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Abstract

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A time series of six trawl surveys was conducted off the west coast of the North Island between 1986 and 1996. 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. 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 the bathymetry and hydrology of the west coast North Island, are described.

The most consistently abundant commercial species on all six surveys were red gurnard and snapper for FMA 9, and red gurnard in FMA 8. Following these were John dory, rig, school shark, spiny dogfish, and trevally, with their biomass ranking varying between years due to large inter-survey fluctuations in the biomass of some species.

For the main target species snapper c.v.s on total biomass were 26, 28, 26, 40, 56, and 29% for FMA 9; and 33, 25, and 38% for FMA 8. For 2+ and 3+ snapper, the numbers of individuals per year class (estimated within a core area sampled by all surveys) ranged from 36 000 to 557 000, with associated c.v.s of 10 to 37%. These year class strength values are used within the SNA 8 population model, and are consistent with values estimated in the SNA 8 model using catch-at-age sampling data.

Species with the lowest c.v.s were red gurnard (FMA 9: 12–30%, FMA 8: 9–37%) and John dory (FMA 9: 10–47%, FMA 8: 25–62%), which were secondary target species. No statistically significant trends were found in pre-recruited, recruited, or year class biomass for any species apart from spiny dogfish. These were found to have increased greatly in abundance between 1986 and 1996 (due to large increases in abundance in the 1994 and 1996 surveys).

Distribution of each species was described, length frequency modes (potential year classes) were identified, and evidence of modal progression was noted. The relative proportions of gonad stages were summarised for female snapper.

Introduction

Background

A time series of six spring/summer (October–December) trawl surveys was conducted off the west coast North Island between 1986 and 1996, defined for the purposes of this review as the area between Cape Reinga (Scott Point) and New Plymouth (Airedale Reef), in water depths of 10–200 m, excluding estuarine areas.

The first two surveys (1986–87) in the time series were consecutive, after which the series became biennial/triennial, with the last survey in 1996. Most of these surveys have been documented in standalone reports with little comparison of the results between surveys (Drury & McKenzie 1992, Drury & Hartill 1993, Langley 1995, Morrison 1998), although Langley (1994) provided a general overview of results for species other than snapper from the Auckland Fisheries Management Area (AFMA) trawl surveys. No reports were completed for the 1986 or

1987 surveys. 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.

The Quota Management System was introduced in 1986 and many 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. From the beginning, the west coast trawl series had a primary objective of determining the relative year class strength (more recently the number of 2+ and 3+ snapper in particular) of juvenile snapper (*Pagrus auratus*), and this has continued up until the present time. John dory (*Zeus faber*) (JDO 1) and red gurnard (*Chelidonichthys kumu*) (GUR 1) are an important bycatch of the inshore trawl fisheries of this area, and have been important target species for monitoring as part of the trawl survey series. In the 1996 survey, tarakihi (*Nemadactylus macropterus*) was also added as a target species, through the addition of strata in the 100–200 m depth range. Other species for which information has been collected include barracouta (*Thyrsites atum*), trevally (*Psuedocaranx dentex*), school shark (*Galeorhinus australis*), and rig (*Mustelus lenticulatus*).

The survey area (Figure 1) has varied from year to year, both in latitudinal extent and depth range. The primary purpose of the series has been to document juvenile snapper abundance, but the decisions made on survey design and rationale were poorly documented for the earlier surveys. In general, the survey area has extended from Scott Point (the northern end of Ninety Mile Beach) to Airedale Point (north of New Plymouth). Area excluded due to foul ground is spatially limited; this includes an area of reef off Tauroa Point, and another off Murawai. The number of strata successfully completed in each survey has varied between years, often due to the rough sea conditions of the west coast. A core central area of the survey strata that has been consistently sampled throughout the time series has been used to derive estimates of relative snapper year class strength, by applying age length keys to snapper population length frequency estimates (derived from the trawl surveys). These estimates are used in the current SNA 8 model (Annala et al. 1999).

The wording of project objectives has varied slightly between surveys, as has the objective emphasis, but can be summarised as follows (based on 1999 survey: note that tarahiki has been a target species only since 1996).

1. To determine the relative distribution and abundance of 2+ and 3+ snapper, John dory, red gurnard, and tarakihi.

2. To collect otoliths from snapper, John dory, red gurnard, and tarakihi

3. To collect length frequency information on all other Quota Management System (QMS) species.

An additional objective scheduled for the 1999 survey was to assess length frequencies, length-weight relationships, and reproductive condition of snapper, John dory, red gurnard, and tarakihi.

Previously only limited reproductive information has been collected for female snapper, and no length-weight data have been collected for any species during previous surveys.

West coast fishery

The west coast has a reasonable area of continental shelf area suitable for trawling, which is the main fishing method (the overall survey area as per the 1994 and 1996 surveys is 24 108 km^2, shown in full extent in Figure 1). Trawl fisheries are seasonal and predominantly target snapper and trevally, with some mixed bag fishing at other times. About 18 000 t of inshore finfish is taken annually from the west coast of the North Island. The main inshore target fisheries are snapper, trevally, and tarakihi. Common bycatch species include John dory, red gurnard, and barracouta. Less common fishing methods include set netting for school shark.

Previous west coast North Island trawl surveys

There have been seven trawl survey series off the west coast North Island; 1986, 1987, 1989, 1991, 1994, 1996 (trip codes – KAH8612, KAH8715, KAH8918, KAH9111, KAH9410, and KAH9615), and one completed in 1999, not included in this review (KAH9915). The general timing of surveys has been between mid October and early December. Snapper have been the primary target species for all these surveys, with adult red gurnard and John dory as secondary target species. Tarakihi has been a target species only since the 1996 survey.

Hydrology and bathymetry of west coast North Island

The water currents of the west coast are poorly known. Between North Cape and the Manukau Harbour entrance, there is a southerly current known as the West Auckland Current. Its extent and magnitude are unknown. Around the Awhitu Peninsula (Manukau), along-shore currents are spread evenly up and down the coast, depending on regional wind directions. Median current speed is 14 cm/s, but extends up to a maximum of about 40 $cm.s^{-1}$.

Further south, in the North Taranaki Bight, currents flow predominantly down the coast (current speed range of 5–30 $cm.s^{-1}$, median 8–13 $cm.s^{-1}$). Less frequent up-coast currents have also been observed. Currents are forced by regional winds, with a higher wind speed threshold needed to reverse the dominant downcoast current flow.

The west coast continental shelf is relatively straightforward in its bathymetry, with a gradual slope occurring from onshore to offshore. There are no known major bathymetric features, apart from some sand bars around the major harbour entrances. It is suspected that the relatively few large harbours that empty out onto this coast (e.g., the Manukau and Kaipara) may be important to the population dynamics of a number of coastal fish species, especially as potential nursery areas.

Methods

Survey area and design

The survey area (see Figure 1) and associated stratification has varied greatly from survey to survey. The 1986 survey was conducted from Scott Point down to Tirua Point in the 10–100 depth range (this survey was also extended to include North Cape and Great Exhibition Bay, which do not form part of the time series presented). The 1987 survey was restricted to the area between Manganui Bluff and Tirua Point. In 1989, the survey was again extended, north to include Ninety Mile Beach and south to New Plymouth (Airedale Reef).

The 1991 survey extent followed that of 1989, with a further extension of the depth range between Scott Point and Airedale Reef out to the 200 m contour. The 10–100 m depth zone between New Plymouth and Mana Island was also included in this survey.

The 1994 survey was cut back to the area between Scott Point and Airedale Reef, while retaining the 200 m depth maximum for strata boundaries. However, due to bad weather, seven of the strata, mainly deeper ones, were not surveyed. The 1996 survey used the same survey extent and stratification as the 1994 survey, as shown in Figure 1.

Surveys before 1996 were of a single phase, stratified random trawl design. Total areas have varied between surveys. Before each survey, trawl stations were randomly generated using the computer program 'Rand_stn v2.1' (Vignaux 1994) with a minimum distance of 1.85 km (1 n. mile) apart specified. Allocation of stations was based on stratum area and previous snapper catch rates, with a minimum of three stations per stratum. For the 1996 survey, a brief second phase was undertaken (after Francis 1984) due to exceptionally calm weather putting the survey well ahead of schedule. Second phase stations were allocated to increase the precision of the snapper biomass estimate, as well as to collect additional John dory for otolithing.

Vessel and gear specifications

RV *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. All trawling was carried out using a high opening bottom trawl (HOBT), with cut-away lower wings and a 40 mm codend. Details of changes to the trawl doors in 1995 are given in Appendix 1.

Trawling procedure

Trawling procedure was standardised for all surveys. Tows were conducted in daylight between 0530 and 1700 hours (NZST). If the station was in an area of foul or the depth was out of range, an area within 2 n. miles (3.7 km) of the station in the same stratum was searched for suitable ground. 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 1.5 n. miles (2.8 km) in length. Distance was estimated using GPS, and/or satnav or radar for earlier surveys. Warp to depth ratios ranged from 16:1 at the shallowest stations to 4:1 for the deeper trawls.

Kaharoa was equipped with Scanmar for the 1996 survey, and doorspread was recorded and averaged over the tow. Headline height was recorded from the netsonde and averaged over the length of the tow. Sea bottom temperature was recorded from a net sonde before the 1996 survey, when Scanmar became available. Sea surface temperature was recorded with a hull-mounted sensor, apart from 1996, where it was not working and measurements were taken using a manually lowered bucket. Before 1996, the method of Kawahara & Tokusa (1981) was used for estimation of doorspread, using the spread of the warps as a surrogate for doorspread.

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 sub-sample of up to 200 randomly selected fish. Biological information was obtained from a random sample of up to 60 fish for snapper. One or more of the following records or samples were taken: length to the nearest centimetre below actual length, otoliths, sex and gonad stage (females only). In the 1996 survey, otoliths were also collected for red gurnard, john dory and tarahiki.

Length-weight data for use in generating length-weight coefficients were not collected in this trawl series before 1996. For the 1999 survey, data have been collected for snapper, red gurnard, John dory, and tarahiki.

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 surveys before 1994 used doorspread values estimated using the method described by Kawahara & Tokusa (1981). The 1994 survey used doorspreads estimated from the equation given by Langley (1995):

$$\text{Doorspread} = 99.8214(1\text{-}e^{-0.0096994(\text{warplength} + 7.3296)})$$

Scanmar was available for the second half of the 1996 survey. For those stations where Scanmar data were not available, an average from those where it was available was substituted for the appropriate depth range. For all surveys, all tows where the gear performance code was 1 or 2 were used for biomass estimations (these codes indicate that the trawl worked well, without problems that could influence catch rates). The relative biomass estimates assume that: the area swept on each tow equals the distance between the doors multiplied by the distance towed; that all fish within the volume swept are caught and there is no escapement; that all fish in the water column are below the headline height and available to the net; that there are no fish from the west coast North Island stocks outside the survey area at the time of survey; and that fish distribution over foul ground is the same as that over trawlable ground (though for the west coast, most foul ground is excluded from biomass calculations).

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. 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 used to scale length frequencies, as given in Appendix 2.

Changes in survey areas across the different surveys complicated the analysis of the time series. Each of the surveys had different survey boundaries and stratification to some extent. However, a core area has been surveyed across the full time series (equivalent to the 1987 survey extent). For this review, this core area was used to provide a time series with a fixed spatial extent. This meant the exclusion of a number of strata (see Appendix 3 for details). Stations falling within FMA 8 (south of the core area) were analysed and presented separately.

Tarakihi, which has been a target species only since 1996, was not included as a reviewed species. This is because the strata in which it occurred in meaningful numbers (over 100 m water depth) have been properly surveyed only since the 1996 survey.

Linear regression analysis was used to examine whether trends in biomass were statistically significant using the computer program Excel 97™ for Windows. The slope of the regression was considered to be significantly greater than zero if $P < 0.05$.

Results

Stations surveyed

The number of stations completed overall in each survey has ranged from 56 to 124 (Table 1), with those falling in the core area ranging from 36 to 57. For the 1994 and 1996 surveys, the anticipated number of stations to be occupied was 110. For the 1994 survey, bad weather, mechanical failures, and crew illness resulted in 12 out of the 25 sampling days for this trip being unavailable. Conversely, during the 1996 survey, unusually calm seas put sampling well ahead of schedule, and a brief second phase was conducted, adding 14 more stations to the original design.

Biomass and precision

Biomass estimates and coefficients of variation for the nine main commercial species are given in Table 2, split by fisheries management area (FMA 8 & FMA 9) (see Figure 1).

In FMA 9, red gurnard consistently dominated the catch. Snapper was second in importance for all years apart from 1986. The biomass of other species was quite variable, with relative rankings changing between years. In FMA 8, biomass estimates were not available from the 1986 and 1987 surveys, as no strata within this area were sampled. For the 1989–96 surveys, red gurnard was again the dominant component of the catch. Other species biomasses were quite variable between years, and there was no consistent species ranking (as in FMA 9).

The coefficient of variation (c.v.) is an indication of the precision of the biomass estimate. For the target species snapper, c.v.s for total snapper biomass for FMA 9 were 35, 27, 15, 26, 19, and 34 (Table 2). For the 0+ year class in FMA 9, these were 55–100% and for the 1+ year class 45–82% (Table 3). In FMA 8, values of 25–38% were achieved for overall snapper biomass; those for 0+ fish were 17–100%, and those for 1+ fish were 37–81%.

The relative number of individuals and c.v.s of 2+ and 3+ snapper (FMA 8 and FMA 9 combined, 1987 survey extent) are the year class parameters currently used in the SNA 8 population model. Estimates for these, and their calculation, were given by Morrison (1998), but are reproduced here for completeness (Table 4). Coefficients of variation ranged from 10 to 37%. During the 1996 survey, the only two-phase survey undertaken, there appeared to be a movement of snapper between several strata, between the first and second phases of the survey. This resulted in a large increase in snapper c.v.s. between the first and second phases. Therefore, caution needs to be exercised in the use of two phase surveys for snapper on the west coast.

The biomass estimates of red gurnard have been reasonably precise (FMA 9, 12–30%; FMA 8, 9–37%), while John dory biomass c.v.s have been less precise (FMA 9, 10–47%: FMA 8, 25–62%). Biomass estimates of other species have been quite variable with c.v.s often exceeding 30%. This is not surprising as station allocations were not optimised for these species. Of the non-target species, rig and school shark were the most precisely estimated.

Biomass trends

Trends in recruited and total biomass for the eight main commercial species in FMA 9 and FMA 8 are shown in Figure 2. No statistically significant trends were found in increasing or declining biomass for any species apart from spiny dogfish in FMA 9, which showed a significant increase ($P = 0.0142$). The power of these tests is limited to some extent by the generally poor c.v.s for many species, which means the data points used in the regression analyses are poorly estimated and incorporate a fair degree of variability.

Where total and recruited biomass were the same, this indicated that most of the catch was of adult size.

Red gurnard, rig, and school shark (FMA 9 only) had a high proportion of pre-recruit biomass in the survey area. Most species displayed marked differences in biomass between years, both in FMA 9 and FMA 8, including barracouta, trevally, school shark, John dory, and rig. There were no consistent trends in biomass either within species or between species in both FMA areas. However, this lack of trends should be viewed with caution, as many of the estimates had high c.v.s.

Little is known about possible seasonal changes in availability of these fish species, at least quantitatively. For instance, adult trevally are anecdotally known to change their behaviour through the year in response to spawning events and the availability of pelagic prey items. This in turn will affect their vunerability to trawl gears and surveys. Such behaviour may be seasonally predictable, but vary in its precise timing from year to year. This suggests that the standard trawl survey assumptions are probably not appropriate for this species.

Water temperature and catch rates

Surface temperatures were collected for all surveys, and indicate that in 1994 the mean temperature was cooler than for other surveys, while 1989 and 1996 were the warmest (Figure 3). Bottom temperatures were only recorded in 1994 and 1996, with the 1994 average being about 1 C^{o} cooler.

Distribution and length frequency

The distribution and size of catches expressed by catch rates ($kg.km^{-2}$) for t he major species are shown in Figure 4 and length frequency distributions in Figures 5 (FMA 9) and 6 (FMA 8). In

Figure 4, all available catch rate data falling within the current survey boundaries are presented, including stations falling north of the core survey area, and in the 100–200 m depth strata (also outside the core area).

Barracouta

Barracouta were distributed throughout the survey area and were caught at between 16 and 60% of stations (Figure 4a). Catch rates were spatially variable from survey to survey, with, for example, the 1989 survey recording the presence of barracouta only as far north as the Manukau Harbour entrance. Higher abundances were recorded in the deeper strata (100–200 m).

Length frequency data were collected for FMA 9 in all years except 1989. A mode of adult fish was present in the 55–85 cm length range, with some evidence for multiple cohorts within this mode from the 1987 survey data (Figure 5a). A small but consistent cohort of juveniles (probably 0+) was evident in the 15–25 cm range for four of the six years (no length data were recorded in 1989).

In FMA 8, barracouta length frequencies showed most fish sampled were mature sized adults of 55–85 cm in 1989, 1994, and 1996 (Figure 6a). The few juveniles that were caught were mostly 15–25 cm (0+)

John dory

John dory were distributed throughout the survey area and were caught at between 39 and 83% of stations (Figure 4b). No spatial trends in catch rates were readily apparent. Numbers in the shallowest strata (10–25 m) were generally lower than in deeper waters. Length frequency distributions for FMA 9 were generally composed of a mode of larger adult fish around 35–45 cm, with females attaining larger sizes (Figure 5b). Although there appear to be several modes in the size range 10–25 cm, Hanchet et al. (1999) showed that these fish came from a single 0+ age class. These juvenile fish were present in most surveys. Few John dory were measured in FMA 8, although the very limited data available suggest a similar size structure (Figure 6b). This suggests that it may be possible to track year class strength in this species using trawl surveys. At present, stratification and station allocation for this species are based on the biomass of all age classes combined, and c.v.s on juveniles (defined as fish under 29 cm) range from 15 to 44% for FMA 9, and 30 to 77% for FMA 8 (Table 3).

Red gurnard

Red gurnard dominated the catch in all surveys, and were caught throughout the survey area, occurring at 94–100% of stations (Figure 4c). They were found across the full depth range sampled (10–200 m), but were most abundant inshore. Spatially, there were no consistent areas of higher or lower catch rates, although in some years certain areas stood out with higher catch rates (such as Ninety Mile Beach in the 1991 survey).

Length frequencies for this species in FMA 9 were consistently dominated by a 20–35 cm mode for males, and a 20–45 cm mode for females (Figure 5c). A distinct mode of juveniles was evident in 1994 only. Females on average tended to be larger, and to attain greater sizes than males. Almost identical results were found for FMA 8, with a small (although less distinctive than for FMA 9) juvenile mode being present (Figure 6c).

Rig

Rig were found throughout the survey area at 45–73% of stations (Figure 4d). There were no areas where catch rates were particularly high, and there was some variation between years (e.g., higher catches off Ninety Mile Beach in 1991 and 1996, as opposed to 1986 and 1989). In general, catch rates tended to be lower around the Taranaki Bight.

Length frequency information collected for this species was modest, and no clear modes were evident for either FMA 9 or FMA 8 (Figures 5d, 6d). Both juveniles and adults were present throughout the survey series.

School shark

School shark were caught at 27–57% of stations (Figure 4e). Catch rates were spatially variable from year to year, with few fish being captured north of the Kaipara Harbour in 1986 and 1989, though in all other years considerably more were encountered. School shark were present over all depths surveyed. They were particularly abundant off Ninety Mile Beach during the 1991 survey.

Too few fish were caught and measured on each survey to show clear modes in the length frequency distributions (Figures 5e, 6e). However, most females were less than 135 cm in total length, while most males were less than 125 cm. For females most fish of this size are immature, but for males 125 cm represents the length at which only 50% of individuals are mature (Hurst et al. 1999).

Snapper

Snapper were caught at 58–88% of stations (Figure 4f). Catch rates were higher in the shallower strata, and were on average lower south of the Manukau Harbour entrance, in 1986, 1991, 1994, and 1996. The length frequencies in FMA 9 (Figure 5f) show clear modal peaks that represent age classes (as verified by otolith readings from the various surveys). One to three peaks are present up to the 25 cm mark, depending on the survey year, and are relatively consistent in their location from year to year. The 2+ and 3+ year old year class strengths (estimated empirically from the trawl survey series, using age-length keys derived from aged otoliths) from these surveys are currently input to the SNA 8 population model (Annala et al. 1999).

The length frequencies for FMA 8 were less clear, and juvenile modes were only present in the 1996 survey at very modest levels compared to those in FMA 9 (Figure 6f). Many of the small snapper taken during the west coast trawl survey are from near the mouths of the large harbours, which may be important as nurseries for small snapper.

Spiny dogfish

Spiny dogfish were uncommon within the general survey area up until the 1994 and 1996 surveys, when they became widely distributed throughout the survey area (Figure 4g). Earlier surveys (1986–91) found spiny dogfish at 6–18% of stations, but the 1994 and 1996 surveys found them at 36 and 26% of stations respectively. Higher catch rates in these years resulted in significantly higher biomass estimates (*see* Table 2). For all surveys, catch rates were consistently higher in the deeper strata.

Length frequency data for this species was modest, even for the 1994 and 1996 surveys, and no clear modes are apparent for either FMA 9 or FMA 8 (Figures 5g, 6g). The only obvious feature of this series is that females tended to be on average larger and to reach larger sizes than males.

Trevally

Trevally were distributed throughout the survey area and were caught at 25–77% of stations (Figure 4h). They were spatially less abundant in the 1987 survey. Few if any trevally were caught in the deeper (100–200 m) strata. Highest catch rates were generally recorded from waters less than 50 m. The relatively high catch rates in 1989 and 1991 were reflected in higher biomass estimates for these surveys (see Table 2), remembering that the core area used for biomass estimation excludes all stations north of Manganui Bluff. A number of modes were evident in the length frequency distributions for FMA9, although these were variable from year to year (Figure 5h). Apparent age classes were present in most if not all years. Juvenile modes of 7–16 cm were present in all surveys, although in 1989 and 1991 few individuals were sampled. In FMA8, length modes were also present, which might represent age classes. Almost no fish under 25 cm were caught (Figure 6h).

Reproductive condition

Data on female snapper gonad stage were collected only for the 1991–96 surveys. Snapper female gonads were mainly in the immature and resting phase (55–93%), with the developing stage accounting for a further 7–31%. During the 1996 survey 26% of female snapper gonads were running ripe.

Discussion

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

Recommendations on the usefulness of undertaking future trawl surveys on the west coast of the North Island are addressed by considering the following questions

- Does the survey design adequately cover the known distribution of the fish?
- Are the levels of precision adequate to monitor trends in biomass?
- Are there any significant trends in biomass and how might they be interpreted?
- Have there been trends in the spatial patterns of the species abundance?
- How do changes in abundance indices from the trawl surveys compare with other available estimates of abundance?
- Are there trends detectable in the fish size frequency and age composition data?
- Are the trends in age composition data from the trawl surveys consistent with age composition data from shed sampling?
- What frequency of surveys would be required to monitor the biomass of the key species through time?
- What are the benefits of developing time series of age data from any of the key species?

The focus of this work was on the four target species, 2+ and 3+ snapper, red gurnard, John dory, and tarakihi.

Snapper

The SNA 8 stock includes the west coast from North Cape down to Mana Island, off Porirua Harbour. The existing trawl survey boundaries (as per the 1994 and 1996 surveys) cover the area down to New Plymouth only, leaving the southernmost area unsurveyed. During the series, snapper were in general more abundant in the upper half to two-thirds of the survey area. Most of the targeted commercial effort for snapper in SNA 8 is aggregated off the coast around the Manukau and Kaipara Harbour entrances.

There was some indication that juvenile snapper may be more abundant in the general vicinity of coastal harbours (e.g., figure 3, Morrison 1998). Fish, in particular juveniles, may also be present at higher abundances within the harbours of this coast (e.g., Hokianga, Kaipara, Manukau), but no empirical data are available to support or refute this contention. Snapper are most commonly caught in inshore waters of northern New Zealand, with rapidly declining catch rates with increasing water depth, down to a maximum of about 200 m (Anderson et al. 1998). The higher catch rates within the west coast time series are in the shallower strata of less than 50 m water depth. There was no obvious spatial variation in catch rates between different years. The historical survey boundaries have been quite variable due to changes in latitudinal extent between years, and a lack of sampling in some strata in some years due to poor weather conditions or other factors. This limits the calculation of 2+ and 3+ indices to a core area of the survey area. In addition, waters less than 10 m in depth are unable to be worked by the survey vessel, and snapper within this zone and in estuaries are not included in survey estimates.

Trawl survey year class strength estimates for 2+ and 3+ snapper have been variable over time. Associated c.v.s have been generally acceptable (10–31%, Annala et al. 1999). 0+ and 1+ snapper numbers can also be estimated from the time series, but are not currently used in the modelling of the stock. For these age classes in particular, a proportion of the population may be unavailable to the sampling gears through possibly being located within the large harbours of the west coast. Despite this, good estimates of snapper year class strengths as 0+ and/or 1+ fish would improve the lead in time of models before such fish recruited to the fished population. It would also allow for more year class strengths to be estimated per survey, which has the potential of providing a greater information return per survey, and perhaps reducing the required frequency of surveys, for snapper at least. Current associated c.v.s are imprecise (0+, 56–100%; 1+, 54–82%), but could be improved in future surveys.

Commercial catch-at-age data have been collected for SNA 8. Results from the 1998–99 fishing year found the 1995 year class to be strong (40% of single trawl catch) and the 1992 year class to be particularly weak (Walsh et al. 1999). The 1993 and 1991 year classes, identified as being strong in previous commercial catch sampling, now contribute only 25% of the single trawl catch. Fish over 8 years of age account for only 13% of the catch (1990 year class or earlier).

Trawl survey estimates show 1991 to have produced a particularly strong year class, but the 1993 year class was average. The 1992 year class strength fell in the lower range of trawl survey indices. The 1995 year class was relatively abundant in the 1996 survey as 0+ fish.

Commercial CPUE analyses carried out on pair trawl data for 1974–97 show a general increase since about 1990 (Davies et al. 1999). The west coast North Island trawl series indices of recruited snapper biomass presented in this report (FMA 8 and FMA 9) do not exhibit any detectable trend through time, suggesting that for larger snapper this series does not track possible change in recruited biomass well. Trawl surveys are acknowledged to be inefficient at capturing larger snapper, which are likely to out-swim the gears and escape.

At the present time it is difficult to assess what the frequency of trawl surveys on the west coast should be for juvenile snapper. Ideally it would be good to develop some form of environmental-recruitment relationship for snapper, similar to that used in the Hauraki Gulf, so that trawl surveys could be targeted at predicted strong or weak year classes to further improve the robustness of such a relationship (Annala et al. 1999). In the absence of such a model (and to posssibly enable one to be developed in the future), the current regime of surveys at three year intervals could be changed to a biennial status. This would provide an estimate of year class strength for all recruiting fish, as either 2 or 3 year olds. It is critical to continue to collect adequate numbers of otoliths during each survey to generate good age-length keys as proportions-at-age have been shown to change between years, perhaps due to interannual changes in growth rates.

Red gurnard

The GUR 1 stock includes the west coast of the north island down to the Taraniki Bight, up around North Cape, and down to East Cape. During the surveys, red gurnard were caught throughout the survey area, with no clear spatial patterns with latitude. Gurnard are most commonly caught throughout New Zealand in waters less than 100 m depth (see Anderson et al. 1998), and the main fisheries operate in less than 100 m (MFish unpubl. data, quoted in Beentjes & Stevenson 2000). The minimum inshore water depth for the west coast surveys is 10 m; gurnard in areas shallower than this are not included in survey estimates. The proportion involved is unknown but is unlikely to be large. All the west coast component of GUR 1 appears to be adequately covered by the current survey extent, along with the northern portion of GUR 8.

Total biomass estimates show no trends over the time series. Coefficients of variation achieved for both FMA 8 and FMA 9 have tended to be good (less than 20%), although some years have been higher. Juvenile size modes were not readily apparent in the time series. Hanchet et al. (2000) found differences in the age and size structure of gurnard along the North Island coastline. Fish from the west and north of the North Island were dominated by 20–30 cm long fish (2 and 3 year olds). Hanchet et al. 2000 used age-length information to determine the biomass of 1+ gurnard, and found large differences in biomass between years. Coefficients of variation were variable (FMA 9, 21–42%; FMA 8, 39–52%). West coast populations in 1994 and 1996 displayed a dominance of younger male fish, with high numbers of 2+ fish in both years. Females had a wider range of ages.

The trawl survey index of abundance has been used in a stock assessment of GUR 1 W (west coast component of GUR 1) (Hanchet et al. 2000). The model used fitted the trawl data reasonably well, and this, in combination with the agreement with the CPUE analyses, showed that the west coast trawl time series is providing a useful index of abundance for this stock.

In summary, the trawl survey appears to cover most of the west coast component of GUR 1, and there was no evidence of strong spatial variation between years. In the recent stock assessment for this area it was recommended that proportion-at-age and 1+ estimates for the trawl series would allow the estimation of year class strength and could improve future assessments by allowing a better fit to the abundance indices (Hanchet et al. 2000). They also noted that until modelling was carried out, an appropriate frequency of trawl survey indices could not be assessed.

John dory

The JDO 1 stock extends from Tirua Point on the west coast, around North Cape and down and across to East Cape. The survey boundaries cover the west coast component of this stock, and the northern part of the west coast part of JDO 2 down to New Plymouth (Airedale Reef). As per the other species examined in this report, that proportion of the stock in less than 10 m was not accessible to the surveys.

During the series, John dory were caught throughout the survey area. Some variation between years in terms of the proportion of strata containing no John dory was apparent, with 1994 having few to no fish being caught at shallower stations south of the Manukau Harbour. John dory are most commonly caught in waters less than 250 m, with a step decline in the proportion of tows in which it occurs as water depth increased (Anderson et al. 1998).

Total biomass estimates were consistent between surveys for FMA 9 for the period 1986–94, but increased sharply in the 1996 survey. Coefficients of variation on these estimates varied in their precision from 10 to 47%. Biomass estimates for FMA 8 were also stable, although the associated c.v.s were higher (25–62%). The John dory population length frequency consistently had two general size modes of fish, split at 30 cm length. Considerable uncertainty exists over the ageing of John dory, but examination of length frequency data by Horn et al. (1999), indicated a mean length of 20 cm at age 1 for both sexes, and mean lengths of 34 and 36 cm for males and females respectively at age 2. Above this size, age estimates remain difficult to determine.

A standardised CPUE index using single bottom trawl data from 1990–97 for JDO 1W (JDO 1 west coast component) showed a decline through the series (Horn et al. 1999), which is not consistent with the trawl series. The trawl series data for JDO 1W and JDO 2W were found to be useful in the first stock assessment using a population model. The availability of year class strength data would greatly enhance the usefulness of the trawl survey indices of abundance (Horn et al. 1999).

The trawl survey appears to cover most of the range of the JDO 1 (W) stock, and the northern part of the western part of JDO 2. The consistency of the biomass indices a fairly stable population. Problems with ageing this species need to be solved, but likely estimates of maximum age are 4 or 8 years (Horn et al. 1999). Given the very stable biomass estimates over time, and the moderate levels of recruitment variation, trawl surveys every three years are probably sufficient to monitor JDO stocks.

Tarakihi

The TAR 1 stock includes the west coast of the North Island from Tirua Point up around North Cape and down and across to East Cape. The component of the TAR 8 stock contained between Tirua Point and New Plymouth is also covered by the survey. Only the 1996 survey had tarakihi specified as a target species.

Non-target species

Although the focus of the surveys was on the three target species (four with the inclusion of tarakihi in 1996), other species were also examined to determine whether the survey is useful for monitoring them. In this analysis we have focussed mainly on the consistency of the biomass indices and the length frequency distributions between years, and on the precision of the indices (c.v.s).

Elasmobranchs

Elasmobranches tend to be reasonably long lived with low recruitment variability and so would be predicted to have consistent biomass estimates between years. During the series, the biomass estimates of rig, school shark and spiny dogfish each varied over an order of magnitude. Although some of their c.v.s were acceptable (e.g., 17–31% for rig in FMA 9), the trawl surveys do not appear to be useful for monitoring their abundance, given the substantial biomass variations between surveys.

For all three species, little useful information appears to be available in the length frequency data. It is likely that for both rig and school shark the larger fish in the population are under-represented when sampled with the bottom trawl gear.

Barracouta

Biomass estimates of barracouta were highly variable between years and had high c.v.s. Variations of 9–11 fold between survey years were present in FMA 9, and to a lesser extent in FMA 8. This may have been related to variable seasonal migration into and out of the survey area for spawning in late winter/early spring (Hurst & Bagley 1989). Juvenile fish were caught only in low numbers, suggesting a limited usefulness of this data in any year class strength indices.

Trevally

Biomass estimates of trevally varied over an order of magnitude for both FMA 8 and FMA 9 between surveys. Associated c.v.s. were high (20–63, 39–56% respectively). Variability in recruitment of 1+ and 2+ fish was high in both FMA 9 (0–5 t, c.v.s 48–100%; 0–41 t, c.v.s 46–100) and FMA 8 (0–89 t, 0–100%; 0–140 t, 15–69%). It is likely that the catchability of trevally may vary from year to year through influences from factors such as temperature and water clarity (Annala et al. 1999, Francis et al. 1999). Therefore recruitment indices should be regarded as uncertain. This uncertainty was allowed for in the stock assessment for this species (Hanchet 1999).

Single trawl commercial catch sampling in 1997–98 found evidence of recruitment variability, with the 1994 and 1985 year classes appearing strong, and the 1989 to 1992 classes being weak. This appears to correlate well with the trawl survey recruitment indices. Hanchet (1999) suggested that there was agreement in some years between the trawl survey data and proportion-at-age from the commercial catch, but that more years of ageing data were required before this relationship could be confirmed.

Conclusions and Recommendations

Snapper

- The main part of the SNA8 stock is adequately covered by the survey boundaries as they currently stand.
- Trawl survey year class strength estimates for 2+ and 3+ snapper appear to track changes in actual recruitment strength reasonably well.
- These estimates form an important input into the SNA 8 model.
- Year class estimates for 0+ and 1+ fish would be useful, and optimisations could be undertaken for future surveys to assess whether acceptable c.v.s on these classes are achievable.
- The value of surveys for determining the abundance of larger fish is questionable, although this was never their intention.
- It is important to continue to collect and process snapper otoliths for each survey to provide survey specific age length keys.
- Future surveys should continue at at least three yearly intervals, if not biennially, to provide year class strength estimates for fish as either 2+ or 3+ individuals.

Red gurnard

- All of the west coast component of GUR 1 appears to be adequately covered by the current survey extent, along with the northern portion of GUR 8.
- Commercial CPUE analysis of the west coast component of GUR 1 (GUR 1W) showed no trend through time, suggesting no recent changes in biomass for this stock, which is in agreement with the trawl survey series.
- The surveys appear to be monitoring both the pre-recruit and recruited components of the GUR 1W stock.

- Proportion-at-age and 1+ estimates for the trawl series would allow the estimation of year class strength and could improve future assessments by allowing a better fit to the abundance indices.
- An appropriate survey frequency for this species cannot be assessed until more stock modelling is carried out, but is likely to be at least every two to three years.

John dory

- It appears that the main part of the west coast component of GUR 1 is adequately covered by the survey.
- Recruitment and total biomass appear to be relatively stable, for both FMA 9 and FMA 8.
- A standardised commercial CPUE showed a decline, which is not consistent with the trawl series.
- The trawl series data for JDO 1W and JDO 2W were found to be useful in the first stock assessment of John dory using a population model.
- The availability of year class strength data would greatly enhance the usefulness of the trawl survey indices of abundance.
- The surveys appear to be monitoring both pre-recruit (1+) and recruited biomass with moderate c.v.s.

Tarakihi

- The existing survey boundaries cover the west coast component of this stock.
- Only the 1996 survey had tarakihi specified as a target species, and it is too soon to assess whether the trawl series is useful in monitoring the status of the stock.

Acknowledgments

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Table 1 : **Survey variables for the WNCI time series, 1986–96.**

	KAH8612*	KAH8715	KAH8918*	KAH9111**	KAH9401	KAH9615
Dates	15 Oct–27 Oct	30 Oct–7 Nov	26 Nov–13 Dec	10 Nov–9 Dec	6 Oct–22 Oct	15 Oct–3 Nov
Total survey area (km^2)	13 437	9 493	16 532	34 636	15 190	21 897
Total stations	79	56	92	108	75	124
Core area stations	48	51	45	36	47	57
Mean distance towed	1.00	0.99	1.50	1.50	1.50	1.51
Mean headline height	-	5.00	5.04	6.05	5.99	6.16
Mean door spread						
10–50 m water depth	-	70.6	80.1	81.0	79.7	81.0
51–100 m water depth	-	80.3	84.6	85.9	84.3	80.6

* survey extended around North Cape into Northland
** survey extended down coast to Wellington
All gear values given are for core area stations only

Table 2 : **Estimated total biomass (t) and coefficient of variation (c.v. %) for the major commercial species.**

FMA 9	KAH8612		KAH8715		KAH8918		KAH9111		KAH9410		KAH9615	
	Biomass	*c.v.* (%)	Biomass	*c.v.* (%)	Biomass	*c.v.* (%)	Biomass	*c.v.* (%)	Biomass	*c.v.* (%)	Biomass	*c.v.* (%)
Barracouta	185	33	2 062	86	191	47	172	62	138	70	1106	46
Jack mackerel												
JMA (generic)	1 226	30	61	74	1 544	34	310	40	143	95	392	79
declivis	–	–	–	–	–	–	–	–	–	–	43	90
novaezelandiae	–	–	81	74	–	–	–	–	415	31	1 176	60
murphyi	–	–	–	–	–	–	–	–	–	–	< 1	100
John dory	207	26	160	16	148	16	216	37	102	47	447	10
Red gurnard	1 763	16	2 022	24	1 013	12	1 846	23	2 498	30	1820	14
Rig	77	17	174	25	27	22	146	31	150	18	165	22
School shark	93	26	383	28	93	26	384	40	208	56	295	29
Snapper	132	32	718	26	424	15	617	26	369	19	740	34
Spiny dogfish	26	78	63	44	21	53	0		337	33	564	76
Trevally	91	36	105	63	360	20	406	43	98	32	117	32
FMA 8												
Barracouta					203	60	68	73	283	50	22	31
Jack mackerel												
JMA (generic)					672	41	232	49	76	62	0	0
declivis					–	–	–	–	–	–	14	45
novaezelandiae					–	–	–	–	364	61	219	37
murphyi					–	–	–	–	–	–	2	82
John dory					68	25	142	62	33	47	19	38
Red gurnard					628	15	817	9	685	22	370	37
Rig					16	42	44	32	106	90	8	45
School shark					58	30	579	69	17	48	12	32
Snapper					523	33	112	25	69	46	119	38
Spiny dogfish					13	60	5	80	570	26	44	34
Trevally					331	45	468	40	9	56	44	39

Notes on jack mackerel
"–" denotes that for a particular survey jack mackerels were not always identified down to species level, but to a generic code ("JMA").
KAH8612 - no catch weights available for 12 stations. Six strata with only one catch weight available.
KAH8715 - no catch weights for JMA from 38 stations, biomass estimate not reliable.

Table 3 : **Estimated pre-recruit 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	Age	KAH8612		KAH8715		KAH8918		KAH9111		KAH9410		KAH9615	
FMA 9	(cm)		Biomass	c.v. (%)	Biomass	c.v. (%)	Biomass	c.v. (%)	Biomass	c.v. (%)	Biomass	c.v. (%)	Biomass	c.v. (%)
John dory	< 29	1+	9	37	3	34	8	22	13	44	13	39	16	15
Red gurnard	10–20	1+	45	26	36	25	11	42	43	30	73	21		
Snapper	6–18	0+	1	55	6	59	3	73	3	56	*	100	10	81
	15–25	1+	36	82	112	65	9	54	66	57	81	45	150	49
Trevally	15–25	1+	5	86	1	51	*	48	*	100	1	86	4	74
	16–27	2+	41	67	5	97	*	100	18	46	*	100	36	83
FMA 8														
John dory	< 29	1+					2	30	1	77	1	63	*	64
Red gurnard	10–20	1+					9	39	6	52	3	47	3	44
Snapper	6–18	0+					0		*	100	0		*	100
	15–25	1+					0		4	81	1	72	10	65
Trevally	15–25	1+					0		0		*	100	*	100
	16–27	2+					0		6	67	0		3	69

* Less than 0.5 t

Table 4 : **Snapper year class strength (YCS) estimates.**

Year class	Number (000s)	Index	c.v.(%)
1984	166.4	0.82	27
1985	557.3	2.73	28
1986	158.9	0.78	10
1987	135.7	0.67	20
1988	35.9	0.18	37
1989	195.5	0.96	32
1991	258.5	1.27	15
1992	160.6	0.79	26
1993	190.1	0.93	31
1994	181.6	0.89	20

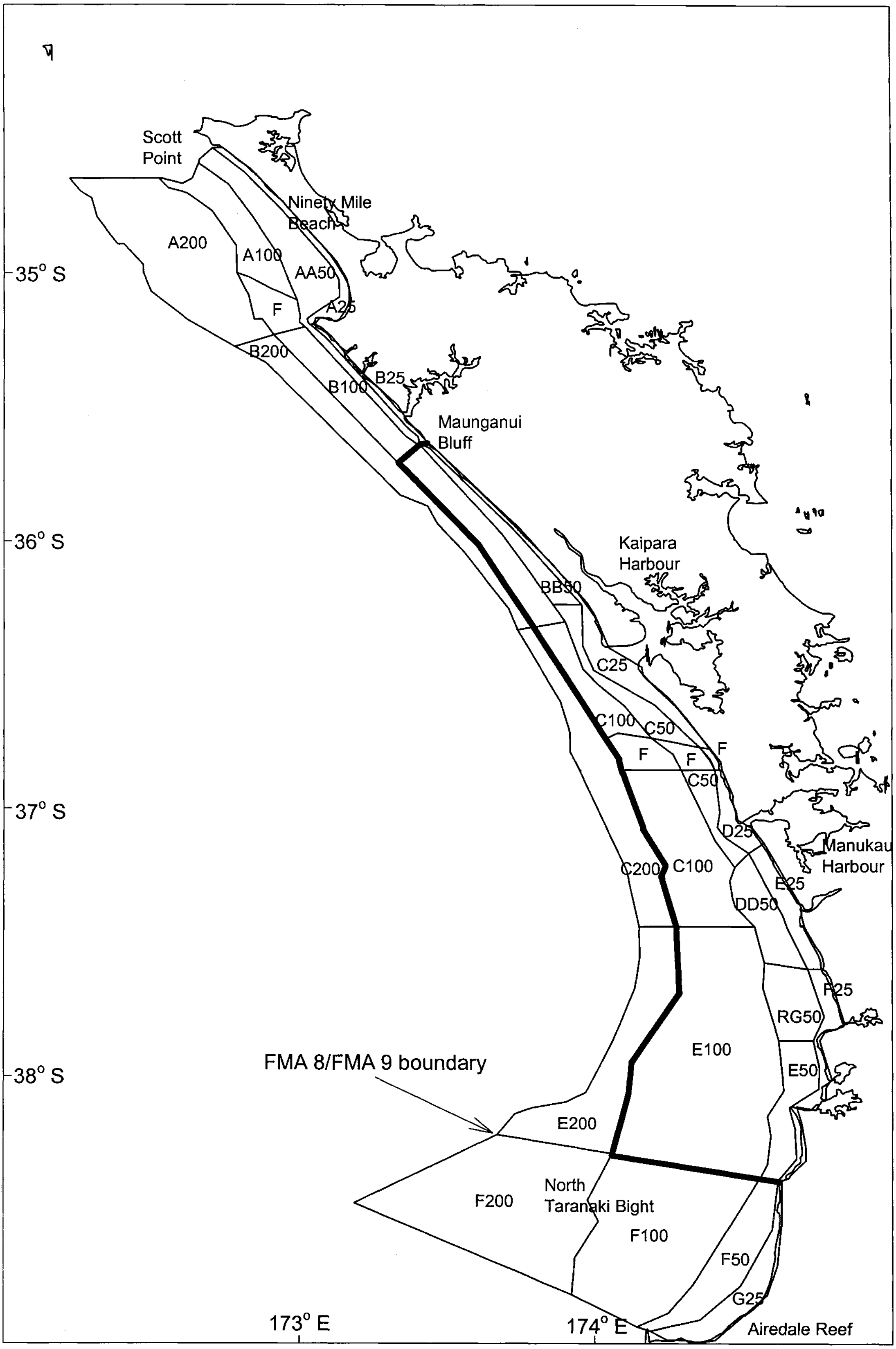


Figure 1: **Survey area and stratum boundaries as per 1996 survey (F, foul ground area). The thick line denotes the core area sampled in all surveys, and used for 2+/3 snapper year class strength estimation. Stratum codes denote relative position down the coast (A-G), followed by the depth zone i.e. 25, 10-25 m depth; 50, 26-50 m depth; 100, 51-100 m depth; 200, 101-200 m depth.**

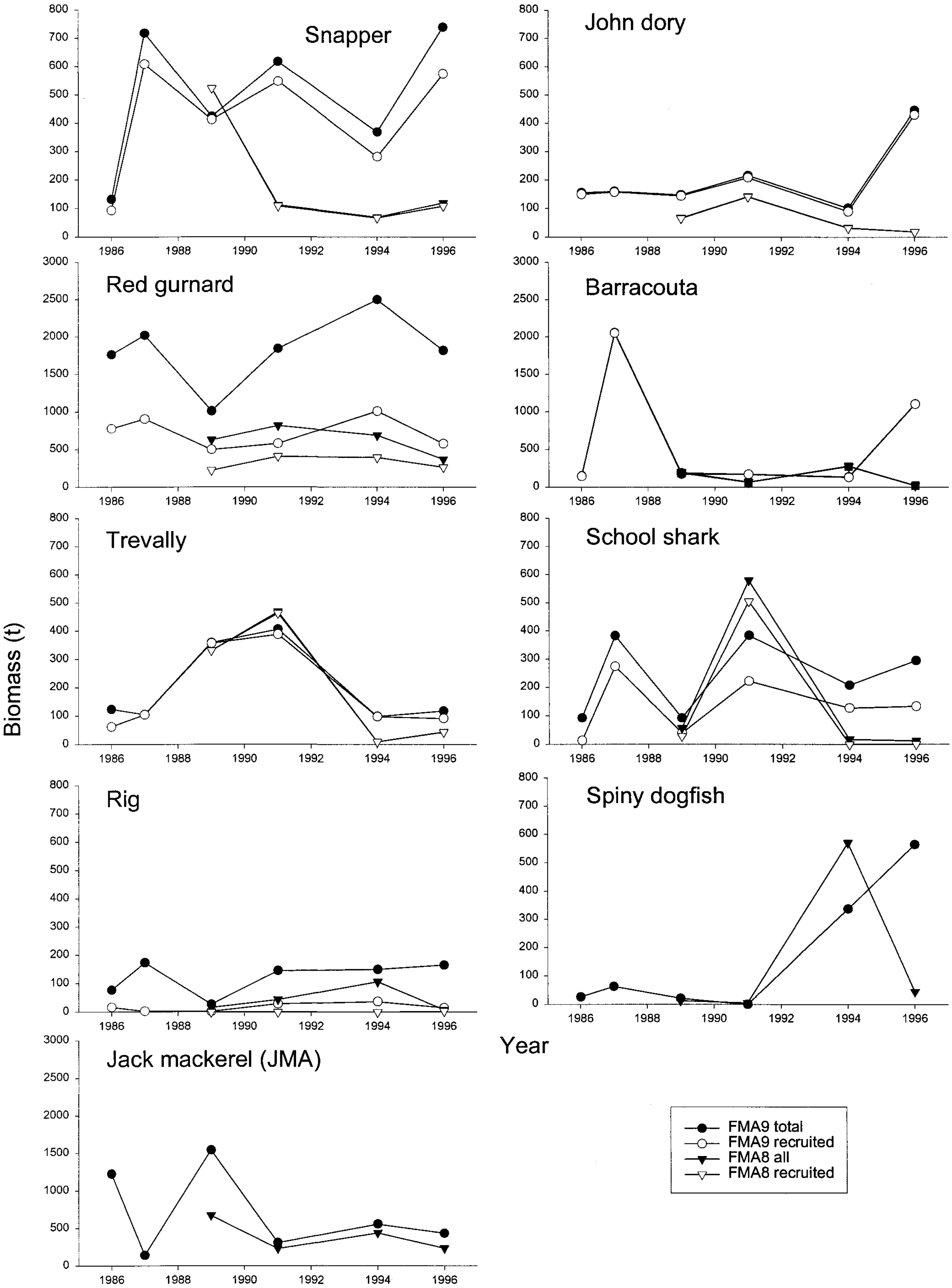


Figure 2: **Estimated biomass in FMA 9 and FMA 8 of the major species, 1986-96. Cut off points for recruited biomass are: snapper, > 25 cm; John dory, >25 cm; red gurnard, > 30 cm; trevally, > 25 cm; school shark, > 90 cm; rig, > 90 cm; spiny dogfish, no cut-off; jack mackerels (JMA), no cut-off.**

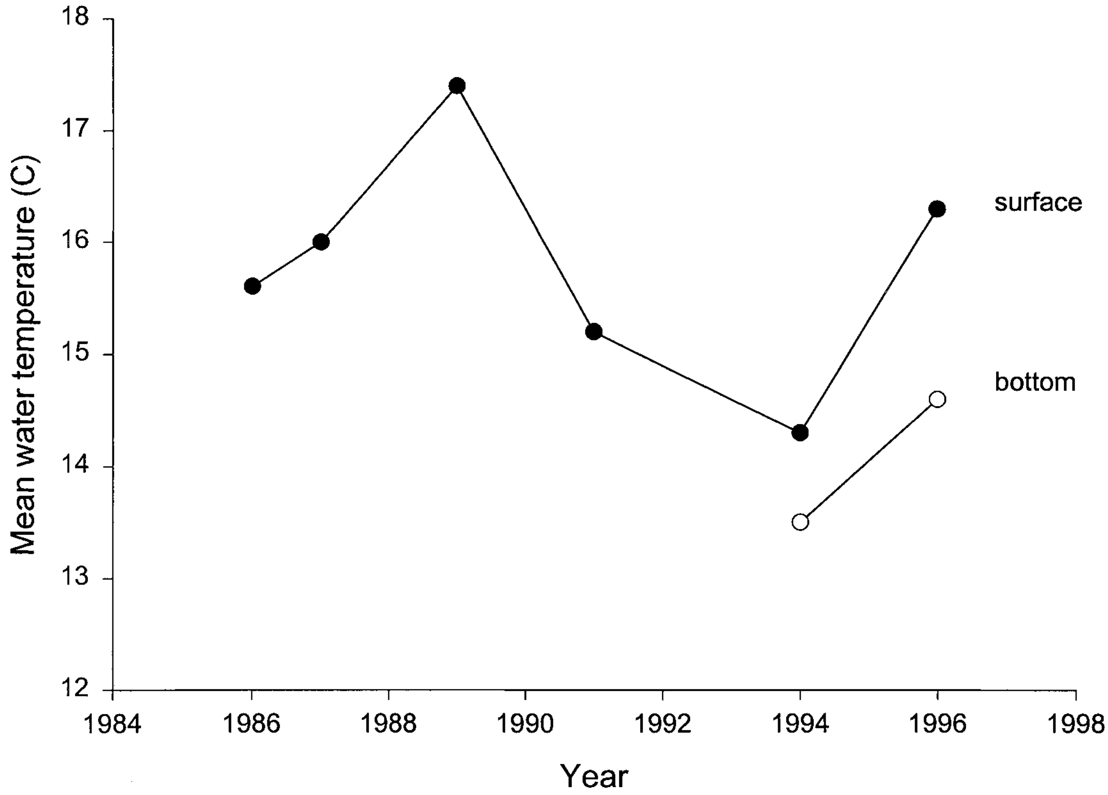


Figure 3: **Mean surface and bottom temperatures recorded during WCNI surveys.**

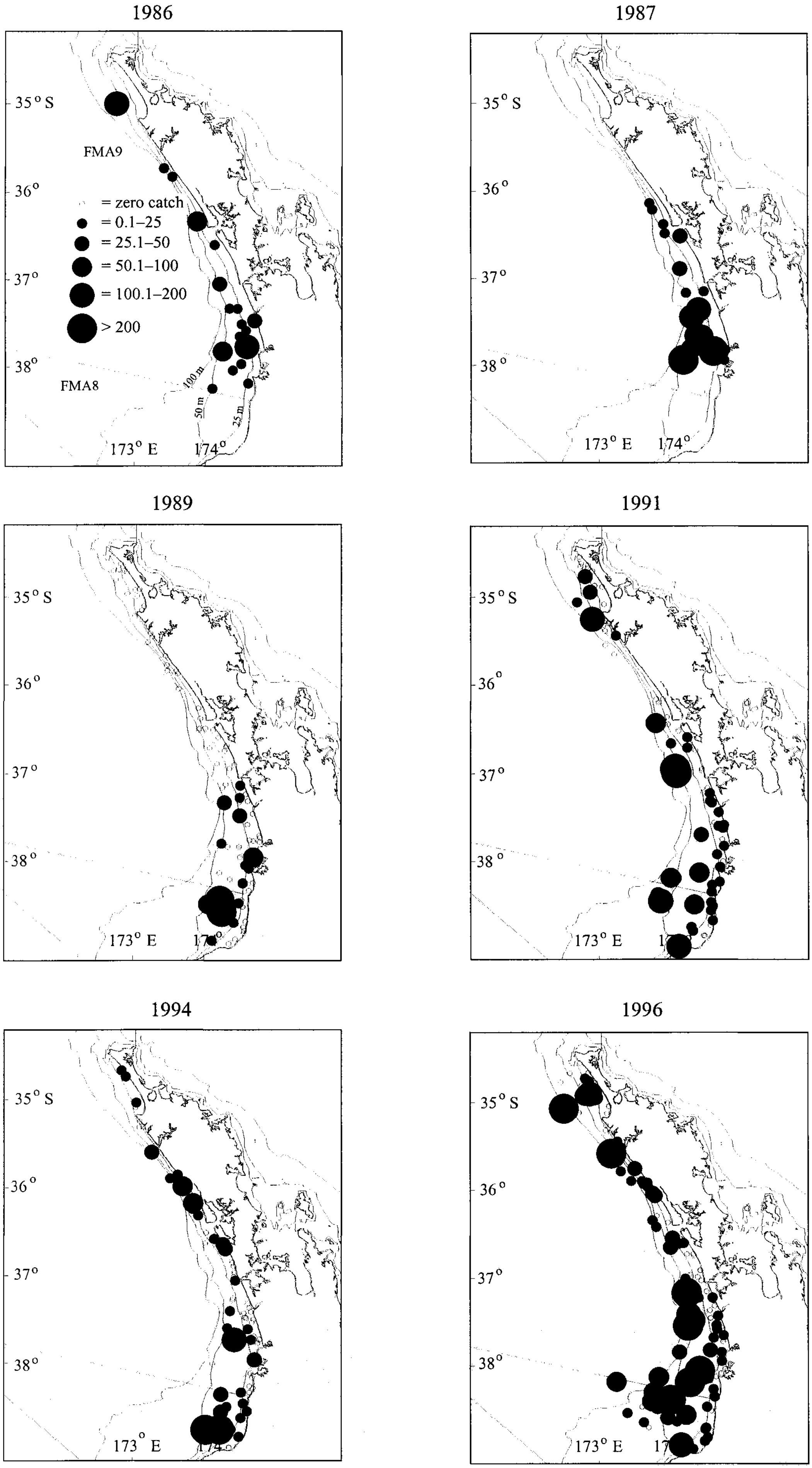


***Figure 4*: Distribution and catch rates (kg.km^{-2}) of the major species.**
a: Barracouta (maximum catch rate 2721.4 kg.km^{-2}).

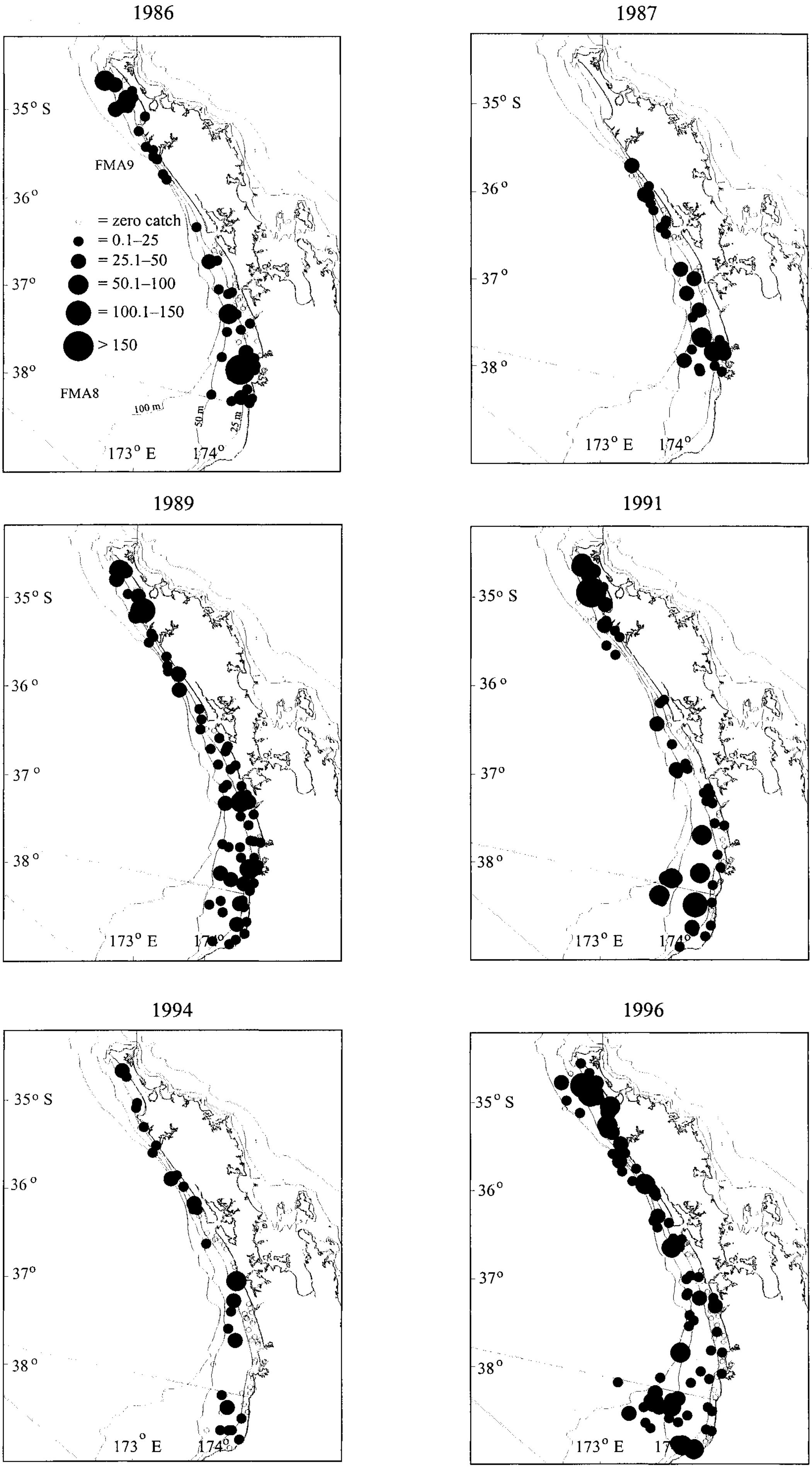


***Figure 4b*: John dory (maximum catch rate 317.3 kg.km^{-2}).**

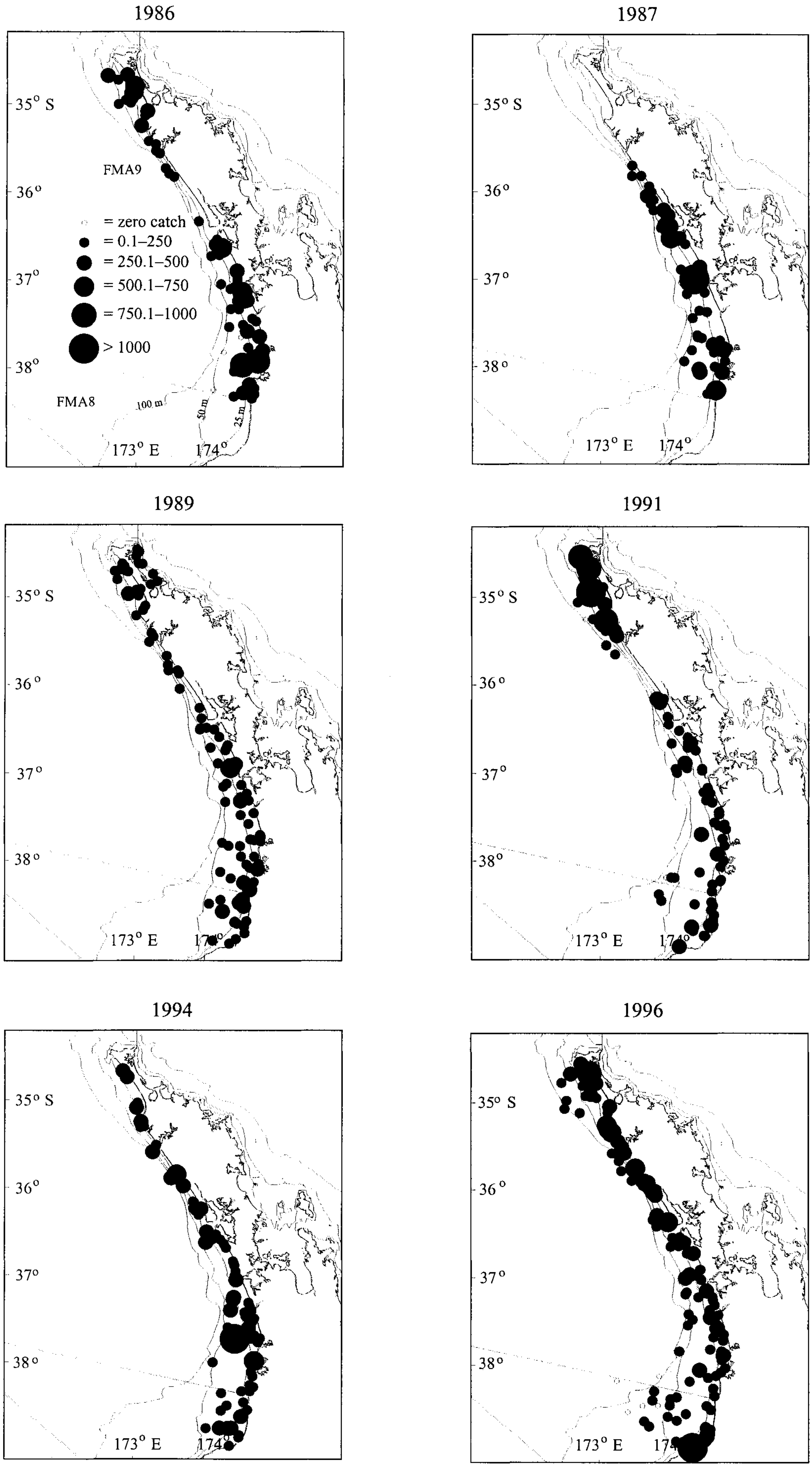


***Figure 4c*: Red gurnard (maximum catch rate 1594.7 kg.km^{-2}).**

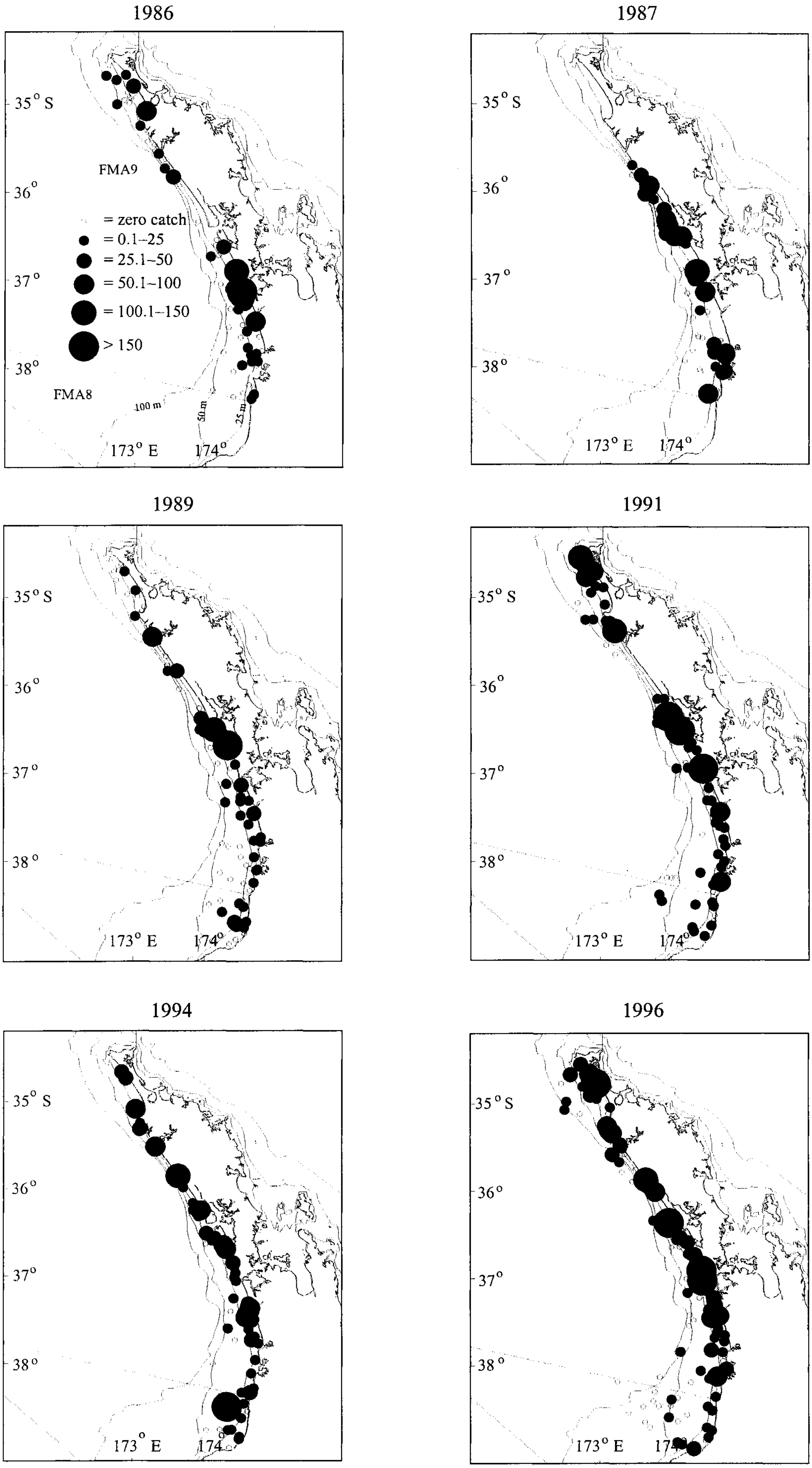


Figure 4d: **Rig (maximum catch rate 472.0 kg.km^{-2})**

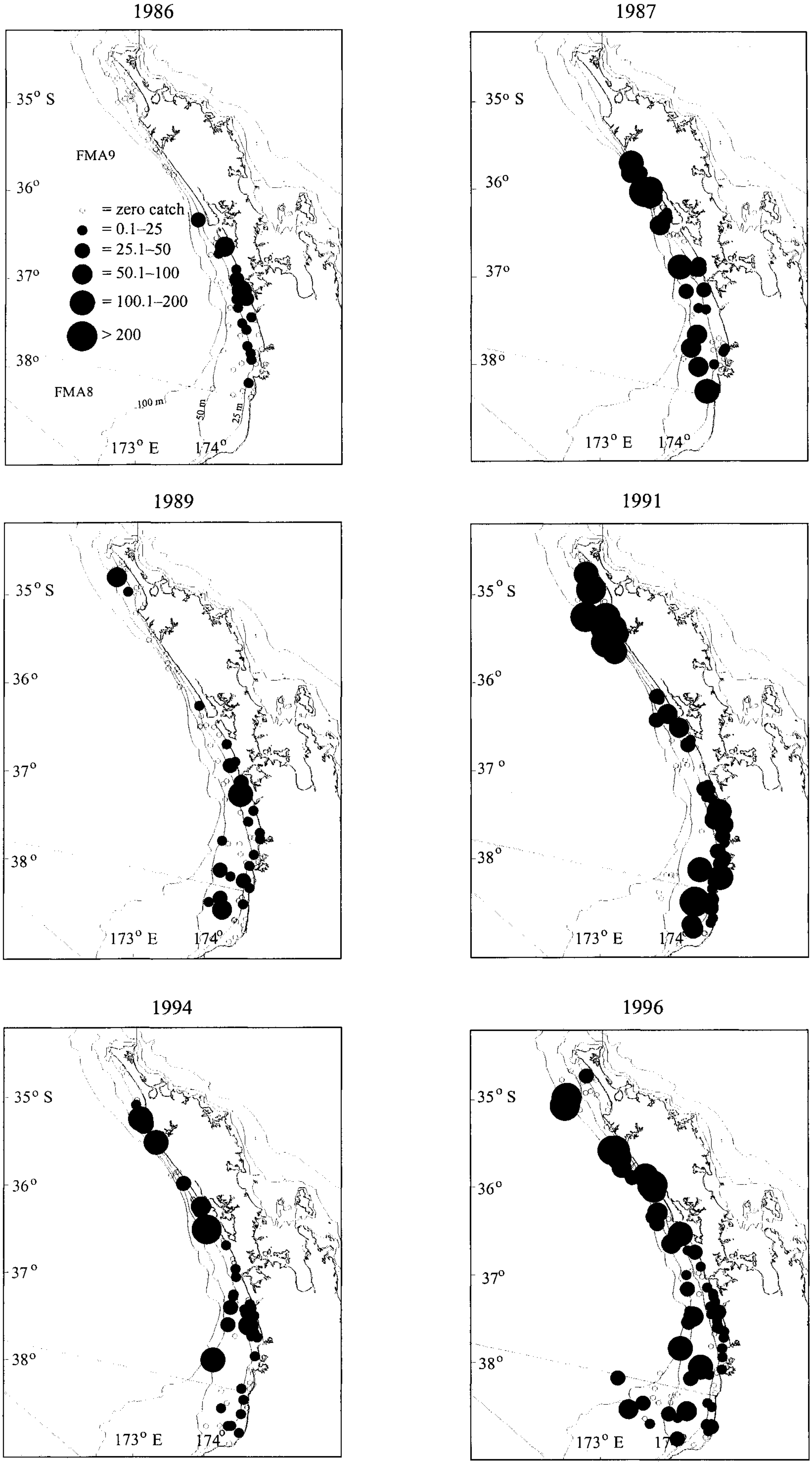


***Figure 4e*: School shark (maximum catch rate 1505.2 kg.km^{-2})**

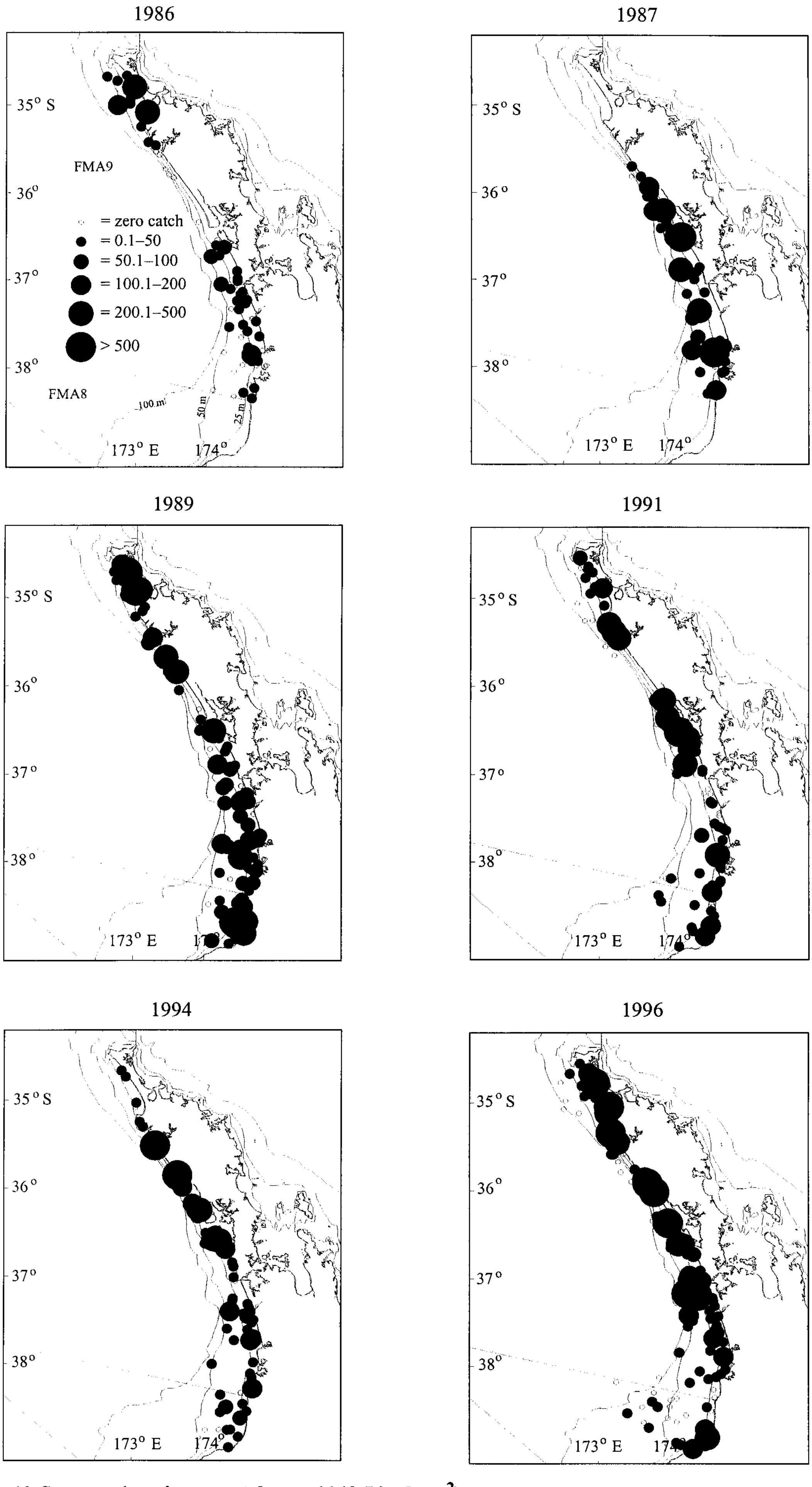


***Figure 4f*: Snapper (maximum catch rate 1140.5 kg.km^{-2})**

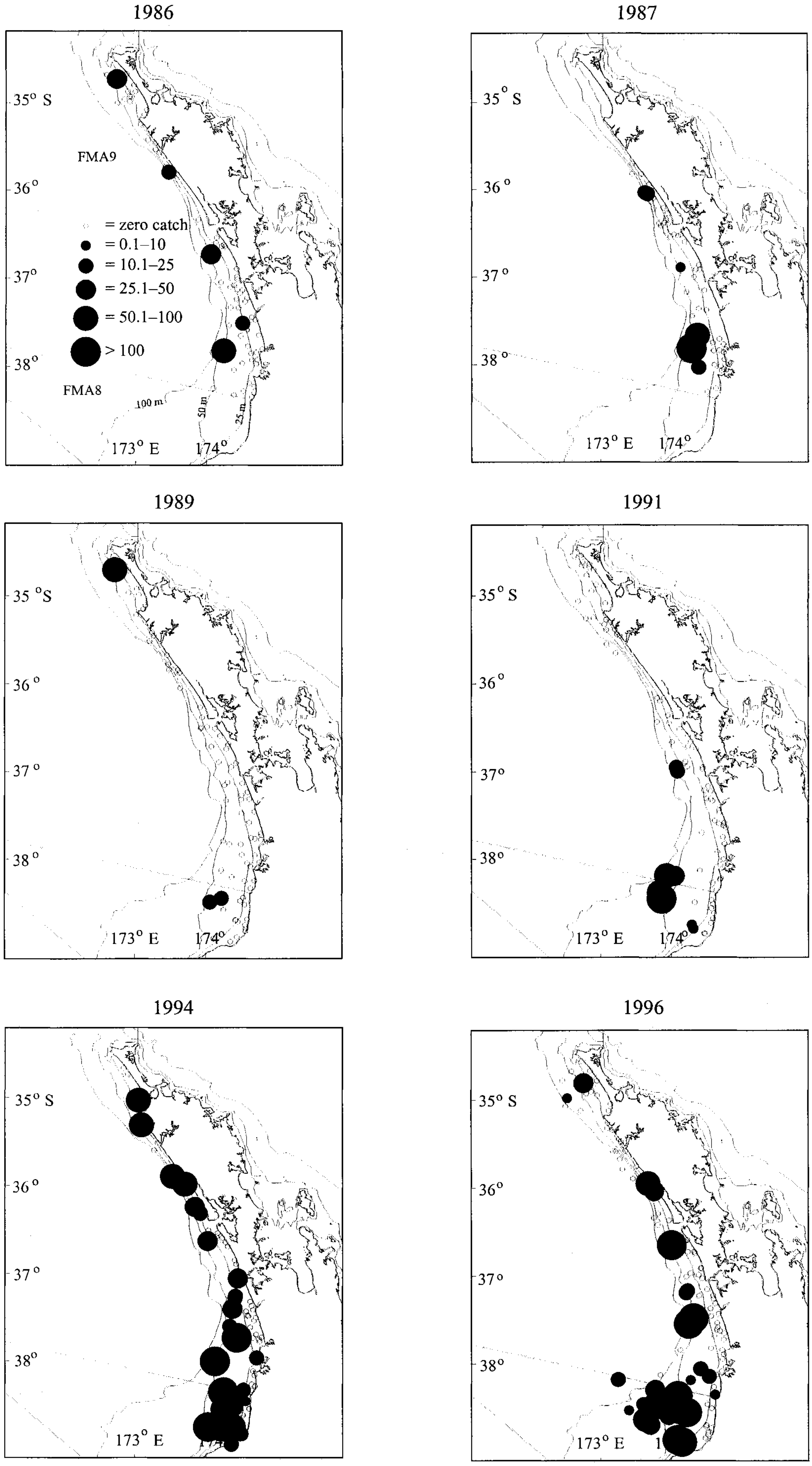


***Figure 4g*: Spiny dogfish (maximum catch rate 1196.5 kg.km $^{-2}$)**

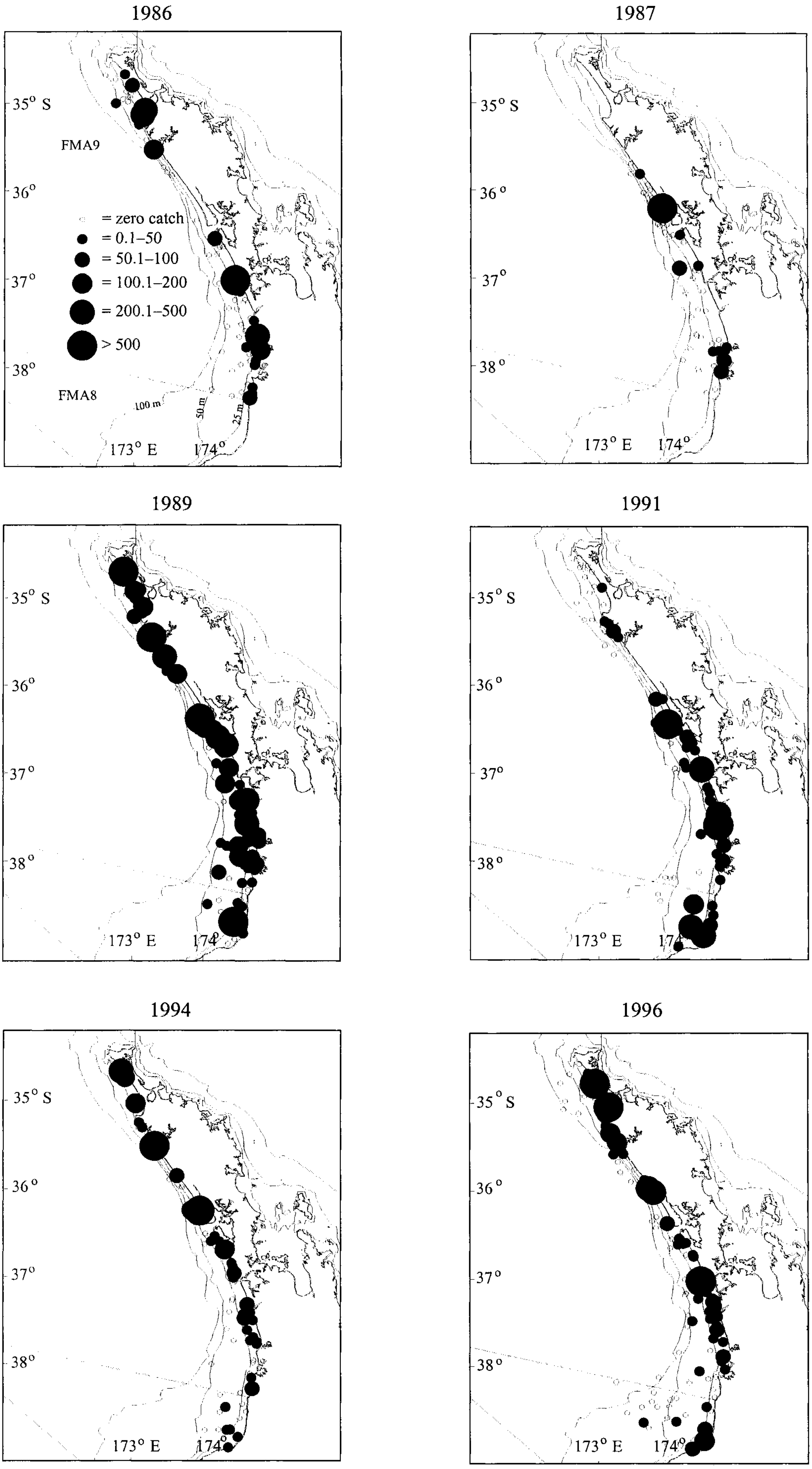


***Figure 4h*: Trevally (maximum catch rate 3350.7 kg.km^{-2})**

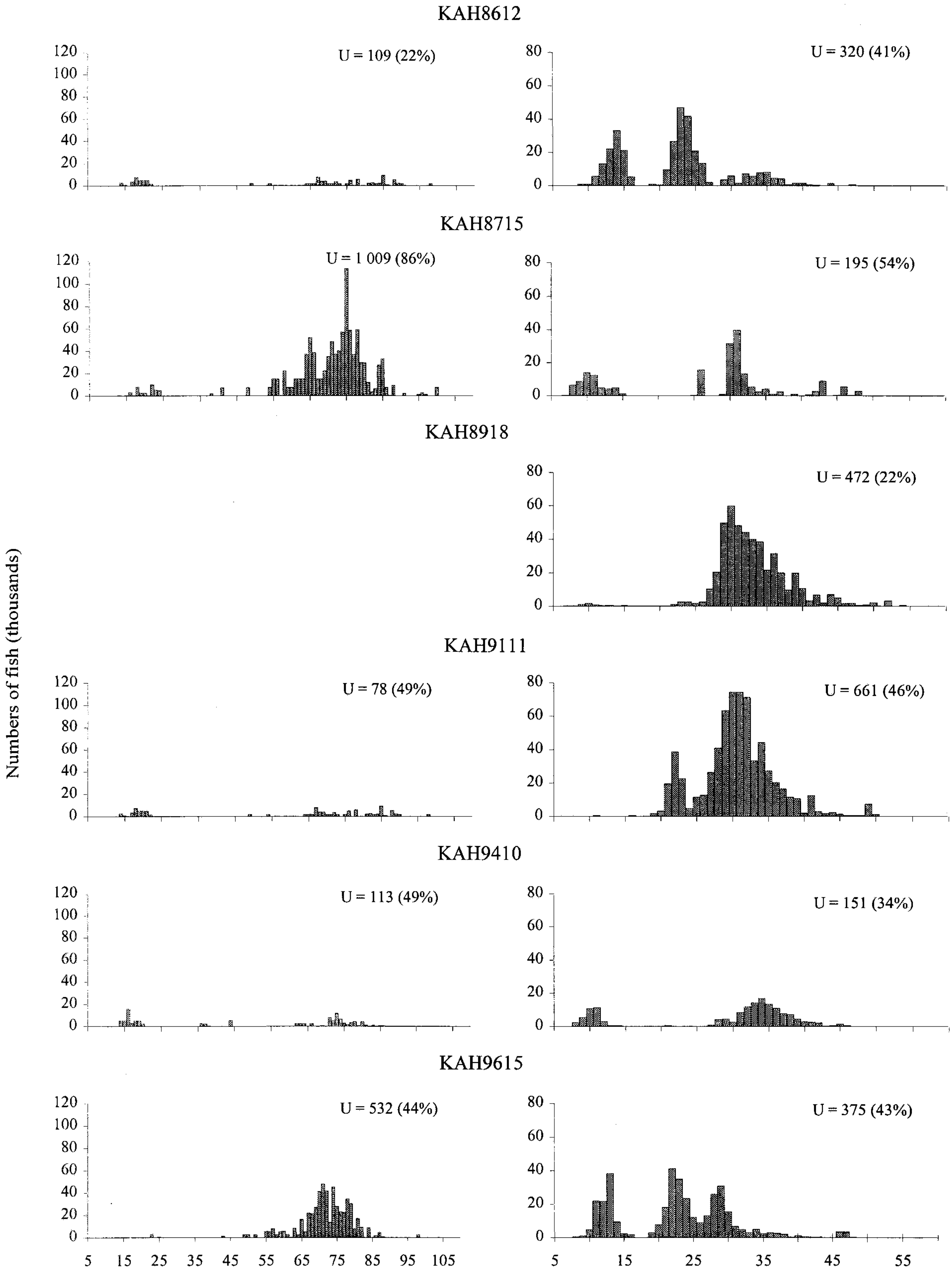


Figure 5a**: Scaled length frequency distribution of the major species (FMA 9) 1986–96, with the estimated total number of fish in the population (and percentage coefficient of variation). M, number of males; F, number of females; U, number of unsexed fish (shaded) measured.**
a: Barracouta (left) and trevally (right)

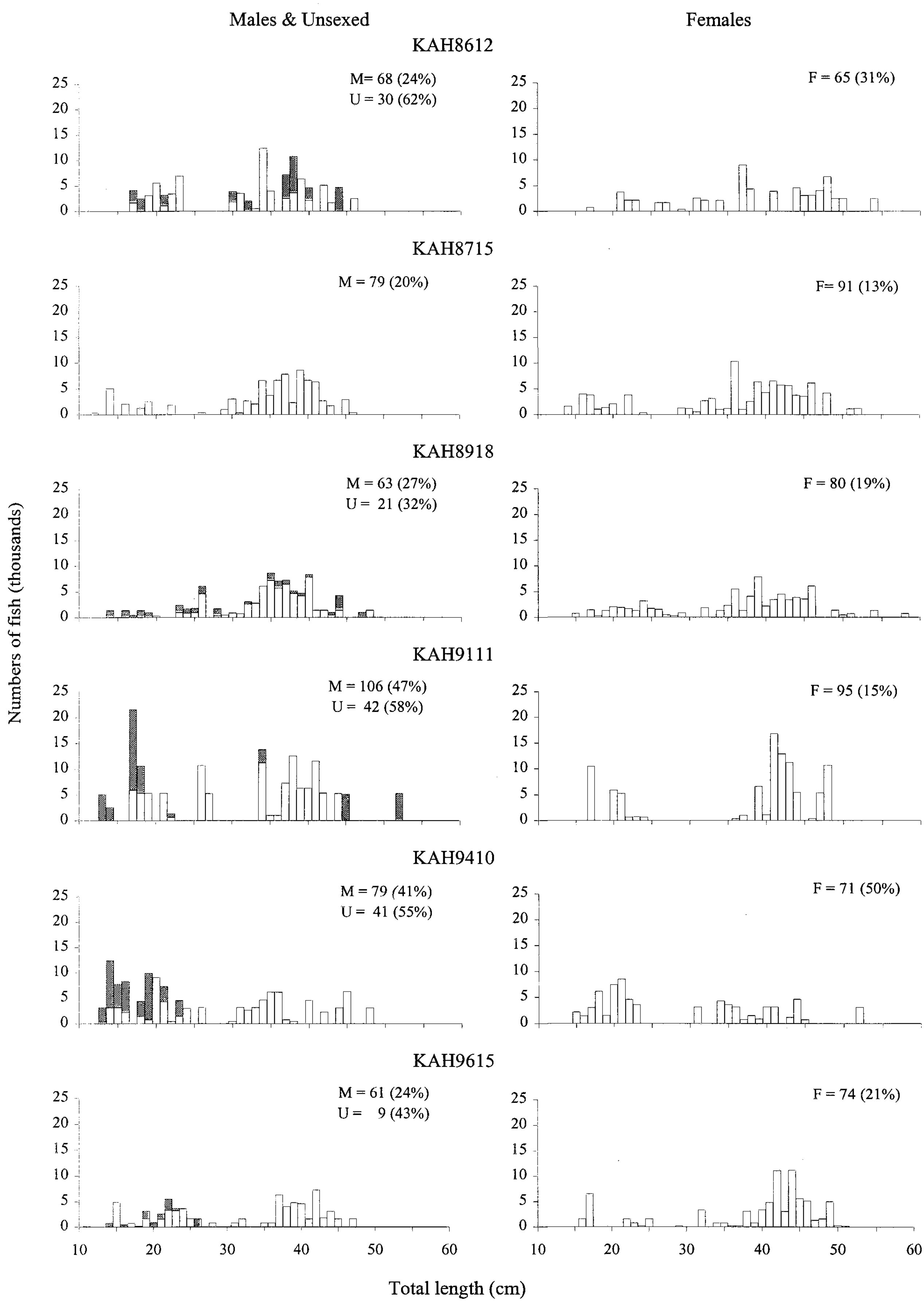


Figure 5b **: John dory**

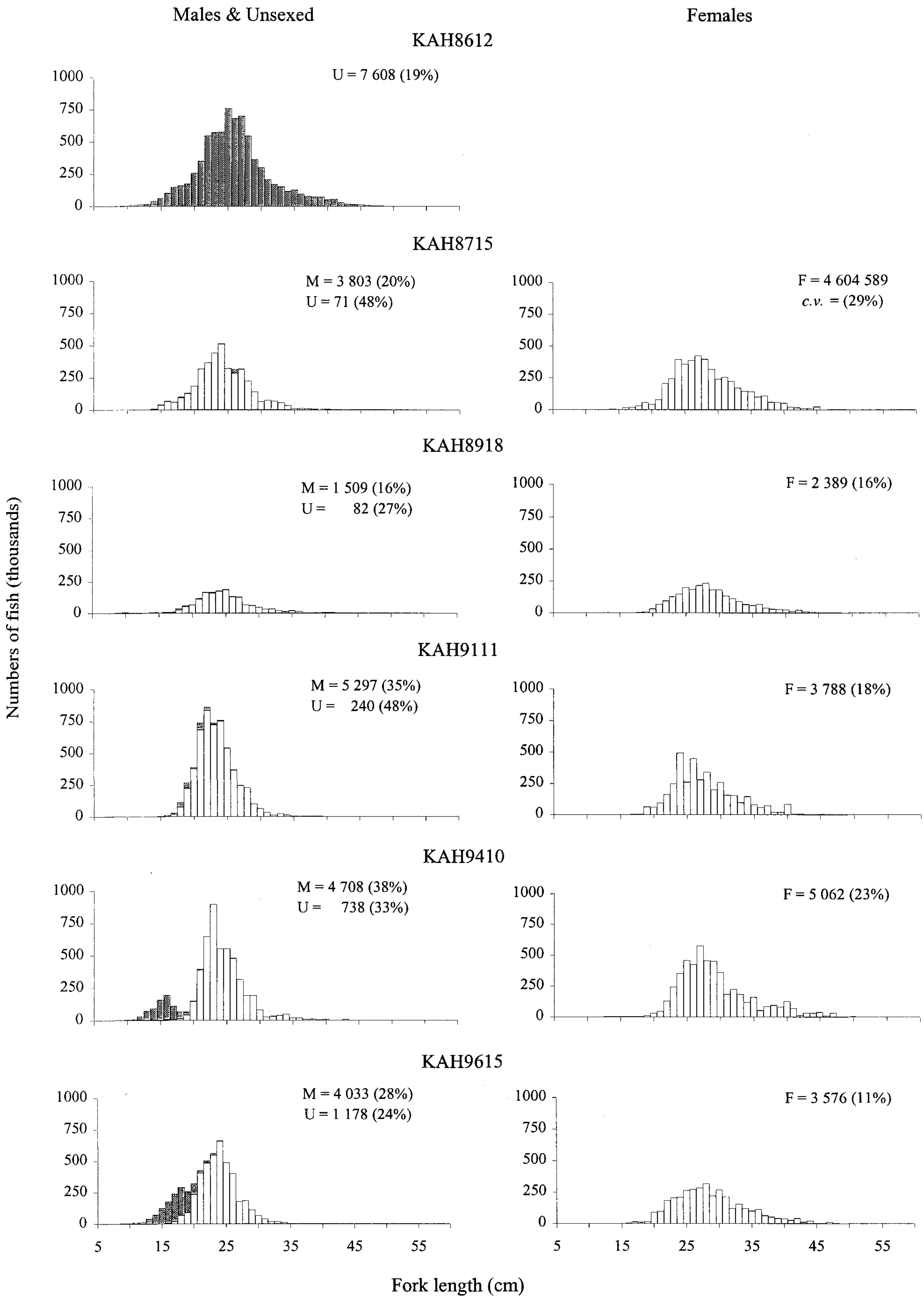


***Figure 5c*: Red gurnard**

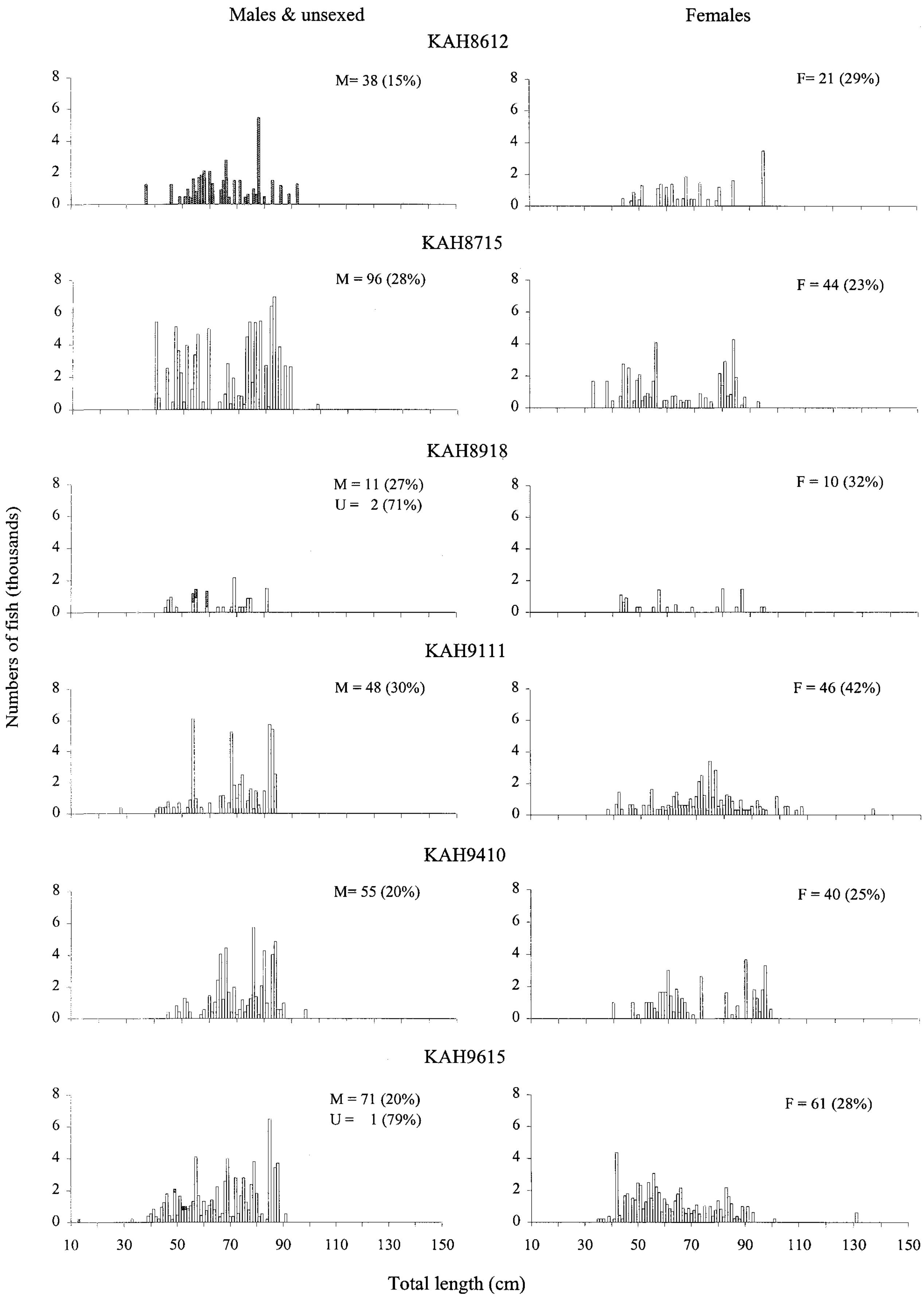


***Figure 5d*: Rig**

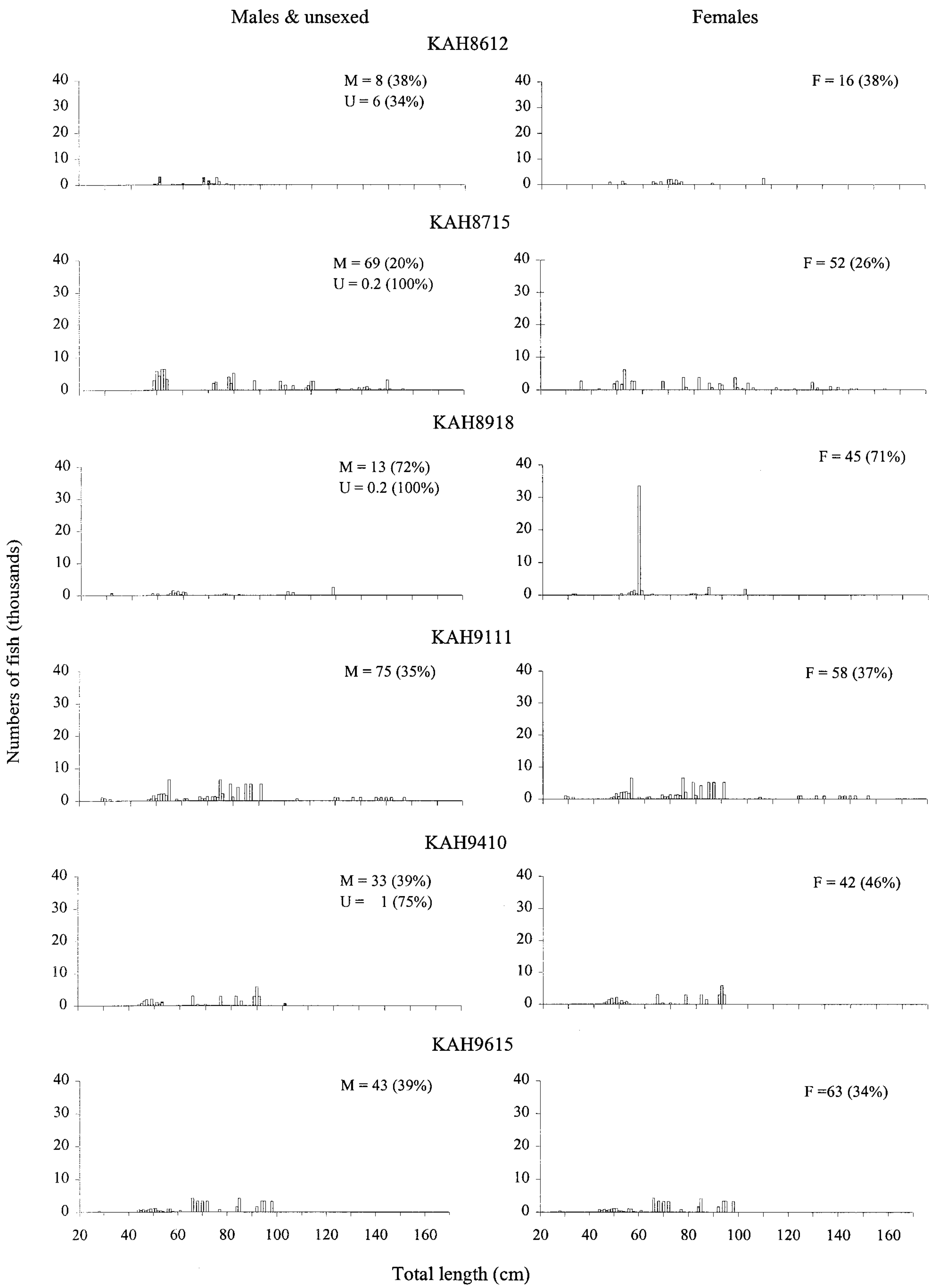


Figure 5e **: School shark**

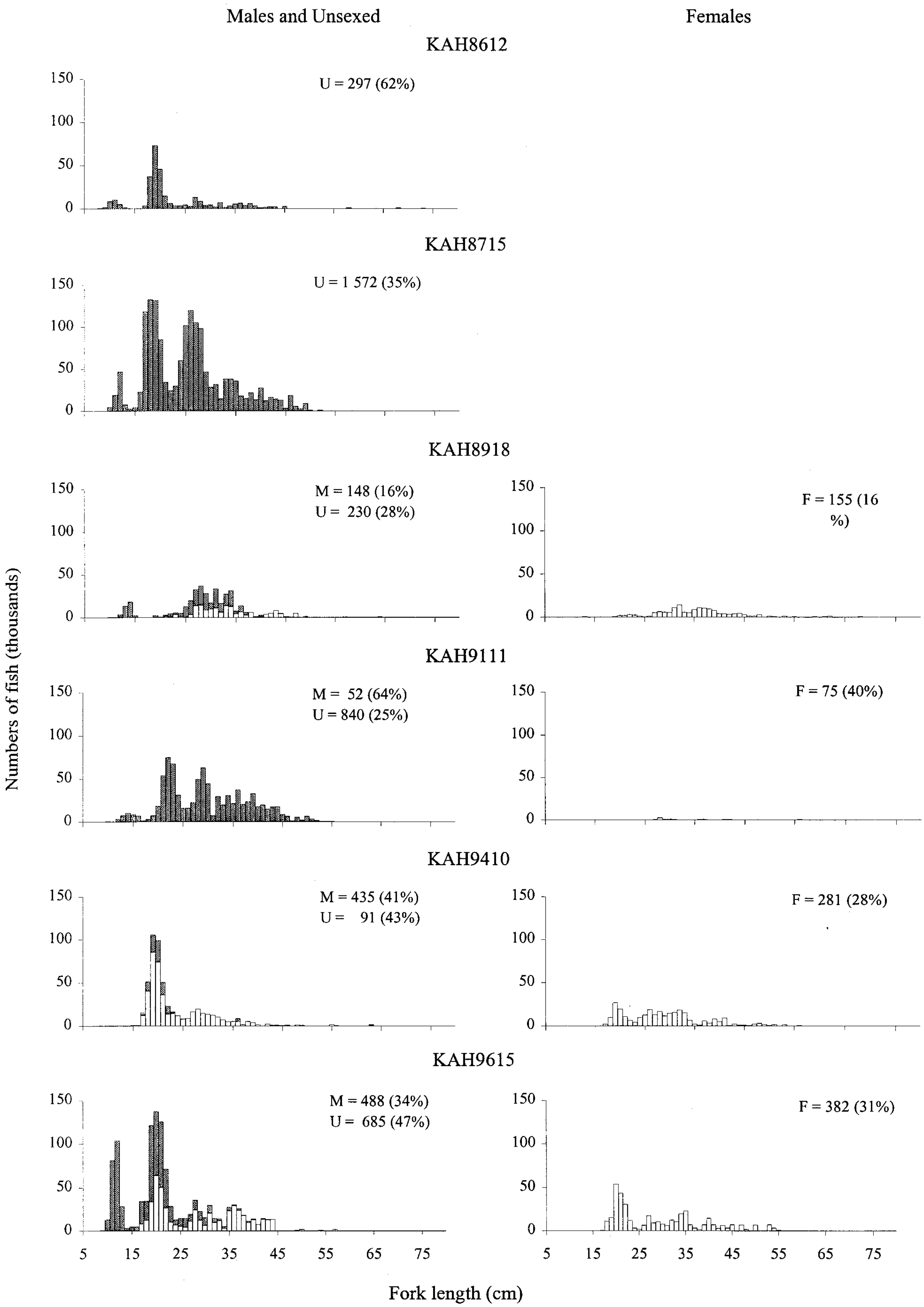


***Figure 5f*: Snapper**

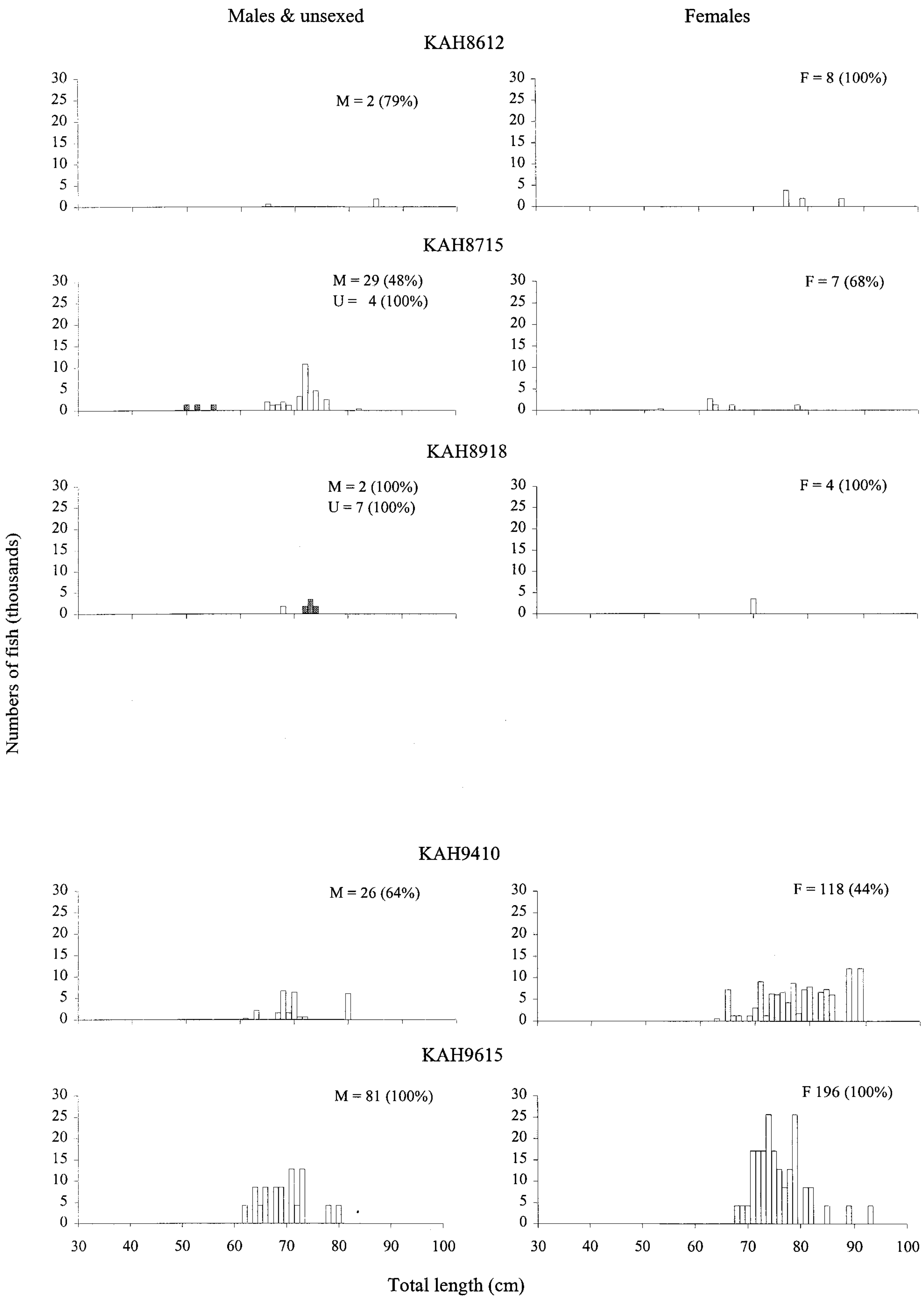


***Figure 5g*: Spiny dogfish**

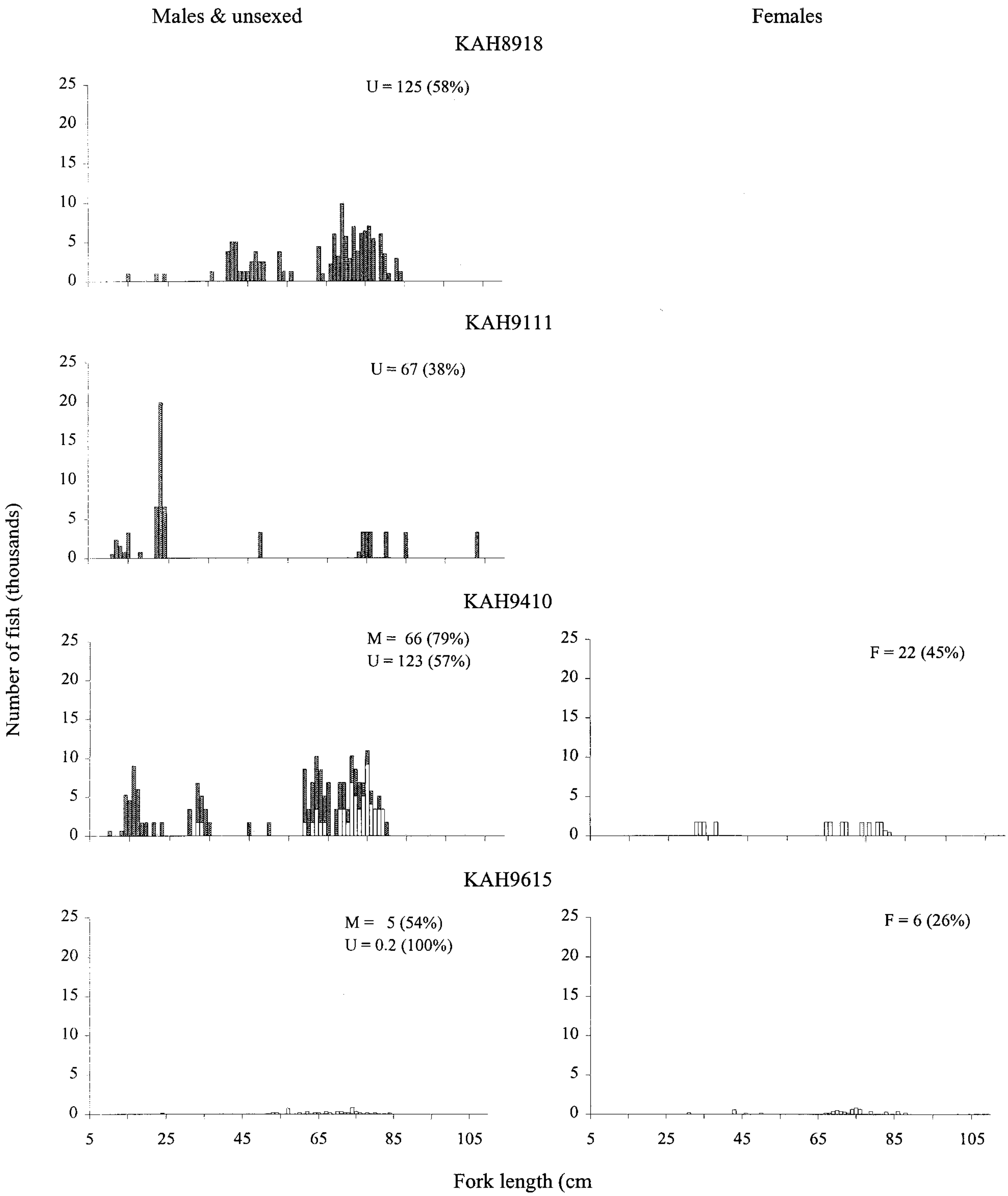


Figure 6a **: Scaled length frequency distribution of the major species (FMA 8), 1989–96, with the estimated total number of fish in the population (and percentage coefficient of variation). M, number of males; F, number of females; U, number of unsexed fish (shaded).**
a **: Barracouta**

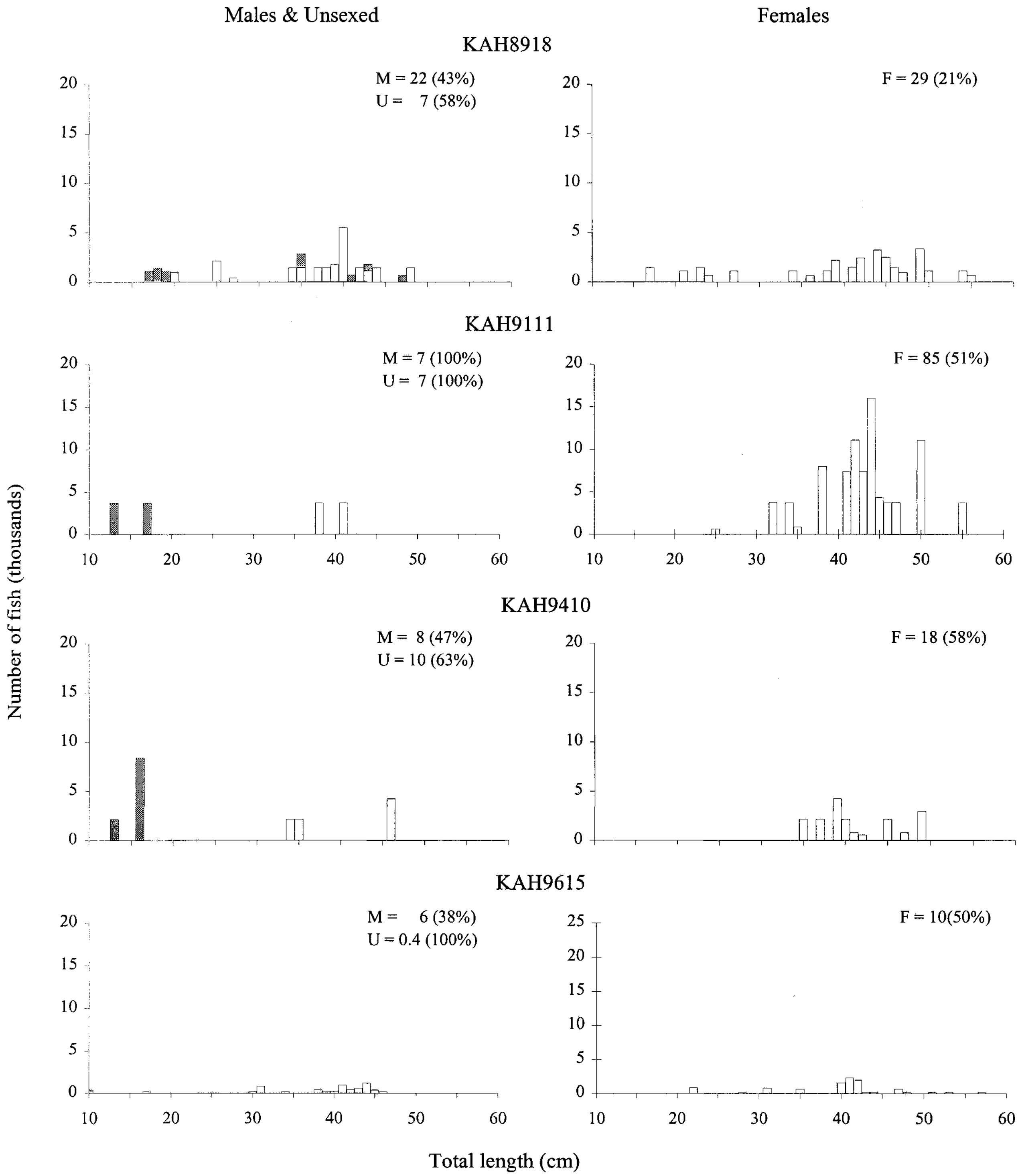


Figure 6b **: John dory**

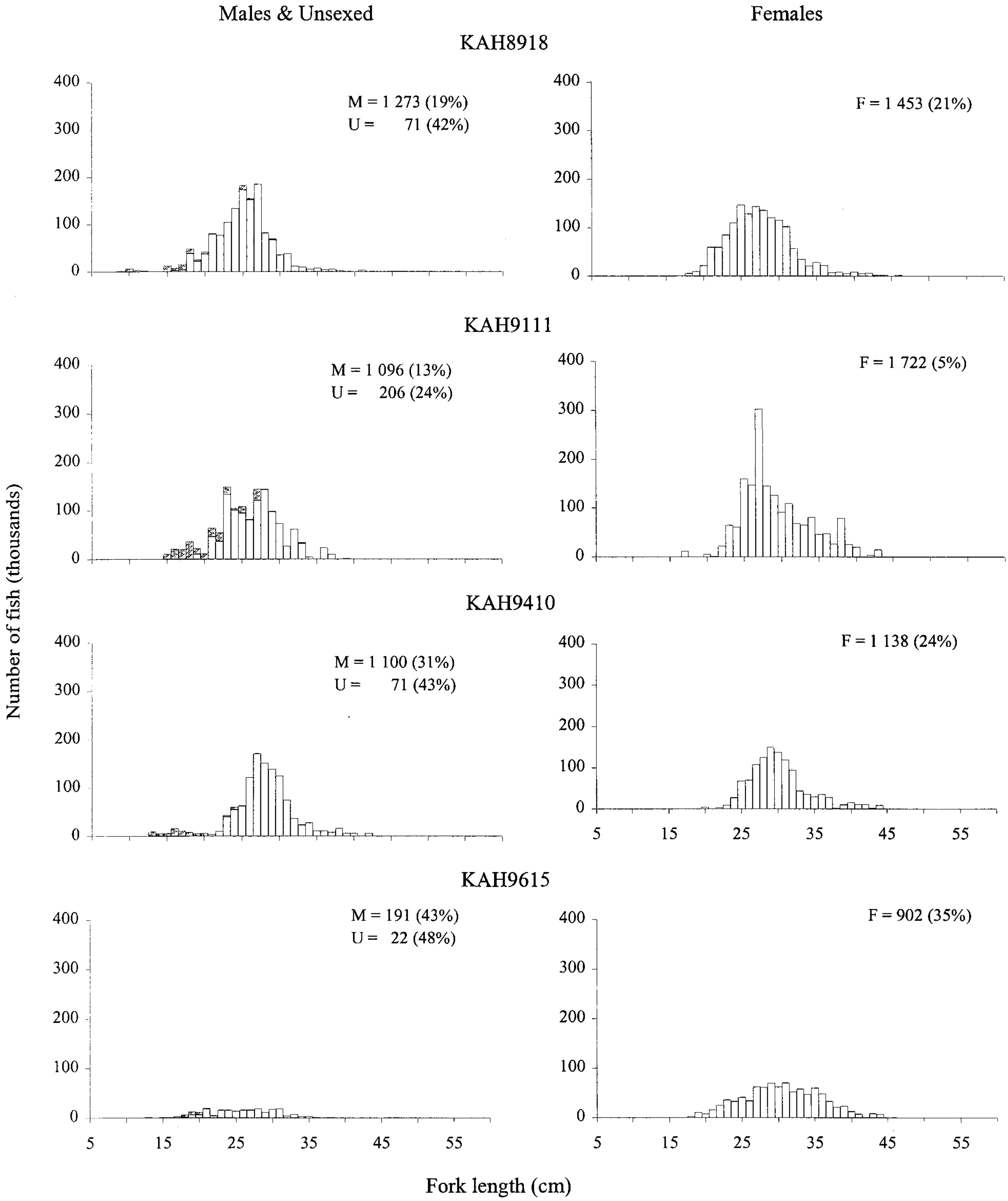


Figure 6c **: Red gurnard**

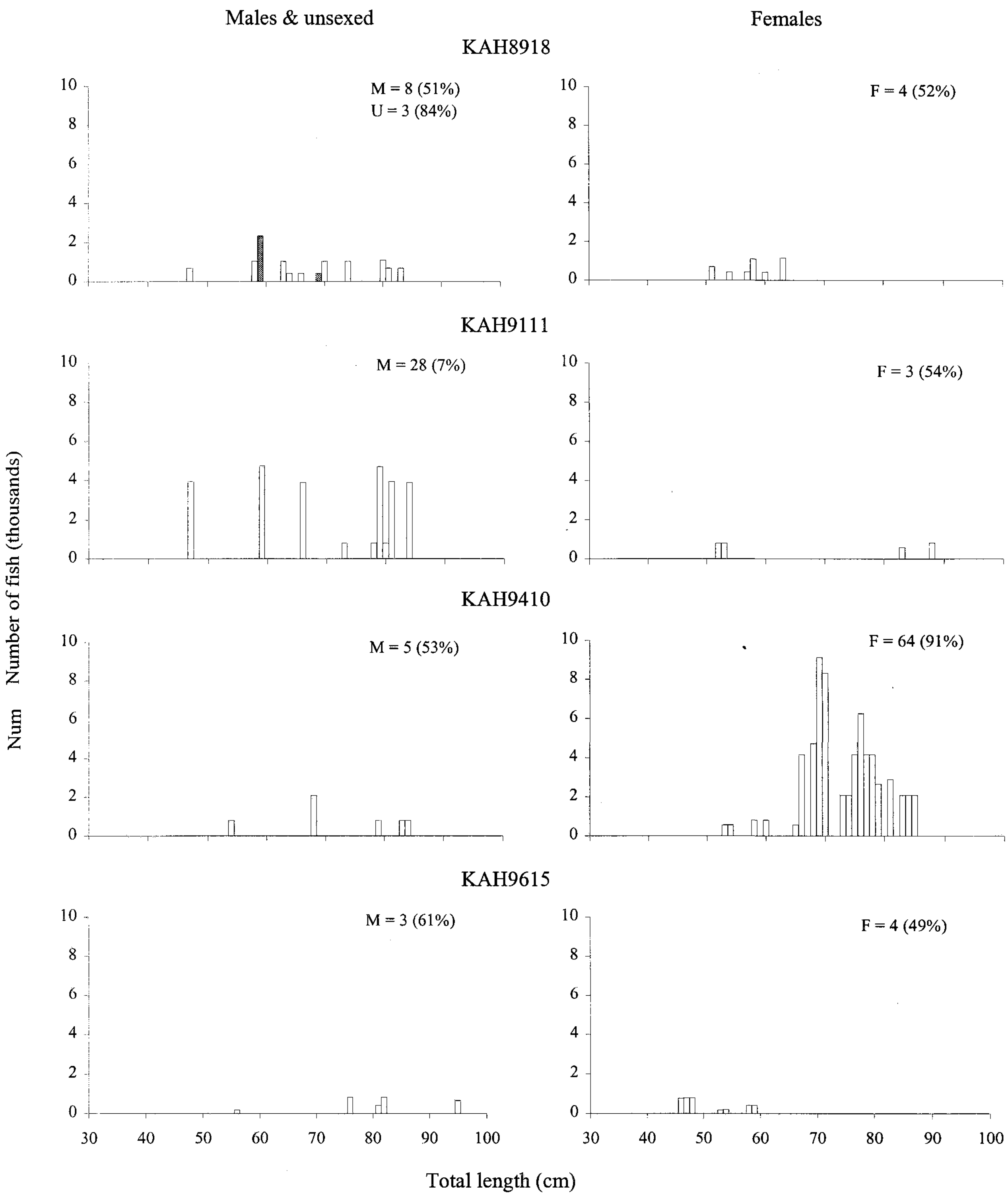


***Figure 6d*: Rig**

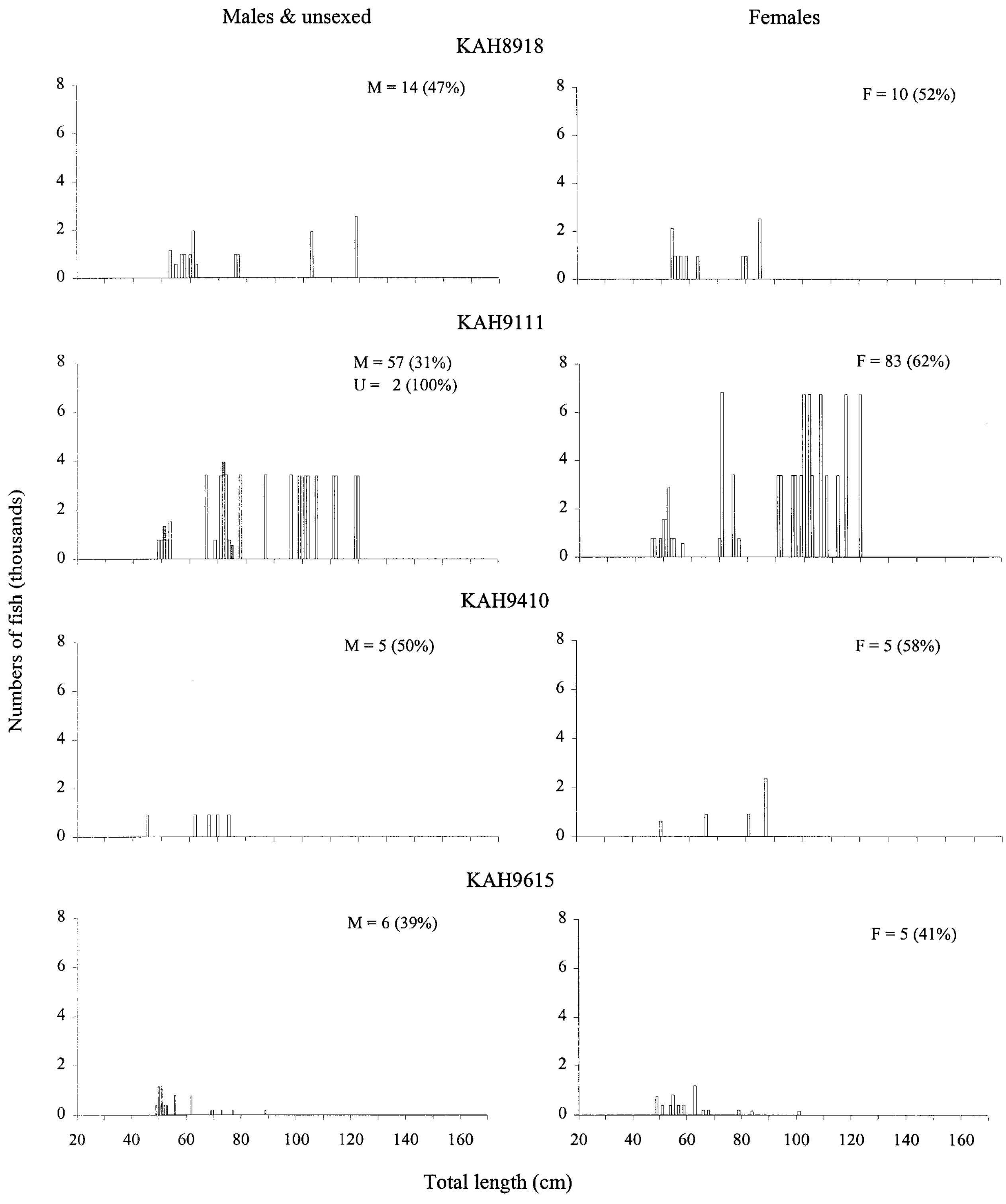


***Figure 6e*: School shark**

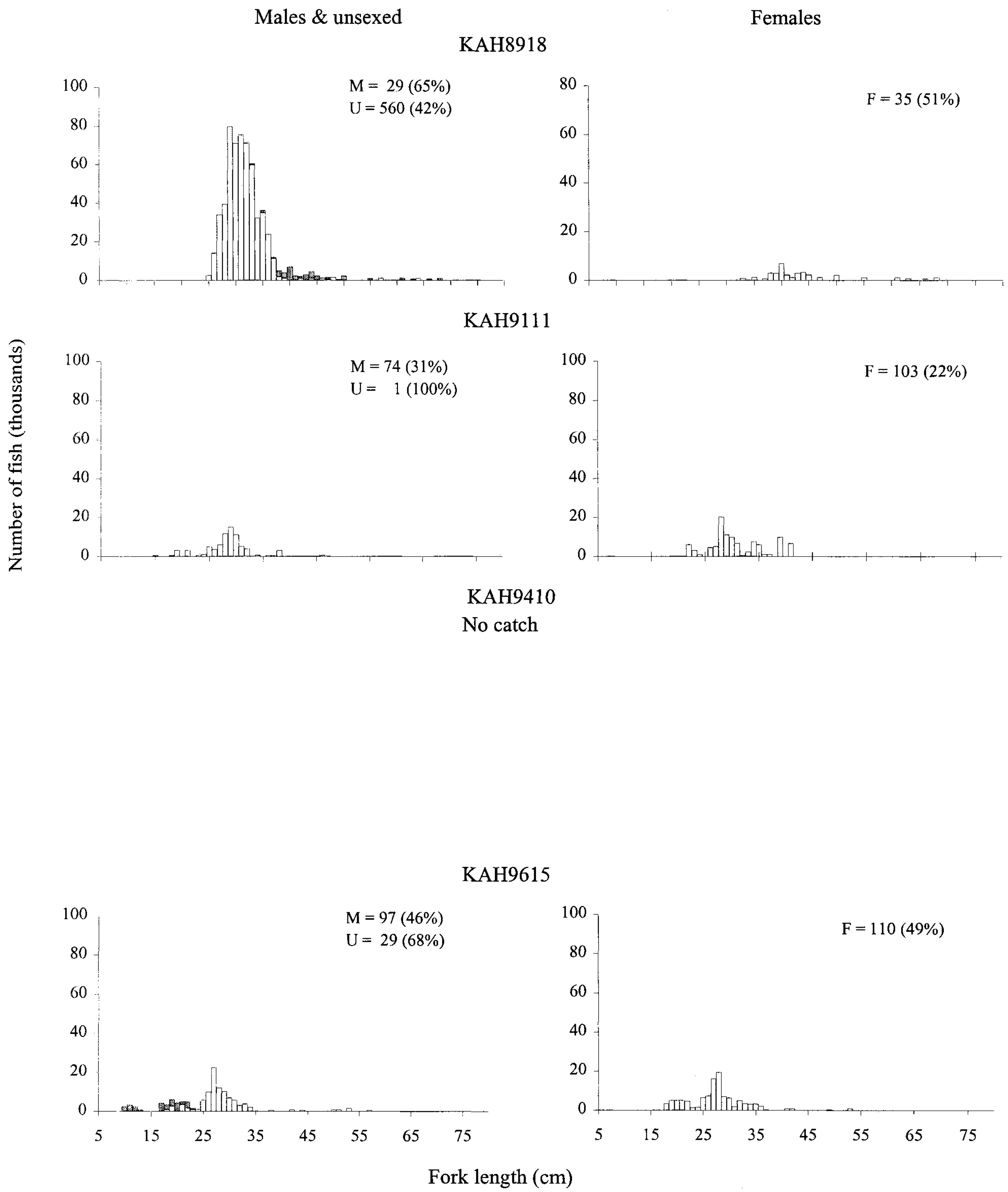
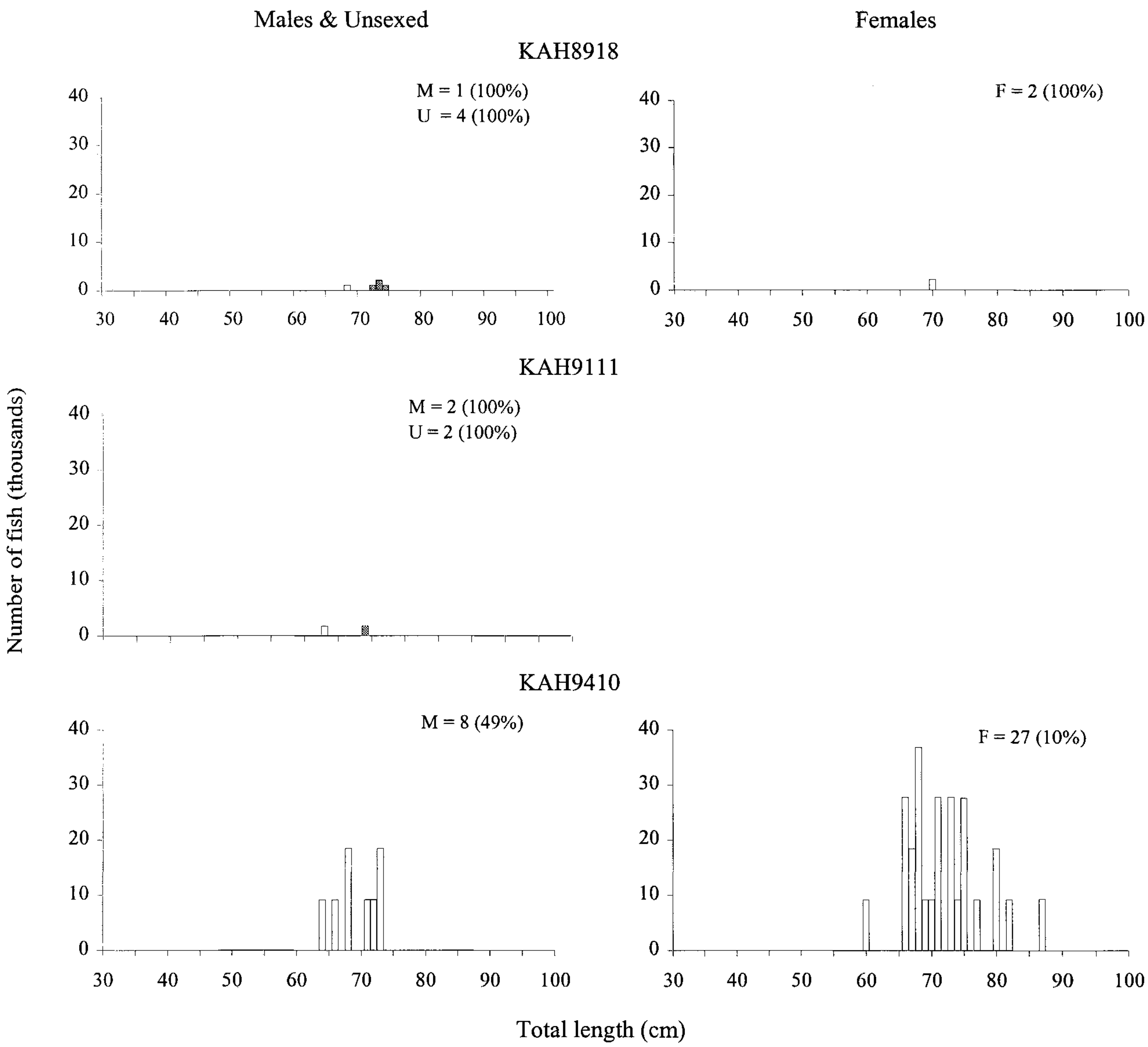


***Figure 6f*: Snapper**



KAH9615
Not measured

***Figure 6g*: Spiny dogfish**

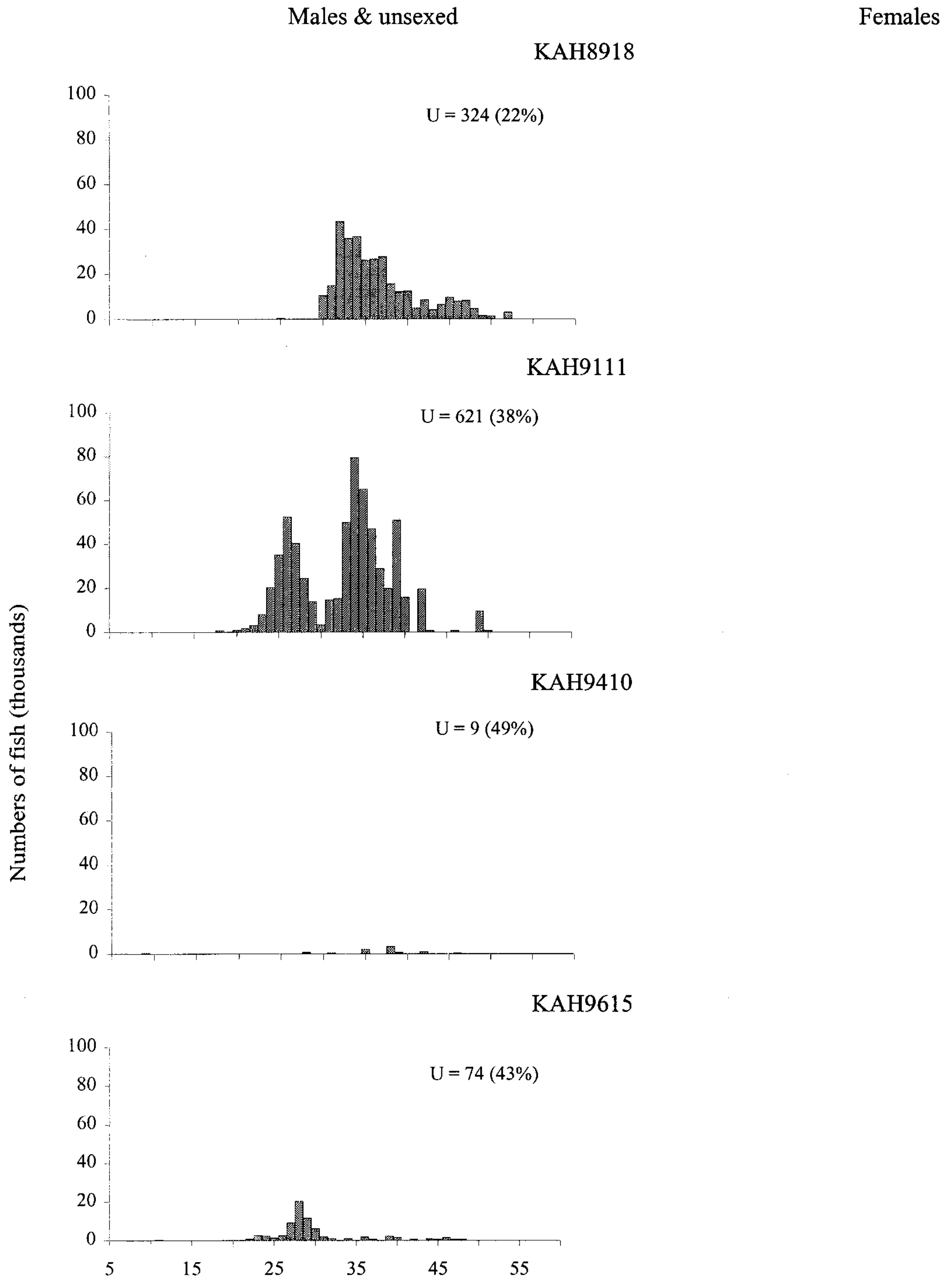


Figure 6h : **Trevally**

Appendix 1: **Trawl gear specifications and net plan.**

Type:	High opening bottom trawl (HOBT) without lower wings
Backstrop:	6.6 m
Sweeps:	55 m x 16 mm diam.
Bridles:	
Top:	55 m x 12 mm diam.
Bottom:	55 m x 16 mm diam.
Headline:	34.5 m
Ground rope:	18.66 m
Ground chains:	2 x 14.5 m x 13 mm diam.
Ground rope weight:	120 kg plus 40 kg added
Floats:	62 x 20 cm
Total floatation:	217 kgf
Vertical opening:	5.5–6.0 m
Codend mesh:	40 mm

Specifications for the old (used before 1995) and new (1995 and beyond) trawl doors.

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

***Appendix 2*: Length-weight relationship parameters used to scale length frequencies and calculate length class biomass estimates. Source of data was NIWA *trawl* database**

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

Species	Year	*a*	*b*	n	Range (cm)	Raw data source
Barracouta	All	0.0091	2.8800	731	25–95	Hurst & Bagley (1989)
John dory	All	0.0120	3.1138	296	13–52	KAH9720
Jack mackerel						
T. novaezelandiae	All	0.0163	2.9230	200	15–40	COR9002
Rig	All	0.0033	3.0529	134	17–135	Francis (1979)
School shark	All	0.0042	3.0303	523	30–166	KAH9618
Snapper	All	0.0341	2.875	903	7–76	KAH9420
Spiny dogfish	All	0.0007	3.4500	1052	43.4–104.4	TAN9501
Trevally	All	0.0156	3.0640			James (1984)

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

	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
Red gurnard	0.6383	0.5922	0.3596	162	8–45	KAH8303

Appendix 3: Analysis parameters

West coast North Island surveys (FMA 9)

KAH8612
Gear performance set to "less than 3"
Strata A1, A2, A3, A4, G1, G2, G3, G4, H1, H2, H3, H4, and half of B1, B2, B3, and B4 excluded
Because: outside area of 1987 survey
Biomass estimates were calculated from catch weights with catch weights for stations 14 and 79 estimated from length frequency data
Effective areas:

strata	area (km^2)
B1	195.17
B2	249.00
B3	121.40
B4	58.63

KAH8715
Same as KAH8612 except:
All strata used with no change to areal availability
Biomass calculated from length frequency data using length-weight regression equation
Because: few catch weights available

KAH8918
Same as KAH8715 except:
All of strata GEB1, GEB2, WCN2, WCN3, WCS4, WCS5, and half of WCN1 and WCS1 and 0.7 of WCS2 excluded
Because: outside area of 1987 survey
Effective areas:

stratum	area (km^2)
WCN1	1177.0
WCS1	1319.5
WCS2	649.5

Biomass estimates calculated from catch data

KAH9111
Same as KAH8715 except:
All of strata A25, A50, A100, A200, B25, B200, C200, E200, F50, F100, F200, G25, G50, G100, H25, H50, I25, I50, and J25 and half of strata B100 excluded
Because: outside area of 1987 survey
Effective area: B100 = 665.5 km^2
Biomass estimates calculated from catch data

KAH9410
Same as KAH8715 except:
All of strata A25, AA50, A100, A200, B25, B200, C200, E200, F50, F100, F200, and G25 and half of strata B100 excluded
Because: outside area of 1987 survey
Effective area: B100 = 665.5 km^2
Area of stratum BB50 set at 323 km^2
Biomass estimates calculated from catch data

KAH9615
Same as KAH9410
Except the effective area of stratum B100 is 666 km^2

West coast North Island surveys (FMA8)

KAH8918
Gear performance set to "less than 3"
Includes strata WCS4, WSC5, half of WCS1 and 0.7 of WCS2
Because: This area is all that was covered in FMA8
Effective areas:

stratum	area (km^2)
WCS1	1319.5
WCS2	1515.5

Biomass estimates calculated from catch data

KAH9111
Same as KAH8918 except:
Includes strata F50, F100, and G25 only
Because: This area is all that was covered in each survey in FMA8
Biomass estimates calculated from catch data

KAH9410
Same as KAH9111

KAH9615
Same as KAH9111

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