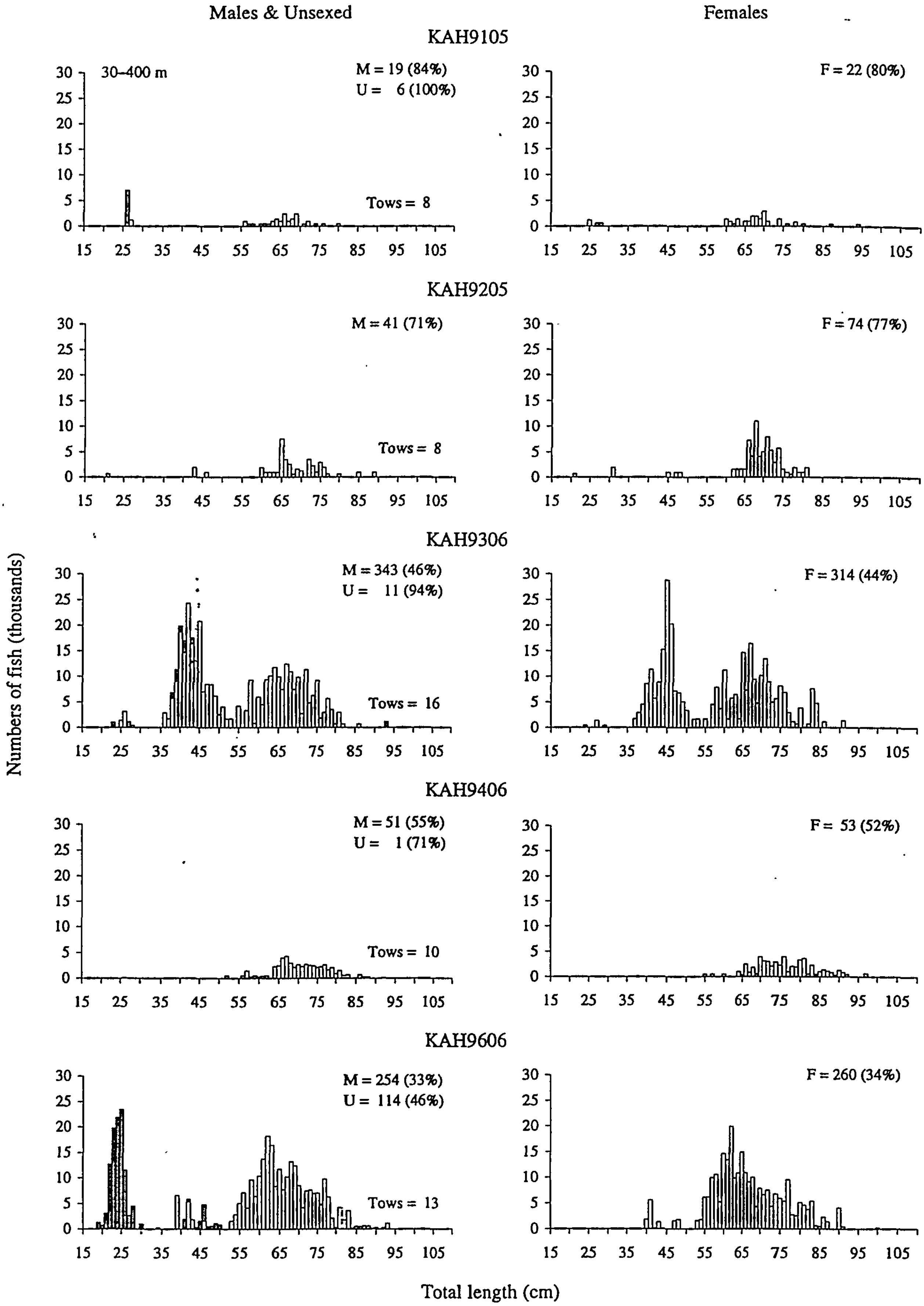


Figure 8h : Hoki

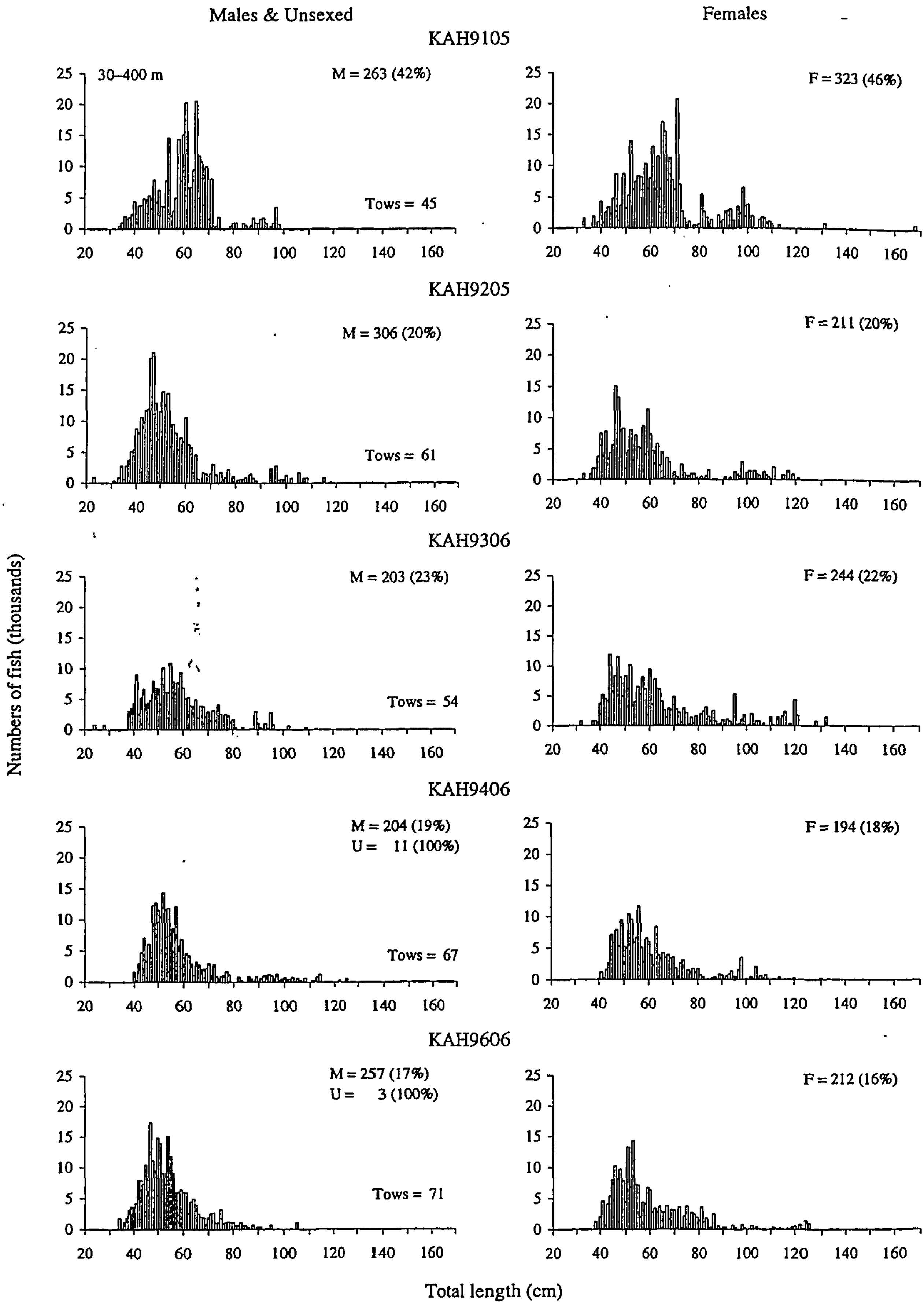


Figure 8i **: Ling.**

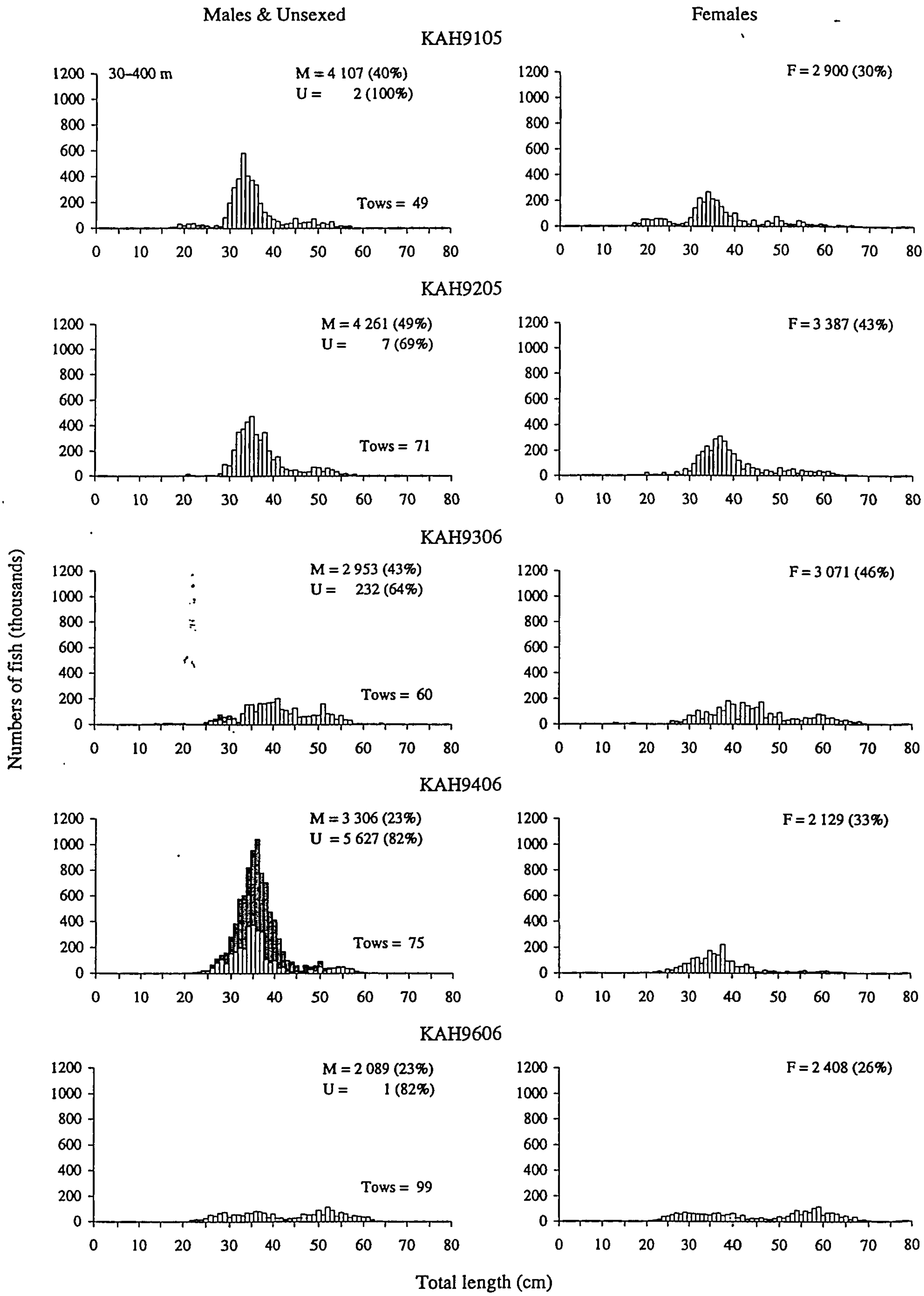


Figure 8j : **Red cod**

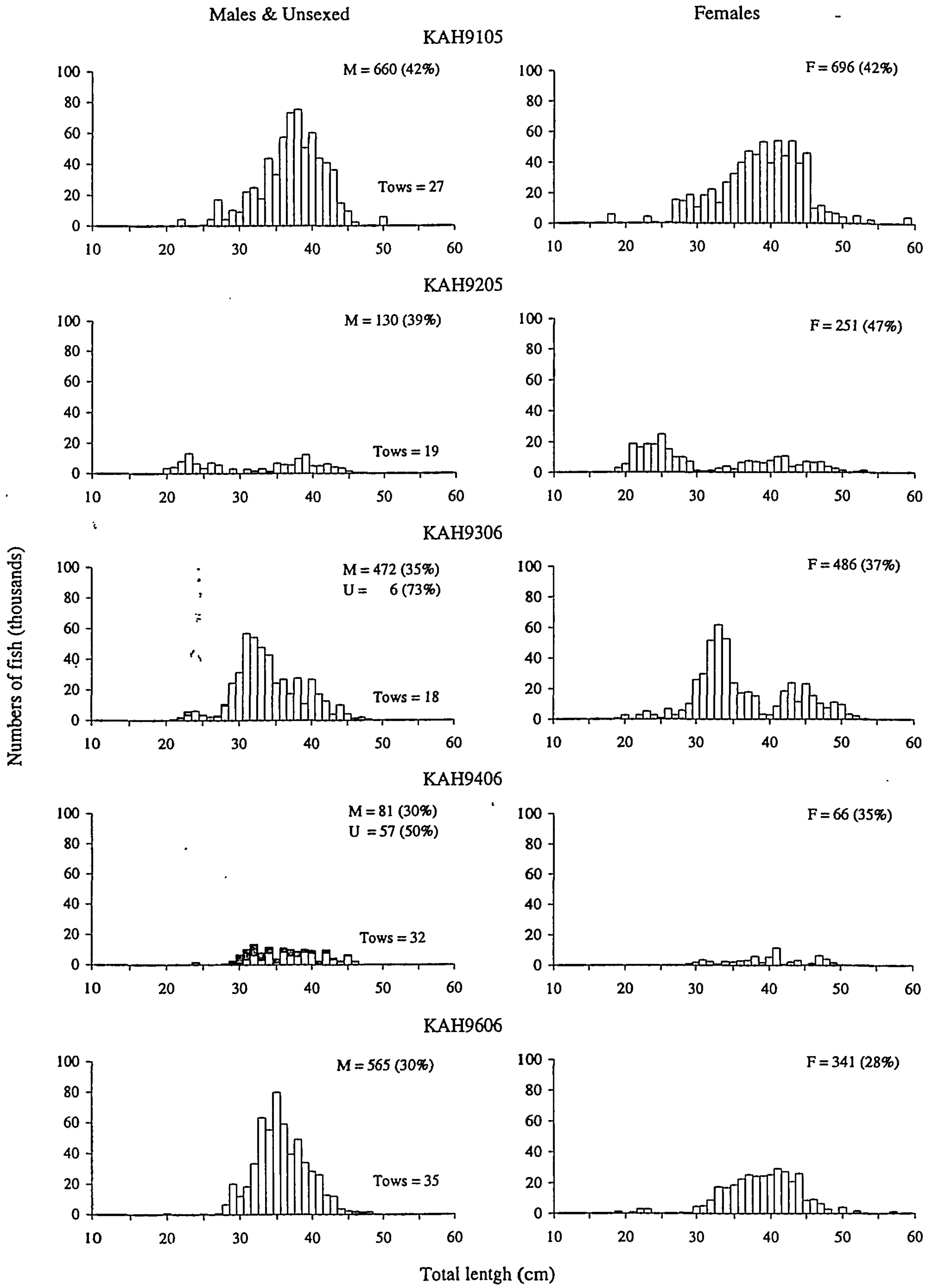


Figure 8k : **Red gurnard.**

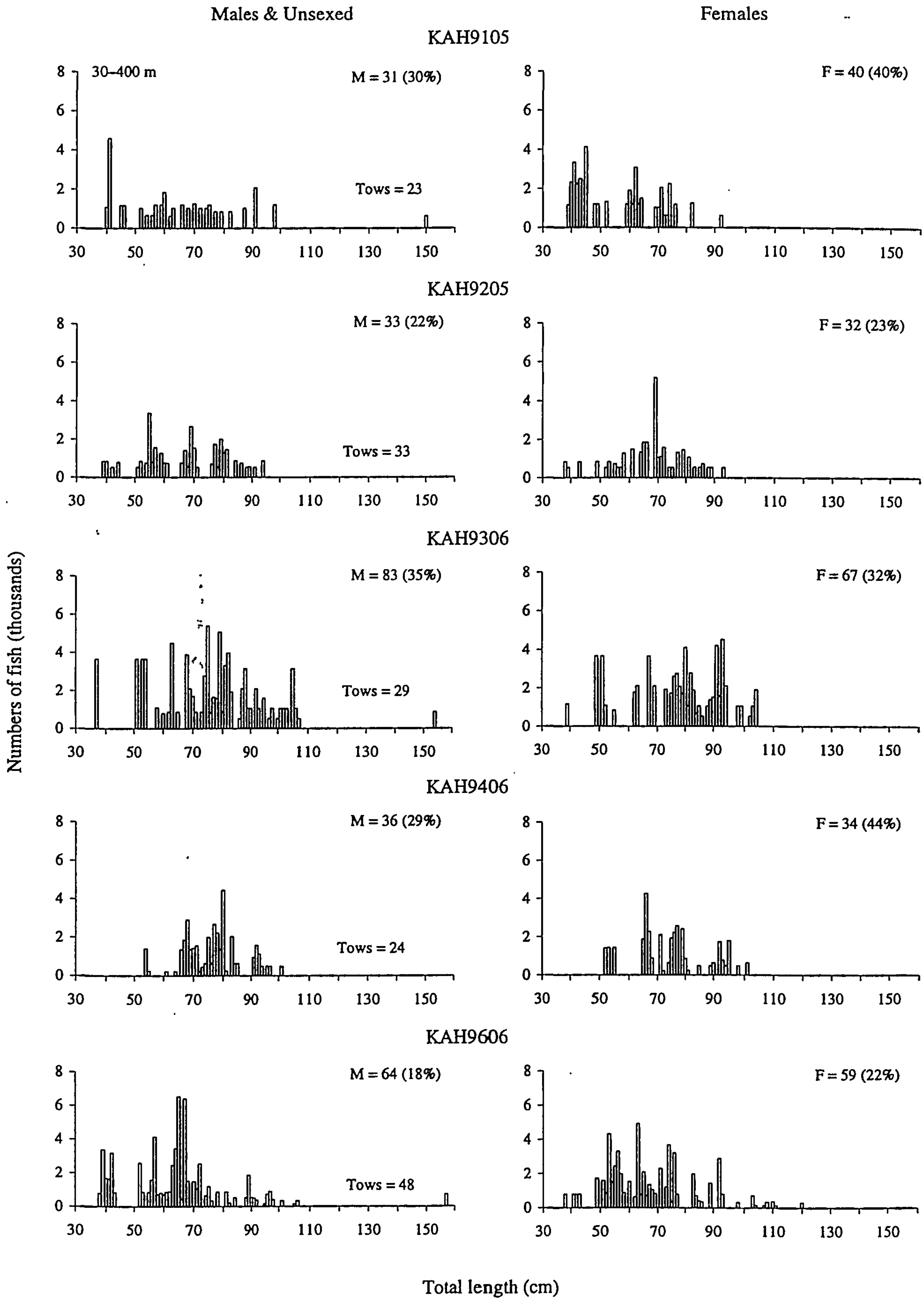


Figure 8l : **School shark.**

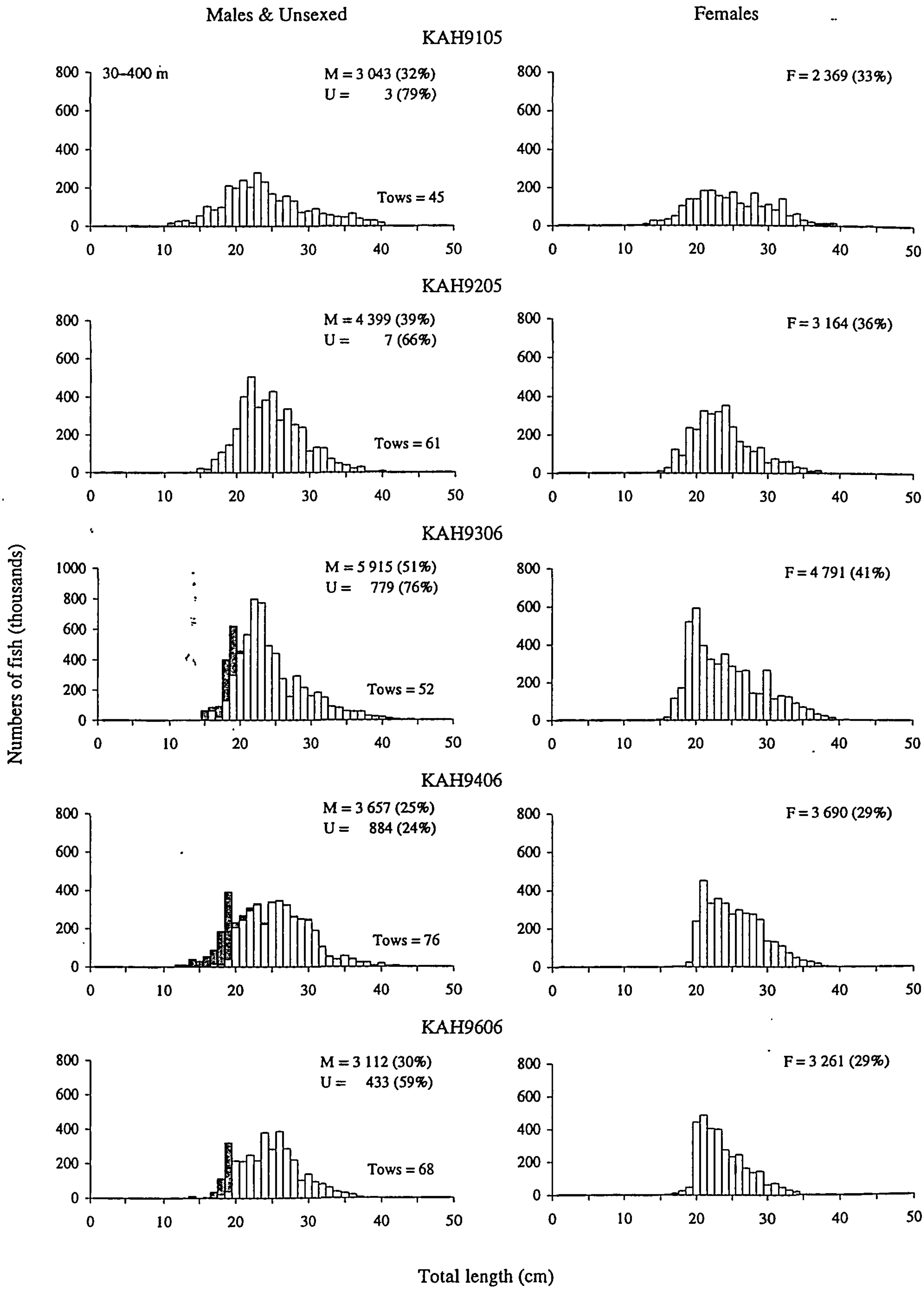


Figure 8m : **Sea perch**

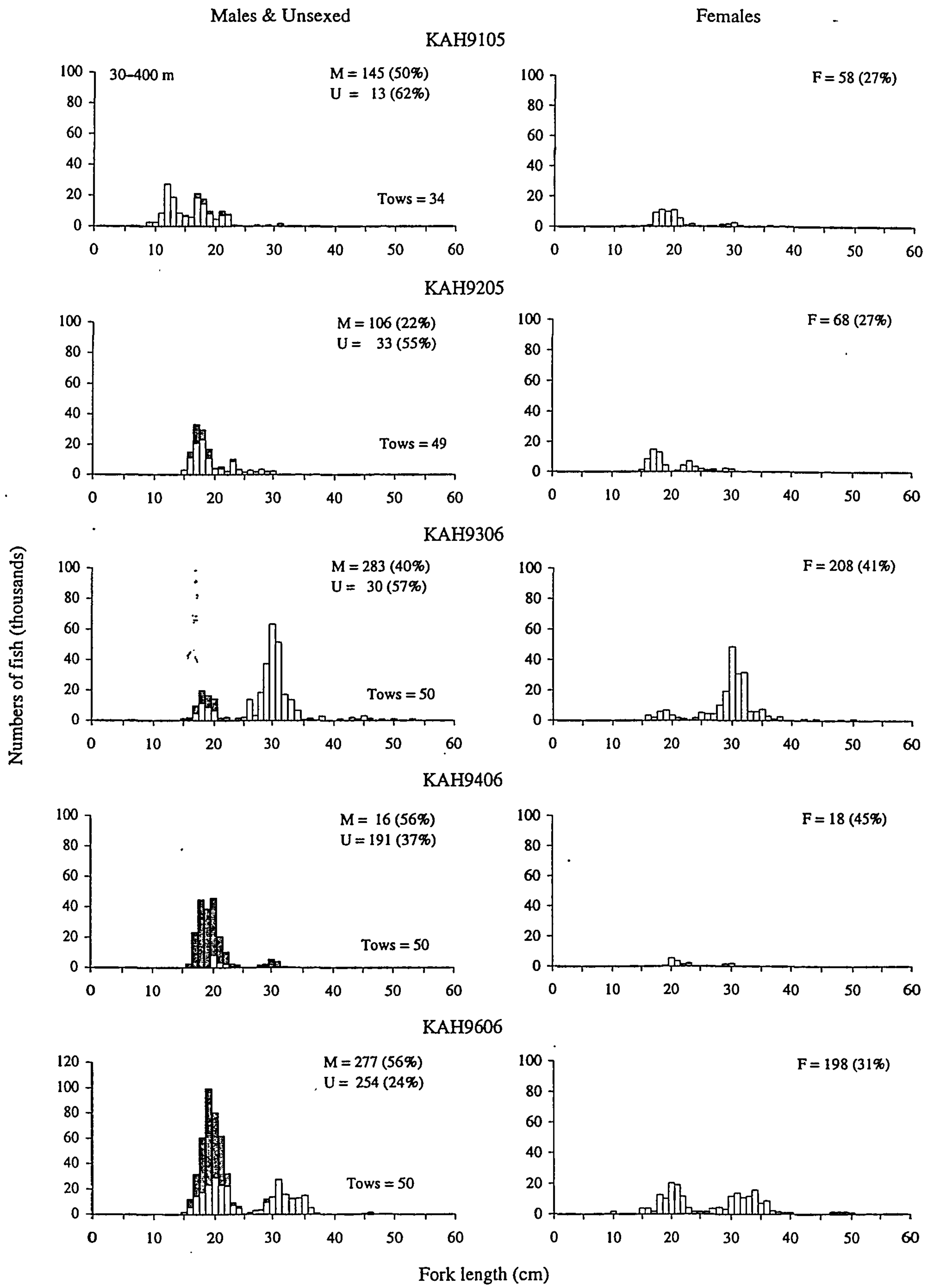


Figure 8n : **Silver warehou**

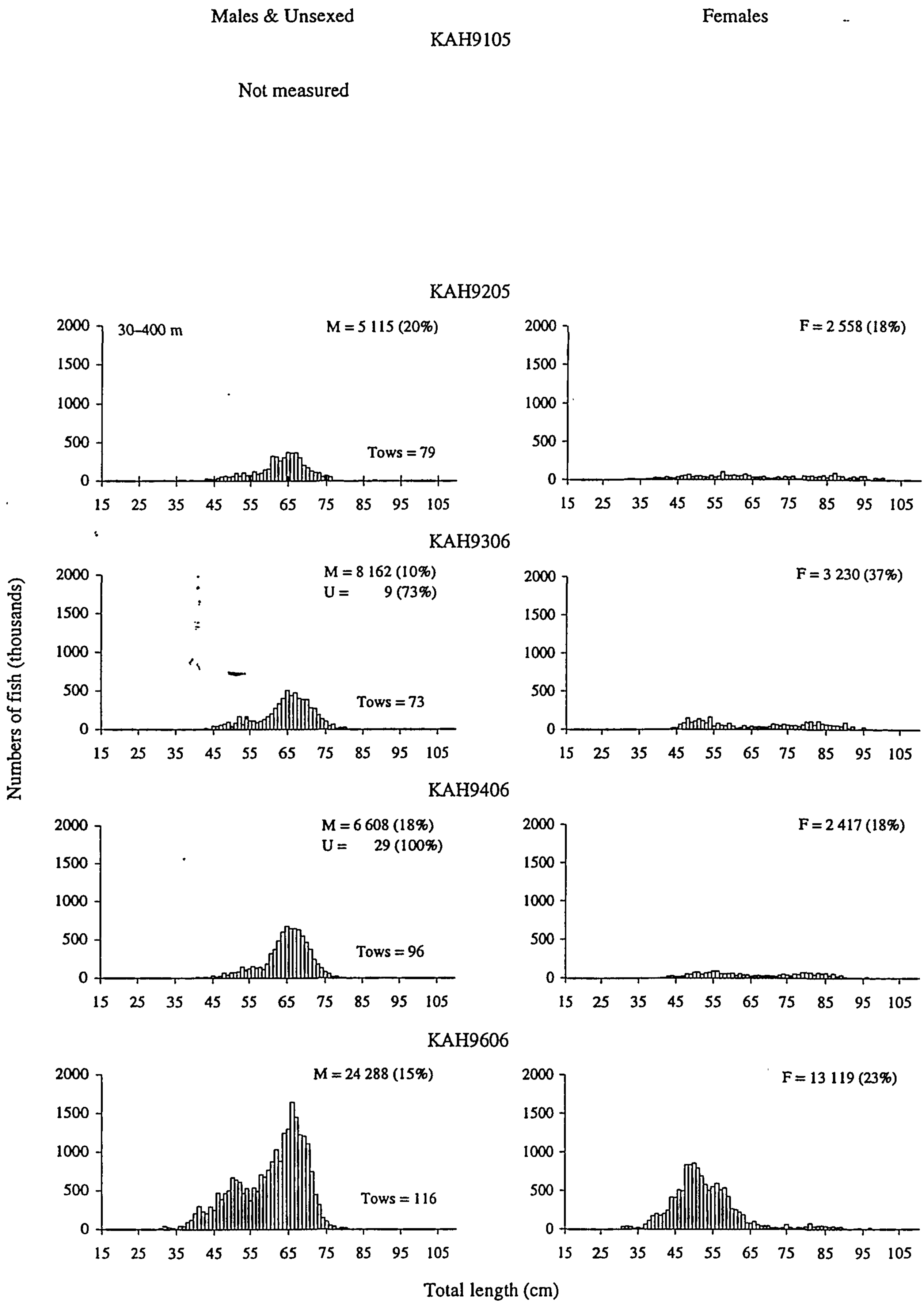


Figure 8o : **Spiny dogfish.**

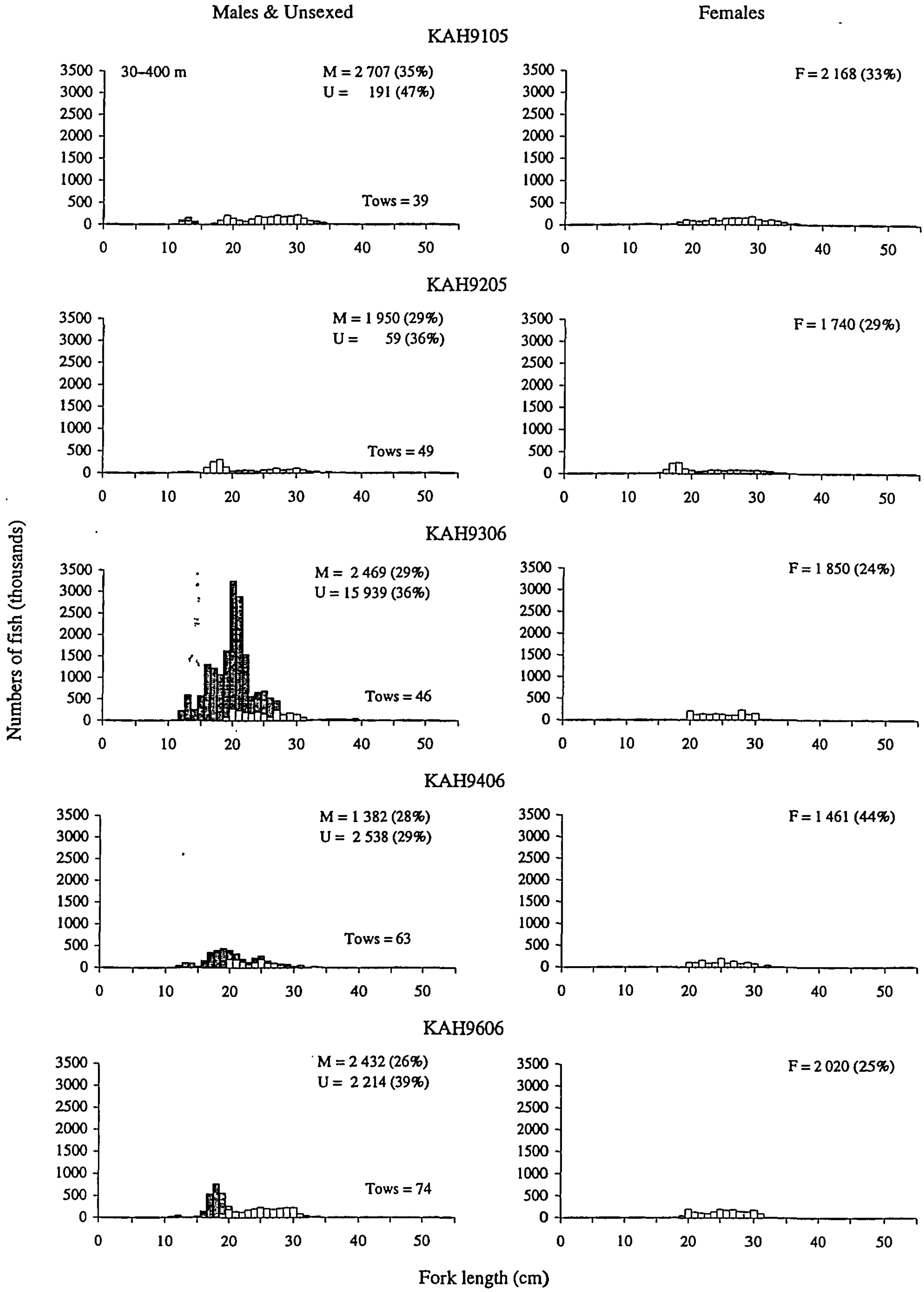


Figure 8p : **Tarakihi**

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	All	0.0091	2.8800	919	15–96	TAN9301
Chilean jack mackerel	All	0.0104	2.9966	184	43.7–61.6	TAN9604
Dark ghost shark	All	0.0025	3.2270	201	42–70	KAH9606
Elephantfish	All	0.0049	3.1654	378	13.4–91	KAH9618
Giant stargazer	1991	0.0155	3.0279	516	16.2–78	KAH9008, KAH9105, KAH9205
	1992	0.0155	3.0279	516	16.2–78	KAH9008, KAH9105, KAH9205
	1993	0.0137	3.0513	183	12–70	KAH9306
	1994	0.0177	2.9880	403	14–74	KAH9406
	1996	0.0140	3.0590	364	14–72	KAH9606
Hapuku	All	0.0044	3.2700	297	41–117	TAN9502
Hoki	All	0.0028	3.0062	1 002	34–105	TAN9401
Ling	All	0.0010	3.3600	213	45–135	SHI8302
Red cod	1991	0.0046	3.1922	500	14–72	KAH9105
	1992	0.0051	3.1643	264	14–71	KAH9205
	1993	0.0048	3.1901	405	11–73	KAH9306
	1994	0.0057	3.1330	701	12–73	KAH9406
	1996	0.0058	3.1270	1 263	12–75	KAH9606
Red gurnard	1991	0.0017	3.4785	227	19–55	KAH9008, KAH9105, KAH9205
	1992	0.0017	3.4785	227	19–55	KAH9008, KAH9105, KAH9205
	1993	0.0367	2.7051	180	19–53	KAH9306
	1994	0.0083	3.0680	128	24–56	KAH9406
	1996	0.0087	3.0540	384	27–57	KAH9606
School shark	All	0.0070	2.9100	804	30–166	Seabrook-Davidson (Unpub.)
Sea perch	All	0.0036	3.4534	266	15–40	KAH9008, KAH9105, KAH9205
Silver warehou	All	0.0065	3.2990	160	22–56	TAN9301
Spiny dogfish	All	0.0007	3.4500	1 052	43.4–104.4	TAN9502
Tarakihi	All	0.0130	3.1005	1500	10–51	KAH9404

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

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