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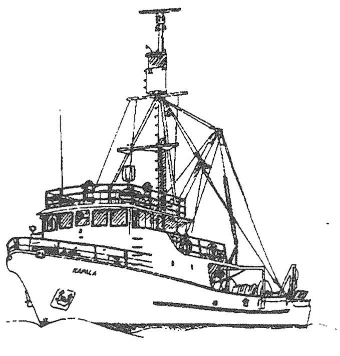

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NON TECHNICAL SUMMARY

95/128 Changes over twenty years in relative abundance of species and size composition of catches from fishery independent surveys on SEF trawl grounds off New South Wales.

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OBJECTIVES:

1. To quantify changes in the comparative abundance of quota and other important upper slope fish since 1976-77.
2. To collect fishery-independent comparative data on the size composition of these trawl-fish after 20 years of exploitation.
3. To collect fishery-independent representative samples of otoliths and other biological information as required by the South East Fishery Assessment Group.

NON TECHNICAL SUMMARY:

In 1976-7, *Kapala* surveyed the NSW upper continental slope, mostly in the area that was to become the SEF Eastern Sector A. These surveys were done off Sydney, Ulladulla and Eden on largely unfished grounds, just as commercial exploitation of fish on the slope was beginning. The surveys were repeated 20 years later, in 1996-7, using the same vessel, trawl gear of the same design and dimensions, and similar sampling protocols. In this report we present the results of these surveys and contrast estimates of relative abundance and size structure of the important fish and shark species. Supplementary data from trawls conducted during the period 1979-81 are used to provide additional comparisons for a subset of species and depths.

Across all areas and surveys, the catch rate of fish (all species combined) in 1996-7 was 32% of that recorded in 1976-7, while the combined catch rate of all commercial fish was 26% of that in 1976-7. These results suggested that the overall fish biomass on the grounds surveyed has substantially decreased and, with the exception of ling, tiger flathead and spiky dogshark, the abundances of the main commercial fish species on the NSW upper slope grounds were very much lower in 1996-7 than were found in 1976-77. In addition, almost all species for which comparative data were available showed a marked decline in the abundances of larger/older fish.

The results of this study indicate large scale changes in the relative abundances of redfish, jackass morwong and ocean perch on the NSW upper slope. Compared to 1976-77, catch rates of redfish during 1996-7 were very small, especially at Ulladulla where the redfish catch rate in 220-385 m was less than 5% of that recorded in 1976-7. In the 1977 surveys, individual catches per hour trawling of jackass morwong as high as 800 kg were taken, but during 1996-97 only seven individuals were caught during the entire survey period. Mean catch rates of ocean perch at Sydney and Ulladulla during 1996-97 were less than 30% of those in 1976-77, while catch rates in 1979-81 were intermediate between those two levels. Off Eden, the 1996-7 mean catch rate of ocean perch, although about half of that for 1976-7, was not statistically significantly different, because of several relatively large catches of small ocean perch in 1996-7 in the shallower depths. The mean sizes of redfish and ocean perch was smaller in 1996-7 at all locations, with the size structures now containing a higher proportion of smaller and presumably younger fish.

The results suggest that, apart from spiky dogsharks, the relative abundances of dogsharks and skates on the NSW upper slope are at very low levels. The magnitude and consistency of this decline among sampling periods, surveys and replicate tows suggest the observed patterns reflect real changes. Although the 1979-81 data were not corrected for the larger gear size, the total catch rates for dogsharks (excluding spiky dogsharks), ghost sharks and skates in each of the three survey areas were between 19% (Eden) and 46% (Ulladulla) of the 1976-77 catch rates, and by 1996-97 had fallen to less than 6% of the initial levels. The greatest change appears to have been to the stocks of upper slope dogsharks of the genus *Centrophorus* (southern, Harrissons and Endeavour), which were virtually absent from the 1996-97 catches.

The impact of the fishery on the stocks of sharks and rays on the NSW slope has followed the pattern of most exploited demersal shark stocks worldwide. In common with many multispecies fisheries that target teleost fishes, the SEF has continued long after the elasmobranches were severely depleted and sharks are now only a minor component of the upper slope commercial catch in the Eastern Sector A of the SEF.

A second group of species have shown less clear changes in relative abundance after 20 years. These species are typically migratory and/or schooling and the evidence for declines after 20 years is more equivocal. Catch rates of gemfish, blue grenadier and mirror dory were highly variable, probably reflecting both the patchy patterns of abundance and the consequent inability of the sampling program to provide reliable estimates of relative abundance. Despite this variability, the large declines in catch rates of gemfish are consistent with stock assessments that indicate significant declines in biomass.

A third group of species has shown little change or increased in relative abundance. Of the SEF quota species, only ling and tiger flathead showed relative abundances similar to or greater than 1976-77. The overall mean catch rates for ling were similar for both survey periods, although there was a large decrease in mean size. Ling seem to have been relatively abundant off southern NSW for a number of years. Catch rates of spiky dogsharks were relatively high during 1996-7, especially off Sydney. Mean catch rates off Ulladulla were about half that of 1976-7 and catches off Eden were about 25% lower. The relatively high catch rates of spiky dogsharks provides an interesting contrast to the other dogsharks. Occasional very large catches suggest they school, but, because of their small size, they are seldom targeted by fishers. Off Sydney, trawling pressure is comparatively light on the outer shelf grounds and in the upper slope depths where spiky dogsharks were most abundant. Off Ulladulla and Eden in those depths, there is more intense trawler activity with other species as targets, and spiky dogsharks were found to be less abundant. In addition, escapement through the 90 mm mesh codends used in the commercial fishery is possibly quite high for small spiky dogsharks.

Interpreting differences in catch rate between 1976-7 and 1996-7 and attributing causal mechanisms is complicated by the range of possible processes that could account for the changes observed. These include the effects of exploitation, natural variability, and non-representative sampling. These possible explanations are not mutually exclusive and indeed it is likely that they will interact. The numerical responses of species to sustained fishing pressure are likely to be influenced by ecological and life history attributes such as their mobility, fecundity and mode of reproduction. Similarly, the impact of environmental change may be exacerbated if those populations are reduced by fishing. Gaining representative estimates of relative abundance will be increasingly difficult as the densities of highly migratory and schooling species decline.

We believe there is a strong basis for inferring that sustained fishing over 20 years is the most likely and predominant cause of the observed changes in the relative abundance and size structure of a subset of commercial species on the New South Wales upper slope. These are: redfish, jackass morwong, ocean perch, Endeavour dogsharks, Harrissons and southern dogsharks, greeneye dogsharks and angel sharks. This interpretation relies on combining data on relative abundance from three time periods in the fishery, changes in the size structure of populations and changes in the fishery itself. The apparent declines in catch rates and changes in size structure are greatest for dogsharks (except spiny dogshark), redfish and jackass morwong, and to a lesser extent, ocean perch.

Interpreting the significance of these changes in relative abundance to the overall status of stocks is difficult because of the poor understanding of the biology, behaviour and distributions of many species. For example, redfish are known to periodically feed in the water column on small fish and crustaceans, reducing their catchability to demersal trawls. The frequency of this behaviour and/or the availability of the prey is unknown. Similarly, although many species were caught commonly on the relatively smooth the trawl grounds, the actual substrate preference of many of these species is unknown. Although more than 80% of the designated grounds were surveyed, much of the intervening seabed was not. The surveyed trawl grounds make up 32% of the total trawlable area on the upper slope between Newcastle and the Horseshoe between 200 and 640 m in depth. There are large areas at these depths, particularly between Jervis Bay and Gabo Island that are untrawlable. These areas are either canyons or 'foul' ground and it is unknown whether these areas replenish populations in the trawled areas. Further, regardless whether they do, there is little information about the size of populations living in these untrawlable areas.

A total of 4015 pairs of otoliths were collected from SEF quota species during 1996. These otoliths came predominantly from tiger flathead, redfish, ocean perch, ling and blue grenadier. The otoliths are presently stored at NSW Fisheries Research Institute and will be forwarded to the Central Ageing Facility when required.

Although the data and analyses presented provide important insights into the status of these species, they do not, of themselves, constitute stock assessments. The data summarised in this report and Kapala Cruise Report 117 have been archived in a disaggregated form in a data report and in electronic form and forwarded to the South East Fishery Stock Assessment Group for inclusion in future assessments.

KEYWORDS:

South East Fishery, New South Wales, upper slope, relative abundance, tiger flathead, redfish, ocean perch, ling, gemfish, blue grenadier, dogsharks.

1. Introduction

1.1 Background

In 1968, two trawlers from Wollongong began trawling on the NSW upper slope targeting mainly redfish but also landing significant catches of gemfish, mirror dory and dogsharks (Diorio 1976). Building on the experiences of the Wollongong trawlers and subsequent exploratory work by NSW Fisheries research vessel *Kapala* in the early 1970's (Gorman and Graham 1975), the fleet fishing the slope off Wollongong and Sydney had increased to about 12 trawlers by 1974, and the gemfish catch alone (principally from a winter spawning run) rose to more than 1,000 t a year. In 1975, *Kapala* charted the upper slope between Crowdy Head and Gabo Island in greater detail than previously, and numerous tows with fish trawling gear were made (Kapala Cruise Reports 24-26).

During 1976-7, surveys of the upper slope grounds off Sydney, Ulladulla and Eden-Gabo Island were completed. Catch rates and size composition data for the main species were presented in Kapala Cruise Reports 30-43 (Gorman and Graham 1976, 1977,1978). During 1975-77, when *Kapala*'s exploratory and survey trawling were being done, many Ulladulla and Eden tuna poling vessels and Danish seiners were converted to trawlers and started fishing upper slope grounds off southern NSW (Graham *et al.* 1982). By 1978, about 50 vessels in ports between Sydney and Eden were rigged for trawling and most were fishing in upper slope depths.

Over the 20 years since the inception of the NSW slope fishery, there have been some marked changes, both in commercial catch rates and in fishing practices (Tilzey 1994). Initially, catch-rates of commercial vessels working on the slope were high, and for about 10 years, production from the slope accounted for more than half the trawl-fish landings in NSW (Tilzey 1994). The slope fishery also expanded southwards into eastern- Bass Strait. Since the mid-1980's, however, catch rates and landed catches of some species have declined, especially on the grounds north of Montague Island. From the mid 1970's to mid 1980's gemfish was the largest volume catch in the South East Trawl fishery. Following the collapse of the gemfish stock and subsequent catch restrictions, NSW trawlers became more reliant on other slope species such as ling, ocean perch and mirror dory, and also directed more effort on to the shelf grounds for redfish, flathead, morwong and warehou. Trawlers working on the slope north of Montague Island, especially off Wollongong and Sydney, now target royal red prawns for a substantial part of each year.

The 1976-7 survey involved stratified random sampling of the upper slope grounds (220-605 m). Three areas (Sydney-Newcastle, Ulladulla- Batemans Bay, and Eden- Gabo Island) were sampled three or four times during 1976-77. During each sampling period, three tows were made in each of eight depths. From the results, mean catch rates and indicated stock sizes were calculated for the important species. Length-frequency data were also collected for commercial species. Large catches of dogsharks (*Centrophorus* spp. and *Squalus* spp.), redfish, ocean perch, mirror dory and ling were caught; significant catches of gemfish, blue grenadier and spotted warehou were occasionally taken. Results were reported in Kapala Cruise Reports Nos. 30, 32, 33-35, 37-40, 42 and 43. (Gorman and Graham 1976, 1977, 1978). Estimated stock sizes were contained in a report to the SEFC Research Group.

During 1979-81, the upper slope grounds between Port Stephens and Gabo Island were surveyed on several occasions. The primary objective of these surveys was to estimate the relative abundances of species such as gemfish, mirror dory, blue grenadier and ribbonfish which migrate along the NSW slope during winter (see Kapala Cruise Reports 57-60, 64, 65, 70-73: Gorman and Graham 1979, 1980, 1981). These surveys provide the opportunity to supplement comparisons between the 1976-7 and 1996-7 surveys with data from the intervening 20 years. Differences in gear and sampling protocols will mean that these additional comparisons are *ad hoc*, but are useful in strengthening inferences about changes during the 20 years between the more structured surveys.

Prior to the present study, the biomass estimates from the 1976-77 survey by *Kapala* were the only fishery-independent estimates of stock abundance for Eastern Sector A slope waters. Although comprehensive scientific trawl surveys of eastern (in 1982-85) and western (in 1987-90) Bass Strait shelf and slope waters have since been done (Wankowski and Moulton 1986, Smith 1995), these surveys have not been repeated. With the exception of orange roughy, estimates of changes in relative abundance in the SEF with time have been derived from fishery-dependent (i.e. catch and effort) data only.

Reliable catch per unit effort data are not available for the commercial trawlers which operated in the fishery at its inception. Information on the changes in catch rates over the full 20 year history of the fishery is anecdotal prior to 1986. It is widely acknowledged that these fishery-derived indices of relative abundance have numerous sources of error because of poor data quality before 1986 through marked changes in the fishing power of vessels and the changes in fishing practice caused by changes in SEF management regulations. Although considerable effort is being directed towards analysis and standardisation of catch rate data for the SEF, doubts persist about their use as stock abundance indices on which TAC limits are still largely based.

1.2 Need

The need for this study, as described in the FRDC application, was as follows:

Few fisheries in the world have been researched before commercial exploitation commenced. The initial *Kapala* survey was done on unfished stocks, just as commercial exploitation of fish on the slope was beginning. The 1996-7 repeat of these surveys will provide fishery-independent estimates of comparative abundance of fish species on the upper slope and document the changes after 20 years of fishing. The same vessel and trawl gear will be used in both surveys.

The 1976-77 surveys were done at Sydney, Ulladulla and Eden and will be repeated in 1996-7 in the same months and using similar methodology as in the first survey. The repeat survey will document changes in relative abundance of the slope populations of such quota species as tiger flathead, ocean perch, redfish and ling, and also other important non-quota species such as angel shark, saw shark, and various dogsharks. Any changes in the catch-rates and size composition of seasonally available species such as mirror dory and gemfish will also be documented.

The high catch rates at the start of the fishery were achieved during the initial 'fishing down' of accumulated stock, typical of most new fisheries. While it has been recognised that the stocks of gemfish have been overfished, there is little fishery independent research data available on the stock levels of other quota and non-quota species on the NSW slope. The TACs set for a number of these slope species have been based on their catch history only; a repeat survey would therefore be of enormous use in the SEF stock assessment process.

Fishery independent biological samples are also needed for some SEF stock assessments. Biological samples, such as length/age data, required for stock assessments of SEF species are currently being collected via the Onboard Scientific Monitoring Program and from ports of landing. Because of targeted fishing practices, some doubts are held about whether the samples taken from the commercial catch are representative of the fishery as a whole. For example, recent (June 1995) SEFAG estimates of ling mortality derived from length/age keys and catch composition data from eastern Sector A ports were extremely high and were thought to have been biased by the disproportionately low representation of older, larger fish in the commercial catch. Much of the fishing effort which provided the samples was confined to the shallower depths of ling's main distribution range (30- 600 m depth).

Otoliths to be collected as part of the proposed study will provide representative biological samples from ling and other quota species (500 ling otoliths from the 1976-77 survey are currently being analysed by the Central Ageing Facility).

1.3 Objectives

The objectives of this project were:

(1) To quantify changes in the comparative abundance of quota and other important upper slope fish since 1976-77 (Chapter 3 and 4).

(2) To collect fishery-independent comparative data on the size composition of these trawl-fish after 20 years of exploitation (Chapter 5).

(3) To collect fishery-independent representative samples of otoliths and other biological information as required by the South East Fishery Assessment Group (Chapter 6).

2. General Methods

2.1 Study locations

The NSW upper slope trawling grounds (200- 650 m depth) are described in detail in Graham and Gorman (1985). The upper slope between Newcastle and the 'Horseshoe', where NSW fish trawlers normally operate, has an area of about 1290 sq. n. miles, approximately 75% of which is trawlable (Table 2.1). Three locations were surveyed (Figure 2.1):

(1) **Sydney**. The ground is between the Norah Head canyon ($33^{0}25'$) and Botany Bay ($34^{0}00'$). The trawlable ground has an approximate area of 35 x 4.5 = 150 sq. n. miles (515 sq. km) and is characterised by a wide gentle slope with no foul areas (except wrecks). The ground is bordered by a deep canyon to the north and a seamount and ammunition dumping area in the south. The ground is now mainly fished for royal red prawns. In survey I in 1976, seven tows (8% of the total Sydney tows done in 1976-7) were done immediately to the north of the Sydney ground, between Norah Head and Newcastle. No tows were made in this area in 1996-97.

(2) **Ulladulla**. Ulladulla to Batemans Bay between latitudes $35^{0}25'$ and $35^{0}50'$. The trawlable ground is approximately 30 x 2.0 = 60 sq.n.m. (205 sq. km) miles in area and is characterised by a relatively steep slope. There are canyons and foul ground to the north in all depths, and to the south in depths greater than about 350 m. A small untrawlable area in 450-570 m is located in the centre of the ground. The Ulladulla ground is trawled intensively for fish and occasionally for royal red prawns.

(3) **Eden**. The Eden- Gabo Island ground is between latitudes $37^{0}05'$ and $37^{0}50'$ and can be divided into two sections. The Eden-Cape Howe ground is a narrow strip inside and between foul ground (depth range 220- 385 m; 30 n.m. x 1.5 n.m.) while the Gabo Island ground is relatively wide with a gentle slope (depth 220- 620 m; 15 n.m. x 5.0 n.m.). The combined total area is approximately 120 sq. n.miles (380 sq.km). The Gabo ground continues south and west in most depths to the Horseshoe (latitude 38^{0} 10'). The area of upper slope between the Gabo Island ground and the Horseshoe is approximately 170 sq.n.m. with about 120 sq.n.m. of trawlable seabed. In 1977, 9 tows (14% of the total in Eden) were done in this southern area; no tows were made in this area in 1996-97.

On each ground, trawling was done along eight isobaths: 220 m (120 fm), 275 m (150 fm), 330 m (180 fm), 385 m (210 fm), 440 m (240 fm), 495 m (270 fm), 550 m (300 fm) and 605 m (330 fm).

2.2 Gear Specifications

Two nets of similar design and with the same headline and footrope lengths were used in 1976-77. They were a 21 m headline Mara net, and a 21 m headline Boris box net (Boris Net Company (UK)). The Mara trawl was a basic two seamed net with 127 mm (5.0 in.) mesh in the wings and 89 mm (3.5 in.) mesh throughout the rest (Kapala Cruise Report No. 30); the Boris box net was a four seamed net with 114 mm (4.5 in.) in the wings and bosom panels and 89 mm mesh from the bosom to the codend. Both nets were towed with 30 m bridles, 45 m sweeps and 1.8 m Vee doors. These nets, rigged with groundropes constructed with 16 pairs of 800 x 200 mm spacer bobbins in the bosom section (Table 2.2, Figure 2.2) were used in 82% of tows. A Mara net rigged with fourteen 300 mm diameter spherical bobbins in the bosom section was used during some surveys off Ulladulla and Eden to cope with some areas with small rock slabs and/or comparatively hard seabed. We assume the fishing power of both nets was the same.

All trawling in 1996-97 was with the same 21 m headline Boris box net used in 1976-7. As then, the net was towed with 30 m bridles, 45 m sweeps and 1.8 m Vee doors. A net plan and details of the groundrope and accessories are in Figure 2.2 & Table 2.2. All areas where the bobbin-rigged trawl was used in 1976-7 (see above) were successfully trawled in 1996-7.

The nets used in 1976-7 and 1996-7 had a mesh size of approximately 90 mm throughout the extension section and codend. This is equivalent to the 3.5 inch mesh that has been used by commercial boats since the fishery commenced. During both survey periods, a maximum of 1480 m of warp was available. Warp scope ratios were 3:1 in depths down to 495 m (270 fm) and the maximum 1480 m of warp was used in 550 m (300 fm) and 605 m (330 fm) depths giving respective scope ratios of 2.7:1 and 2.5:1. This small reduction in scope ratios between depths was not considered sufficient to significantly alter the geometry (gear spread etc.) of the gear in relation to any comparisons of catch rates across depths.

2.3 Survey methods

1976-7

All locations were surveyed three or four times. At each location, three tows per survey were planned for each of the eight depths. During some surveys, fewer than three tows per depth were completed because of bad weather and/or time constraints. The order of depths was randomised but on most occasions two or three of the tows within a particular depth were done successively on the same day. Tow duration was initially two hours (Sydney, Survey I) but was subsequently reduced to one hour for most tows. Of the 246 tows done in 1976-7, 89% were of one hour duration. All catch rates have been standardised to one hour by simple proportional scaling. Trawling speed was approximately 3.0 knots (based on constant warp loadings and radar fixes when possible). Most tows (85%) in 1976-7 and all tows in 1996-7 were made during daylight. Details of which tows were done in daylight, and their duration may be found in the data report (Hodgson *et al.* 1997) held at the NSW Fisheries Research Institute library.

1996-7

In 1996-7 the same locations were surveyed in, as close as possible, the same months as they were surveyed in 1976-77 (Table 2.3). Three surveys, each completed over 5-6 weeks, were done at each location. During each survey, three tows were made in each of the eight depths and, where possible, the tows were distributed along the length of the ground (each ground was arbitrarily divided north and south and at least one of the three tows in any depth was done in north and south sections). The start position of each tow was the nearest point from the finish of the previous tow from which there was sufficient distance to complete the tow; depending on depth, current and sea conditions, up to 6 n.m. was covered during shooting and towing. Each tow was for one hour at 3.0 knots; trawling speed and positions were derived from GPS fixes. All tows were made during daylight hours.

The number of tows done per day depended on the number of daylight hours available and on depth (shooting and recovering the gear each took up to 50 minutes on the deeper grounds). Depending on depth, between two and three hours were required per tow (shooting, towing, hauling, steaming to next depth). Up to four tows were scheduled per day. The randomization of the order in which tows were done was constrained such that only one tow was done per isobath per day and, unless unavoidable, adjacent depths were not sampled within any day.

2.4 Catch sampling

In 1976-77, almost all catches were boxed and the weights (45 kg/box) of commercial and other important species were recorded. The weights of some very large catches of redfish were estimated. Length frequency data (by sex for sharks) were collected for commercial species from most tows. All fish from small catches were measured and large catches were subsampled by selecting boxes of fish at random. A species list of all fishes was also compiled for each tow.

During 1996-97, the number, weight, and length distributions (by sex for SEF Quota species and sharks) of all commercial and some non-commercial species were recorded from each tow. Large catches were subsampled for length frequency data (a minimum of 50 fish were randomly selected for measuring). Total weight of non-commercial fish and individual weights and numbers of the main non-commercial species were recorded. Numbers only were recorded for all other non-commercial species of fishes, crustaceans, molluscs and echinoderms.

The catch weights recorded were for whole fish of all sizes. Commercial species were defined as those which are marketed in NSW (see Table 2.4). Species that are sometime marketed but discarded at other times, such as spiky dogshark, jack mackerel and ribbonfish were included. Non-commercial species are defined as those that are always discarded by fishers. Common names for species used in the text and tables, taxonomic names, and their commercial status are listed in Table 2.4. Throughout the text, the common name 'ocean perch' refers to the slope species only (*Helicolenus barathri*). The second species, *H. percoides*, was caught in very small numbers in 220-275 m.

For all data analyses, catch rates of Harrissons and southern dogsharks (*Centrophorus harrissoni* and *C. uyato*) were combined because these externally similar species were not separated during the initial 1976 surveys off Sydney and Ulladulla.

A recent taxonomic revision of the sharks and rays of Australia (Last and Stevens 1995) distinguished several new, as yet undescribed species of *Squalus* dogsharks. Two species, the eastern highfin (*Squalus* sp. B) and northern longnose (*Squalus* sp. F) were identified in the 1996 catches at Sydney and Ulladulla. The 1976-77 length frequency data for spiky dogsharks (*S. megalops*) caught at Sydney contains a number of males longer than 50 cm which were probably the larger *Squalus* sp. B. Similarly, inspection of the 1976-77 length data for greeneye dogshark suggests that those catches were most probably a mixture of *Squalus* sp. F and the larger *Squalus mitsukurii*.

In 1996-7, otoliths were collected from all SEF quota species (except mirror dory) during surveys I and II in each location. Otoliths were taken from fish over the full size range of each species, and up to five fish per cm size class per sex.

2.5 Fish Measuring

Length data were collected for all commercial fishes and one non-commercial species (spiny flathead). During 1976-7, fish were measured from most, but not all tows. The length distributions presented for all species have been expanded to represent the total number caught in those tows sampled. When subsampling occurred, the sampled fraction is indicated as the [number measured(total caught in tows sampled)].

In the 1996-7 surveys, all commercial fish (or subsamples of large catches) from all tows were measured and the length distributions presented have been expanded to represent the total catch. The degree of subsampling is represented on the appropriate figures as [number measured(total caught)]. Where practicable, all SEF quota species and sharks were sexed; most juvenile ocean perch (<20 cm), gemfish (<40 cm), mirror dory (<25 cm) and redfish (<12 cm) were not sexed. The mode of measurement (fork, total, or standard length) for particular species is indicated in the captions for the length frequency graphs.

2.6 Analysis

Differences in catch rate were analysed using a four factor analysis of variance. Three factors, Period (1976-77 and 1996-97), Location (Eden, Ulladulla and Sydney) and Depth (220-275, 330-385, 440-495, and 550-605 fm) were considered fixed and orthogonal. The fourth factor, Survey, was nested within the Location * Period interaction term and was orthogonal to Depth. In 1976-7 the surveys were repeated 3 (Eden) or 4 (Ulladulla and Sydney) times. All locations were sampled twice in 1996-7 except Eden which was surveyed 3 times. Although differing numbers of surveys were done among periods and locations, all treatment combinations for the core orthogonal block Location * Period * Depth were present. Expected Mean Squares were calculated using the Goodnight and Speed (1978) algorithm. The analyses of variance were done in PROC GLM in SAS using type III sums of squares. The impact of the missing cells introduced by differing numbers of surveys in 1976-7 and 1996-7 had little impact on the significance tests of the higher level factors. All the available data were used because of the relatively low number of surveys underlying inferences about patterns in the fishery. Data were transformed prior to analysis after inspection of residual plots. Transformations are as indicated in the relevant tables.

Determination of an appropriate Mean Square estimate for the interaction term Survey * Depth was problematic because of the missing cells. This term, although of little interest in itself, was used as the denominator in F tests for the interactions Depth * Location and Depth * Location * Period. There appears little consensus in the literature as to what course to follow in such instances. The extreme option of balancing the dataset by reducing the number of surveys to two in all instances made little difference to the F tests that did not use the Survey * Depth term.

Several features of the operations of the vessel made the Survey * Depth interaction term difficult to interpret. In 1976-7, tows within a depth stratum were done consecutively and often within a day. In 1996-7, the order of shots was randomised among depths to guard against the confounding effects of time of day. Such underlying patterns may further confound the interpretation of a Survey * Depth interaction term because differences in the relative abundance or catchability of fish may change over short periods of time. This interaction term is therefore interpreted only as a indication of small-scale spatio-temporal variability.

Significant F ratios in the analyses of sets of means indicate that there were differences among means, but not where those differences were. *A posteriori* tests (Ryan's tests) were used to identify those differences. The results of Ryan's tests are reported in the text with a reference made to the test in parentheses following the statement of difference. In all instances $p = 0.05$.

2.7 1979-81 Survey gear and methods

The surveys done in 1979-81 used a range of net designs, sizes and rigs (Table 2.5). Initially in 1979, the standard 21 m Boris box net (Figure 2.2) was used (32 tows), but was later substituted with a much larger, higher opening 56 m headline Engel balloon trawl to optimise the capture of gemfish and ribbonfish. The Engel net was constructed with 200 mm meshes in the wings grading to 100 mm meshes in front of the extension section; the extension section and codend were of 90 mm mesh (see Kapala Cruise Report 56). The groundrope was rigged with 300 mm diameter rubber discs in the bosom section and 50 mm diam. discs along the wings. The Engel net was towed with 1.8 m Vee doors during 1979 (42 tows), and with 2.4 m Vee doors during 1980 and 1981 (88 tows). Opportunistic trawling off Sydney (18 tows) and Ulladulla (1 tow), was also carried out with 24 and 27 m headline prawn nets (constructed with 45 mm mesh netting throughout). The Boris, Engel and prawn nets were all rigged with sweeps and bridles of similar lengths to the standard gear used during 1976-7 and 1996-7.

Data collected in 1979-81 has been grouped into three 'surveys' although these can not be considered in the same way as the 1976-7 or 1996-7 surveys. Trawling in 1979-81 was between Port Stephens and the Horseshoe south-west of Gabo Island. Because the main target species was gemfish, most tows were done during June-October (Table 2.6) and in depths between 300 and 500 m (Table 2.7). Tow duration was between 30 and 120 minutes with most (70%) for 60 minutes (Table 2.8). Almost all tows (95%) were during daytime. Consecutive tows were seldom in the same depth and the same depth was only occasionally sampled twice on any particular day. Sampling protocols were otherwise the same as those described for the 1976-7 surveys.

Only data from tows on the three grounds surveyed in 1976-7 and 1996-7 were used for comparisons. Where necessary, catch rates have been scaled to tows of one hour. No attempt has been made to standardise catch rates for the type of gear. We assume the fishing power of the trawls used during 1979-81 was equal to or greater than that of the standard 21 m Boris box net used in 1976-7 and 1996-7.

Because of the nature of the fishing done and differences in the structure of the survey 'design' in 1979-81, comparisons with the other surveys are possible only for a subset of species and depths. Comparisons are made only for non-migratory species (ocean perch, ling, sharks and skates). Because there were insufficient tows in depth zones 1 and 4, only data from tows in depth zones 2 and 3 were used for comparison (Table 2.7). These depths have been pooled to increase replication. Comparisons are therefore based on the catches from the two depth zones 300-410 m and 420-520 m (165-225 and 230-285 fm), standardised to tows of one hour duration, irrespective of gear-type. For the purposes of these comparisons, data from 1976-7 and 1996-7 have been aggregated in the same manner. The data are presented graphically as mean ± 95% confidence intervals and not analysed further. Sample sizes were n = 6 for surveys in 1976-7 and 1996-7 and ranged between n = 9 and 32 in 1979-81. Where pooled means are presented in the text they are accompanied by the 95% C.I. calculated on the pooled standard error.

Table 2.1 Estimated areas of NSW upper slope (180-630 m), trawlable ground and survey grounds with percentage surveyed in 1996-97.

	Trawlable		Untrawlable		Total	
	Area ($n.miles^2$)	% surveyed	Area ($n.miles^2$)	% total	Area ($n.miles^2$)	% surveyed
Regions						
Newcastle- Norah Head (33°00'-33°25')	120	0	40	25	160	0
Norah Head-Botany Bay (33°25'-34°00')	150	83	40	21	190	66
Botany Bay-Jervis Bay (34°00'-35°10')	225	0	100	31	325	0
Jervis Bay-Montague Is. (35°10'-36° 15')	85	59	90	51	175	29
Montague Is.-Eden (36°15'-37°05')	75	0	50	40	125	0
Eden-Horseshoe (37°05'-38°10')	240	46	85	26	325	35
Total	**895**	**32**	**395**	**31**	**1290**	**22**
Survey Grounds						
Sydney (33°25'-34°00'):	150	83	40	21	190	66
Ulladulla (35°25'-35°50'):	60	83	15	20	75	67
Eden-Gabo Is. (37°05'-37°50'):	120	88	55	21	175	64
Total:	**330**	**86**	**110**	**26**	**440**	**65**

Table 2.2 Trawling gear specifications

Trawl warps		1460 m x 14 mm, 6 x 19 SWR (steel wire rope)
Trawl doors-rectangular vee		1.8 m x 1.1 m, 310 kg (ballasted)
Sweeps		46 m x 16 mm SWR
Upper bridles		30 m x 8 mm SWR
Lower bridles		30 m x 16 mm SWR
Headline		21.3 m x 14 mm comb. wire
Flotation		16 x 203 mm diameter floats
Fishing line		25.3 m x 18 mm PE rope
Ground rope:	bosom section	7.8 m x 16 mm SWR with 16 pairs 200 mm x 100 mm dense PE spacer bobbins
	wing sections	8.3 m x 16 mm SWR served with 75 mm rubber discs
	total weight	210 kg

Table 2.3 Temporal distribution of surveys during 1976-77 and 1996-97.

1976	1977	1996/97
Sydney I: April 27 - May 27	Sydney III: May 24 - June 16	Sydney I: May 22 - June 19, 1996
Sydney II: Oct. 7 - Oct. 14	Sydney IV: Sept. 12 - Sept. 28	Sydney II: Sept. 17 - Oct. 14, 1996
	Ulladulla III: April 27 - May 5	
Ulladulla I: June 8 - July 8		
	Ulladulla IV: Aug. 2 - Aug. 11	Ulladulla I: Aug. 13 - Sept. 11, 1996
Ulladulla II: Nov. 10 - Dec. 1		Ulladulla II: Nov. 13 - Dec. 11, 1996
	Eden I: March 18: March 23	Eden III: March 16 - March 30, 1997
	Eden II: July 12 - July 19	Eden I: July 2 - July 31, 1996
	Eden III: Oct. 12 - Oct. 16	Eden II: Oct. 22 - Nov. 12, 1996

Table 2.4 Common and taxonomic names for all commercial and non commercial species.

COMMERCIAL SPECIES	
Alfonsino	*Beryx splendens*
Barracouta	*Thyrsites atun*
Bass groper	*Polyprion americanus*
Blue eye	*Hyperoglyphe antarctica*
Blue grenadier	*Macruronus novaezelandiae*
Conger eel	*Conger verreauxii*
Dogshark-Endeavour	*Centrophorus moluccensis*
Dogshark-Harrissons	*Centrophorus harrissoni*
Dogshark-southern	*Centrophorus uyato*
Dogshark-brier	*Deania calcea*
Dogshark-highfin	*Squalus* sp. B
Dogshark-longnosed	*Deania quadrispinosa*
Dogshark-greeneye	*Squalus mitsukurii*
	Squalus sp. F
Dogshark-spiky	*Squalus megalops*
Dory-john	*Zeus faber*
Dory-king	*Cyttus traversi*
Dory-silver	*Cyttus australis*
Dory-mirror	*Zenopsis nebulosus*
Flathead-tiger	*Neoplatycephalus richardsoni*
Gemfish	*Rexea solandri*
Gemfish-longfinned	*Rexea antefurcata*
Ghostshark-longfin	*Chimaera* sp. B
Ghostshark-silver	*Hydrolagus ogilbyi*
Giant cardinalfish	*Epigonus telescopus*
Gurnard-painted	*Pterygotrigla andertoni*
Gurnard-red	*Chelidonichthys kumu*
Hapuku	*Polyprion oxygeneios*
Imperador	*Beryx decadactylus*
Latchet	*Pterygotrigla polyommata*
Ling	*Genypterus blacodes*
Mackerel-blue	*Scomber australasicus*
Mackerel-jack	*Trachurus declivis*
Morwong-jackass	*Nemadactylus macropterus*

Table 2.4 Continued from previous page.

COMMERCIAL SPECIES continued.	
Morwong-rubberlip	*Nemadactylus douglasi*
Ocean perch-inshore	*Helicolenus percoides*
Ocean perch-offshore	*Helicolenus barathri*
Oilfish	*Ruvettus pretiosus*
Pigfish	*Bodianus* sp.
Redfish	*Centroberyx affinis*
Ribaldo	*Mora moro*
Ribbonfish	*Lepidopus caudatus*
Rudderfish	*Centrolophus niger*
Shark-angel	*Squatina* sp. A
Shark-eastern saw	*Pristiophorus* sp. A
Shark-gummy	*Mustelus antarcticus*
Shark-school	*Galeorhinus galeus*
Snapper	*Pagrus auratus*
Southern rock cod	*Pseudophycis barbata*
Stargazer-blue	*Pleuroscopus pseudodorsalis*
Stargazer-green	*Gnathagnus innotabilis*
Stargazer-speckled	*Kathetostoma canaster*
Warehou-blue	*Seriolella brama*
Warehou-spotted	*Seriolella punctata*
Warehou-white	*Seriolella caerulea*
Velvet leatherjacket	*Meuschenia scaber*
NON COMMERCIAL SPECIES	
Cucumberfish	*Chlorophthalmus nigripinnis*
Flathead-spiny	*Hoplichthys haswelli*
Skates-misc.	*Raja* spp.
Whiptails-misc.	Fam. Macrouridae
Crab-antler	*Latriellopsis petterdi*
Crab-red paddle	*Ovalipes molleri*

Table 2.5 Gear types used during 1979-81.

	Sydney			Ulladulla			Eden-Gabo Is.		
	1979	1980	1981	1979	1980	1981	1979	1980	1981
Boris box	11	-	-	3	-	-	18	-	-
Engel (1.8m doors)	12	-	-	13	-	-	15	-	-
Engel (2.4m doors)	-	10	8	4	11	12	-	14	29
Prawn trawl	13	3	2	-	-	1	-	-	-
Total	**36**	**13**	**10**	**20**	**11**	**13**	**33**	**14**	**29**

Table 2.6 Temporal distribution of tows during 1979-81.

	Sydney			Ulladulla			Eden		
	1979	1980	1981	1979	1980	1981	1979	1980	1981
February	-	-	-	-	-	1	-	-	-
March	-	-	-	-	-	-	-	-	-
April	-	-	-	-	-	-	-	-	-
May	-	-	1	3	-	5	-	-	9
June	6	-	-	-	11	-	-	14	18
July	16	10	3	3	-	1	18	-	-
August	-	-	5	5	-	3	-	-	-
September	3	-	-	3	-	2	-	-	2
October	5	-	1	3	-	-	15	-	-
November	-	-	-	2	-	-	-	-	-
December	6	3	-	-	-	1	-	-	-
Total	**36**	**13**	**10**	**19**	**11**	**13**	**33**	**14**	**29**

Table 2.7 Trawling depths during 1979-81.

	Sydney			Ulladulla			Eden		
Depth Zone	**1979**	**1980**	**1981**	**1979**	**1980**	**1981**	**1979**	**1980**	**1981**
220-275	3	1	0	2	2	0	6	3	4
330-385	16	4	3	9	7	7	19	7	14
440-495	17	7	6	8	2	6	8	4	9
550-605	0	1	1	1	0	0	0	0	2
Total	**36**	**13**	**10**	**20**	**11**	**13**	**33**	**14**	**29**

Table 2.8 Trawl duration during 1979-81.

	Sydney			Ulladulla			Eden		
Tow Duration (to nearest 5 mins)	**1979**	**1980**	**1981**	**1979**	**1980**	**1981**	**1979**	**1980**	**1981**
30	0	0	0	0	0	0	1	0	0
45	0	1	2	2	0	0	1	0	1
60	18	10	8	5	11	10	26	9	28
75	2	0	0	1	0	1	1	1	0
90	2	1	0	4	0	1	4	4	0
105	2	0	0	1	0	0	0	0	0
120	12	1	0	7	0	1	0	0	0
Total	**36**	**13**	**10**	**20**	**11**	**13**	**33**	**14**	**29**

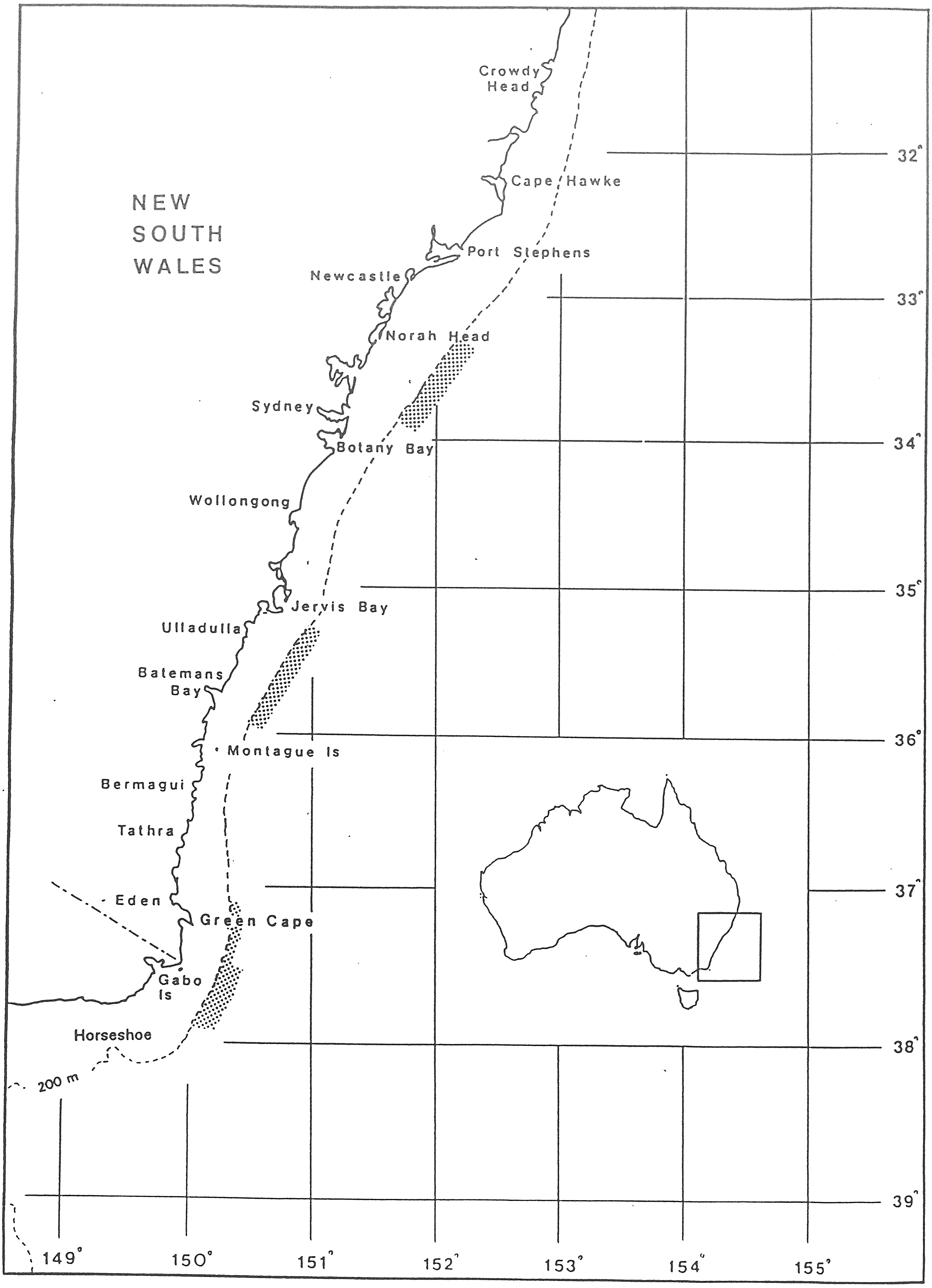

Figure 2.1 Location of surveyed areas (stippled) and their approximate areal extent.

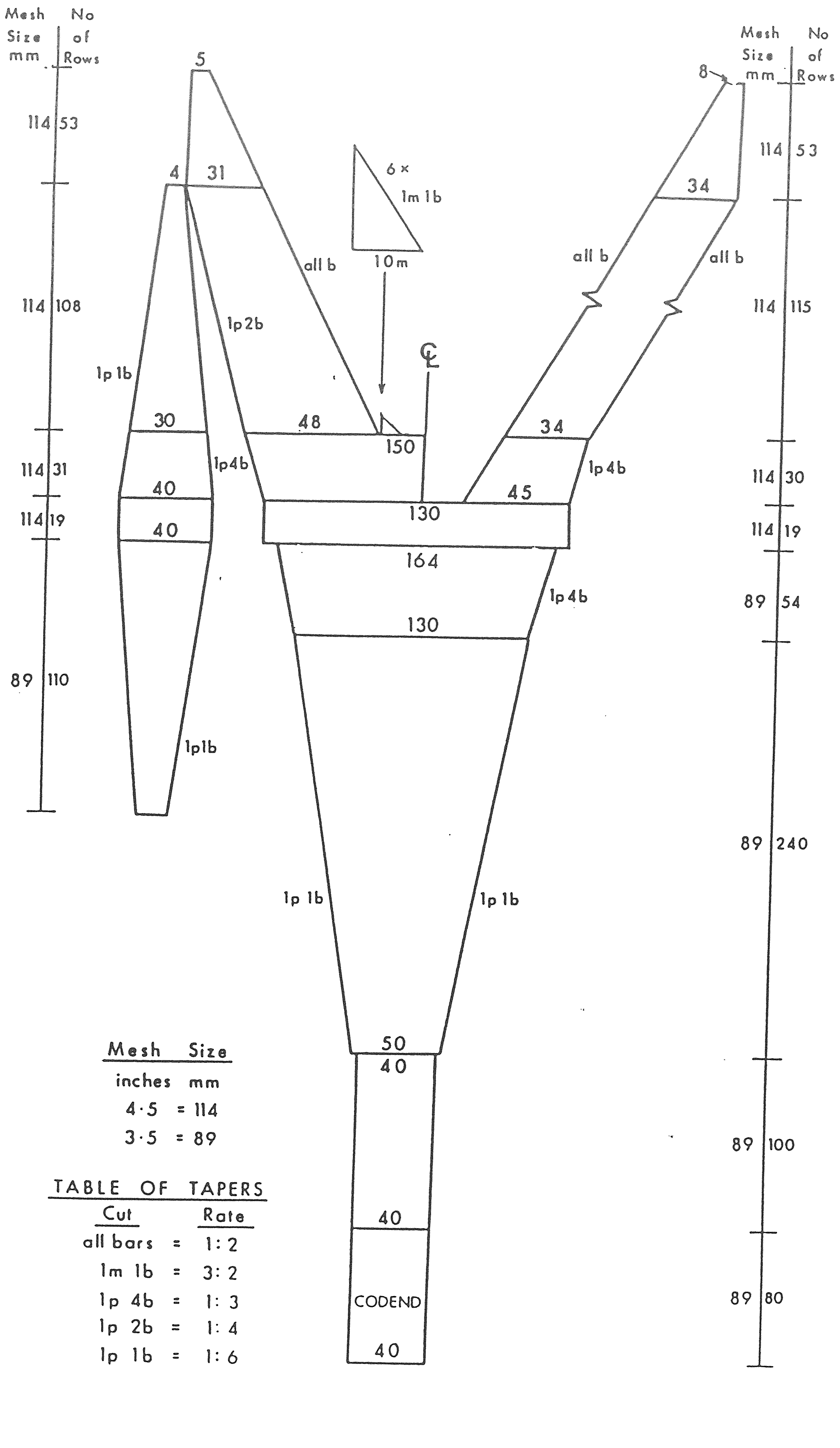

Figure 2.2 Net plan for 21 m headline Boris box trawl.

3. Comparison of 1976-7 and 1996-7 Catch Rates

Objective 1. To quantify changes in the comparative abundance of quota and other important upper slope fish since 1976-77.

This objective has been achieved by repeating the 1976-7 surveys. *Kapala* used the same nets and similar sampling protocols to resurvey the trawl grounds in 1996-7. Supplementary data from surveys done on the grounds in 1979-81 are used to provide an estimate of relative abundance of non-migratory species during the intervening 20 years. In this chapter we present the results of the 1996-7 surveys and analyse differences in catch rates with those observed in 1976-7. In the following chapter we compare these results with those of the 1979-81 surveys.

3.1 Results

The results of many of the analyses suggest that catch rates were influenced by more than one of the sources of variation (e.g. effects of location depend on depth). This complexity makes discussion of the results difficult because the necessary reliance on a series of statistical tests to differentiate differences among means. For each of the variables analysed, the reader is referred to analysis variance tables for the underlying significance tests and reference is made in the text to Ryan's tests as the basis for statements about the significance of differences among means. The word 'significant' is used to refer to statistical significance. In addition, more general, and more simple patterns are reported in the text as mean ± S.E. and reported in Table 3.1. These general patterns need to be interpreted in light of the complexities revealed by the statistical analyses.

3.1.1 Aggregated Catches

Total catch

The mean combined catch rates of all fish across all locations decreased substantially between 1976-7 (681 kg/h) and 1996-7 (216 kg/h). At Sydney and Eden, the 1996-7 mean total catch rates (222 and 253 kg/h respectively) were 30-40% of that in 1976-7. The greatest reduction was at Ulladulla where the mean total catch rate in 1996-7 (166 kg/h) was approximately 20% of that recorded during 1976-7.

At all locations, differences between 1976-7 and 1996-7 depended on depths (Figure 3.1, Table 3.2). Although catches were lower in 1996-7 at all depths, the ranking of mean total catches at each depth differed between periods (Ryan's tests). In 1976-7 catch rates were greatest in depth zone 3 and smallest in zone 4 (Ryan's tests). In 1996-7, catch rates were greatest in depth zone 2 (Ryan's tests). The only depths in which the 1996-7 catch rates were equal to or greater than those in 1976-7 were in 220 m at Sydney where large catches of spiky dogsharks were taken in 1996, and in 385 m at Eden where an exceptionally large catch of juvenile blue grenadier greatly increased the mean catch rate (Figure 3.1).

Depth-related patterns in catch rates varied significantly among locations (Table 3.2). Catch rates at Sydney were significantly smaller than those at Ulladulla and Eden in depth zones 3 and 4, but were greater in depth zone 1, Table 3.2, Ryan's tests). The three locations did not differ in depth zone 2 (Ryan's tests). There were signficant differences between surveys within depths, periods and locations (Table 3.2).

Total commercial catch

Catch rates of commercial species were significantly greater in 1976-7 (mean 568 kg/h) than in 1996-7 (148 kg/h). There was also a reduction in variability in catch rates among replicate tows within a survey and among surveys (Figure 3.2). The commercial catch as a proportion of the total catch changed from approximately 84% in 1976-7 to 69% in 1996-7.

The proportional representation of species in the commercial catch also changed between the two survey times. In 1976-7 the commercial catch consisted of small catches of a large number of species. Only redfish, Harrissons and southern dogsharks were caught in proportions >10% of the commercial catch. In contrast, the bulk of the 1996-7 commercial catch was comprised of only a small number of species; almost 75% of the commercial catch was just four species, spiky dogsharks, blue grenadier, ling and ocean perch. Spiky dogsharks dominated the commercial catches at Sydney (59%), while blue grenadier and ling collectively formed 55-56% of the catches on the grounds at Ulladulla and Eden.

Differences among depths in catch rates were not consistent among locations (Figure 3.2, Table 3.2). At Ulladulla and Eden, catch rates of commercial fish were greatest in depth zone 3, whereas in Sydney mean catch rates were greatest in depth zone 1 (Ryan's tests).

Catch rates were highly variable among surveys within depths, periods and locations (Table 3.2). For example, in 1977 at Ulladulla, depth zone 2, the mean catch rate for survey 3 was 372 kg/h, while that of survey 4 was nearly 5 times greater (1752 kg/h). This unusually large catch rate in survey 4 was due to large catches of redfish (see below).

Non-commercial species

Pooled over all surveys and locations, the catch rate of non-commercial fish in 1996-7 was approximately half that of 1976-7 (68 and 113 kg/h respectively). Differences in mean catch rates between periods varied with depth zones (Figure 3.3, Table 3.2). Mean catch rates were significantly smaller at all locations and depths except depth zone 4 (Ryan's tests).

Overall, the proportion of non-commercial fish in the total catch almost doubled between 1976-7 and 1996-7, from 17 to 31%. Over half the 1976-7 trash catch consisted of skates and spiny flathead; mean catch rates for these fish species exceeded 50 kg/h in several depth zones in each area (Figure 3.3) and averaged (across all areas and depths) 33 and 25 kg/h respectively.

During the 1996-7 surveys, catches of skates and spiny flathead were much smaller (6 and 10 kg/h respectively). The other main components on the non-commercial catch were cucumber fish and whiptails.

Differences among locations in catch rates of non-commercial species varied among depths (Figure 3.3, Table 3.2). At Eden catches were greatest in depth zone 4 and smallest in depth zone 1 (Ryan's tests). In contrast, the Sydney catch rates were smallest in depth zone 4 and greatest in the two most shallow depth zones (Ryan's tests). Although depth related patterns in catches at Ulladulla were similar to those in Sydney, *a posteriori* tests failed to separate estimates of mean catch rates among depths.

3.1.2 SEF Quota species

Blue Grenadier

Although significantly more blue grenadier were caught in 1996-7 than 1976-7 (Table 3.3), catches were sporadic and unpredictable (Figure 3.4, Table 3.3) in both periods. For example, the largest catch (1700 kg) was recorded in depth zone 3 at Ulladulla in August 1977, however, another tow in the same depth zone in the same survey yielded only 5 kg. Similarly, although catches in 1996-7 were generally less than 40 kg, several catches of juveniles (see Chapter 5) of up to 350 kg per tow were recorded at Ulladulla in November 1996, again in depth zone 3.

There were significant but depth-specific differences in catch rates among locations (Table 3.3). At Sydney, blue grenadier were caught only in depth zones 3 and 4, and in significantly lower numbers compared to Ulladulla and Eden (Figure 3.4, Ryan's tests). Catch rates at Ulladulla and Eden were greatest in depth zones 3 and 4 (Figure 3.4) although the largest catch was recorded in depth zone 2. Overall, catches were greatest in Eden and least in Sydney at all depths except in depth zone 1 where there were no significant differences among locations (Figure 3.4, Ryan's tests). Small catches were taken in depth zone 1 at Eden but no blue grenadier were caught at Sydney or Ulladulla (Figure 3.4).

The highly variable catch rates of blue grenadier were reflected in the significant differences among surveys within depth zones (Figure 3.4, Table 3.3). Patterns in catches of this species were typified by large differences among surveys within locations, periods and depth zones. For example, catches were small in Eden in March and July 1977 but much larger in October. Similarly, catch rates in 1996-7 were low (<125 kg/h), except in May when a large catch (1380 kg) was taken in depth zone 2 (none were caught in another tow during the same survey).

Ling

Catch rates of ling differed among depths and between periods and locations (Figure 3.5, Table 3.3, Ryan's tests). Pooled across locations, significantly more ling were caught in 1976-77 than 1996-7 in depth zone 4 but not in depth zones 1 and 3 (Ryan's tests). In contrast, catch rates were higher in 1996-7 in depth zone 2 (Figure 3.5, Ryan's tests). Catch rates were significantly lower at Sydney over all depths except depth zone 1 (Ryan's tests). Ulladulla and Eden were not different at any depth zone except depth zone 1 where small but significant catches were made at Eden (Figure 3.5, Ryan's tests). In both periods and at all locations, significantly more ling were caught on the deeper grounds trawled (between 440 and 605 m), however, the rank order of mean catch rates differed between periods and locations, confirming the complex differences in relative abundance between periods and among depths.

There were significant differences among surveys within each Location-Period combination (Figure 3.5, Table 3.3). These differences were greatest at Sydney, which is near the northern limit of ling's natural distribution (Figure 3.6).

Redfish

Catches in 1996-7 were significantly smaller than those in 1976-7 (mean 4.8 and 115.0 kg/h respectively, pooled across Location, Depth, and Survey). Catch rates at Ulladulla were much greater than those of Sydney and Eden (Figure 3.6). Several very large catches were recorded in Ulladulla in 1976-7 (e.g. 6,000 kg at 275 m in April 1977 and 7,000 kg at 330m in August 1977. All catches at Ulladulla in 1996-7 were less than 36 kg. At Sydney, large catches were recorded in May 1977 and May 1996 (Figure 3.6). In May 1996 a catch of 490 kg was recorded; all other catches at Sydney were less than 26 kg. At Eden relatively large catches of up to 350 kg were made in July 1977. In contrast all catches at Eden in 1996 were less than 34 kg and only 2 fish were caught in the last survey, in March 1997.

Catches of redfish were highly variable, reflecting the clumped distribution of the species (Figure 3.6). Catches were recorded only in depth zones 1 and 2 at all locations (Figure 3.6). Significantly more redfish were caught in depth zone 1 (220 to 275 m) than in depth zone 2 (330 to 385 m) (Ryan's tests).

Mirror dory

Catch rates of mirror dory reflect the seasonal movements and patchy distribution typical of this species (Figure 3.7). There was no significant difference among survey periods in catch rates of mirror dory. In both periods and at all locations, catch rates were greatest in the middle depths surveyed (between 330 and 495 m) although these patterns were complicated by significant and inconsistent differences among surveys (Figure 3.7, Table 3.3). For example, the Sydney catch rates were low in both survey I in 1976-7 and survey I in 1996-7 (Figure 3.7). Both surveys were in April-May and were probably too early in the year to catch fish from the annual spawning aggregation. Survey III in 1976-7 was done in May- June, at the time of year when mirror dory were expected to be more abundant, hence larger catch rates.

Catch rates in Ulladulla were relatively small (Figure 3.7) and were greatest in the July survey in 1976-7 when one tow in depth zone 3 yielded 1,200 kg and two others caught more than 500 kg (Figure 3.8). Similarly, Eden catch rates were relatively low for all surveys and depth zones except for survey III (October 1977), depth zone 3 when the average catch rate was 374 kg/h, with a maximum individual catch of 1300 kg.

Ocean Perch

Catch rates of ocean perch significantly declined between 1976-7 and 1996-7 at Sydney and Ulladulla but not Eden (Figure 3.8, Table 3.3, Ryan's tests). There were no significant differences in catch rate among locations in 1976-7 but there were in 1996-7 when catches were significantly smaller in Sydney than either Ulladulla or Eden (Ryan's tests).

Although small catches were recorded in shallow depth strata at Ulladulla and Eden, ocean perch were caught in greatest quantities between 440 and 605 m (Figure 3.8). There were large but inconsistent differences among depths between survey periods (Figure 3.8, Table 3.3). There were significant reductions in depth zones 2, 3 and 4 but not in depth 1, in which more ocean perch were caught in 1996-7 (Ryan's tests). In Sydney, reductions were greatest in depth zones 3 and 4 where trawlers mainly target royal red prawns in 400- 550 m.

Tiger flathead

Tiger flathead were caught at all three locations in depth zones 1 and 2 only (Figure 3.9). Catch rates were significantly greater in Depth zone 1 (Table 3.3, Ryan's tests). At all locations catches were small and sporadic, causing significant differences among surveys within Depth, Period and Location (Table 3.3.). At Sydney, catch rates were greater in autumn than in surveys done in spring, suggesting a seasonal pattern in catchability. There was no evidence of seasonality at Ulladulla or Eden. There were no significant differences among periods or locations in catch rates of tiger flathead, nor did these factors interact with Depth (Table 3.3).

Jackass morwong

Jackass morwong were caught only in Ulladulla and Eden and only in depth zones 1 and 2 (Figure 3.10). Overall, catch rates in depth zones 1 and 2 at Ulladulla in 1976-7 (3.0 ± 0.9 kg/h) were an order of magnitude smaller than in Eden (69.5 ± 24.9 kg/h). In 1996-7, only one jackass morwong was caught at Ulladulla and only five were caught at Eden (Figure 3.10). When analysed, these broad patterns were obscured by the large variances among estimates of mean catch rate caused by the zero catches in Sydney and in depth zones 3 and 4 at all locations. (Figure 3.10, Table 3.5). These patterns caused a significant interaction between Depth, Period and Location (Table 3.5). At smaller spatial scales, there appeared to be greater consistency (see non-significant effects of Survey and Survey x Depth terms in the analysis (Table 3.5).

Gemfish

Catch rates of gemfish were highly variable among surveys, as expected for this schooling and migratory species (Figure 3.11, Table 3.3). At all locations, large but variable catches were reported in 1976-7 (Figure 3.11). Corresponding catches in all surveys in 1996-7 were uniformly small, despite the similar timing (Figure 3.11). At Ulladulla, the relatively large catch rates recorded in July 1976 and August 1977 (surveys I and IV) coincided with the winter spawning migrations. Catches at other times of the year were generally much smaller (Figure 3.11). At Sydney, relatively low catch rates were observed in all depths and surveys except in September 1977 depth zone 2. This survey coincided with the post-spawning southward migration of gemfish. The corresponding survey in September 1996 recorded lower catch rates (Figure 3.11).

Overall, catches were similar in Eden and Ulladulla, and significantly smaller in Sydney (Figure 3.11, Ryan's tests). Significantly more gemfish were caught in 1976-7 than in 1996-7 in all depth zones except depth zone 4 where catch rates were always low (Figure 3.11, Ryan's tests).

Spotted warehou

Catches of spotted warehou were mostly small and sporadic (Figure 3.12). At Ulladulla catches were made in depth zones 1, 2 and 3 in August 1977 only. At Eden small catches were made at all depths in 1996-7 and in depth zones 1 and 2 in 1977. None were caught at Sydney at any time (Figure 3.12). Catch rates varied significantly among surveys within depths, periods and locations (Figure 3.12, Table 3.3). For example at Ulladulla in 1976-7 depth zone 2, the mean catch rate of survey 4 was 103 kg/h while all other surveys in this depth zone yielded zero catches. Overall catch rates did not vary significantly among locations or periods but were significantly smaller in depth zones 3 and 4 compared to shallower depths (zones 1 and 2) (Figure 3.12, Ryan's tests).

Other commercial quota species

Small quantities of blue eye, john dory, inshore ocean perch and blue warehou were also caught. Mean catch rates for these species were less than 1 kg/h and collectively they contributed less than 1% to the total catch. The reader is directed to the companion data report (Hodgson *et al.* 1997) held at the NSW Fisheries Research Institute library for catch details of blue eye.

3.1.3 Commercial non-quota teleosts

Ribbonfish was the only commercial non-quota species that contributed more than 1% of the total catch. The mean catch rate of ribbonfish in 1976-7 was 10.8 ± 4.7 kg/h in 1976-7 and 6.9

± 3.0 in 1996-7. Other species caught in small quantities (mean <5 kg/h) were: painted gurnard, green stargazer, speckled stargazer, king dory, latchet, ribaldo, jack mackerel, oilfish, rudderfish, hapuku, bass groper, silver dory, alfonsin, blue stargazer, barracouta, imperador, pigfish, snapper, conger eel, southern rock cod, blue mackerel, velvet leatherjacket, white warehou, giant cardinalfish, rubberlip morwong, longfin gemfish and red gurnard. Of these, catch details of ribbonfish, painted gurnard, green stargazer, king dory, latchet and ribaldo are provided in Hodgson *et al.* (1997), held at the NSW Fisheries Research Institute library.

3.1.4 Commercial sharks

Eastern angel shark

There were large but inconsistent differences in catch rates of angel sharks among periods, locations and depths (Figure 3.13, Table 3.4). The magnitude of this variability was such that changes between 1976-7 and 1996-7 can only be discussed with reference to both depth and location. Angel sharks were caught at all three locations, but only in small quantities at Eden. The greatest average catch rate at Eden was 6.6 kg/h (survey II, depth zone 1 in 1976) compared with maximum mean catch rates of 86 and 160 kg/h at Sydney and Ulladulla respectively (survey I, depth zone 1 1976). Angel sharks were caught almost exclusively in depth zones 1 and 2 (220 - 385 m). At all locations, a total of only 16 kg was caught in depth zone 3 and none were caught in depth zone 4. The highest catch rate recorded in 1996-7 was 6.0 ± 1.9 kg/h in depth zone 1, survey 1. In addition to this complexity in patterns of catches at larger spatial scales, there were signficant but inconsistent differences among surveys within depth strata (Table 3.4).

Endeavour dogshark

Significantly more Endeavour dogsharks were caught in 1976-7 compared to 1996-7 (Figure 3.14, Table 3.4). In 1976-7 the mean catch rate was 12.5 ± 1.8 kg/h (pooled across locations, depths and surveys) compared to only 0.1 ± 0.1 kg/h in 1996-7. Only 12 sharks were caught at Sydney in 1996-7 and none at Ulladulla or Eden.

During 1976-7, endeavour dogsharks were caught in all depth zones in Sydney and Ulladulla, but catches were greatest in depth zones 2 and 3. Catch rates were significantly greater in Sydney compared to Ulladulla and both were significantly greater than at Eden where only one shark was caught in Eden in depth zone 2 (Ryan's tests).

Catch rates were highly variable among surveys, and these patterns were inconsistent among depth zones (Table 3.4). For example, excluding depth zone 4, catch rates in survey I in 1976 at Ulladulla were much greater than subsequent surveys and the magnitude of this difference increased with depth. In depth zone 3, survey I, the mean catch rate was 71 kg/h while in subsequent surveys mean catch rates were <5 kg/h.

Greeneye dogshark

Greeneye dogsharks were caught at all locations and depth zones (Figure 3.15). There were large and inconsistent differences in catches among the depth - location - period combinations, which caused a significant high order interaction term (Table 3.4). Mean catch rates (locations, depth zones and surveys pooled), decreased from 44.7 kg/h in 1977 (maximum of 720 kg in one tow) to 1.2 kg/h 20 years later. At Eden, only one greeneye dogshark was caught in all the 1996-7 surveys. In 1976-7 catch rates were greatest in Sydney (mean 92.3 ± 12.7 kg/h) and least in Eden (7.2 ± 2.1) and a mean of 21.7 ± 3.0 kg/h was recorded in Ulladulla.

When analysed there was significant variability among surveys within depth zones, periods and locations. For example, catches at Eden were small and sporadic and generally less than 10 kg/h, except in survey 1, 1976-7. Catch rates in survey I, March 1977, averaged 17.5 kg/h compared to just 0.6 and 1.8 kg/h for surveys II and III 1977. In contrast, mean catch rates in Sydney and Ulladulla were greatest for survey II 1976 in all depth zones.

Spiky dogshark

Spiky dogsharks were caught only in depth zones 1 and 2, except at Eden where a small catch (12.5 kg in total) was recorded in depth zone 3 in 1996 (Figure 3.16). Differences in catch rates among depths depended on location (Figure 3.16, Table 3.4). Catch rates in depth zone 1 were significantly greater than in zone 2 and both were significantly greater than in depth zones 3 and 4 (Figure 3.16, Table 3.4, Ryan's tests). Catch rates are similar between locations for depth zones 2, 3 and 4; catches in Sydney were significantly greater than Ulladulla and Eden at depth zone 1.

There were no significant differences in catch rates of spiky dogsharks between 1976-7 and 1996-7 (Figure 3.16, Table 3.4). At Sydney, mean catch rates in depth zones 1 and 2 in 1996-7 (179.3 ± 74.9 kg/h) were twice that in 1976-7 (82.2 ± 14.5) (Figure 3.16, Table 3.4). At Ulladulla and Eden the 1996-7 rates (30.4 ± 9.6 and 31.7 ± 7.7 kg/h respectively) were less than those in 1976-7 (61.1 ± 11.4 and 41.5 ± 10.6 kg/h respectively) (Figure 3.16). In all locations in depth zones 1 and 2 spiky dogsharks made up a greater percentage of the total catch in 1996-7 compared to in 1976-7 (Figure 3.16, Tables 3.6 & 3.7).

Harrissons and southern dogsharks

Data for these two species of *Centrophorus* were combined as they were not distinguished in early surveys. In those surveys in 1976-7 where the two species were separated, approximately 80% of the combined catch were southern dogsharks and 20% Harrissons.

Harrisons and southern dogsharks were caught in all depth zones and at all locations (Figure 3.17). Catch rates varied significantly among depths but were inconsistent between periods and locations (Figure 3.17, Table 3.4). Shallow depths (220- 275 m) had significantly smaller catch rates at all locations. The unusually large catch in depth zone 1, survey II at Sydney was from a night tow. There seems to be an inshore movement by these species at night as during the day, few were caught in these shallow depths. Catch rates were similar for all three locations in depth zones 1 and 2, however Sydney had significantly smaller catches in depth zone 3, and Ulladulla catch rates were greater than Sydney and Eden in depth zone 4.

Catches of *Centrophorus* spp. were significantly smaller in 1996-7 compared to 1976-7 for all depths (Figure 3.17, Table 3.4). Overall, catches declined from 126.3 ± 17.7 to 0.4 ± 0.1 kg/h in 20 years. A total of 14 southern and 8 Harrisson's dogsharks (mostly juveniles) were caught during 1996-7 on all grounds. There were significant differences in catch rates among depths in 1976-7 but not in 1996-7 (Figure 3.17, Table 3.4). In 1976-7, catches were smallest in depth zone 1 and greatest in depth zone 4 (Ryan's tests). Catches in 1996-7 were similarly small in all depth zones, ranging from zero in depth zone 1 to an average of 1.4 kg per hour in depth zone 4.

Longnose dogshark

Catches of longnose dogsharks were sporadic and highly variable among surveys within depth zones, periods and locations (Figure 3.18, Table 3.4, Ryan's tests). High catch rates during July- November and low catches at other times suggests there are seasonal patterns in catchability or abundance (Figure 3.18). The exception to this was at Eden in depth zone 4 where unusually large catches were taken in March 1977 (mean 298 kg/h; Figure 3.18).

Mean catch rates were significantly higher in 1976-7 than in 1996-7 (15.6 and 1.4 kg/h respectively; Table 3.4, Ryan's tests). In 1976-7 longnose dogsharks comprised 2.3% of the total catch while in 1996-7 they comprised only 0.6%. In both periods longnose dogsharks were ranked the 10th most caught species (by weight) despite the decline in catch rates (Figure 3.18, Table 3.7). Longnose dogshark catches also varied significantly among depths within locations (Figure 3.18, Table 3.4). Catch rates did not differ among locations except at depth zone 4 where catches were significantly smaller at Sydney (Figure 3.18, Ryan's tests).

Other commercial sharks

Small quantities of school shark, gummy shark, sawshark, longfin ghostshark, silver ghostshark and highfin dogshark and were also caught. All of these species showed reduced catch rates between the two sampling periods (except for the highfin dogshark which was not identified in the 1976-7 catches). Saw, gummy, and longfin ghost sharks were all caught in smaller quantities in 1996-7 compared to 1976-7, although catches were generally small at all times. School sharks were caught mainly off Ulladulla and Eden with catches up to 100 kg/h made in 1976-7. Not a single school shark was caught in 1996-7. Silver ghostsharks were caught at all locations during both survey periods. The highest mean catch rates in 1976-7 were off Sydney and Eden where they exceeded 50 kg/h in a number of depths. The greatest catch of silver ghostshark in any tow during 1996-7 was 7 kg.

3.1.5 Non-commercial (trash) species

Spiny flathead

Spiny flathead were caught at all depths and locations (Figure 3.19). Mean catch rates were greatest in the depth zone 2 at Sydney and Ulladulla (Table 3.3, Ryan's tests). At Eden, catch rates in depth zones 2 and 3 were similar and both were significantly greater than in depth zone 1 or 4 (Figure 3.19, Ryan's tests).

Differences in catch rates between the two periods varied among depth zones. In depth zones 2 and 3, catches were significantly lower in 1996-7 than in 1976-7 (Figure 3.19, Ryan's tests). In contrast, in depth zone 1 catch rates were significantly greater in 1996-7 and in depth zone 4 they were not significantly different (Ryan's tests). The overall contribution of spiny flathead to the total catch (approximately 5%) was similar between the two sampling periods (Figure 3.19, Table 3.7). There was significant small scale variation in catch rates among surveys within locations and periods (Figure 3.19, Table 3.3).

Miscellaneous skates

Catch rates of skates were similar at all locations but varied significantly among depths and periods (Figure 3.20, Table 3.4). In 1976-7 skates were caught at an average rate of 32.6 kg/h and contributed 4.8% of the total catch and almost 30% of the non-commercial catch (Figure 3.20, Table 3.6). Catch rates were significantly lower in 1996-7 (mean 5.8 kg/h) and comprised only 2.7% of the total catch and less than 10% of the non-commercial catch (Figure 3.20, Table 3.7).

Skates were caught in significantly greater quantities in depth zone 3 than in depth zones 2 and 4 (Ryan's tests). Catches in depth zone 1 were significantly smaller than all other depths (Ryan's tests). There was also significant variability among surveys within locations, periods and depths (Figure 3.20, Table 3.4).

Crabs

Large quantities of non commercial red paddle crabs and/or antlered crabs were caught at Ulladulla and Eden in depth zones 1-3 in 1996-7. Catch rates as high as 170 kg/h were recorded and in a number of tows, crabs outweighed catches of fish. In 1976-7 catches of crabs were negligible (K. Graham, pers. obs.) and therefore were not quantified.

Table 3.1 Mean catch rates (with SE) for total fish, total commercial fish and important species caught during 1976-77 and 1996-97. For comparison, data were pooled across all depths (220-605 m) or across 220-385 m for those species caught principally in the shallow depths.

	All Locations				Sydney				Ulladulla				Eden-Gabo Is.			
	1976-7		1996-7		1976-7		1996-7		1976-7		1996-7		1976-7		1996-7	
	Mean Catch (kg/h)	SE	Mean Catch (kg/h)	SE	Mean Catch (kg/h)	SE	Mean Catch (kg/h)	SE	Mean Catch (kg/h)	SE	Mean Catch (kg/h)	SE	Mean Catch (kg/h)	SE	Mean Catch (kg/h)	SE
220-605 m																
Total Fish	680.9	49.0	215.7	18.3	548.2	36.7	222.2	45.3	847.7	117.1	166.4	14.7	638.6	70.6	253.0	30.2
Total Comm. Fish	567.7	47.7	148.3	16.9	408.1	32.0	163.8	41.3	758.9	116.1	110.8	12.4	530.4	61.3	168.5	29.3
Harr. & Sthn dog.	126.3	17.7	0.4	0.1	49.5	9.1	0.2	0.2	151.8	31.6	1.0	0.4	203.4	48.3	<0.1	
Greeneye dogshark	44.8	5.5	1.2	0.3	92.4	12.7	2.7	0.7	21.8	3.1	1.2	0.6	7.5	0.2	<0.1	
Ocean perch	41.2	3.5	13.1	1.2	38.4	5.3	6.6	1.4	47.3	6.8	14.2	1.9	36.8	6.0	17.2	2.3
Mirror dory	35.9	9.0	6.7	1.0	27.2	6.6	9.0	2.8	44.3	16.5	4.6	0.9	36.9	24.1	6.6	1.3
Skate	32.7	3.0	5.5	0.8	33.0	4.3	8.1	1.9	32.6	6.1	3.9	0.9	32.4	4.5	5.0	1.2
Ling	26.1	2.6	25.0	2.9	13.2	2.6	3.0	0.9	35.3	4.8	25.5	4.2	31.8	5.7	41.4	5.8
Spiny flathead	24.9	3.2	10.0	1.4	40.6	6.6	15.1	3.5	18.8	5.0	6.3	1.3	10.6	2.1	9.2	2.3
Blue grenadier	19.3	7.6	34.5	9.5	0.5	0.3	4.3	1.5	29.1	19.5	38.2	10.3	33.0	10.1	54.6	22.8
Longnose dogshark	15.7	4.1	1.4	0.4	9.6	2.8	0.2	0.2	12.2	2.8	2.7	1.0	29.5	14.8	1.2	0.6
Endeavour dogshark	12.3	1.8	0.2	0.1	24.5	3.9	0.5	0.2	8.1	2.4	<0.1		0.1	0.1	0	
Gemfish	11.1	1.7	0.8	0.2	3.9	1.4	0.6	0.2	13.2	3.0	0.6	0.2	18.7	4.3	1.1	0.4
Silver ghostshark	8.3	1.2	0.3	0.1	7.9	1.7	0.6	0.2	2.2	0.6	0.3	0.1	17.4	3.3	<0.1	
220-385 m																
Total Fish	700.7	77.4	246.0	31.6	675.4	55.3	378.2	78.6	920.7	198.0	131.1	11.3	430.2	70.6	247.2	52.5
Total Comm. Fish	591.1	77.2	179.8	30.2	501.9	51.6	283.7	75.1	848.7	198.7	83.9	9.5	362.7	44.5	185.3	51.9
Redfish	214.2	74.2	9.6	5.7	26.2	12.1	25.3	20.3	545.2	195.6	5.3	1.9	23.4	6.4	1.3	0.6
Spiky dogshark	64.0	7.4	75.5	22.3	82.2	14.5	192.4	74.7	61.8	11.3	28.4	8.4	41.5	10.6	31.7	7.8
Angel shark	32.6	5.3	1.3	0.4	27.3	6.3	2.7	0.8	60.8	11.9	1.2	0.7	1.5	0.6	0.4	0.4
Jackass morwong	19.6	7.1	<0.1		0		<0.1		3.0	0.9	<0.1		69.5	25.0	<0.1	
Ribbonfish	19.4	8.3	11.8	5.6	45.0	21.8	12.8	6.8	6.0	3.0	3.8	2.4	1.9	1.3	16.7	12.9
Tiger flathead	10.5	1.6	6.0	1.2	12.1	3.2	11.4	3.4	9.7	3.2	6.4	1.7	9.2	2.7	2.1	0.7
Spotted warehou	5.5	2.8	4.2	1.7	0		0		14.2	7.4	<0.1		1.1	0.4	7.3	3.4
Painted gurnard	9.0	1.7	1.8	0.6	21.6	3.8	6.1	2.0	2.7	1.1	<0.1		0		<0.1	
Gummy shark	5.5	1.1	1.1	0.3	4.1	1.3	2.7	0.9	2.6	0.7	<0.1		11.3	3.3	0.7	0.4
Saw shark	4.8	0.9	2.5	0.8	8.5	2.0	7.9	2.4	2.0	0.5	0.3	0.1	3.4	1.4	<0.1	
School shark	3.4	1.0	0		0.1	0.1	0		5.6	2.5	0		4.9	1.8	0	

Table 3.2 Summary analysis of variance tables for analyses of catch rates (kg/h). Type III sums of squares were used. Note the different df for *F* are due to missing values for trash and commercial catches. F ratios in bold are statistically significant.

ANOVAs Source of variation	df for *F*	Total catch	Total trash	df for *F*	Total commercial catch
Location	2, 12	0.96	1.18	2, 12	1.23
Depth	3, 36	**5.28**	**4.52**	3, 36	**5.57**
Loc x Dep	6, 36	**11.30**	**13.11**	6, 36	**7.39**
Period	1, 12	**34.54**	**15.66**	1, 12	**39.42**
Loc x Per	2, 12	0.78	2.31	2, 12	0.49
Per x Dep	3, 36	**3.28**	**8.06**	3, 36	2.06
Loc x Per x Dep	6, 36	2.33	2.35	6, 36	2.18
Survey (Loc x Per)	12, 327	**4.78**	**2.82**	12, 333	**4.35**
Dep x Sur (Loc x Per)	36, 327	**1.68**	**1.74**	36, 333	**1.94**
Residual MS		0.40	0.40		0.51
Transformations			all Log (x+1)		

Table 3.3 Summary analysis of variance table for analyses of catch (kg/h) for teleost species. Type III sums of squares were used. F ratios shown in bold are statistically significant at p = 0.05.

ANOVAs Source of variation	df for *F*	Blue grenadier	Ling	Redfish	Mirror dory	Ocean perch	Tiger flathead	Spiny flathead	Gemfish	Spotted warehou
Location	2, 12	**10.06**	**20.89**	3.55	0.71	**6.91**	0.82	**10.98**	**4.74**	2.35
Depth	3, 36	**20.48**	**141.15**	**28.68**	**7.57**	**112.52**	**59.92**	**36.67**	**11.10**	**2.97**
Loc x Dep	6, 36	**2.50**	**10.67**	1.73	0.67	**2.86**	0.76	**6.80**	2.28	1.25
Period	1, 12	**5.91**	0.33	**5.62**	0.29	**15.98**	0.15	**5.51**	**29.68**	0.11
Loc x Per	2, 12	0.43	3.66	3.30	0.69	**4.56**	0.83	3.30	3.16	1.43
Per x Dep	3, 36	1.68	**9.71**	2.74	1.75	**21.38**	1.30	**8.79**	**6.38**	0.97
Loc x Per x Dep	6, 36	0.59	1.18	2.02	0.53	1.01	1.54	0.78	1.47	0.67
Survey (Loc x Per)	12, 333	**2.48**	**4.04**	1.46	**2.30**	**2.27**	1.59	0.57	1.91	**2.77**
Dep x Sur (Loc x Per)	36, 333	**5.86**	1.30	**2.31**	**5.63**	**1.81**	**5.12**	**2.96**	**2.46**	**2.38**
Residual MS		0.74	0.87	1.43	0.99	0.69	0.32	0.88	0.70	0.36
Transformations		all Log (x+1)								

Table 3.4 Summary analysis of variance table for analyses of catch (kg/h) for elasmobranchs. Type III sums of squares were used. F ratios shown in bold are statisitically significant.

ANOVAs Source of variation	df for *F*	Eastern angel shark	Endeavour dogshark	Greeneye dogshark	Spiky dogshark	Harrissons & southern dogsharks	Long nose dogshark	Skates
Location	2, 12	**8.90**	**6.41**	**8.67**	**4.32**	2.83	2.20	0.25
Depth	3, 36	**40.36**	2.11	**9.20**	**231.01**	**37.57**	**24.57**	**11.08**
Loc x Dep	6, 36	**9.60**	1.01	**3.75**	**2.97**	**2.39**	**2.68**	1.99
Period	1, 12	**21.91**	**10.35**	**27.03**	0.00	**183.33**	**20.73**	**38.96**
Loc x Per	2, 12	**5.04**	3.76	2.51	0.74	1.89	0.03	0.67
Per x Dep	3, 36	**13.26**	2.25	0.52	0.17	**28.50**	2.58	2.45
Loc x Per x Dep	6, 36	**3.48**	1.31	**4.75**	0.96	1.09	0.65	2.05
Survey (Loc x Per)	12, 333	1.88	**5.50**	**9.36**	1.58	1.69	1.45	1.30
Dep x Sur (Loc x Per)	36, 333	**2.27**	**1.73**	**1.93**	1.04	1.30	**1.92**	**3.69**
Residual MS		0.57	0.76	0.69	1.31	1.86	1.05	0.99
Transformation				all Log (x+1)				

Table 3.5 Summary analysis of variance table for analyses of catch (kg/h) where D*S(LP) has been pooled with the error SS (marked *), and D*S(LP) and S(LP) have been pooled with error SS (marked**). Type III sums of squares were used. F ratios shown in bold are statisitically significant at p = 0.05.

ANOVAs Source of variation	df for *F*	Jackass morwong**	df for *F*	Spiky dogshark*
Location	2, 381	**56.19**	2, 12	**4.32**
Depth	3, 381	**43.61**	3, 369	**239.41**
Loc x Dep	6, 381	**22.02**	6, 369	**3.08**
Period	1, 381	**94.78**	1, 12	0.00
Loc x Per	2, 381	**49.04**	2, 12	0.74
Per x Dep	3, 381	**39.59**	3, 369	0.18
Loc x Per x Dep	6, 381	**18.57**	6, 369	0.99
Survey (Loc x Per)			12, 369	1.63
Dep x Sur (Loc x Per)				
Residual MS		0.332		1.311
Transformation		all Log (x+1)		

Table 3.6 Total catches with % of total fish catch and occurrence (no. of tows in which species was caught) for total fish, total commercial fish, all commercial species, trash fish and main trash species taken during the 1976-77 surveys.

	All Areas			Sydney			Ulladulla			Eden		
	Total catch (kg)	% total catch	No. of tows	Total catch (kg)	% total catch	No of tows	Total catch (kg)	% total catch	No of tows	Total catch (kg)	% total catch	No of tows
Total Fish	**167506**	**100.0**	**246**	**50982**	**100.0**	**93**	**76291**	**100.0**	**90**	**40234**	**100.0**	**63**
Total Comm. Fish	**139666**	**83.4**	**246**	**37951**	**74.4**	**93**	**68301**	**89.5**	**90**	**33414**	**83.0**	**63**
Harr. & Sth. dog.*	31119	18.6	157	4648	9.1	57	13658	17.9	60	12813	31.9	40
Redfish	28270	16.9	65	1284	2.5	15	26168	34.3	36	818	2.0	14
Greeneye dogshark	11027	6.6	181	8593	16.9	88	1964	2.6	62	470	1.2	31
Ocean perch	10137	6.1	187	3568	7.0	64	4253	5.6	73	2316	5.8	50
Mirror dory	8841	5.3	161	2527	5.0	65	3991	5.2	64	2323	5.8	32
Spiky dogshark	8445	5.0	109	4029	7.9	42	2965	3.9	37	1451	3.6	30
Ling	6411	3.8	153	1230	2.4	43	3179	4.2	68	2002	5.0	42
Blue grenadier	4745	2.8	77	44	<0.1	8	2622	3.4	34	2079	5.2	35
Angel shark	4324	2.6	81	1339	2.6	33	2932	3.8	42	53	0.1	6
Longnose dogshark	3849	2.3	92	889	1.7	34	1100	1.4	37	1860	4.6	21
Ribbonfish	3361	2.0	56	2756	5.4	22	513	0.7	29	92	0.2	5
Endeavour dogshark	3021	1.8	93	2282	4.5	60	733	1.0	31	6	<0.1	2
Gemfish	2731	1.6	151	367	0.7	38	1189	1.6	63	1175	2.9	50
Jackass morwong	2580	1.5	51	3	<0.1	2	144	0.2	19	2433	6.1	30
Silver ghostshark	2033	1.2	115	734	1.4	44	201	0.3	32	1098	2.7	39
Tiger flathead	1382	0.8	76	593	1.2	27	467	0.6	31	322	0.8	18
Painted gurnard	1187	0.7	65	1059	2.1	44	128	0.2	21	0	0	0
Gummy shark	736	0.4	66	201	0.4	23	141	0.2	22	394	1.0	21
Spotted warehou	723	0.4	19	0	0	0	684	0.9	7	39	0.1	12
Green stargazer	634	0.4	68	531	1.0	38	102	0.1	29	1	<0.1	1
Sawshark	631	0.4	53	417	0.8	21	95	0.1	20	119	0.3	12
Yellow stargazer	581	0.4	45	0	0	0	120	0.2	24	461	1.2	21
King dory	535	0.3	81	151	0.3	32	128.5	0.2	29	255	0.6	20
School shark	492	0.3	29	5	<0.1	1	317	0.4	16	172	0.4	12
Latchet	370	0.2	13	367	0.7	11	3	<0.1	2	0	0	0
Longfin ghostshark	342	0.2	39	108	0.2	17	74	0.1	10	160	0.4	12
Ribaldo	301	0.2	16	0	0	0	63	<0.1	7	238	0.6	9
Blue eye	235	0.1	27	10	<0.1	2	42	<0.1	7	183	0.5	18
Jack mackerel	208	0.1	25	43	<0.1	7	159	0.2	16	6	<0.1	2
Oilfish	155	0.1	6	110	0.2	4	45	<0.1	2	0	0	0
Rudderfish	50	<0.1	10	23	<0.1	5	22	<0.1	4	5	<0.1	1
Inshore ocean perch	43	<0.1	14	2	<0.1	2	38	<0.1	11	3	<0.1	1
John dory	35	<0.1	9	0	0	0	12	<0.1	6	23	<0.1	3
Hapuku	32	<0.1	4	0	0	0	18	<0.1	2	14	<0.1	2
Bass groper	31	<0.1	4	23	<0.1	3	0	0	0	8	<0.1	1
Silver dory	21	<0.1	7	1	<0.1	1	0	0	0	20	<0.1	6
Alfonsin	14	<0.1	12	10	<0.1	6	4	<0.1	6	0	0	0
Blue stargazer	14	<0.1	5	0	0	0	14	<0.1	5	0	0	
Barracouta	5	<0.1	2	0	0	0	5	<0.1	2	0	0	0
Imperador	3	<0.1	4	1	<0.1	1	2	<0.1	3	0	0	0
Pigfish	3	<0.1	5	0	0	0	3	<0.1	5	0	0	0
Snapper	3	<0.1	1	0	0	0	3	<0.1	1	0	0	0
Conger eel	2	<0.1	1	0	0	0	2	<0.1	1	0	0	0
Southern Rock cod	2	<0.1	1	0	0	0	0	0	0	2	<0.1	1
Blue mackerel	<1	<0.1	1	<1	<0.1	1	0	0	0	0	0	0
Velvet leatherjacket	<1	<0.1	1	<1	<0.1	1	0	0	0	0	0	0
Total Trash	**27841**	**16.6**	**246**	**13031**	**25.6**	**93**	**7990**	**10.5**	**90**	**6820**	**17.0**	**63**
Skate	8043	4.8	201	3064	6.0	67	2938	3.9	78	2041	5.1	56
Trash sharks & rays	**6354**	**3.8**	**246**	**3048**	**6.0**	**93**	**1455**	**1.9**	**90**	**1851**	**4.6**	**63**
Spiny flathead	6132	3.7	166	3771	7.4	72	1695	2.2	52	666	1.7	42
Misc. whiptails	4250	2.5	229	1039	2.0	86	916	1.2	80	2295	5.7	63

* not seperated in early surveys.

Table 3.7 Total catches with % of total fish catch and occurrence (no. of tows in which species was caught) for total fish, total commercial fish, all commercial species, trash fish and main trash species taken during the 1996-97 surveys.

	All Areas			Sydney			Ulladulla			Eden		
	Total catch (kg)	% total catch	No. of tows	Total catch (kg)	% total catch	No. of tows	Total catch (kg)	% total catch	No. of tows	Total catch (kg)	% total catch	No. of tows
Total Fish	**35587**	**100.0**	**165**	**10667**	**100.0**	**48**	**8984**	**100.0**	**54**	**15936**	**100.0**	**63**
Total Comm. Fish	**24463**	**68.7**	**165**	**7862**	**73.7**	**48**	**5984**	**66.6**	**54**	**10617**	**66.6**	**63**
Spiky dogshark	6507	18.3	82	4618	43.3	22	767	8.5	23	1122	7.0	37
Blue grenadier	5556	15.6	92	206	1.9	12	1908	21.2	36	3442	21.6	44
Ling	4126	11.6	123	144	1.4	18	1375	15.3	44	2607	16.4	61
Ocean perch	2167	6.1	144	317	3.0	30	765	8.5	53	1085	6.8	61
Ribbonfish	1215	3.4	56	408	3.8	26	100	1.1	12	707	4.4	18
Mirror dory	1084	3.1	107	430	4.0	31	239	2.7	33	415	2.6	43
Redfish	829	2.3	45	606	5.7	12	143	1.6	17	80	0.5	16
Tiger flathead	519	1.5	49	273	2.6	18	172	1.9	18	74	0.5	13
Spotted warehou	318	0.9	19	0	0	0	1	<0.1	1	317	2.0	18
Longnose dogshark	216	0.6	23	10	0.1	2	131	1.5	11	75	0.5	10
Sawshark	207	0.6	25	191	1.8	18	13	0.2	5	3	<0.1	2
Greeneye dogshark	188	0.5	37	127	1.2	25	60	0.7	11	1	<0.1	1
Painted gurnard	149	0.4	31	147	1.4	21	1	<0.1	7	<1	<0.1	3
Jack mackerel	145	0.4	28	15	0.1	8	51	0.6	11	78	0.5	9
Green stargazer	142	0.4	29	128	1.2	21	7	<0.1	5	7	<0.1	3
Ribaldo	139	0.4	19	0	0	0	33	0.4	6	106	0.7	13
Barracouta	135	0.4	8	0	0	0	0	0	0	135	0.9	8
Gemfish	126	0.4	46	27	0.3	14	27	0.3	16	72	0.5	16
Angel shark	110	0.3	18	64	0.6	10	31	0.3	7	15	0.1	1
Longfin ghostshark	109	0.3	19	8	<0.1	4	41	0.5	6	60	0.4	9
Gummy shark	90	0.3	16	65	0.6	11	2	<0.1	1	23	0.2	4
Yellow stargazer	85	0.2	17	0	0	0	6	<0.1	2	79	0.5	14
King dory	68	0.2	60	9	<0.1	14	9	0.1	19	50	0.3	27
Silver dory	52	0.2	22	1	<0.1	1	8	<0.1	8	43	0.3	13
Southern dogshark	52	0.2	13	0	0	0	50	0.6	12	2	<0.1	1
Silver ghostshark	48	0.1	29	27	0.3	13	16	0.2	11	5	<0.1	5
Inshore ocean perch	27	<0.1	14	<1	<0.1	2	2	<0.1	3	24	0.2	9
Endeavour dogshark	24	<0.1	9	23	0.2	8	1	<0.1	1	0	0	0
Blue warehou	19	<0.1	2	0	0	0	0	0	0	19	0.1	2
Blue eye	18	<0.1	4	0	0	0	5	<0.1	1	13	<0.1	3
Rudderfish	15	<0.1	3	0	0	0	5	<0.1	1	10	<0.1	2
Harrissons dogshark	15	<0.1	5	9	<0.1	2	6	<0.1	3	0	0	0
Highfin dogshark	12	<0.1	6	9	<0.1	5	3	<0.1	1	0	0	0
Hapuku	9	<0.1	3	0	0	0	0	0	0	9	<0.1	3
Jackass morwong	5	<0.1	5	1	<0.1	1	1	<0.1	1	3	<0.1	3
Imperador	4	<0.1	9	1	<0.1	3	1	<0.1	3	1	<0.1	3
Alfonsin	2	<0.1	9	1	<0.1	4	<1	<0.1	2	1	<0.1	3
Latchet	2	<0.1	2	1	<0.1	1	0	0	0	1	<0.1	1
White warehou	1	<0.1	3	<1	<0.1	1	0	0	0	<1	<0.1	2
Giant cardinalfish	1	<0.1	1	0	0	0	0	0	0	1	<0.1	1
Rubberlip morwong	<1	<0.1	1	<1	<0.1	1	0	0	0	0	0	0
Longfin gemfish	<1	<0.1	1	<1	<0.1	1	0	0	0	0	0	0
Red gurnard	<1	<0.1	1	<1	<0.1	1	0	0	0	0	0	0
Velvet leatherjacket	<1	<0.1	1	<1	<0.1	1	0	0	0	0	0	0
Total Trash	**11125**	**31.3**	**165**	**2805**	**26.3**	**48**	**3000**	**33.4**	**54**	**5319**	**33.4**	**63**
Misc. whiptails	4777	13.4	156	239	2.2	40	1458	16.2	54	3079	19.3	62
Trash sharks & rays	2152	6.1	147	710	6.7	41	514	5.7	49	928	5.8	57
Spiny flathead	1648	4.6	0	726	6.8	0	340	3.8	0	582	3.7	0
Skate	909	2.6	0	388	3.6	0	204	2.3	0	317	2.0	0

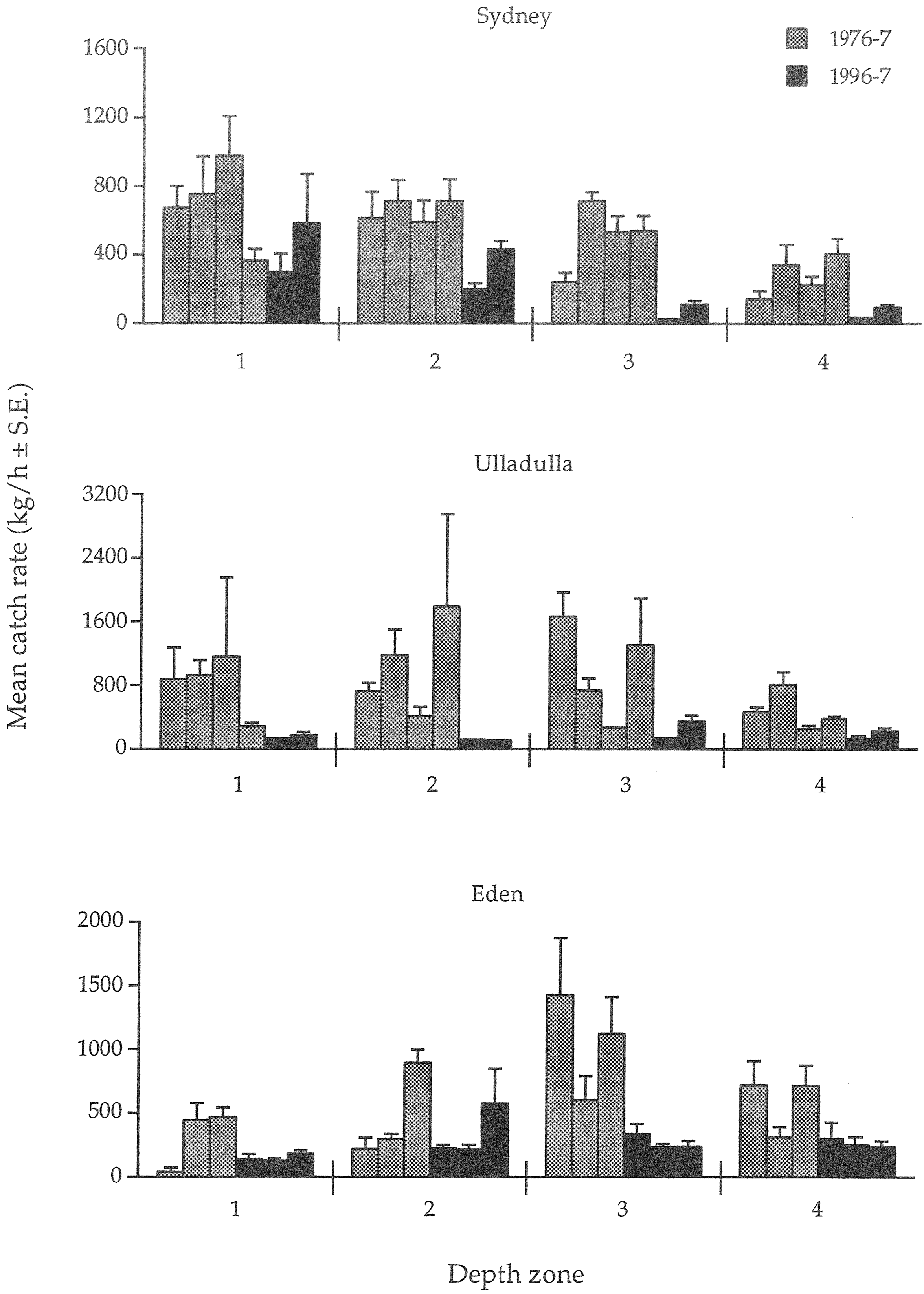

Figure 3.1 Mean catch rate (kg/h ± S.E.) of total catch per survey. Depth zones are: 1, 220 - 275 m; 2, 330 - 385 m; 3, 440 - 495 m; 4, 550 - 605 m.

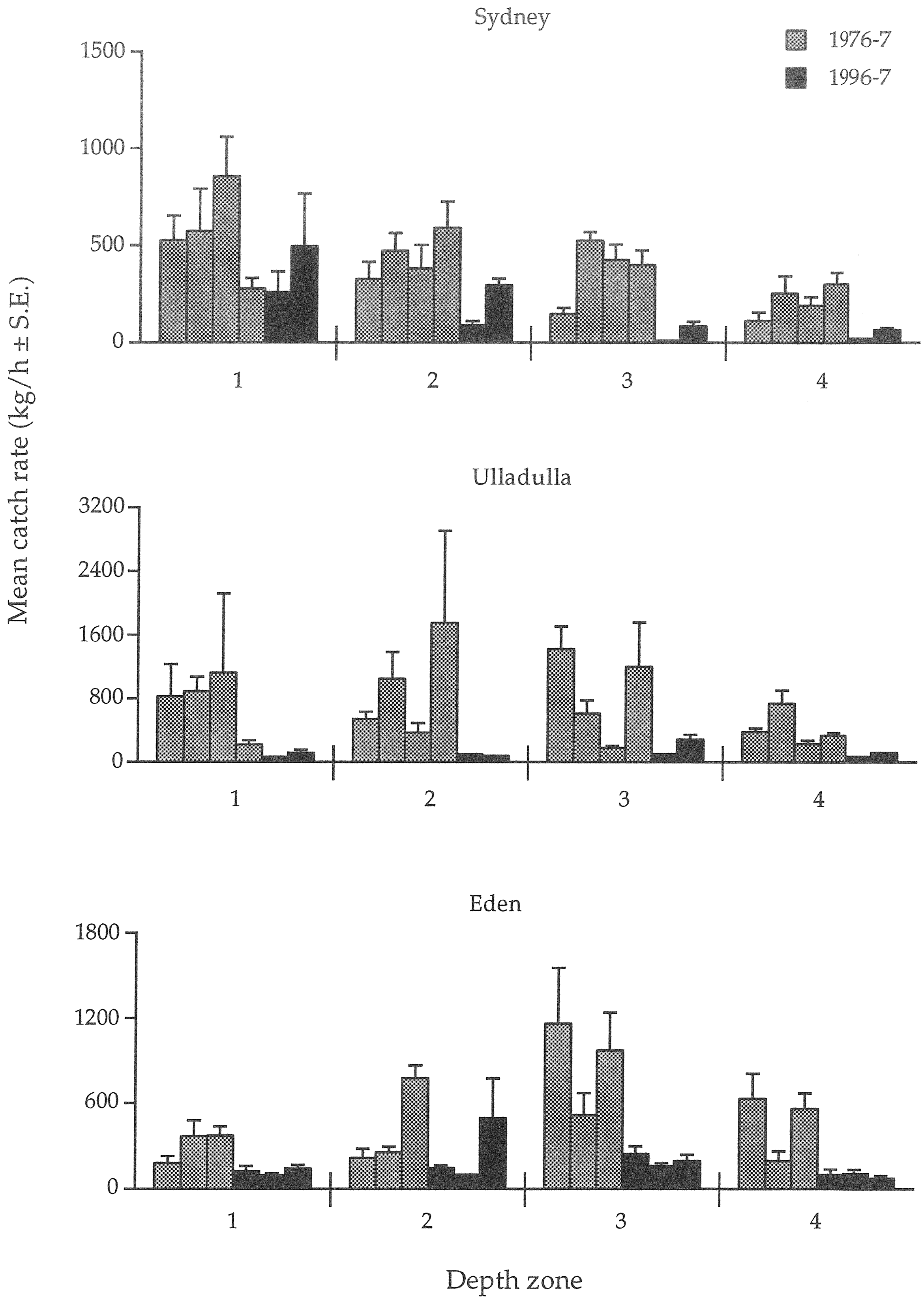

Figure 3.2 Mean catch rate (kg/h ± S.E.) of total commercial catch per survey. Depth zones are: 1, 220 - 275 m; 2, 330 - 385 m; 3, 440 - 495 m; 4, 550 - 605 m.

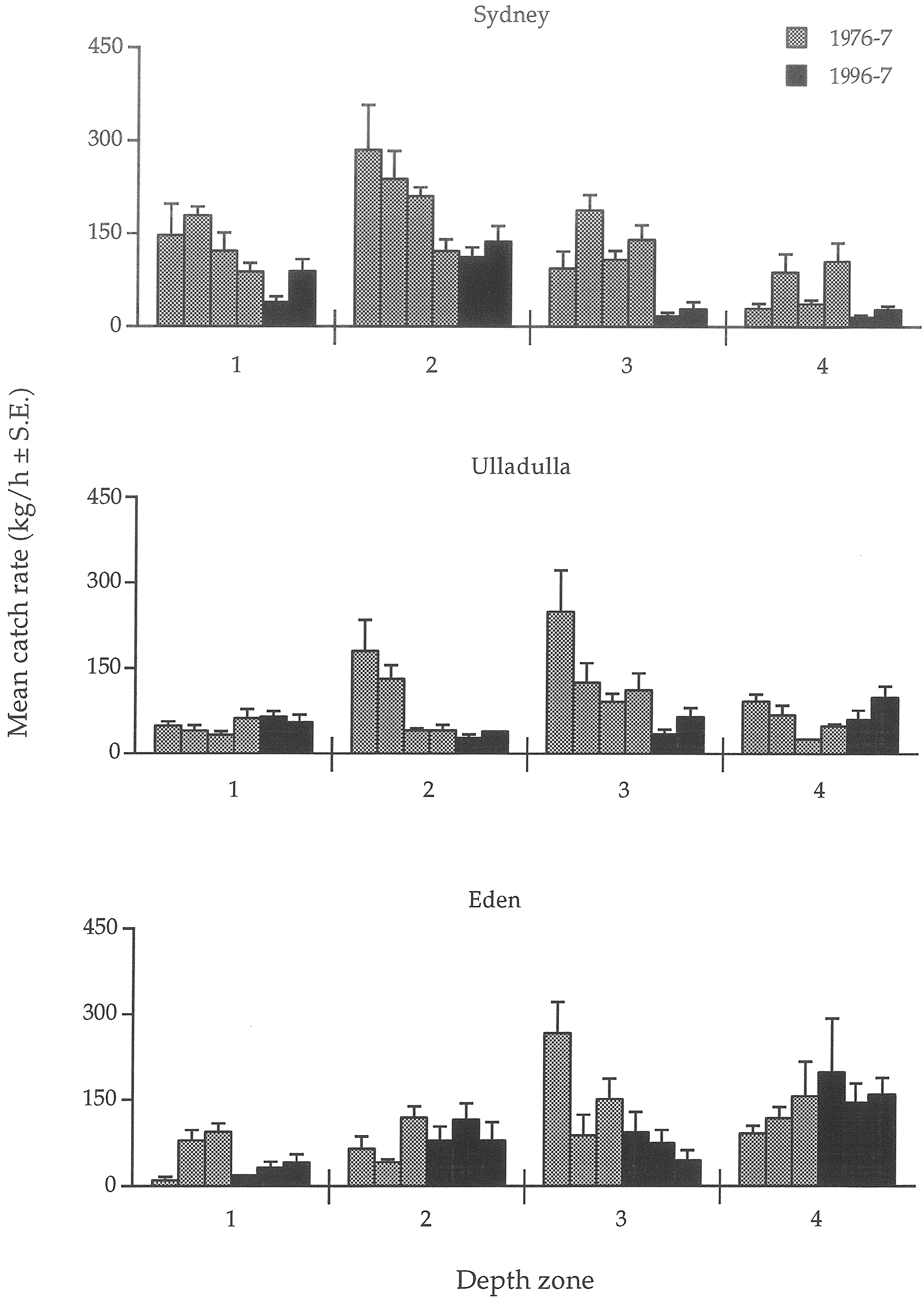

Figure 3.3 Mean catch rate (kg/h ± S.E.) of total non-commercial fish per survey. Depth zones are: 1, 220 - 275 m; 2, 330 - 385 m; 3, 440 - 495 m; 4, 550 - 605 m.

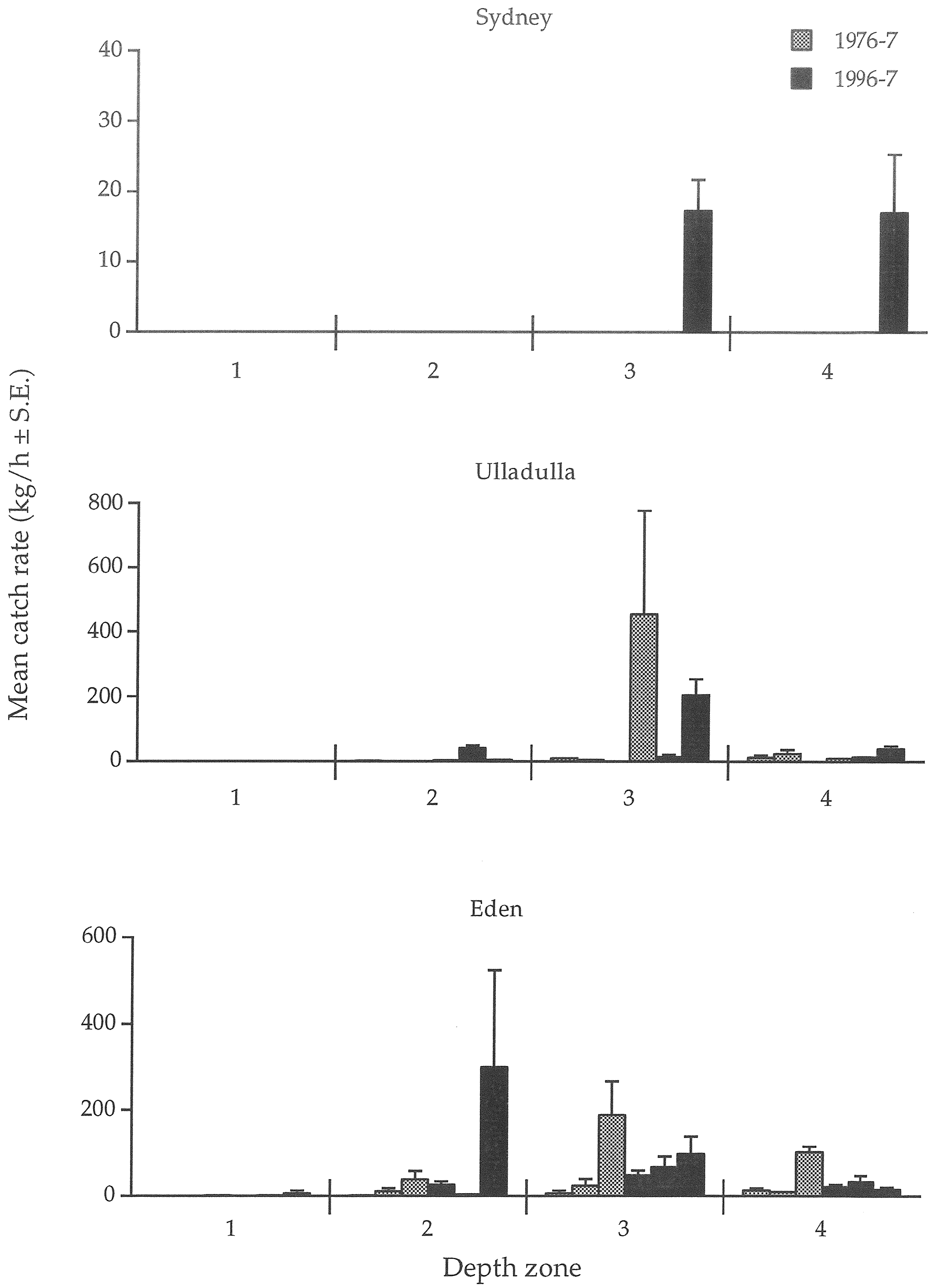

Figure 3.4 Mean catch rate (kg/h ± S.E.) of blue grenadier per survey. Depth zones are: 1, 220 - 275 m; 2, 330 - 385 m; 3, 440 - 495 m; 4, 550 - 605 m.

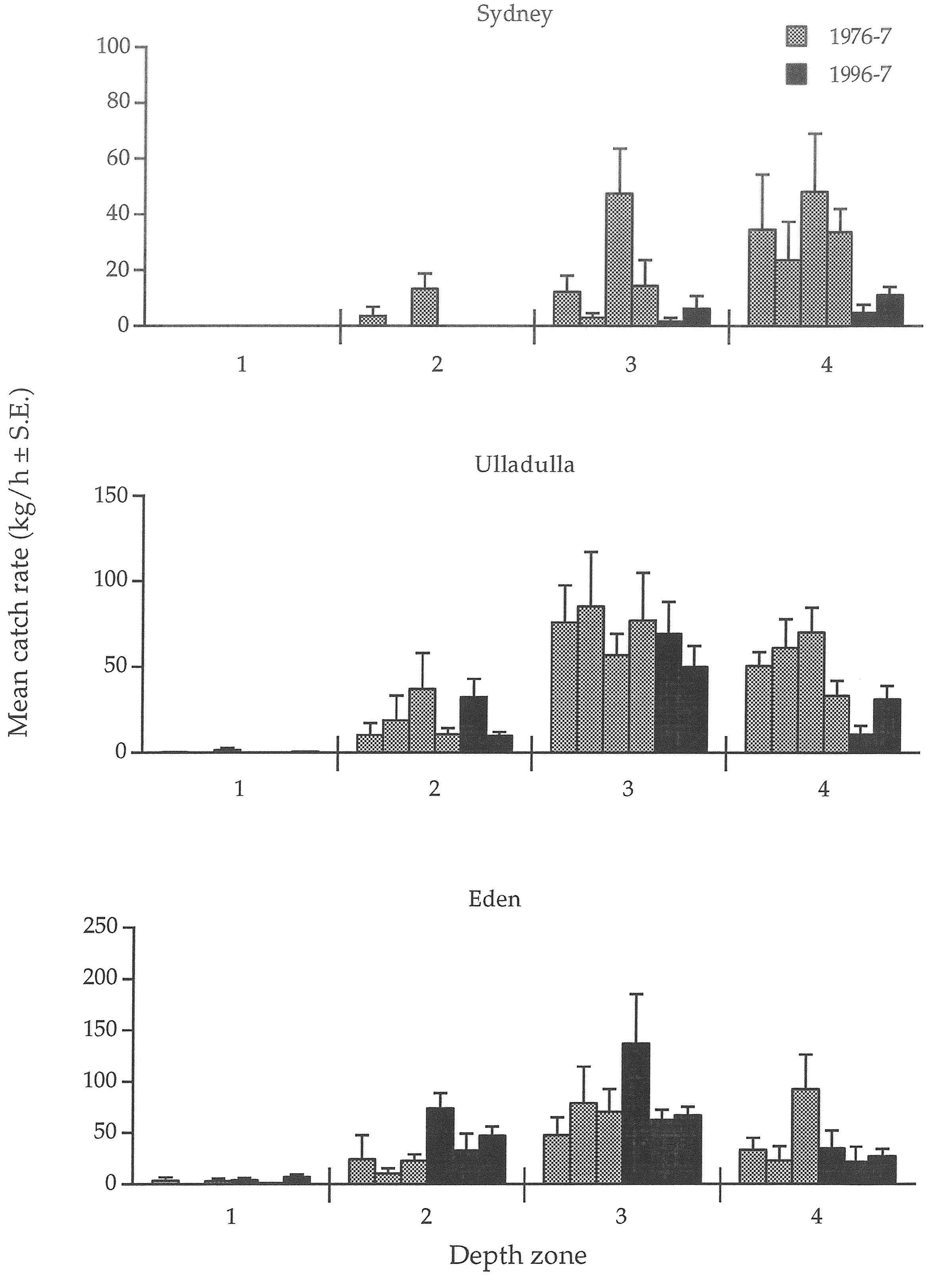

Figure 3.5 Mean catch rate (kg/h ± S.E.) of ling per survey. Depth zones are: 1, 220 - 275 m; 2, 330 - 385 m; 3, 440 - 495 m; 4, 550 - 605 m.

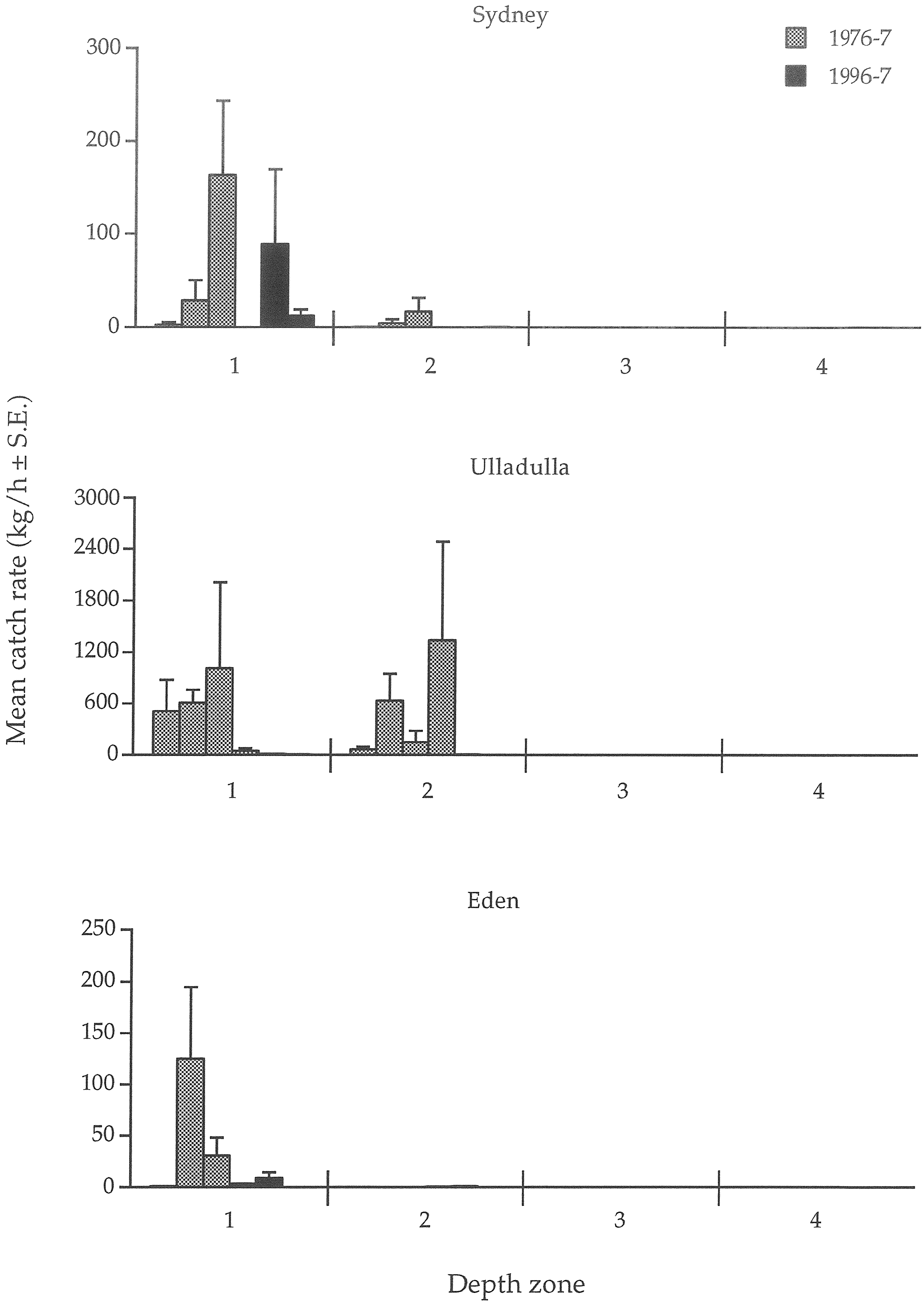

Figure 3.6 Mean catch rate (kg/h ± S.E.) of redfish per survey. Depth zones are: 1, 220 - 275 m; 2, 330 - 385 m; 3, 440 - 495 m; 4, 550 - 605 m.

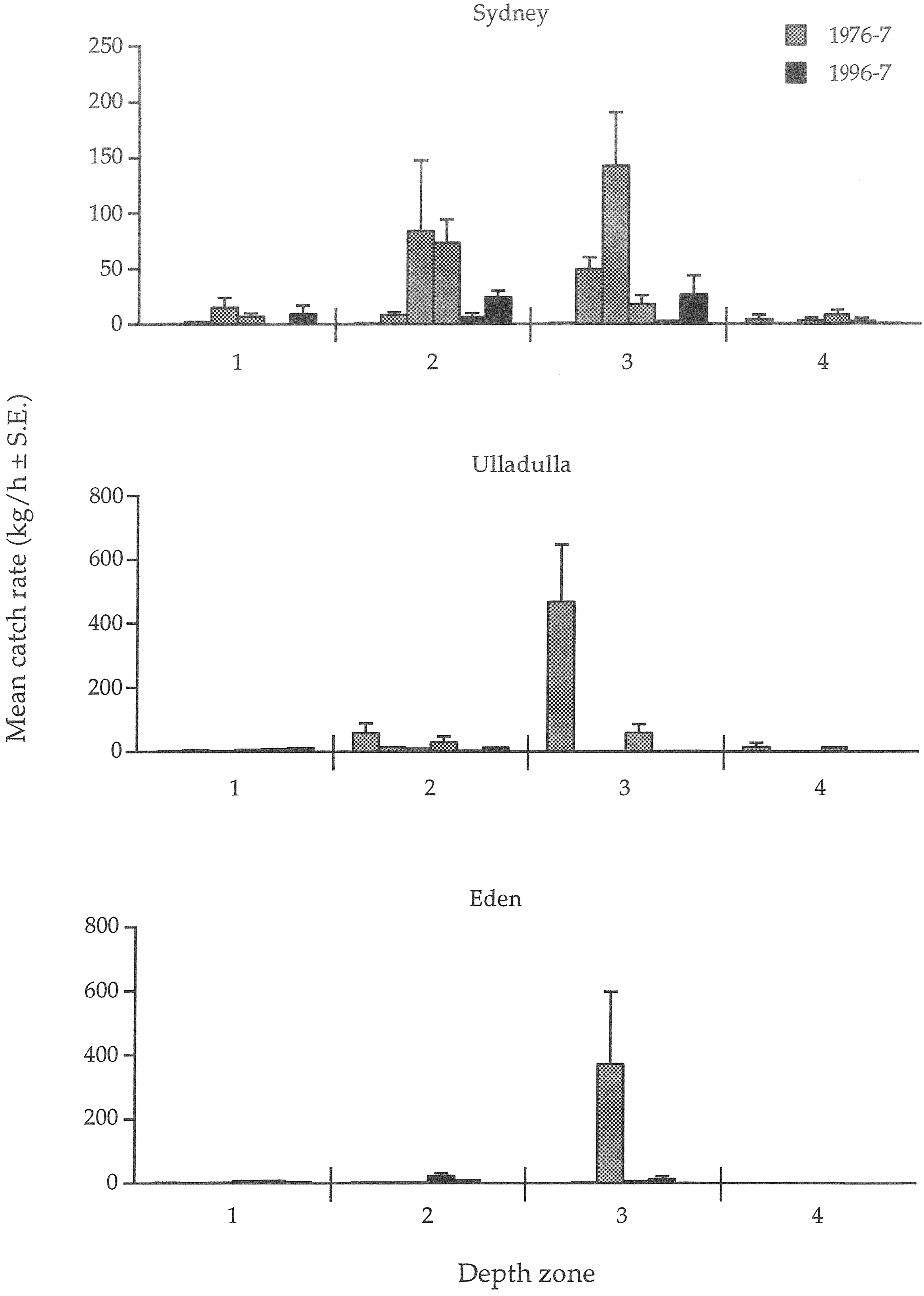

Figure 3.7 Mean catch rate (kg/h ± S.E.) of mirror dory per survey. Depth zones are: 1, 220 - 275 m; 2, 330 - 385 m; 3, 440 - 495 m; 4, 550 - 605 m.

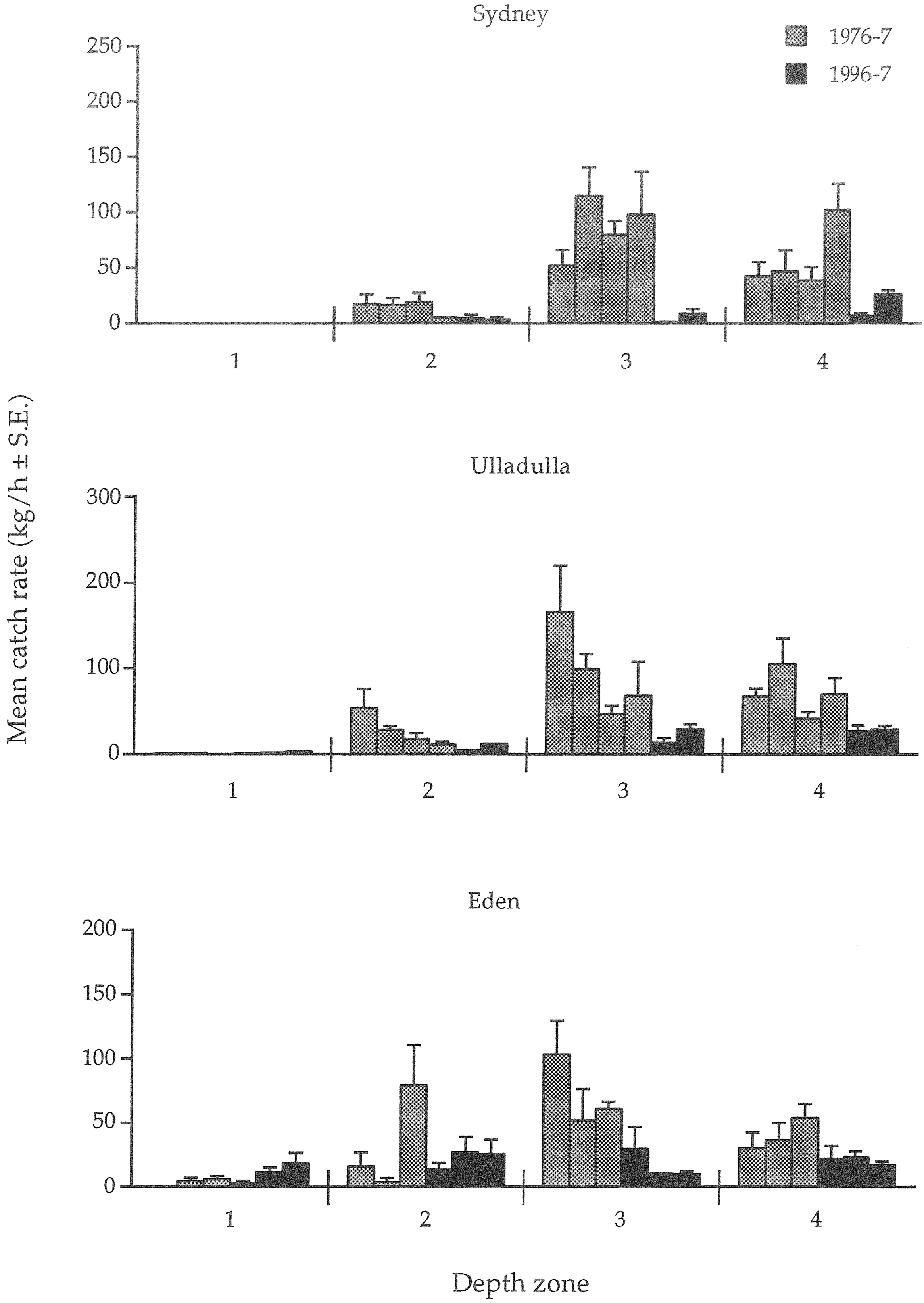

Figure 3.8 Mean catch rate (kg/h ± S.E.) of ocean perch per survey. Depth zones are: 1, 220 - 275 m; 2, 330 - 385 m; 3, 440 - 495 m; 4, 550 - 605 m.

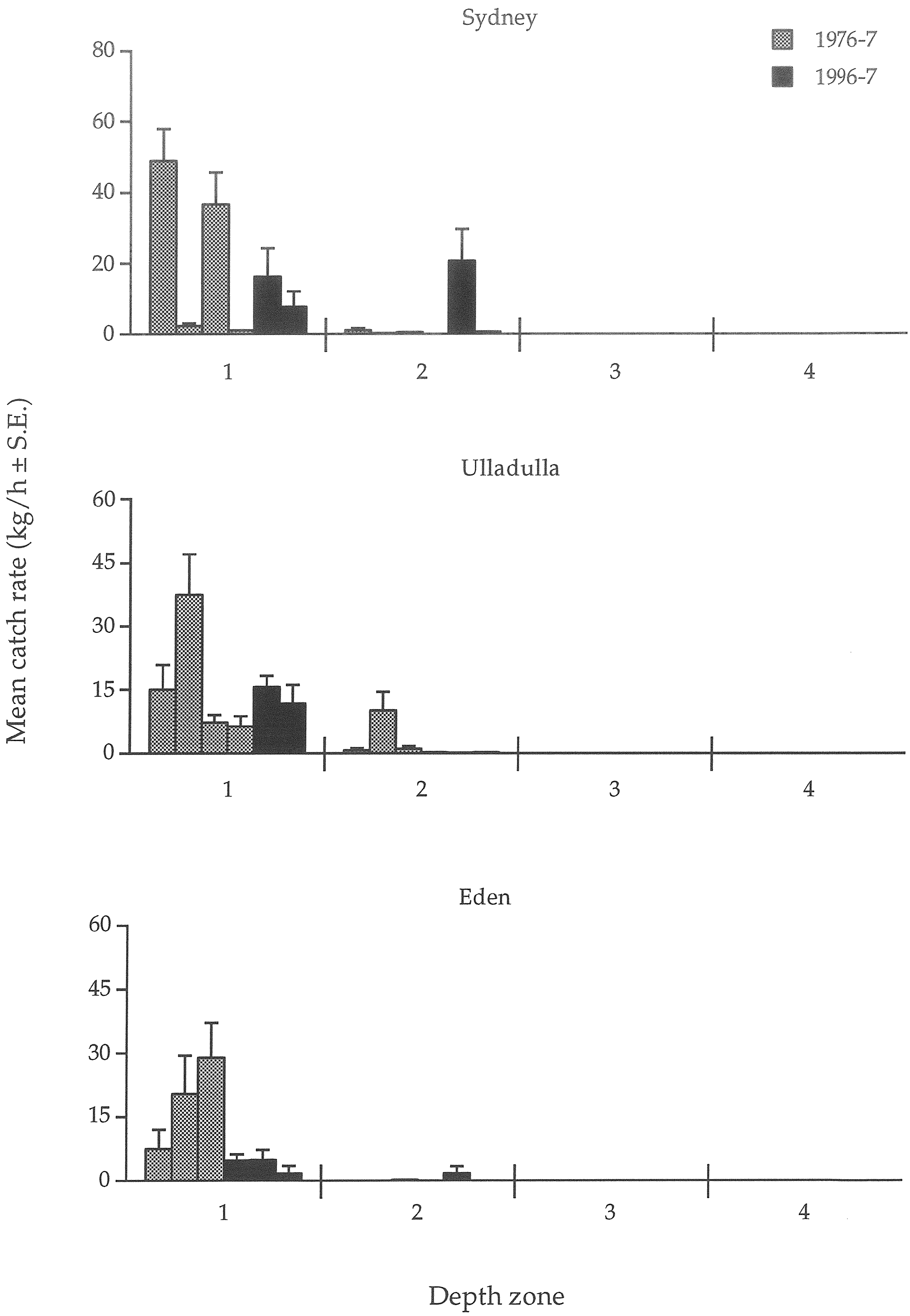

Figure 3.9 Mean catch rate (kg/h ± S.E.) of tiger flathead per survey. Depth zones are: 1, 220 - 275 m; 2, 330 - 385 m; 3, 440 - 495 m; 4, 550 - 605 m.

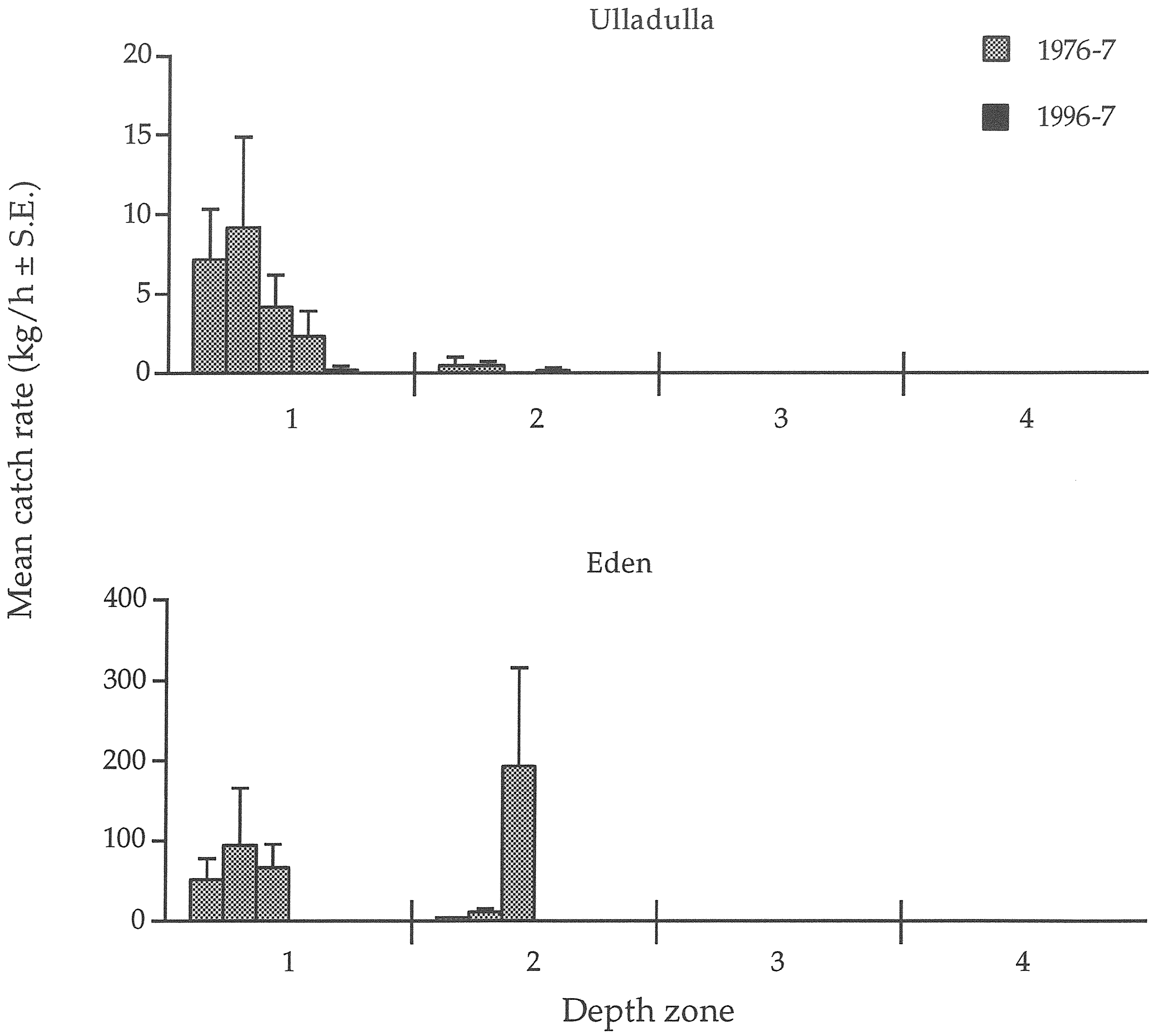

Figure 3.10 Mean catch rate (kg/h ± S.E.) of jackass morwong per survey. Depth zones are: 1, 220 - 275 m; 2, 330 - 385 m; 3, 440 - 495 m; 4, 550 - 605 m. None were caught in Sydney.

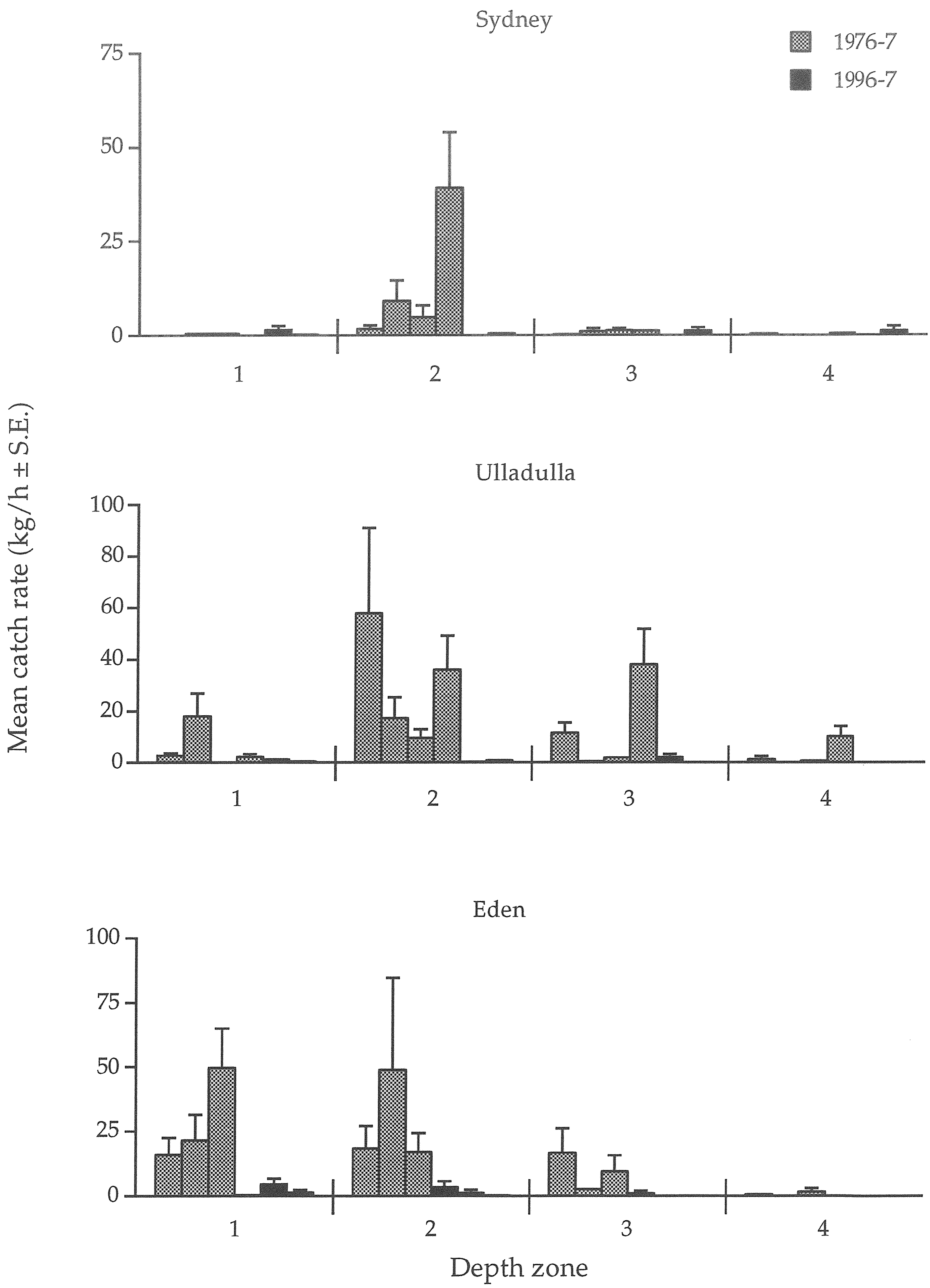

Figure 3.11 Mean catch rate (kg/h ± S.E.) of gemfish per survey. Depth zones are: 1, 220 - 275 m; 2, 330 - 385 m; 3, 440 - 495 m; 4, 550 - 605 m.

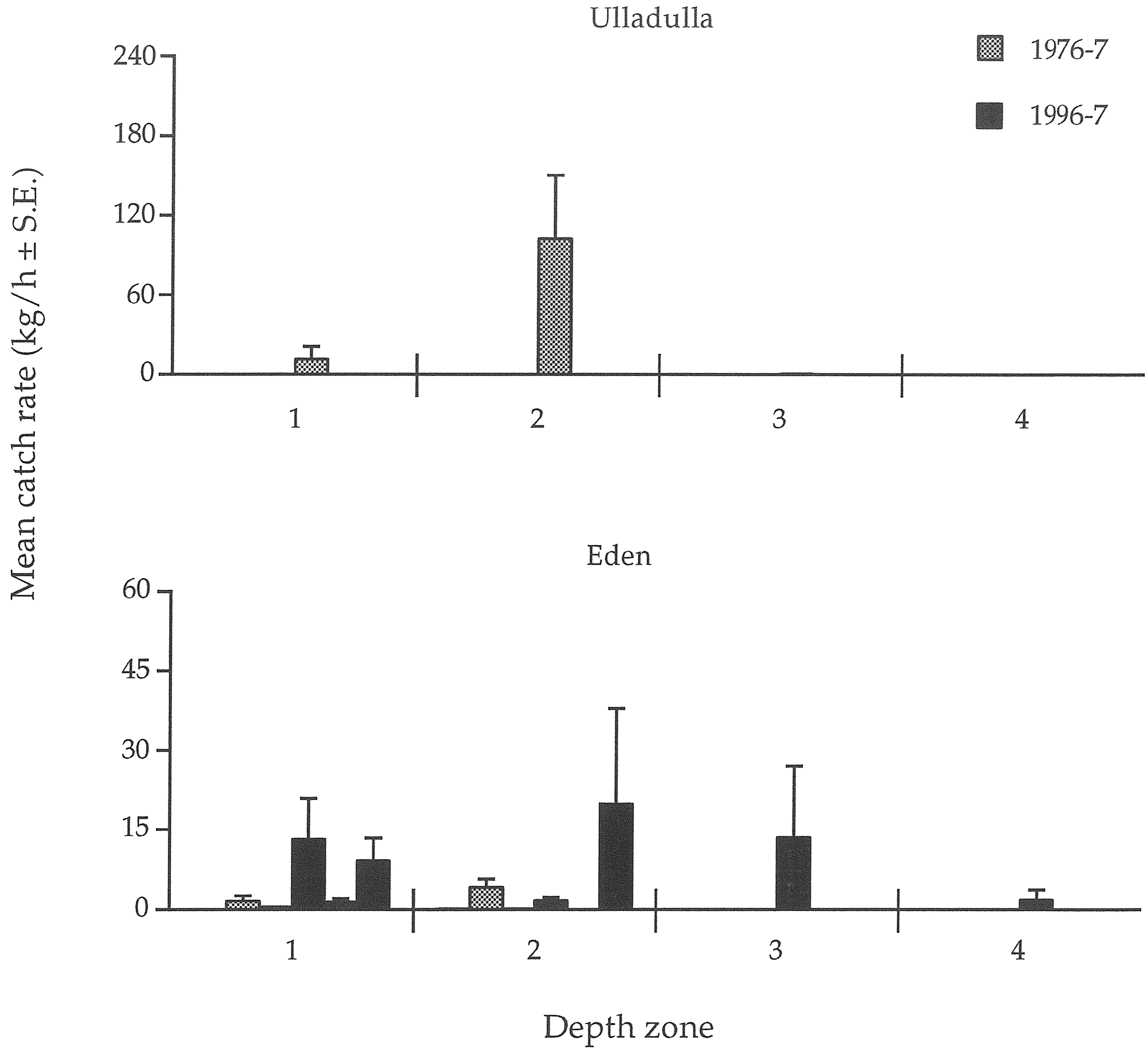

Figure 3.12 Mean catch rate (kg/h ± S.E.) of spotted warehou per survey. Depth zones are: 1, 220 - 275 m; 2, 330 - 385 m; 3, 440 - 495 m; 4, 550 - 605 m. None were caught in Sydney.

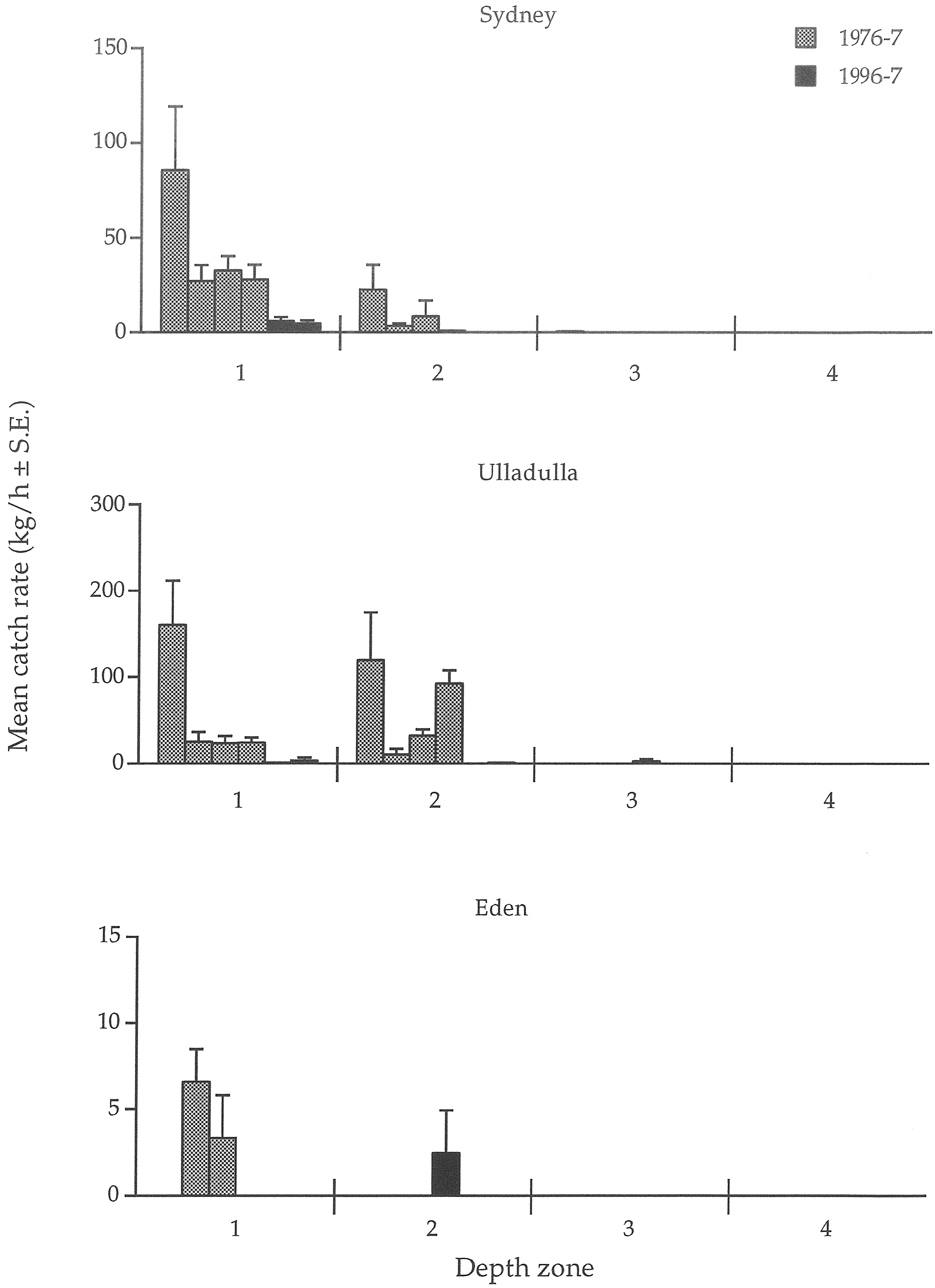

Figure 3.13 Mean catch rate (kg/h ± S.E.) of angel shark per survey. Depth zones are: 1, 220 - 275 m; 2, 330 - 385 m; 3, 440 - 495 m; 4, 550 - 605 m.

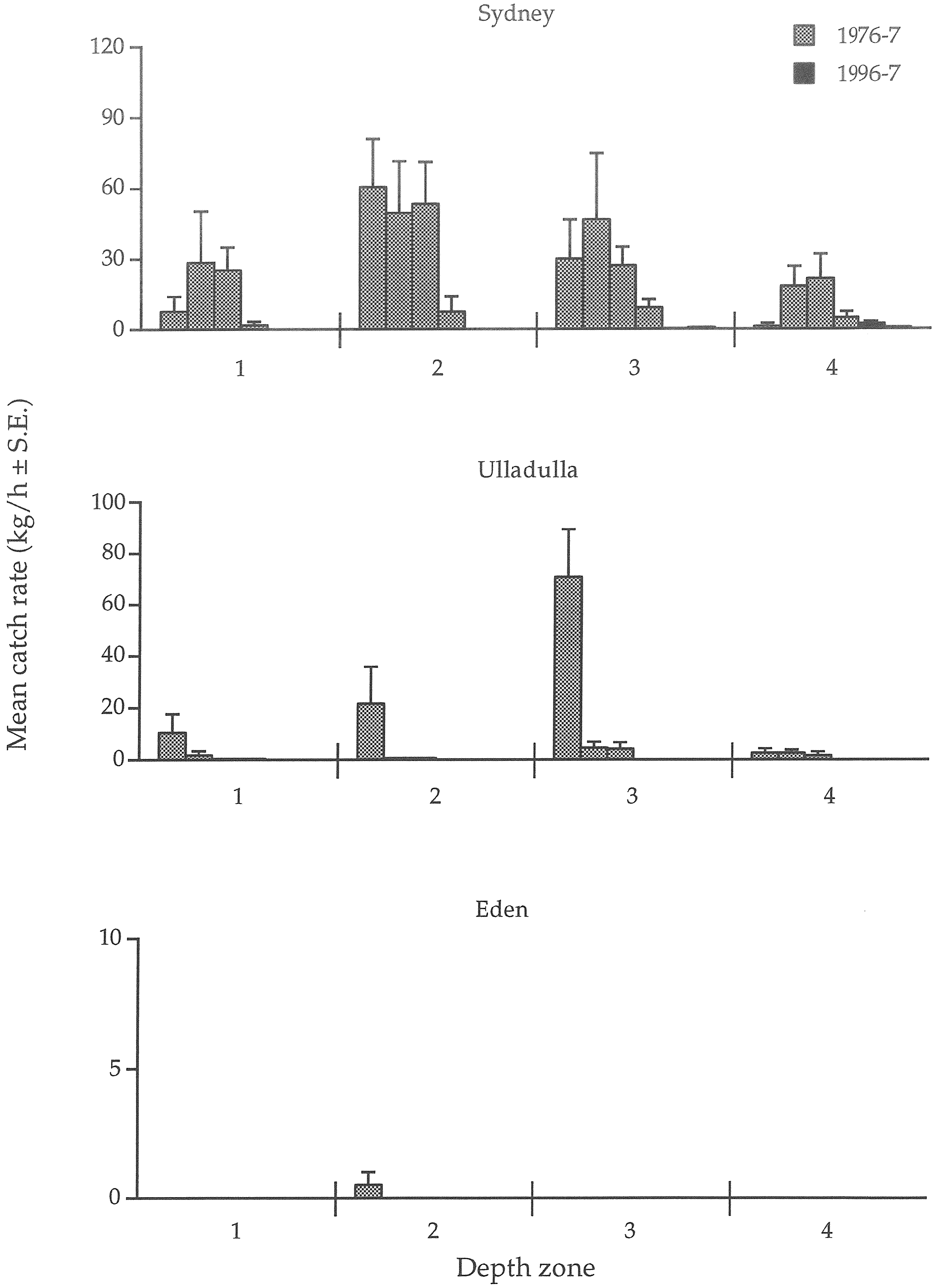

Figure 3.14 Mean catch rate (kg/h ± S.E.) of endeavour dogshark per survey. Depth zones are: 1, 220 - 275 m; 2, 330 - 385 m; 3, 440 - 495 m; 4, 550 - 605 m.

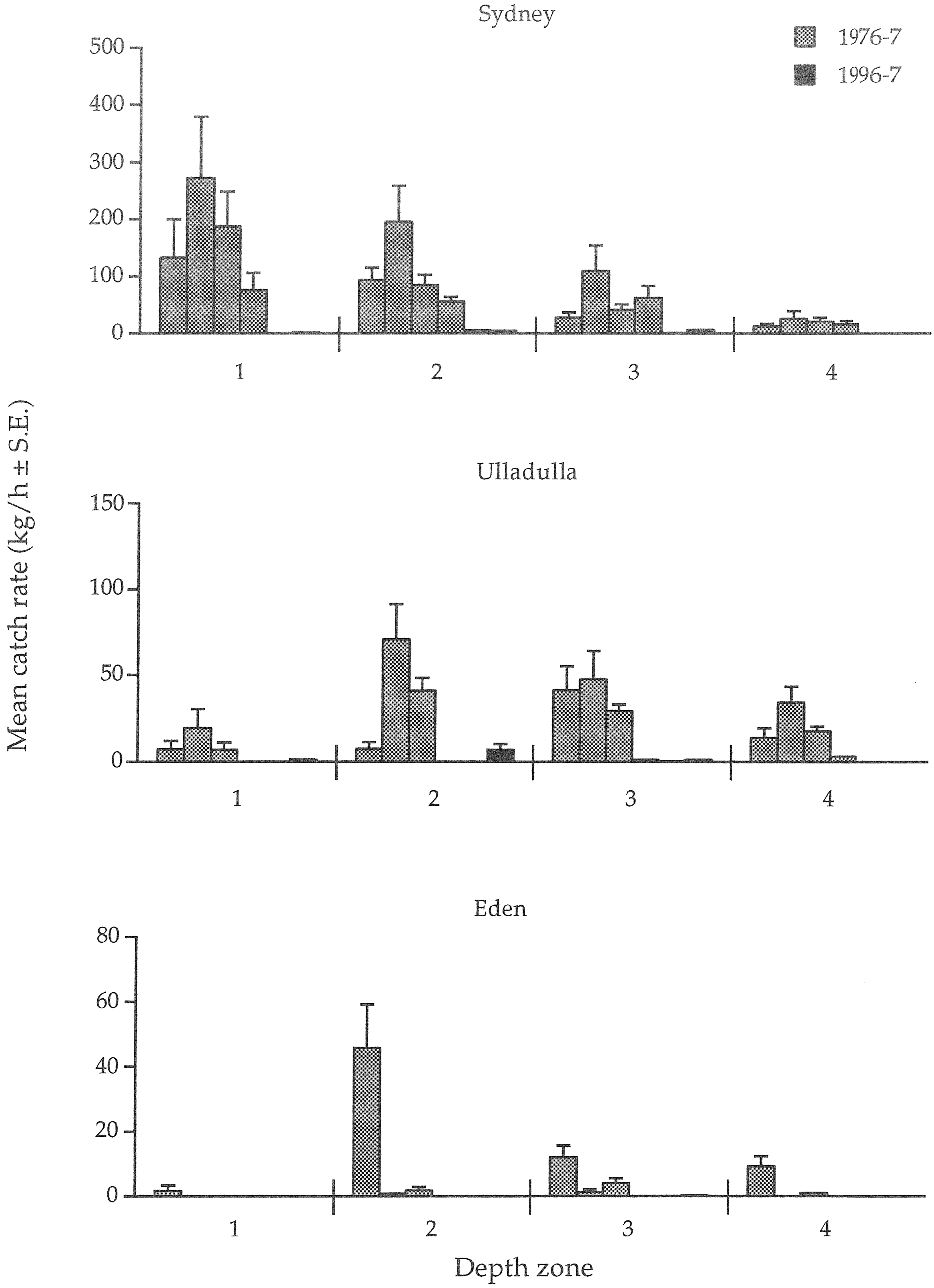

Figure 3.15 Mean catch rate (kg/h ± S.E.) of greeneye dogshark per survey. Depth zones are: 1, 220 - 275 m; 2, 330 - 385 m; 3, 440 - 495 m; 4, 550 - 605 m.

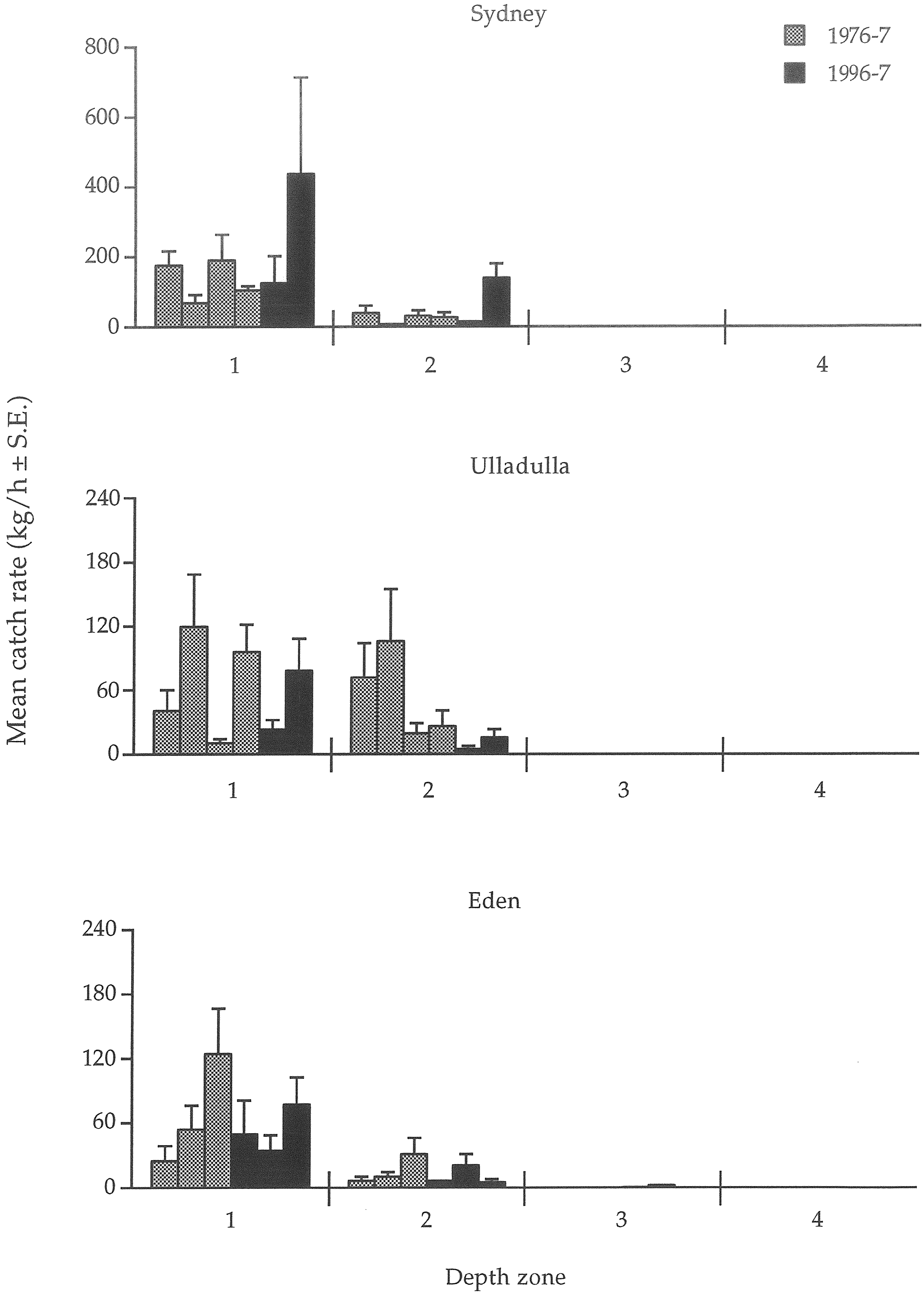

Figure 3.16 Mean catch rate (kg/h ± S.E.) of spiky dogshark per survey. Depth zones are: 1, 220 - 275 m; 2, 330 - 385 m; 3, 440 - 495 m; 4, 550 - 605 m.

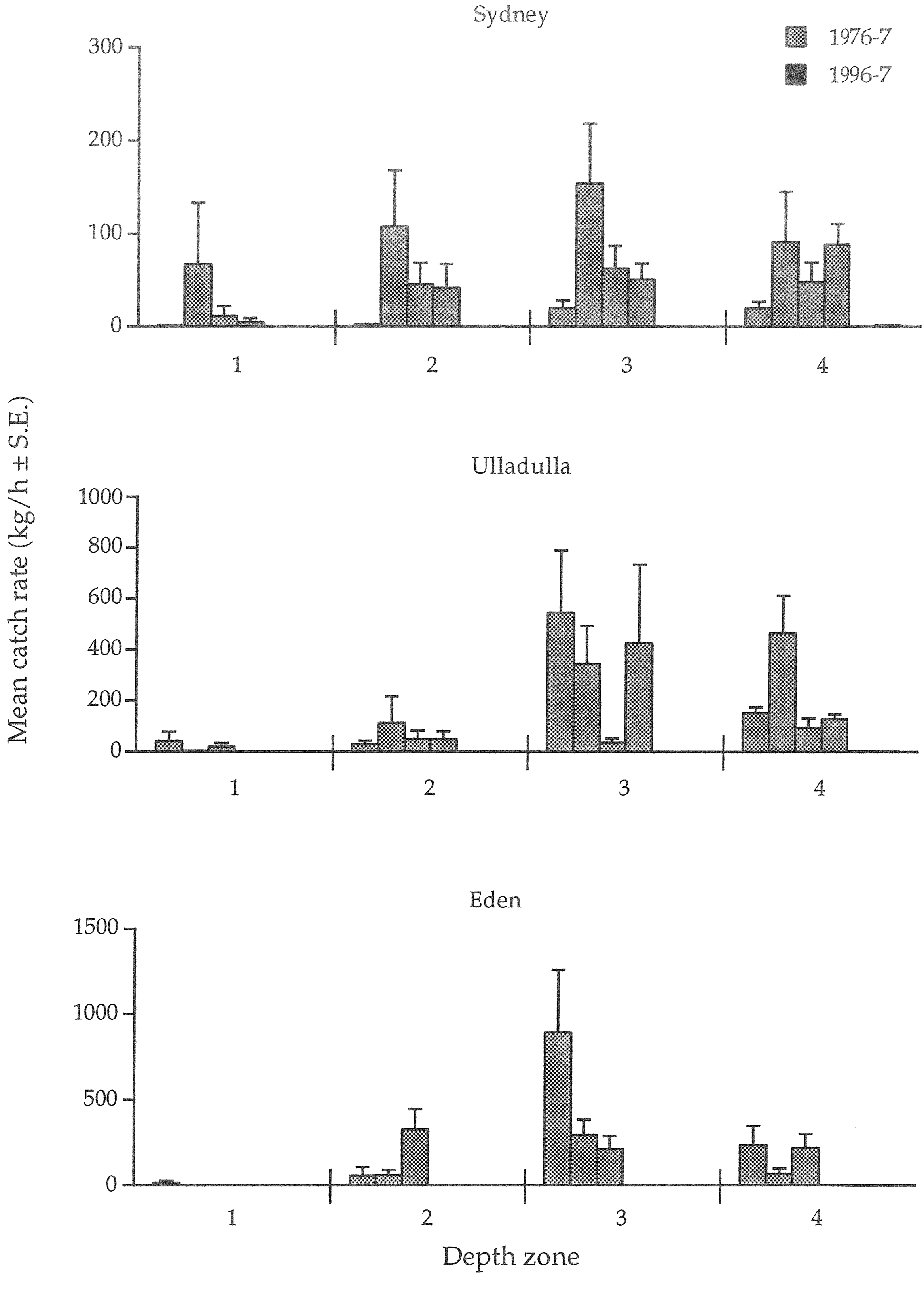

Figure 3.17 Mean catch rate (kg/h ± S.E.) of Harrissons and southern dogshark per survey. Depth zones are: 1, 220 - 275 m; 2, 330 - 385 m; 3, 440 - 495 m; 4, 550 - 605 m.

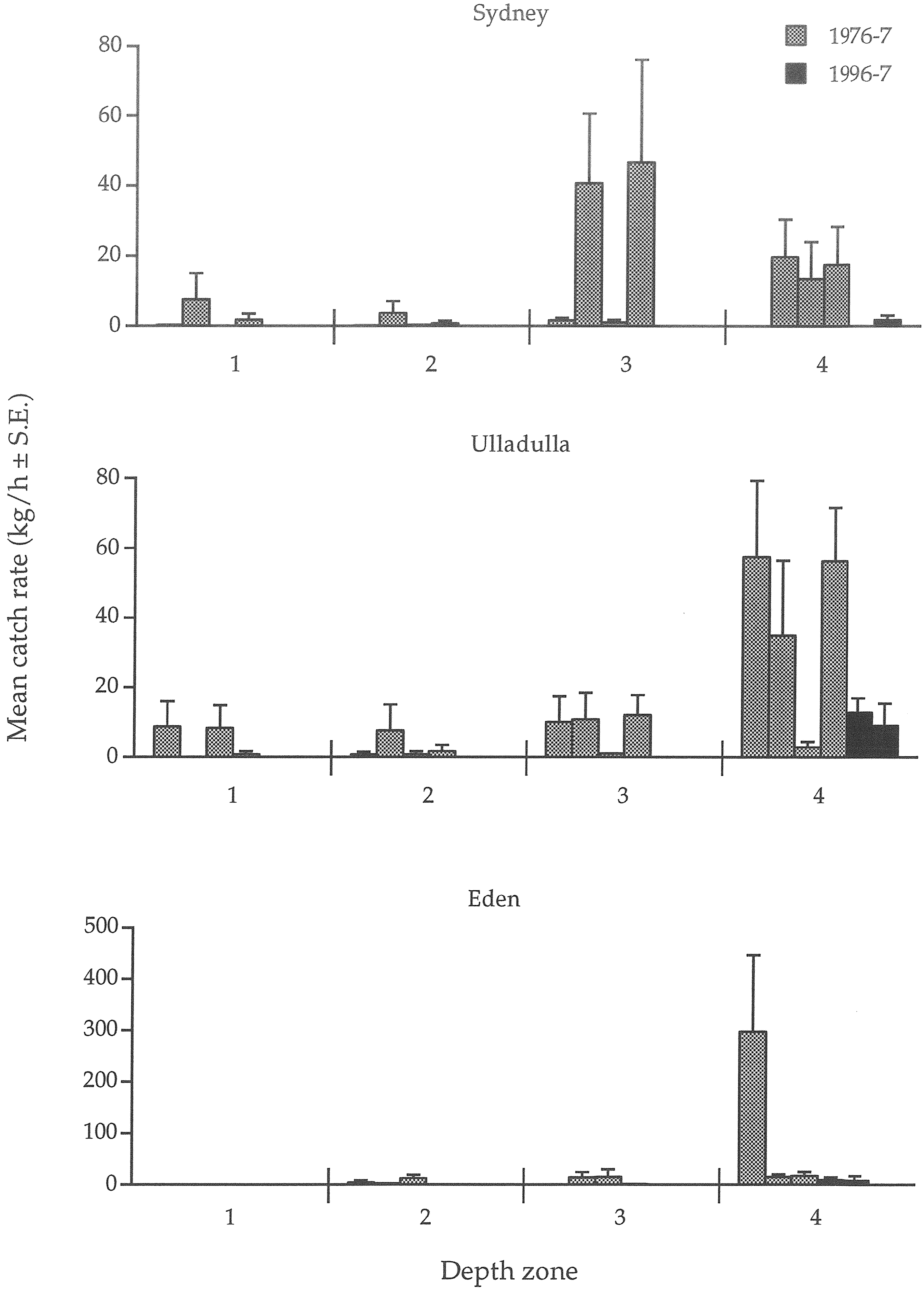

Figure 3.18 Mean catch rate (kg/h ± S.E.) of longnose dogshark per survey. Depth zones are: 1, 220 - 275 m; 2, 330 - 385 m; 3, 440 - 495 m; 4, 550 - 605 m.

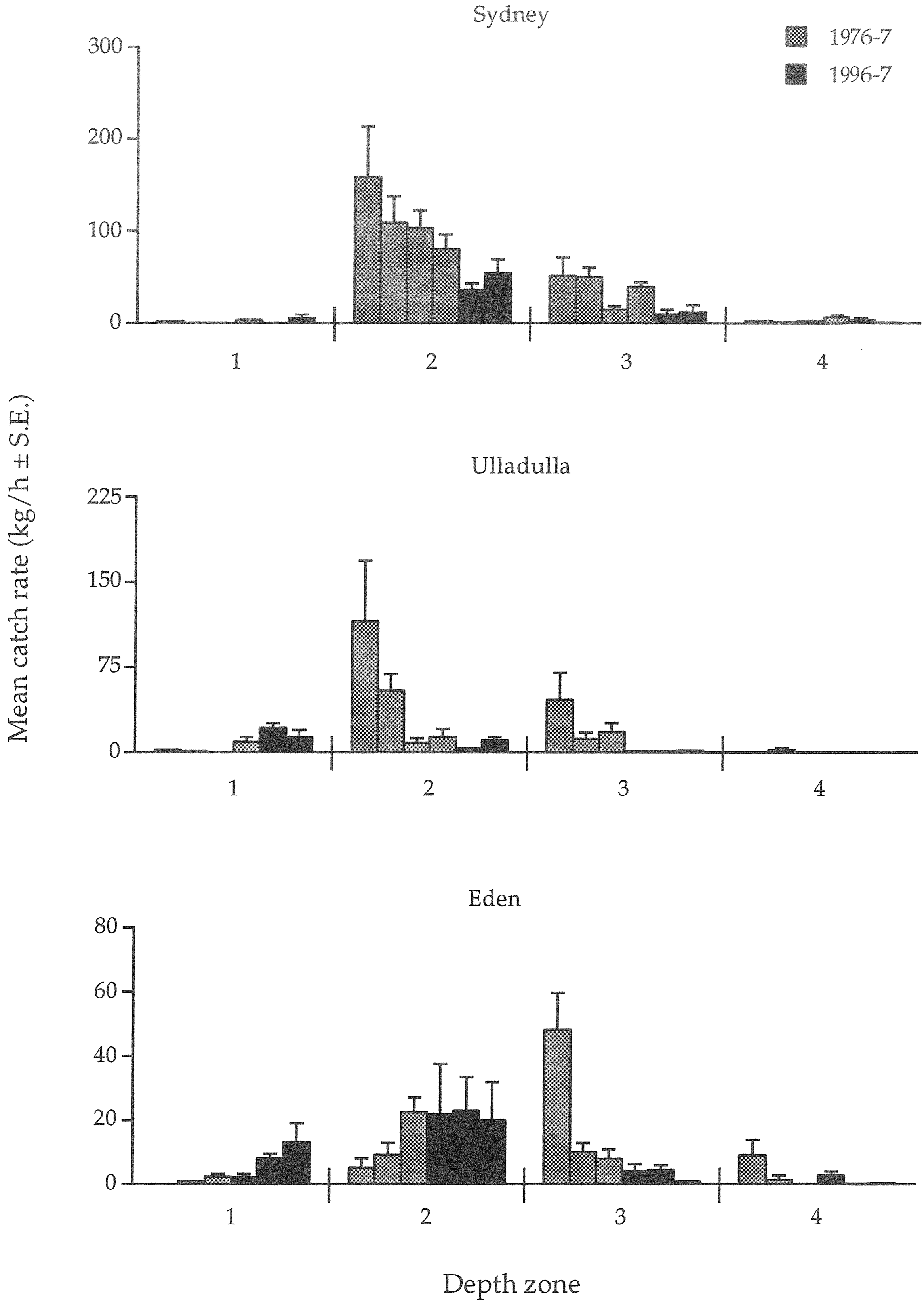

Figure 3.19 Mean catch rate (kg/h ± S.E.) of spiny flathead per survey. Depth zones are: 1, 220 - 275 m; 2, 330 - 385 m; 3, 440 - 495 m; 4, 550 - 605 m.

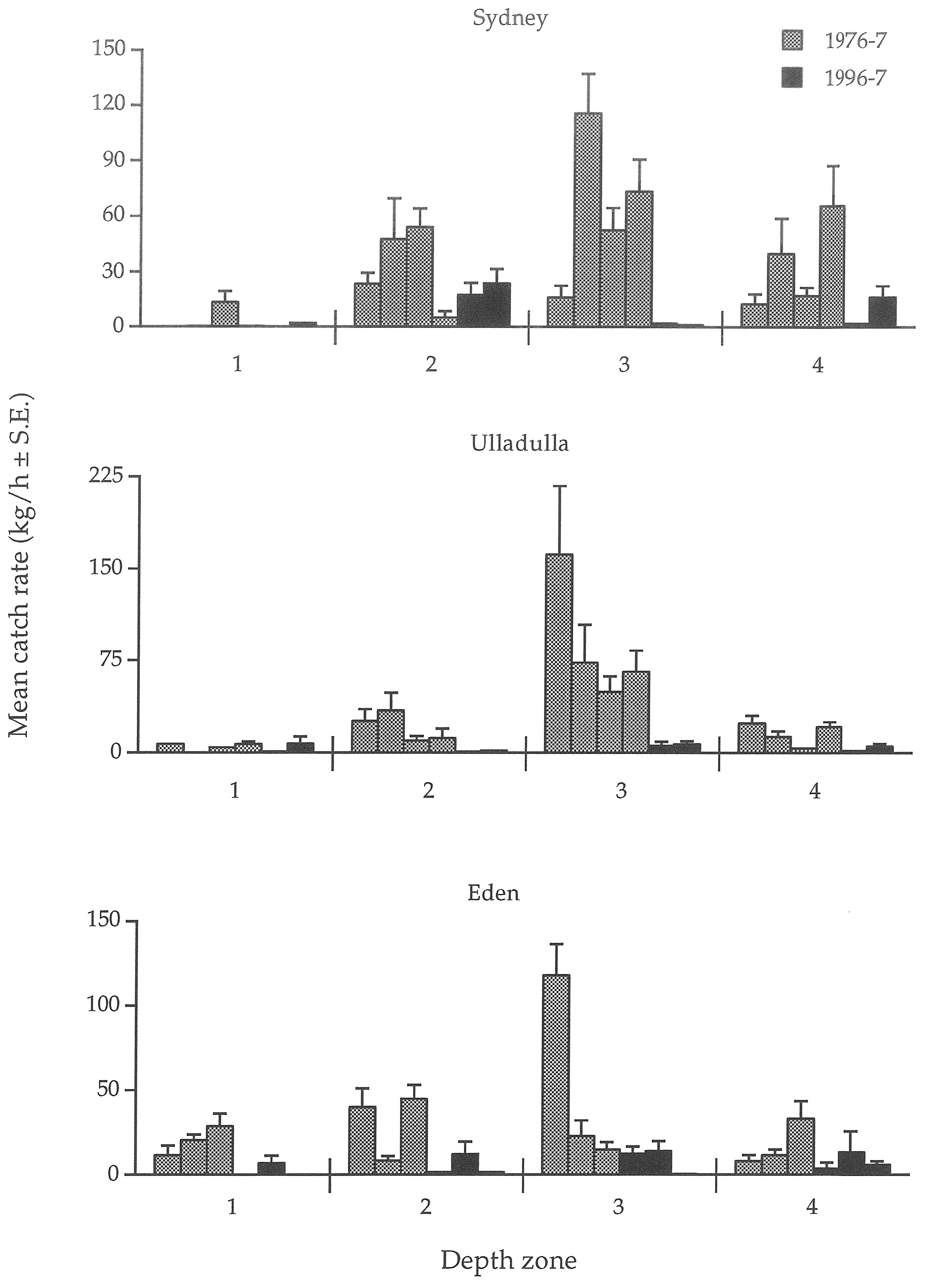

Figure 3.20 Mean catch rate (kg/h ± S.E.) of skates per survey. Depth zones are: 1, 220 - 275 m; 2, 330 - 385 m; 3, 440 - 495 m; 4, 550 - 605 m.

4. Comparison of 1976-7 and 1996-7 catch rates with 1979-81 survey results

Objective 1. To quantify changes in the comparative abundance of quota and other important upper slope fish since 1976-77.

In this chapter we present supplementary data collected during 1979-81 as part of other surveys on the NSW slope trawl grounds. Review of these data were not included in the FRDC contract but add significantly to the interpretation of differences presented in Chapter 3.

4.1 Results

Because of the nature of the fishing done and differences in the structure of the survey 'design' in 1979-81, comparisons with the other surveys are possible only for a subset of species and depths. Comparisons are made only for non-migratory species (ling, ocean perch, sharks and skates). Because there were insufficient tows in depth zones 1 and 4, only data from tows in depth zones 2 and 3 were used for comparison (Table 2.7). These depths have been pooled to increase replication. Comparisons are therefore based on the catches from the two depth zones 300-410 m and 420-520 m (165-225 and 230-285 fm), standardised to tows of one hour duration, irrespective of gear-type. For the purposes of these comparisons, data from 1976-7 and 1996-7 have been aggregated in the same manner. The data are presented graphically as mean ± 95% confidence intervals and not analysed further. Sample sizes were n = 6 for surveys in 1976-7 and 1996-7 and ranged between n = 9 and 32 in 1979-81. Where pooled means are presented in the text they are accompanied by the 95% C.I. calculated on the pooled standard error.

4.1.1 Quota species

Ling

Across all locations there were no clear trends in the mean catch rates of ling among survey periods (Figure 4.1). The overall mean catch rate increased slightly from 31.4 kg/h in 1976-7 to 36.4 kg/h in 1979-81 and 39.5 kg/h in 1996-7. At Sydney mean catch rates were similar in 1976-7 and 1979-81 (11.7 and 12.2 kg/h respectively) but were smaller in 1996-7 (2.0 kg/h). The 1976-7 and 1979-81 survey mean catch rates were all less than 10 kg/h at Sydney except for one survey in each period, both yielding a mean catch of about 30 kg/hr. Catch rates at Ulladulla were more uniform among surveys. Mean catch rates were 45.8, 35.3 and 40.3 kg/h for 1976-7, 1979-81 and 1996-7 respectively. At Eden, however, there was an increasing trend with catch rates increasing from 40.1 kg/h in 1976-7 to 59.3 kg/h in 1979-81 and 66.1 kg/h in 1996-7. Within each location there was considerable variability both among and within surveys (Figure 4.1).

For this comparison, data were pooled over depth zones 2 and 3 although ling catch rates in 1976-7 and 1996-7 were greatest in depth zones 3 and 4 (see Chapter 3), particularly for Sydney where few were caught in depth zone 2.

Ocean Perch

There was a decreasing trend in catch rates of ocean perch across all areas with catch rates in 1979-81 intermediate of those in 1976-7 and 1996-7 (Figure 4.2). Mean catch rate (locations and surveys pooled) declined from 54.9 kg/h in 1976-7 to 18.7 kg/h in 1979-81, and in 1996-7 to 13.4 kg/h. Changes at Sydney and Ulladulla were greatest and more consistent among surveys than in Eden (Figure 4.2). Mean catches at Sydney reduced from 50.6 kg/h in 1976-7 to 12.0 in 1979-81 and 4.6 in 1996-7, less than 10% of the 1976-7 catch. Mean catch rates in 1979-81 at Ulladulla were 50% of those in 1976-7 and only 24% of the 1976-7 catch rates in 1996-7. At Eden, catch rates in 1979-81 and 1996-7 were similar (17.7 and 18.9 kg/h respectively), but smaller than in 1976-7 (52.5 kg/h). Note that the depths used in this comparison do not represent the depth ranges in which ocean perch are most abundant. Data presented in Chapter Three indicate that the relative abundance of ocean perch is greatest in depth zones 3 and 4.

4.1.2 Commercial sharks

Endeavour dogshark

Endeavour dogsharks were caught predominantly at Sydney although there were relatively large catches recorded at Ulladulla in the first survey in 1976 (Figure 4.3). Mean catch rates at Sydney declined from 35.4 kg/h in 1976-7 to 6.1 and 0.3 kg/h in 1979-81 and 1996-7 respectively. Catch rates in 1979-81 and 1996-7 were 17% and 0.7% of that recorded in 1976-7. Catches in Ulladulla declined in a similar way, from 13 kg in 1976-7 to just 0.1 kg in 1979-81 and zero in 1996-7. The relatively large mean catch rate at Ulladulla in 1976-7 was caused by the catches recorded in survey I (46.1 kg/h); surveys 2- 4 averaged less than 2.5 kg/h. Catches in the period 1979-81 were in the 1980 survey only (mean 0.6 kg/h). Only 1 Endeavour dogshark (3 kg) was caught at Eden in survey 1 1977.

Harrissons and southern dogsharks

Harrissons and southern dogsharks were caught in progressively smaller quantities over time at all locations (Figure 4.4). Overall, the mean catch rate in 1979-81 (44.9 kg/h) was approximately 25% of that in 1976-7 (173.3 kg/h). The decline from 1979-81 to 1996-7 was even greater in magnitude; the 1996-7 catch rate (0.1 kg/h) was 0.03% of the 1976-7 rate. The rate of change was greatest at Eden where the mean catch rate decreased from 308 kg/h to 29 kg/h in 3 years and to 0.1 kg/h over the next 15-18 years. There was considerable variability in mean catch rates in 1976-7, both within and among surveys caused by several large catches (see Chapter 3). This variability declined with time and the catches in 1996-7 were uniformly very small (Figure 4.4).

Spiky dogshark

Overall, mean catch rates changed in the three sampling periods from 17.3 kg/h in 1976-7 to 5.5 kg/h in 1979-81 and finally to 15.4 kg/h in 1996-7 (Figure 4.5). At Ulladulla and Eden 1996-7 catch rates (5.1 and 6.2 kg/h) were similar to those in 1979-81 (mean 5.4 and 6.6 kg/h). In contrast catch rates at Sydney increased from 4.4 kg/h in 1979-81 to 38.5 in 1996-7. It is important to note that the catch rates reported for these comparisons are pooled over depth zones 2 and 3 but spiky dogsharks were caught in depth zones 1 and 2 only (Chapter Three). The comparisons reported here are therefore representative only of depth zone 2. In common with catch rates of the other sharks, there was considerable variability within and among surveys. In contrast, however, catch rates of spiky dogsharks remained large and variable through time, particularly in Sydney (Figure 4.5).

Greeneye dogshark

Overall, mean catch rates of greeneye dogsharks declined from 45.2 in 1976-7 to 7.6 and finally to 2.0 kg/h in 1996-7. The 1979-81 catch rates were approximately 20, 15 and 5% of those in 1976-7 at Sydney, Ulladulla and Eden respectively (Figure 4.6). Catch rates in 1996-7 were 4.6 kg/h and 2.0 kg/h at Sydney and Ulladulla, 42 and 28% of the respective 1979-81 catch rates. No greeneye dogsharks were caught at Eden in 1996-7.

Longnose dogshark

Catches in 1976-7 were relatively large but highly variable (8.3 kg/h pooled over all locations). Catches in the two later periods had declined to 1.7 in 1979-81 and 0.1 kg/h in 1996-7. Associated with these declines was a reduction in variability among replicate tows and among surveys (Figure 4.7). At Sydney, the mean catch rate in 1979-81 (1.9 kg/h) was less than 10% of the mean catch rates of surveys 2 and 4 1976-7, but similar to those of surveys 1 and 3, 1976-7.

Angel shark

Comparisons of catch rates among the three sampling periods was done only for Sydney and Ulladulla because insufficient angel sharks for comparison were caught at Eden in any period. At Sydney, angel sharks were caught in small quantities in 1976-7 (mean 4.4 kg/h) and none were caught in 1979-81 or 1996-7 (Figure 4.8). Catch rates at Ulladulla declined from 32.7 kg/h in 1976-7 to 8.9 in 1979-81 and 0.3 kg/h in 1996-7 . Catch rates in 1976-7 were, however, very different among surveys ranging from a mean catch rate of 59.8 kg/h in survey 1 to just 5.0 in survey 2.

4.1.3 Non-commercial species

Miscellaneous skates

Mean catch rates of skates were similar among locations and decreased from 48.6 in 1976-7 to 21.1 in 1979-81 and 7.0 kg/h in 1996-7 (Figure 4.9). At Ulladulla and Eden, catch rates in 1979-81 were 61 and 52% of the respective 1976-7 catch rates and the 1996-7 catch rates were 7.2 and 15.2% of those in 1976-7. In contrast, the greatest difference at Sydney was between 1976-7 and 1979-81 where catch rates were decreased from 47.8 to 11.8 kg/h. The 1996-7 mean catch rate (11.0 kg/h) was similar to that in 1979-81.

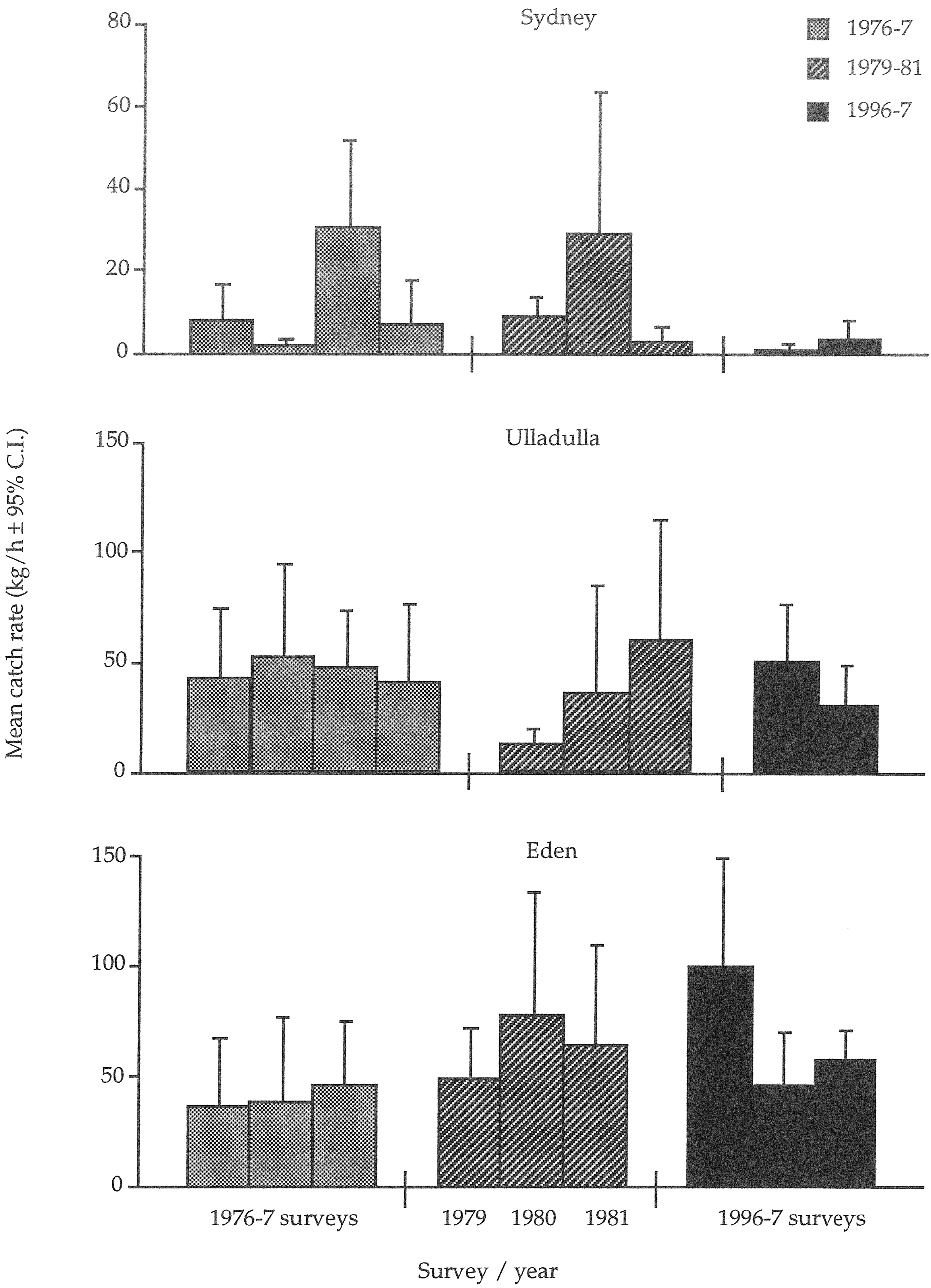

Figure 4.1 Mean catch rate (kg/h ± 95% C.I.) of ling per survey. Data are pooled for depth zones 2 and 3.

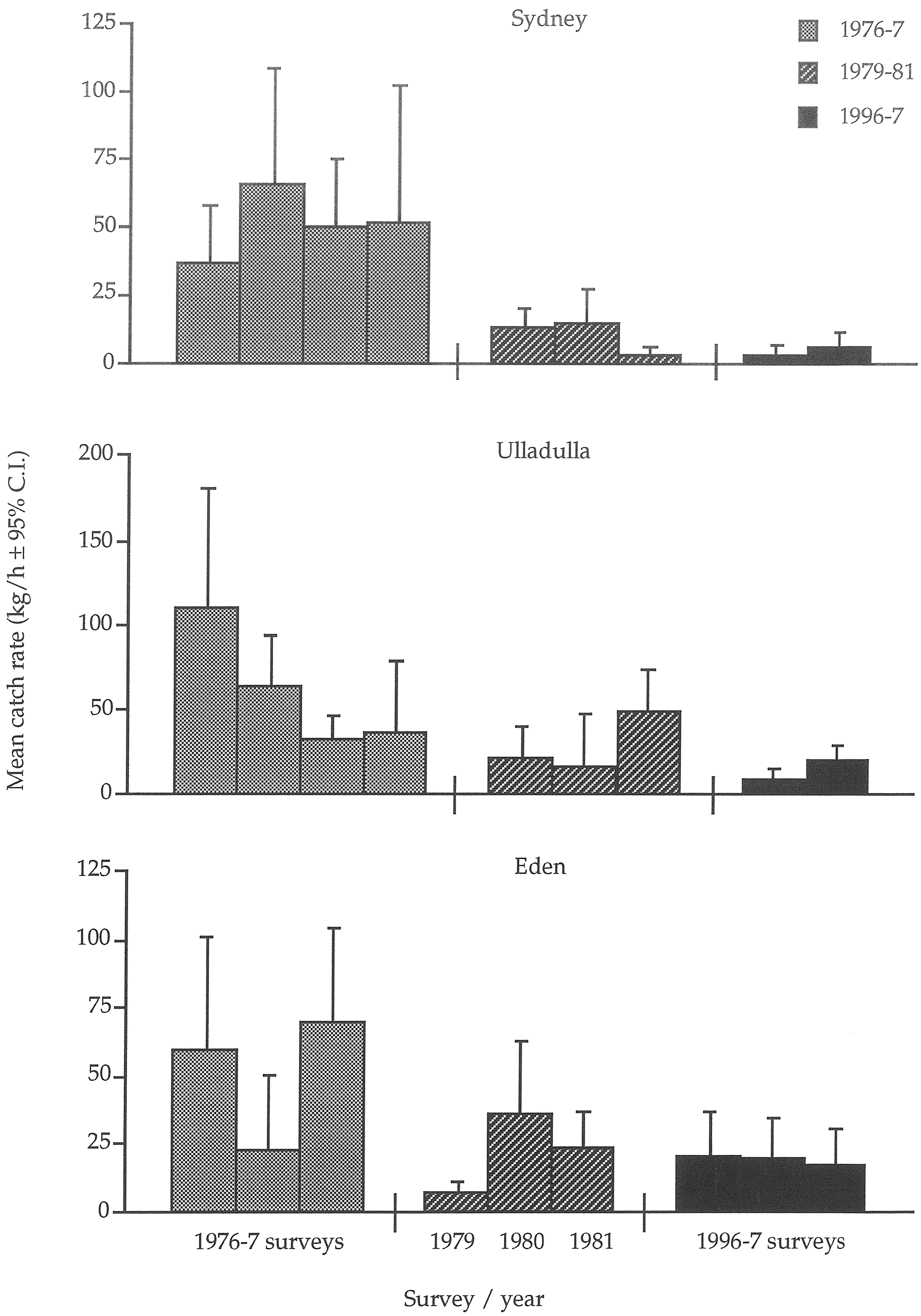

Figure 4.2 Mean catch rate (kg/h ± 95% C.I.) of ocean perch per survey. Data are pooled for depth zones 2 and 3.

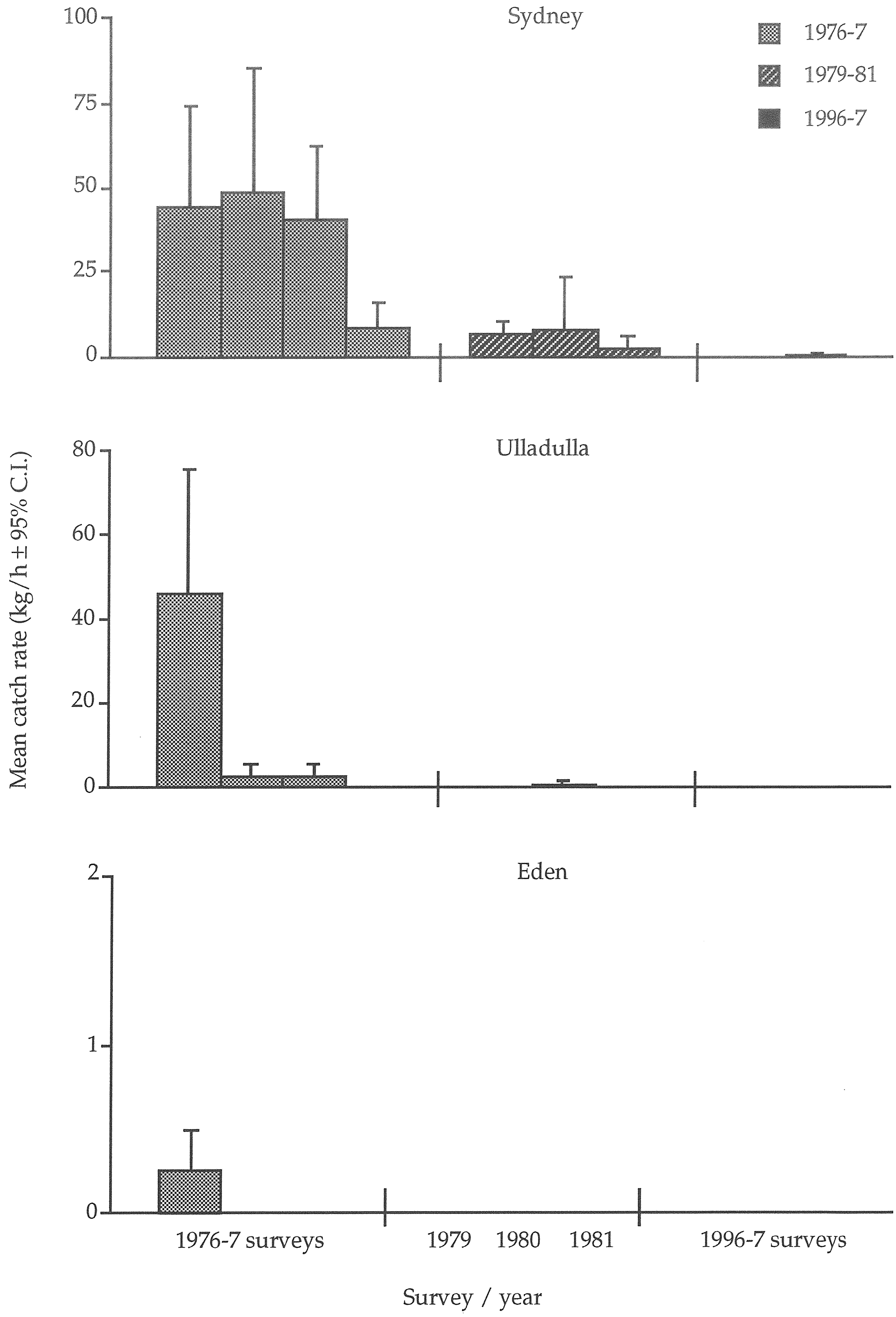

Figure 4.3 Mean catch rate (kg/h ± 95% C.I.) of Endeavour dogshark per survey. Data are pooled for depth zones 2 and 3.

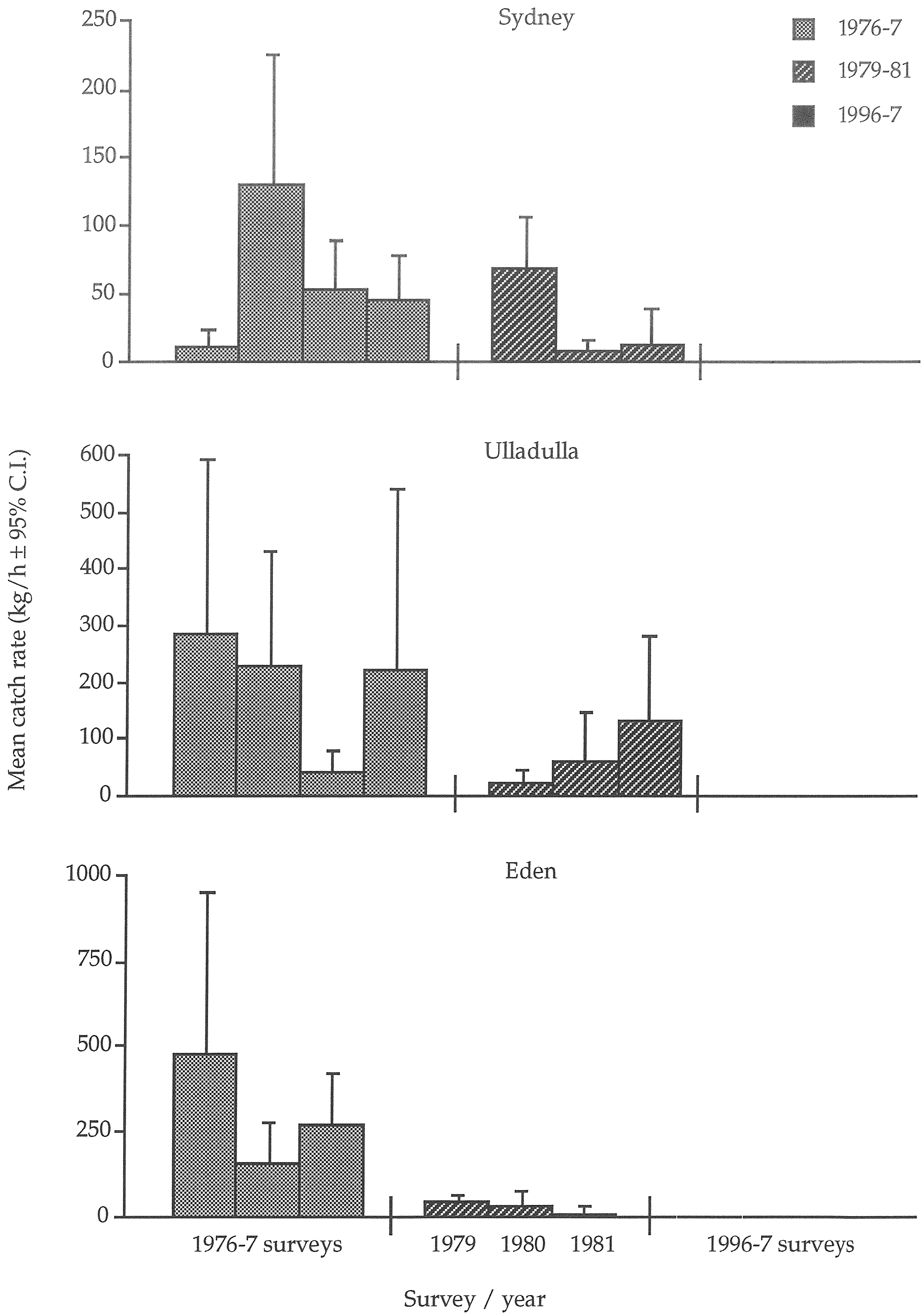

Figure 4.4 Mean catch rate (kg/h ± 95% C.I.) of Harrisons and southern dogsharks per survey. Data are pooled for depth zones 2 and 3.

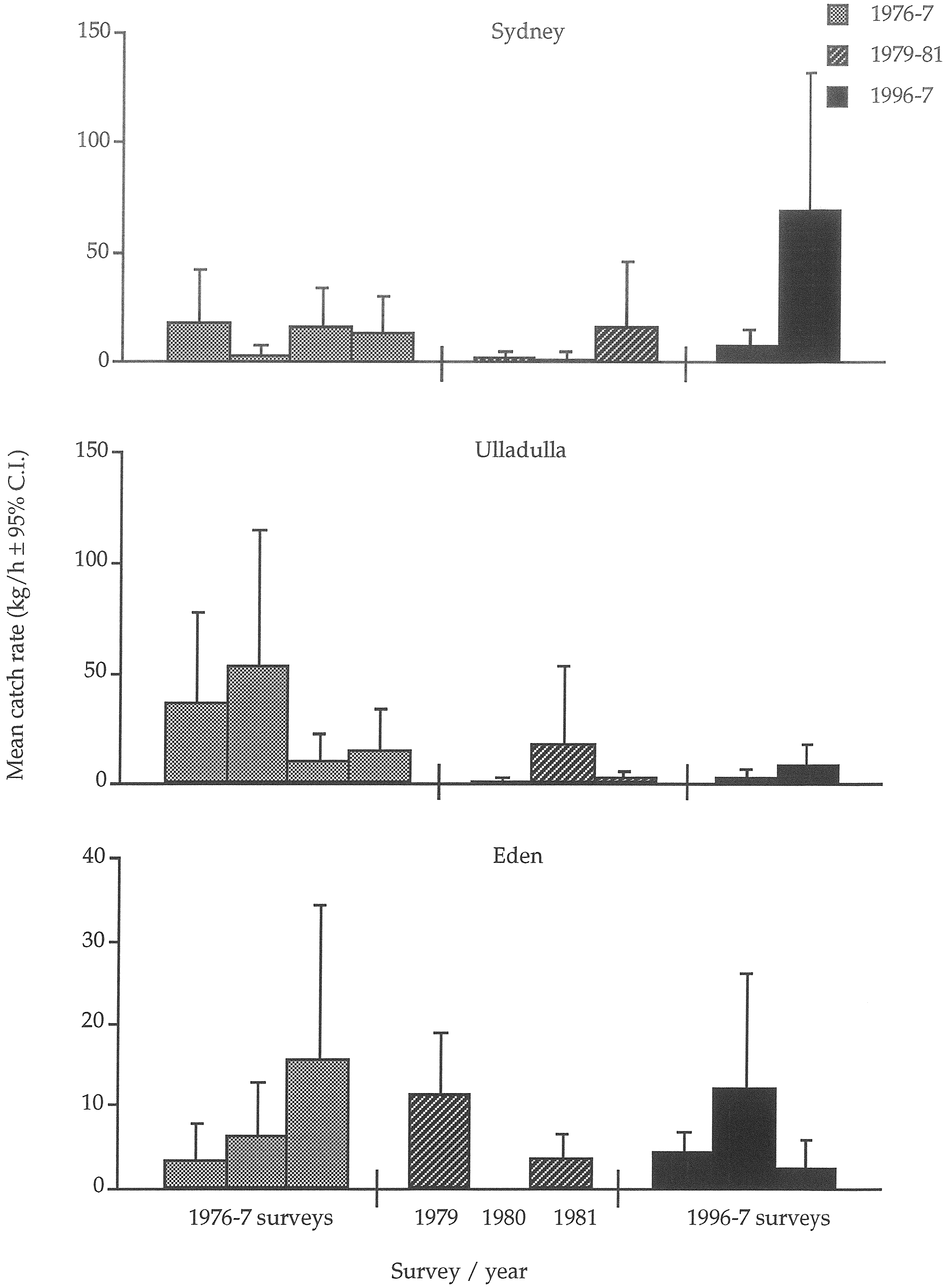

Figure 4.5 Mean catch rate (kg/h ± 95% C.I.) of spiky dogshark per survey. Data are pooled for depth zones 2 and 3.

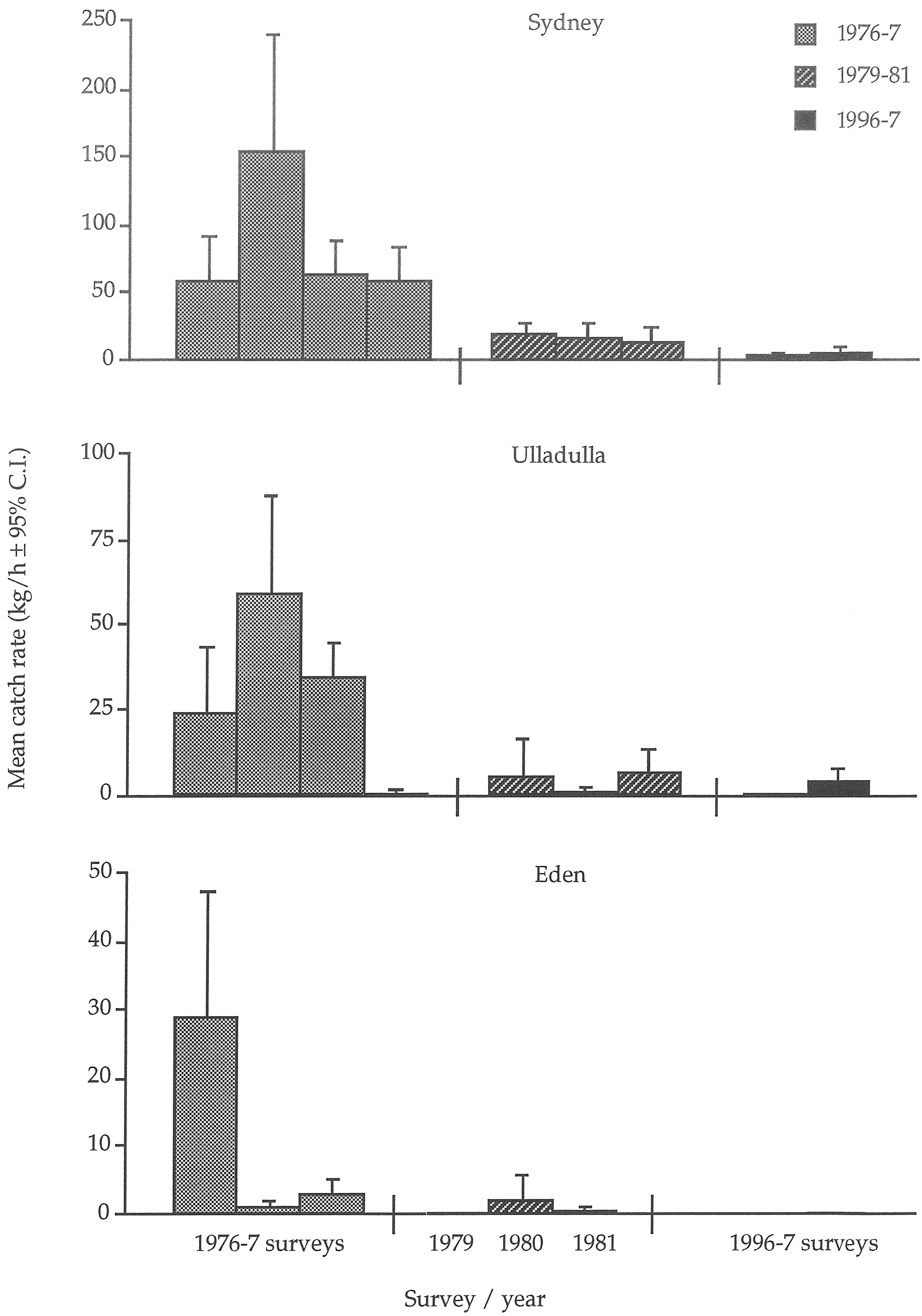

Figure 4.6 Mean catch rate (kg/h ± 95% C.I.) of greeneye dogshark per survey. Data are pooled for depth zones 2 and 3.

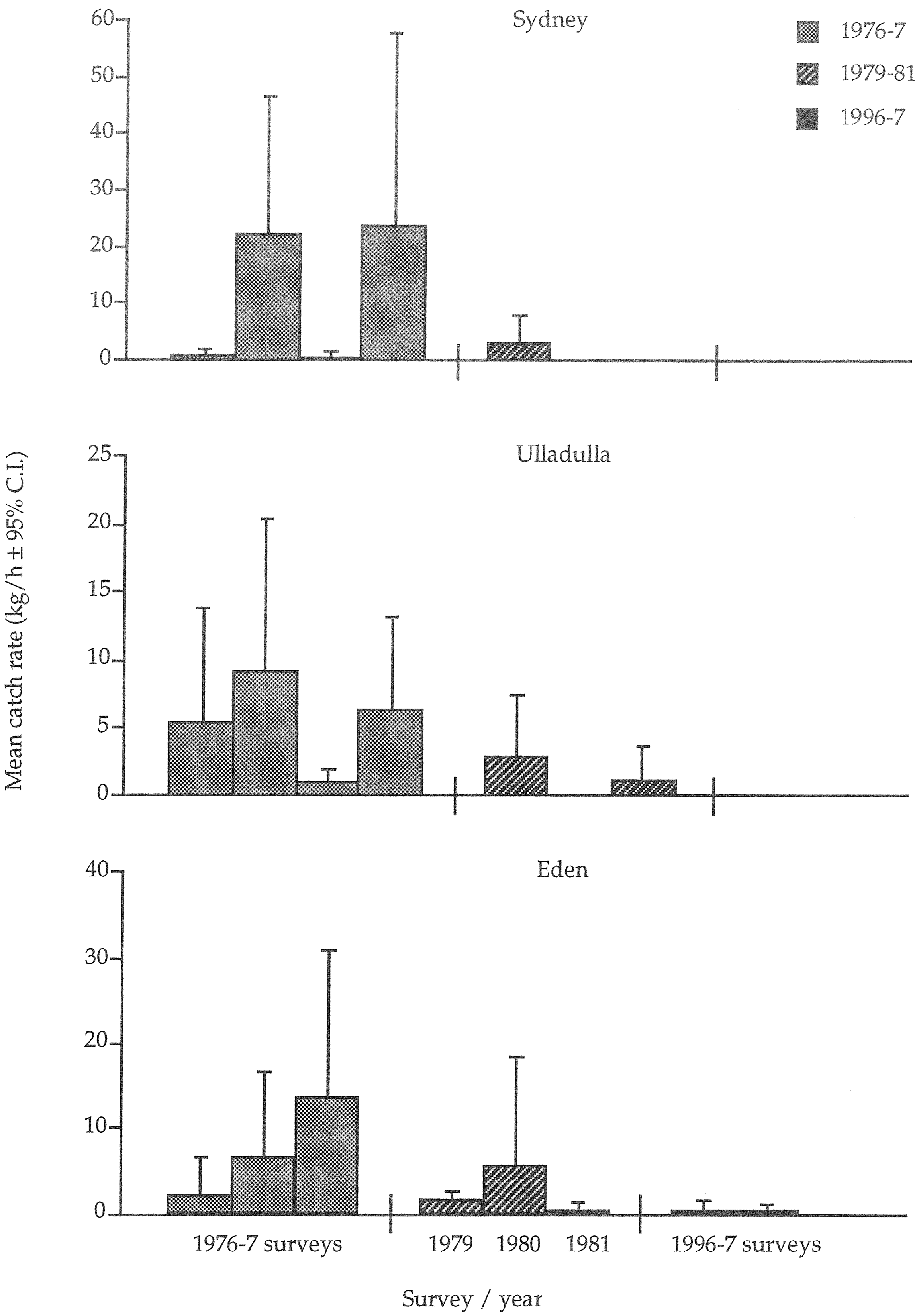

Figure 4.7 Mean catch rate (kg/h ± 95% C.I.) of long nose dogshark per survey. Data are pooled for depth zones 2 and 3.

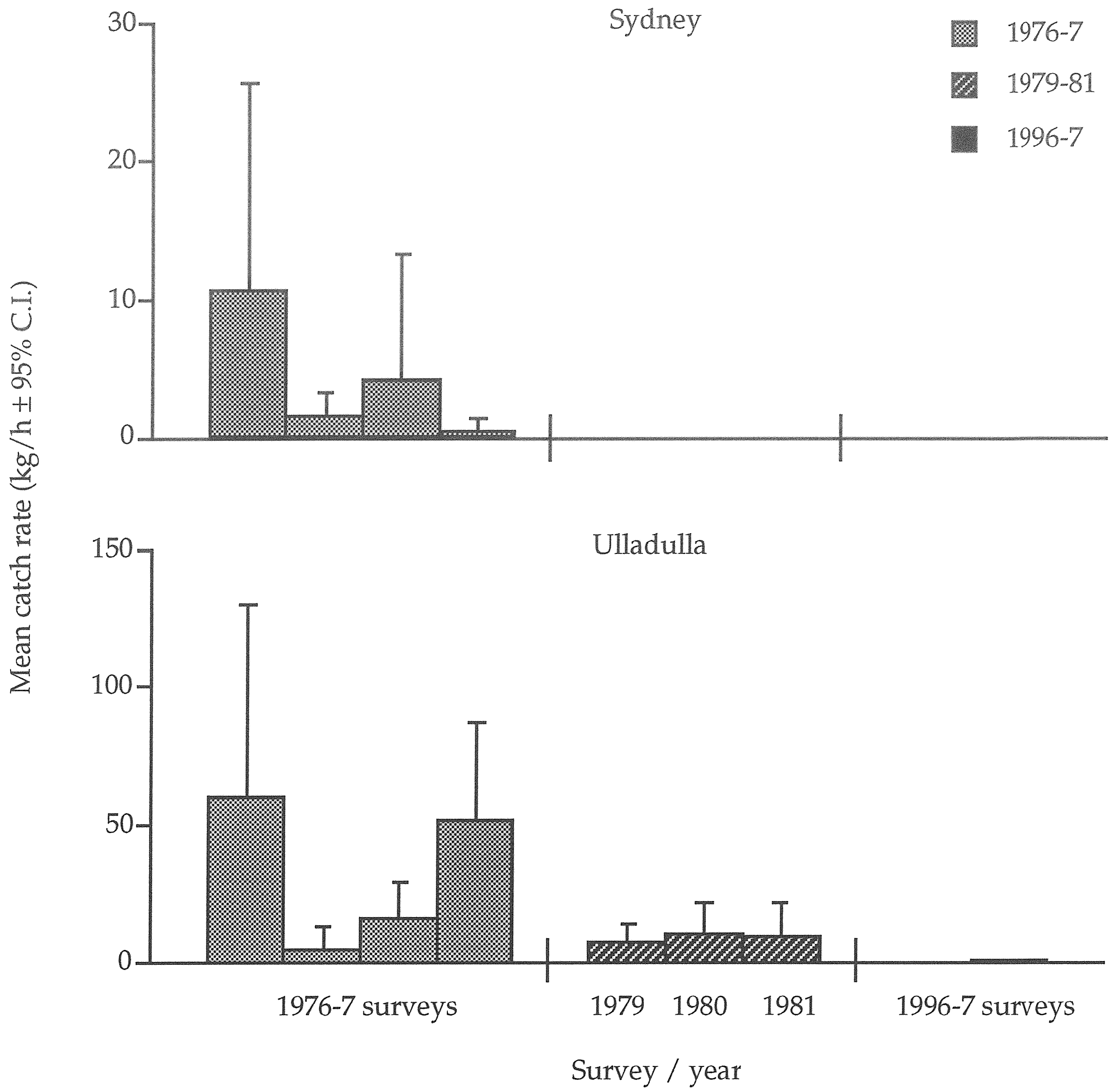

Figure 4.8 Mean catch rate (kg/h ± 95% C.I.) of angel shark per survey. Data are pooled for depth zones 2 and 3.

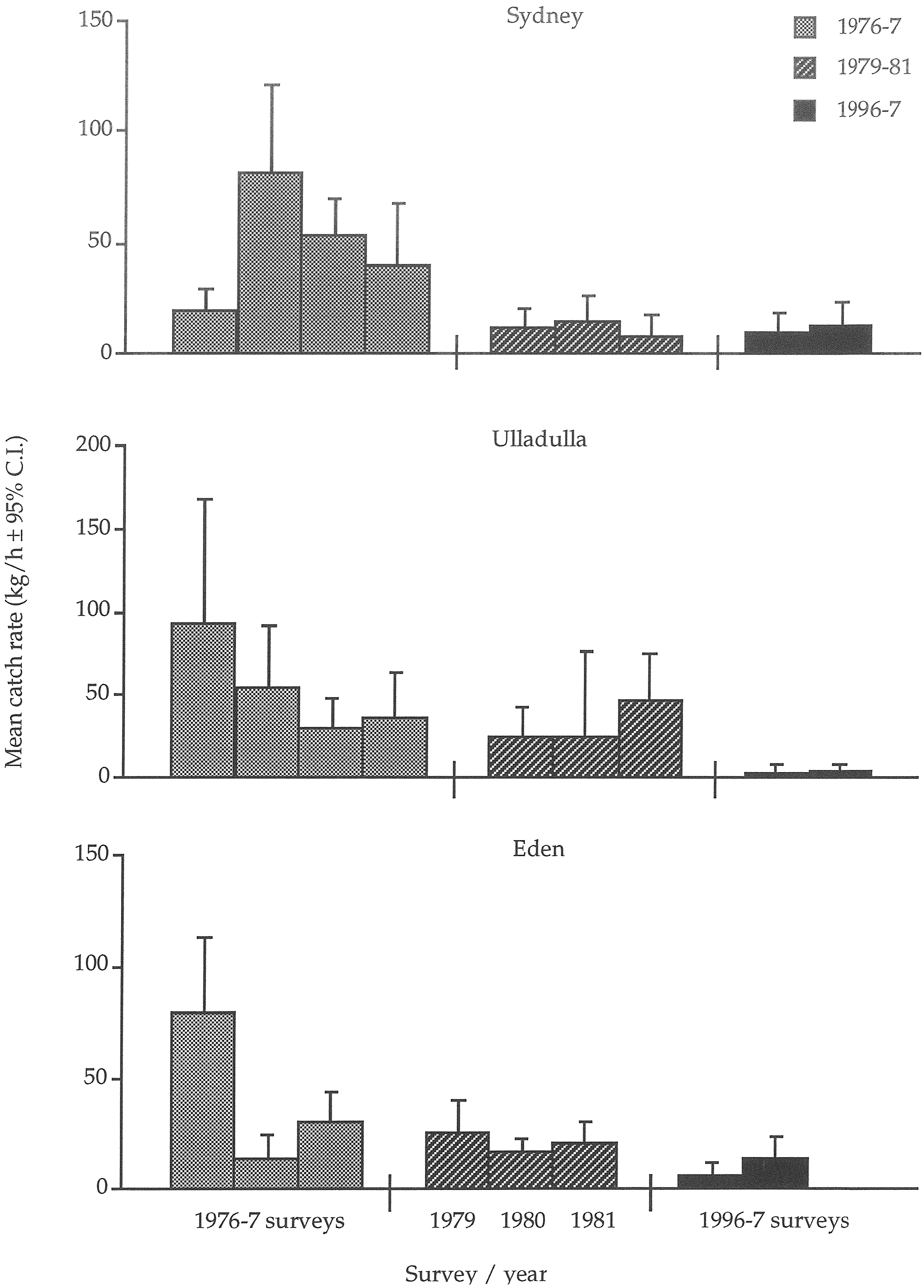

Figure 4.9 Mean catch rate (kg/h ± 95% C.I.) of skate per survey. Data are pooled for depth zones 2 and 3.

5. Comparison of 1976-7 and 1996-7 length frequency data.

Objective 2. To collect fishery-independent comparative data on the size composition of these trawl-fish after twenty years of exploitation

This objective has been achieved by comparing the length frequency distributions of species between the 1976-7 and 1996-7 surveys. For a subset of species, particularly the dogsharks, insufficient numbers were caught in 1996-7 to provide representative length-frequency distributions.

5.1 Results

In this section we report the length-frequencies of the major commercial species by location and depth. Comparisons of length structure between sexes in the teleost fishes are made only for 1996-7 because sexes were not separated in 1976-7. Sharks were sexed in both sampling periods, allowing comparisons where sufficient numbers were caught. Data are plotted only when sample sizes were greater than 30. There is a large number of graphs associated with the length frequency distributions for all 16 species. For brevity in the body of the report, all figures associated with this chapter are presented as an Appendix.

5.1.1 SEF Quota species

Blue grenadier

In 1976-7, at all locations, almost all the blue grenadier caught were longer than 70 cm (Figure 5.1.1). The great majority were caught at Ulladulla and Eden, and those few caught off Sydney were all adults. In contrast, the 1996-7 catch was comprised almost totally of a single cohort of juveniles between 35 and 50 cm with very few blue grenadier longer than 55 cm being caught (Figure 5.1.1).

The length frequency distributions were similar among depths at each location (Figures 5.1.2-4). The cohort of juveniles which dominated the 1996-7 catches was present in depth zones 3 and 4 off Sydney (Figure 5.1.2), zones 2-4 off Ulladulla (Figure 5.1.3) and all 4 zones off Eden (Figure 5.1.4). In 1976-7 at Ulladulla and Eden, there was a trend toward bimodality with increasing depth (Figures 5.1.3-4). Interpretation of this bimodality is difficult, however, because these data were collected from different surveys over two years (most of the blue grenadier from 550-605 m were caught in 1976 and most in 440-495 m from one catch in 1977). In addition, because the sexes were not separated in 1976-7 it is impossible to determine whether any of this bimodality was attributable to sex-specific differences in size. There was no evidence in 1996-7 (Figures 5.1.5-7) suggesting that differences in the size or relative abundances of males and females could account for these patterns. Those few fish longer than 90 cm measured in 1996-7 (n = 16) were, however, all female.

Ling

The pooled data for the three areas (Figure 5.2.1) clearly show that there has been a substantial reduction in the relative numbers of ling larger than 70 cm. At all locations there was a reduction in the mean length and size ranges of ling caught. In 1976-7, ling caught at all locations ranged in size between about 40 and 130 cm TL, with over half of the ling larger than 70 cm. In 1996-7, most ling caught were between 40 and 70 cm TL. That the overall mean catch rate (by weight) across the three locations was similar for the two periods suggests that, by number, ling were more abundant in 1996-7.

Within each sampling period, the size structure of ling was similar at all locations (Figure 5.2.1). However, there were differences in depth-related patterns within locations (Figures 5.2.2-4). In Sydney, ling were caught in greatest numbers in the deeper slope waters and none were caught in depth zone 1. Similarly, only small numbers of ling were caught in the shallowest depth zone in Ulladulla and Eden. At Ulladulla and Eden in 1996-7 there was an increase in the mean size of ling with increasing depth. Mean sizes of ling caught in 330-385 m off Ulladulla and Eden were 52.0 ± 0.4 cm and 54.9 ± 0.2 cm and had increased to 66.7 ± 1.1 cm and 66.8 ± 0.9 cm respectively in 550-605 m.

Insufficient numbers of ling were caught off Sydney in 1996-7 to reliably quantify differences in the size of males and females (Figure 5.2.5). At Ulladulla and Eden in 1996, sizes of male and female ling were broadly similar (Figures 5.2.6- 7). However, the majority of fish >80 cm (80% pooled across locations and depths) were female.

Redfish

There was a marked change in the size of redfish caught off Sydney between 1976-7 and 1996-7 (Figure 5.3.1). The average size of redfish caught off Sydney in 1996 was 16.4 ± 0.02 cm compared to 23.2 ± 0.1 cm in 1976-7. This difference was progressively less pronounced off Ulladulla and Eden (Figure 5.3.1). The data indicate that, at Sydney, almost all the large/old fish (>20 cm) present in 1976-7 have been replaced by smaller/younger fish <20 cm. In contrast, at Ulladulla and Eden, although the bulk of the large/old fish has been fished down to relatively very small numbers (Chapter 3), the size distributions had changed little between 1976-7 and 1996-7.

At all locations and in both sampling periods, redfish were caught only in depth zones 1 and 2 (220-385 m) and the great majority of these were caught in zone 1. In 1976-7 at all locations, there was an increase in mean size between depth zones 1 and 2 of 16.9 to 23.2 cm (Figures 5.3.2-4). Insufficient fish were caught in 1996-7 to provide reliable estimates of the length structure in depth zone 2. Sizes of males and females were similar within locations, depths and sampling periods (Figures 5.3.5-7).

Mirror dory

The sporadic catches of mirror dory taken in 1976-7 were mostly of adult fish larger than 40 cm with very few juveniles smaller than 35 cm (Figure 5.4.1). Except for Sydney catches in 330-495 m where a substantial proportion of the catches was of adults (>40 cm), most of the 1996-7 catches in all locations comprised small fish (<35 cm) caught in 220-385 m (Figures 5.4.2-4).

The change in size composition of the catches between 1976-7 and 1996-7 was most marked for Eden where the mean size of mirror dory fell from 44.3 ± 0.1 cm to 31.5 ± 0.2 cm. The length-frequency distributions were unimodal at Sydney and Eden in both sampling periods but, at Ulladulla, there was a small 'cohort' of fish between 15 an 20 cm TL caught in 1996-7 (Figure 5.4.1).

In Sydney, the changes in length structure between sampling periods differed among depths (Figure 5.4.2). Catches in 1976-7 were mostly of adult fish (35-55 cm TL) and this pattern was consistent among depths. The 1996-7, mirror dory caught in depth zones 1 and 2 were predominantly small fish (30-35 cm) although there were some larger fish recorded from depth zone 2 (Figure 5.4.2). In depth zone 3, almost all fish caught in 1996-7 were adults and were of a similar size range to those caught in 1976-7. Insufficient fish were caught in depth zone 4 to allow a reliable comparison (Figure 5.4.2).

By contrast, the sizes of fish caught off Ulladulla in 1976-7 and 1996-7 were similar in depth zones and 1 and 3. Catches in depth zone 1 were dominated by relatively small fish in both survey periods (Figure 5.4.3). Insufficient fish were caught in either 1976-6 or 1996-7 in depth zone 4 to allow comparisons. In Eden, insufficient numbers of mirror dory were caught in 1996-7 in depth zones 1, 2 and 4 to allow comparisons (Figure 5.4.4). In depth zone 3, although the mean size of fish caught between periods was similar (44.5 ± 0.1 cm in 1976-7 and 41.4 ± 0.7 cm in 1996-7) the range of sizes of fish caught increased between periods (Figure 5.4.4).

There were complex depth-related patterns in sizes of males and females mirror dory caught in 1996-7 (Figures 5.4.5-7). At all locations, in depth zone 1, sizes of males and females were similar, whereas in depth zone 2 there was broad overlap in the distributions for all sizes except that females dominated the sizes classes greater than 45 cm TL. In Sydney and Eden, in depth zone 3 there was a greater contrast between males and females; most mirror dory greater than 45 cm TL were females (Figure 5.4.5). Insufficient fish were caught in depth zone 3 at Ulladulla and in depth zone 4 at all locations to allow comparisons.

Ocean perch

The comparative length data show a great reduction in the relative numbers of large ocean perch (>30 cm) between 1976-7 and 1996-7 (Figure 5.5.1). There were large changes in mean size although the overall size ranges of ocean perch were similar between sampling periods. The mean sizes of ocean perch in 1976-7 were between 30 and 32 cm FL at the three locations but, in 1996-7, mean sizes fell to 25-26 cm. The 1976-7 distributions were left skewed with modes at approximately 35 cm, whereas in 1996-7 the modes were at 20-25 cm and the distributions tended towards right-skewness.

Changes in length-frequency distributions between periods were depth- and location-specific (Figures 5.5.2-4). Although the range of sizes was similar in depth zones 2-4 off Sydney in 1976-7, the mode increased with increasing depth (Figure 5.5.2). This trend toward increasing mean size with increasing depth was also present in 1996-7 but was less pronounced, as was the skewness of the distributions. Changes at Ulladulla and Eden were very similar to those described for Sydney except that there was very little difference between sampling periods in length structures in the deepest zone (550 - 605 m; Figure 5.5.3-4). Insufficient ocean perch were caught in depth zone 1 at Ulladulla in 1976-7 to allow comparisons among periods. At Eden, catches in depth zone 1 were predominantly small fish (<25 cm) in both 1976-7 and 1996-7 (Figure 5.5.4).

There were no clear differences in the size range of male and female ocean perch in 1996-7 (Figures 5.5.5-7) although females dominated the length distributions at lengths greater than 35 cm TL in depth zones 3 and 4.

Tiger flathead

The length frequency distributions of tiger flathead at all three locations were very similar in 1976-7 and 1996-7 (Figure 5.6.1) showing only a small reduction in mean size. Pooled across all locations, the mean size of tiger flathead decreased from 41.0 ± 0.1 cm to 38.5 ± 0.1 cm.

At all locations, the great majority of tiger flathead were caught in zone 1 (220 - 275 m) although small catches were recorded in depth zone 2. Because of the dominance of fish from depth zone 1 in the total catch, patterns in length distributions by depth (Figures 5.6.2-4) were similar to those pooled across depth zones (Figure 5.6.1).

Female tiger flathead dominated the catch at all locations and depths (Figure 5.6.5-7). Pooled across locations, 17% of tiger flathead caught in depth zone 1 were male and, similarly, 10% in zone 2 were males. No males longer than about 40 cm TL were caught. In Sydney, Ulladulla, and Eden, 90, 80, and 89% respectively of the total catches was comprised of females.

Jackass morwong

Insufficient jackass morwong were caught in 1996-7 to allow comparison with the sizes of fish caught in 1976-7 (Figure 5.7.1). The 1976-7 length distributions of jackass morwong at Ulladulla and Eden were similar, both in size range and mode (Figures 5.7.2-3). A total of only three jackass morwong were caught off Sydney. Comparison between depths was possible only at Eden in 1976-7 (Figure 5.7.3) where fish caught in depth zone 2 (40.3 ± 0.1 cm FL) were larger than those from depth zone 1 (36.7 ± 0.1).

Gemfish

Although there appears to have been large changes in the length frequency distribution of gemfish between periods, small sample sizes in 1996-7 limit the inferences that can be made about changes in size structure (Figure 5.8.1). In both sampling periods, the length distributions of gemfish were multi-modal except at Sydney were only small fish were caught in any numbers (Figure 5.8.1). Up to five peaks in the frequency distribution are apparent at Ulladulla and Eden in 1976-7. However, the definition of the modes of small fish is blurred because data were pooled from surveys in a number of months in the year.

At all locations, more than 94% of gemfish (by number) were caught between 120 - 210 fm (Figures 5.8.2-4). Off Sydney in depth zone 1, only small catches were recorded in both periods and almost all were juveniles (Figure 5.8.2). In depth zone 2, the 1976-7 catch was dominated by juveniles between 20 and 40 cm FL caught in October 1976. Those adults (>60 cm) caught were almost all taken in September 1977 and were probably post-spawning fish returning south. At Ulladulla, the numbers of large gemfish were greater with increased depth (Figure 5.8.3). Small gemfish (<60 cm) were caught during all survey whereas, those >60 cm FL were almost all caught during July- August surveys. At Eden, only a small proportion of gemfish were adult fish; relatively large numbers of immature fish were caught in depth zones 1 and 2 (Figure 5.8.4).

In 1996-7,insufficient numbers of gemfish large enough to be sexed were caught to allow comparisons of sex-related patterns in size structure among locations and depths (Figures 5.8.5-7).

Spotted warehou

Spotted warehou were caught in sufficient numbers to graph only off Ulladulla (1976-7) and Eden (1996-7) (Figure 5.9.1). The Ulladulla fish, caught during one survey in 1977, were all relatively large (40-55 cm) (Figure 5.9.2). Spotted warehou off Eden in 1996-7 were mainly 35-45 cm with a second small mode at 45-55 cm. The larger fish were mostly caught in zone 1 (Figure 5.9.3). The size range and frequency of males and females were similar (Figure 5.9.4).

5.1.2 Commercial sharks

Angel shark

The overall size range and size composition of angel sharks caught off Sydney and Ulladulla in 1976-7 were similar (Figure 5.10.1). The relatively small number caught off Sydney in 1996 were mostly smaller than those taken in 1976-7 (Figure 5.10.1). When size data were pooled across all locations and depths, there was a decrease in the mean size of angel sharks from 77.6 ± 0.6 cm (n = 1026) in 1976-7 to 58.6 ± 3.1 cm (n = 44) in 1996-7. The largest individual caught in 1996-7 was 100 cm compared to 130 cm in 1976-7. Almost all the angel sharks caught in 1996-7 were sexually immature.

At both Sydney and Ulladulla the mean size of angel sharks (caught in 1976-7) increased with depth from 73.2 ± 0.7 cm in depth zone 1 to 83.4 ± 0.8 cm in depth zone 2 (Figures 5.10.2-3). There was also an increase in the minimum size observed in these depth zones from 30 cm in depth zone 1 to 45 cm in depth zone 2. At both locations and in both depth zones the length frequency distributions were unimodal.

At both Sydney and Ulladulla, female angel sharks were larger than males (Figure 5.10.4-5). Both male and female sharks had a similar minimum length of approx. 30 cm TL but the maximum length for males was about 100 cm while the longest females caught were 130 cm TL.

Endeavour dogshark

In 1976-7, the differences length structures of the total catches (Figure 5.11.1) and among depth zones (Figures 5.11.2-3) between Sydney and Ulladulla reflect the relative frequencies of males and females at these locations. At Sydney, 96 % of the catch comprised males, mainly adults, with a mean size of 82.1 ± 1.9 cm (Figure 5.11.4). In contrast, catches at Ulladulla were dominated by immature females (84%) with a mean size of 66.0 ± 1.2 cm (Figure 5.11.5). The maximum size observed for male Endeavour dogsharks was 83 cm TL whereas females reached sizes up to 94 cm TL.

Only one individual was caught off Eden in 1976-7 and a total of only 12 Endeavour dogsharks were caught in the 1996-7 survey period, all being taken off Sydney.

Greeneye dogshark

At Sydney and Ulladulla, although a similar size range of greeneye dogsharks was caught in 1976-7 and 1996-7 (Figure 5.12.1), there were fewer individuals longer than 70 cm TL in the latter period. Only one individual was caught at Eden in 1996-7. In 1976-7, bimodal length frequency distributions with similar modes and spreading over similar size ranges were observed at all locations (Figure 5.12.1).

At Sydney and Ulladulla, the length frequency distributions were increasingly bimodal with increasing depth (Figures 5.12.2-3). This trend was caused by the increasing prominence of a mode at approximately 75 cm TL. The size structure of the relatively small catches at Eden in 1976-7 in depth zone 2 was more unimodal than the comparable length distributions observed at Sydney and Ulladulla (Figure 5.12.4).

Interpretation of these patterns is complicated by the recent recognition that the catches comprised two species of greeneye dogsharks, *Squalus* sp. F and *Squalus mitsukurii* (Last and Stevens 1994). The observed bimodality appears to reflect differences in the size distributions of the two species. Male *Squalus* sp. F range in size at maturity between 50 and

65 cm TL and females grow to about 75 cm; male *S. mitsukurii* are typically 65-80 cm long at maturity and female *S. mitsukurii* reach over 100 cm (K. Graham, unpub. data). The male size distributions are clearly bimodal (Figures 5.12.5-7) probably representing mostly *Squalus* sp. F (50-65 cm) and *S. mitsukurii* (65-80 cm) respectively. Females reach up to 96 cm but showed no well defined modes. It is most likely that females greater than 80 cm were all *S mitsukurii*.

Spiky dogshark

At all locations, similar sized spiky dogsharks were caught in 1976-7 and 1996-7 (Figure 5.13.1). The exceptions to this broad pattern were a small increase in the mean size of sharks between sampling periods at Sydney (from 47.7 ± 0.1 cm to 50.2 ± 0.1 cm), and the presence of sharks smaller than 30 cm in the Eden samples in 1996-7. The size structure of spiked dogsharks in Eden was bimodal in both sampling periods.

Off Eden, the clear and consistent difference in the sizes of mature males and females (see Figures 5.13.5-10) produced a bimodal length structure at all depths off Eden for which sufficient sharks were caught (Figures 5.13.1 & 4). This pattern was not as distinct at Sydney or Ulladulla where most of the catch comprised females (Figures 5.13.2-3).

The size distributions for depth zones 1 and 2 were similar at Ulladulla and Eden for the two periods but, for the 1996-7 catches off Sydney, showed a greater proportion of larger (female) sharks in zone 2 (Figures 5.13.2-4). This may explain the increase in overall mean size of the Sydney spiky dogsharks. In 1976-7 and 1996-7, females dominated the catches at Sydney (88 and 93% of totals) and Ulladulla (84 and 82%). In contrast, males accounted for 69 and 76% of the catches off Eden (Figures 5.13.5-7). Male spiky dogsharks rarely exceeded 50 cm in length while most females were between 45 and 60 cm TL. The males between 50 and 60 cm TL recorded in 1976-7 were probably the recently described eastern highfin dogshark (*Squalus* sp. B).

Harrissons dogshark

The 1976-7 catches comprised mostly adults between 85 and 110 cm TL (Figure 5.14.1-4). The length frequency distribution at Sydney was bimodal, primarily reflecting differences in the sizes of males and females (Figure 5.14.5). The mean size of females in Sydney, pooled across depths was 100.1 ± 1.4 cm whereas the average length of males was 84.6 ± 1.5 cm. At Ulladulla these differences were less clear, probably because too few females were caught to reliably describe the size range (Figure 5.14.6).

Off Eden, the bimodal distribution was clearly evident only in depth zone 2 (Figure 5.14.7). In the deeper depth zones there were few females larger than males. It is interesting that in depth zone 2, where there were many large females, there were few smaller juveniles. In depth zones

3 and 4, however there were more juveniles, both male and female, and fewer large females (>95 cm) (Figure 5.14.7).

Only seven Harrissons dogsharks were caught in 1996-7.

Southern dogshark

Only 14 southern dogsharks were caught in 1996-7. In 1976-7, at Sydney, the length frequency distributions were dominated by large females ranging from 95-110 cm TL (Figures 5.15.2 and 5). In contrast, at Ulladulla and Eden, a much wider size range of sharks were caught (Figure 5.15.1, 3-4). Many juveniles (40- 80 cm) and mature males (80- 90 cm) were caught, but proportionally fewer mature females (95- 110 cm) were observed (Figures 5.15.6-7). No males larger than 93 cm TL were observed at any location or depth. The length distributions and relative representation of males and females were similar among depths (Figures 5.15.5-7).

5.1.3 Non-commercial species

Spiny flathead

The overall length data for the three locations (Figure 5.16.1) indicate a large-scale reduction in the numbers of large spiny flathead >40 cm. Over all locations, the mean size of spiny flathead in 1976-7 was 39.0 ± 0.1 cm compared to 31.2 ± 0.1 cm in 1996-7. The size distributions at Sydney and Ulladulla were left skewed with a mode at 43 cm TL (Figure 5.16.2-3). At Eden, the mode was slightly larger (44 cm TL) and the distribution was more normal (Figure 5.16.4). In 1996-7, the length distributions at all locations were normally distributed (Figure 5.16.1).

6. Collection of Otoliths from SEF Quota species.

Objective 3. To collect fishery-independent representative samples of otoliths and other biological information as required by the South East Fishery Assessment Group

A total of 4015 pairs of otoliths were collected from 9 SEF quota species were collected in 1996. These were predominantly from blue grenadier, ling, ocean perch, redfish and tiger flathead, reflecting the relative abundance of SEF quota species. The collection is being held at NSW Fisheries Research Institute, Cronulla.

6.1 Results

A total of 4015 pairs of otoliths were collected from 9 SEF quota species (Table 6.1); 2495 pairs were collected during the first surveys in each area, and the remainder during Survey II. None was collected during Survey III off Eden. Otoliths were not collected from mirror dory because the extremely small size of their otoliths made it impractical to collect them at sea. The collection is presently stored at FRI, Cronulla.

For each species, the size range and number at each size increment sampled for otoliths is representative of the overall size range and frequency of each species caught in each area. For species commonly caught, such as blue grenadier, ling, ocean perch, redfish and tiger flathead, otoliths were collected from five fish of each sex in each cm size class within their main size range. For species caught in small numbers (warehous, large gemfish and jackass morwong), all fish were sampled for otoliths.

Table 6.1 Number of otoliths collected from SEF quota species, 1996-7. Numbers are pooled over surveys and depth zones. Lengths are pooled into 5cm increments. U = unsexed, M = male and F = female.

Species	Length (cm)	Sydney U	Sydney M	Sydney F	Ulladulla U	Ulladulla M	Ulladulla F	Eden U	Eden M	Eden F	All locations U	All locations M	All locations F
BLUE GRENADIER	20-24	0	0	0	0	0	0	0	0	0	0	0	0
	25-29	0	0	0	0	0	0	0	0	0	0	0	0
	30-34	0	0	0	0	5	10	0	1	3	0	6	13
	35-39	0	0	0	0	15	22	0	16	14	0	31	36
	40-44	0	23	28	0	35	32	0	41	49	0	99	109
	45-49	0	13	29	0	12	31	0	39	51	0	64	111
	50-54	0	0	0	0	2	6	0	8	37	0	10	43
	55-59	0	0	0	0	0	3	0	1	6	0	1	9
	60-64	0	0	0	0	0	0	0	0	0	0	0	0
	65-69	0	0	0	0	0	0	0	0	2	0	0	2
	70-74	0	0	0	0	0	0	0	0	4	0	0	4
	75-79	0	0	0	0	0	0	0	2	2	0	2	2
	80-84	0	0	0	0	0	0	0	8	10	0	8	10
	85-89	0	0	1	0	2	7	0	4	9	0	6	17
	90-94	0	0	0	0	0	2	0	1	6	0	1	8
	95-99	0	0	1	0	0	3	0	0	1	0	0	5
	100-101	0	0	0	0	0	1	0	0	1	0	0	2
	105-109	0	0	0	0	0	0	0	0	0	0	0	0
	110-114	0	0	0	0	0	0	0	0	1	0	0	1
	TOTAL:	0	36	59	0	71	117	0	121	196	0	228	372
OCEAN PERCH	5-9	0	0	0	1	0	0	4	0	0	5	0	0
	10-14	3	1	1	8	0	0	14	0	0	25	1	1
	15-19	15	8	10	32	7	2	26	7	6	73	22	18
	20-24	0	59	57	0	66	56	1	48	47	1	173	160
	25-29	0	57	66	0	62	61	0	43	24	0	162	151
	30-34	0	42	48	0	44	50	0	69	47	0	155	145
	35-39	0	11	24	0	26	42	0	22	57	0	59	123
	40-44	0	0	4	0	1	6	0	4	16	0	5	26
	TOTAL	18	178	210	41	206	217	45	193	197	104	577	624
REDFISH	10-14	0	2	5	0	0	0	0	0	1	0	2	6
	15-19	0	86	83	0	14	34	0	16	8	0	116	125
	20-24	0	21	20	0	26	58	0	30	54	0	77	132
	25-29	0	0	1	0	3	9	0	19	44	0	22	54
	30-34	0	0	0	0	0	0	0	1	4	0	1	4
	35-39	0	0	0	0	0	0	0	0	0	0	0	0
	TOTAL	0	109	109	0	43	101	0	66	111	0	218	321
TIGER FLATHEAD	25-29	0	1	0	0	11	10	0	0	0	0	12	10
	30-34	0	35	30	0	7	54	0	3	2	0	45	86
	35-39	0	24	63	0	9	41	0	11	27	0	44	131
	40-44	0	3	36	0	2	14	0	6	35	0	11	85

Table continued on next page.

Table 6.1 Continued from previous page.

TIGER	45-49	0	0	23	0	0	2	0	0	8	0	0	33
FLATHEAD	50-54	0	0	4	0	0	0	0	0	2	0	0	6
	55-59	0	0	1	0	0	0	0	0	0	0	0	1
	TOTAL	0	63	157	0	29	121	0	20	74	0	112	352
LING	30-34	0	0	0	0	1	0	0	0	0	0	1	0
	35-39	0	0	0	0	1	0	0	0	1	0	1	1
	40-44	0	0	0	0	13	10	0	11	6	0	24	16
	45-49	0	0	0	0	24	29	0	26	15	0	50	44
	50-54	0	1	0	0	31	45	0	47	36	0	79	81
	55-59	0	0	3	0	29	38	0	57	50	0	86	91
	60-64	0	1	7	0	25	48	0	43	44	0	69	99
	65-69	0	4	6	0	25	27	0	18	36	0	47	69
	70-74	0	1	14	0	5	25	0	11	24	0	17	63
	75-79	0	1	8	0	2	17	0	7	10	0	10	35
	80-84	0	0	4	0	1	9	0	4	10	0	5	23
	85-89	0	0	2	0	2	9	0	1	2	0	3	13
	90-94	0	0	0	0	3	4	0	2	2	0	5	6
	95-99	0	0	1	0	1	3	0	0	6	0	1	10
	100-104	0	0	2	0	0	6	0	1	0	0	1	8
	105-109	0	0	0	0	0	0	0	0	3	0	0	3
	110-114	0	0	0	0	0	3	0	0	3	0	0	6
	115-119	0	0	0	0	0	0	0	1	3	0	1	3
	120-124	0	0	0	0	0	2	0	0	2	0	0	4
	125-129	0	0	0	0	0	0	0	0	0	0	0	0
	130-134	0	0	0	0	0	0	0	0	0	0	0	0
	TOTAL	0	8	47	0	163	275	0	229	253	0	400	575
SPOTTED	25-29	0	0	0	0	0	0	0	0	0	0	0	0
WAREHOU	30-34	0	0	0	0	0	0	0	0	0	0	0	0
	35-39	0	0	0	0	0	0	0	5	0	0	5	0
	40-44	0	0	0	0	0	0	0	9	8	0	9	8
	45-49	0	0	0	0	0	0	0	3	22	0	3	22
	50-54	0	0	0	0	0	0	0	4	18	0	4	18
	55-59	0	0	0	0	0	0	0	0	2	0	0	2
	TOTAL	0	0	0	0	0	0	0	21	50	0	21	50
BLUE	25-29	0	0	0	0	0	0	0	0	1	0	0	1
WAREHOU	30-34	0	0	0	0	0	0	0	1	3	0	1	3
	35-39	0	0	0	0	0	0	0	3	3	0	3	3
	40-44	0	0	0	0	0	0	0	0	1	0	0	1
	45-49	0	0	0	0	0	0	0	2	0	0	2	0
	50-54	0	0	0	0	0	0	0	1	0	0	1	0
	55-59	0	0	0	0	0	0	0	0	0	0	0	0
	TOTAL	0	0	0	0	0	0	0	7	8	0	7	8
JACKASS	25-29	.	.	.	.	.	.	.	.	.	0	1	0
MORWONG	30-34	.	.	.	.	.	.	.	.	.	0	0	0
	35-39	.	.	.	.	.	.	.	.	.	0	0	1

Table continued on next page.

Table 6.1 Continued from previous page

JACKASS	40-44	.	.	.	.	.	.	.	.	.	0	0	1
MORWONG	45-49	.	.	.	.	.	.	.	.	.	0	0	0
	50-54	.	.	.	.	.	.	.	.	.	0	0	0
	55-59	.	.	.	.	.	.	.	.	.	0	0	0
	TOTAL	.	.	.	.	.	.	.	.	.	0	1	2
GEMFISH	21-29	.	.	.	.	.	.	.	.	.	0	4	0
	30-34	.	.	.	.	.	.	.	.	.	0	5	0
	35-39	.	.	.	.	.	.	.	.	.	0	0	0
	40-44	.	.	.	.	.	.	.	.	.	0	4	2
	45-49	.	.	.	.	.	.	.	.	.	0	2	9
	50-54	.	.	.	.	.	.	.	.	.	0	2	1
	55-59	.	.	.	.	.	.	.	.	.	0	6	7
	60-64	.	.	.	.	.	.	.	.	.	0	1	2
	65-69	.	.	.	.	.	.	.	.	.	0	4	0
	70-74	.	.	.	.	.	.	.	.	.	0	0	0
	75-79	.	.	.	.	.	.	.	.	.	0	2	1
	80-84	.	.	.	.	.	.	.	.	.	0	0	3
	85-89	.	.	.	.	.	.	.	.	.	0	0	1
	90-94	.	.	.	.	.	.	.	.	.	0	0	0
	95-99	.	.	.	.	.	.	.	.	.	0	0	1
	100-104	.	.	.	.	.	.	.	.	.	0	0	2
	TOTAL	.	.	.	.	.	.	.	.	.	0	30	29

7. Discussion

7.1 Preamble

Interpreting differences in catch rate between 1976-7 and 1996-7 and suggesting causal mechanisms is complicated by the range of possible processes that could account for the changes observed. These may be divided into three broad classes: (i) the fishery, (ii) natural variability, and (iii) non-representative sampling. These possible explanations are not mutually exclusive and indeed it is likely that they will interact. The numerical responses of species to sustained fishing pressure are likely to be influenced by ecological and life history attributes such as their mobility, fecundity and mode of reproduction. Similarly, the impact of environmental change may be exacerbated if those populations are reduced by fishing. Gaining representative estimates of relative abundance may be increasingly difficult as the densities of migratory and/or schooling species such as gemfish, blue grenadier and redfish decline. Below we outline the evidence for real change in relative abundance and size structure for species or groups of species whose abundance appears to have changed in similar ways. Finally we discuss the likelihood of alternative explanations for the changes observed.

7.2 Sampling Methods

The 1976-77 *Kapala* surveys of the upper slope grounds between Broken Bay and Gabo Island were carried out close to the inception of the NSW slope fishery and at a time when trawling had probably made little change to the pre-exploitation state of the upper slope fish stocks. Overall catch rates were high for many species, particularly when the small size of the survey nets (compared to commercial gear) is considered. The 1996-7 repeat survey was carried out with more stringent sampling protocol which ensured better randomisation among trawling times/depths. Several tows in the 1976-7 survey were at night when some species are less catchable and consequently probably lowered their mean catch rates. In contrast, all 1996-7 trawling was during daytime, and all practical means were employed to ensure optimal and representative sampling. For example, the utilisation of a GPS and trackplotter in 1996-7 enabled very accurate positioning and trawling speed to be maintained. During 1976-7, trawl speed was estimated from radar positions taken over relatively long distances from the coast; during many tows, the cumulative effects of poor radar conditions, sea surface currents and sea state would have militated against optimal gear performance. Trawl to trawl performance is inherently variable (Wathne 1977, Byrne et al. 1981) but it is felt that if any biases were present in the sampling procedures, they would tend to reduce overall catch rates during the 1976-7 surveys and, conversely, elevate catch rates in 1996-7.

7.3 Species with widespread and/or large reductions in relative abundance

The overall catch rate for total fish in 1996-7 was 68% less than was recorded in 1976-7 and the reduction in the catch rates of total commercial fish was 74%, suggesting a substantial decrease in the overall fish biomass on the grounds surveyed. Individually, the following commercial species showed large reductions in relative abundance: redfish, jackass morwong, ocean perch, Endeavour dogshark, Harrissons and southern dogsharks, greeneye dogshark and angel shark. Furthermore, for redfish and ocean perch, the length frequency data also indicated that there had been a substantial fish-down of large/old fish.

Redfish

The results of this study indicate a great reduction in the relative abundance of redfish on the NSW upper slope. Compared to 1976-77, catch rates of redfish during 1996-7 were very low, especially at Ulladulla where the overall catch rate was less than 5% of that in 1976-7. Associated with this reduction in catch rates, the mean size of redfish was less at all locations and the size structure, especially for Sydney, was dominated by smaller and presumably younger fish. The size data indicated that the old stock of large fish had been severely depleted and, off Sydney at least, replaced by smaller fish.

The commercial catch off southern NSW is now taken mainly on outer shelf grounds and comprises relatively small redfish with a mean size between 17 and 19 cm (Liggins 1997). Although the annual landed commercial catch has been relatively high in recent years, sustained by a pulse of fish that entered the redfish catches in 1990-91, the available evidence suggests there has been a long term decline in commercial catches and mean length of landed redfish (Rowling 1994b).

We suggest that the stocks of large (old) redfish and jackass morwong (see below) which were present on the upper slope at the inception of the slope fishery represented the "accumulated" stocks previously unexploited. The mean size of redfish increases with depth (Chen et al. 1997) indicating that the upper slope stock are recruited from the continental shelf depths. However, with the sustained trawling effort on the outer shelf over the last twenty years (often targeting redfish and, in the south, jackass morwong), fewer redfish or jackass morwong are surviving to "accumulate" on the upper slope, and those that do are quickly exploited.

Jackass morwong

Jackass morwong have all but disappeared from the upper slope off Ulladulla and Eden in the 20 years since 1976-7. Large jackass morwong were caught in great numbers in 220-385 m off Eden-Gabo Island at the inception of the slope fishery. In the 1977 surveys, individual catches as high as 800 kg were taken, but during surveys by *Kapala* in similar depths off Eden-Gabo Island during 1979-81, the average catch rate of jackass morwong was less than 5 kg/hour (unpubl. *Kapala* data), and during 1996-97 a total of only seven individuals was caught during the entire survey. There was a high degree of consistency among replicate tows and surveys within periods and location, suggesting that these estimates are representative.

It appears that the slope stock of jackass morwong off southern NSW was removed very early in the fishery, suggesting that the fishery now relies on recruits. Smith (1994) concluded that the current SEF catch was sustainable, although Chesson (1996) reported that there is evidence that commercial trawler catch rates of jackass morwong have shown a slow decline since 1987. The SEF-wide annual TAC of 1500 t has not been caught since its inception in 1992.

Ocean perch

The observed reduction in overall catch rate (by weight) and size structure suggest a decline in the relative abundance of large ocean perch consistent with prolonged exploitation. Mean catch rates of ocean perch at Sydney and Ulladulla during 1996-7 were less than 30% of those in 1976-7. Catch rates in 1979-81 were intermediate between those two levels (Figure 4.2). The 1996-7 catch rates off Eden, although about half of those in 1976-7, were not statistically significantly different, largely because of several relatively large catches of small ocean perch in 1996-7 in the shallower depths. By number, the relative abundance of small ocean perch off Eden may have increased in the shallower depths.

Ocean perch belong to the family Scorpaenidae, the members of which typically inhabit hard and/or rough substrates. It is conceivable, therefore, that untrawlable areas adjacent to the trawl grounds act as refugia for sexually mature ocean perch and supply recruits to the fishery. Inspection of the *Kapala* trawl ground charts indicates that approximately 31% of the seabed between Newcastle and the Horseshoe in waters between 200 and 640 m deep is untrawlable (Table 1.1). The contribution of these areas to stocks of ocean perch on trawled grounds is unknown.

Chesson (1996) stated that the catch rates of ocean perch declined in the Eastern Sector of the SEF between 1975 and 1986, and that standardised CPUEs were "fairly stable" over the period 1986-1990. Park (1994) suggested that the decline in mean size of ocean perch in the Eastern Sector may be indicative of a decline in abundance, and that their apparent longevity and small brood size made them susceptible to over-fishing. The SEF-wide TAC for ocean perch of 574 t has not been landed (since 1992) and no stock assessments have been completed (Chesson 1996).

Sharks and skates

It is clear from the results that, apart from spiky dogshark, the abundances of sharks and skates on the NSW upper slope are at comparatively very low levels. Unlike several of the teleosts where there was a substantial reduction in numbers of large fish but relatively high numbers of juveniles, very few sharks and skates of any size were caught. The magnitude and consistency of this decline among sampling periods, surveys and replicate tows suggest the observed patterns reflect real changes. Although the 1979-81 data were not corrected for the larger gear size used during those years, the total catch rates for dogsharks (excluding spiky dogsharks), ghost sharks and skates were between 19% (Eden) and 46% (Ulladulla) of the 1976-77 catch rates, and by 1996-97 had fallen to less than 6% of the initial levels. Although no stock assessments for SEF management purposes are done for any shark species (Tilzey 1994, Chesson 1995, 1996), the dramatic reduction in relative abundance is consistent with severe over-fishing.

In addition to the data reported here, declines in shark abundance have been documented in other Kapala surveys. The first survey of the upper slope was for deepwater prawns in 1971-72. The mean catch rate (across all depths) for dogsharks off Sydney-Port Stephens was 137 kg/h. During further prawn trawling in the period 1975-82 this catch rate had declined to 40 kg/hour (Graham and Gorman 1985).

The greatest change appears to have been to the stocks of upper slope dogsharks of the genus *Centrophorus* (southern, Harrissons and Endeavour) which were virtually absent from the 1996-97 catches. During the 1976-77 *Kapala* surveys, more than 27 t of *Centrophorus* dogsharks were caught off Ulladulla and Eden with a combined mean catch rate of 178 kg/h. Liggins (1996, 1997) estimated that the total annual commercial catch of *Centrophorus* dogsharks by all Ulladulla and Eden trawlers off southern NSW averaged 19 tonnes during the three years 1993-95 and 23 t for 1996, with a maximum mean catch rate of 24 kg/trawler day (assuming 50% of observed trawler days were fished in slope depths).

Greeneye dogsharks of both species (*Squalus mitsukurii* and *Squalus* sp. F) were also caught in comparatively very small numbers during 1996-7. The more commonly caught of the two species (*Squalus* sp. F) was first identified from Queensland (Last and Stevens 1994) and the recent *Kapala* catches have extended its known range to southern NSW. The 1976-7 length frequency distributions suggest that *Squalus* sp. F was the main component of the greeneye dogshark catches. That so few were caught on the Sydney ground in 1996 suggests that the local population at least has been greatly reduced in numbers.

Relatively large catches of angel, school, gummy and saw sharks were made in 1976-7 in the shallower depths (220-385 m). In 1996-7, catch rates of angel, gummy and saw sharks were comparatively very low, and no school sharks were caught in any area in 1996-7. In contrast, the abundance of spiky dogsharks appears to have not changed appreciably. All these species have similar distributions on the outer shelf and upper slope and are therefore probably subjected to similar fishing pressure. However, only the larger and commercially more valuable angel, gummy and school sharks appear to have suffered a substantial decline in numbers on the upper slope since 1976-77. Angel sharks are caught almost totally by trawling, but school and gummy sharks are heavily fished by gill-nets in Bass Strait waters which may also impact on any recruitment of those species onto the NSW coast.

The impact of the fishery on the stocks of sharks and rays on the NSW slope has followed the pattern of most exploited demersal shark stocks worldwide. In common with many multispecies fisheries that target teleost fishes, the SEF has continued long after the elasmobranches have been severely depleted (see also Compagno 1990). Sharks are now only a minor component of the commercial catch from the upper slope in the Eastern Sector of the SEF (Liggins 1996, 1997). The susceptibility of elasmobranches to stock collapse has been widely reported in the literature (Holden 1973, Compagno 1990, Hoenig and Gruber 1990, Pratt and Casey 1990, Stevens et al. 1997, and references therein). Life history attributes that predispose sharks to overexploitation include slow growth, late onset of sexual maturity, low fecundity, low natural mortality and, often, ovoviporous reproduction which may cause a more direct stock - recruitment relationship (see Holden 1973, Hoenig and Gruber 1990 for review). During *Kapala* surveys, information has been collected on several of these attributes for dogsharks on the NSW continental slope (K. Graham unpubl. data). The data show that all species reach maturity when they are close to their maximum size. Southern dogsharks produce only a single pup at any time and Harrissons dogsharks produce one or, more commonly, two pups. Spiky dogsharks have a maximum of three pups, and of the two greeneye dogsharks, up to 10 pups were observed in *Squalus mitsukurii*, and up to five in *Squalus* sp. F. Gestation time is not known for any of these species, but breeding is probably less often than annual.

Off NSW, the three *Centrophorus* species, *Deania quadrispinosa, Squalus* sp. F, *S. mitsukurii*, and several species of non-commercial sharks and skates are confined almost totally to upper slope depths. *C. harrissoni, Squalus* sp. F and most of the skates appear to be endemic to Australia (Last and Stevens 1994). The severe depletion in numbers of all sharks and skates on the NSW slope trawl grounds (and probably on all other heavily trawled slope grounds off southern Australia) may ultimately impact on the biological viability of these species in Australian waters.

Spiny flathead

One of the common non-commercial species on the upper slope, spiny flathead, exhibited similar responses to exploitation as ocean perch. Across all locations and depths, the mean catch rate in 1996-7 was about 25% of that in 1976-7. The size data showed a decrease in mean size between the two survey periods of almost 8 cm indicating a major reduction in the numbers of large spiny flathead, particularly off Sydney and Ulladulla.

7.4 Migratory species and/or species difficult to sample

The species in this group are typically migratory and/or schooling, or have unpredictable recruitment onto the NSW slope. Estimates of the abundance of these species were highly variable at small spatial and temporal scales, probably reflecting both non-representative sampling and their patchy distributions.

Gemfish

Gemfish migrate along the NSW upper slope in winter which makes trawl survey sampling difficult and consequently, comparisons between the two survey periods also difficult. However, the 1996 catch rates for gemfish were lower than previously, especially for small gemfish caught in 220-385 m. Until about 1989, there were significant commercial landings (>100 t) of small gemfish from outer shelf and upper slope waters (150-400 m) throughout the year; this "summer catch" has since declined (Rowling 1994b). Surveys by *Kapala* in 1989 and during 1993-4 off southern NSW outer shelf grounds found that juvenile gemfish were absent on grounds where previously they were abundant (Graham 1989, Graham *et al.* 1995). The decline in the size of the gemfish spawning stock has been well documented by Rowling (1994, 1997), and the small number of juveniles caught during 1996-7 adds to the evidence for overall stock decline.

Mirror dory

Mirror dory have a less defined migration than gemfish but concentrate towards the central NSW slope for spawning in winter. Relatively large catches of pre and post spawning mirror dory are taken by commercial trawlers through the winter and spring months. For this study, their migratory behaviour make representative sampling and consequently, comparisons between the two survey periods difficult. One result that was interesting was the predominance of sub-adult (<35 cm) mirror dory in the 1996-7 catches. Liggins (1997) reported that the mirror dory catches by Ulladulla and Eden trawlers in 1993-6 were also dominated by small fish <35 cm.

Blue grenadier

The natural occurrence, abundance and size composition of blue grenadier off NSW are known to vary greatly. While the overall catch rate (by weight) was similar for the two sampling periods, the 1976-7 catches comprised mainly large fish (>70 cm) while the great majority of grenadier caught in 1996-7 were from a single cohort of juveniles. Because of their variable recruitment onto the NSW slope, no conclusions about the abundance or size composition of blue grenadier can be drawn from the results of this study.

Spotted warehou

As with blue grenadier, catches of spotted warehou were sporadic and highly variable, and no conclusions about their abundance and size composition can be made.

7.5 Species showing little change or increased relative abundance

Ling

Of the SEF Quota species, ling and tiger flathead were the only species to show little change in relative abundance (by weight) between 1976-7 and 1996-7. The overall mean catch rates for ling were similar for both survey periods although there was a large decrease in mean size. The shift in size composition of catches indicates a marked reduction in the numbers of ling larger than 70 cm but, conversely, suggests an increase in their numerical abundance.

Fishers here reported that ling were apparently "more abundant on trawling grounds in 1993" (Chesson 1996). Kapala Cruise Reports 114 and 115 (Graham *et al.* 1995, 1996) highlighted an apparent abundance of juvenile ling on the deeper shelf grounds during 1993-4. The fish probably would have recruited to the slope fishery by 1996-7.

Tiger flathead

Although tiger flathead were a relatively small component (<2%) of the total catches in 1976-7 and 1996-7, there was no significant difference in catch rates between the two periods. Similarly, the length distributions for 1976-7 and 1996-7 were almost identical. Both these results reflect the apparent long-term stability of the tiger flathead stock and size composition (Rowling 1994c).

Spiky dogshark

Catch rates of spiky dogsharks were relatively high during 1996-7, especially off Sydney, partially due to some very large catches off Sydney. Mean catch rates off Ulladulla were about half that of 1976-7 while catches off Eden were about 25% lower.

The relatively high catch rates of spiky dogsharks provides an interesting contrast to the other dogsharks. The fact that the relative abundance of this species in 1996-7 appears similar to that at the inception of fishery probably relates to a number of factors. Occasional very large catches suggest that spiky dogsharks school. However, because of their small size, they are seldom targeted by fishers. Off Sydney, trawling pressure is comparatively light on outer shelf grounds and in the upper slope depths (220-330 m) where the highest catch rates were recorded. In the same depths off Ulladulla and Eden, where there is more intense trawler activity with other species as targets, spiky dogsharks were found to be less abundant than off Sydney and mean catch rates a little lower than 1976-7. Another factor which may aid their survival is escapement through the 90 mm mesh codends used on commercial vessels; escapement is possibly quite high for small spiky dogsharks.

Liggins (1997) reports that the proportion of spiky dogshark catches retained by fishers varies between Ulladulla (100%) and Eden (40%), which probably reflects the size composition of the catches which consisted mainly of larger females at Ulladulla, and small males of unmarketable size off Eden.

Non commercial crabs

The capture during 1996-97 of large numbers of crabs (red paddle and antlered crabs) off Ulladulla and Eden-Gabo Island was an unexpected result of the survey. Observers on board southern NSW trawlers have also reported large incidental catches of crabs since 1993 (G. Liggins *pers. comm.*). There are no records of significant catches of crabs on these grounds by *Kapala* in previous surveys (to 1981). Crabs may scavenge dead fish discarded from trawlers and therefore would have been provided with an enhanced supply of food resulting in their proliferation.

7.6 Summary/Conclusions

The results of this study indicate that the total fish biomass and, with the exception of ling, tiger flathead and spiky dogshark, the abundances of the main commercial fish species on the NSW upper slope grounds were very much lower in 1996-7 than were found in 1976-77. In addition, almost all species for which comparative data are available, there has been a marked decline in the relative abundances of larger/older fish.

We believe there is a strong basis for inferring that sustained fishing over 20 years is the most likely and important cause of these observed changes. This interpretation relies on the combined evidence of data on relative abundance from three time periods in the fishery, changes in the size structure of populations and changes in the fishery itself. The apparent declines in catch rates are greatest for dogsharks (except spiky dogshark), redfish, jackass morwong and, to a lesser extent, ocean perch. Significant reductions in the mean sizes/numbers of large fish were also observed for ling, ocean perch, redfish, angel shark and spiny flathead.

It is difficult to sustain the conclusion that natural fluctuations in abundance or environmental change are the principal or even major causal explanation for the changes in relative abundance of most sharks, redfish, jackass morwong, ocean perch and spiny flathead. The respective reductions in overall catch rates of these taxa between 1976-7 and 1996-7 were approximately 95, 90, 95, 99, 70 and 60%. In contrast, the overall catch rates of ling, tiger flathead and spiky dogshark do not appear to have greatly changed. For gemfish, mirror dory and blue grenadier, their patchy distributions or unpredictable recruitment off NSW have resulted in highly variable catch rates suggesting that the surveys did not adequately sample these species. Appeals for environmental change or natural fluctuations in abundance to account for the observed differences in catch rate must accommodate these diverse and species-specific responses.

It should also be noted that contrasting catch rates of juvenile gemfish and mirror dory were observed. As juveniles, both these species are more commonly caught in the shallower depths of the upper slope (200-400 m) and do not appear to have seasonal variations in abundance. In 1996-7, very few juvenile gemfish were caught in these depths compared to 1976-7, a result which further suggests recruitment failure. In contrast, comparatively large numbers of juvenile mirror dory were caught in 1996-7.

Interpreting the significance of the observed changes in relative abundance to the overall status of stocks is difficult because of the poor understanding of the biology, behaviour and distributions of many species. For example, redfish are known to periodically feed in the water column on small fish and crustaceans, making them unavailable to demersal trawls. The frequency of this behaviour and/or the availability of the prey is unknown. Similarly, although many species were caught commonly on the relatively smooth trawl grounds, their broader habitat preference is unknown. More than 80% of the designated grounds were surveyed, but much of the intervening seabed was not. The surveyed trawl grounds made up 32% of the total trawlable area on the upper slope between Newcastle and the Horseshoe between 200 and 640 m in depth. There are large areas at these depths, particularly between Jervis Bay and Gabo Island that are untrawlable. These areas are either deep canyons or 'foul' ground and the extent to which these areas replenish populations in the trawled areas is unknown. Further, even if they do not, there is little information about the size of populations living in these untrawlable areas.

The relatively low catch rates of commercial species recorded during 1996-7 are consistent with recent changes to the fishery. Initially, comparatively high catch rates of commercial species provided a year-round fishery on all the slope grounds between Sydney and eastern Bass Strait. During this period, the unexploited or accumulated stock was fished down, as is typical of most new fisheries, especially those targeting demersal stocks. In recent years, the fishery appears to have become more reliant on new recruits. Trawling for fish on the upper slope north of Montague Island has now become more seasonal with most being done during winter when gemfish and mirror dory migrate north and ling become more available. During the rest of the year, most slope trawling, especially off Wollongong and Sydney, is for royal red prawns.

One of the primary objectives of this study was to quantify changes in the relative abundance of species on the NSW and adjacent upper slope trawl grounds. Although the data presented provide important insights into the status of these species, the analyses reported can not be considered a full stock assessment. For the SEF quota species, the sustainability of current exploitation is considered on an annual basis. The latest assessments (Chesson 1996) indicate that gemfish is over-exploited and the TACs for ocean perch, mirror dory and jackass morwong were not caught last year. The dramatic declines in dogsharks (except spiky dogshark) suggests they are grossly over-exploited. There have been no formal stock assessments for these species, possibly reflecting their present scarcity and relative unimportance in the fishery.

The data summarised in this report and Kapala Cruise Report 117 have been archived in a disaggregated form in a data report and in electronic form and forwarded to the South East Fishery Stock Assessment Group.

8. Recommendations and implications

8.1 Benefits

These surveys have provided the first long-term fishery independent comparison of catch rates and length frequency distributions of commercial fish species on the NSW slope trawl grounds in the SEF. The results will benefit all stakeholders in the fishery by contributing to the information base necessary to ensure its long-term sustainability.

8.2 Intellectual property and valuable information

No patentable inventions or processes have been developed as part of this project. All results have been forwarded to the South East Fishery Stock Assessment Group for use in stock assessments only. NSW Fisheries and FRDC retain the right to publish relevant scientific articles and other public domain literature.

8.3 Further development

Although the FRV *Kapala* has been de-commissioned the nets and trawl doors have been retained to allow further repeat surveys by chartered vessels. The analyses of differences in catch rate and length frequency distributions presented here will be further developed as they are incorporated into assessments of the status of individual species. These assessments would be further strengthened by the inclusion of age distribution data following reading of the otoliths collected in 1996-7.

8.4 Staff

Neil Andrew
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Penny Brett
Master and crew of the *Kapala*.

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Appendix. Length frequency distributions of important species caught during 1976-7 and/or 1996-7.

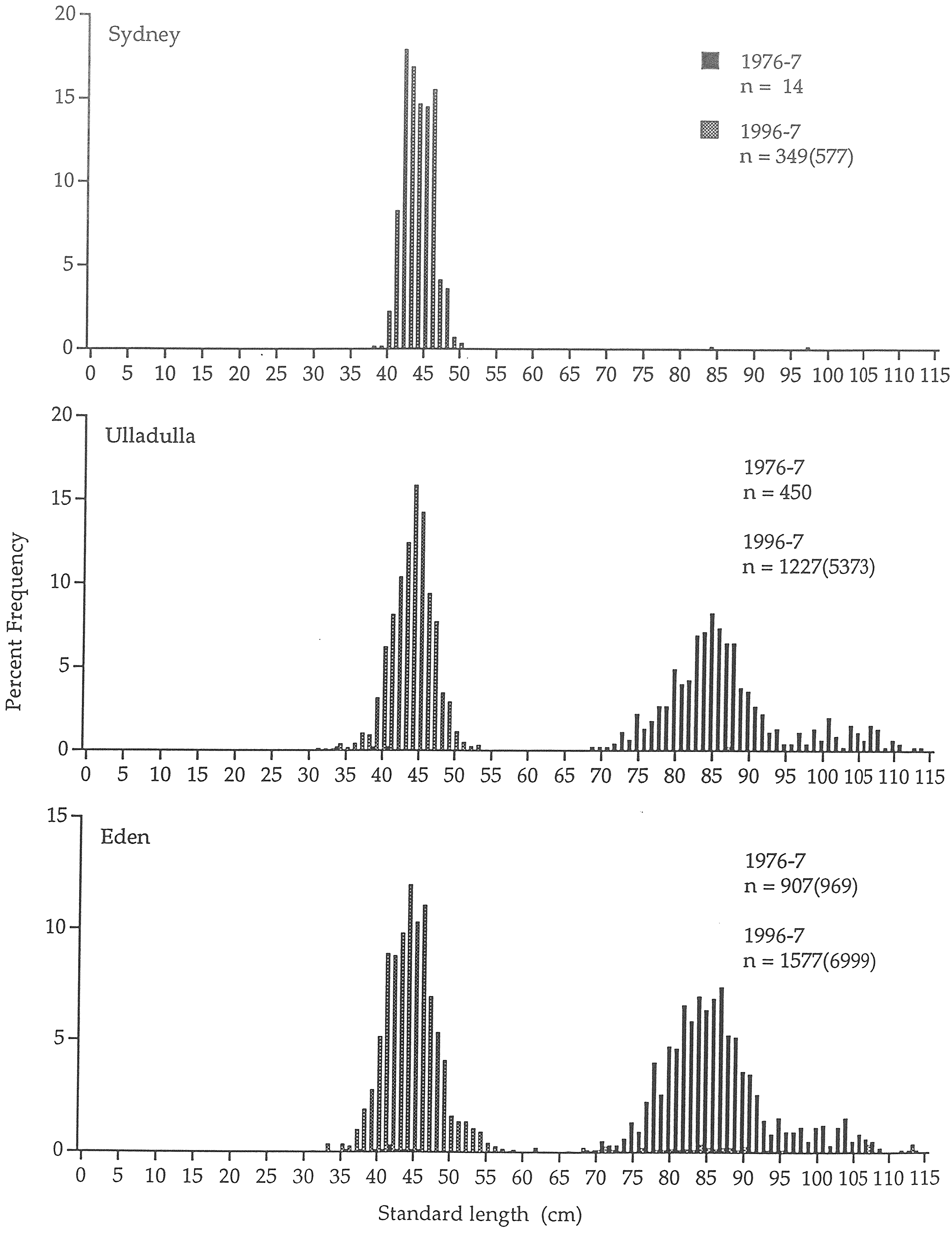


Figure 5.1.1. Length frequency distributions of blue grenadier caught in 1976-7 and 1996-7. Sample sizes indicated for 1976-7 are n = no. measured (total no. in tows sampled). For 1996-7, n = total no. caught, or when subsampled, n = total no. measured (total no. caught).

220 - 275 m

None caught

330 - 385 m

None caught

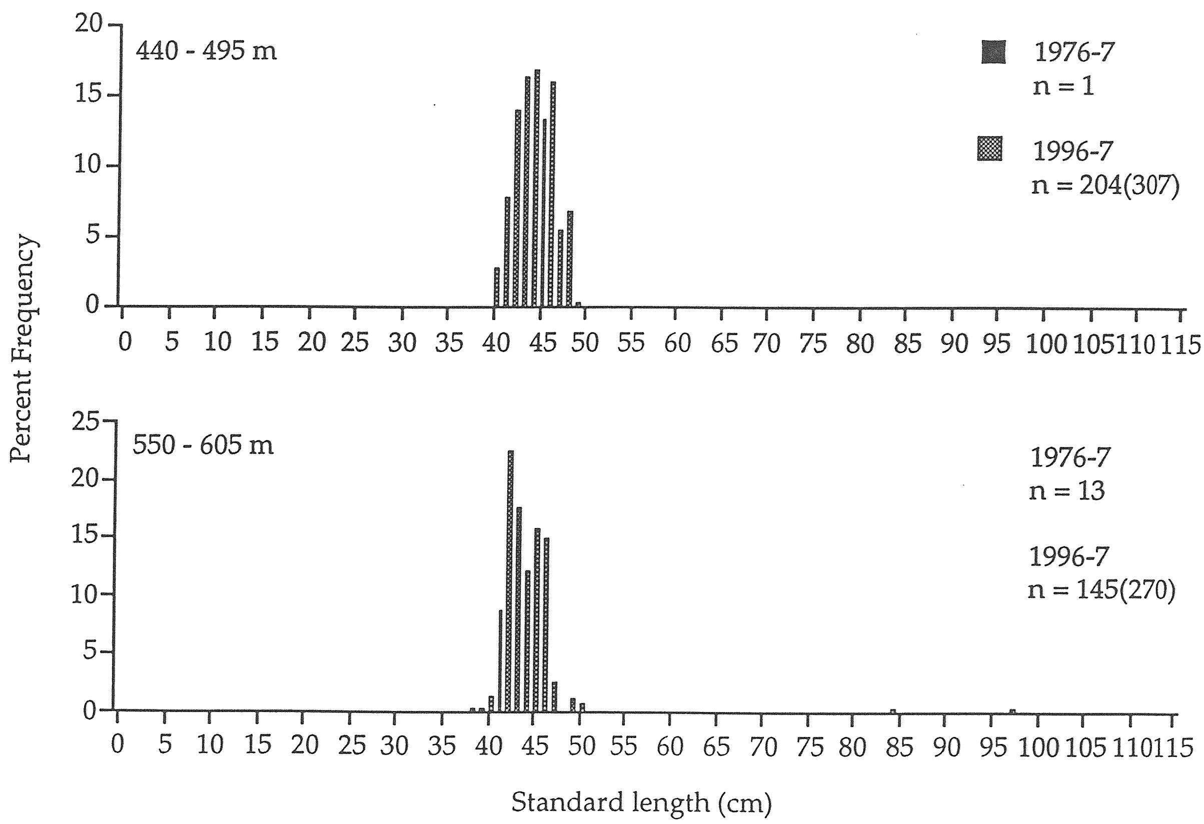


Figure 5.1.2. Length frequency distributions of blue grenadier caught off Sydney in 1996-7. Sample sizes indicated for 1976-7 are n = no. measured (total no. in tows sampled). For 1996-7, n = total no. caught, or when subsampled, n = total no. measured (total no. caught).

220 - 275 m

1976-7 None caught
1996-7 n = 5

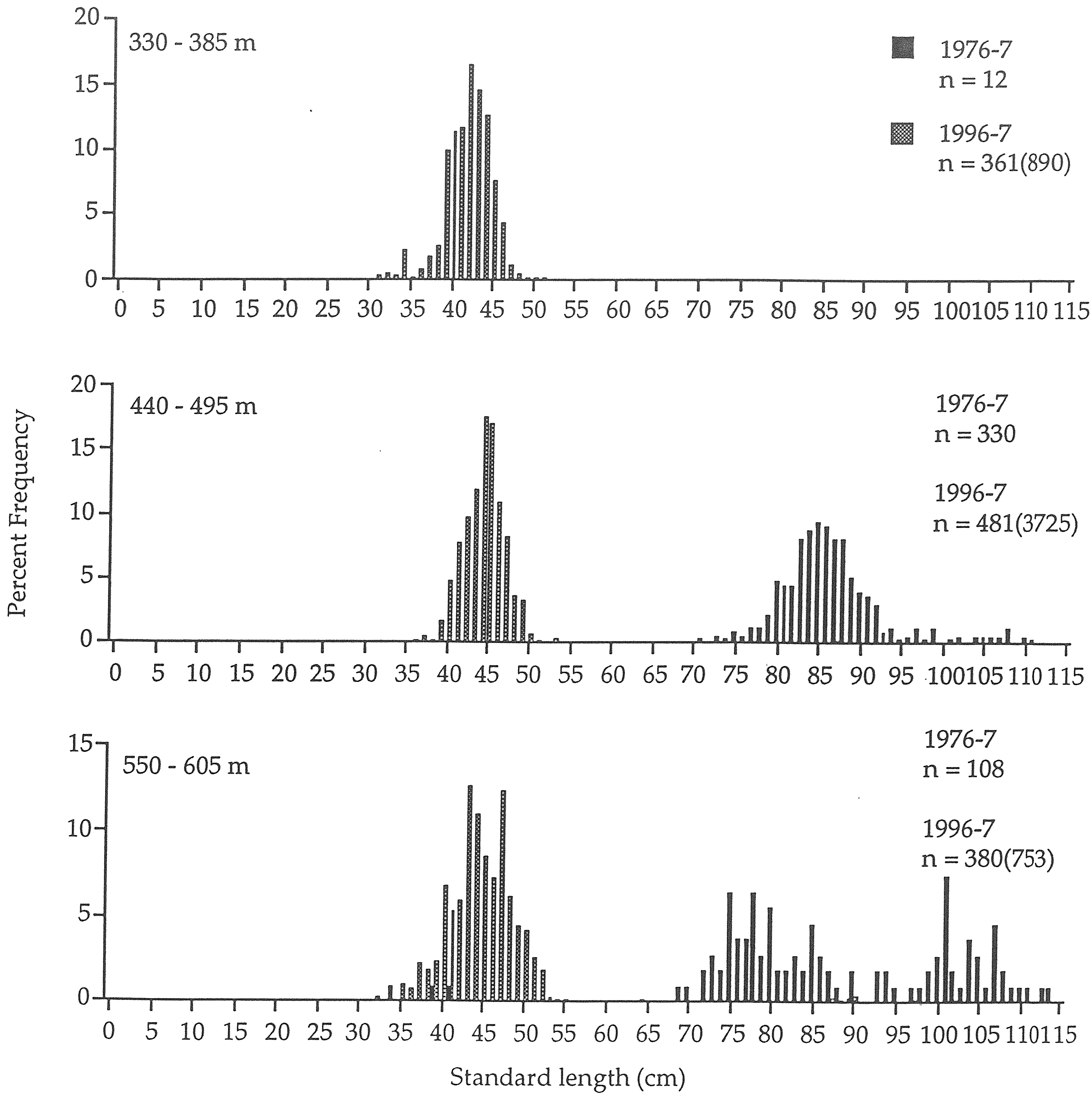


Figure 5.1.3. Length frequency distributions of blue grenadier caught off Ulladulla in 1976-7 and 1996-7. Sample sizes indicated for 1976-7 are n = no. measured (total no. in tows sampled). For 1996-7, n = total no. caught, or when subsampled, n = total no. measured (total no. caught).

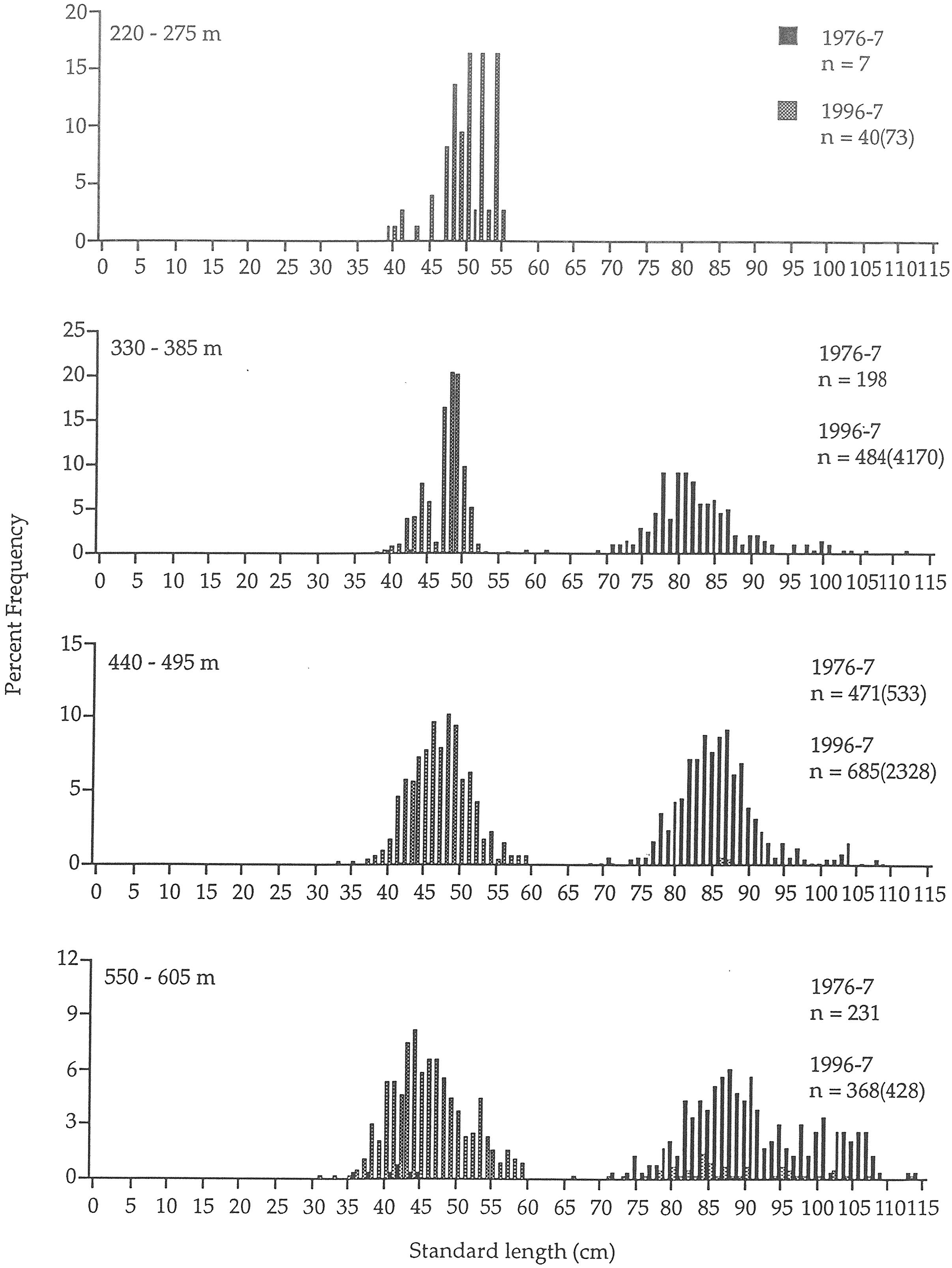


Figure 5.1.4. Length frequency distributions of blue grenadier caught off Eden in 1976-7 and 1996-7. Sample sizes indicated for 1976-7 are n = no. measured (total no. in tows sampled). For 1996-7, n = total no. caught, or when subsampled, n = total no. measured (total no. caught).

220 - 275 m

None caught

330 - 385 m

None caught

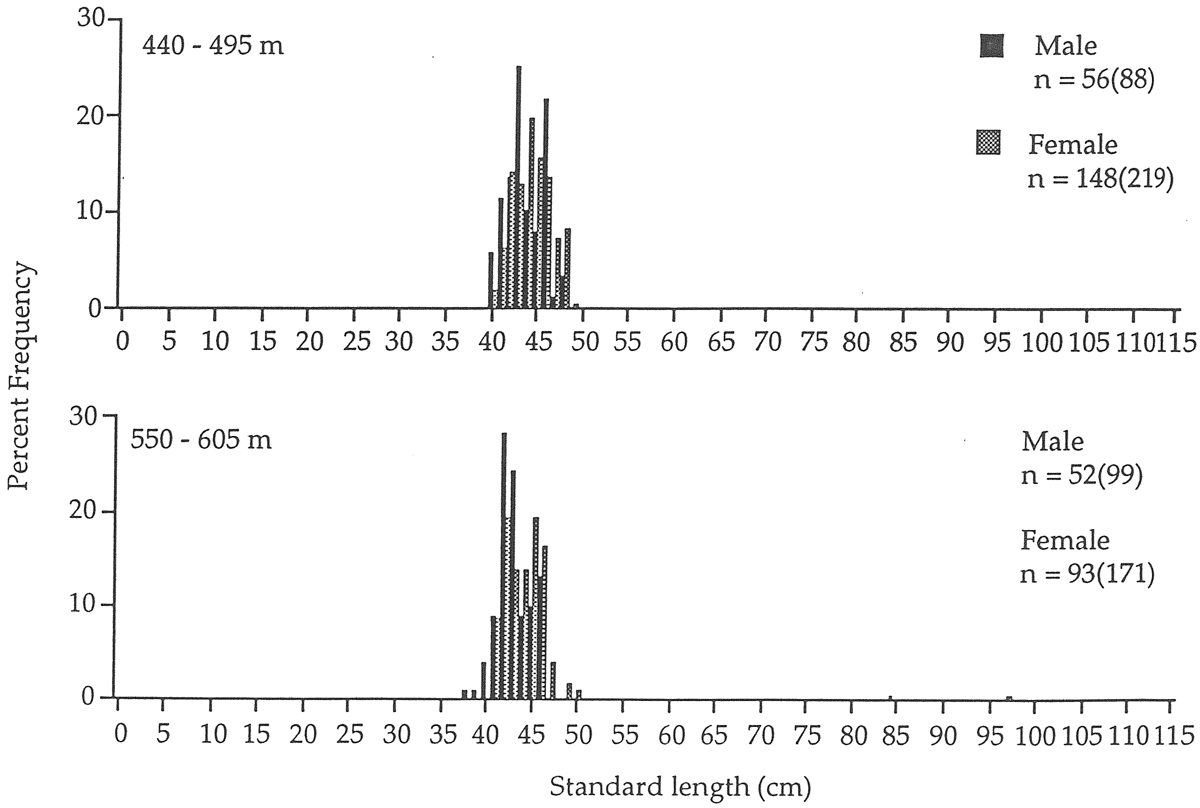


Figure 5.1.5. Length frequency distributions of male and female blue grenadier caught off Sydney in 1996-7. Sample sizes indicated as n = total no. caught, or when subsampled, n = total no. measured (total no. caught).

220 - 275 m

1976-7 None caught
1996-7 n = 5

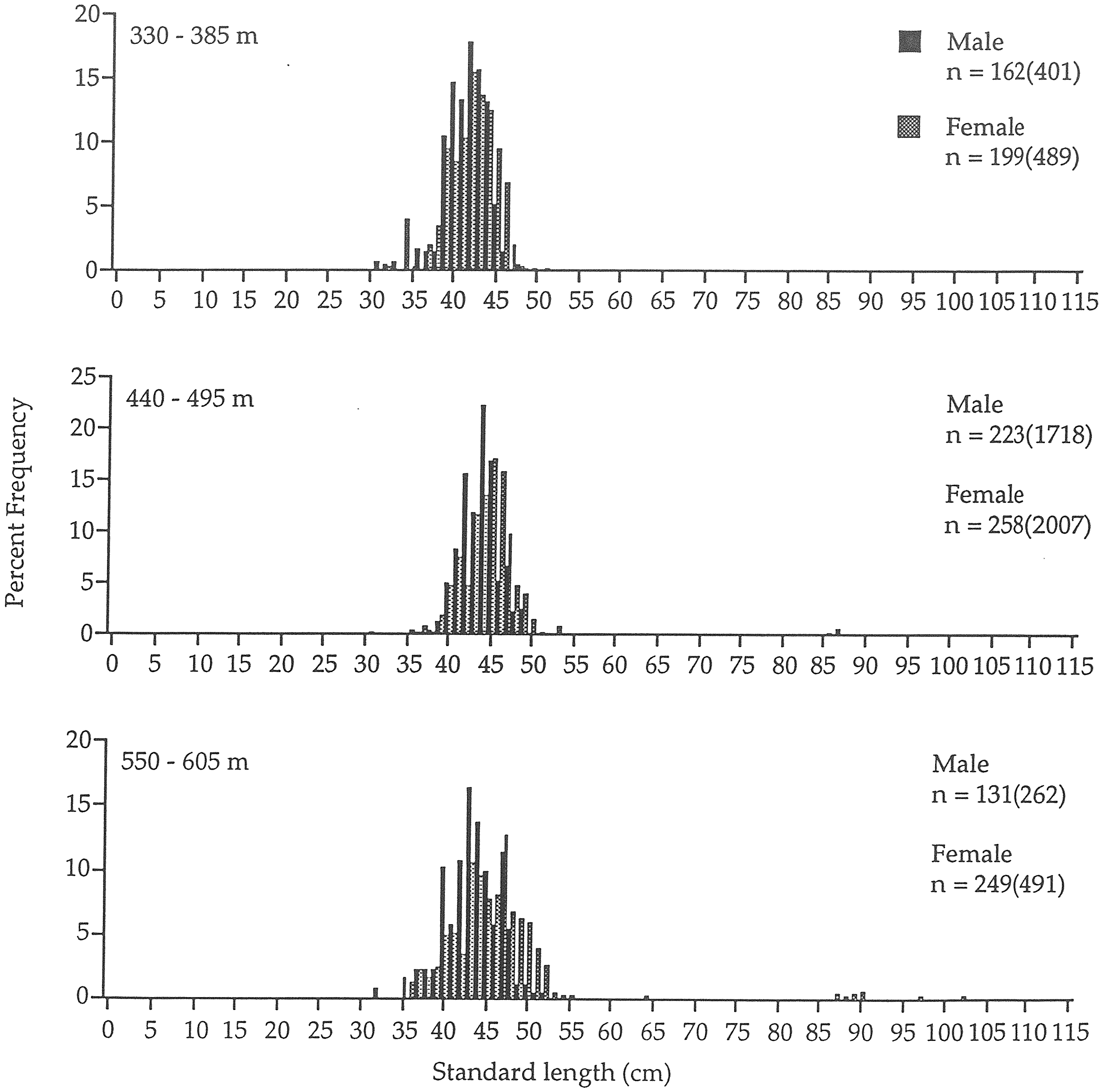


Figure 5.1.6. Length frequency distributions of male and female blue grenadier caught off Ulladulla in 1996-7. Sample sizes indicated as n = total no. caught, or when subsampled, n = total no. measured (total no. caught).

220 - 275 m

Male n = 20(37)
Female n = 20(36)

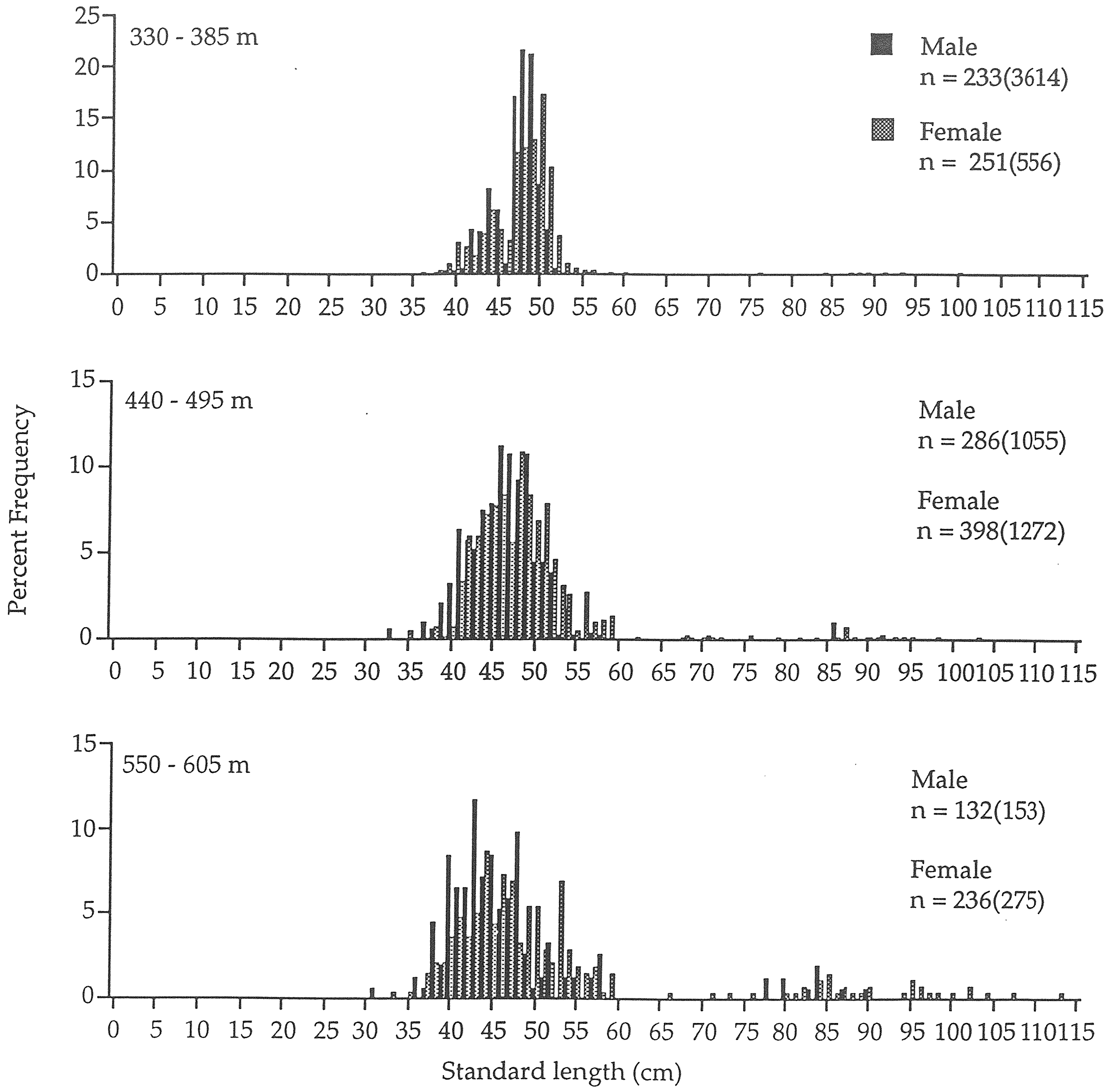


Figure 5.1.7. Length frequency distributions of male and female blue grenadier caught off Eden in 1996-7. Sample sizes indicated as n = total no. caught, or when subsampled, n = total no. measured (total no. caught).

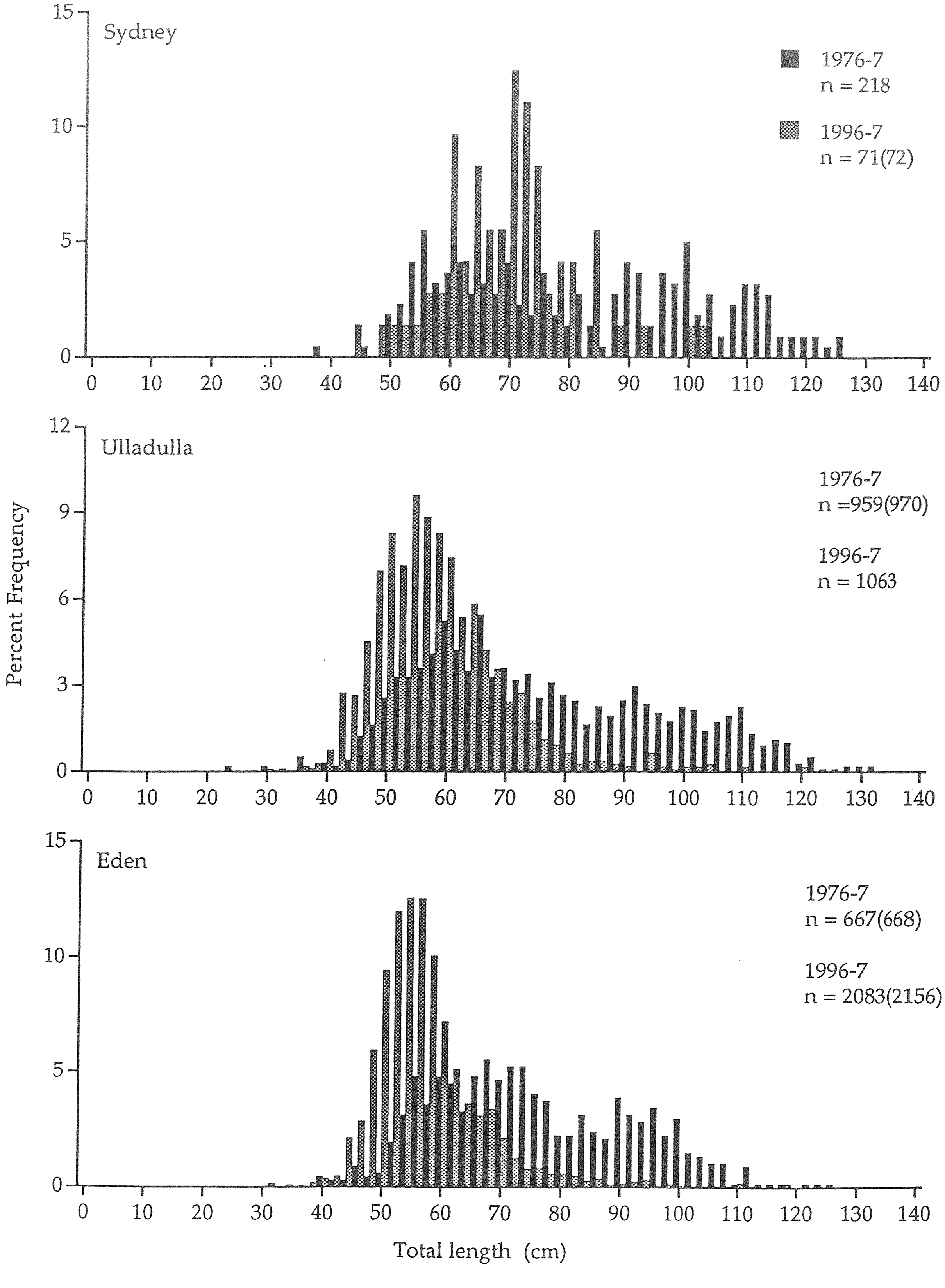


Figure 5.2.1. Length frequency distributions of ling caught in 1976-7 and 1996-7. Sample sizes indicated for 1976-7 are n = no. measured (total no. in tows sampled). For 1996-7, n = total no. caught, or when subsampled, n = total no. measured (total no. caught).

220 - 275 m

None caught

330 - 385 m

1976-7 n = 15
1996-7 n = 0

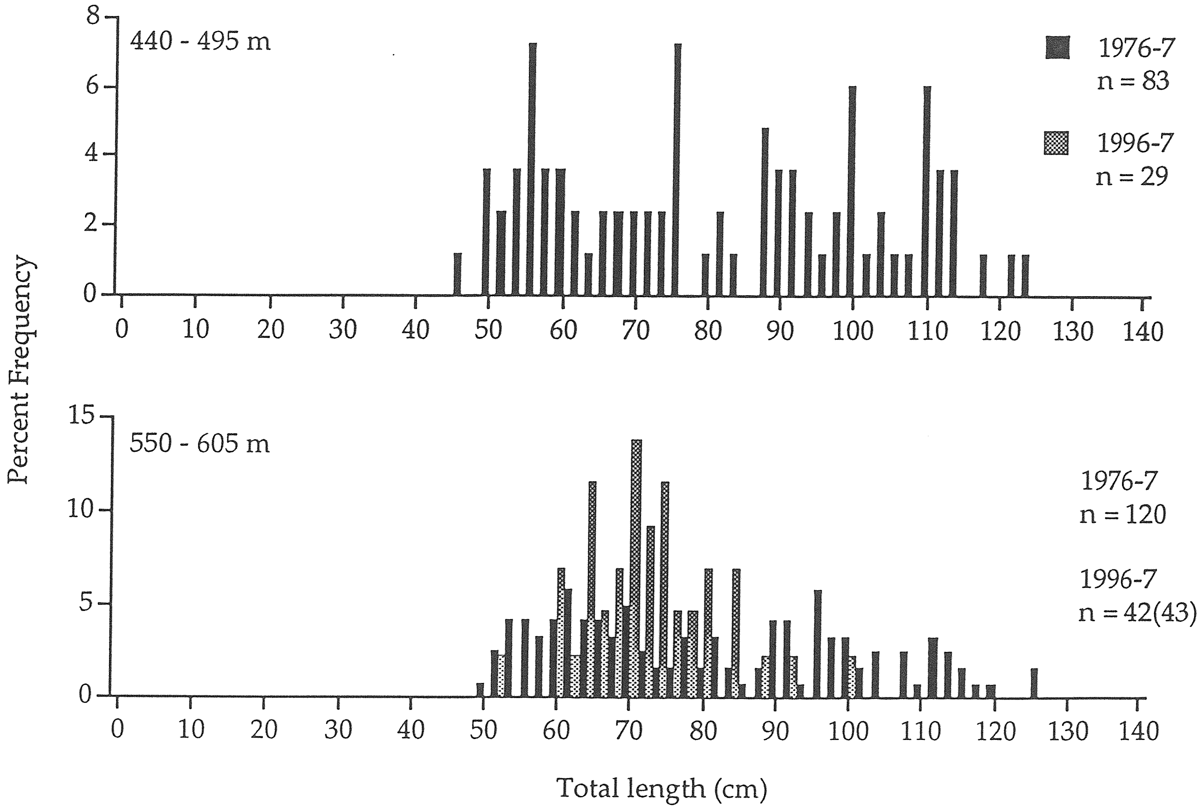


Figure 5.2.2. Length frequency distributions of ling caught off Sydney in 1976-7 and 1996-7. Sample sizes indicated for 1976-7 are n = no. measured (total no. in tows sampled). For 1996-7, n = total no. caught, or when subsampled, n = total no. measured (total no. caught).

220 - 275 m

1976-7 n = 3
1996-7 n = 7

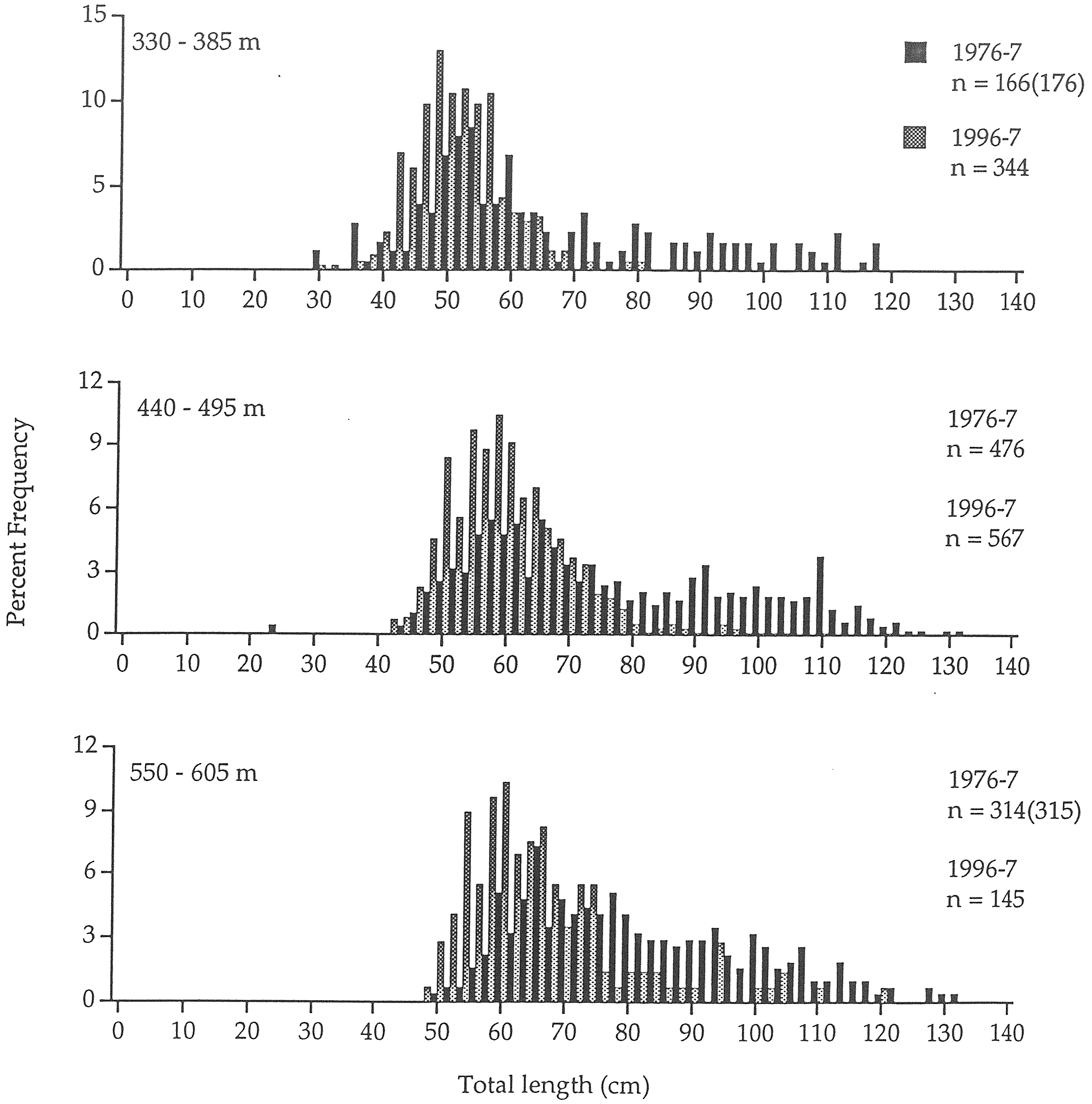


Figure 5.2.3. Length frequency distributions of ling caught off Ulladulla in 1976-7 and 1996-7. Sample sizes indicated for 1976-7 are n = no. measured (total no. in tows sampled). For 1996-7, n = total no. caught, or when subsampled, n = total no. measured (total no. caught).

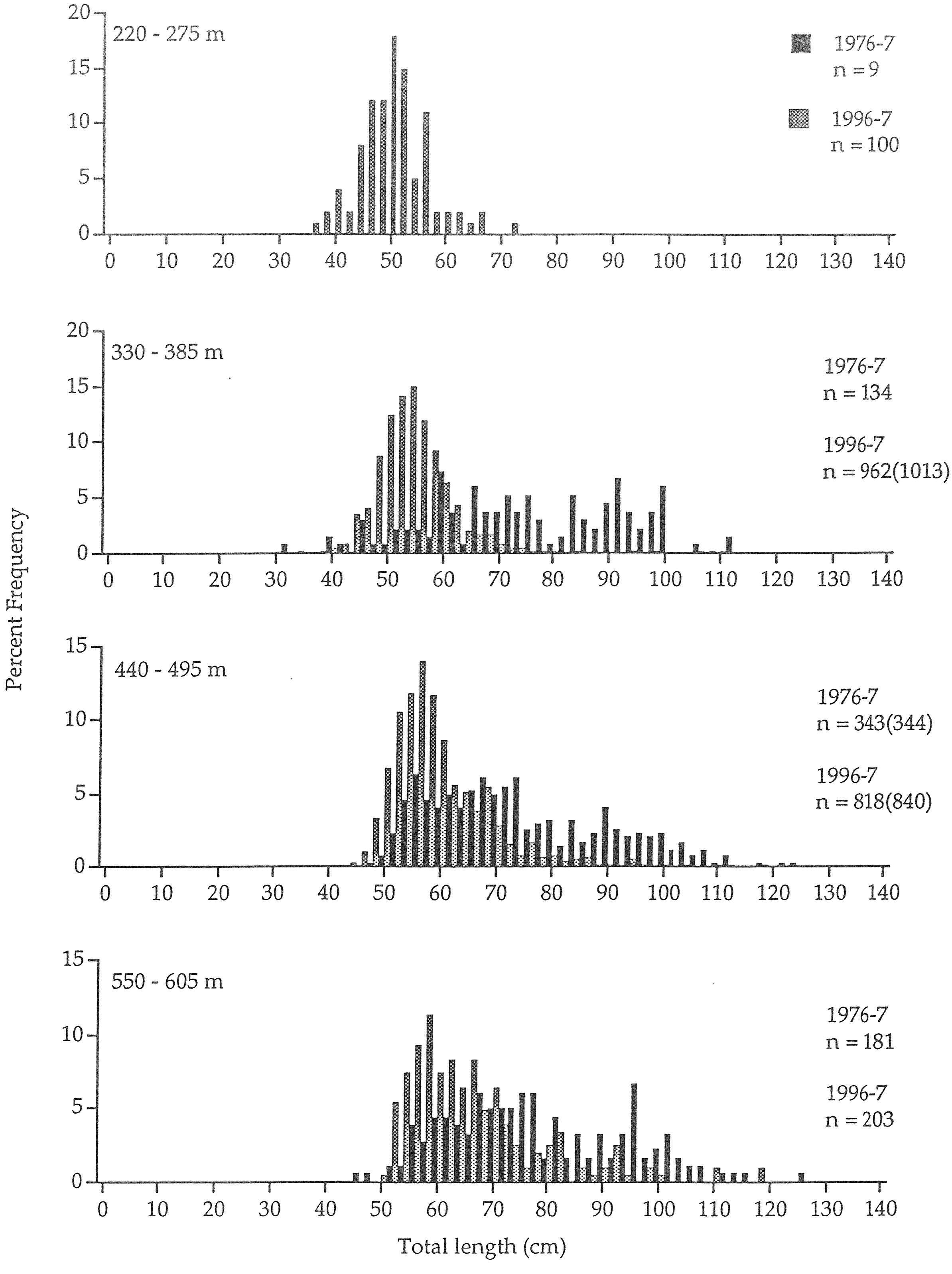


Figure 5.2.4. Length frequency distributions of ling caught off Eden in 1976-7 and 1996-7. Sample sizes indicated for 1976-7 are n = no. measured (total no. in tows sampled). For 1996-7, n = total no. caught, or when subsampled, n = total no. measured (total no. caught).

220 - 275 m

None caught

330 - 385 m

None caught

440 - 495 m

Male n = 8
Female n = 21

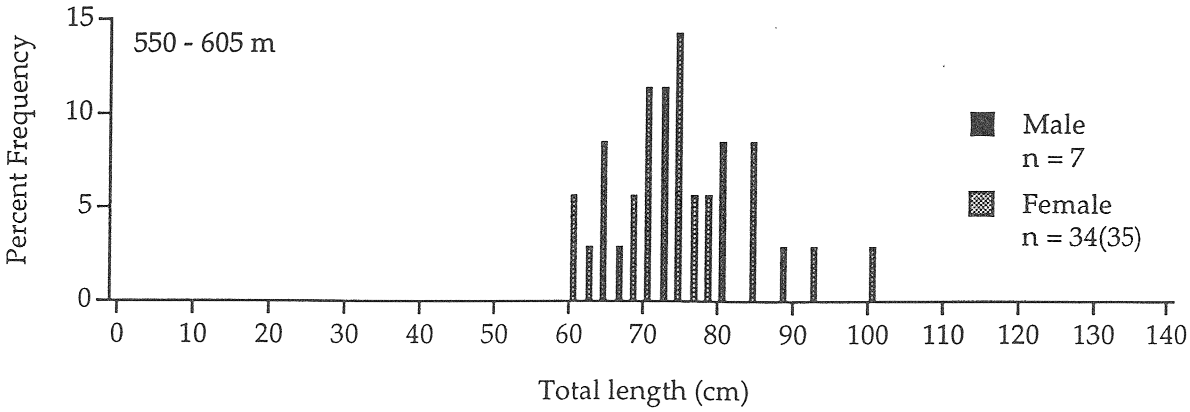


Figure 5.2.5. Length frequency distributions of male and female ling caught off Sydney in 1996-7. Sample sizes indicated as n = total no. caught, or when subsampled, n = total no. measured (total no. caught).

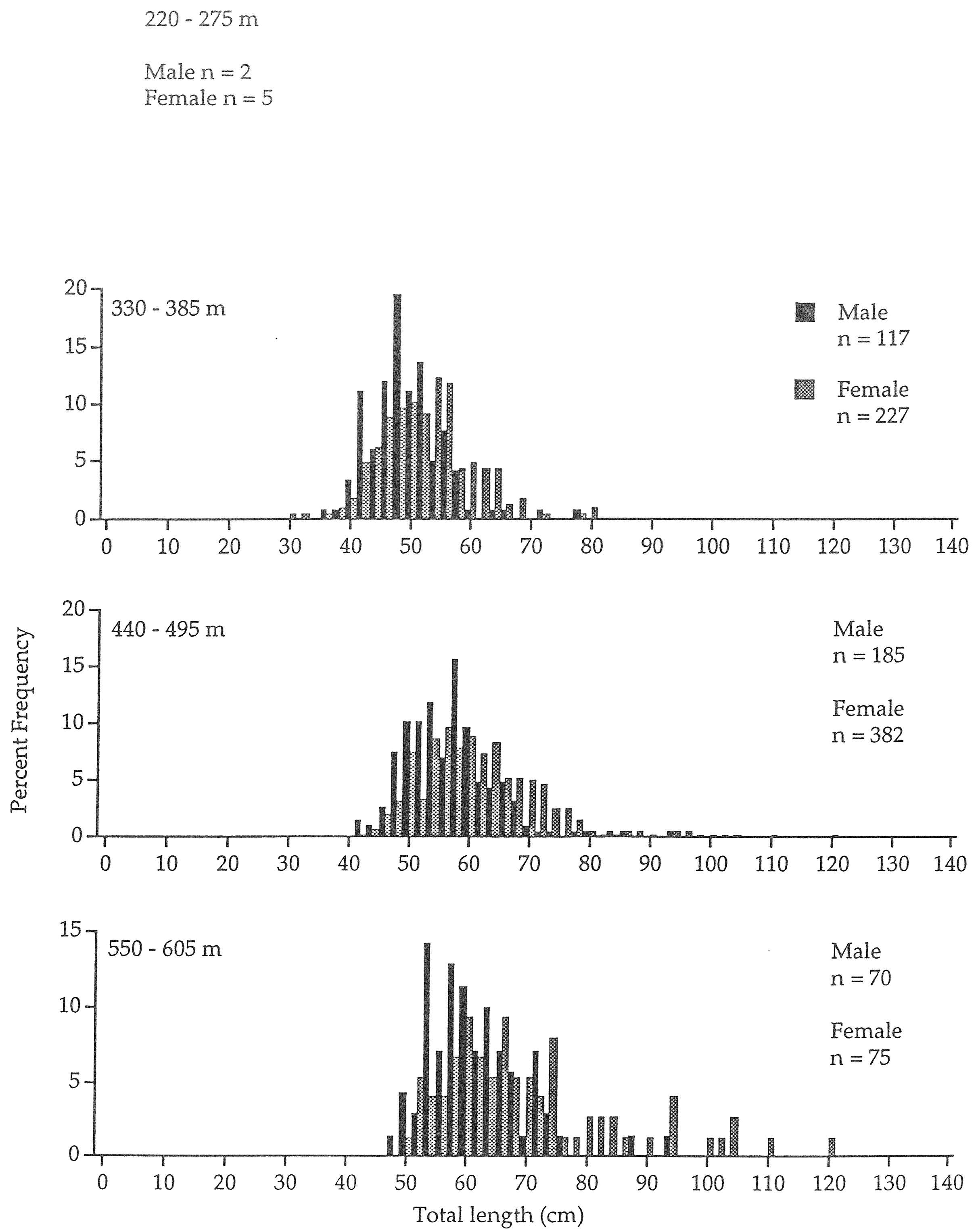


Figure 5.2.6. Length frequency distributions of male and female ling caught off Ulladulla in 1996-7. Sample sizes indicated as n = total no. caught, or when subsampled, n = total no. measured (total no. caught).

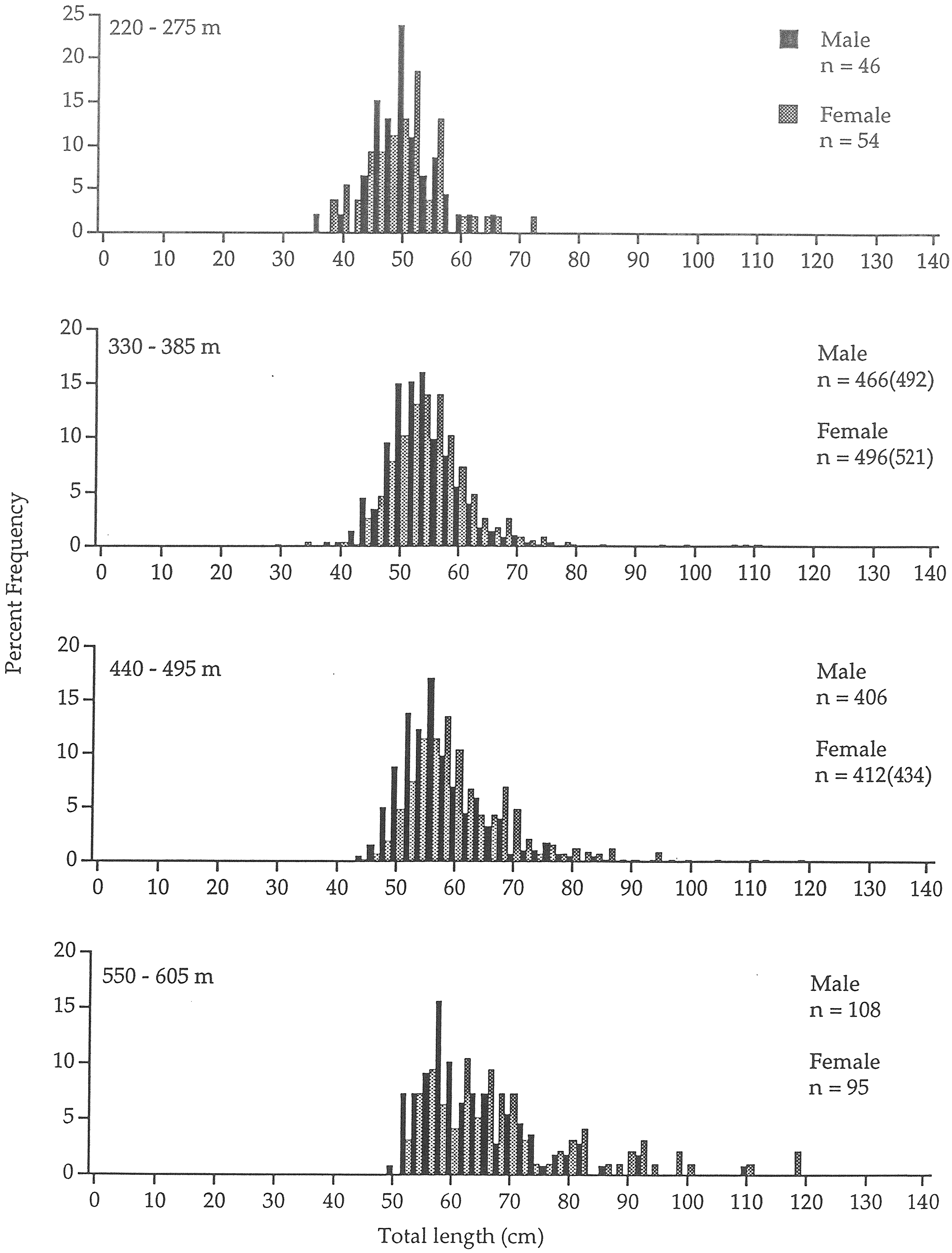


Figure 5.2.7. Length frequency distributions of male and female ling caught off Eden in 1996-7. Sample sizes indicated as n = total no. caught, or when subsampled, n = total no. measured (total no. caught).

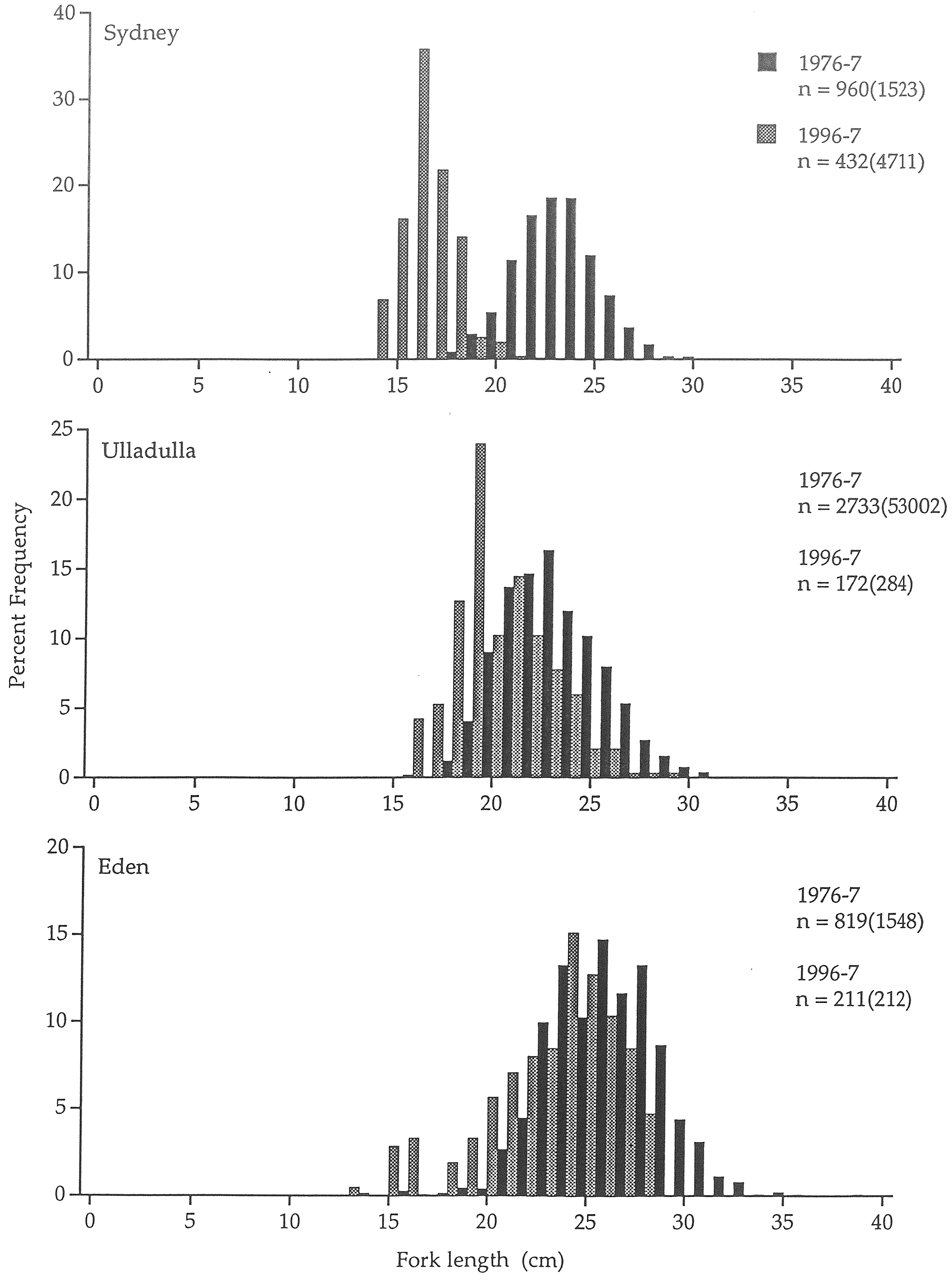
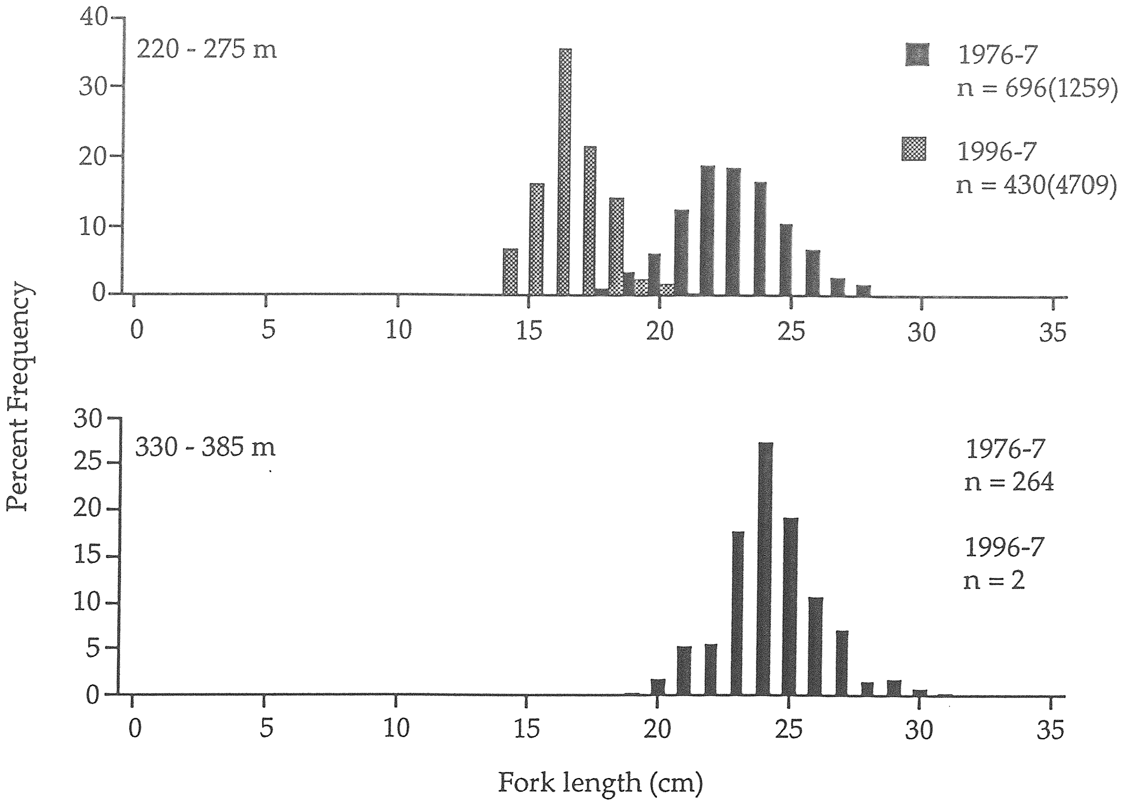


Figure 5.3.1. Length frequency distributions of redfish caught in 1976-7 and 1996-7. Sample sizes indicated for 1976-7 are n = no. measured (total no. in tows sampled). For 1996-7, n = total no. caught, or when subsampled, n = total no. measured (total no. caught).



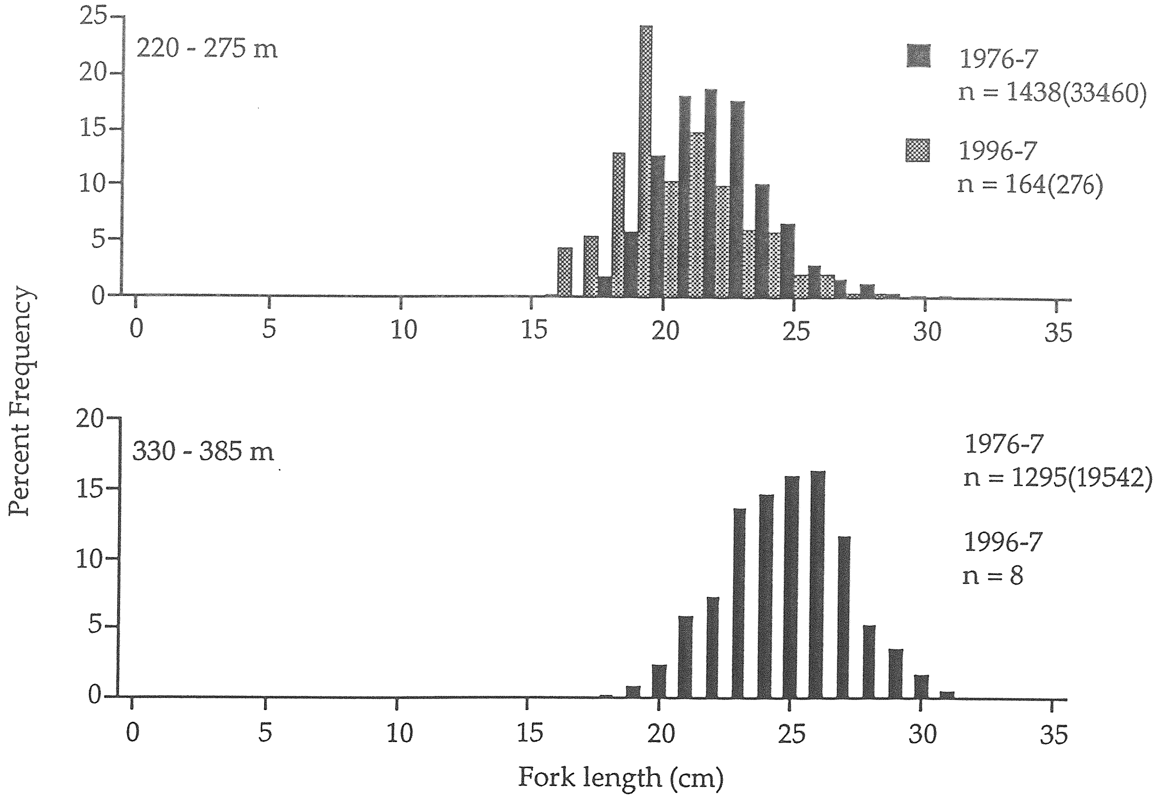
440 - 495 m

None caught

550 - 605 m

None caught

Figure 5.3.2. Length frequency distributions of redfish caught off Sydney in 1976-7 and 1996-7. Sample sizes indicated for 1976-7 are n = no. measured (total no. in tows sampled). For 1996-7, n = total no. caught, or when subsampled, n = total no. measured (total no. caught).



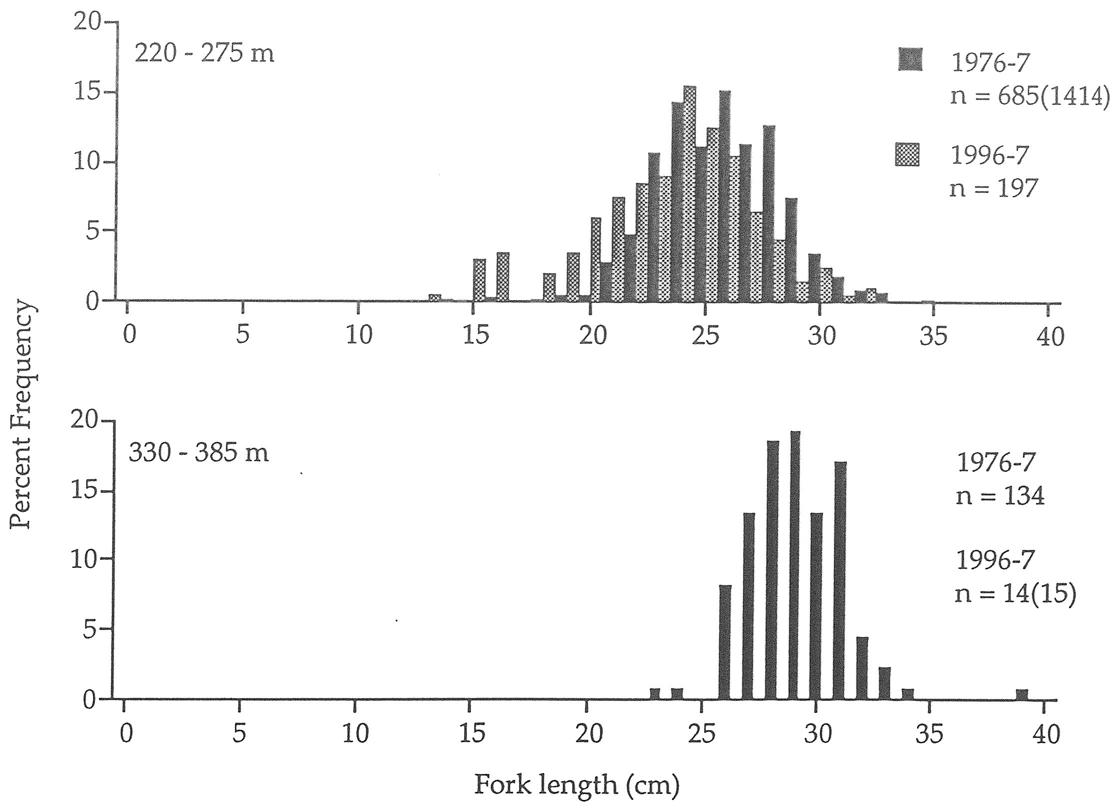
440 - 495 m

None caught

550 - 605 m

None caught

Figure 5.3.3. Length frequency distributions of redfish caught off Ulladulla in 1976-7 and 1996-7. Sample sizes indicated for 1976-7 are n = no. measured (total no. in tows sampled). For 1996-7, n = total no. caught, or when subsampled, n = total no. measured (total no. caught).



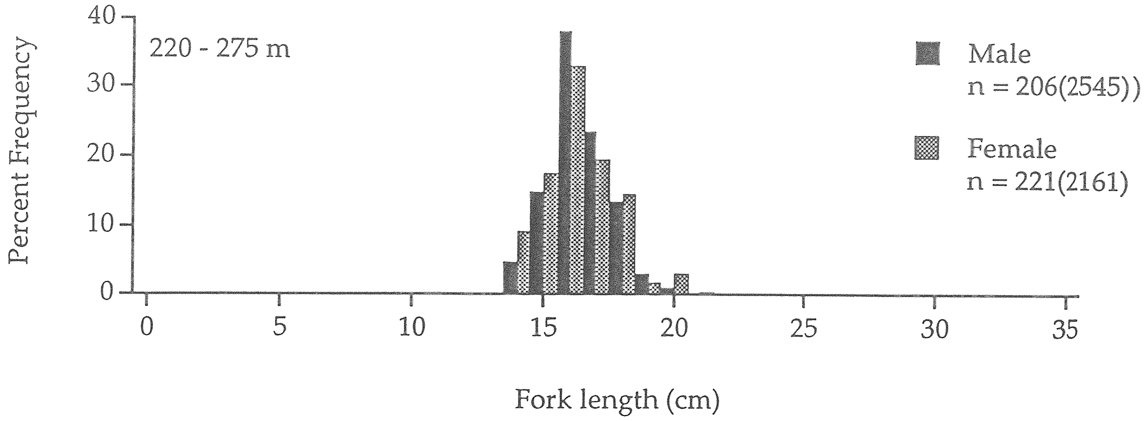
440 - 495 m

None caught

550 - 605 m

None caught

Figure 5.3.4. Length frequency distributions of redfish caught off Eden in 1976-7 and 1996-7. Sample sizes indicated for 1976-7 are n = no. measured (total no. in tows sampled). For 1996-7, n = total no. caught, or when subsampled, n = total no. measured (total no. caught).



330 - 385 m

Male n = 1
Female n = 1

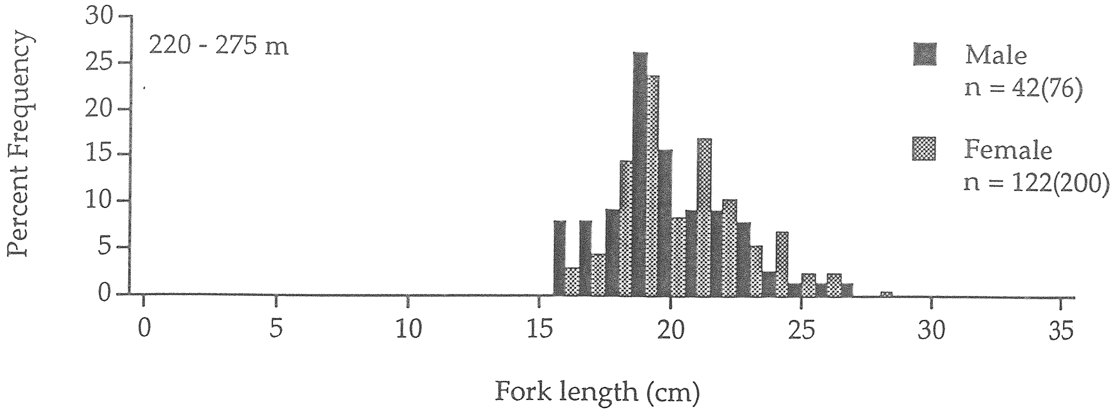
440 - 495 m

None caught

550 - 605 m

None caught

Figure 5.3.5. Length frequency distributions of male and female redfish caught off Sydney in 1996-7. Sample sizes indicated as n = total no. caught, or when subsampled, n = total no. measured (total no. caught).



330 - 385 m

Male n = 5
Female n = 3

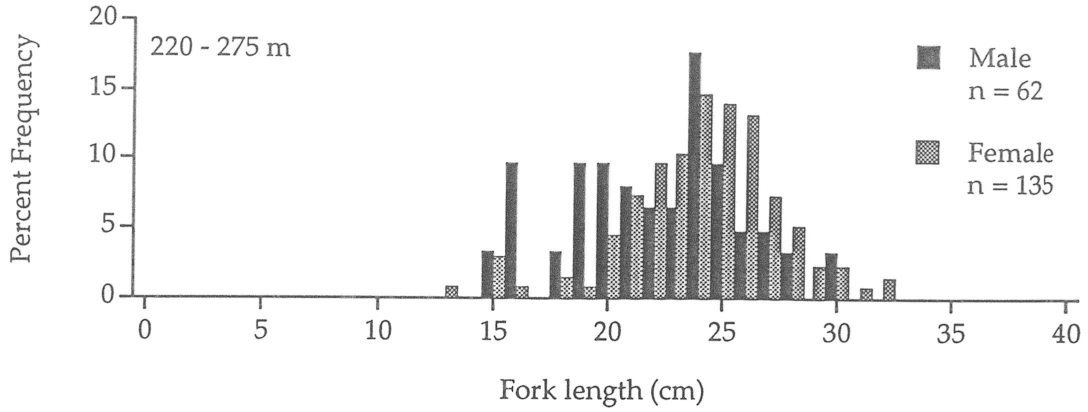
440 - 495 m

None caught

550 - 605 m

None caught

Figure 5.3.6. Length frequency distributions of male and female redfish caught off Ulladulla in 1996-7. Sample sizes indicatedas n = total no. caught, or when subsampled, n = total no. measured (total no. caught).



330 - 385 m

Male n = 6
Female n = 8(9)

440 - 495 m

None caught

550 - 605 m

None caught

Figure 5.3.7. Length frequency distributions of male and female redfish caught off Eden in 1996-7. Sample sizes indicated as n = total no. caught, or when subsampled, n = total no. measured (total no. caught).

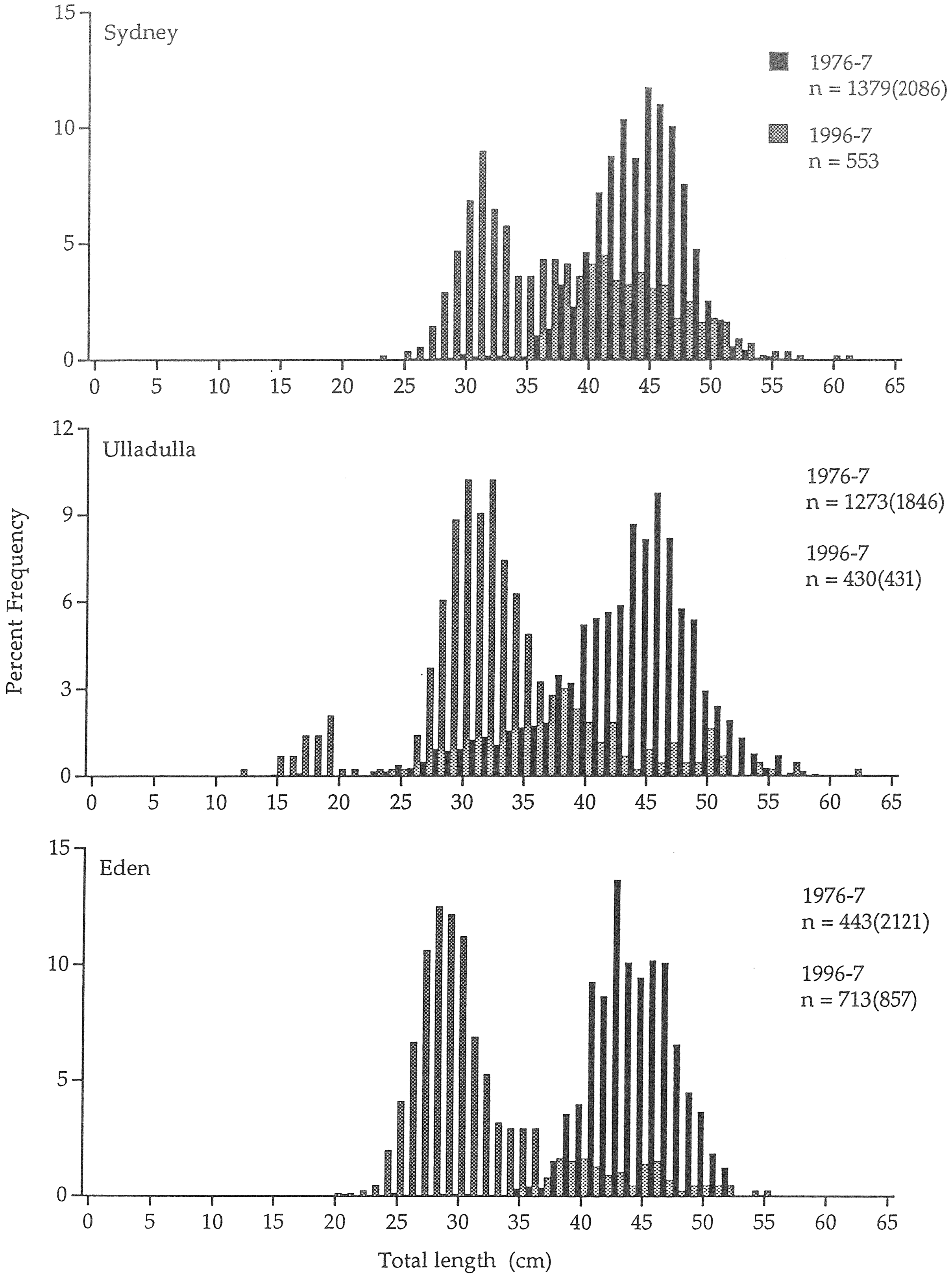


Figure 5.4.1. Length frequency distributions of mirror dory caught in 1976-7 and 1996-7. Sample sizes indicated for 1976-7 are n = no. measured (total no. in tows sampled). For 1996-7, n = total no. caught, or when subsampled, n = total no. measured (total no. caught).

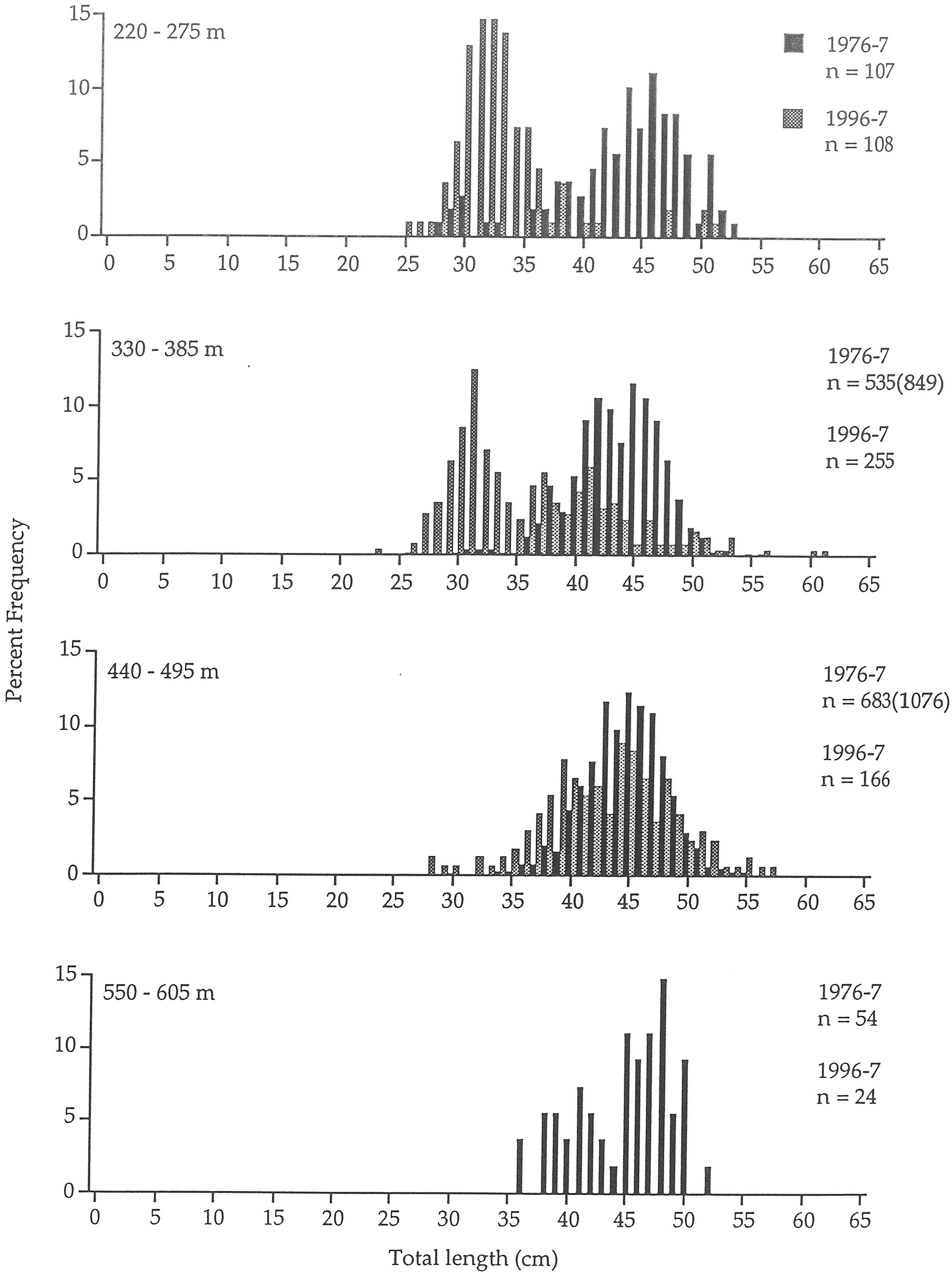


Figure 5.4.2. Length frequency distributions of mirror dory caught off Sydney in 1976-7 and 1996-7. Sample sizes indicated for 1976-7 are n = no. measured (total no. in tows sampled). For 1996-7, n = total no. caught, or when subsampled, n = total no. measured (total no. caught).

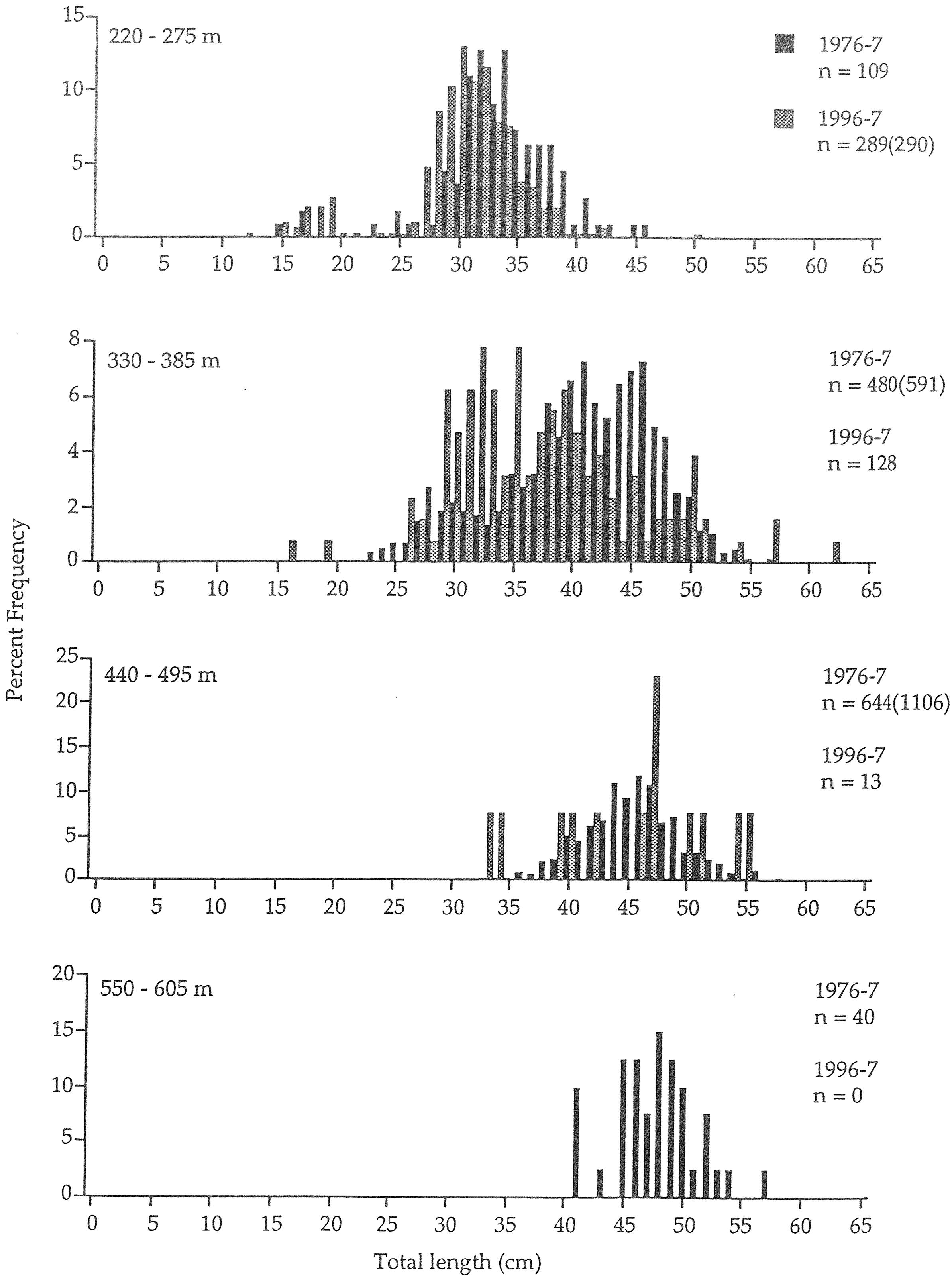
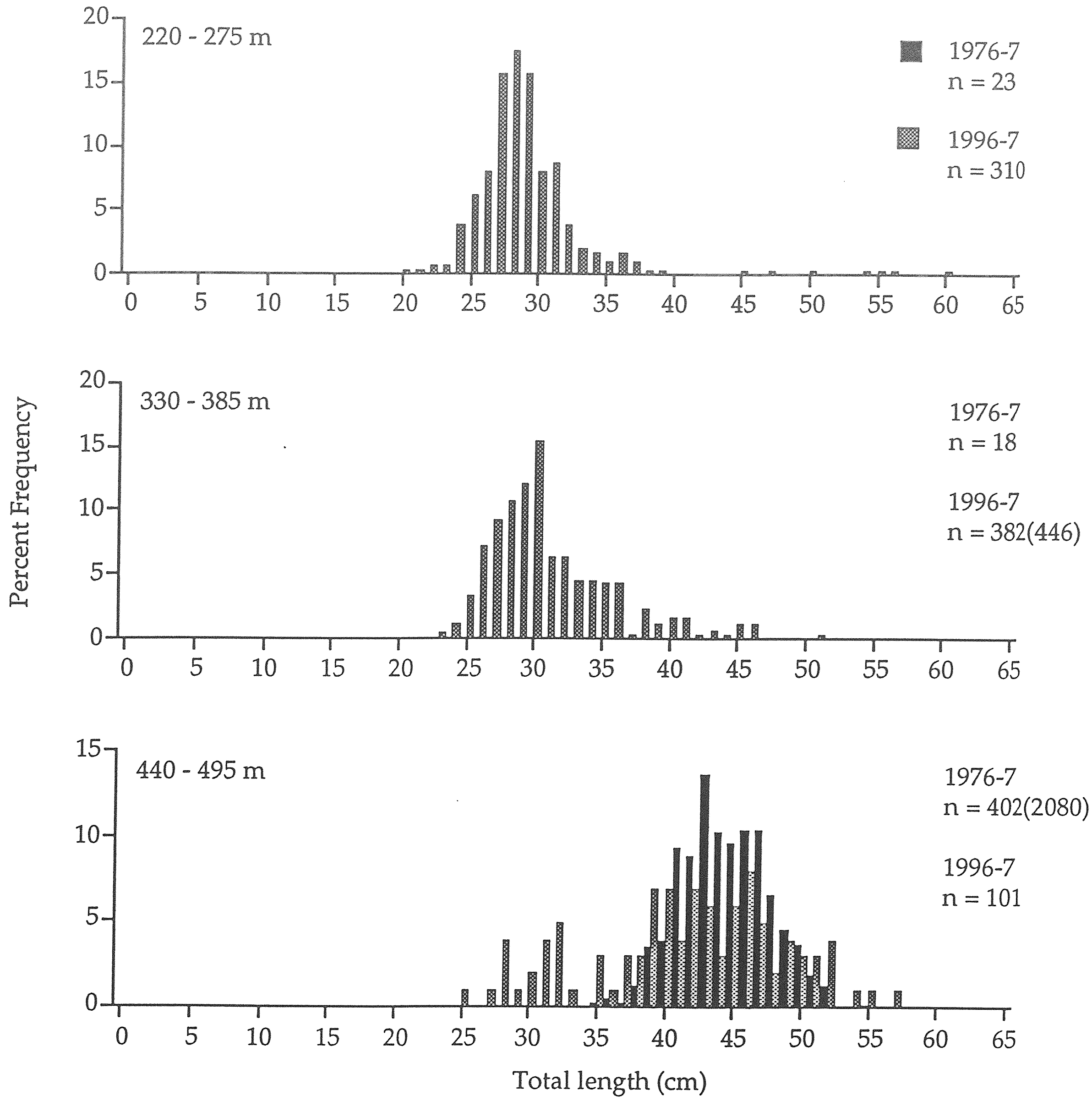


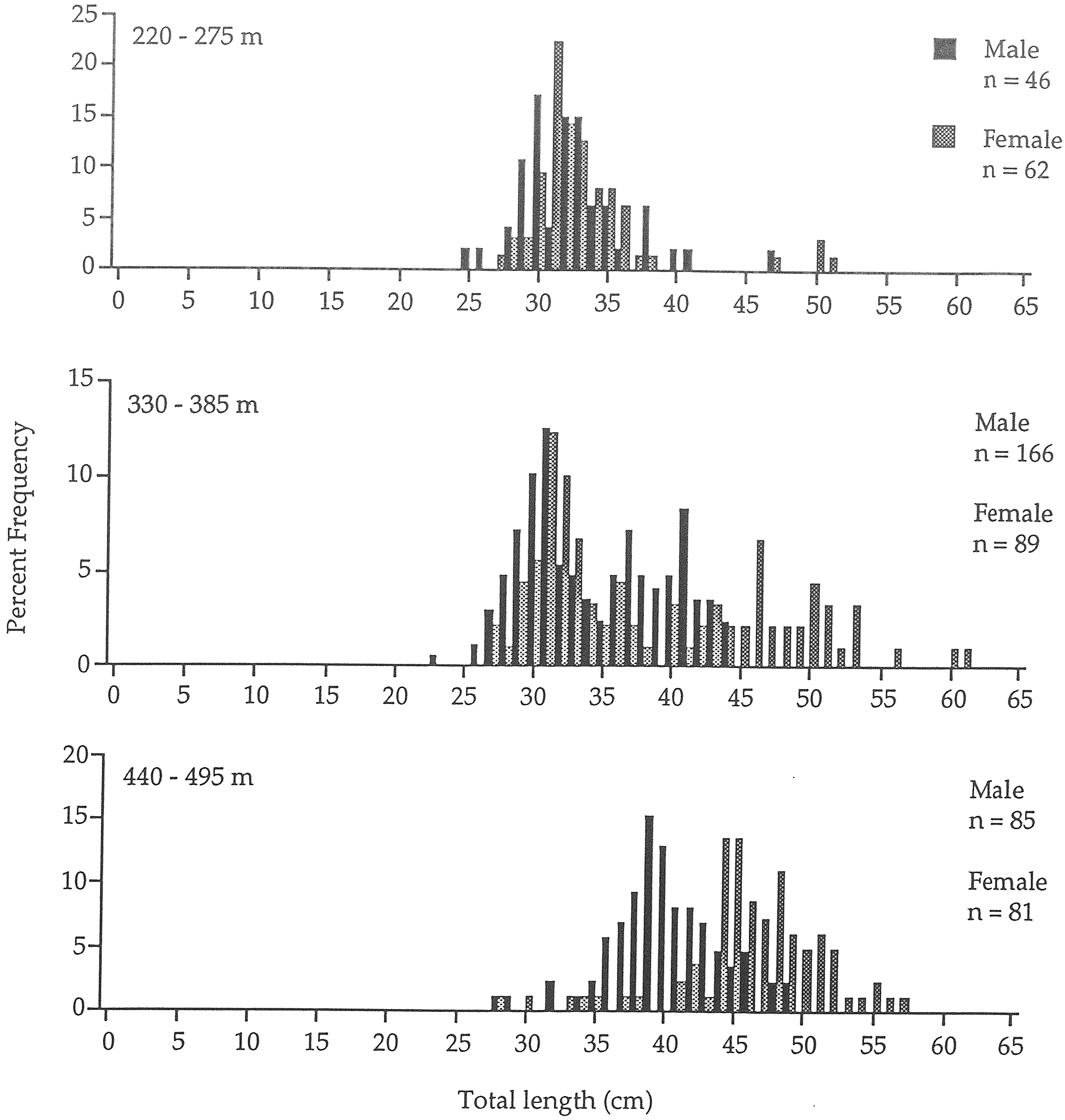
Figure 5.4.3. Length frequency distributions of mirror dory caught off Ulladulla in 1976-7 and 1996-7. Sample sizes indicated for 1976-7 are n = no. measured (total no. in tows sampled). For 1996-7, n = total no. caught, or when subsampled, n = total no. measured (total no. caught).



550 - 605 m

None measured

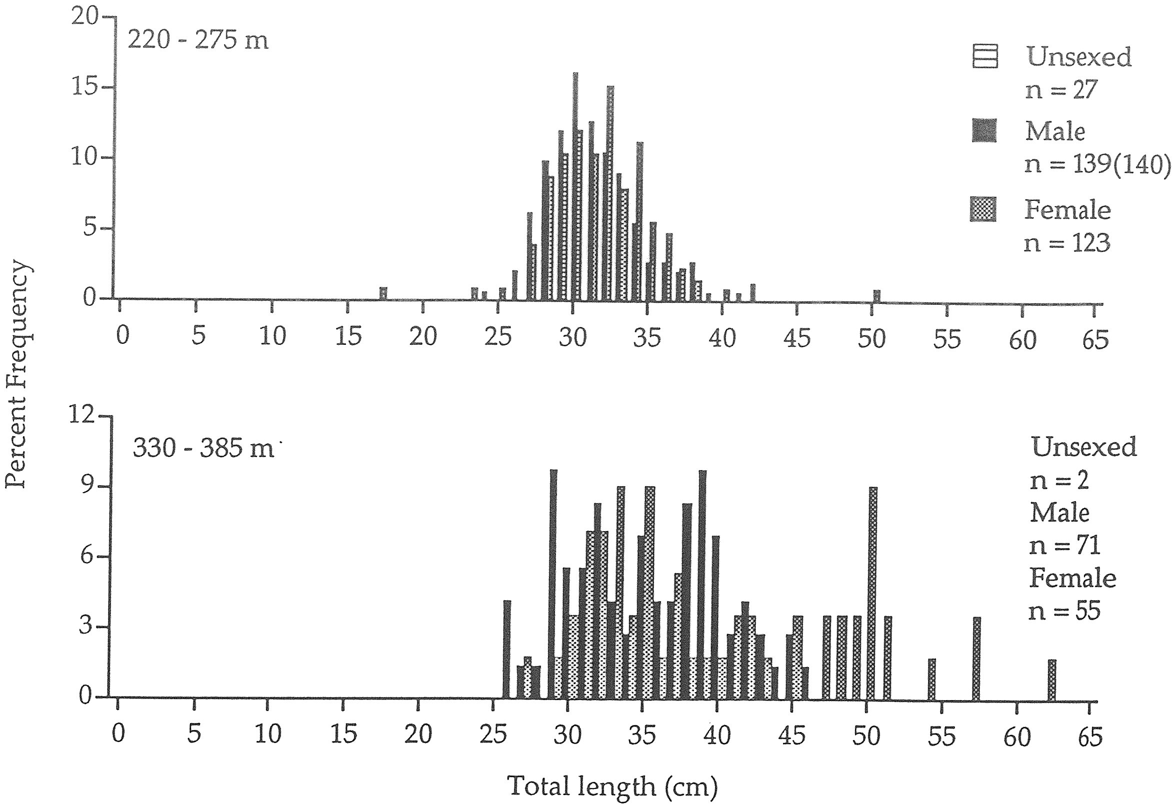
Figure 5.4.4. Length frequency distributions of mirror dory caught off Eden in 1976-7 and 1996-7. Sample sizes indicated for 1976-7 are n = no. measured (total no. in tows sampled). For 1996-7, n = total no. caught, or when subsampled, n = total no. measured (total no. caught).



550 - 605 m

Male n = 18
Female n = 6

Figure 5.4.5. Length frequency distributions of male and female mirror dory caught off Sydney in 1996-7. Sample sizes indicated as n = total no. caught, or when subsampled, n = total no. measured (total no. caught).



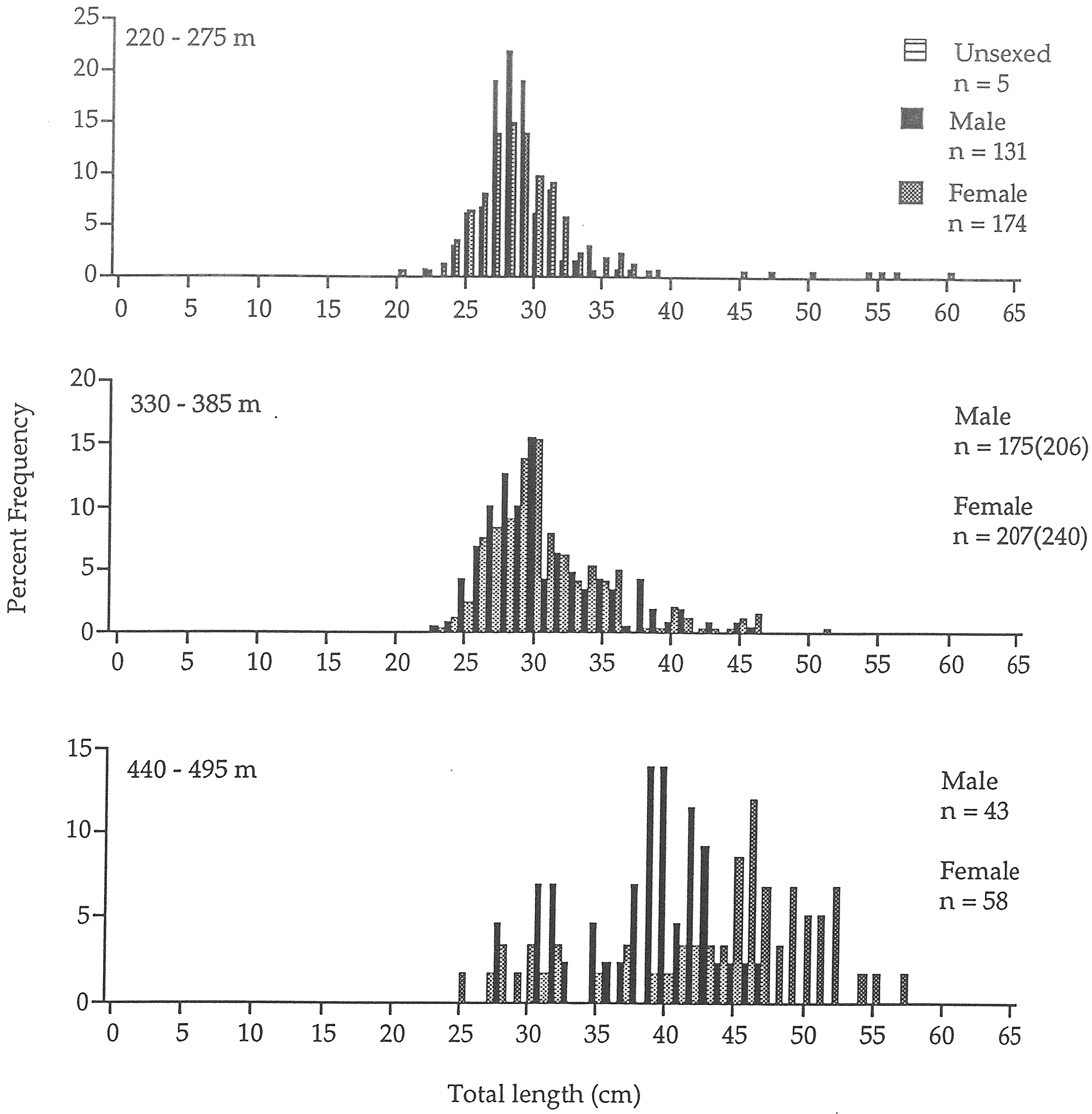
440 - 495 m

Male n = 5
Female n = 8

550 - 605 m

None caught

Figure 5.4.6. Length frequency distributions of male and female mirror dory caught off Ulladulla in 1996-7. Sample sizes indicated as n = total no. caught, or when subsampled, n = total no. measured (total no. caught).



550 - 605 m

None caught

Figure 5.4.7. Length frequency distributions of male and female mirror dory caught off Eden in 1996-7. Sample sizes indicated as n = total no. caught, or when subsampled, n = total no. measured (total no. caught).

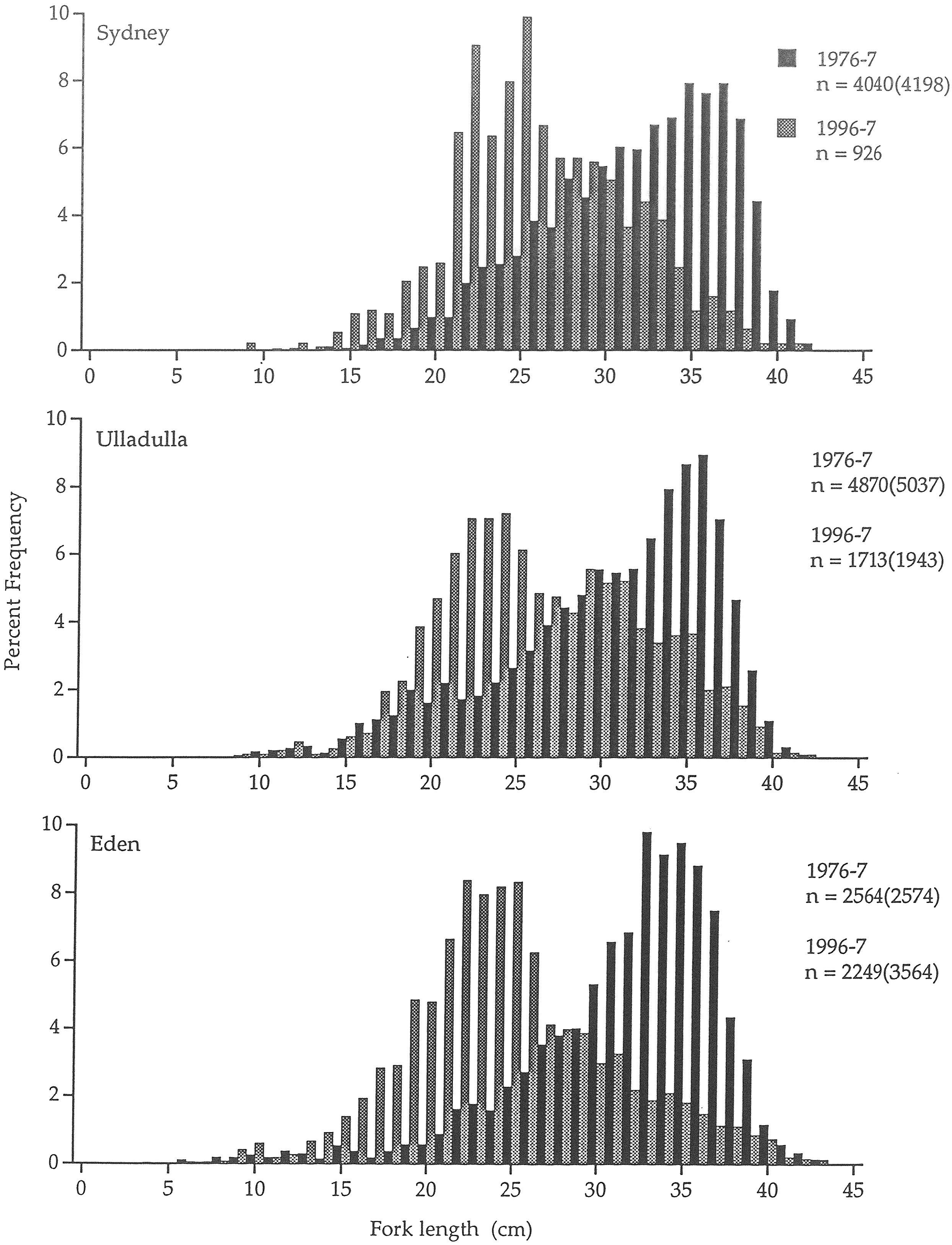


Figure 5.5.1. Length frequency distributions of ocean perch caught in 1976-7 and 1996-7. Sample sizes indicated for 1976-7 are n = no. measured (total no. in tows sampled). For 1996-7, n = total no. caught, or when subsampled, n = total no. measured (total no. caught).

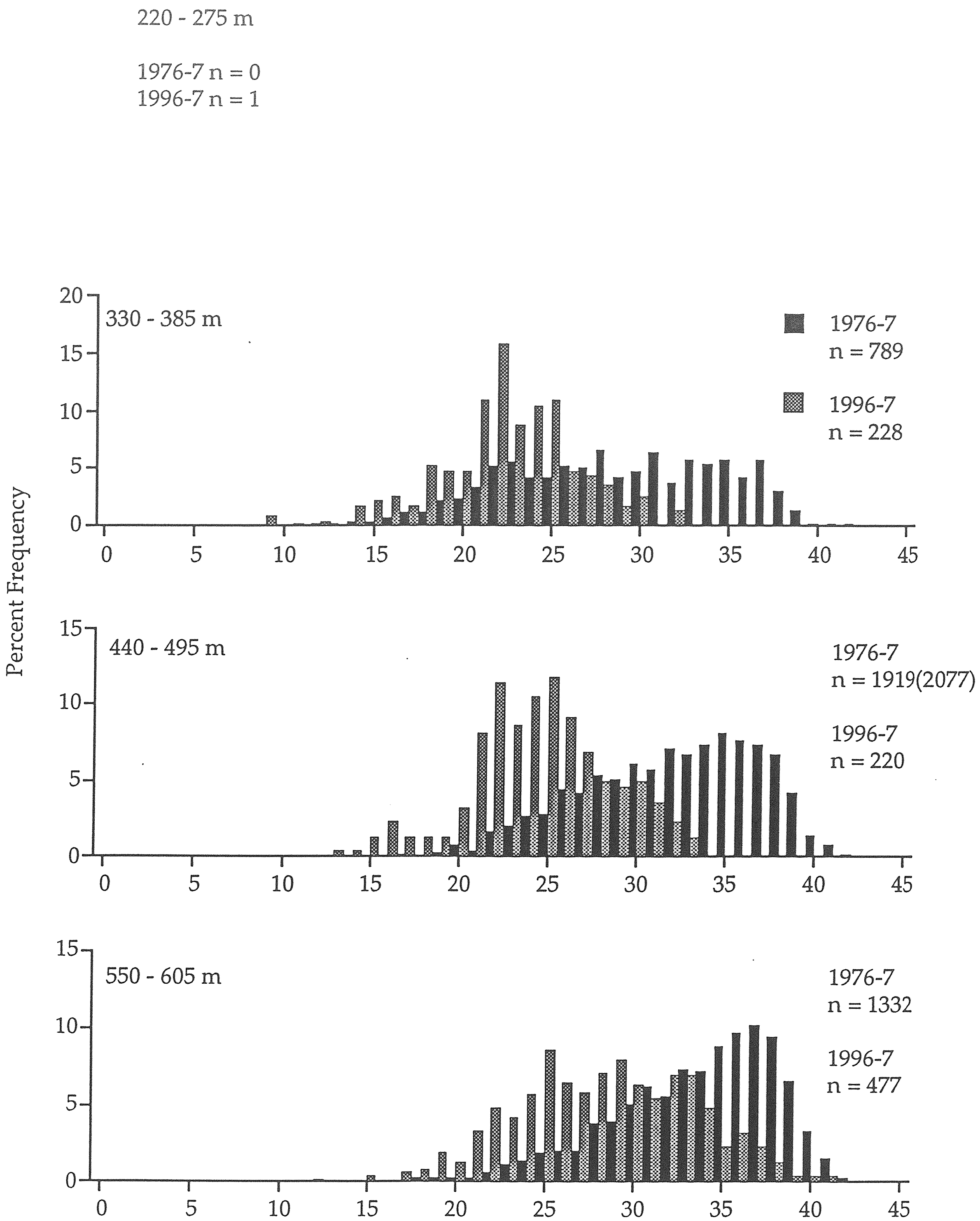


Figure 5.5.2. Length frequency distributions of ocean perch caught in Sydney off 1976-7 and 1996-7. Sample sizes indicated for 1976-7 are n = no. measured (total no. in tows sampled). For 1996-7, n = total no. caught, or when subsampled, n = total no. measured (total no. caught).

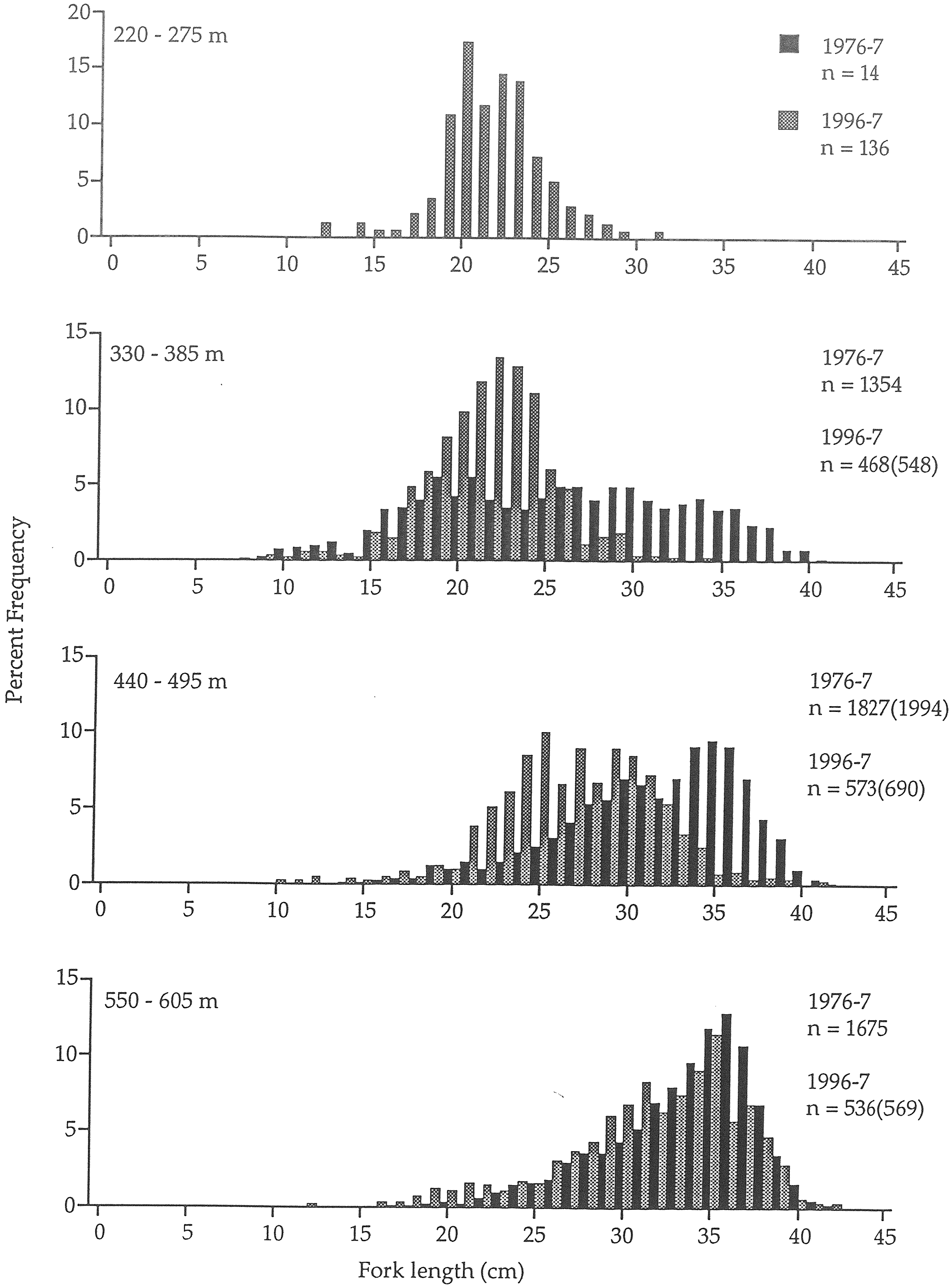


Figure 5.5.3. Length frequency distributions of ocean perch caught off Ulladulla in 1976-7 and 1996-7. Sample sizes indicated for 1976-7 are n = no. measured (total no. in tows sampled). For 1996-7, n = total no. caught, or when subsampled, n = total no. measured (total no. caught).

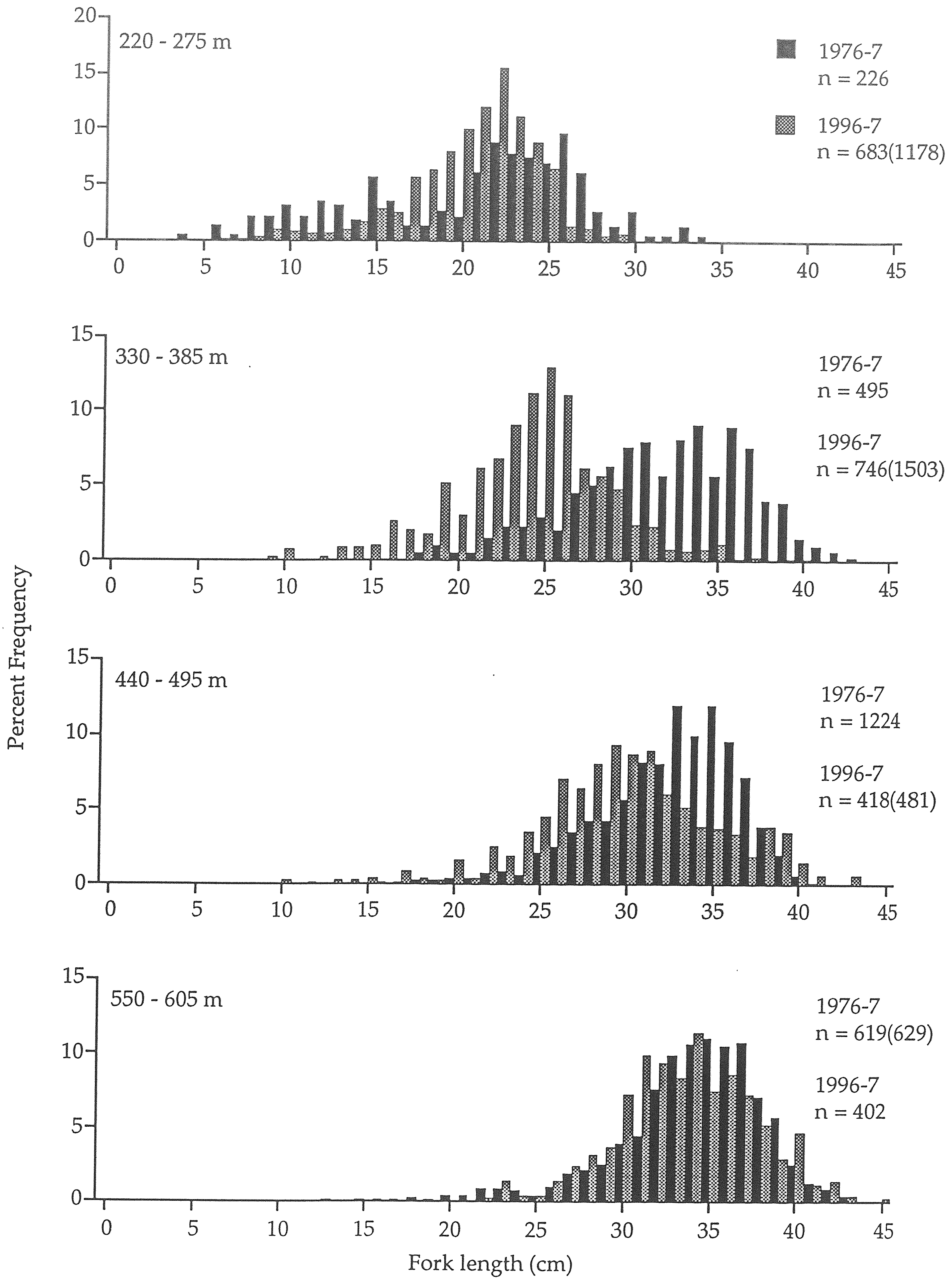


Figure 5.5.4. Length frequency distributions of ocean perch caught off Eden in 1976-7 and 1996-7. Sample sizes indicated for 1976-7 are n = no. measured (total no. in tows sampled). For 1996-7, n = total no. caught, or when subsampled, n = total no. measured (total no. caught).

220 - 275 m

Male n = 0
Female n = 1

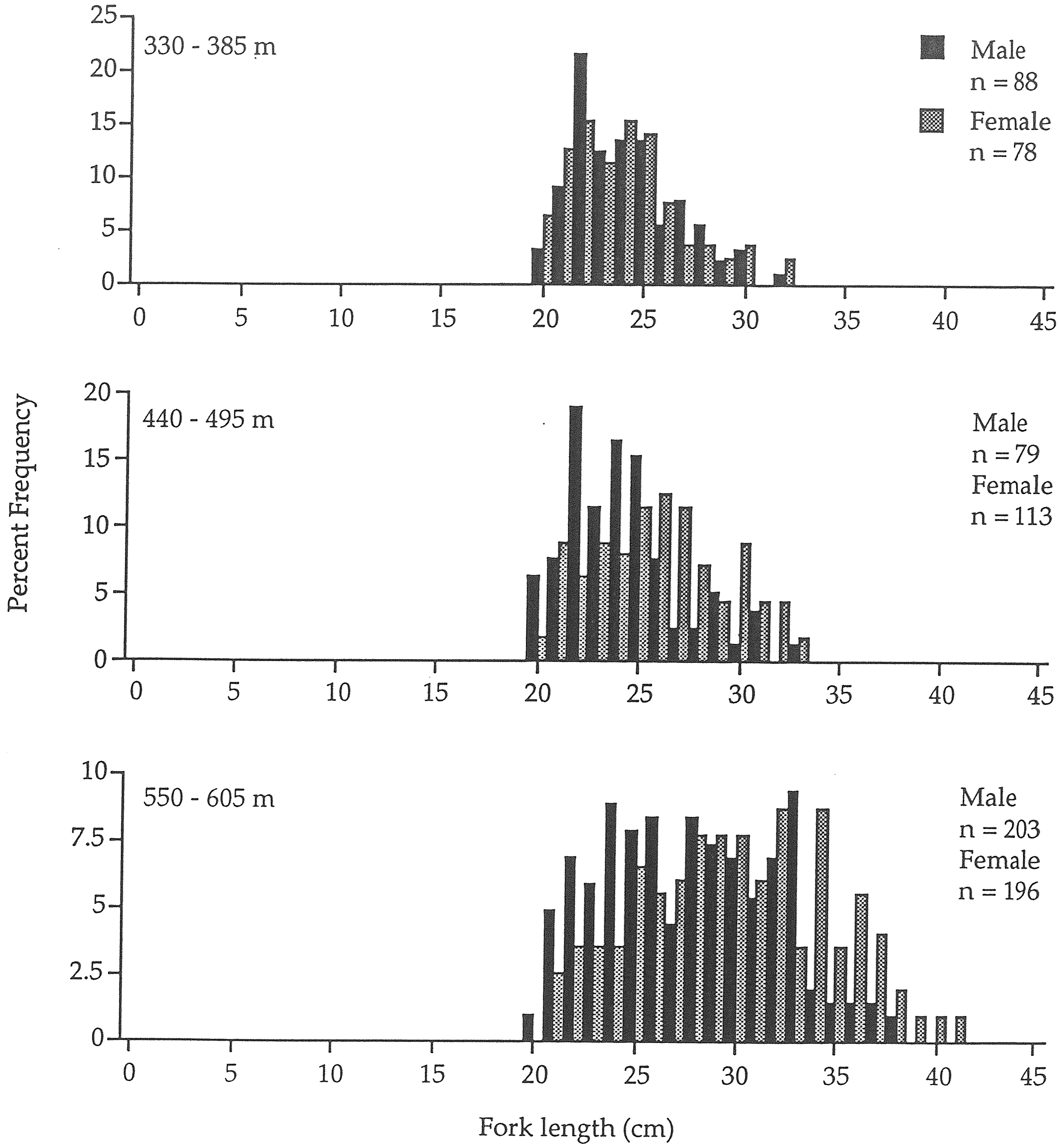


Figure 5.5.5. Length frequency distributions of male and female ocean perch caught off Sydney in 1996-7. Sample sizes indicated as n = total no. caught, or when subsampled, n = total no. measured (total no. caught).

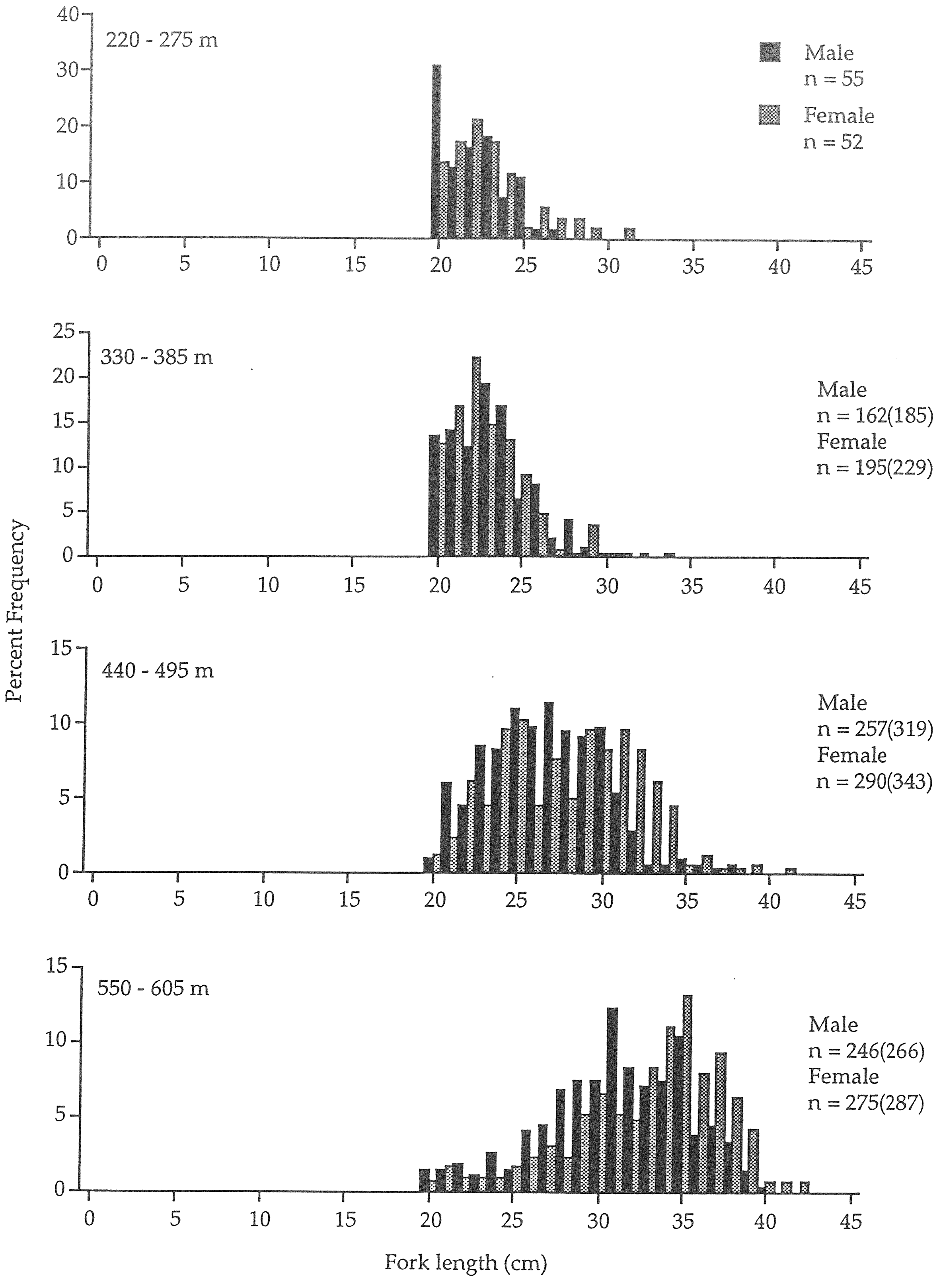


Figure 5.5.6. Length frequency distributions of male and female ocean perch caught off Ulladulla in 1996-7. Sample sizes indicated as n = total no. caught, or when subsampled, n = total no. measured (total no. caught).

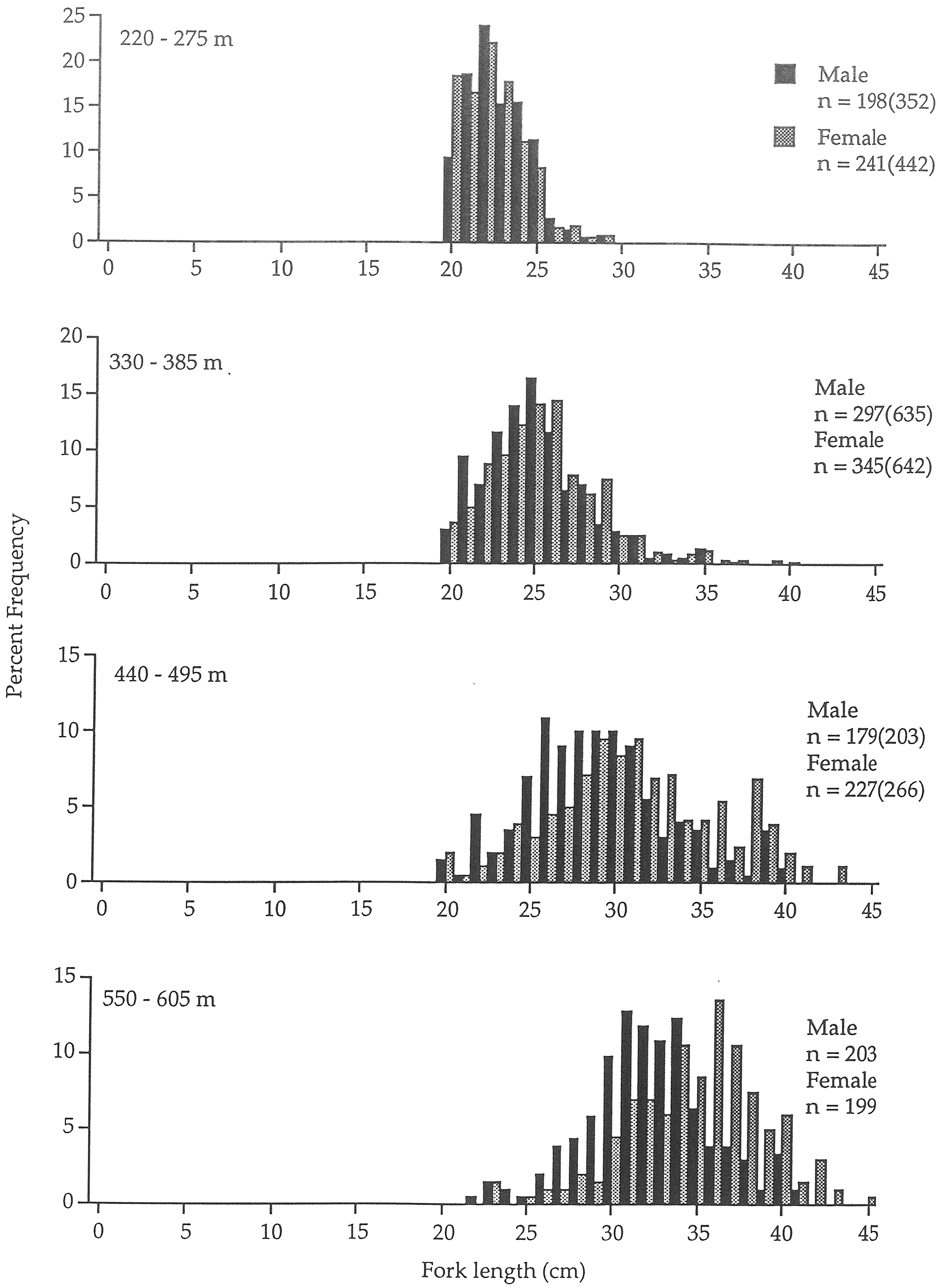


Figure 5.5.7. Length frequency distributions of male and female ocean perch caught off Eden in 1996-7. Sample sizes indicated as n = total no. caught, or when subsampled, n = total no. measured (total no. caught).

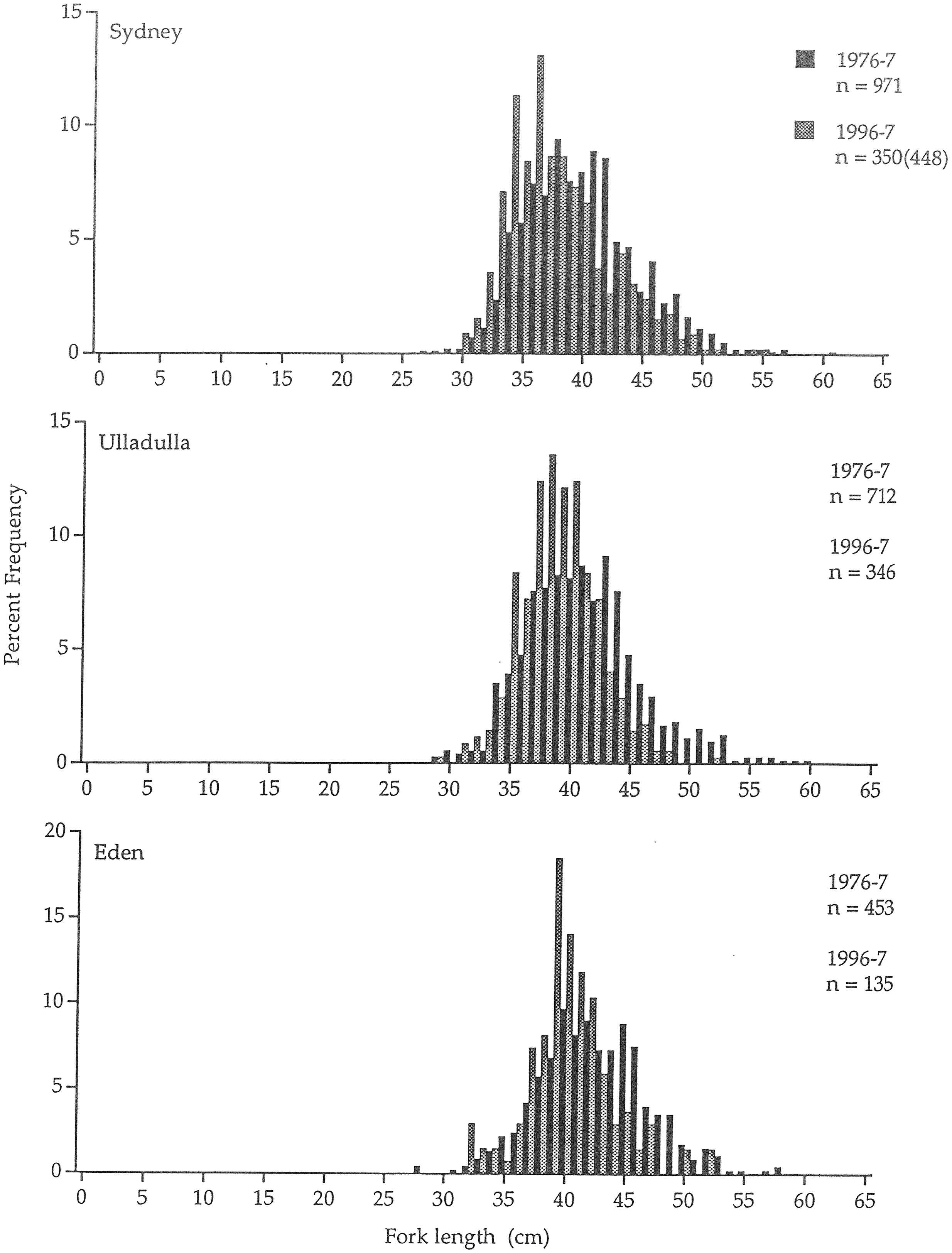
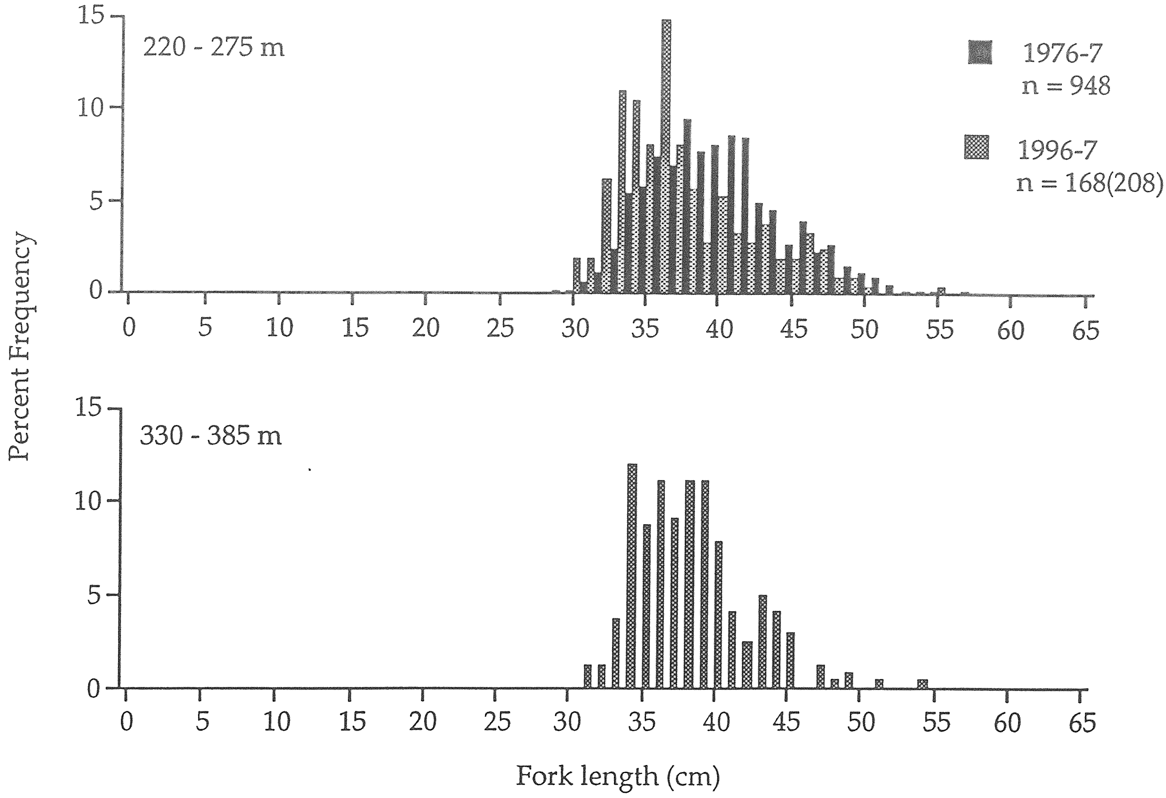


Figure 5.6.1. Length frequency distributions of tiger flathead caught in 1976-7 and 1996-7. Sample sizes indicated for 1976-7 are n = no. measured (total no. in tows sampled). For 1996-7, n = total no. caught, or when subsampled, n = total no. measured (total no. caught).



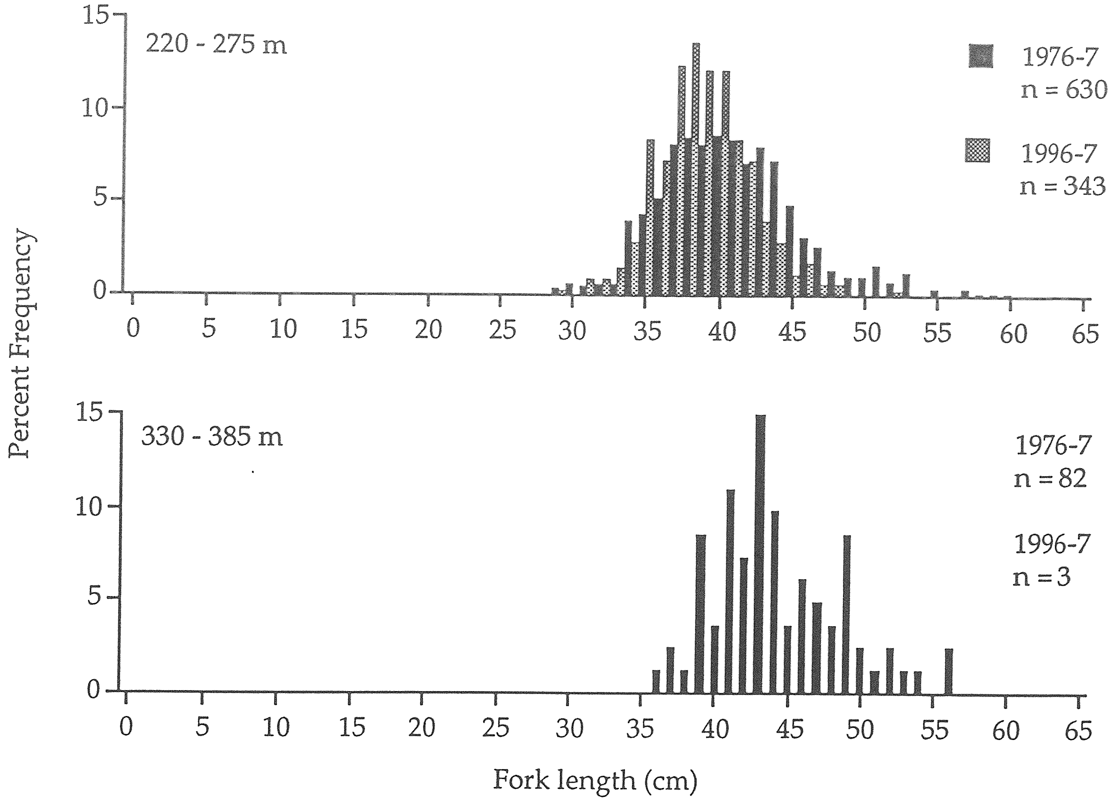
440 - 495 m

None caught

550 - 605 m

None caught

Figure 5.6.2. Length frequency distributions of tiger flathead caught off Sydney in 1976-7 and 1996-7. Sample sizes indicated for 1976-7 are n = no. measured (total no. in tows sampled). For 1996-7, n = total no. caught, or when subsampled, n = total no. measured (total no. caught).



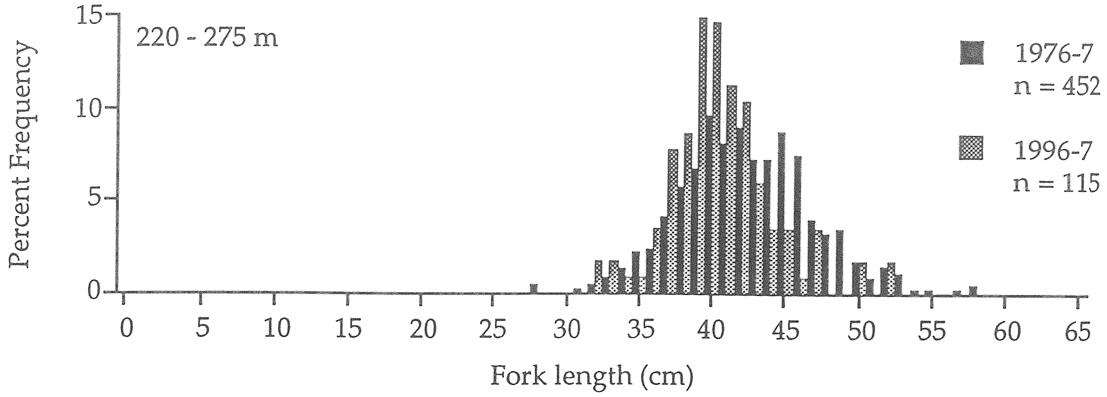
440 - 495 m

None caught

550 - 605 m

None caught

Figure 5.6.3. Length frequency distributions of tiger flathead caught off Ulladulla in 1976-7 and 1996-7. Sample sizes indicated for 1976-7 are n = no. measured (total no. in tows sampled). For 1996-7, n = total no. caught, or when subsampled, n = total no. measured (total no. caught).



330 - 385 m

1976-7 n = 1
1996-7 n = 20

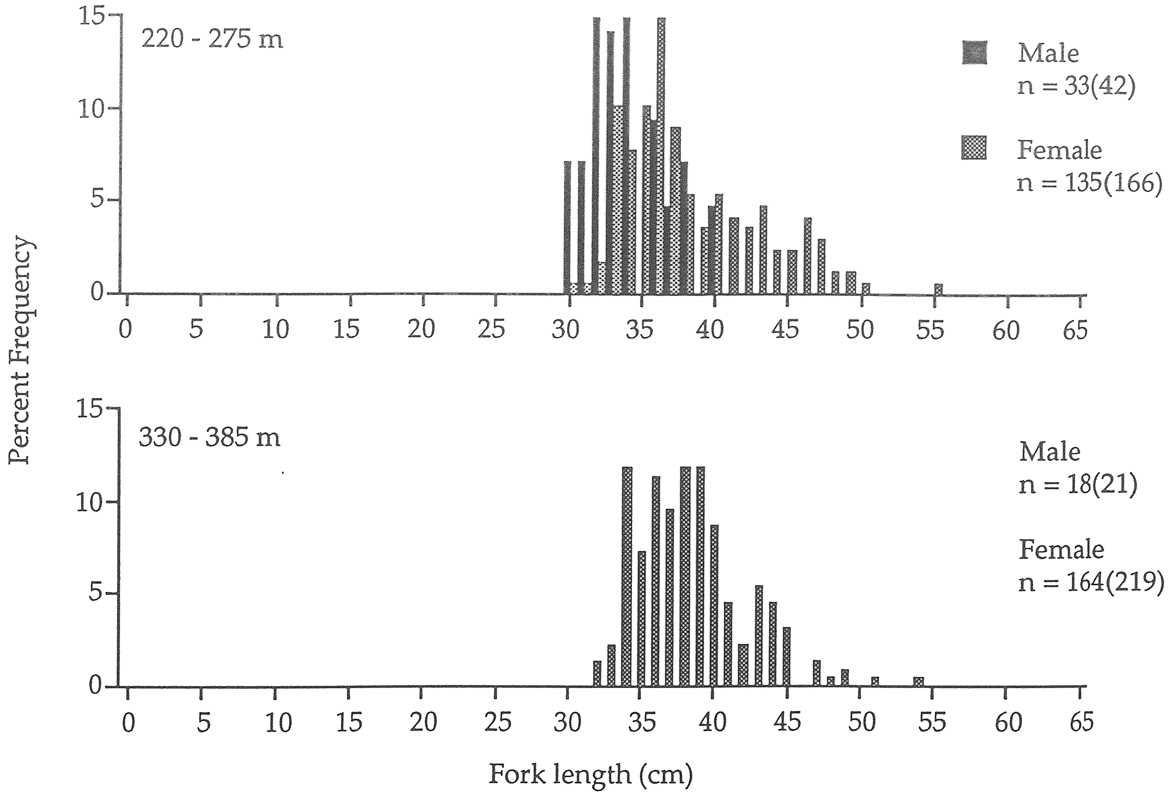
440 - 495 m

None caught

550 - 605 m

None caught

Figure 5.6.4. Length frequency distributions of tiger flathead caught off Eden in 1976-7 and 1996-7. Sample sizes indicated for 1976-7 are n = no. measured (total no. in tows sampled). For 1996-7, n = total no. caught, or when subsampled, n = total no. measured (total no. caught).



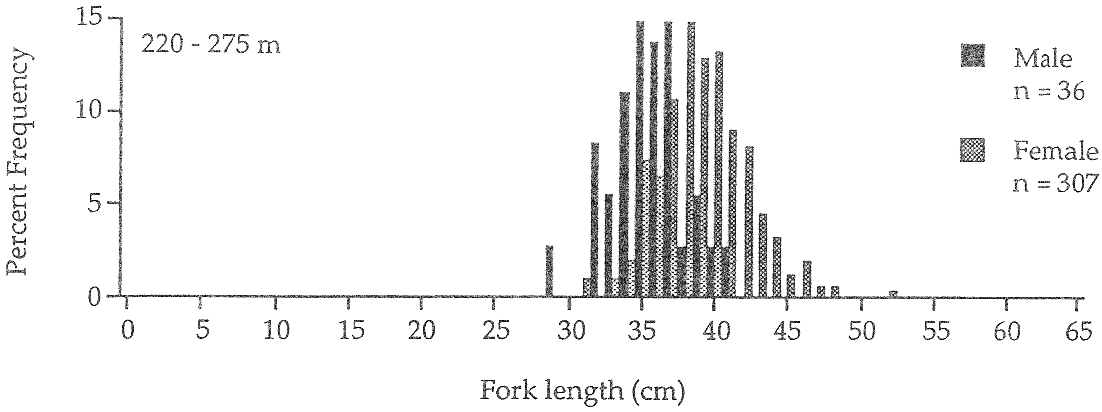
440 - 495 m

None caught

550 - 605 m

None caught

Figure 5.6.5. Length frequency distributions of male and female tiger flathead caught off Sydney in 1996-7. Sample sizes indicated as n = total no. caught, or when subsampled, n = total no. measured (total no. caught).



330 - 385 m

Male n = 1
Female n = 2

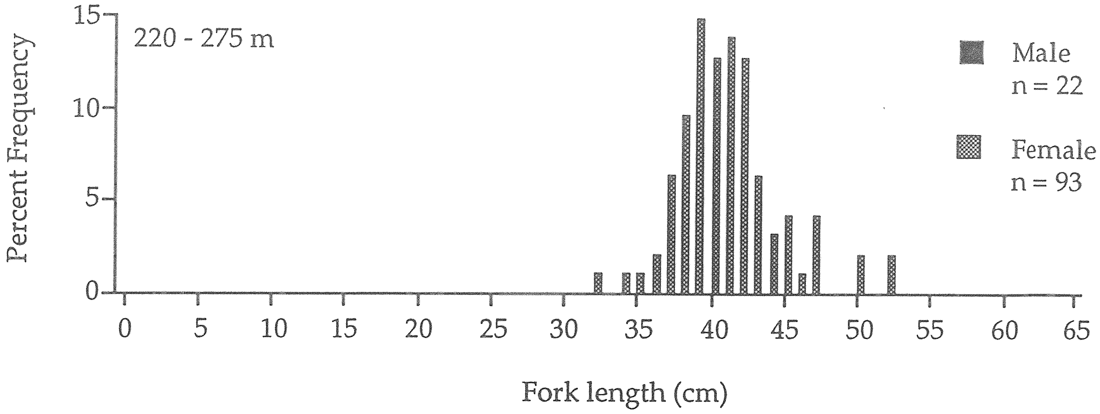
440 - 495 m

None caught

550 - 605 m

None caught

Figure 5.6.6. Length frequency distributions of male and female tiger flathead caught off Ulladulla in 1996-7. Sample sizes indicated as n = total no. caught, or when subsampled, n = total no. measured (total no. caught).



330 - 385 m

Male n = 2
Female n = 18

440 - 495 m

None caught

550 - 605 m

None caught

Figure 5.6.7. Length frequency distributions of male and female tiger flathead caught off Eden in 1996-7. Sample sizes indicated as n = total no. caught, or when subsampled, n = total no. measured (total no. caught).

Sydney

1976-7 n = 2
1996-7 n = 1

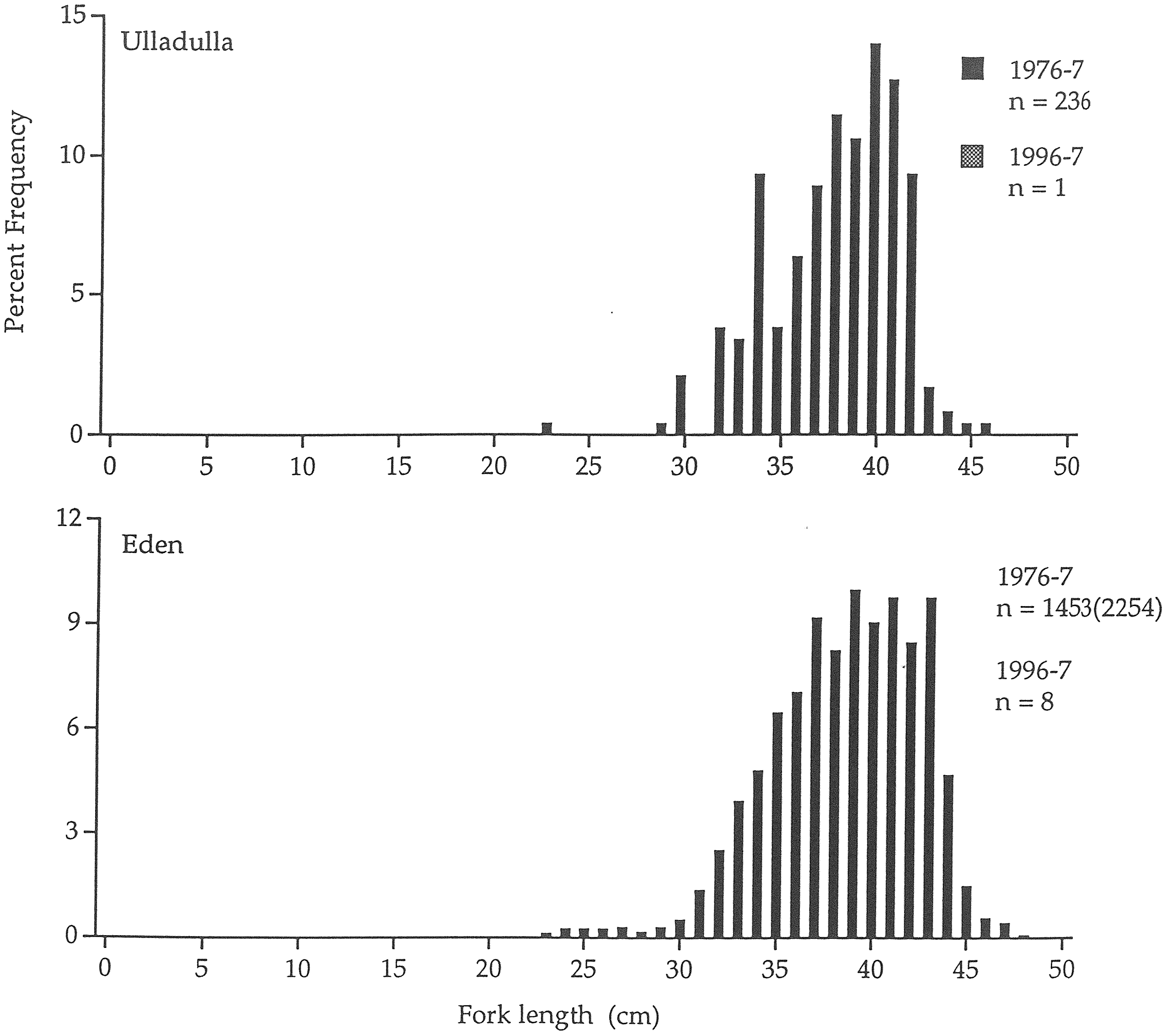
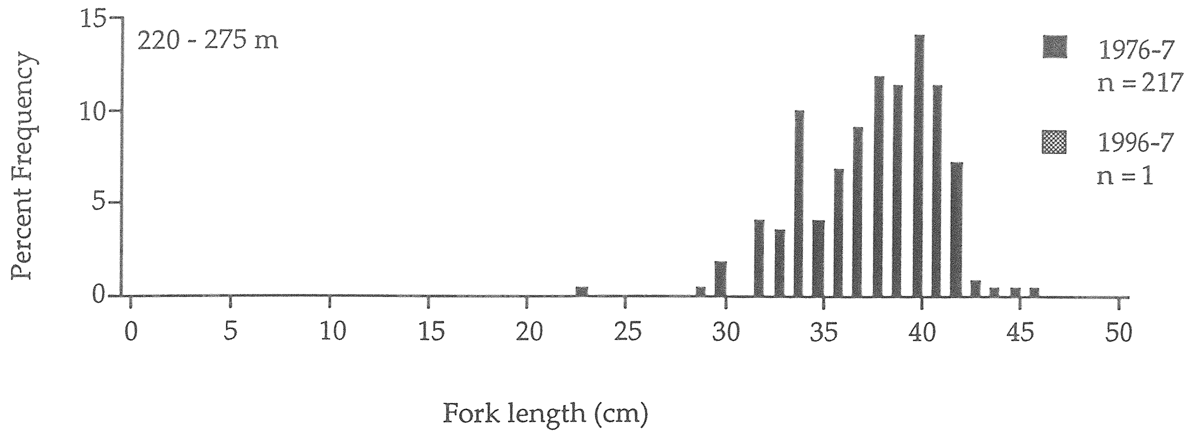


Figure 5.7.1. Length frequency distributions of jackass morwong caught in 1976-7. Sample sizes indicated for 1976-7 are n = no. measured (total no. in tows sampled). For 1996-7, n = total no. caught, or when subsampled, n = total no. measured (total no. caught).



330 - 385 m

1976-7 n = 19
1996-7 n = 0

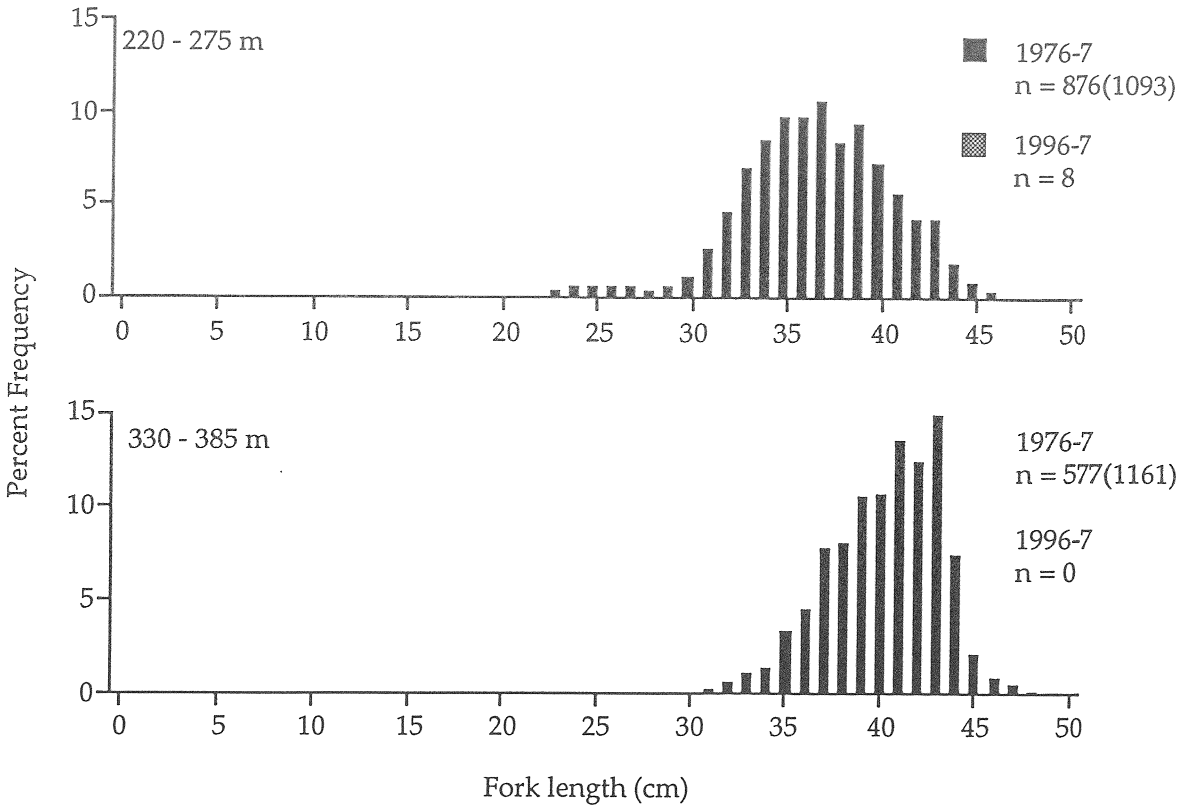
440 - 495 m

None caught

550 - 605 m

None caught

Figure 5.7.2. Length frequency distributions of jackass morwong caught off Ulladulla in 1976-7. Sample sizes indicated for 1976-7 are n = no. measured (total no. in tows sampled). For 1996-7, n = total no. caught, or when subsampled, n = total no. measured (total no. caught).



440 - 495 m

None caught

550 - 605 m

None caught

Figure 5.7.3. Length frequency distributions of jackass morwong caught off Eden in 1976-7. Sample sizes indicated for 1976-7 are n = no. measured (total no. in tows sampled). For 1996-7, n = total no. caught, or when subsampled, n = total no. measured (total no. caught).

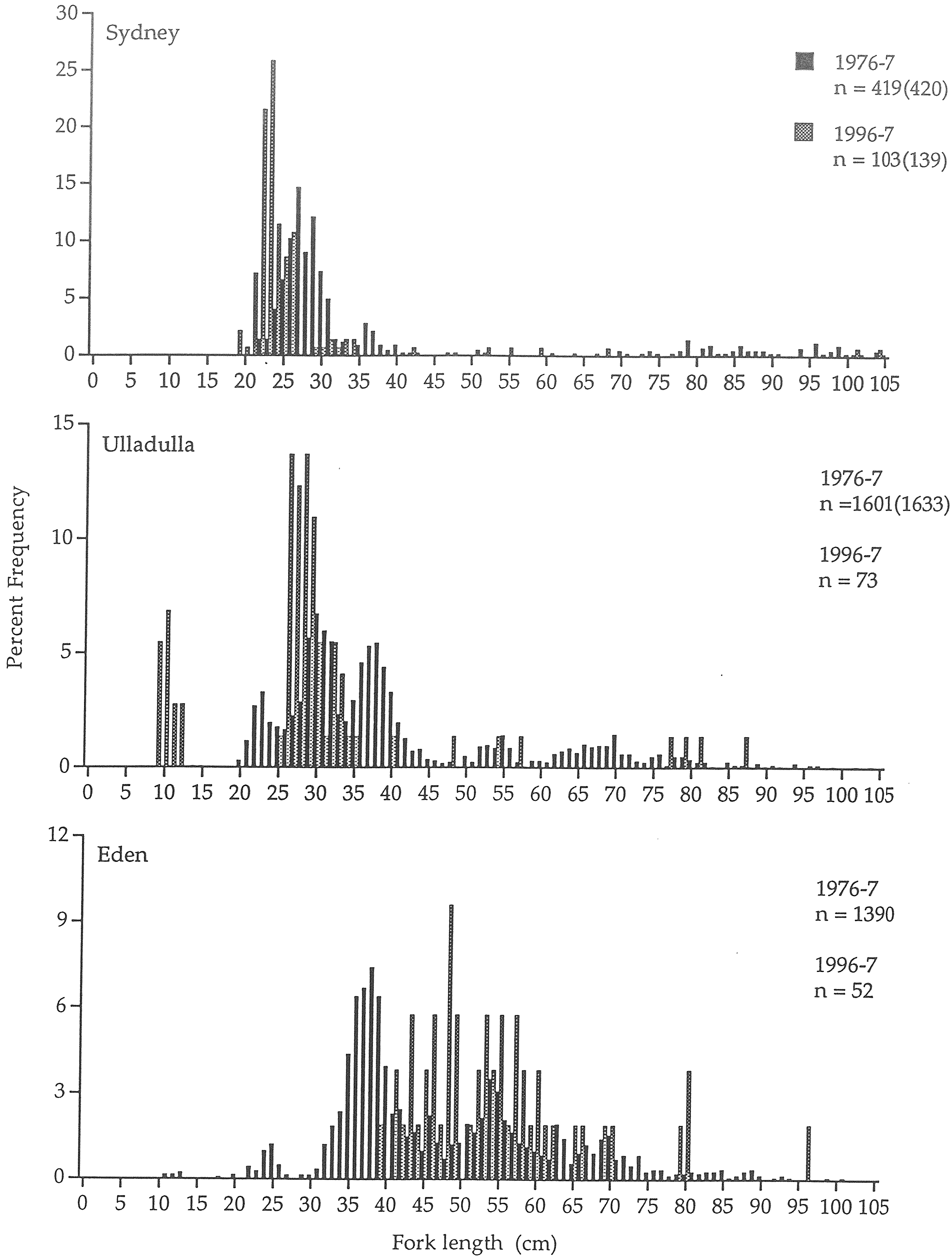
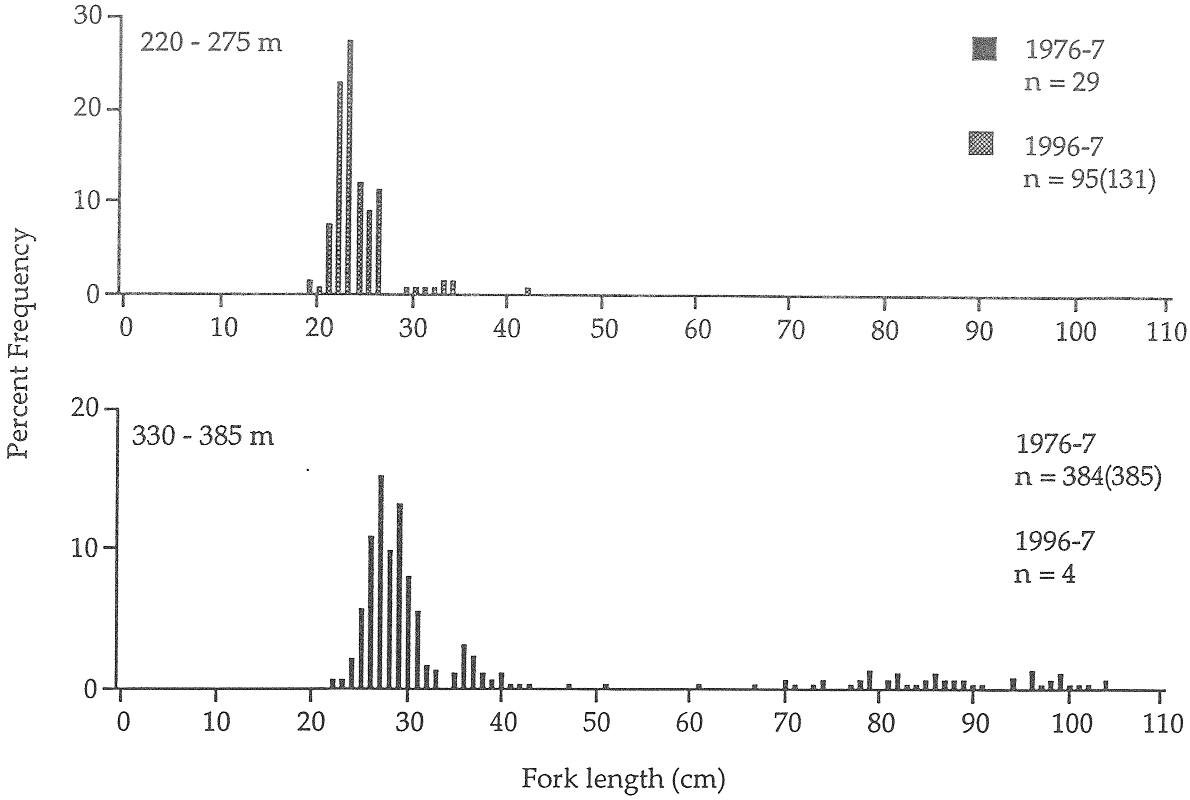


Figure 5.8.1. Length frequency distributions of gemfish caught in 1976-7 and 1996-7. Sample sizes indicated for 1976-7 are n = no. measured (total no. in tows sampled). For 1996-7, n = total no. caught, or when subsampled, n = total no. measured (total no. caught).



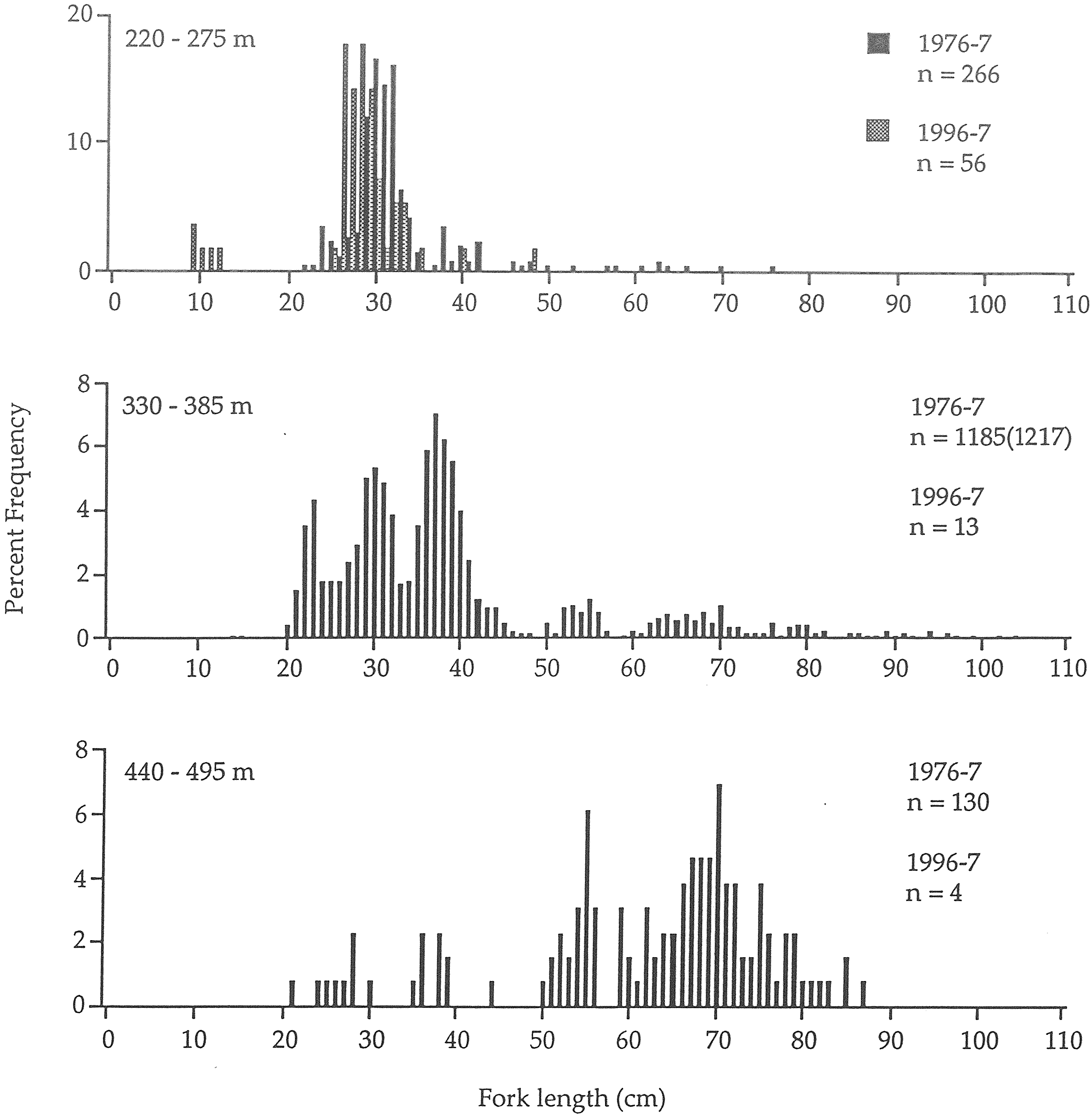
440 - 495 m

1976-7 n = 6
1996-7 n = 3

550 - 605 m

1976-7 n = 0
1996-7 n = 1

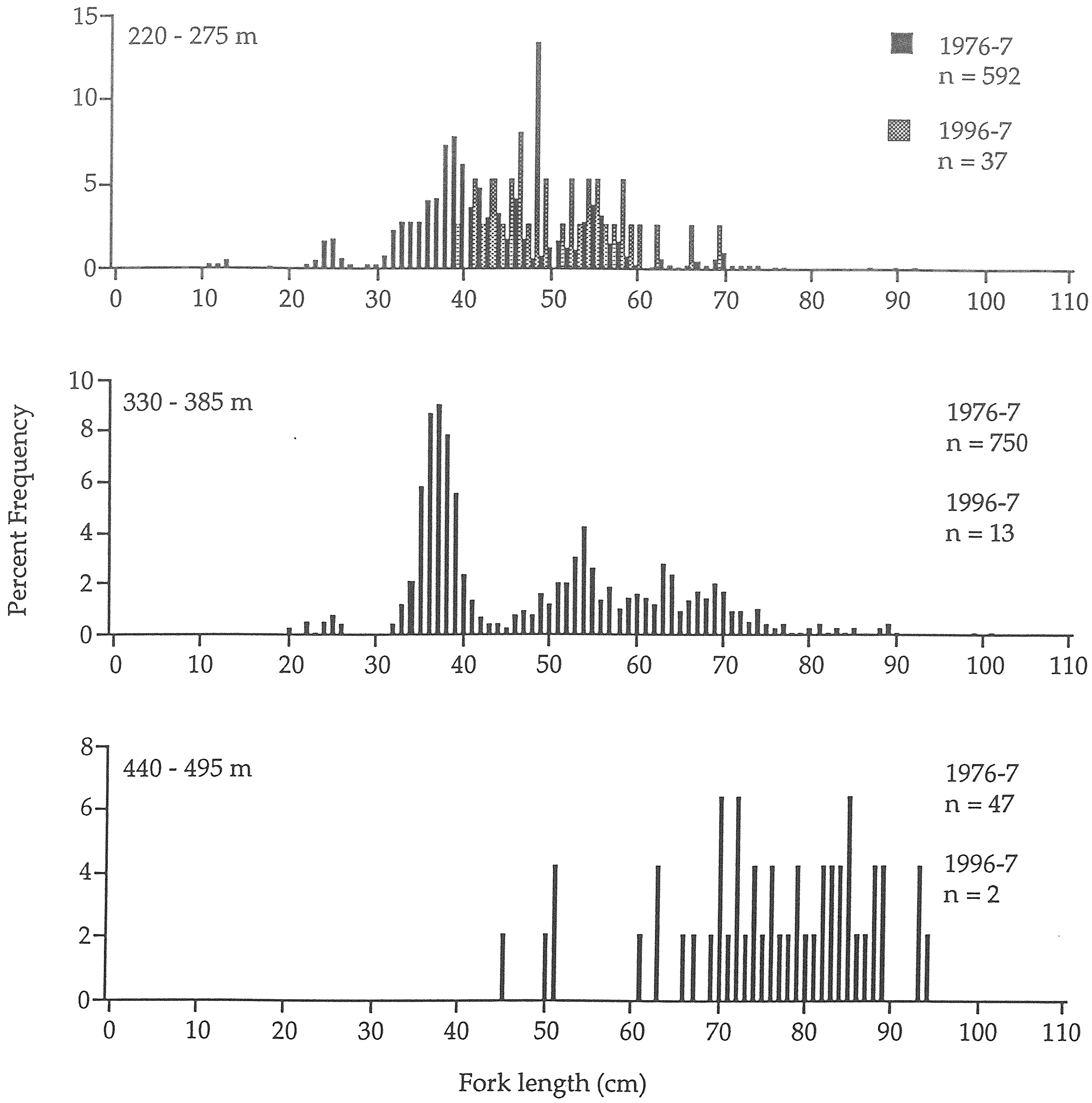
Figure 5.8.2. Length frequency distributions of gemfish caught off Sydney in 1976-7 and 1996-7. Sample sizes indicated for 1976-7 are n = no. measured (total no. in tows sampled). For 1996-7, n = total no. caught, or when subsampled, n = total no. measured (total no. caught).



550 - 605 m

1976-7 n = 20
1996-7 n = 0

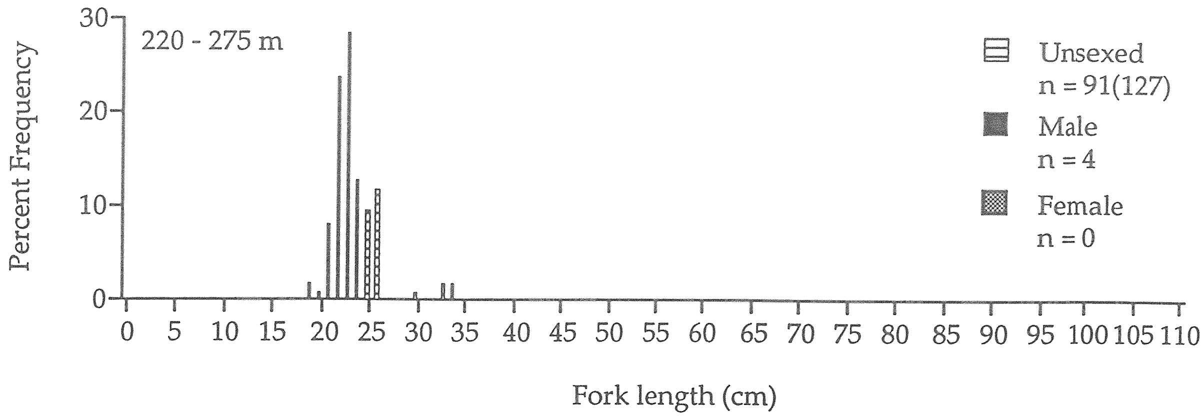
Figure 5.8.3. Length frequency distributions of gemfish caught off Ulladulla in 1976-7 and 1996-7. Sample sizes indicated for 1976-7 are n = no. measured (total no. in tows sampled). For 1996-7, n = total no. caught, or when subsampled, n = total no. measured (total no. caught).



550 - 605 m

1976-7 n = 1
1996-7 n = 0

Figure 5.8.4. Length frequency distributions of gemfish caught off Eden in 1976-7 and 1996-7. Sample sizes indicated for 1976-7 are n = no. measured (total no. in tows sampled). For 1996-7, n = total no. caught, or when subsampled, n = total no. measured (total no. caught).



330 - 385 m

Unsexed n = 0
Male n = 2
Female n = 2

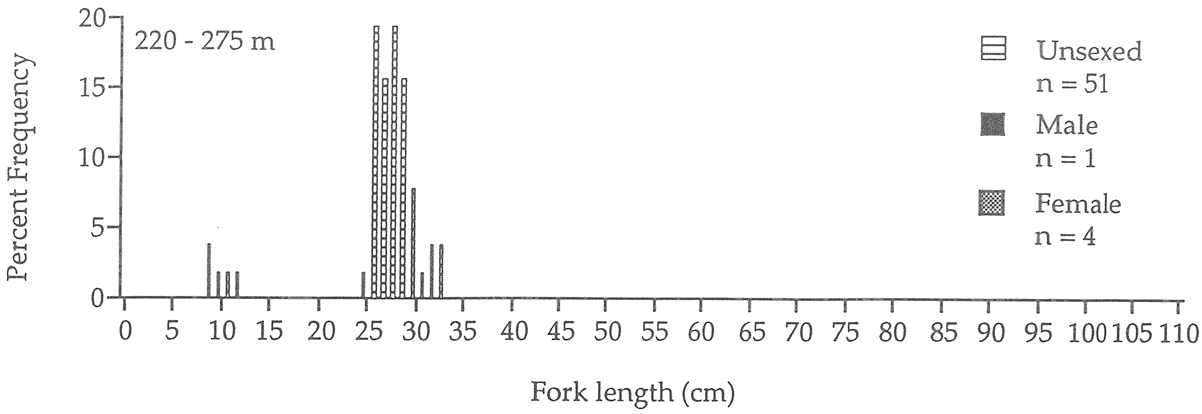
440 - 495 m

Unsexed n = 1
Male n = 1
Female n = 1

550 - 605 m

Unsexed n = 0
Male n = 0
Female n = 1

Figure 5.8.5. Length frequency distribution of gemfish caught off Sydney in 1996-7. Sample sizes indicated as n = total no. caught, or when subsampled, n = total no. measured (total no. caught).



330 - 385 m

Unsexed n = 9
Male n = 2
Female n = 2

440 - 495 m

Unsexed n = 0
Male n = 2
Female n = 2

550 - 605 m

None caught

Figure 5.8.6. Length frequency distributions of gemfish caught off Ulladulla in 1996-7. Sample sizes indicated as n = total no. caught, or when subsampled, n = total no. measured (total no. caught).

220 - 275 m

Male n = 15
Female n = 22

330 - 385 m

Male n = 3
Female n = 10

440 - 495 m

Male n = 1
Female n = 1

550 - 605 m

None caught

Figure 5.8.7. Insufficient numbers of gemfish were caught off Eden in 1996-7 to plot reliable length frequency distributions. Sample sizes indicated as n = total no. caught.

Sydney

None caught

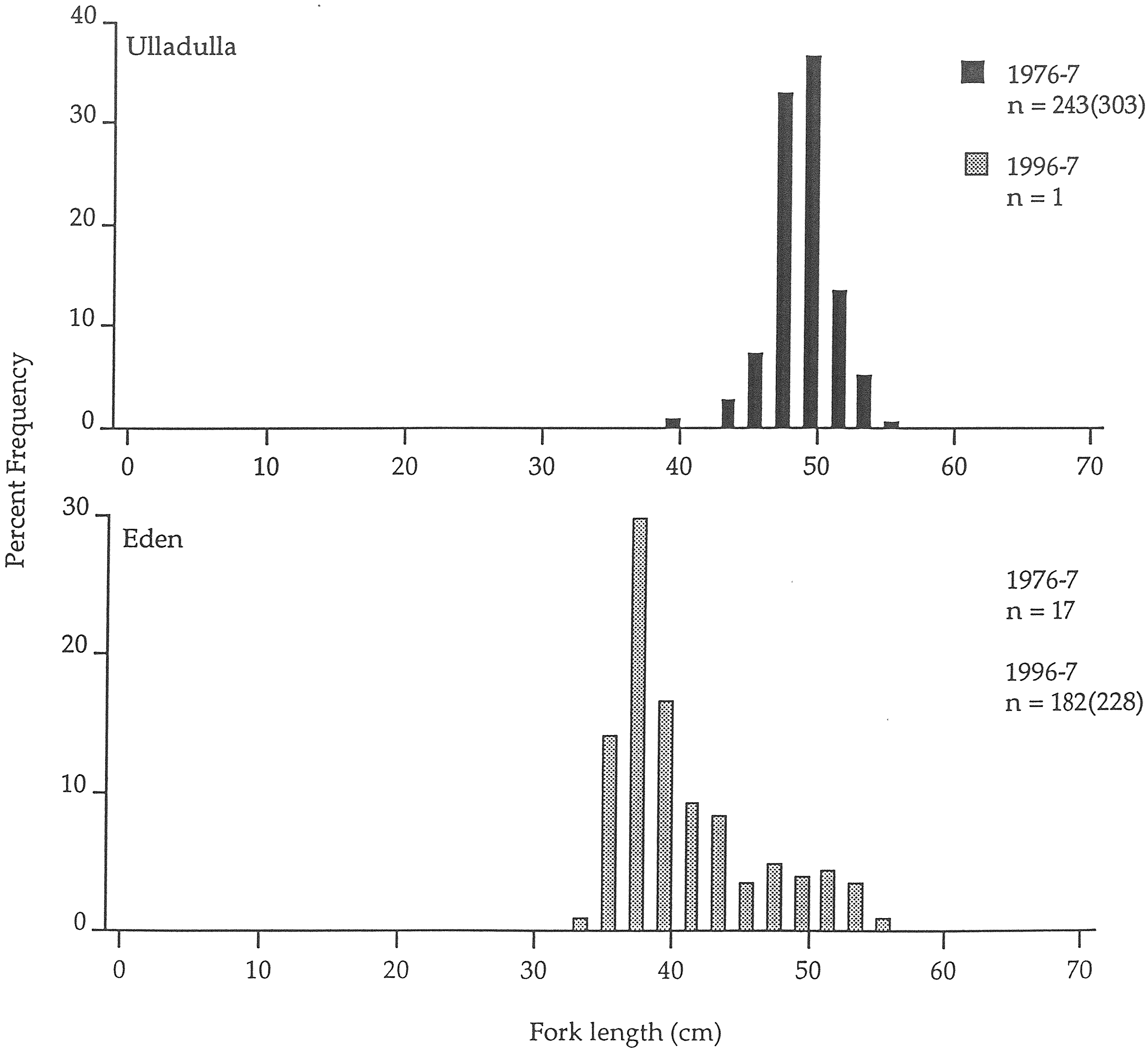
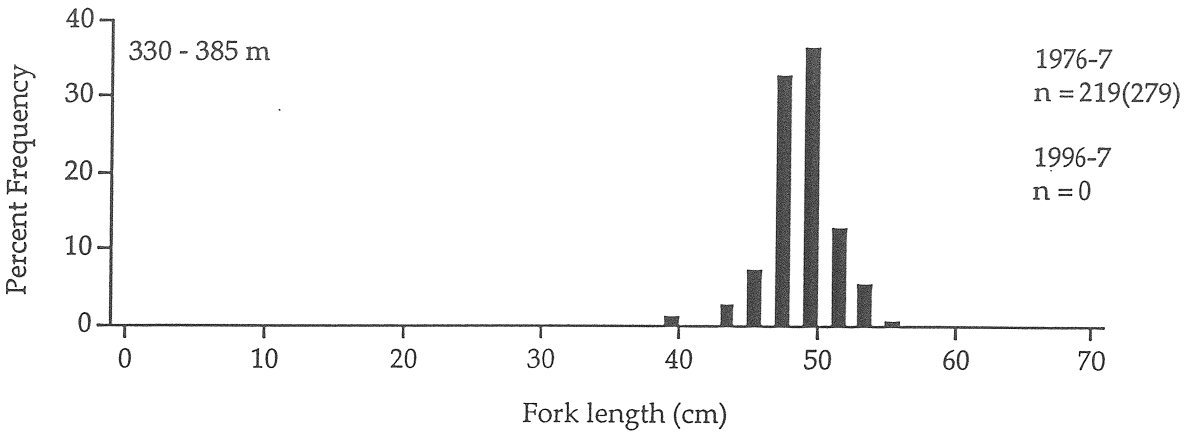


Figure 5.9.1. Length frequency distributions of spotted warehou caught in 1976-7 and 1996-7. Sample sizes indicated as n = total no. measured (total no. caught).

220 - 275 m

1976-7 n = 24

1996-7 n = 1



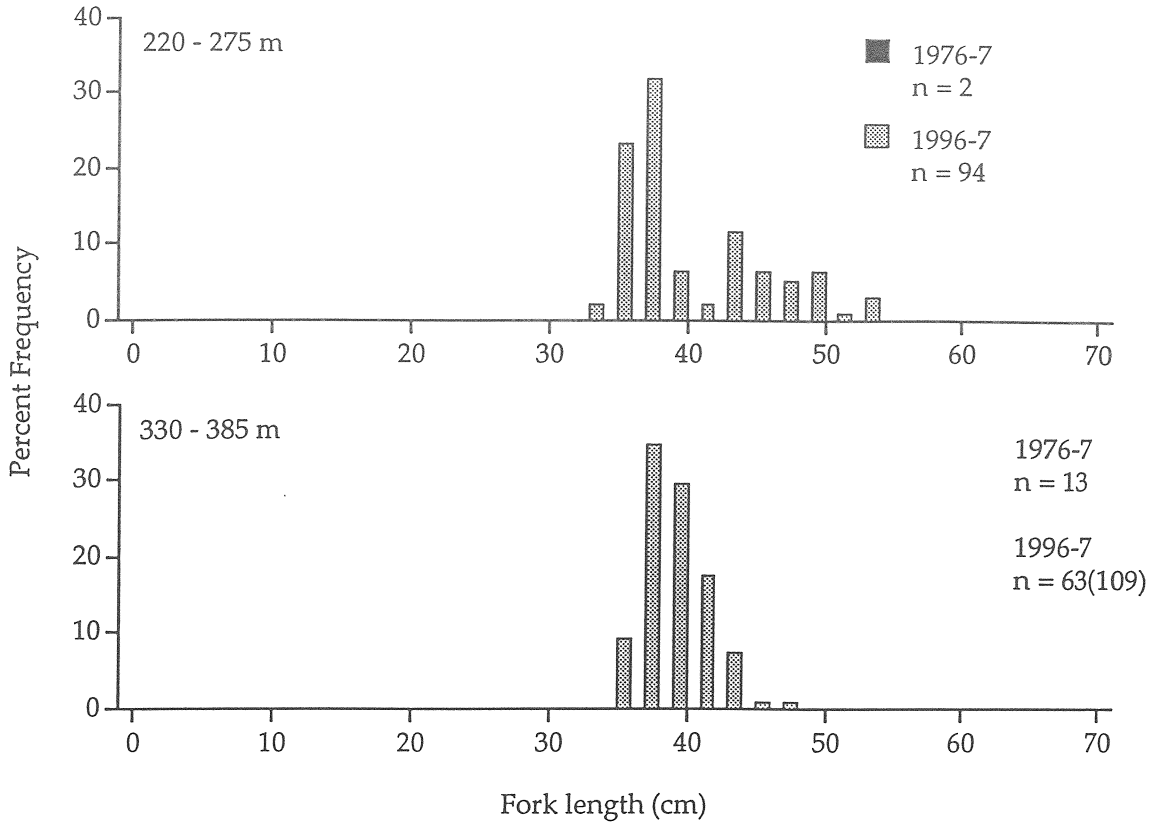
440 - 495 m

None caught

550 - 605 m

None caught

Figure 5.9.2. Length frequency distributions of spotted warehou caught off Ulladulla in 1976-7. Sample sizes indicated as n = total no. measured (total no. caught).



440 - 495 m

1976-7 n = 0

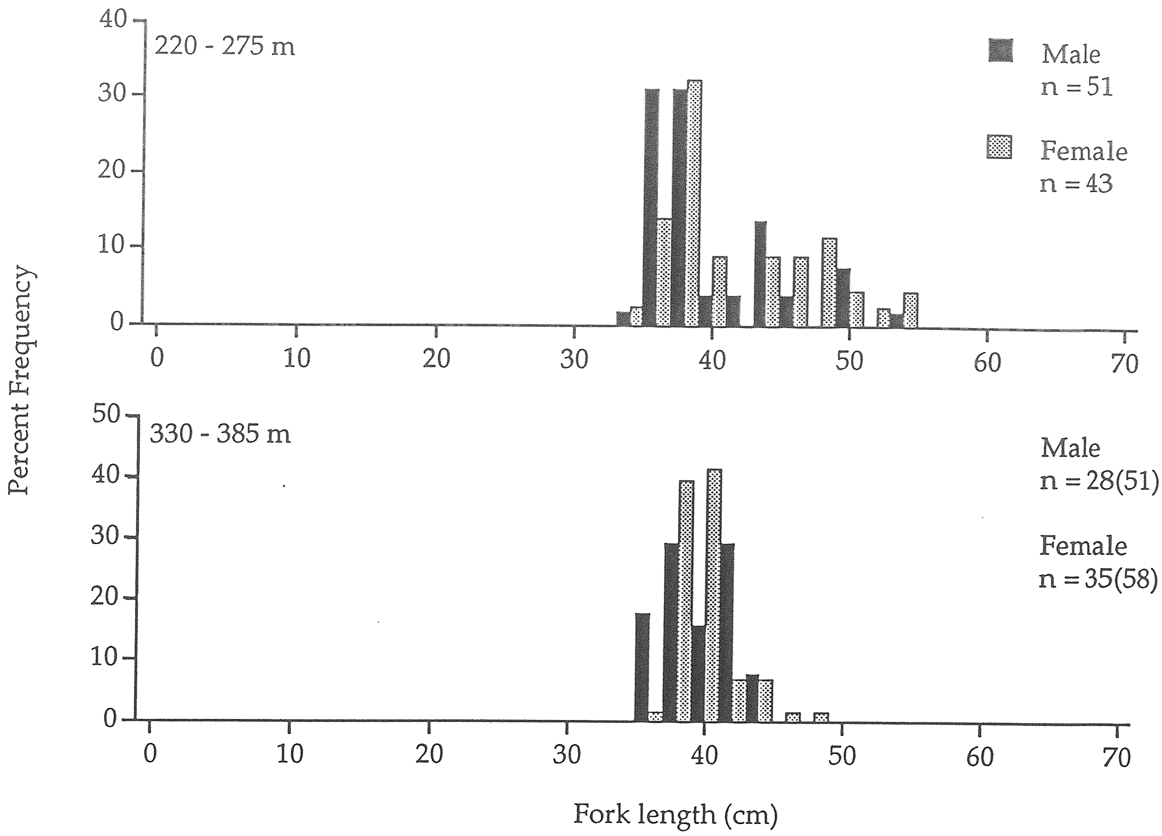
1996-7 n = 23

550 - 605 m

1976-7 n = 0

1996-7 n = 2

Figure 5.9.3. Length frequency distributions of spotted warehou caught off Eden in 1996-7. Sample sizes indicated as n = total no. measured (total no. caught).



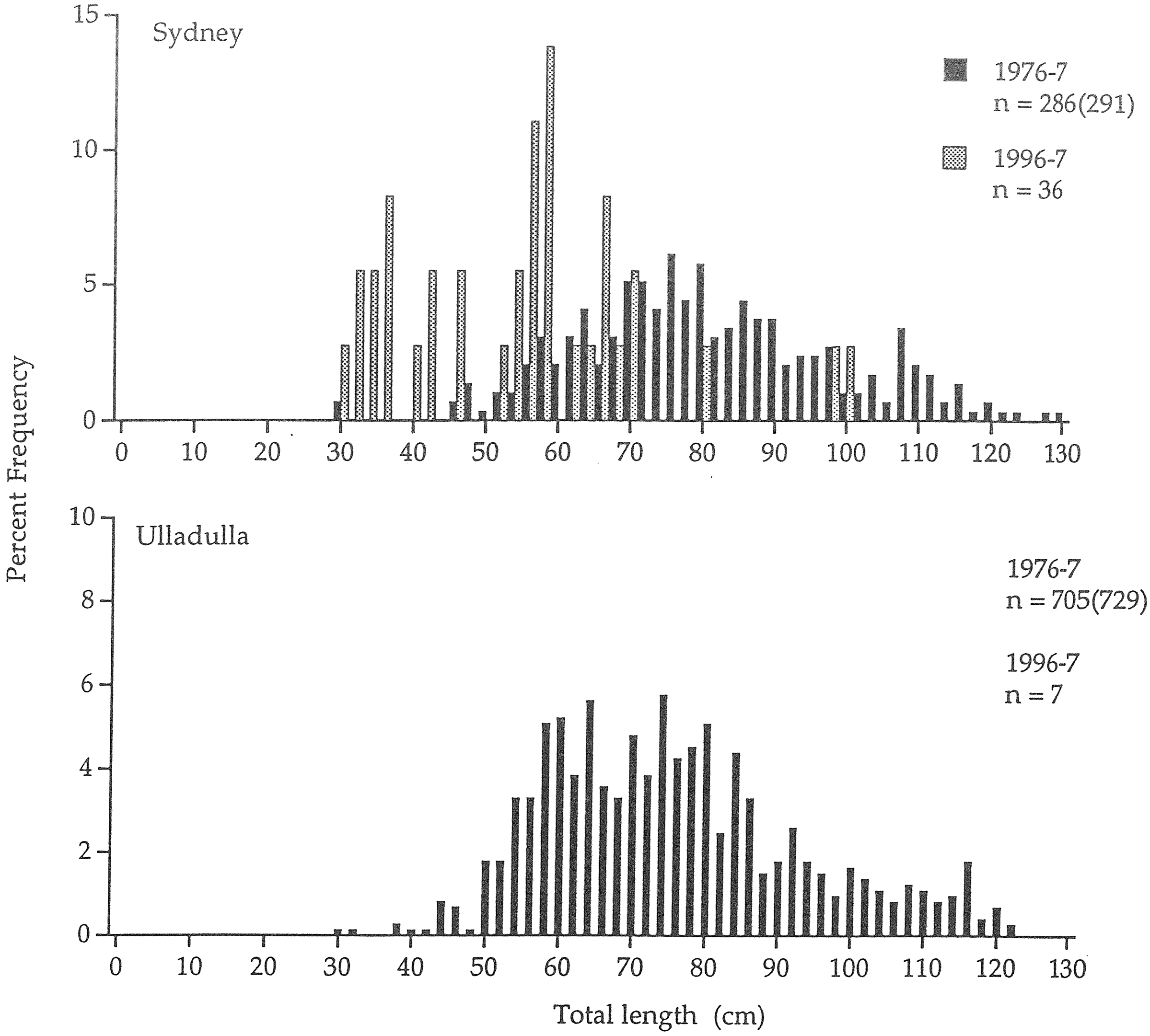
440 - 495 m

male n = 0
female n = 23

550 - 605 m

male n = 0
female n = 2

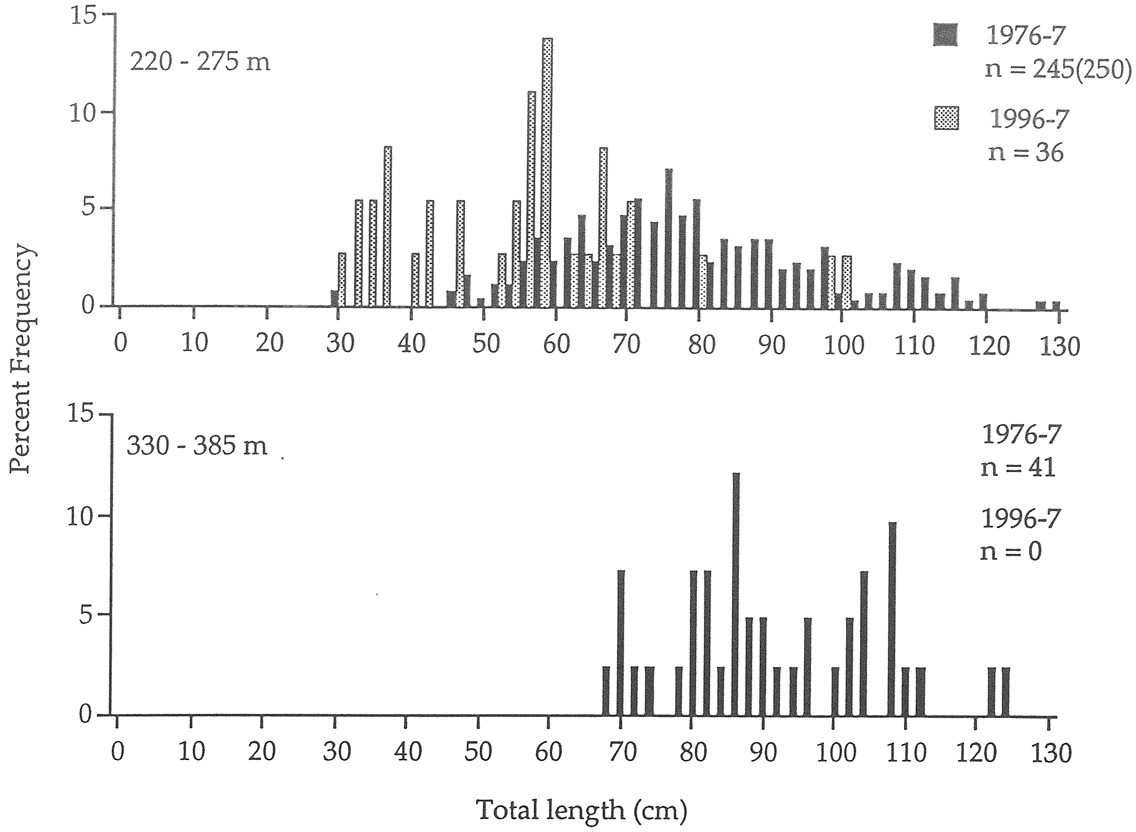
Figure 5.9.4. Length frequency distributions of male and female spotted warehou caught off Eden in 1996-7. Sample sizes indicated as n = total no. measured (total no. caught).



Eden

1976-7 n = 6
1996-7 n = 1

Figure 5.10.1. Length frequency distributions of angel shark caught in 1976-7 and 1996-7. Sample sizes indicated for 1976-7 are n = no. measured (total no. in tows sampled). For 1996-7, n = total no. caught, or when subsampled, n = total no. measured (total no. caught).



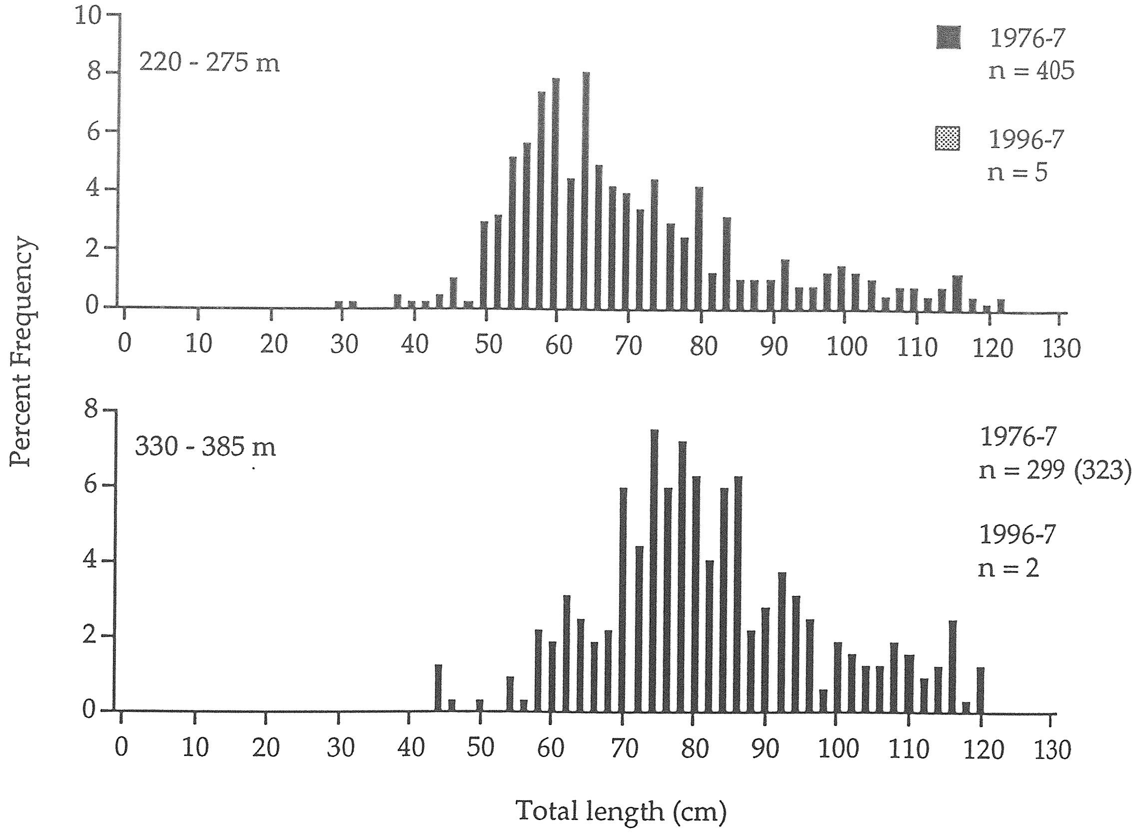
440 - 495 m

None measured

550 - 605 m

None measured

Figure 5.10.2. Length frequency distributions of angel shark caught off Sydney in 1976-7 and 1996-7. Sample sizes indicated for 1976-7 are n = no. measured (total no. in tows sampled). For 1996-7, n = total no. caught, or when subsampled, n = total no. measured (total no. caught).



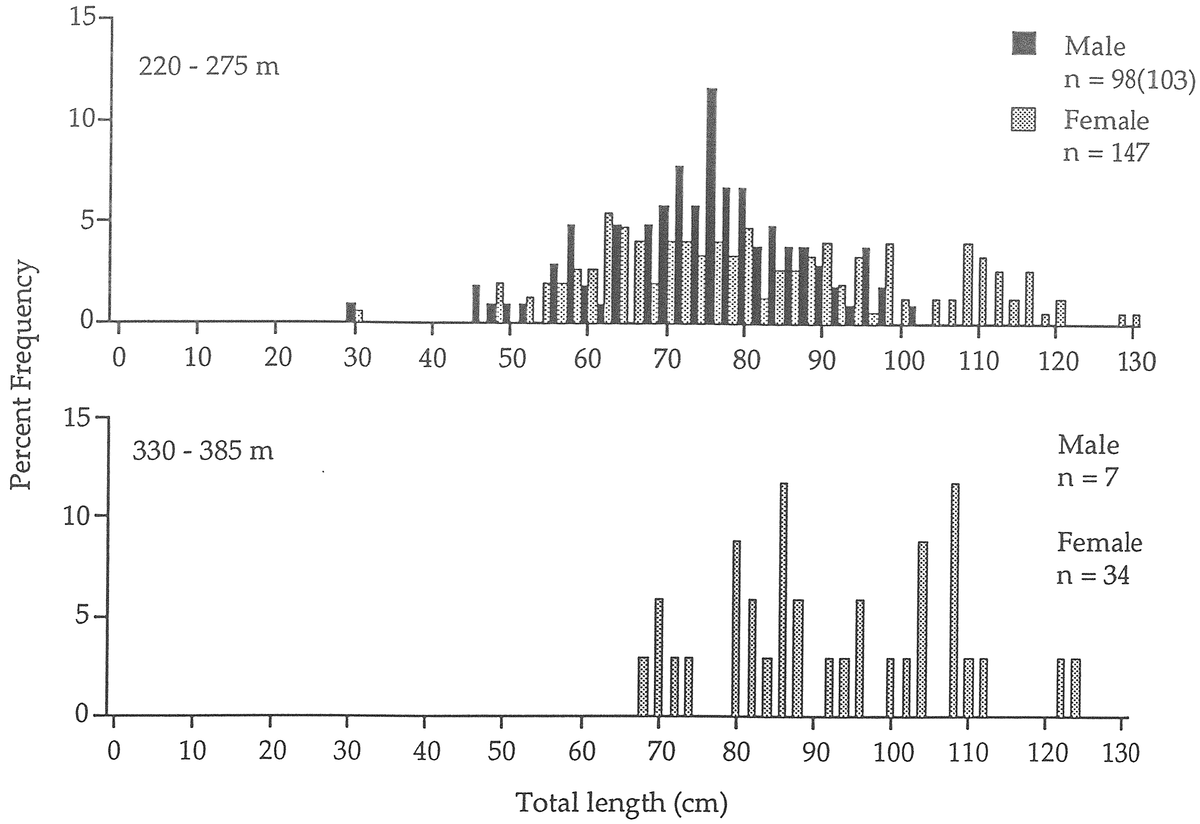
440 - 495 m

None measured

550 - 605 m

None measured

Figure 5.10.3. Length frequency distributions of angel shark caught off Ulladulla in 1976-7. Sample sizes indicated for 1976-7 are n = no. measured (total no. in tows sampled). For 1996-7, n = total no. caught, or when subsampled, n = total no. measured (total no. caught).



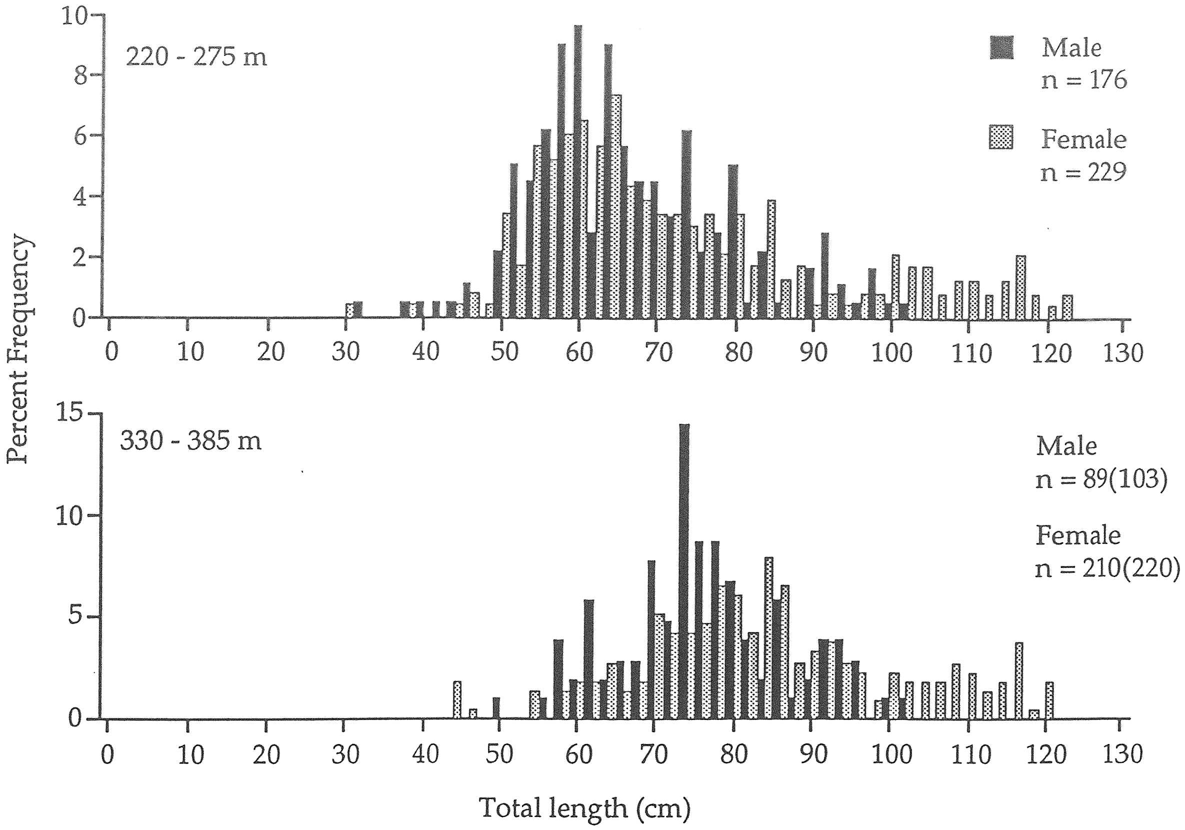
440 - 495 m

None measured

550 - 605 m

None measured

Figure 5.10.4. Length frequency distributions of male and female angel shark caught off Sydney in 1976-7. Sample sizes indicated as n = total no. caught, or when subsampled, n = total no. measured (total no. caught).



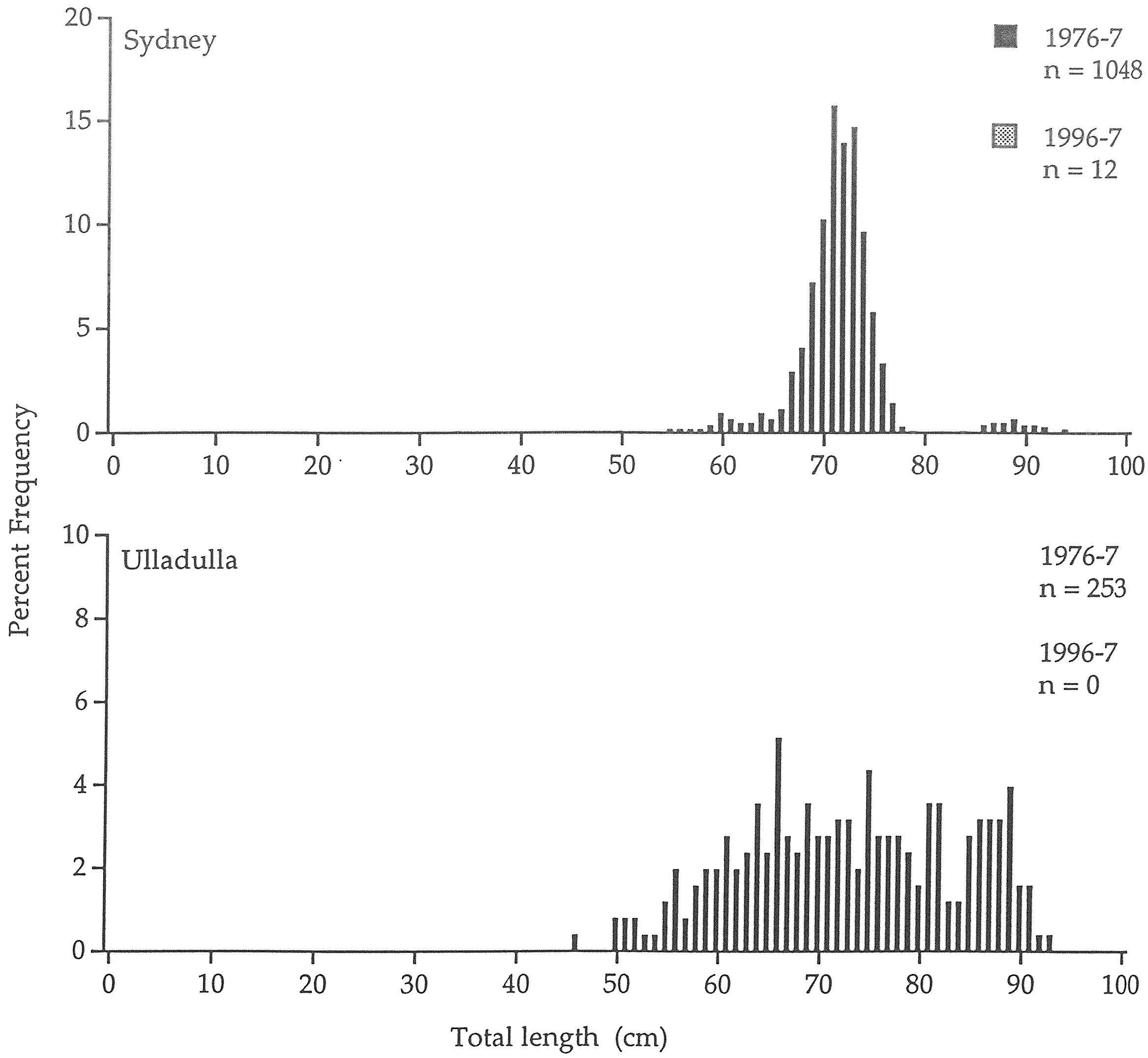
440 - 495 m

None measured

550 - 605 m

None measured

Figure 5.10.5. Length frequency distributions of male and female angel shark caught off Ulladulla in 1976-7. Sample sizes indicated as n = total no. caught, or when subsampled, n = total no. measured (total no. caught).



Eden

1976-7 n = 1
1996-7 n = 0

Figure 5.11.1. Length frequency distributions of Endeavour dogshark caught in 1976-7. Sample sizes indicated for 1976-7 are n = no. measured (total no. in tows sampled). For 1996-7, n = total no. caught, or when subsampled, n = total no. measured (total no. caught).

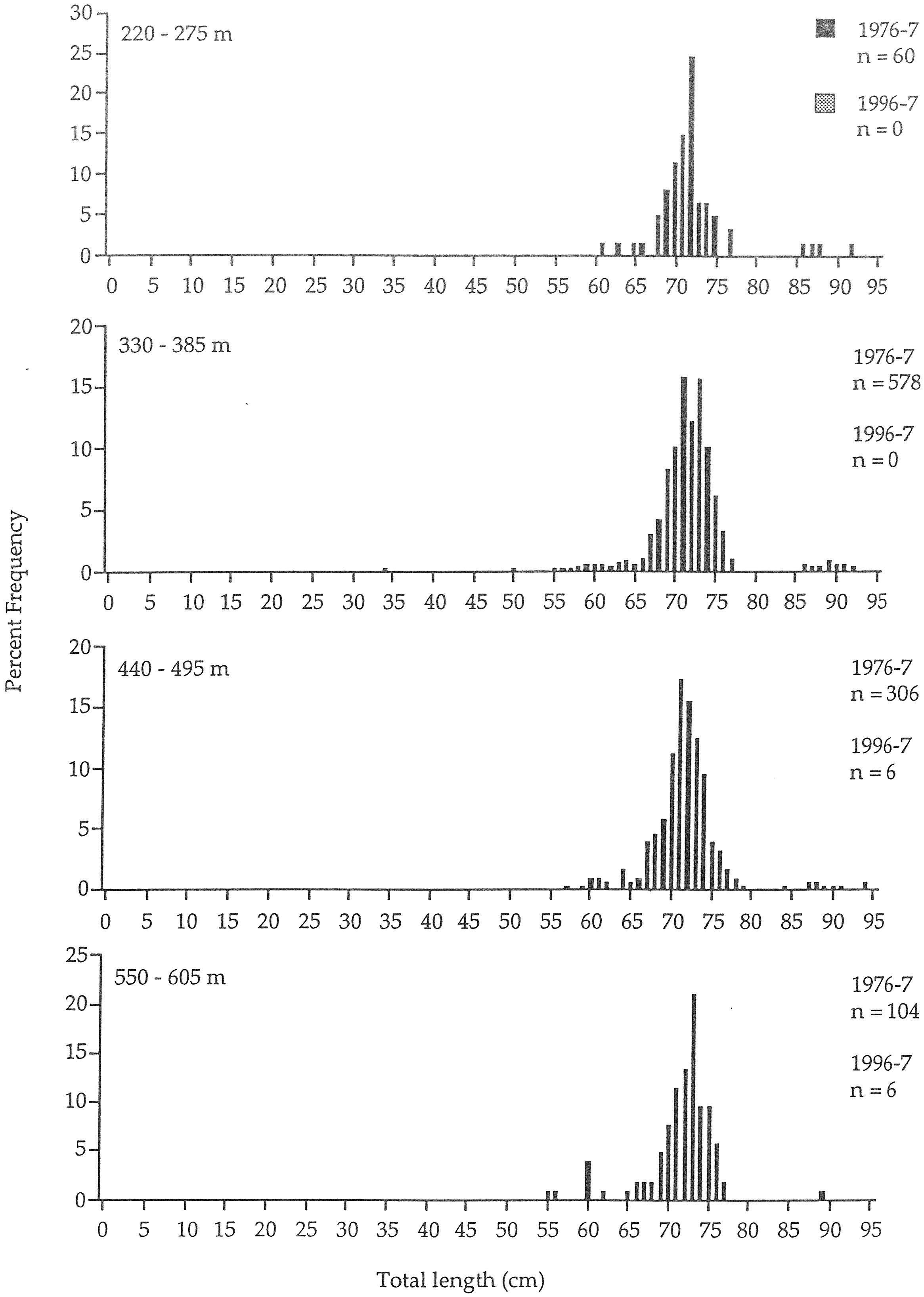
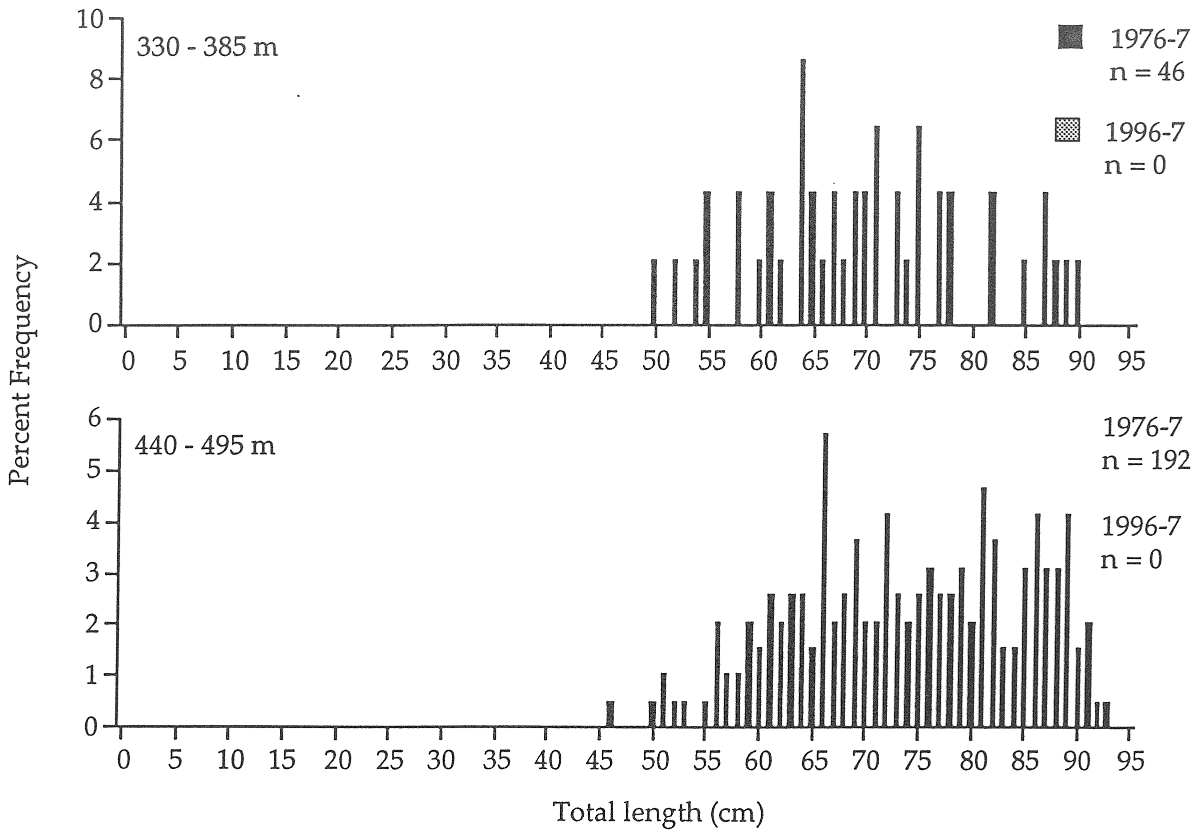


Figure 5.11.2. Length frequency distributions of Endeavour dogshark caught off Sydney in 1976-7. Sample sizes indicated for 1976-7 are n = no. measured (total no. in tows sampled). For 1996-7, n = total no. caught, or when subsampled, n = total no. measured (total no. caught).

220 - 275 m

1976-7 n = 8
1996-7 None measured



550 - 605 m

1976-7 n = 7
1996-7 None measured

Figure 5.11.3. Length frequency distributions of Endeavour dogshark caught off Ulladulla in 1976-7. Sample sizes indicated for 1976-7 are n = no. measured (total no. in tows sampled). For 1996-7, n = total no. caught, or when subsampled, n = total no. measured (total no. caught).

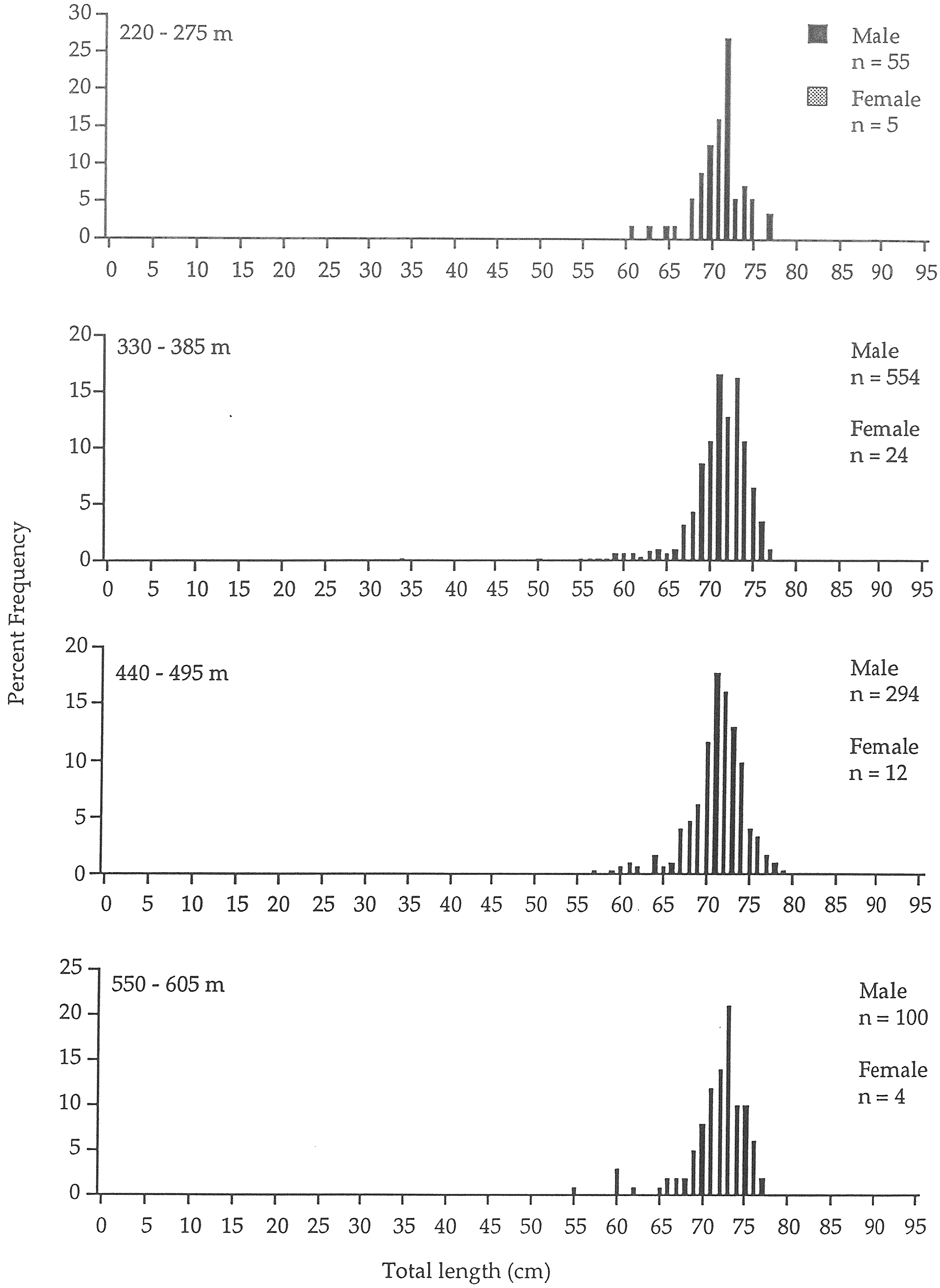
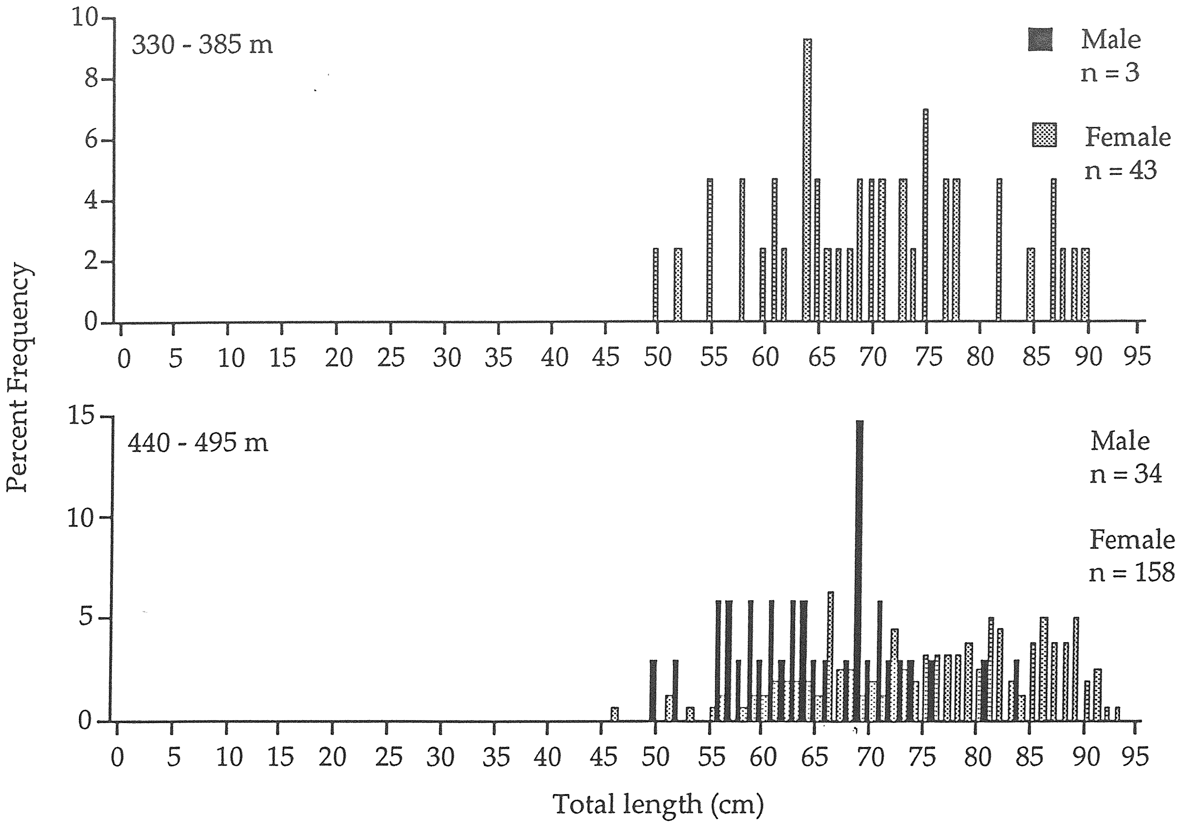


Figure 5.11.4. Length frequency distributions of male and female Endeavour dogshark caught off Sydney in 1976-7. Sample sizes indicated as n = total no. caught, or when subsampled, n = total no. measured (total no. caught).

220 - 275 m

Male n = 0
Female n = 8



550 - 605 m

Male n = 4
Female n = 3

Figure 5.11.5. Length frequency distributions of male and female Endeavour dogshark caught off Ulladulla in 1976-7. Sample sizes indicated as n = total no. caught, or when subsampled, n = total no. measured (total no. caught).

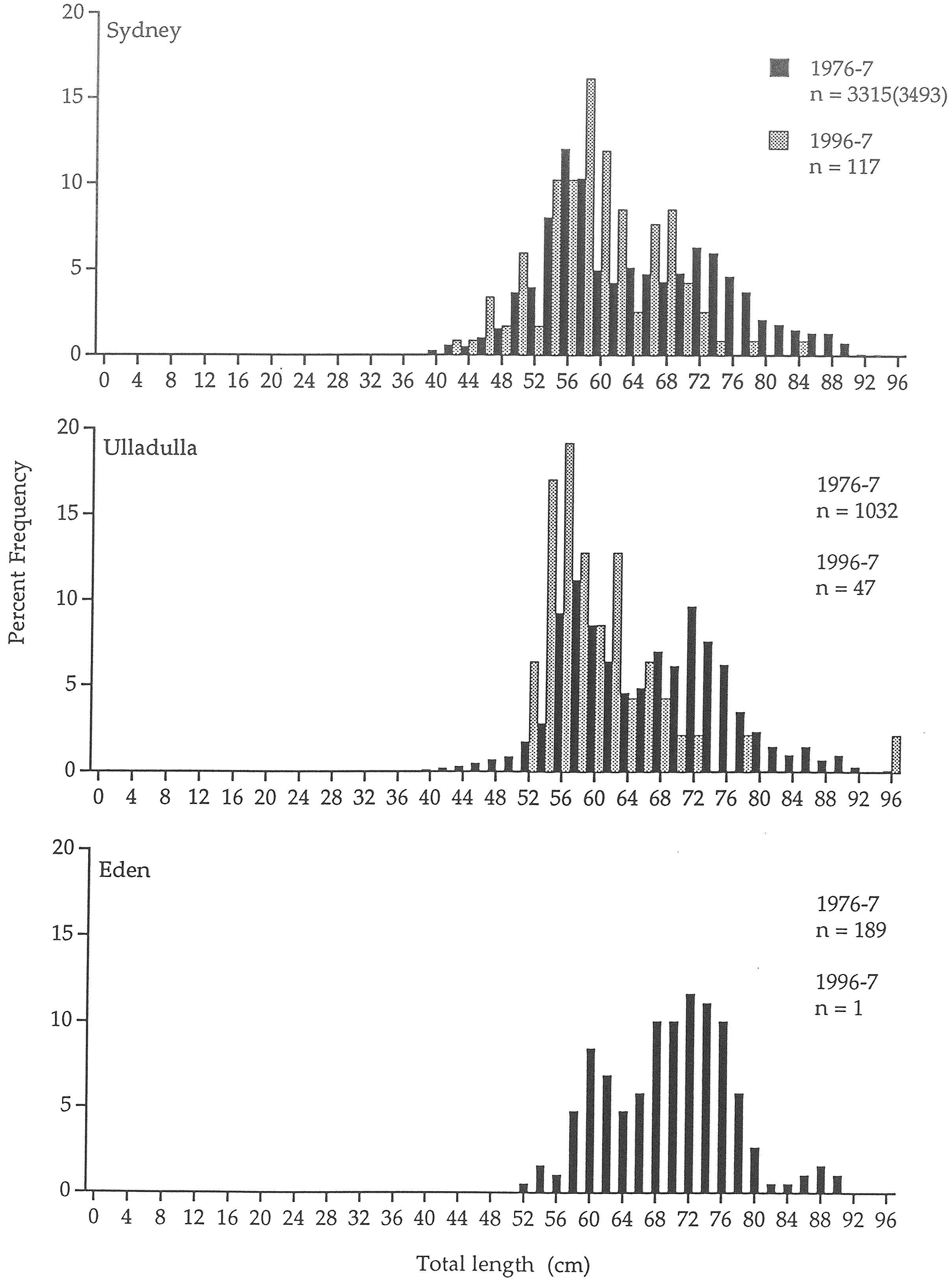


Figure 5.12.1. Length frequency distributions of greeneye dogshark caught in 1976-7 and 1996-7. Sample sizes indicated for 1976-7 are n = no. measured (total no. in tows sampled). For 1996-7, n = total no. caught, or when subsampled, n = total no. measured (total no. caught).

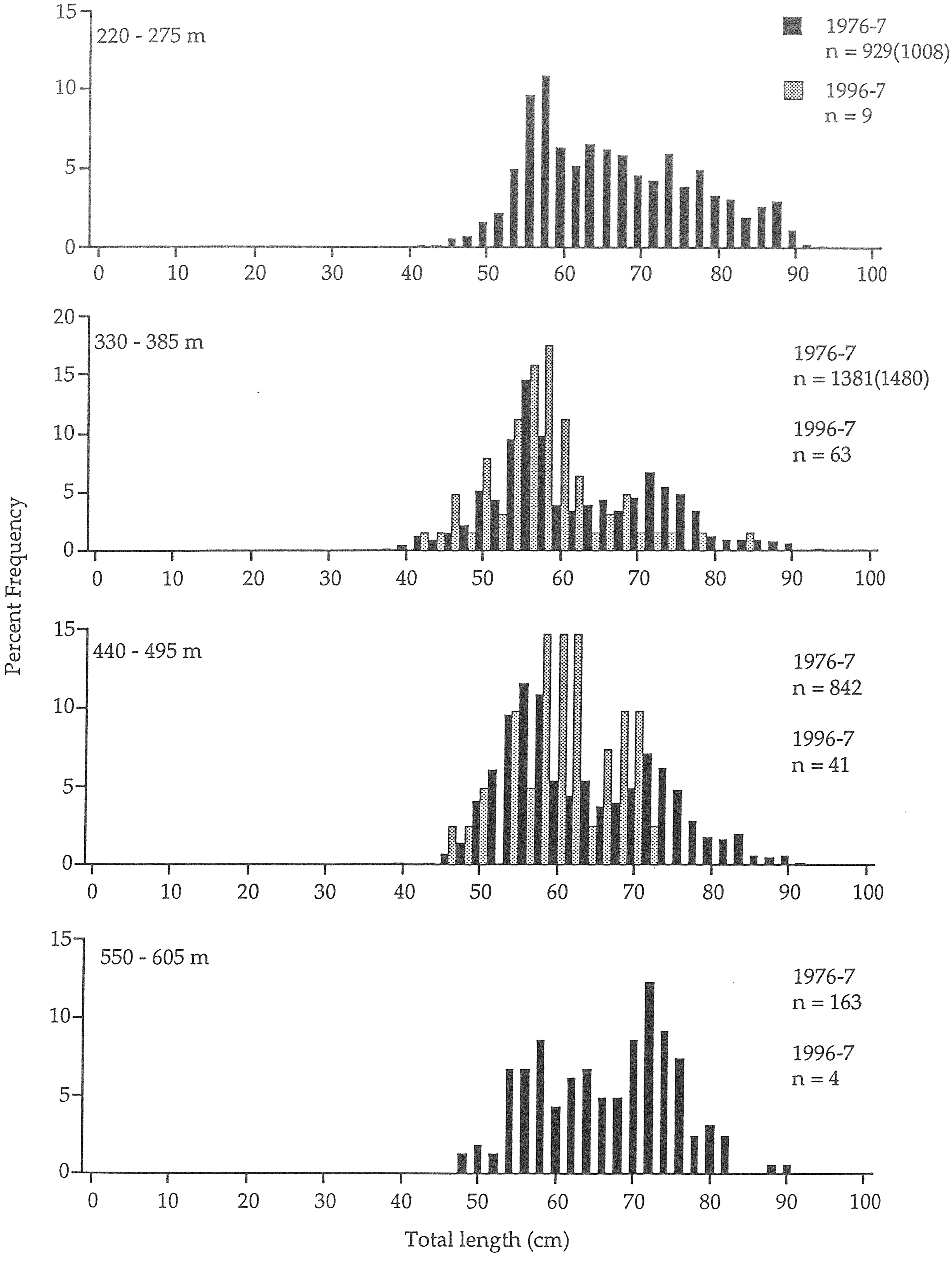


Figure 5.12.2. Length frequency distributions of greeneye dogshark caught off Sydney in 1976-7 and 1996-7. Sample sizes indicated for 1976-7 are n = no. measured (total no. in tows sampled). For 1996-7, n = total no. caught, or when subsampled, n = total no. measured (total no. caught).

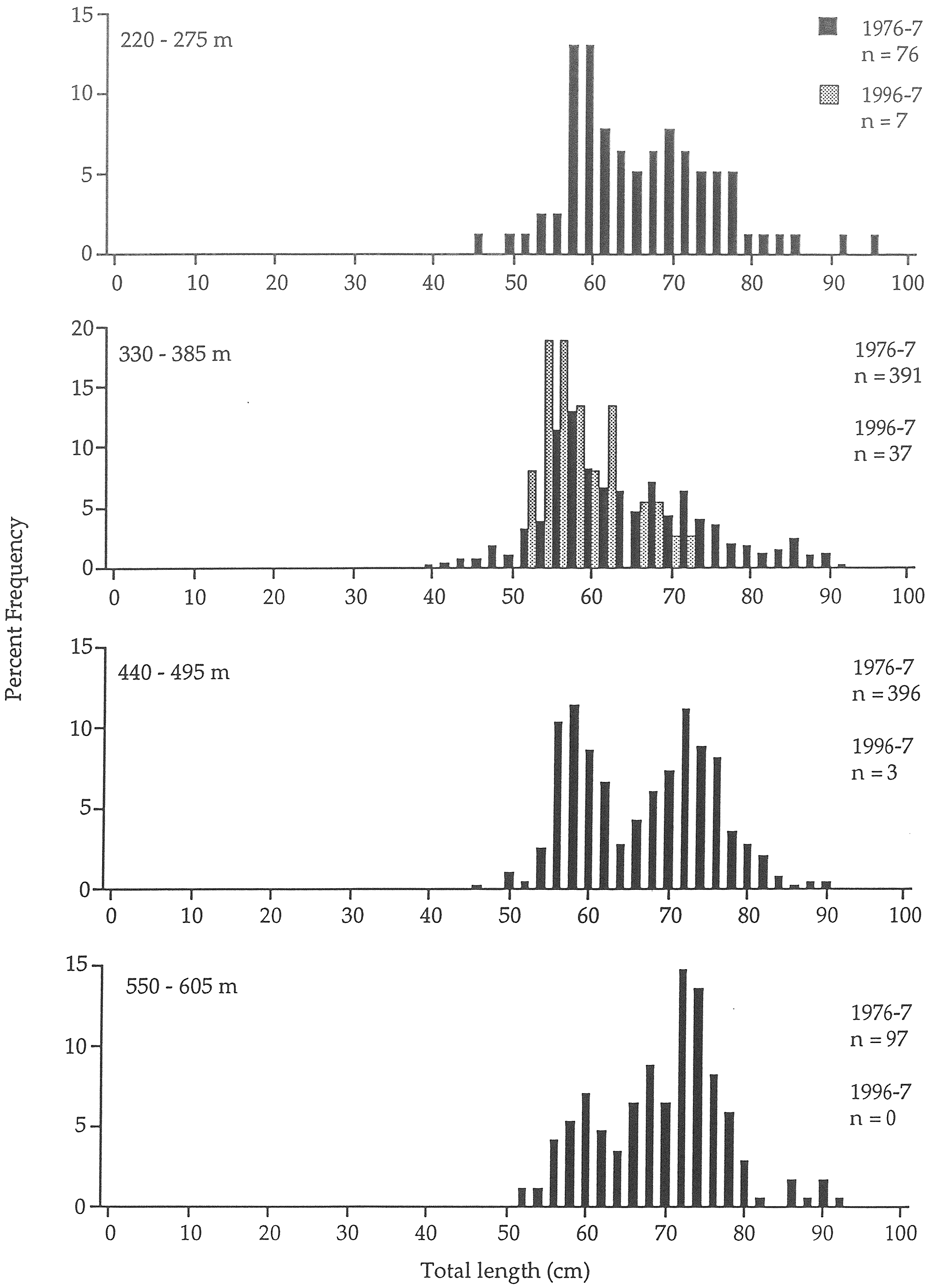
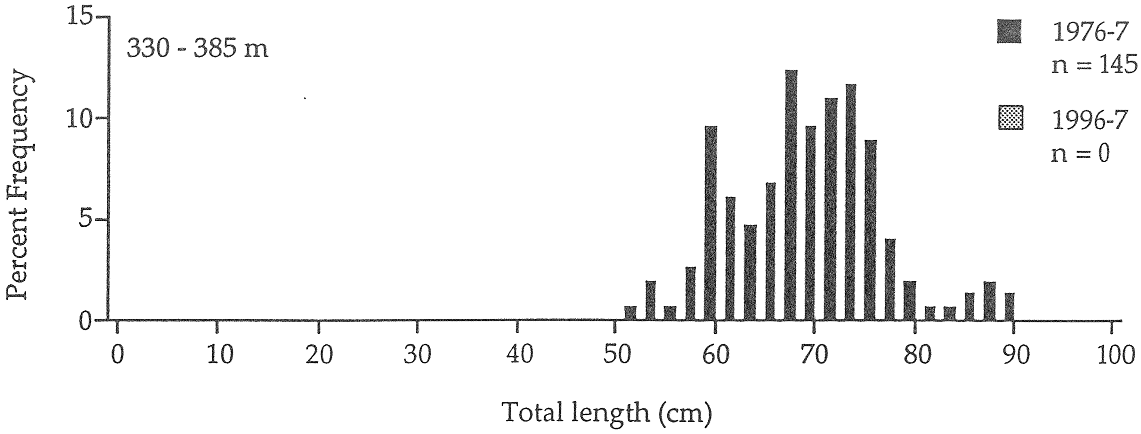


Figure 5.12.3. Length frequency distributions of greeneye dogshark caught off Ulladulla in 1976-7 and 1996-7. Sample sizes indicated for 1976-7 are n = no. measured (total no. in tows sampled). For 1996-7, n = total no. caught, or when subsampled, n = total no. measured (total no. caught).

220 - 275 m

1976-7 n = 5
1996-7 None measured



440 - 495 m

1976-7 n = 17
1996-7 n = 1

550 - 605 m

1976-7 n = 22
1996-7 None measured

Figure 5.12.4. Length frequency distributions of greeneye dogshark caught off Eden in 1976-7. Sample sizes indicated for 1976-7 are n = no. measured (total no. in tows sampled). For 1996-7, n = total no. caught, or when subsampled, n = total no. measured (total no. caught).

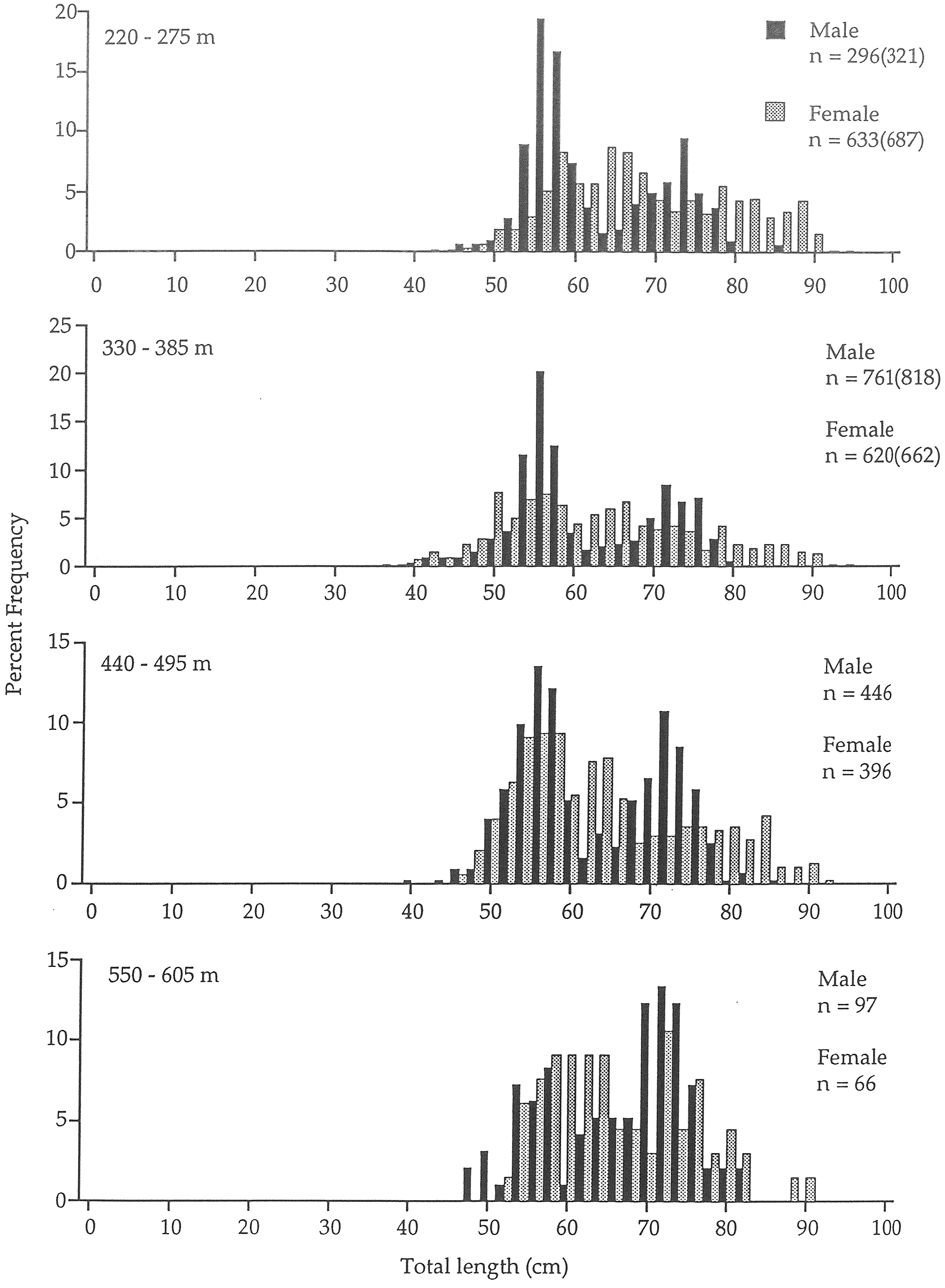


Figure 5.12.5. Length frequency distributions of male and female greeneye dogshark caught off Sydney in 1976-7. Sample sizes indicated as n = total no. caught, or when subsampled, n = total no. measured (total no. caught).

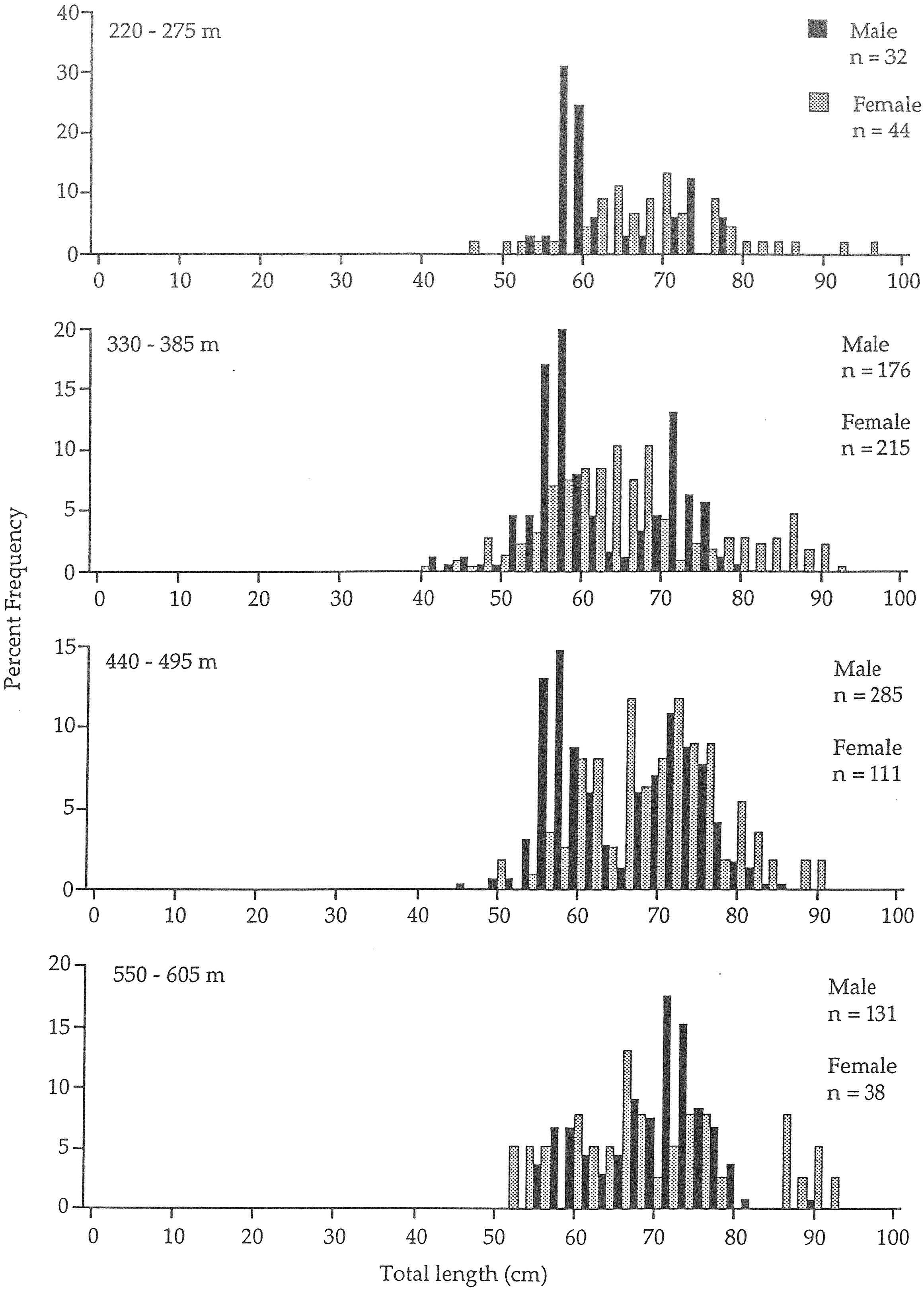
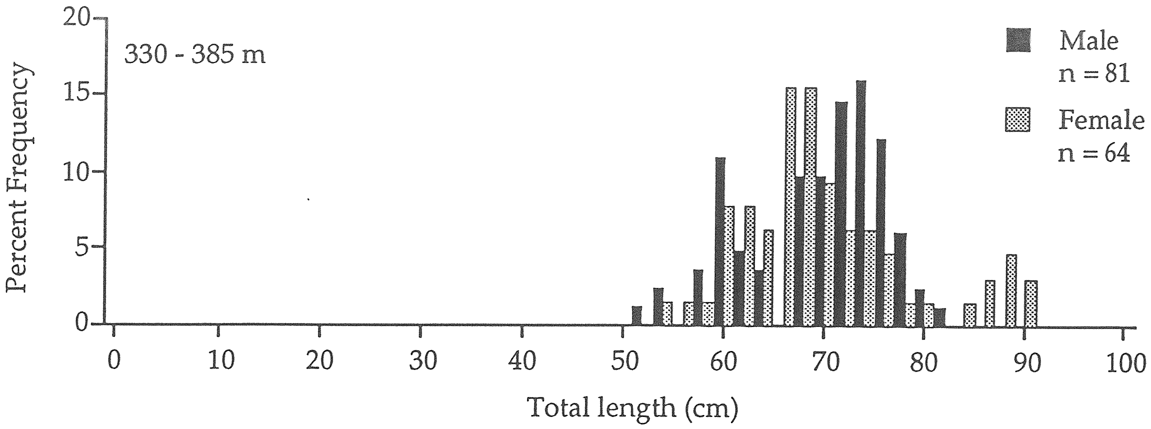


Figure 5.12.6. Length frequency distributions of male and female greeneye dogshark caught off Ulladulla in 1976-7. Sample sizes indicated as n = total no. caught, or when subsampled, n = total no. measured (total no. caught).

220 - 275 m

Male n = 3
Female n = 2



440 - 495 m

Male n = 16
Female n = 1

550 - 605 m

Male n = 20
Female n = 2

Figure 5.12.7. Length frequency distributions of male and female greeneye dogshark caught off Eden in 1976-7. Sample sizes indicated as n = total no. caught, or when subsampled, n = total no. measured (total no. caught).

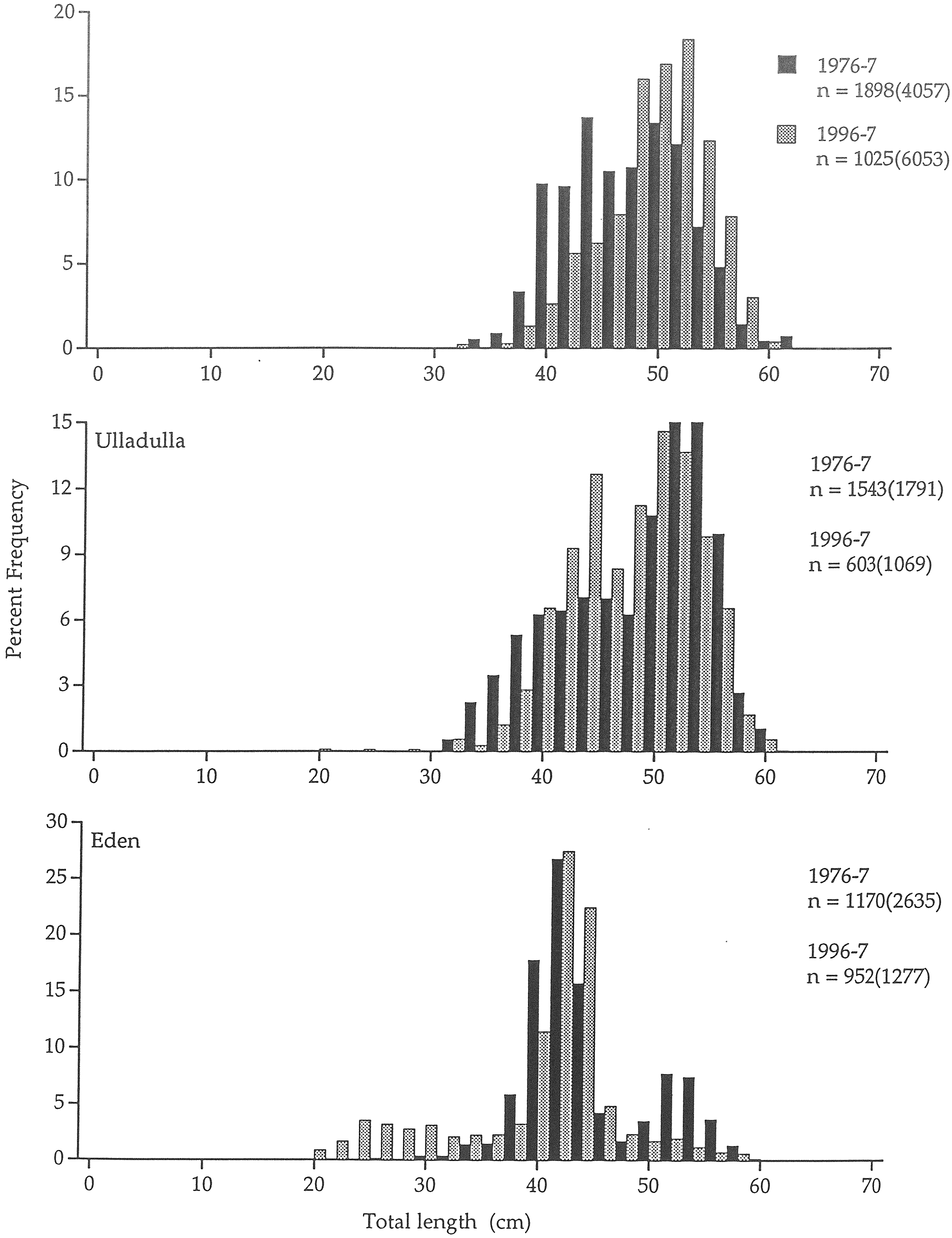
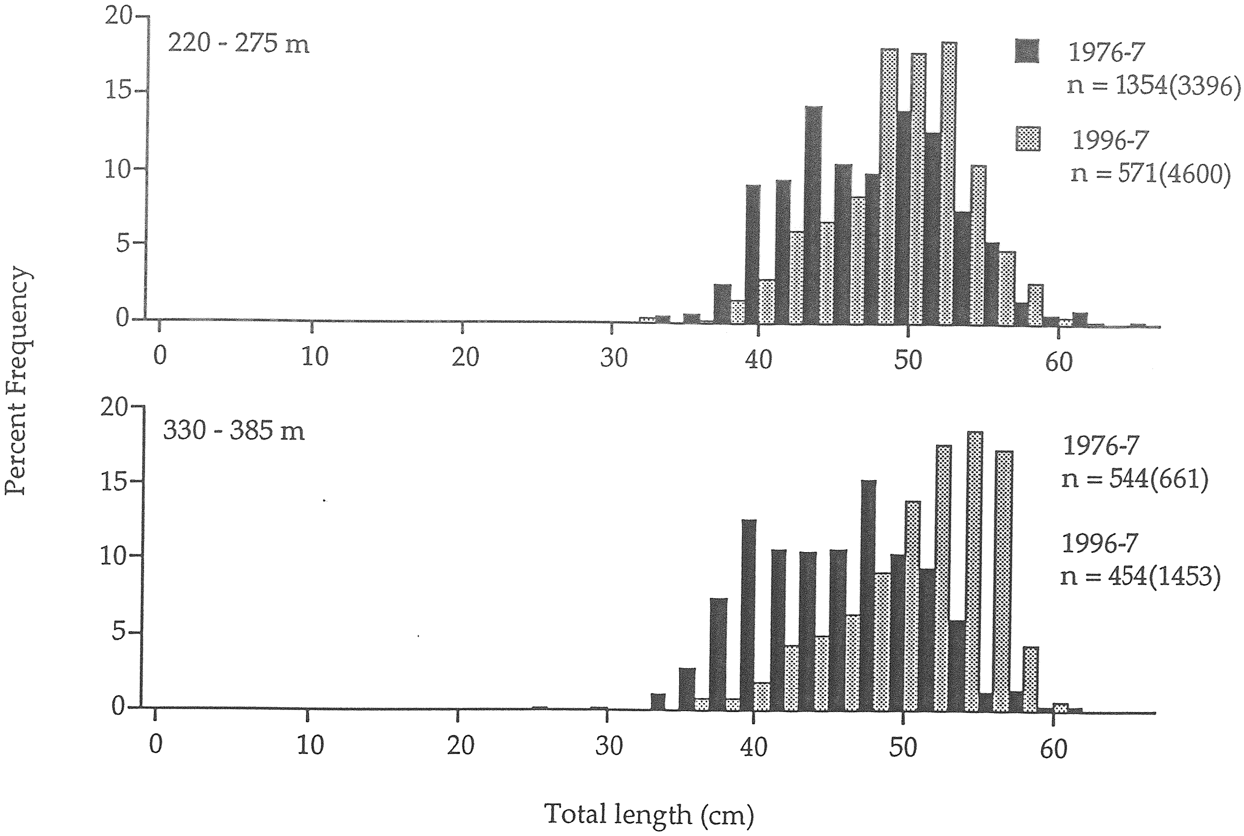


Figure 5.13.1. Length frequency distributions of spiky dogshark caught in 1976-7 and 1996-7. Sample sizes indicated for 1976-7 are n = no. measured (total no. in tows sampled). For 1996-7, n = total no. caught, or when subsampled, n = total no. measured (total no. caught).



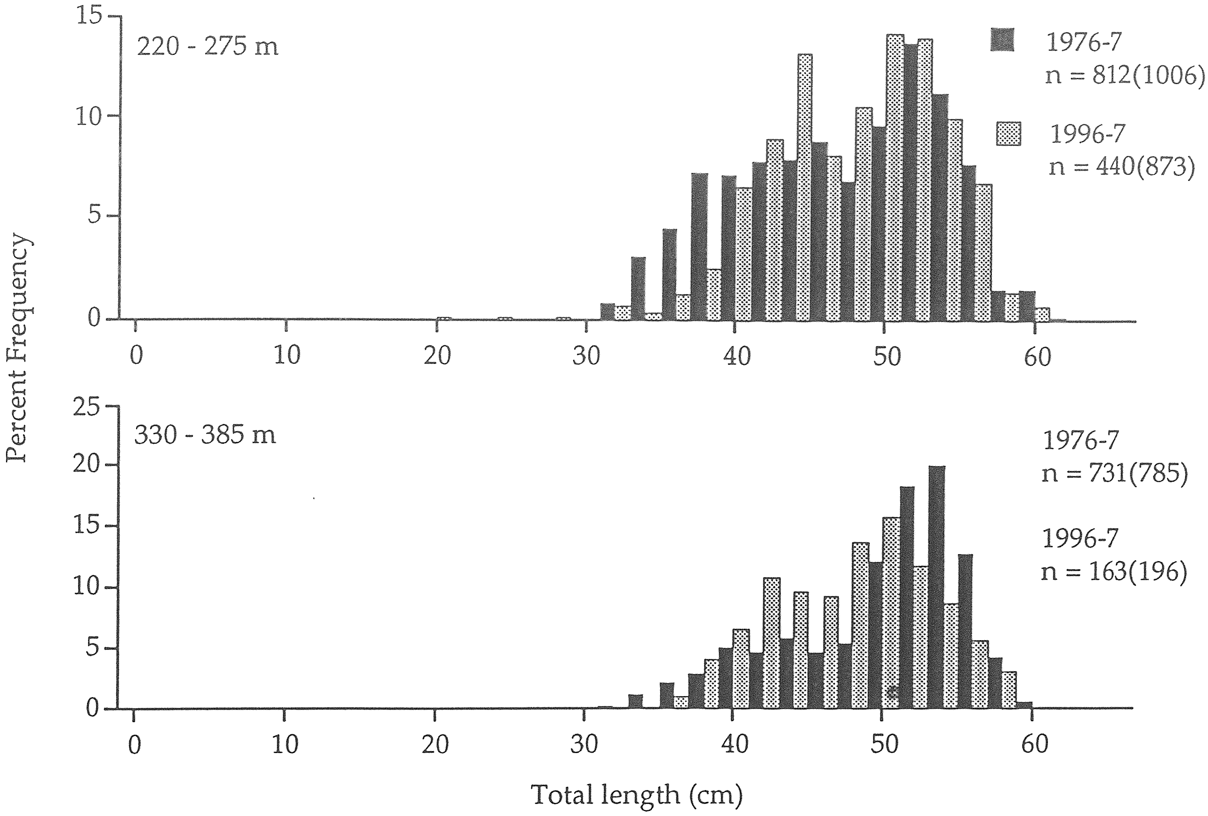
440 - 495 m

None measured

550 - 605 m

None measured

Figure 5.13.2. Length frequency distributions of spiky dogshark caught off Sydney in 1976-7 and 1996-7. Sample sizes indicated for 1976-7 are n = no. measured (total no. in tows sampled). For 1996-7, n = total no. caught, or when subsampled, n = total no. measured (total no. caught).



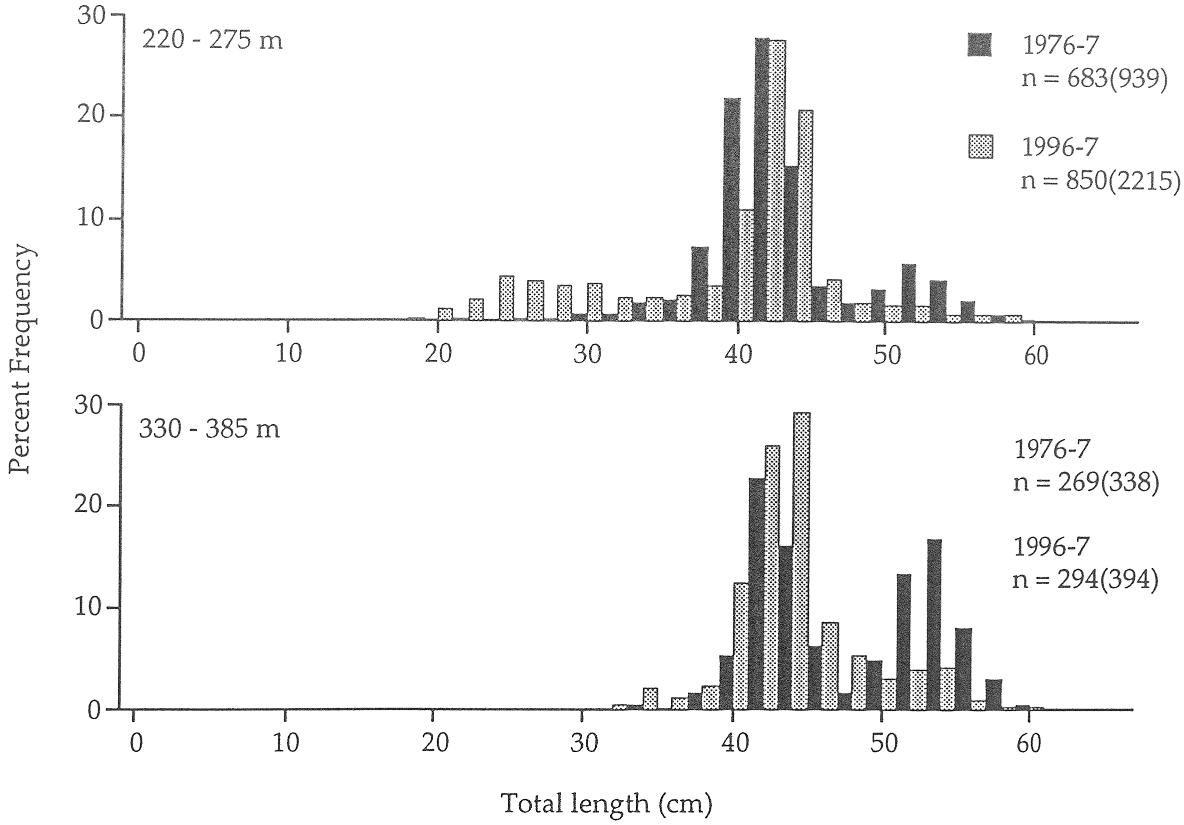
440 - 495 m

None measured

550 - 605 m

None measured

Figure 5.13.3. Length frequency distributions of spiky dogshark caught off Ulladulla in 1976-7 and 1996-7. Sample sizes indicated for 1976-7 are n = no. measured (total no. in tows sampled). For 1996-7, n = total no. caught, or when subsampled, n = total no. measured (total no. caught).



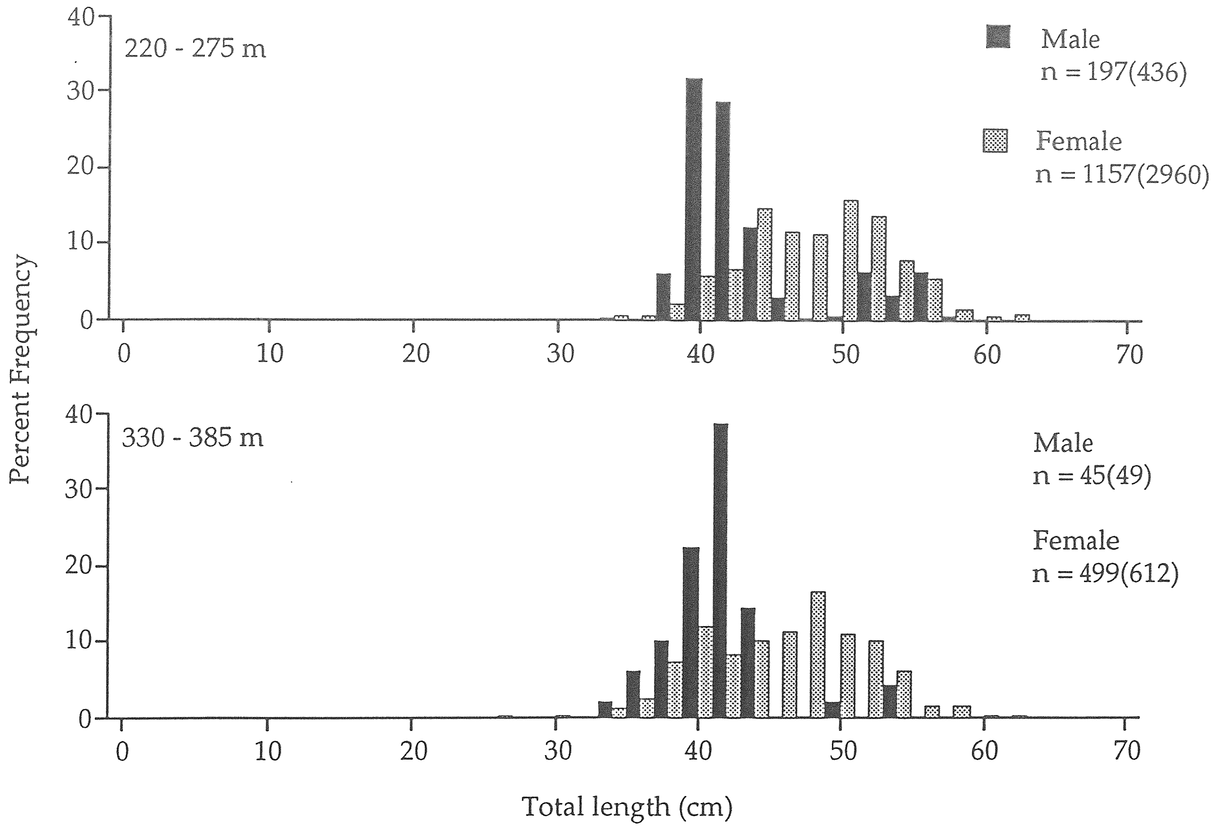
440 - 495 m

1976-7 None measured
1996-7 n = 26

550 - 605 m

None measured

Figure 5.13.4. Length frequency distributions of spiky dogshark caught off Eden in 1976-7 and 1996-7. Sample sizes indicated for 1976-7 are n = no. measured (total no. in tows sampled). For 1996-7, n = total no. caught, or when subsampled, n = total no. measured (total no. caught).



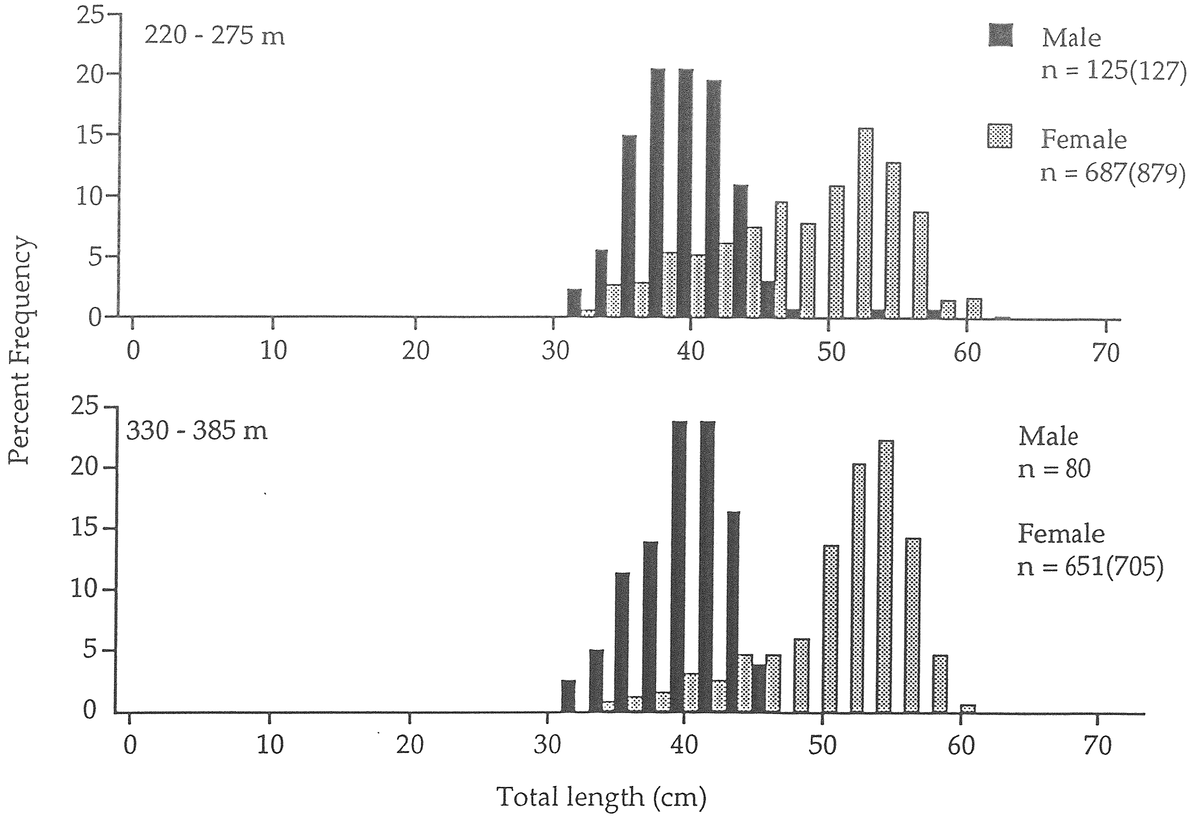
440 - 495 m

None measured

550 - 605 m

None measured

Figure 5.13.5. Length frequency distributions of male and female spiky dogshark caught off Sydney in 1976-7. Sample sizes indicated as n = total no. caught, or when subsampled, n = total no. measured (total no. caught).



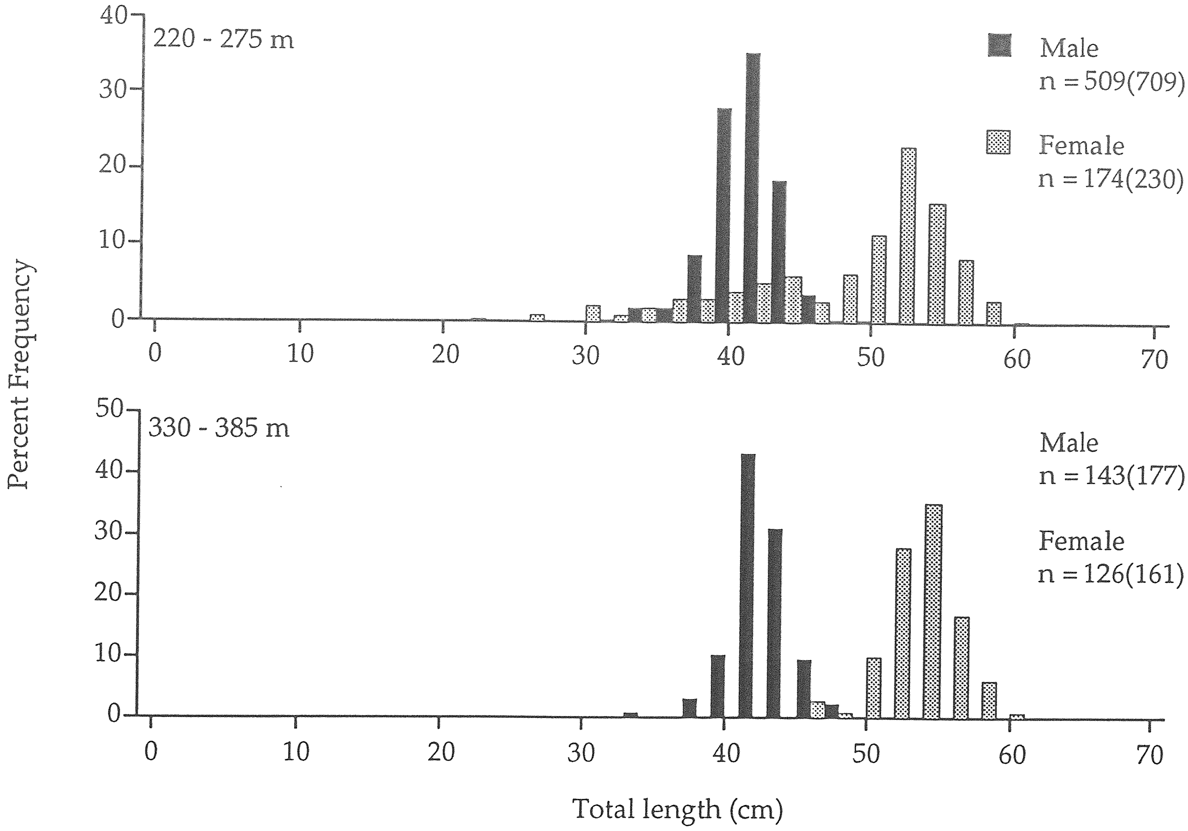
440 - 495 m

None measured

550 - 605 m

None measured

Figure 5.13.6. Length frequency distributions of male and female spiky dogshark caught off Ulladulla in 1976-7. Sample sizes indicated as n = total no. measured (total no. in tows sampled).



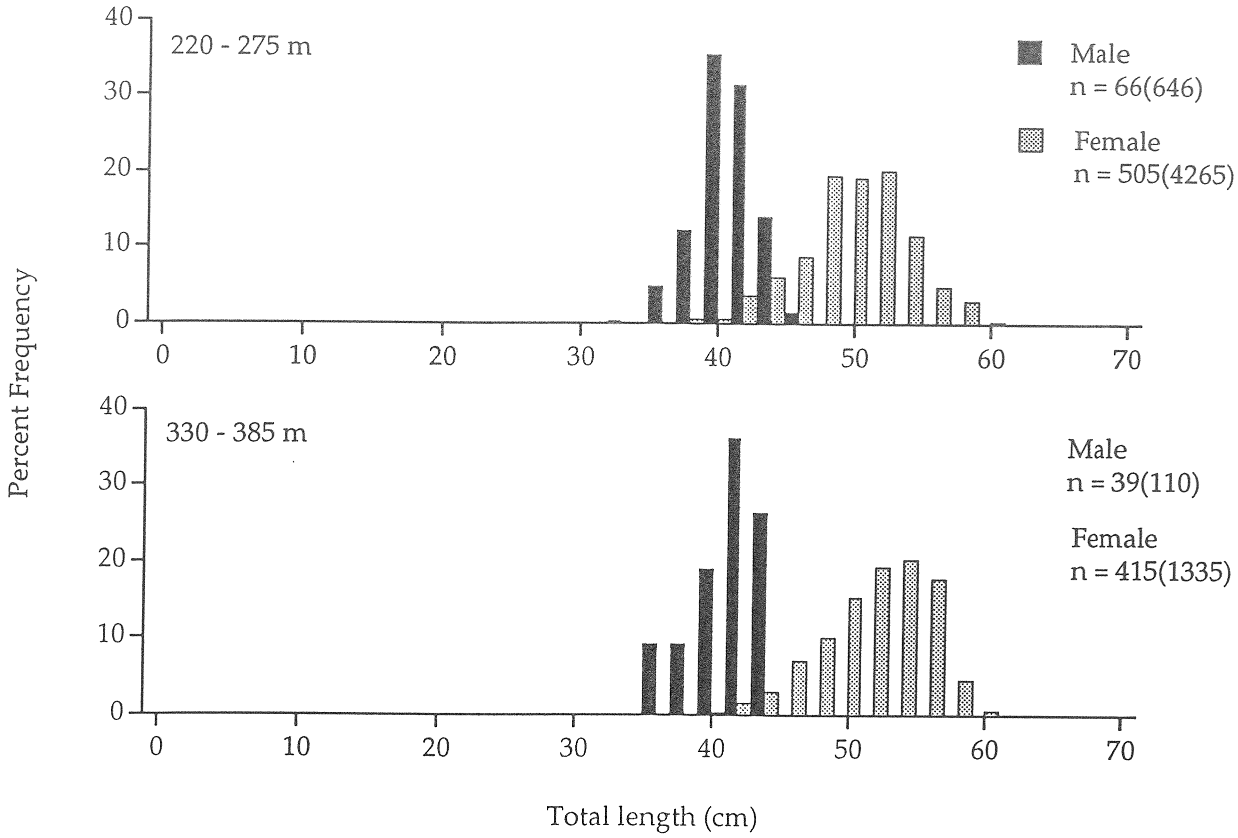
440 - 495 m

None measured

550 - 605 m

None measured

Figure 5.13.7. Length frequency distributions of male and female spiky dogshark caught off Eden in 1976-7. Sample sizes indicated as n = total no. caught, or when subsampled, n = total no. measured (total no. caught).



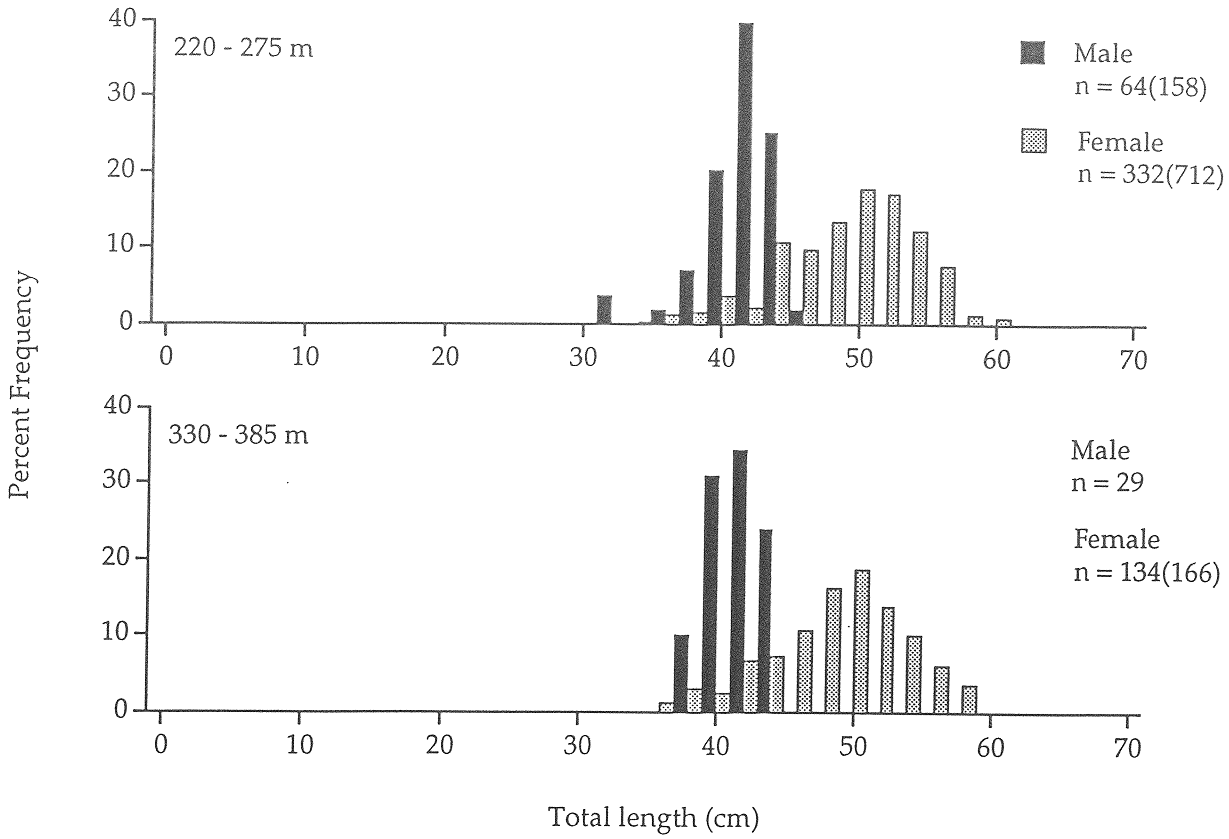
440 - 495 m

None caught

550 - 605 m

None caught

Figure 5.13.8. Length frequency distributions of male and female spiky dogshark caught off Sydney in 1996-7. Sample sizes indicated as n = total no. caught, or when subsampled, n = total no. measured (total no. caught).



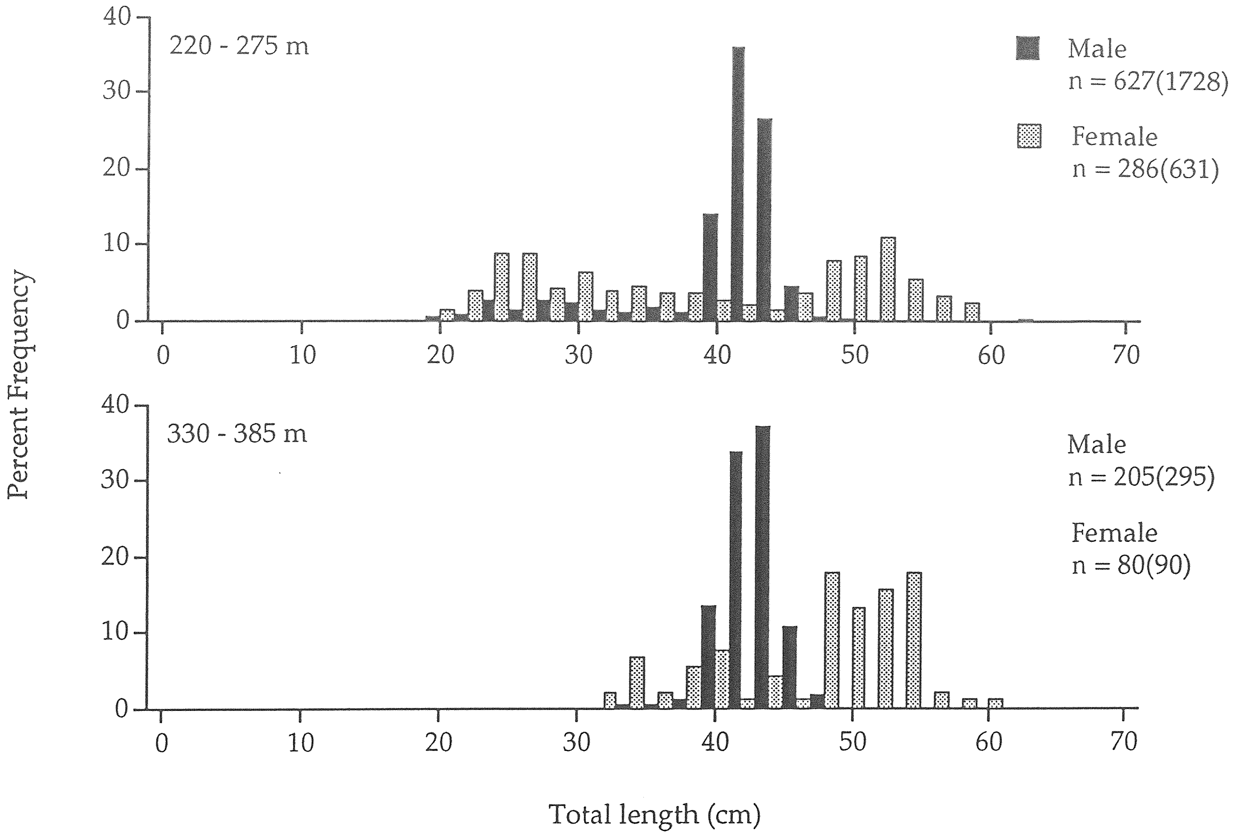
440 - 495 m

None caught

550 - 605 m

None caught

Figure 5.13.9. Length frequency distributions of male and female spiky dogshark caught off Ulladulla in 1996-7. Sample sizes indicated as n = total no. caught, or when subsampled, n = total no. measured (total no. caught).



440 - 495 m

Male n = 18
Female n = 4

550 - 605 m

None caught

Figure 5.13.10. Length frequency distributions of male and female spiky dogshark caught off Eden in 1996-7. Sample sizes indicated as n = total no. caught, or when subsampled, n = total no. measured (total no. caught).

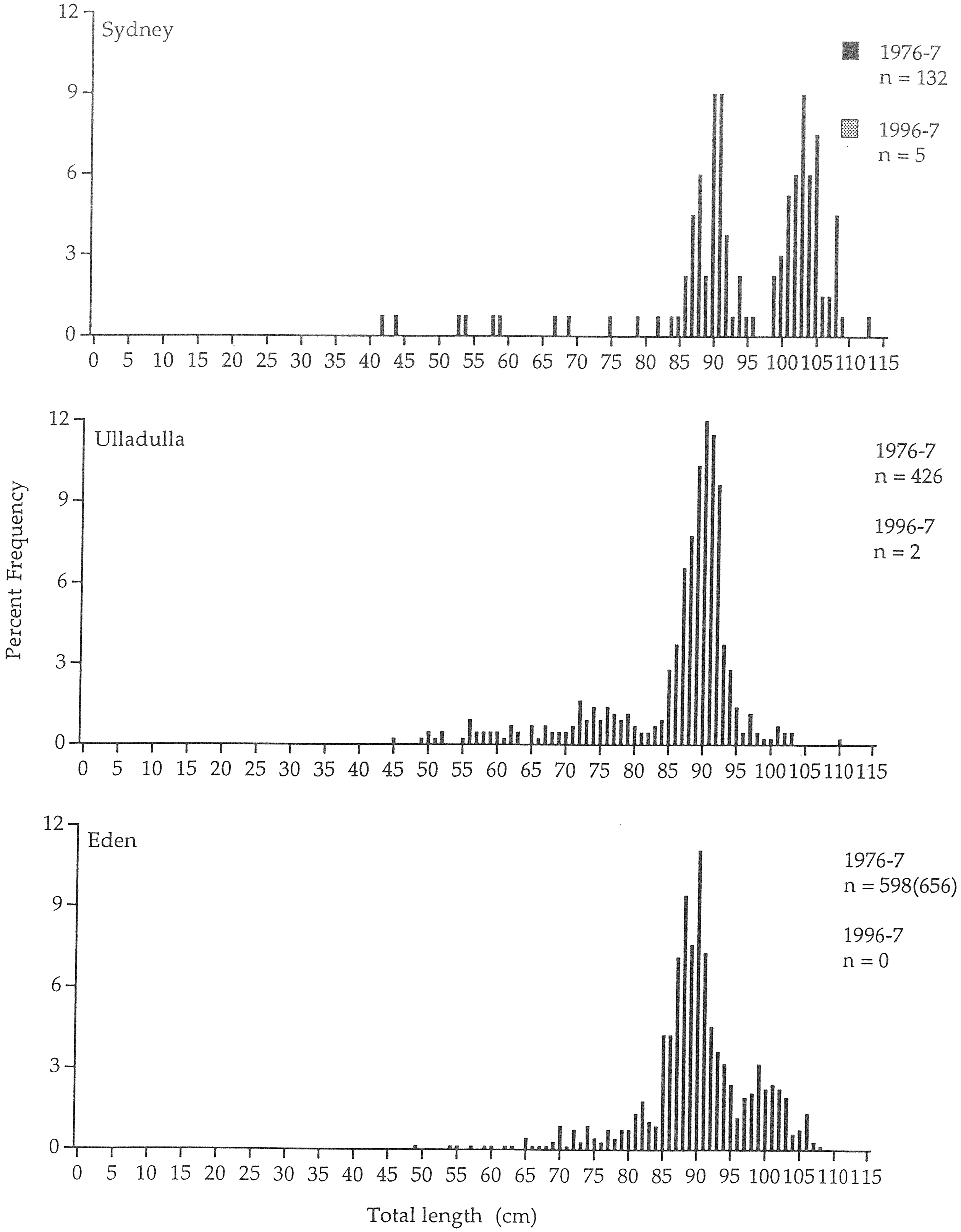


Figure 5.14.1. Length frequency distributions of Harrissons dogshark caught in 1976-7. Sample sizes indicated for 1976-7 are n = no. measured (total no. in tows sampled). For 1996-7, n = total no. caught, or when subsampled, n = total no. measured (total no. caught).

220 - 275 m

1976-7 n = 7
1996-7 None measured

330 - 385 m

1976-7 n = 20
1996-7 None measured

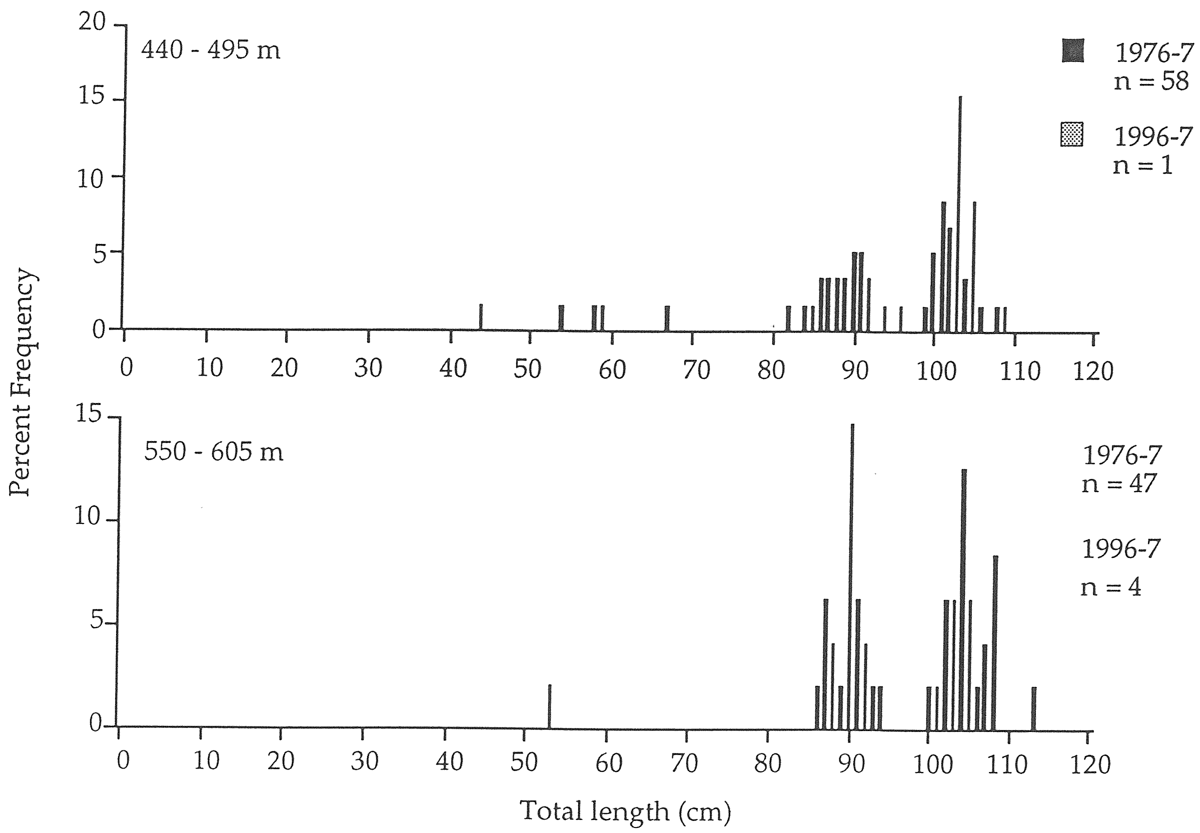


Figure 5.14.2. Length frequency distributions of Harrissons dogshark caught off Sydney in 1976-7. Sample sizes indicated for 1976-7 are n = no. measured (total no. in tows sampled). For 1996-7, n = total no. caught, or when subsampled, n = total no. measured (total no. caught).

220 - 275 m

1976-7 n = 20
1996-7 None measured

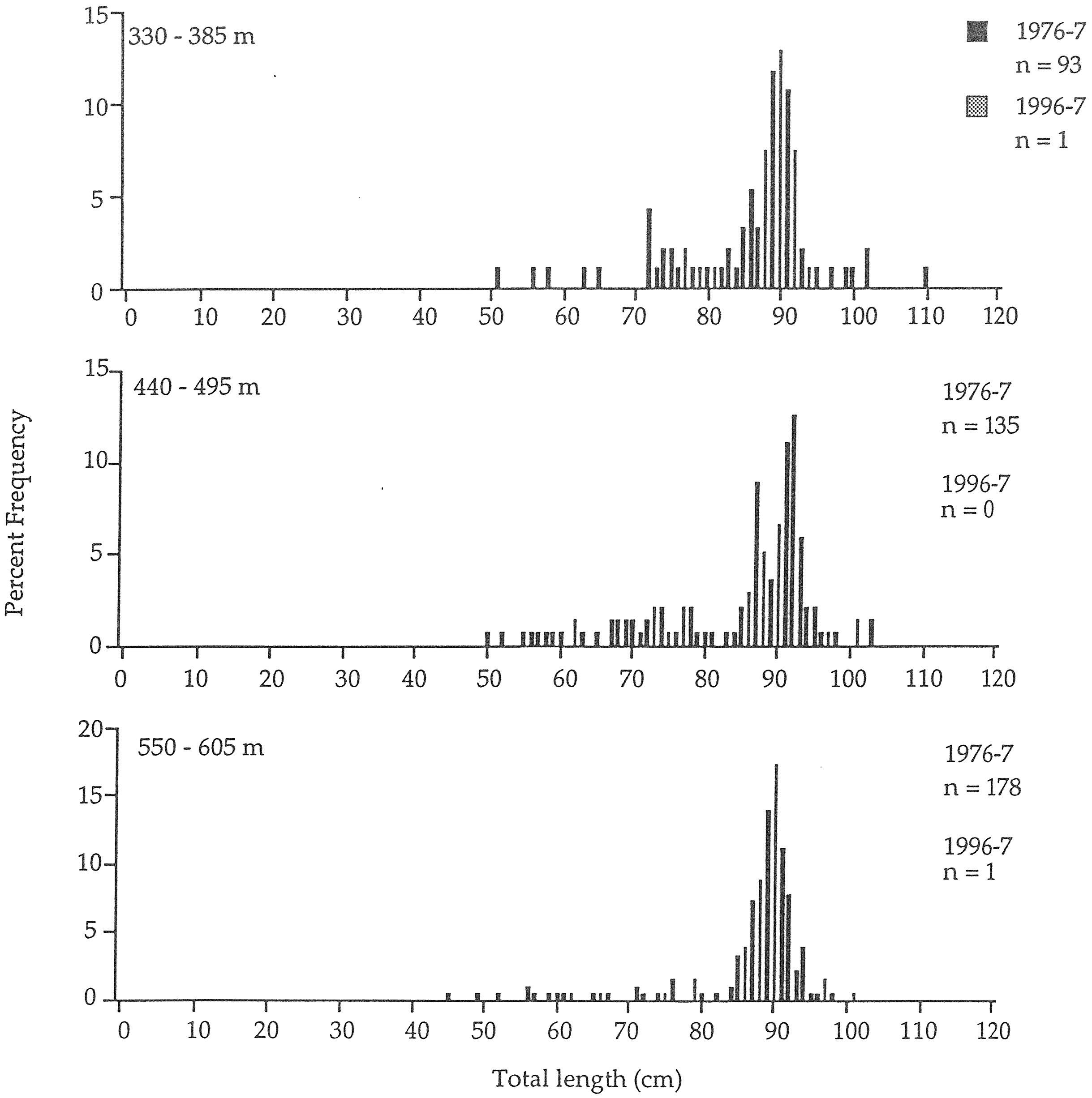


Figure 5.14.3. Length frequency distributions of Harrissons dogshark caught off Ulladulla in 1976-7. Sample sizes indicated for 1976-7 are n = no. measured (total no. in tows sampled). For 1996-7, n = total no. caught, or when subsampled, n = total no. measured (total no. caught).

220 - 275 m

1976-7 n = 9
1996 None measured

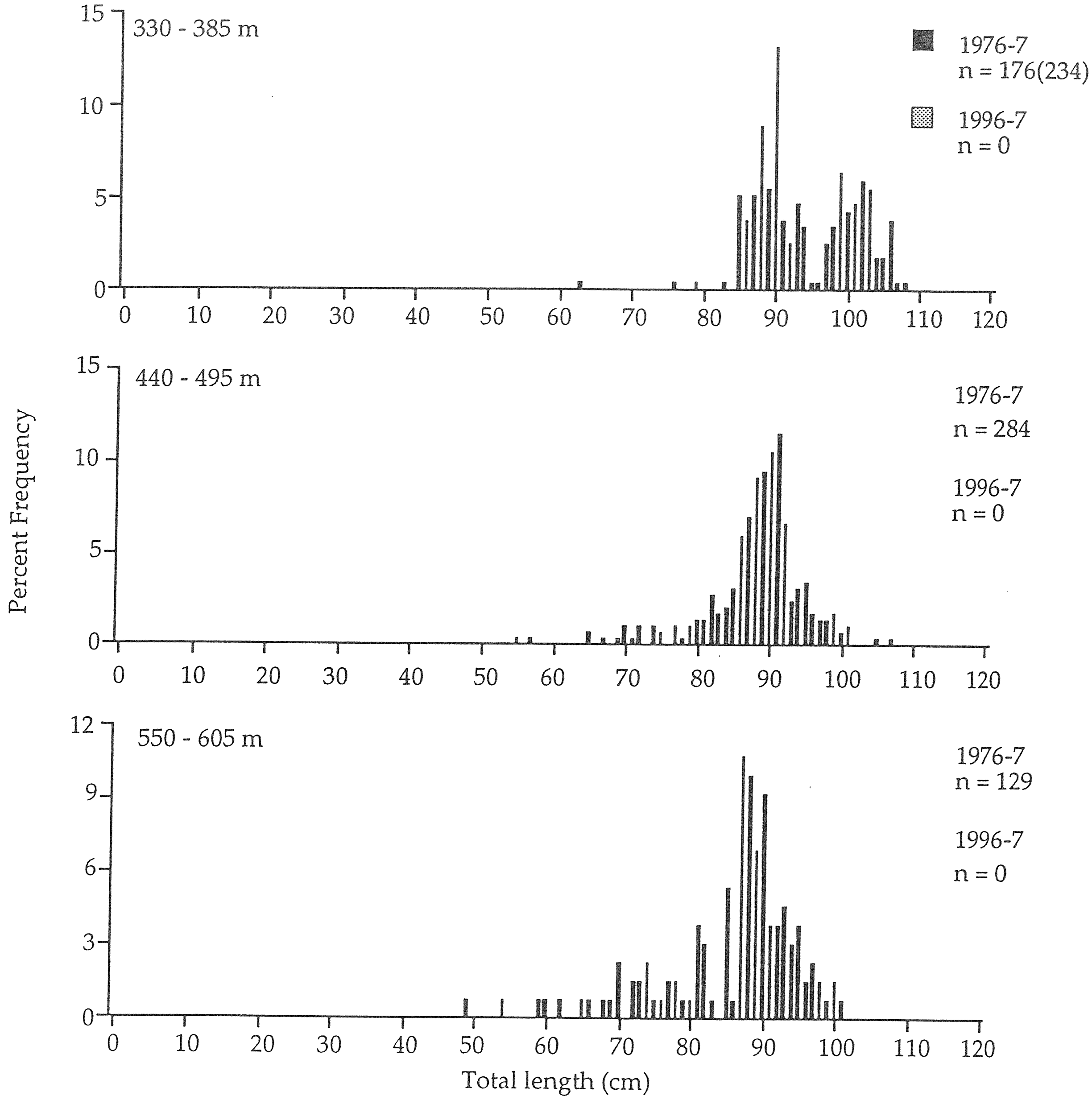


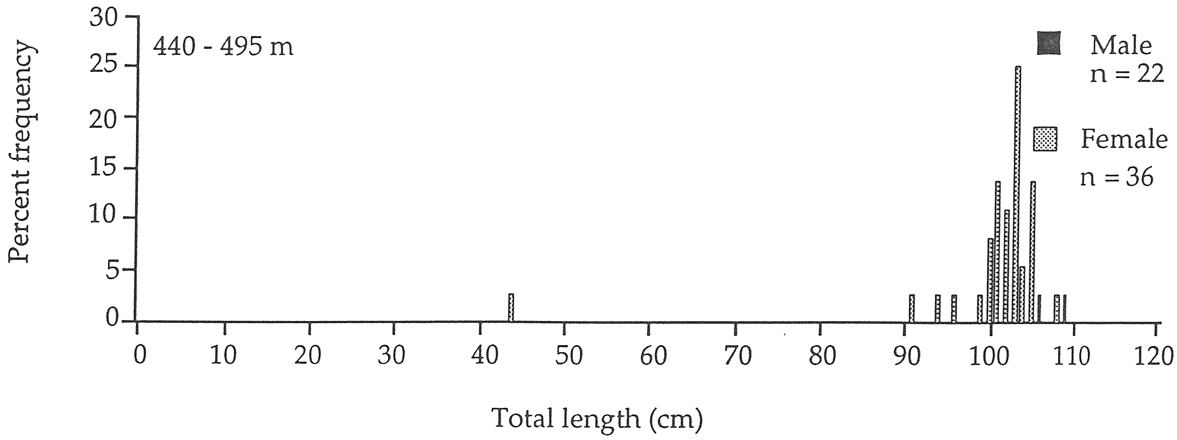
Figure 5.14.4. Length frequency distributions of Harrissons dogshark caught off Eden in 1976-7. Sample sizes indicated for 1976-7 are n = no. measured (total no. in tows sampled). For 1996-7, n = total no. caught, or when subsampled, n = total no. measured (total no. caught).

220 - 275 m

Male n = 7
Female n = 0

330 - 385 m

Male n = 9
Female n = 11



550 - 605 m

Male n = 21
Female n = 26

Figure 5.14.5. Length frequency distributions of male and female Harrissons dogshark caught off Sydney in 1976-7. Sample sizes indicated as n = total no. caught, or when subsampled, n = total no. measured (total no. caught).

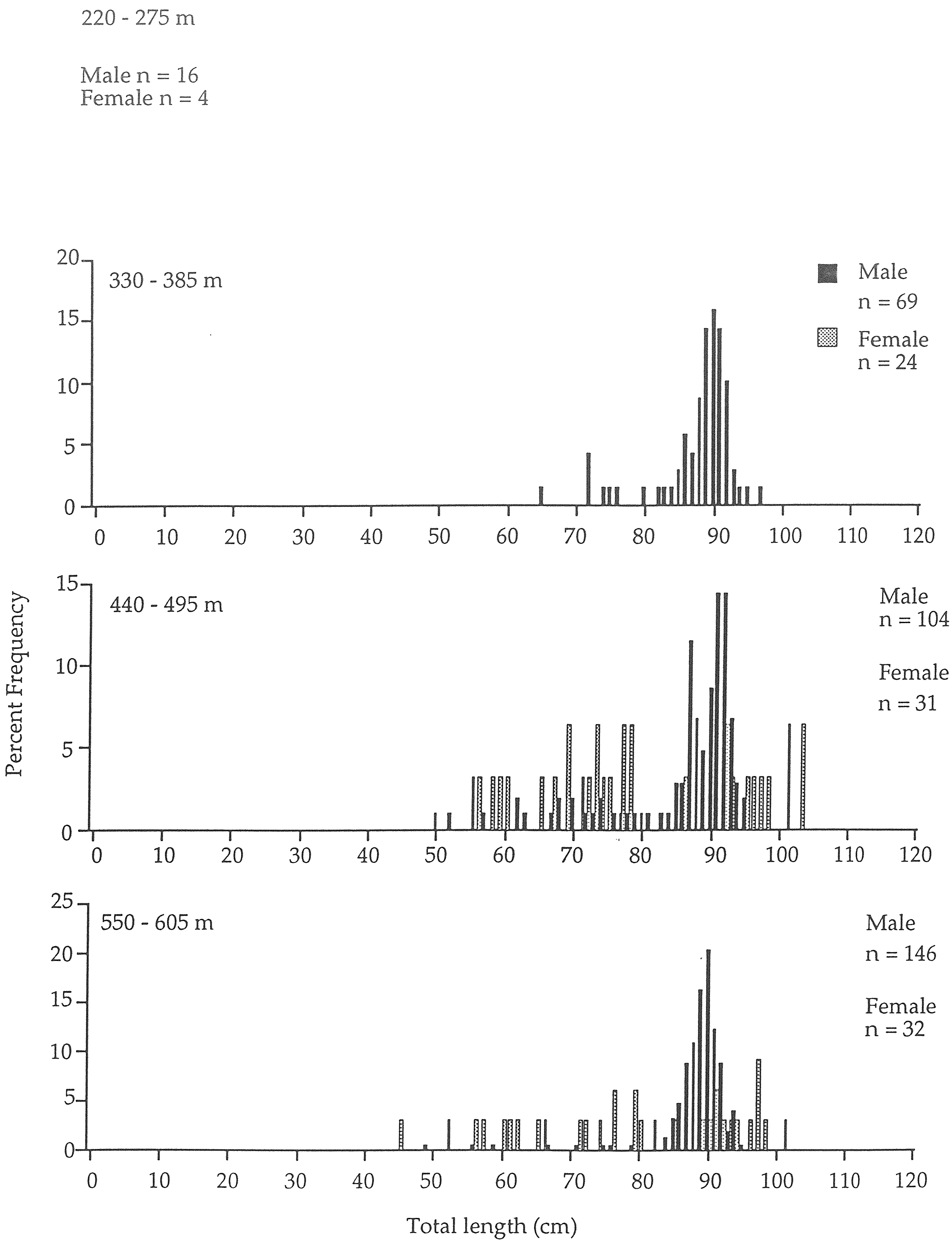


Figure 5.14.6. Length frequency distributions of male and female Harrissons dogshark caught off Ulladulla in 1976-7. Sample sizes indicated as n = total no. caught, or when subsampled, n = total no. measured (total no. caught).

220 - 275 m

Male n = 6
Female n = 3

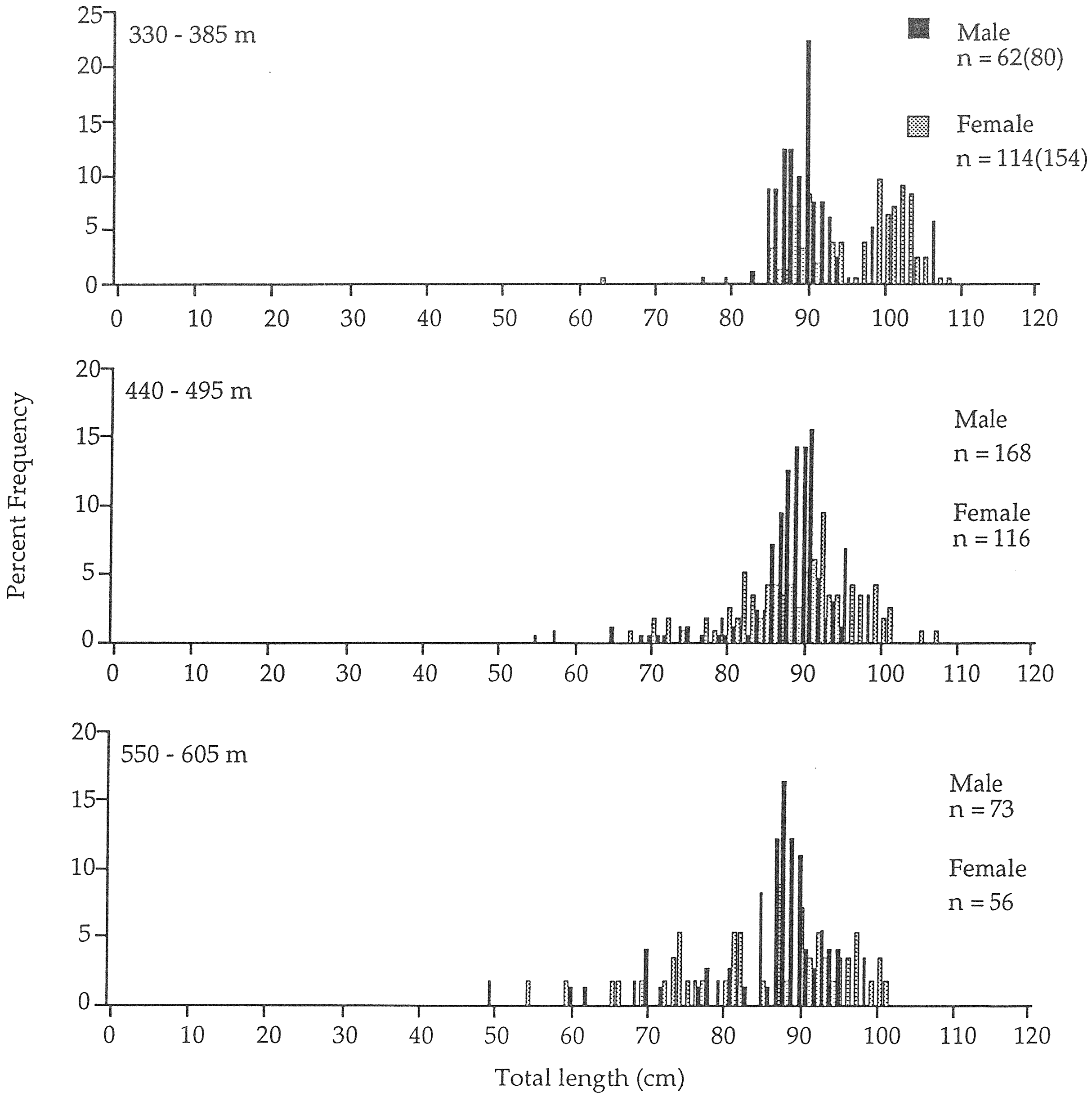


Figure 5.14.7. Length frequency distributions of male and female Harrissons dogshark caught off Eden in 1976-7. Sample sizes indicated as n = total no. caught, or when subsampled, n = total no. measured (total no. caught).

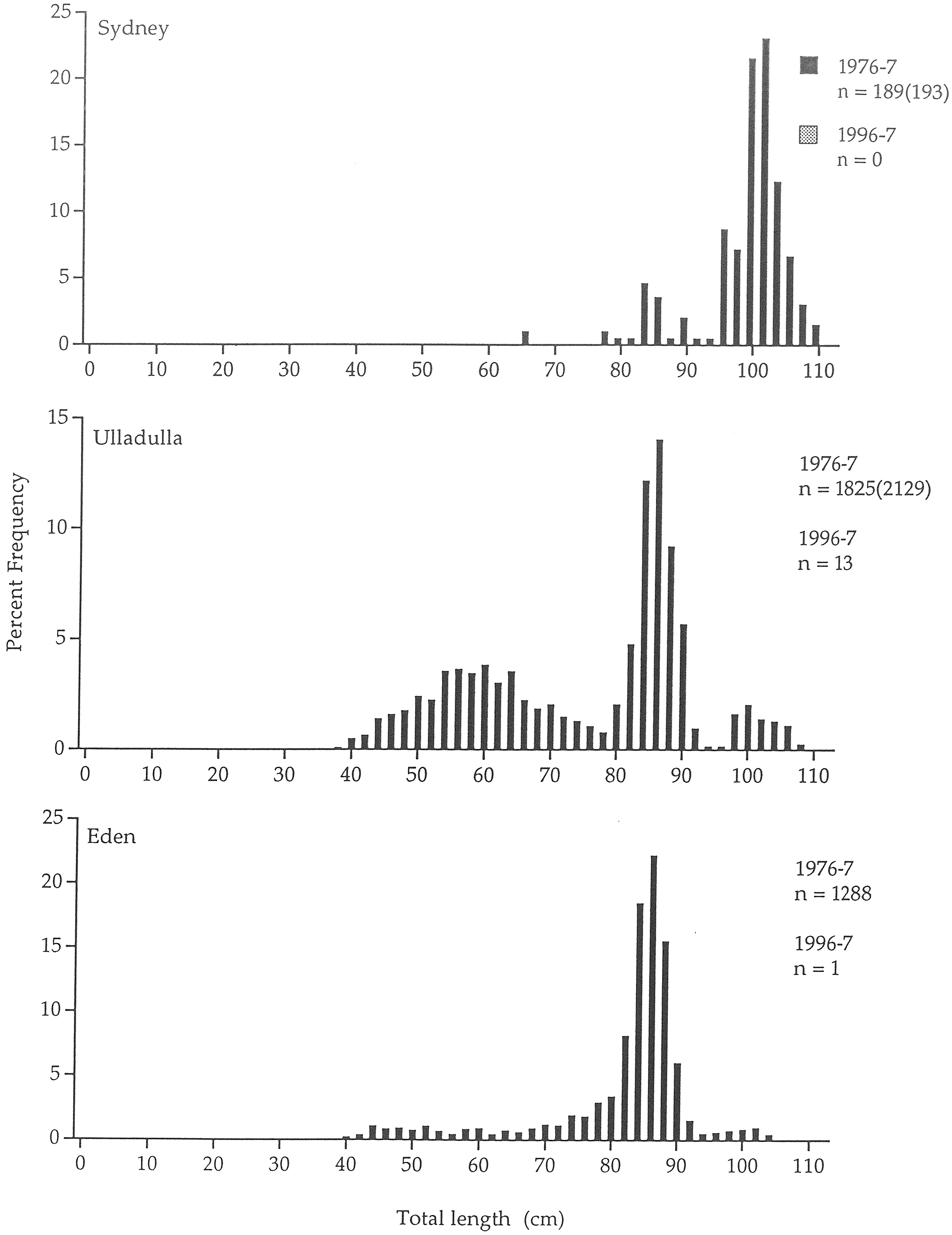


Figure 5.15.1. Length frequency distributions of southern dogshark caught in 1976-7. Sample sizes indicated for 1976-7 are n = no. measured (total no. in tows sampled). For 1996-7, n = total no. caught, or when subsampled, n = total no. measured (total no. caught).

220 - 275 m

1976-7 n = 9
1996-7 None measured

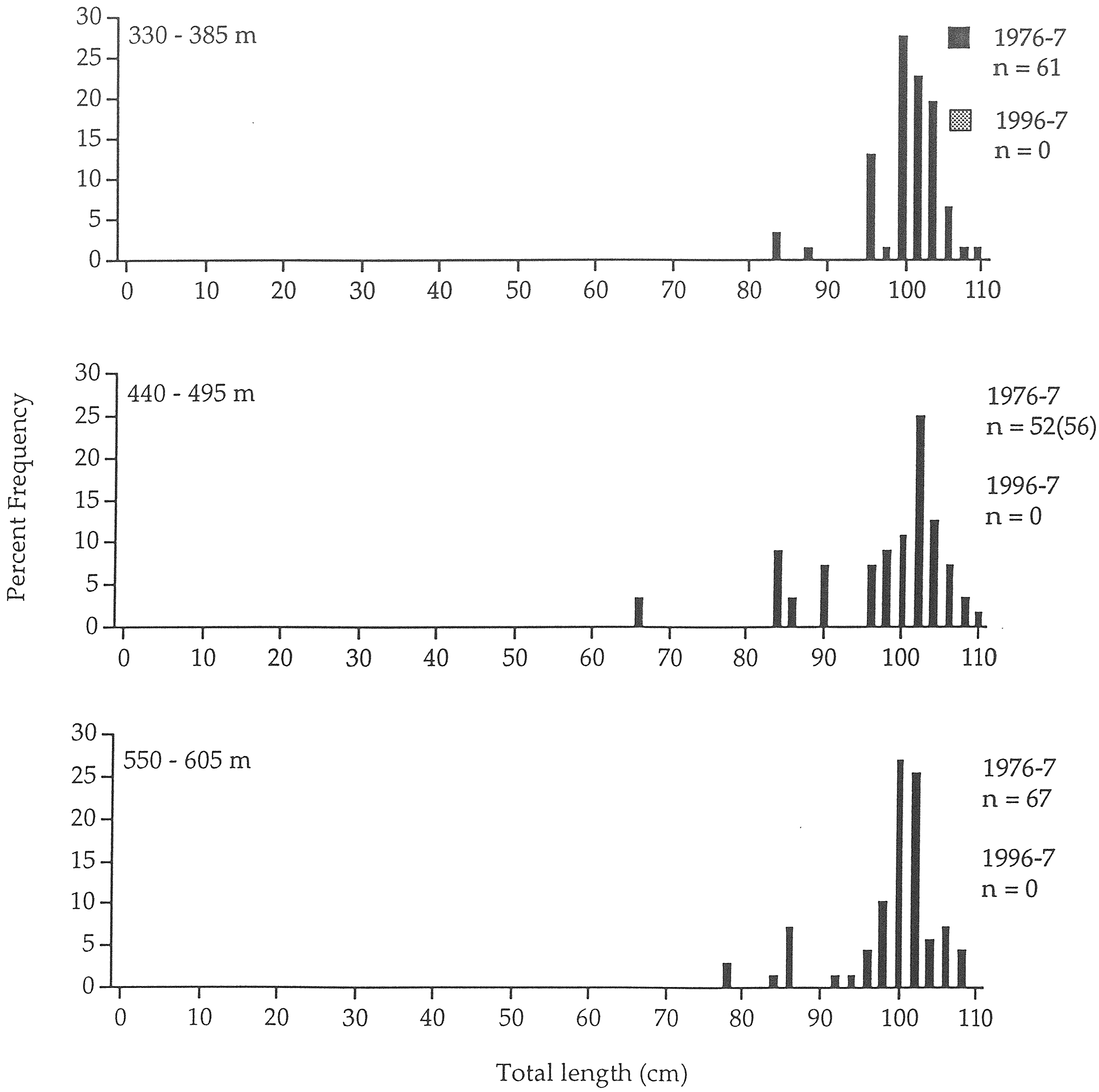


Figure 5.15.2. Length frequency distributions of southern dogshark caught off Sydney in 1976-7. Sample sizes indicated for 1976-7 are n = no. measured (total no. in tows sampled). For 1996-7, n = total no. caught, or when subsampled, n = total no. measured (total no. caught).

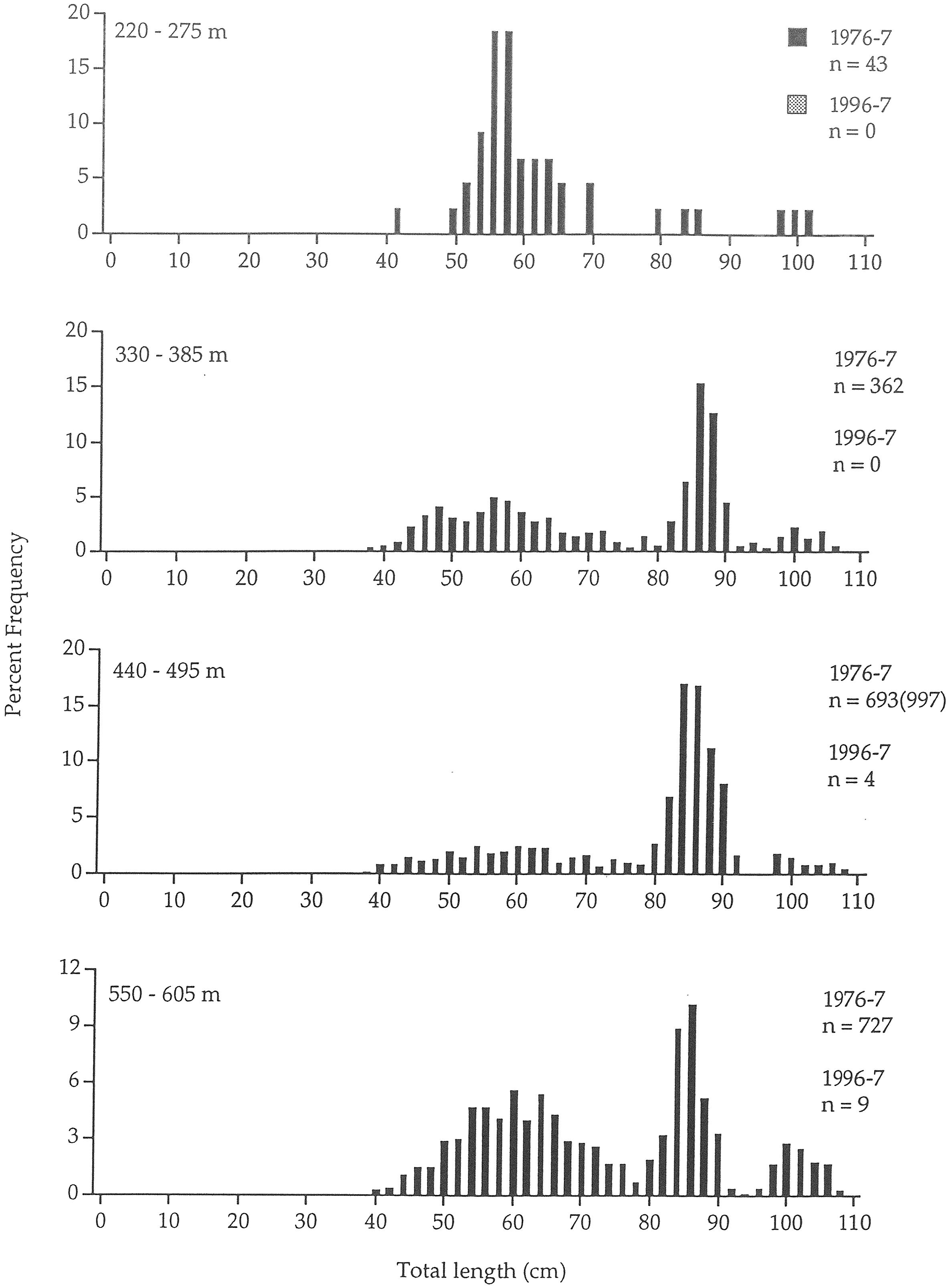


Figure 5.15.3. Length frequency distributions of southern dogshark caught off Ulladulla in 1976-7. Sample sizes indicated for 1976-7 are n = no. measured (total no. in tows sampled). For 1996-7, n = total no. caught, or when subsampled, n = total no. measured (total no. caught).

220 - 275 m

1976-7 n = 8
1996-7 None measured

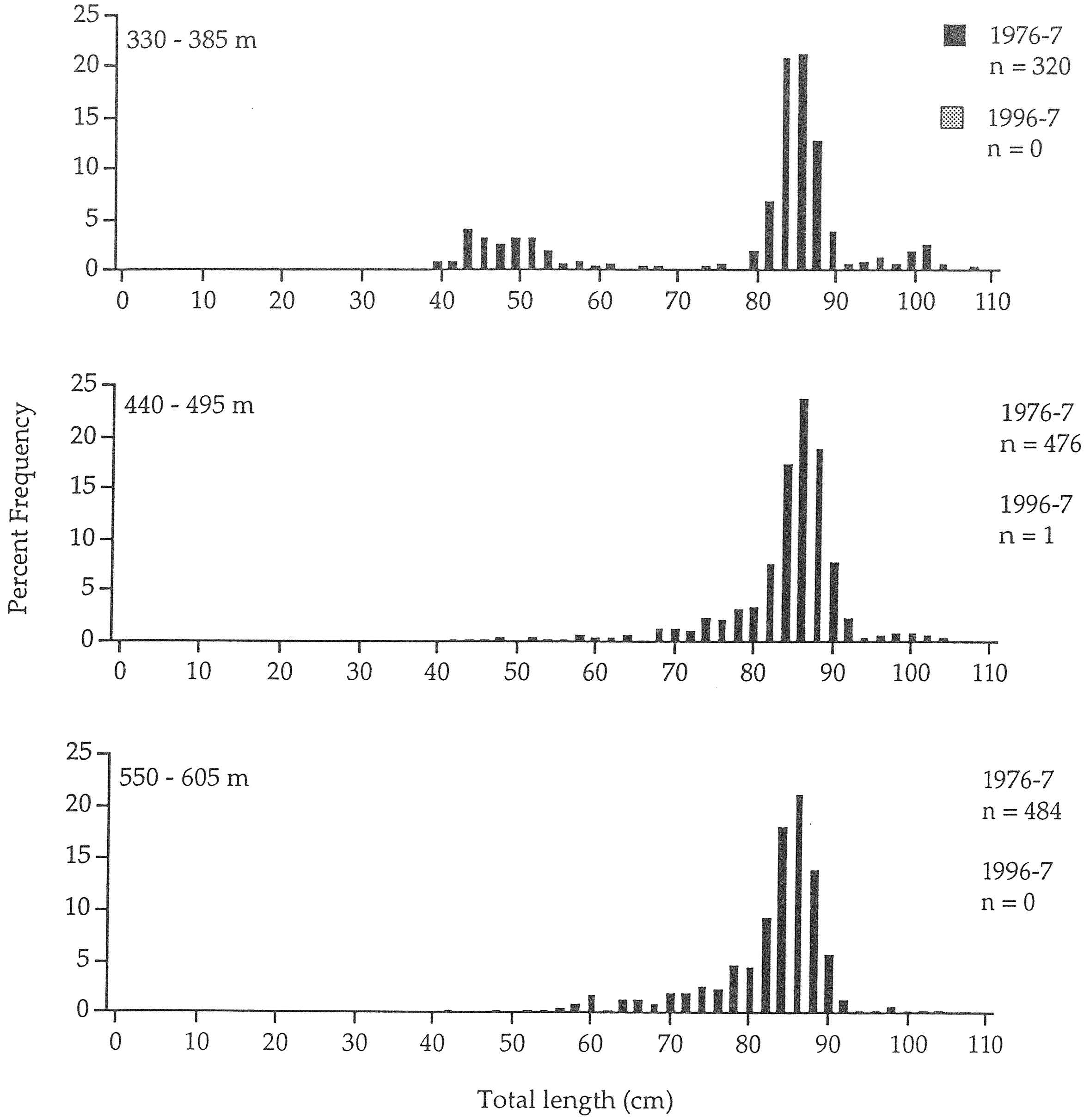


Figure 5.15.4. Length frequency distributions of southern dogshark caught off Eden in 1976-7. Sample sizes indicated for 1976-7 are n = no. measured (total no. in tows sampled). For 1996-7, n = total no. caught, or when subsampled, n = total no. measured (total no. caught).

220 - 275 m

Male n = 2
Female n = 7

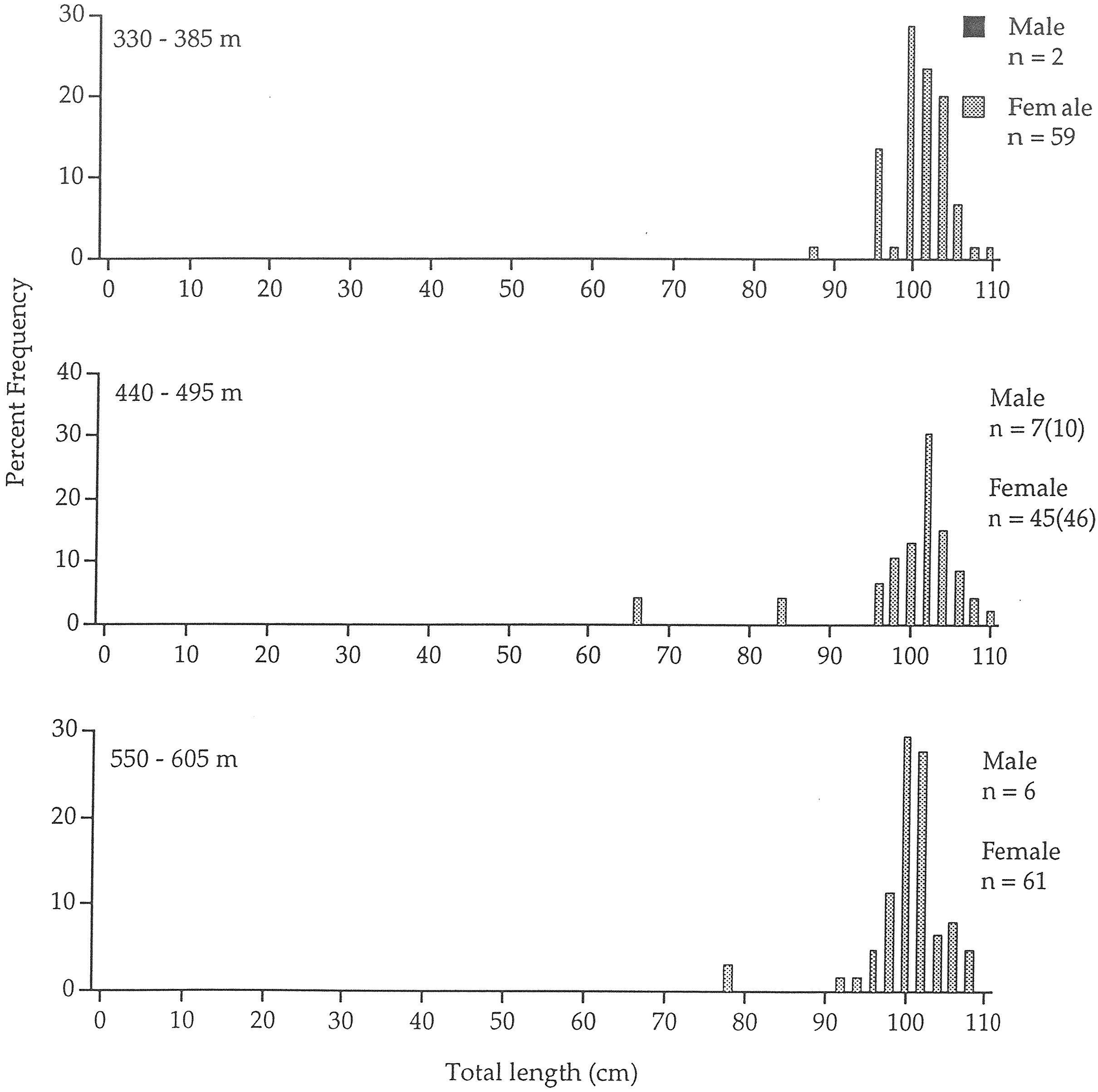


Figure 5.15.5. Length frequency distributions of male and female southern dogshark caught off Sydney in 1976-7. Sample sizes indicated as n = total no. caught, or when subsampled, n = total no. measured (total no. caught).

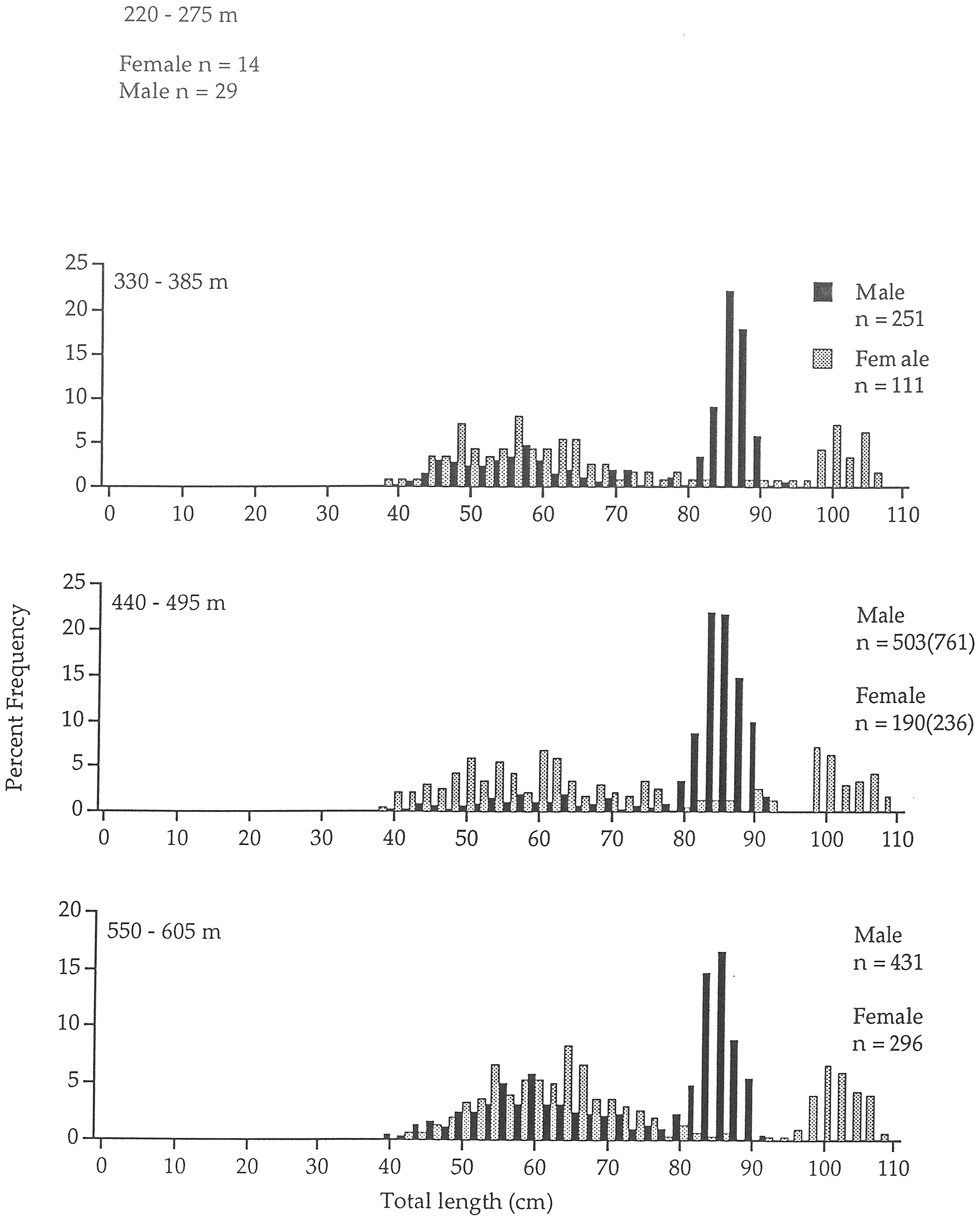


Figure 5.15.6. Length frequency distributions of male and female southern dogshark caught off Ulladulla in 1976-7. Sample sizes indicated as n = total no. caught, or when subsampled, n = total no. measured (total no. caught).

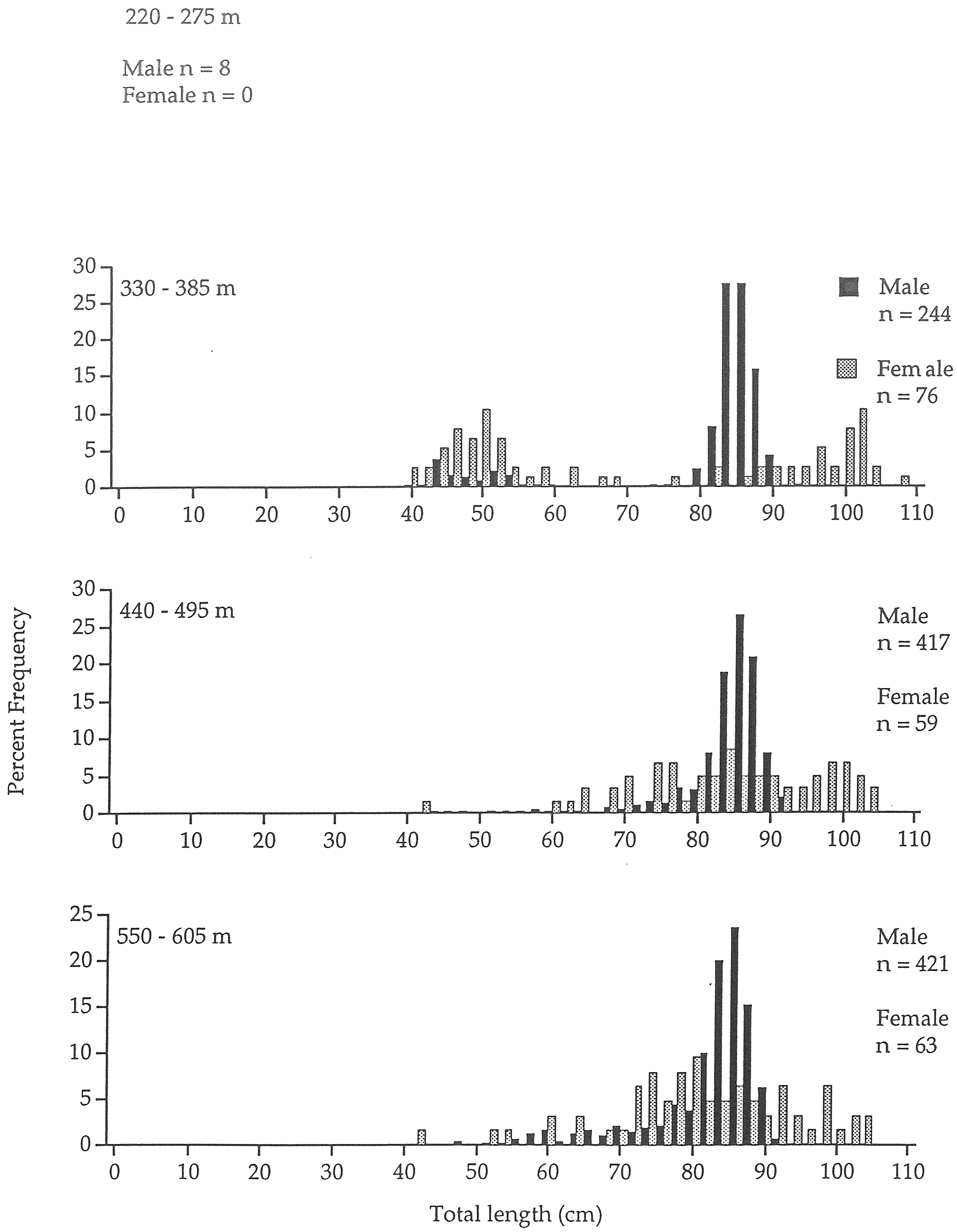


Figure 5.15.7. Length frequency distributions of male and female southern dogshark caught off Eden in 1976-7. Sample sizes indicated as n = total no. caught, or when subsampled, n = total no. measured (total no. caught).

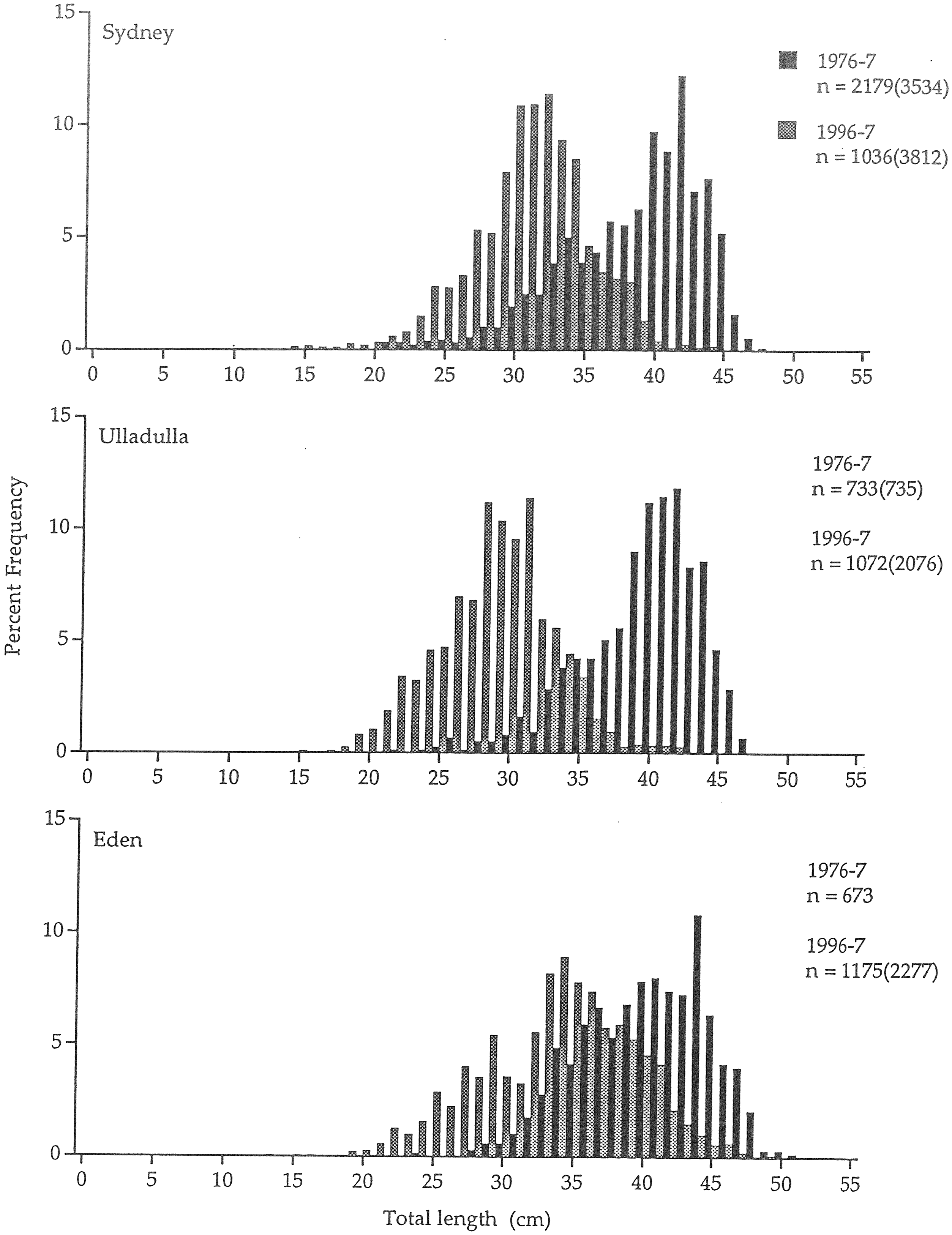


Figure 5.16.1. Length frequency distributions of spiny flathead caught in 1976-7 and 1996-7. Sample sizes indicated for 1976-7 are n = no. measured (total no. in tows sampled). For 1996-7, n = total no. caught, or when subsampled, n = total no. measured (total no. caught).

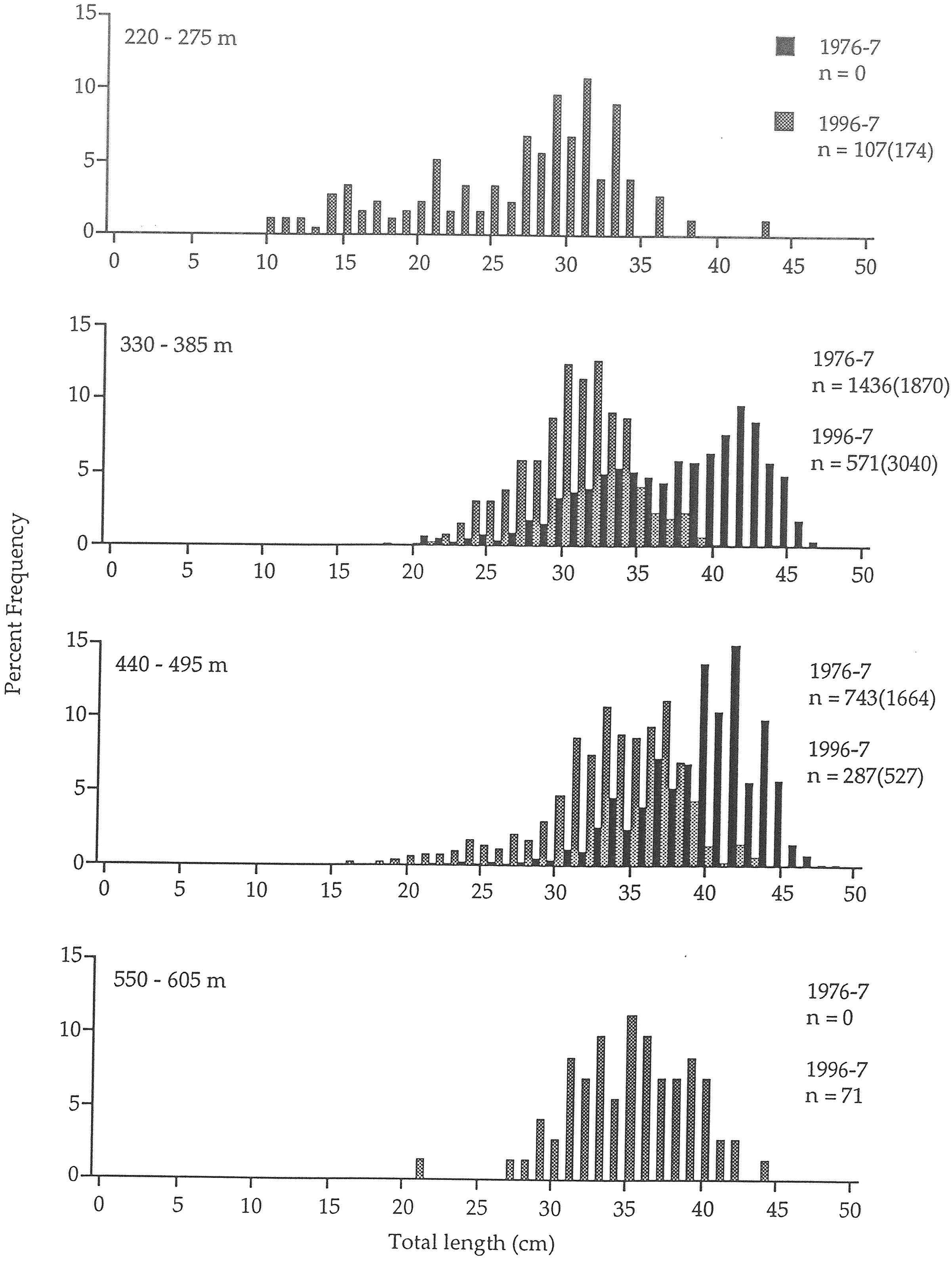
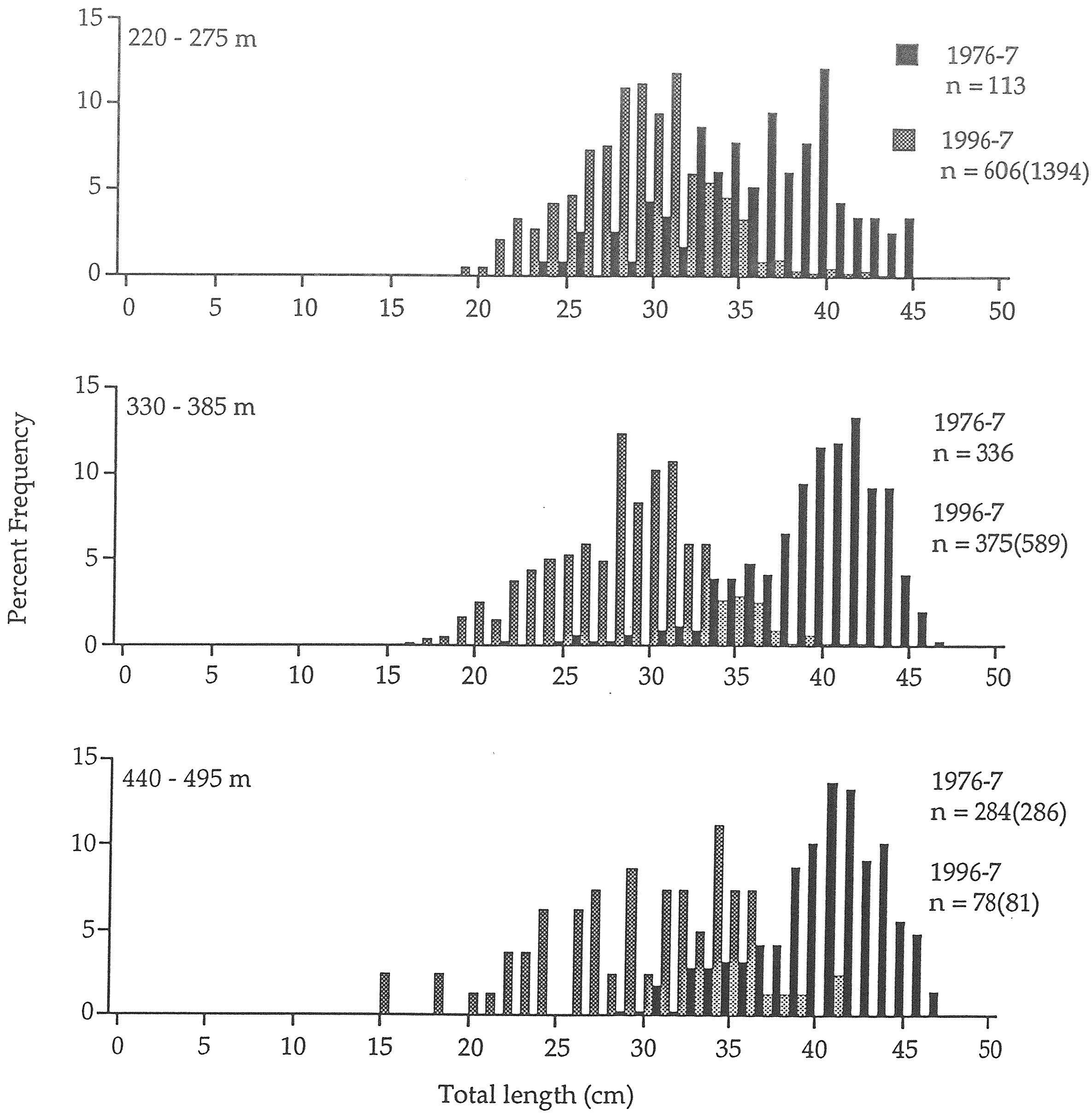


Figure 5.16.2. Length frequency distributions of spiny flathead caught off Sydney in 1976-7 and 1996-7. Sample sizes indicated for 1976-7 are n = no. measured (total no. in tows sampled). For 1996-7, n = total no. caught, or when subsampled, n = total no. measured (total no. caught).



550 - 605 m

1976-7 n = 0
1996-7 n = 12

Figure 5.16.3. Length frequency distributions of spiny flathead caught off Ulladulla in 1976-7 and 1996-7. Sample sizes indicated for 1976-7 are n = no. measured (total no. in tows sampled). For 1996-7, n = total no. caught, or when subsampled, n = total no. measured (total no. caught).

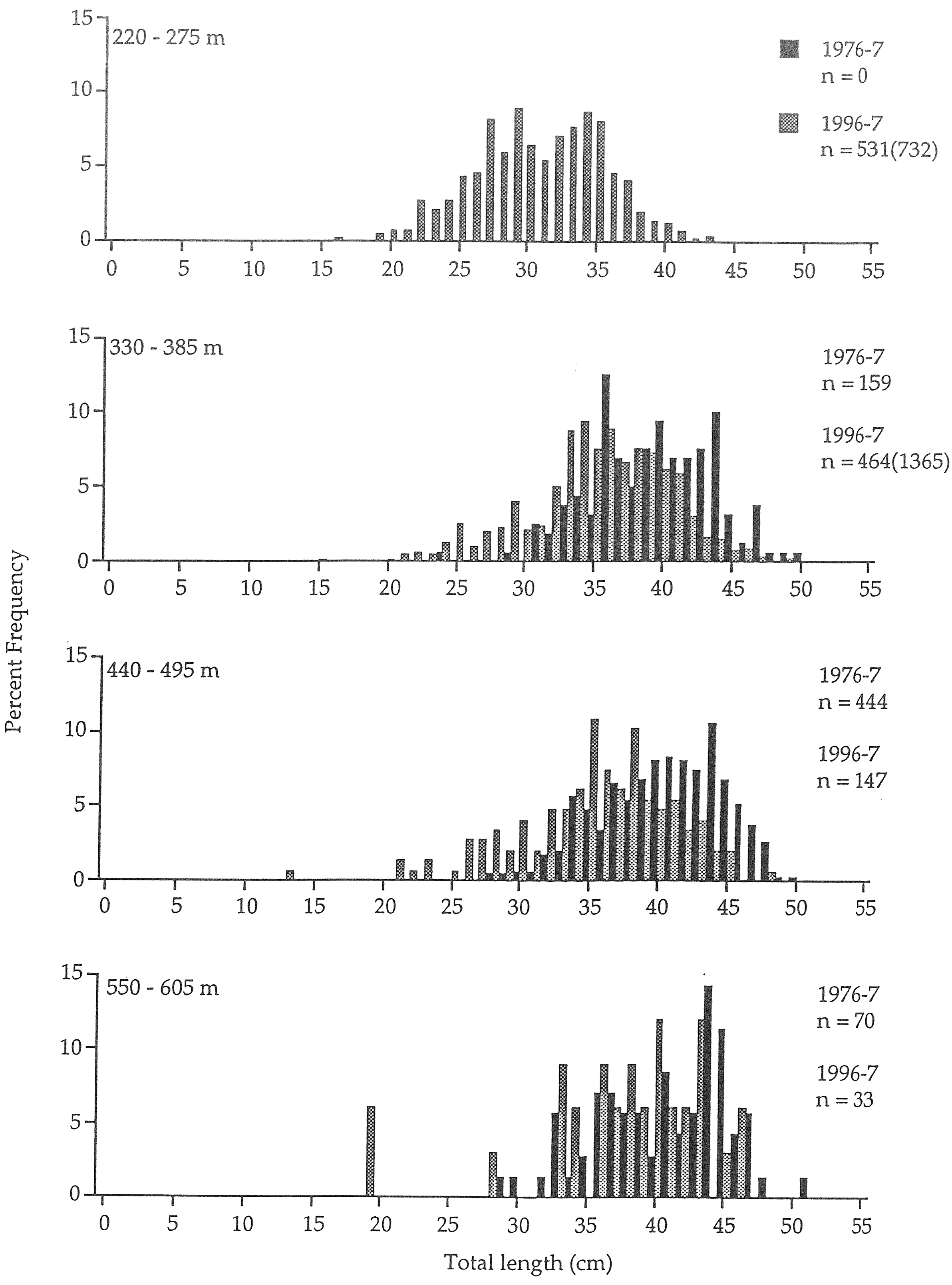


Figure 5.16.4. Length frequency distributions of spiny flathead caught off Eden in 1976-7 and 1996-7. Sample sizes indicated for 1976-7 are n = no. measured (total no. in tows sampled). For 1996-7, n = total no. caught, or when subsampled, n = total no. measured (total no. caught).