FISHERIES DEPARTMENT
WESTERN AUSTRALIA

REPORT Nº 75

Published by the Director of Fisheries, Perth,
under the authority of the Hon. Minister for Fisheries.

The Commercial Shark Fishery in Temperate Waters of Western Australia

BY

D. I. HEALD

PERTH
WESTERN AUSTRALIA

1987

Fisheries Department
108 Adelaide Terrace
PERTH, W.A.

1987

REPORT NO. 75

THE COMMERCIAL SHARK FISHERY IN TEMPERATE WATERS OF WESTERN AUSTRALIA

by

D.I. HEALD

Western Australian Marine Research Laboratories
Fisheries Department
P.O. Box 20, North Beach
Western Australia 6020

ISSN 0726 0733

ISBN 07309 1600 6

CONTENTS

		Page
	ABSTRACT	7
I	INTRODUCTION	9
II	MATERIALS & METHODS	10
	A. Data sources	10
	(i) Fisheries Department	10
	(ii) Australian Bureau of Statistics	10
	(iii) Field study data	11
	(iv) Metropolitan fish market samples	11
	(v) Shark research logbook data	11
	(vi) Marine and Harbours Dept. files	12
	B. Catch & Effort data	12
	(i) Catch	12
	(ii) Fishing effort	12
	C. Laboratory techniques	13
	(i) Catch	13
	(ii) Indices of relative abundance	13
III	DESCRIPTION OF THE FISHERY	16
	A. Species	16
	B. Regions	16
	C. Fishing methods, boats, gear & techniques	17
	D. Seasons & fishermen	22
	E. Transport & marketing of the catch	22
IV	STATE OF THE FISHERY	23
	A. General	23
	B. Species	25
	C. Size composition of commercial shark species	30
	D. Relationship between shark fishing and other types of fishing	31
V	DISCUSSION	34
	A. Catch & Effort	34
	B. Species	36
	C. Regions	40
	D. Boats, gear & fishing techniques	40
	E. Fishing intentions of shark fishermen	40
VI	CONCLUSIONS	41
VII	ACKNOWLEDGEMENTS	42
VIII	REFERENCES	43
IX	APPENDICES	66

TABLES

		Page
1.	Regional catches of shark in W.A. (kg live) in 1949 compared with the catch of other fish and crustacea. The shark catches are expressed as a percentage of the total fish and crustacea catch (T.F.C.C).	44
2.	Shark species caught by commercial fishermen in Western Australian waters. An asterisk (*) denotes that the species is not usually sold for human consumption in W.A.	45
3.	The 1983/84 regional and total shark catches by method are shown in tonnes live weight. Within each region, the proportion of the catch taken by each fishing method is shown as a percentage of the regional catch.	46
4.	Details of boat construction and equipment in 1982/83. Data were obtained from Marine and Harbours files.	47
5.	The mean length of gillnet (metres) used per boat and the number of gillnet boats (N) operating in each region for the years 1975/76 to 1983/84. In addition the actual number of boats, irrespective of regions, is shown. The ratio D/A shows the change in mean net length per boat for each region over the 9 year period. The boat growth ratio (*) is the ratio of the mean number of boats fishing in 1982/83 and 1983/84, to the mean number of boats fishing in 1975/76 and 1976/77, ie. (C+D/A+B).	48
6.	This table shows the means and ranges for: length of gillnet or longline used or alternatively, the number of hooks used by dropline and handline boats in the sample encountered on the November-December 1982 field trip. Boats are grouped by region visited and by fishing method used within each region. As some boats use a combination of gears, the number of different boats operating in each region may be less than the sum of the figures given in the 'Size of sample' column.	49
7.	The numbers of boats by catch class landing shark in W.A., and the proportion (PPN) of 'active' and 'part-time' boats in the fleet is shown for 6 selected years. Boats have been arbitrarily divided according to their annual catch into 'part-time/seasonal' boats [those catching up to 5 tonne live weight of shark per year] and 'active seasonal / full time' [those boats catching more than 5 tonnes live weight per year]. Boats catching less than 1 tonne of shark each year are assumed to have taken this shark catch incidentally to other target fishing operations.	50

Page

8. The annual numbers of longline and handline boats operating in each region and the total numbers of boats by method, irrespective of region, are shown. The boat growth ratio, (G+H/E+F) see below, expresses any trend in boat numbers over the 9 year period computed by averaging the number of boats operating from 2 recent years compared with 2 earlier years. A ratio of less than 1 signifies a reduction in the numbers of boats using longlines or handlines in each region. Dropline boat numbers for 1983/84 are also shown. Note that the total number of boats operating per method and region (*) exceeds the true number operating when boats fish shark in more than 1 region and with more than 1 fishing method in any fiscal year. 51

9. The regional shark catch (tonnes live weight) by month for 1983/84 shows the seasonality of landings. Peak catching months are shown by an underline. When comparing other tables, note the difference in catch which results from the exclusion of skates and rays from this table. 52

10. The 1983/84 shark species catch in tonnes live weight by region and the total catch by all methods for each region and species are shown. 53

FIGURES

1. The W A coast, divided into shark fishing regions composed of 1 degree ABS blocks and the 200 m contour are shown. 54

2. The total annual catch of shark in W.A., in tonnes live weight by calendar year (o.....o, Fisheries Department records) and fiscal year (o——————o, ABS records) is given. 55

3. (a) The combined catch of all elasmobranch species except skates and rays for the statistical regions Geraldton to Esperance is shown in tonnes live weight by histogram bars. Effort is shown in equivalent units of gillnet km. days (□- - - - - - - - - - - -□) and catch per unit of effort (CPUE) is shown as kg/gillnet km. day (△——————————△). 56

(b) The total number of gillnet, longline and handline boats from 1975/76 to 1983/84 are shown, irrespective of region .

4. The catch of whiskery shark is shown in tonnes live weight by histogram bars. Effort is shown in equivalent units of gillnet km. days (□- - - - - - - - - - -□) and CPUE is shown as kg/gillnet km. day (△——————————△) The regions are (a) W.A., excluding Northwest and Exmouth regions, (b) Busselton region, (c) Albany region and (d) Esperance region for the period from 1975/76 to 1983/84. 57

5. The catch of bronze whaler shark is shown in tonnes live weight by histogram bars. Effort is shown in equivalent units of gillnet km. days (□- - - - - - - - - -□) and CPUE is shown as kg/gillnet km. day (△——————————△) The regions are (a) W.A. excluding Northwest and Exmouth regions, (b) Metropolitan region, (c) Busselton region and (d) Albany region for the period from 1975/76 to 1983/84. 58

6. The catch of gummy shark is shown in tonnes live weight by histogram bars. Effort is shown in equivalent units of gillnet km.days (□- - - - - - - - - - -□) and CPUE is shown as kg/gillnet km. day (△——————————△) The regions are (a) W.A. excluding Northwest and Exmouth regions, (b) Busselton region, (c) Albany region and (d) Esperance region for the period from 1975/75 to 1983/84. 59

7. The partial length frequency composition is shown for (a) whiskery shark, Furgaleus ventralis, (b) bronze whaler shark (Carcharhinus obscurus) and (c) gummy shark (Mustelus antarcticus) caught in summer 1978 and measured at the Perth metropolitan markets. The formulae to convert partial lengths to total lengths are given for each species in Appendix III, p 69 . 60

Page

8. The partial length frequency composition is shown for whiskery shark, Furgaleus ventralis, for (a) spring 1984, (b) summer 1985; bronze whaler shark, Carcharhinus obscurus for (c) spring 1984, (d) summer 1985 and gummy shark (Mustelus antarcticus) for (e) spring 1984, (f) summer 1985. The formulae to convert partial lengths to total lengths are given for each species in Appendix III, p 69. 61

9. The composition of the entire 1982/83 catch (tonnes live) from all fishing activities is shown for A. the total group of 60 boats encountered on the 1982 field study, B. the 24 west coast boats and C. the 36 south coast boats. In this sample, bait species were taken by various methods such as purse seines, beach seines and gillnets, whereas large scalefish were those either caught on the same gear and at the same time as shark, or by handline on or near grounds fished for shark. 62

10. Figure 10 shows the wholesale value of the 1982/83 catch of those boats whose catch composition is shown in Figure 9. The pie diagrams show A. the value of the combined catches of the 60 boats from the west and south coasts, B. the value of the total catches of 24 west coast boats and C. the value of the total catches of 36 south coast boats. 63

11. Mean catch per boat (tonnes live) in 1982/83 is shown when the fleet of boats (which caught shark during the year) was directed at (a) shark, (c) rock lobster, (e) tuna, (g) bait and (i) other species groups. Mean nominal effort (boat days as histogram bars) and number of boats operating (figures on top of the bars) are given for (b) shark, (d) rock lobster, (f) tuna, (h) bait and (j) other species groups. Only those shark fishermen who were defined as 'active' or 'part-time' (see definition, p 32) were selected and they were placed in method categories by the method they principally used when fishing for shark. Bait is defined here as salmon, mullet species, herring, scaly mackerel, anchovy, sandy sprat, pilchard, butterfish, and buffalo bream. 'Other species groups' includes jewfish, mackerel, snapper, baldchin groper, Samson fish, skipjack, crabs, prawns, squid, mussels, abalone, and other large scalefish not defined as bait. 64

APPENDICES

1. The Australian Bureau of Statistics Monthly Return. 66
Appendix Figure 1. The commercial fisheries production monthly return. 67

2. Changes in gummy shark abundance in Geographe Bay. 68

3. Size composition and regressions. 70

ABSTRACT

The Western Australian-based mixed gear fishery for edible shark generally operates from Geraldton to Esperance in waters shallower than 10 fm to a maximum depth of 100 fm. In 1983/84, the total catch was 1262 tonnes live weight. The total shark catch was taken by 158 gillnet boats, 45 longline boats and 152 handline boats. However, nearly two thirds (62%) of these boats caught 1 tonne or less in 1983/84 and were assumed to rely more heavily on other target fisheries than shark.

Of the 20 or so species of shark caught in W.A., 3 species together comprise two thirds of the total catch by weight. These are whiskery shark (Furgaleus ventralis, 23%), bronze whaler spp.(dominated by Carcharhinus obscurus, 29%) and gummy shark (Mustelus antarcticus , ca. 11%). In some regions other species are more important than gummy shark.

If fishing effort is not taken into account, the trend towards increased annual catch tends to create a false impression of optimism for this fishery. In fact, total fishing effort has grown sharply in the W.A. fishery from 4048 gillnet km.days in 1975/76 to 17170 gillnet km.days in 1983/84, a 420% increase since reliable effort figures first became available from the Australian Bureau of Statistics. Gillnets, which took 90% by weight of the total catch, also contributed most to total fishing effort in 1983/84. During the period compared, the number of gillnet boats increased from 79 in 1975/76 using a mean length of 686 m of net, to 158 boats in 1983/84 using a mean length of 1698 m of net. The maximum length of gillnet used was 6500 m. Longliners set up to 12 000 m of gear. As intra-regional competition for the limited shark resource has increased, so too has effort, and falling catch rates, wherever they occur, have forced some fishermen mainly dependent on shark to leave the industry; to purchase and set more and more gear each year in an attempt to remain economically viable or to place even greater pressure on other fisheries.

It is important to note that this report is based on a retrospective analysis of historic ABS catch and CPUE data and as such does contain certain biases. New research logbook data which should enable correction of the biases have been collected since October 1985. These data, in conjunction with a more intensive analysis of the historic ABS data, will help refine estimates of catch and effort and should produce more accurate measures of abundance for the major species in the fishery.

The W.A. stock of whiskery shark is thought to be fully exploited with clear regional trends of declining catch per unit effort (CPUE) evident. For example, the CPUE for this species has fallen well below the level of economic viability on most grounds in the Metropolitan region. CPUE from the fished population of mostly neo-natal and juvenile bronze whaler shark has shown no general trend in W.A., except to reflect a likely increase in recruit abundance in 1979/80. In the last 3 years, the CPUE of gummy shark, which like whiskery shark is fished mainly as an adult, is probably also a source for concern. In the Esperance region, the calculated effort on

gummy shark may have been underestimated by a significant factor in the last 2 years. When considered together with the underestimation of gummy shark catch, the effect may significantly alter the low CPUE recorded for 1983/84.

Fishing intention (targeting) by individual boats was examined using catch, and boat days as a measure of fishing effort. This allowed some degree of comparison between boats within each method category. It was shown that many shark fishermen on both coasts depend strongly on their income from other fisheries apart from shark, such as rock lobster or the Shark Bay snapper fishery on the west coast, or tuna fishing on the south coast.

Overseas experience of shark fisheries has shown that they are prone to collapse when a single species is heavily exploited. It is felt that, even in a multi-species fishery such as that in W.A., there may be serious problems with individual species such as whiskery shark, because the general attributes of shark populations may apply to W.A. species viz.:

(1) Low fecundity (up to 32 young/breeding female in some species but less in many other species such as whiskery, bronze whaler or gummy).

(2) A long parturition period (some species may breed biennially)

(3) Slow growth rates.

(4) Exploitation across a major part of the range of the species distribution, particularly for whiskery and gummy shark.

I INTRODUCTION

Currently two distinct multi-species fisheries focusing on shark operate in Western Australia. In northern waters a foreign based gillnet fleet fishes for a suite of tropical shark and fish from the Monte Bello Is north through the Timor Sea and beyond, whilst in cool temperate southern waters a locally-based mixed gear fishery occurs from the Abrolhos Is south and east to the W.A. border. This report is only concerned with the southern fishery.

Commercial shark fishing was first undertaken out of Bunbury in 1941 when Mr Nic Soulos and Mr Victor Veale used a longline in Leschenault Inlet to catch principally 'gummy' sharks. Later that year they were joined by two other boats. By 1942 the Bunbury fishing fleet had increased to 6 boats and shark fishing was conducted in the ocean waters around Bunbury as well as in the Inlet, which diminished in importance in the ensuing years (Whitley, 1943). During the later years of the war, despite the lack of catch statistics for the period, it is believed that the shark fishery extended to a number of other centres. By 1949, the shark catch in some regions was beginning to be significant (Table 1); it comprised 4% of the total fish catch and up to 3% of the total fish and crustacean catch. In 1983/84 the shark catch comprised 7% of the total fish catch, or for comparison with this early data, 3% of the total fish and crustacean catch by weight.

The W.A. shark fishery expanded considerably between 1950 and 1970 and, apart from an anticipated problem with mercury in shark - which caused effort and catch to drop considerably between 1972/73 and 1975/76 - the growth of the fishery was considered healthy. When the 1980/81 figures from the Australian Bureau of Statistics (ABS) became available in 1982, they revealed a 10% fall in total catch. Later in 1982, two fisherman were forced to leave the Metropolitan fishery due to alleged poor catch rates and several other experienced fishermen left in 1984. Due to the long period which had elapsed since previous field studies, it became necessary to look at the state of the fishery on a regional basis with a field study. The following objectives were proposed for the November/December field trip:

1. Meet and liaise with professional shark fishermen at important regional centres and to discuss the state of the fishery.

2. Issue shark research logbooks to obtain data on species catches by number, method, region and period. This would supplement data on catch weight already being received in the compulsory monthly returns of commercial fisheries production.

3. Examine monthly returns from the relevant fishermen's commercial fisheries production books to assess the relative importance of shark in the total fishing income.

4. Make sea trips from ports on boats using varicus gears to observe the impact of improved technology on the gear and fishing methods.

5. Collect relevant biological data on important commercial species.

The preliminary results from these objectives have been made available to the Director of Fisheries although analysis of the logsheet data (objective 2.) must await a significant return of logsheets. This report gives a preliminary assessment of the state of the fishery up to the 1983/84 fishing year and makes some recommendations from the results on which to base a future management strategy for the shark fishery.

For the purposes of this report, a 'shark fisherman' is defined as one who deliberately selects a method or fishing ground which will allow him to catch predominantly shark for the period during which he is intentionally engaged in fishing. Likewise, a shark boat is defined as a fishing vessel which has been specially fitted with gear which will allow it to maximize its catch of shark when operating on appropriate fishing grounds during the whole year or at certain times during a year. Few boats are totally committed to fishing for shark for the entire year but 9% spent at least 140 days fishing primarily for shark in 1983/84.

II MATERIALS AND METHODS

A. Data Sources

Six separate sources of data have been used in the compilation of this report.

(i) Fisheries Department files

These files have provided an invaluable source of mainly catch data for this report. The earliest complete shark catches on file are from the 1940's. There are also some comments on species, fishing areas and methods contained in these records.

(ii) Australian Bureau of Statistics (ABS)

This was the most comprehensive source of data used. Routine summaries from the ABS were reworked for the period 1975/76 to 1983/84 inclusive to obtain catch and effort by species, fishing method and region. The regions comprise specific groupings of ABS statistical blocks (Figure 1). The analysis by region rather than by block served two purposes :

(a) To enable the grouping together of sufficient records for a statistically significant comparison among regions in the fishery;

(b) To preserve the confidentiality of information recorded in monthly returns of commercial fisheries production.

(iii) Field study data

During the field study in November/December 1982 a sample of 72 fishermen who caught shark were interviewed at the ports of Esperance, Albany, Augusta, Busselton, Bunbury, Mandurah and in the Jurien vicinity. Information was sought about fishing methods and operations, gear and the relative importance of shark in the total fish catch when targetting on species other than shark. Opinions on the state of the fishery were obtained from fishermen. Supplementary biological information was also collected on commercial shark species during sea trips from Esperance, Albany and Augusta.

(iv) Metropolitan fish market samples

Sampling at the markets provided species length/weight data every year from 1974 to 1978 inclusive. Size composition data for commercial species sampled from 1978 together with data for the 3 most important species from September 1984 and January/February 1985 (= summer 1985) market samples were presented in this report because they are the most recent set of data containing sufficient measurements to have been of use. The carcass of each shark was identified to species, then measured for partial length and partial weight. The partial length measurement is defined as the straight line between the anterior origin of the first dorsal fin (scar) and the origin of the upper lobe of the caudal fin; or the origin of the dorsal precaudal pit in those species in which the pit is present. The partial weight (also called the landed, dressed or cleaned weight) was recorded to the nearest 0.1 kg and applies to a headed and gutted finless carcass.

(v) Shark Research Logbook data.

Since the issue of 122 research logbooks to shark fishermen contacted during or after the 1982 field study, some monthly logsheets have been returned from most regions. The limited information collected has, however, been used to gain a preliminary understanding of some aspects of fishing practice such as depths worked and details of gear used. It is now becoming possible to verify the accuracy of some of the ABS data from gillnet, longline, handline and dropline boats.

Out of a total number of 122 fishermen who caught more than 1 tonne of shark in 1983/84, only 7 (14%) kept logbooks. With the issue of the new bound and simplified logbook, the research branch has made every effort to improve upon this disappointing figure.

(vi) Marine and Harbours Department files.

Constructional and survey data on licenced commercial fishing boats were obtained as computer printouts from the Department of Marine and Harbours. These data were used to build up a picture of the shipboard ancillary equipment and construction characteristics of a typical gillnet, longline, handline boat or dropline boat.

B. Catch and Effort data.

(i) Catch.

(a) Records of annual landings of all species combined were kept by the Fisheries Department between 1951 and 1964.

(b) From 1961/62 to 1974/75, the ABS split landings into the categories of 'shark' and 'skates, rays and other'.

(c) Since 1974/75, amendments suggested by the Department of Fisheries were incorporated by ABS to provide a more detailed account of the main species in the 'shark' category of (b) above. Information is now collected separately for; whiskery shark, bronze whaler, gummy shark, carpet shark, 'other shark' and 'skates rays and other'. Because of these changes, it is not possible to compare 'shark' prior to 1974/75 with 'other shark'.

(ii) Fishing Effort.

The ABS files were the only source of fishing effort data.

(a) Prior to 1974/75, no comprehensive summaries of fishing effort, apart from limited data on handline fishing, were produced by ABS.

(b) From 1974/75, separate statistics for effort generated by gillnets and longlines became available. Details of fishing effort recorded by ABS for each shark boat completing a monthly return include;

(1) gear length, (2) numbers of hooks or nets used, (3) days fished per month, (4) average number of sets per day and (5) average hours fished daily per block per month.

The method by which these various effort parameters are standardized into a single measure of effort is described in Laboratory techniques.

C. Laboratory techniques

A discussion of the laboratory methods and statistical techniques used on the data is given below.

(i) Catch

Catch data from the two sources (Fisheries Department and ABS) were converted to metric units (tonnes live weight) as necessary. For example, old Departmental files were recorded in pounds live weight and needed conversion. In the event, these records could be used only to give total annual catches of shark (all species combined).

Shark catch data from ABS for 1974/75, were considered unsuitable for use because whilst some fishermen continued to record in pounds, others had changed over to kilograms earlier than expected and did not always specify the units used on their monthly returns. When coding, these data were apparently treated as though all returns were in pounds which led to a component of underestimation in the species catches for that year.

Since 1974/75 extra precautions were taken during coding of monthly returns to ensure that all were recorded in kilograms landed weight. Conversion of data to live weight occurs after summation by block, region and/or species. The standard formula used by ABS for all fish is:

$$\text{LIVE WEIGHT(tonnes)} = \frac{\text{LANDED WEIGHT (kg)} \times 1.59}{1000}$$

Catch and effort data were derived for the Geraldton to Esperance regions only because the species composition in the Northwest and Exmouth regions was entirely different. Also, little shark was landed in the various method categories in Northwest and Exmouth regions, according to ABS records up to 1983/84.

(ii) Indices of relative abundance

When a unit stock is exploited by several groups of vessels using different methods of capture, it has been proposed by Gulland (1969, p53) that the catch rate of one group of vessels be selected for use as the best index of density, and the total effort be then estimated by dividing the total catch from the fishery by the selected catch per unit of effort (CPUE).

Within the shark fishery, effort is recorded separately for each method of capture (i.e. gillnet, longline and handline) and the assumption is made that no vessel uses two methods of capture

simultaneously. These 3 methods annually account for nearly all of the total shark catch by weight. The method producing the greatest catch is the gillnet, and accordingly the gillnet CPUE is assumed to be the best measure of density (i.e. CPUE = CPUEg). Within each region, the gillnet CPUE has therefore been calculated for each species and for all species combined, by dividing the annual gillnet catch by the gillnet effort expended to produce that catch. The steps involved to calculate the annual CPUE for each region, and for each species, and for all species combined were :

For the chosen region and species :

1. Calculate the annual shark catch from all gillnet sets in that region, Cg.

2. Calculate the total gillnet effort expended to take the gillnet shark catch for that region, Eg.

3. Calculate the CPUE by dividing Cg by Eg.

   i.e. CPUE = CPUEg = Cg / Eg

   By now dividing the total annual catch for each species (and for all species combined) within each region by the calculated CPUE for the same species and region, an estimate of total effort for that species and region is produced. That is, the approach suggested by Gulland (1969, p53) is used to determine the equivalent gillnet effort which would be required to produce the same total annual catch for the species as was produced by the 3 methods combined. Following on from previous steps, the procedure is set out below.

   For the chosen region and species :

4. Calculate the total annual shark catch for the 3 major methods for that region, Ct.

5. Divide the calculated CPUE for the species, within that region, into Ct, to produce an estimate of the total annual effort, Et, corresponding to Ct.

   i.e. Et = Ct / CPUE

The effort for each species was then summed over all regions to produce an estimate of total effort for that species.

Effort estimates produced for each species within a region will vary slightly because the achieved catch rates for each species reflect natural variation about a mean value associated with the density of shark within a region.

Similarly, the best single measure of the total annual effort for all species combined is that calculated using the combined species, rather than the sum of the total efforts calculated for individual species. This is because the effort on one species is not independent of the effort on the other species.

Fishing effort has been independently calculated for each species with the assumption that there was no annual trend in fishing effort directed at one particular species - even though seasonally directed fishing is likely to occur. A degree of species target fishing is achieved by the selection of appropriate mesh size and fishing grounds. Although in general the number of days fished by gillnet boats for each species was the same, when different quantities of fishing effort were recorded for different shark species on a monthly return, then the largest effort figure was used in the total CPUE calculation.

The ABS catch data in this report have provided a useful description of both the regional and total shark catch in Western Australia but were less satisfactory for estimating relative abundance of individual species. In this respect the data should be treated with caution as they contain certain biases identified below.

Some fishermen do not split their shark catch into separate species but lump the catches of all species under the 'other shark' category. This applies to all regions, but in the Esperance region, it is thought up to half the 'other shark' category may be comprised of gummy shark. Such a recording bias would cause the reported gummy shark catch to be underestimated by up to 50%. If the proportions of different species in the 'other shark' category for the Esperance region remain similar from year to year, and the proportion of each species in this category combined for all regions, also remains similar from year to year, then the direction of the trends shown in the catch and CPUE graphs will be correct, respectively for Esperance region gummy shark and for Western Australian gummy shark but the magnitudes shown will underestimate the true values.

The effort statistic is defined here as a product of net length and days fished (i.e. gillnet kilometre.days). Although different species of shark may behave differently throughout a 24 hour period, this could not be taken into account in the effort formula because fishemen's records do not contain the necessary information.

To refine the final data set before computation, the computer was asked to define as valid only records for which the stated gillnet length exceeded 30 m to eliminate invalid and amateur net lengths from the data file.

In the calculation of fishing effort, it was also assumed that fishermen set their nets once per 24 hours. However,

in the Esperance region of the fishery, 'seasonally active' boats have been working 2 sets per 24 hours in recent years. Unfortunately, some of the data have not been recorded correctly (see Appendix 1). Thus Esperance region effort is likely to be understated by an unknown amount.

III DESCRIPTION OF THE FISHERY

A. Species

Many species of shark are caught in Western Australian waters by professional fishermen. The more commonly caught species are listed by family groups in Table 2. Those species usually of little commercial importance are shown by asterisk. This report deals only with the 3 most important species viz.; whiskery, bronze whaler and gummy shark in the southern W.A. fishery. For these species it is assumed that: shark recorded as gummy shark relates only to one species Mustelus antarcticus. Shark recorded as bronze whaler relates principally to one species, Carcharhinus obscurus, but small numbers of another whaler, the copper shark, C.brachyurus, are present in bronze whaler catches. Shark recorded as whiskery shark, Furgaleus ventralis, relates only to one species in W.A. Whiskery and bronze whaler shark are more abundant in west coast catches whereas gummy shark become progressively more important on the south coast, east of Walpole. A species CPUE should be considered to be a reliable measure of relative abundance only when it is representative of a single unit of stock of the species. Regional CPUE figures, whilst they represent trends, cannot be considered to be as meaningful as those figures applying to the entire W.A. fishery for a species, because of the likely movement of stock between regions and into deepwater beyond the range currently fished. There are also difficulties in adjusting catching power between boats within and between regions so that the fishing effort can be expressed as effective rather than the nominal effort used.

B. Regions

Since 1982, the W.A. coast has been divided into 7 regions for the convenient analysis of the catch statistics (Fig. 1). These coastal regions are comprised of groups of 1 degree fishing blocks designated by the ABS. Each block is specified by a 4 digit number representing the flanking latitude and longitude at the top left-hand corner of the block. The major fishing ports and anchorages within these regions are:

Region 1. Northwest - no significant shark fishing ports yet.

Region 2. Exmouth - Port Hedland, Exmouth.

Region 3. Geraldton - Geraldton, Dongara (29°14'S 114°56'E)

Region 4. Metropolitan - Jurien, Cervantes (29°14'S 114°33'E), Greenhead (30°04'S 114° 58'E), Two Rocks (31°30'S 115°36'E), Fremantle (32°04'S 115°45'E) and Mandurah (32°30'S 115°42'E).

Region 5. Busselton - Bunbury, Canal Rocks (33°39'S 115°E), Cowaramup Bay (33°51'S 114°59'E), Kilcarnup (33°57'S 114°59'E), Hamelin Bay (34°13'S 115° 01'E) and Augusta (34°19'S 115°09'E).

Region 6. Albany - Windy Harbour (34°50'S 116°E) Walpole (34°58'S 116°43'E) and Albany.

Region 7. Esperance - Hopetoun (33°57'S 120°07'E), Esperance and Mundrabilla beach (32°10'S 127°43'E).

C. Fishing methods, boats, gear and techniques.

(i) Methods

There are 3 main methods by which sharks are caught viz., gillnets, longline and handlines plus several minor methods. The principal capture method from the inception of the fishery and through the 1950's was longline. Multifilament gillnets (or ragnets, as they became popularly known) started to replace longlines in the late 1950's. With the introduction in the early 1960's of monofilament gillnet - which has all but replaced multifilament gillnet - net fishing has become the most important method for the capture of shark. According to the ABS data, the minor methods include droplines, trawling, shark caught in rock lobster pots and fish traps, trolling and shark caught incidentally to beach seining operations for salmon.

In 1983/84, the 3 main methods produced a total catch of 1250 tonnes live weight (99% of the total W.A. catch). Gillnet took 1115 tonnes (88%), longline took 87 tonnes (7%) and handline took 47 t or 4%, (Table 3). Thus gillnets are the most important method in all regions except at Exmouth where handline catches account for 60% of that region's catch. In the Albany region, a higher proportion of the catch, 31%, is taken on longline than in any other region. The most important minor method was dropline which took about 6 tonnes or 0.5% of the total catch (Table 3). Only the 3 main methods plus droplining will be covered in respect of gear details, any fishing strategies used and the types of boats and their equipment.

(ii) Boats, gear and techniques

In the period from 1976 to November 1982, the following improvements have been noted for shark

boats, gear and fishing techniques :

1. Sharp rises in the cost of diesel have produced a greater emphasis on fuel economy, with changes in design of hulls to reduce drag, fuel efficient propellers, and increased use of sails becoming evident on the older 'rock lobster' type of vessels, to improve fuel efficiency and assist the main engine.

2. Limited use of colour echo sounders to allow better discrimination of bottom topography and hardness.

3. More radar sets have been installed to improve positioning of boats on fishing grounds and to assist with locating nets at night or in rough weather. Usually 1 or more net fleets have a radar reflector attached to the Dahn buoy.

(a) Gillnet fleet

Within the last 5 years, boats which are specifically or principally designed to catch shark using gillnet, have entered the fishery. As equipment continues to be upgraded, the gear now considered to be standard for gillnet boats includes :

1. net reels and spreaders,
2. bow or beam rollers to recover nets,
3. heavier duty winches and gearing to enable more net to be set and lifted from deeper water and
4. wash wells and brine tanks or freezer space; especially on boats which have caught tuna.

Gillnet boats, especially on the south coast East of Albany, now tend to set their gillnets for shorter periods to improve the quality of the product and reduce losses from damage to caught fish by sea lice and leatherjacket attack. This method is adopted from the standard operating procedures for longliners.

In 1983/84, 158 boats used gillnets. Details of boat construction for the gillnet fleet are given in Table 4. Using mean values to describe the average gillnet boat, it would most often be constructed of bondwood, have a hull 11.4m long and a gross weight of 12.5 tonnes. The main engine would have a power rating of about 132 kW. The boat would be equipped with an echo sounder and may have radar (about one third have radar). The usual

level of manning would be 2 crew including the skipper.

Two sources of data have been used to calculate the mean lengths of gillnet operated by the total W.A. gillnet fleet and its regional components. The more accurate estimate of mean length of gillnet is provided by the ABS in Table 5. For 1983/84, the mean gillnet length for the W.A. gillnet fleet was 1659m. Data on regional mean gillnet lengths were also derived on the Nov/Dec 1982 field study (Table 6). The data in Table 6 thus comprise a subset of the mean gillnet lengths for each region shown in Table 5. In the following figures, mean lengths from Table 5 for 1982/83 are shown first and compared with the mean lengths derived from interview data on the field study (lengths shown from Table 6 in brackets). The respective mean lengths for the 4 regions where comparison is possible were 1301m (1200 m) for the Metropolitan region, 1893m (2100 m) for the Busselton region, 1532m (1300 m) for the Albany region, and 2949m (4200 m) for the Esperance region.

Although the data obtained during the field study were generally derived from much smaller samples of boats, the mean gillnet lengths (except Esperance) are in reasonable agreement with the ABS data, especially when the small sample sizes for Metropolitan region (8 boats out of 41), Albany region (6 boats out of 36) and Esperance region (11 boats out of 21) are considered.

From a small logbook sample, the mean mesh size used by gillnet boats was 7", with a range of meshes from 5.5" to 8.5" being used. Boats which kept logbooks set gillnets for 9.9 hours per day on average (range 1-24 hours), however this mean is not representative of regional operations such as at Esperance. Those gillnet sets which exceed 9 hours duration are usually made overnight whilst those of shorter duration usually occurred over night. There ar insufficient data on depth zones fished to estimate mean depth and depth range fished, although it is known that only longline boats can easily currently operate deeper than 100 fm.

General comments from net fishermen indicated that they could alter the desired species composition of their catch by selecting fishing ground and bottom type within the constraints of season and depth range able to be fished. For instance, it

was widely believed by gillnet fishermen that whiskery shark catches were better over rough 'coral' or rocky bottom. Bronze whaler and gummy shark were more likely to be found on sand or soft bottom and wobbegong shark kept a territory around reef. A boat rotated its area of operation every day or so, as fishing on the same ground tended to reduce catch rates and this practice enabled it to keep up with a moving school of sharks. Most nets were weighted so that they fished at or near the bottom. About 23% of boats which caught less than 1 tonne live weight of shark per year used gillnets, as did 79% of boats which caught between 1-5 tonnes per year and 91% of those which caught more than 5 tonnes (footnotes, Table 7).

(b) Longline Fleet

During the 9 year span of data shown in Table 8, the proportion of longline boats decreased from 16% of the gillnet, longline and handline fleet in 1975/76 to 13% of that fleet in 1983/84, although during the same period, the actual number of longline boats in the shark fishery increased from 32 to 49 (Table 8). Approximately 10% of vessels which caught less than 1 tonne live weight were using longlines; 10% of those which caught 1-5 tonnes and 7% of those which caught more than 5 tonnes of shark were also longline boats (footnotes, Table 7). Dimensions and constructional details of longline boats are given in Table 4. The most commonly encountered hull material was bondwood. Longline boats had a mean length of 11.3m, a mean gross weight of 11.4 tonnes and a slightly more powerful engine (of 145kW) than that of gillnet boats. The average longline boat was manned by a crew of 2 including the skipper and equipped with an echo sounder. It was more likely to have a radar unit (62% of the sample of 25 boats, Table 4) than a gillnet boat.

The only reliable source of data available to calculate longline gear parameters was collected during the 1982 field study (Table 6). When the regional figures for longlines were combined from Table 6 for Metropolitan, Busselton, Albany and Esperance regions, it was found that the mean longline length was 6800m. Using the normal spacing of ca. 7m between hooks, this length of gear would contain about 970 hooks. From limited logbook data, longline boats operated at an average depth of 23.9 fm (range 7-50 fm).

Gear was set for 2-18 hours; 9.3 hours on average.

Various baits were used depending on seasonal availability. These included; herring, sea mullet, pilchard, octopus, squid, parrotfish, yellow-eye mullet, scaly mackerel and tuna. Qualities sought from the bait were its retention on a hook, odour and oiliness. Molluscan bait was often preferred for its enhanced retention. Longlines were favoured by the boats which used them because they provided an economic method of catching. When set, longlines were weighted and buoyed at regular intervals to reduce losses of gear from sharks biting through the mainline. Longlines may be rigged to fish near the surface, in mid-water, or at the bottom but in the southern temperate fishery they were exclusively set near the bottom.

(c) Handline Fleet.

In 1983/84, 152 boats used handlines to catch shark. Many boats also used handlines as a supplementary method, either to gillnetting or longlining, but not at the same time as they used the former. From Table 4, the average handline boat fishing for sharks was 12.3 m long and weighed 11.3 tonnes. Its main engine was rated at 151 kw on average. It had an echo sounder and 36% of the boats were equipped with radar. A handline boat commonly used 2 lines, but may have used up to 6. Approximately 53% of the vessels which caught less than 1 tonne live weight of shark per year were handliners and 9% of those which caught 1-5 tonne per year, but only 2% of the those boats that caught more than 5 tonne of shark per year were handline boats. The average depth fished was 25 fm (from logbooks), usually near lumps or over broken bottom. Baits commonly used were herring, mullet, parrotfish or tuna. Although it was a cheap method to use, handlining could not produce catch rates which were competitive with longliners or gillnet boats. Advantages were that handlines could be used in depths beyond the reach of many gillnet boats, and were cheaper to rig than a longline.

(d) Dropline Boats.

In 1983/84, 22 boats used droplines to catch mainly fish and some shark (Table 8), compared with about 8% (6 boats) of the 72 sampled in the 1982 field trip. When field trip data were combined with logbook data it appeared that dropline boats set between

30-150 hooks (up to 25 hooks/line). Droplining however, was still a minor method when compared with the catch taken by gillnets, longlines or handlines, but was rapidly growing in importance. Although dropline catches contributed a small fraction to the total shark catch at present, (6 tonnes in 1983/84) it was expected that this method would make a more significant contribution in the years to come.

D. Seasons and fishermen

Table 9 shows total shark catch by region and month for 1983/84 (ABS data). The seasonality in catch, due to seasonally changing patterns of effort and shark abundance in each region indicated that :

1. For Geraldton region, the catching period is not well defined, but appears to occur in spring, summer and early winter;

2. for Metropolitan region, the peak catching periods are spring, early and late summer, early autumn and early winter;

3. for Busselton region, the peak catching periods are spring, early and late summer and autumn;

4. for Albany region, the best period was October;

5. whereas for Esperance region the peak catching periods occur in summer, early autumn and winter.

These data could be interpreted using seasonality of fishing effort by 'part-time' shark boats. For example, on the west coast 'part-time' boats may have been engaged in other fisheries such as rock lobster, line fishing for jewfish or snapper, trawling for prawns or trapping or droplining in northern regions. South coast shark boats may also have been engaged in salmon fishing, estuarine gillnetting, handlining or tuna fishing; or abalone diving, off season to fishing for sharks.

Thus few boats in the shark fishery spent the entire year directing fishing effort on shark and its scalefish by - catch. A large proportion of professional fishermen engaged in shark fishing did so either on a seasonal or part-time basis (Table 7).

E. Transport and Marketing of the catch.

Catch disposal operated differently in the Metropolitan region (Fig. 1) than in country centres. In the former region, the major wholesaler was Perth metropolitan markets and fishermen using this outlet usually transported their own catch to this market. This even occurred when fish were not caught off the Metropolitan region but as far away as Augusta in the south or Dongara

in the north. Ten or so years ago, a considerable number of shark fishermen used the railway system of train/road haulage from Bunbury, Albany, Esperance and Geraldton. The service was later abolished by Westrail. Fishermen despatching from these areas now tended to use trucking companies on which they could rely for safe, speedy, delivery to the point of sale.

Daily sales are made by an auction system organized at the major markets. The principal buyers are fish shop proprietors who bid against one another and the major wholesalers. The wholesalers fillet shark for resale at retail price levels to hotels, seafood restaurants and other outlets. Smaller quantities of shark are also bought directly from fishermen by individual fish shop owners.

In regional country centres such as Esperance and Albany, there were several shark buyers who purchased large quantities for reselling to W.A. agents and wholesalers or retailers in Melbourne, N.S.W. and S.A. Some of these buyers were also shark fishermen.

From Esperance, some shark was sold locally to cater for local demand and the tourist trade and significant quantities of fresh shark and fish were also taken to population centres of the hinterland region such as Kambalda, Coolgardie and Kalgoorlie, Norseman and Southern Cross. In centres such as Bunbury, Busselton, Albany and Geraldton, more of the shark caught was sold directly to local fish outlets than was sold in the Metropolitan region. In the Metropolitan region, a large part of the shark caught was sold to major markets which required consistent supply due to their large turnover. Most of the shark which was delivered to the Perth Metropolitan Markets was chilled on layered ice, however, large deliveries from distant sources usually arrived frozen.

IV. STATE OF THE FISHERY.

A. General

The total annual catch of shark in the W.A. fishery has shown a steady increase with some fluctuation, such as the period between 1972/73 and 1974/75 when adverse publicity following the discovery of mercury in some Australian fish including sharks, caused a period of uncertainty in the fishery (Figure 2). At that time, there was a decrease in effort and subsequent catch. The trend lines fitted through the annual catches in phases 1 (1961/62-1972/73) and 2 (1972/74-1983/84) (Fig. 2) show that the landings have increased at a greater rate in phase 2. In 1983/84, the total catch of shark was 1262 tonnes live weight, a rise of 9% from the 1982/83 catch, although it did not exceed the record catch of 1328 tonnes live weight in 1981/82. Figure 3a shows catch for all species except skates and rays, fishing effort from gillnet, longline and handline methods combined only and CPUE for the southern fishery for shark ie. the Geraldton to Esperance regions

inclusive. Skates and rays have been excluded as they are a minor component of the total catch in these regions and the species change between regions. The graph shows that, in response to increasing effort between 1975/76 and 1983/84, total catch also increased, although it has levelled out somewhat since 1979/80. CPUE has fluctuated between 72 and 153 kg/gillnet km.day but in 1983/84 was at its lowest over the period examined.

A number of factors influence the level of total fishing effort, the more important of which are known to be: (a) the number of boats operating in the fishery; (b) the period for which the gear is fished for each set; (c) changes in the amount of gear (length of nets or number of hooks) being used; (d) the fishing power of the boat/skipper/gear combination; and (e) the proportion of bad weather days within the fishing season/year, which will differ for different sized boats. Figure 3b shows changes in the number of boats catching shark by gillnet, longline or handline. There has been a nett growth in numbers of boats, using each method, between 1975/76 and 1983/84. In 1983/84 there was a ratio of about 3 gillnet and 3 handline boats operating for each longline boat. Since 1979/80, the number of gillnet and handline boats has levelled off and the number of longline boats has declined slightly. To express the changes in hours fished and amount of gear worked as a single measure of fishing effort by boats using different catching methods, gillnet boats were selected from the total shark fleet, not only because this method takes most of the catch, but also because it provides the best opportunity for comparison between regions.

Table 5 shows the number of gillnet boats operating annually in each region of the fishery together with the mean length of net set per region each year since 1975/76. All regions have experienced an increase in the mean length of net set. For example, among the more striking increases in mean net length between 1975/76 and 1983/84 were: 608m to 1554m in the Metropolitan region; 622m to 1692m in the Albany region; and 618m to 2582m in the Esperance region. This increase was also indicated by the ratio of the mean net length in 1983/84 to the mean length in 1975/76 which showed that between these years it increased, almost 3-fold in Geraldton, Metropolitan and Albany regions and 4-fold in Esperance and Northwest regions (Table 5).

There has also been an increase in the number of gillnet boats operating in each region. The largest growth in numbers of gillnet boats was shown in the Geraldton region (an increase from 4 to 19 boats), producing a boat growth ratio of 6.2 (Table 5).

From Table 8 it is apparent that there have also been increases of 150% and 160% respectively, in the number of boats working longlines and handlines. Of this group of boats, many returned only an incidental catch of shark for the year (footnotes, Table 7). Nevertheless, 7 handline

boats and 28 longline boats caught more than 1 tonne live weight of shark during the year.

Some information was available on the amount of gear used by longline, handline and dropline boats. This was determined by interview during the 1982 field trip (Table 6). Although there were small numbers of boats providing data for some of the categories in Table 6, the limited comparisons which can be made with ABS data for 1982/83 on the mean net lengths being operated in Metropolitan, Busselton and Albany regions (Table 5), show reasonable agreement with the means of 1982 data (Table 6). From the sample of 23 longline boats (Table 6), the mean length of longline set was estimated to range from 1700m for Metropolitan region and increased southward to 9900m for Esperance region. Insufficient handline boats were sampled to warrant comment, but the 9 boats who were working or intended to work droplines used between 30 - 72 hooks (Table 6).

B. Species

Table 10 shows the total catch by species and the combined species catches for the different regions into which the coastal shark fishery has been divided. The category 'other shark' is used for those fishermen who do not split their catches into individual species before sale. It would therefore have contained varying proportions of the 3 major species depending on region. As a result, these species are underestimated by region and year. According to Table 10 however, the 3 most important species are bronze whaler (29%), whiskery (22%) and gummy shark (more than 11%). It is thought that although these percentages are conservative, the relative proportions would not change greatly as they were likely to be similar in the 'other shark' category.

Geographic distributions of these species in W.A. are incompletely reflected in the regional catch figures of Table 10. For example, the W.A. distribution of whiskery shark (Furgaleus ventralis) is from Exmouth to Esperance and the species is found to a depth of 160fm, at least on the west coast of W.A (Heald, unpublished). Bronze whaler (Carcharhinus obscurus) is distributed throughout W.A. waters to at least 100fm (Heald, unpublished) and gummy shark (Mustelus antarcticus) is found from the Geraldton region to Esperance to a depth of at least 120fm on the south coast and west coast (Heald, unpublished), although it is not known how the density of the stock varies with depth outside the depth range currently fished.

(i) Whiskery shark

In Figure 4(a-d), a comparison of the total W.A. whiskery shark catch, effort and CPUE was made with that for Busselton, Albany and Metropolitan regions. In W.A. waters, the fishery for whiskery shark was based mainly on the adult stock and juveniles were poorly represented in catches taken by

the various gears. Whiskery shark landings for 1983/84 were 282 tonnes which was 22% of the total catch of all species (Table 10). Esperance region's catch data for whiskery shark (more than 75 tonnes, Table 10) was not included in the comparison because significant catches of this species were mixed with gummy shark when sold. The mixed whiskery/gummy catches subsequently recorded as 'other shark' on ABS monthly returns have been largely from this region, and the high proportion of this type of mixture in 'other shark' has resulted in a greater underestimate of the whiskery shark catch from Esperance, than from other regions. Fig. 4(a) showed that catch has also increased in response to increasing fishing effort for whiskery shark in W.A. The CPUE has varied between approximately 18 and 55 kg/gillnet km.day from 1975/76 to 1983/84 although the amplitude of these fluctuations has increased in recent years. The CPUE was at its lowest in 1983/84.

(a) Busselton region

About half of the total W.A. catch of whiskery shark came from Busselton (Fig. 4b, Table 10) in 1983/84 and about one third of the total fishing effort on whiskery shark was expended in this region, working primarily lightly exploited grounds. In 1983/84 the CPUE fell below the previous 8 year average in the Busselton region (Fig. 4b). Fishing effort has continued to grow since 1979/80, partly due to the entry of 2 new large boats and 1 older but highly efficient shark boat into the fishery in this region. A large part of the increase in the catch between 1979/80 and 1980/81 can be attributed directly to these boats alone. Whiskery shark comprised about 44% of the shark catch for Busselton region (calculated from Table 10).

(b) Albany region

The Albany whiskery shark catch of 38 tonnes in 1983/84, was the lowest of all regions compared and the CPUE of 15 kg/gillnet km.day was equal to the average for W.A. and similar to the Metropolitan region's CPUE. Whiskery shark comprised at least 20% of this region's catch and the region contributes about 14% to the total W.A. catch of this species (from Table 10).

(c) Metropolitan region

Good catch rates of whiskery shark are no longer experienced in the Metropolitan region. Despite large increases in fishing effort, particularly in recent years, the whiskery shark catch has remained relatively static at 30-60 tonnes between 1978/79 and 1983/84 (Fig. 4d). During

that time the CPUE has continued to fall to a level where it has now become unprofitable for boats to concentrate on whiskery shark. The CPUE was 18 kg/gillnet km.day in 1983/84. Verbal advice from the few remaining fishermen (April 1985) suggested that whiskery shark were then very scarce in that region. Boats have been placed on the market and at least 3 fishermen have left the shark fishery. The whiskery shark component from the Metropolitan region made up 19% of the region's combined species catch, but used to comprise at least 34% about 9 years ago.

(ii) Bronze whaler shark.

Catch, effort and CPUE for bronze whaler shark are given in Figure 5. It is assumed that shark of this species caught within the 3 regions shown form a unit stock of Carcharhinus obscurus. As bronze whaler is less important in catches in the Esperance region, it has been excluded from this data set. The bronze whaler fishery between Geraldton and Esperance is based almost entirely on juveniles and is heavily dependent on annual recruitment, particularly in Metropolitan, Busselton and Albany regions. The magnitude of the catch is thought to reflect recruit strength in any one year.

In 1983/84, a record bronze whaler catch of 361 tonnes live weight was taken. It comprised 29% of the total state catch (Fig. 5a, Table 10). It's magnitude was thought to be both a function of the large effort rise in the overall fishery and an enhanced catchability of bronze whaler shark in the warmer current off the W.A. west coast reported by fishermen in 1984.

In the 3 most recent years shown in Fig. 5a, the catch rate has fluctuated around 20 kg/gillnet km.day, following a high value in 1979/80 (Figs 5b, 5c and 5d), which was thought to reflect the high recruit abundance at that time in those regions.

(a) Busselton region.

Approximately 50% of the W.A. catch of bronze whaler was taken in the Busselton region for one third of the total W.A. fishing effort. Effort has steadily increased on this species since 1975/76 (Fig. 5b). CPUE has varied considerably since 1979/80.

(b) Albany region.

Bronze whaler catches at Albany, which have varied slightly since 1980/81 (Fig. 5c), account for about 11% of the total State catch (Table 10) but 22% of the Albany catch

in 1983/84. The fishing effort in 1983/84 was about 2000 gillnet km.days (Fig. 5c), and has risen only slightly in the 9 year period. CPUE is similar to the W.A. average for the species.

(c) Metropolitan region.

The 1983/84 catch of bronze whaler for this region was 103 tonnes or about 30% of the W.A. catch (Fig. 5 d, Table 10) and 34% of this region's total catch. In the 9-year period since 1975/76 shown in Fig. 5d, fishing effort has grown 8-fold. The CPUE for bronze whaler in the Metropolitan region (Fig. 5d) has remained near the average value for W.A. (Fig 5a), in the 3 most recent years on the graph.

(iii) Gummy shark.

Figure 6 shows the catch, effort, and CPUE of gummy shark, Mustelus antaracticus for Western Australia, Busselton, Albany, and Esperance regions. On a State basis, gummy shark comprised at least 11% of the total catch of shark (Table 10), but its proportion in the catch within each region was quite variable. The Metropolitan region, which probably contributed less than 3% to the total catch of this species in W.A. has been omitted from this data set. It had previously been assumed that for the 3 regions compared in W.A. the data related to one unit stock, which was distributed in Australia between the Houtman Abrolhos Is and Bass Strait. However, evidence has recently become available to suggest that there are in fact at least 3 species of gummy shark in Western Australian waters viz. Mustelus manazo (Gloerfelt-Tarp and Kailola 1984 & Heald, unpublished), an undescribed plain bronze form (i.e. no white spots) from the Abrolhos Is, caught in 22fm (Heald, unpublished) and a form of gummy shark which Whitley (1945c) described as Emissola ganearum. Whitley stated that this Western Australian form or 'race' of the gummy shark was completely different from the Victorian form in that the W.A. form lacked uterine partitions, had differently marked juveniles in utero and grew to a much larger size than Mustelus antarcticus, and hence properly deserved the new species name. This important finding needed to be further investigated. Hence in October 1985, a detailed study to differentiate between stocks began using gel electrophoresis, vertebral counts and a thorough documentation of the reproductive anatomy and biology. As with other species, fishing effort on gummy shark has been increasing since 1976/77. Catch, in the same period, increased until 1981/82, but fell to 137 tonnes in 1983/84.

(a) Busselton region.

Busselton's gummy shark catch has not exceeded 12 tonnes in the last 9 years (Fig. 6b). The low catches have occurred with an increase in the fishing

effort, particularly since 1979/80. In 1983/84, effort had increased 4-fold on its 1975/76 value and has doubled since 1981/82. CPUE, which was about 1 kg/gillnet km.day in 1983/84 is now at its lowest ever level. There is also evidence to suggest that changes have occurred in the relative abundance of the gummy shark population which decreased significantly between 1943 and 1979 in Geographe Bay. This is discussed in detail in Appendix 2.

(b) Albany region.

The gummy shark catch for Albany in 1983/84 (Fig. 6c), remained around 40 tonnes live weight, slightly below the previous year's catch. About one quarter of the total W.A. catch of gummy shark was taken from the Albany region, and at least 14% of the region's catch was gummy shark (Table 10). If significant amounts of Albany's 'other shark' catch of 50 tonnes are sent to Melbourne then it is likely that the shark sold would be mainly a mixture of whiskery and gummy shark. Consequently the Albany gummy shark catch may have also been underestimated and the CPUE figure may have been conservative. Effort has been rising since 1979/80 but no significant trend in CPUE has emerged.

(c) Esperance region.

Esperance region supplies over 66% of the total W.A. gummy shark catch; a landing of 86.5 tonnes live weight was reported in 1983/84 (Table 10). Gummy shark is thought to comprise up to half the total number of shark caught by gillnets in this region. A significant underestimation of that catch occurs due to the common practice of mixing gummy shark and whiskery shark together (approximately 50:50) for Melbourne market requirements, and recording these as 'other shark'. Similarly, it would be difficult to accept the Esperance gummy shark CPUE figures which differ somewhat due to underestimation of the reported catch and effort in this region. Catches of gummy shark at Esperance remain at high levels and have accounted for much of the total W.A. catch of this species since 1978/79 (Fig. 6d). Effort has increased 8-fold since 1975/76. It has been stated by Esperance fishermen that the effort figures for the last 2 years at least may be underestimated by a factor of up to 2 for some of them, due to the false assumption of 1 set per day. Thus the true CPUE may differ either way from the calculated value of 20 kg/gillnet km.day. The direction of the bias in the true value cannot be accurately calculated from the current data because of the underestimation of the catch and the relative inconsistencies of recording effort data (see Indices of relative abundance (p15).

C. Size composition of commercial shark.

Sampling for length and weight composition of the species catch was undertaken from 1974 until late 1978 and recommenced in September 1984 at the Metropolitan markets. However, only data from 1978, September 1984 and summer 1985 have been used in this report. This is because there is an unknown longevity associated with each of the 3 commercial species and it is therefore difficult to predict whether year classes measured would still be alive in the present fishery. Data collected at these markets before September 1984 are also of limited use because mesh size used for capture cannot be associated with the measurements. These markets sell a greater proportion (30%-60%) of the total shark catch than any other wholesale outlet and therefore provided an economic opportunity to sample some of the lower west coast and southwest coast catches. Considerable regional bias occurs in the receivals of shark at these markets. A larger part of the catches of the Busselton, Albany and Metropolitan regions is sold directly to local outlets than catches delivered to the Metropolitan markets from the other regions. Little of Esperance region's catch is sold at the Perth metropolitan markets - most is exported inter-state. Length frequency histograms are shown in Figures 7 and 8. It is expected that biases in size composition will occur at the metropolitan markets due to differences between the sizes of shark sold there when compared with those sold elsewhere. Likewise, mesh selectivity will exert a variable effect on measured length composition when suppliers use different mesh sizes.

The partial length/partial weight regressions are constructed from unpublished data (D.I.Heald) but the partial length/total length regressions are based on catch sampling by D.I.Heald from 1973-1975, presented in Hancock, Edmonds and Edinger (1977). These are given in Appendix 3.

(i) Whiskery shark.

The partial length distribution of whiskery shark for combined males and females had a single mode of 67 cm in late 1978 (Fig. 7a). The mean partial weight at the mode was 6.5 kg. There were also 2 very small sharks, about 22 cm in length which did not belong to the main modal group. In September 1984 (Fig. 8a), the total length at the mode was 62 cm, based on 1136 whiskery shark from combined regions with an overall corresponding mean partial weight of 5 kg from 263 measurements. In summer 1985, a unimodal distribution for whiskery shark was also observed with a mode again at 62 cm.

(ii) Bronze whaler shark

There were 3 distinct modal groups present in the combined male and female partial length frequency

distributions of bronze whaler shark in late 1978 (Fig. 7b). Using the statistical separation routine NORMSEP (Cohen, A.C. in Abramson 1971), it was possible to separate these 3 groups and calculate the mean, variance and numbers of shark in each. Group 1, with a mean total length of 44 cm, contained 74% of the sample; group 2, with a mean total length of 68 cm, contained 21% of the sample whilst group 3, with a mean total length estimated to be 85 cm, contained 5% of the sample. The mean partial weights associated with the 3 groups were 4.7 kg, 15.2 kg and 28.5 kg respectively. The distribution was positively skewed (Sk = 0.758) due to the presence of the 2 larger groups. The overall mean partial length for the distribution was 51.2 cm and the mean dressed weight was 7.0 kg. In September 1984 (Fig. 8c), the mean partial length of 505 bronze whalers measured at the markets was 47 cm and the associated partial weight was 6.8 kg (198 measurements). In the summer of 1985 (Fig. 8d), a unimodal distribution of 816 shark, with a mode at 42 cm was found. Almost no shark larger than 62 cm were found in the summer 1985 market sample, a few larger than that size were found in spring 1984, whereas a significant proportion of the summer 1985 sample was larger than 62 cm in partial length.

(iii) Gummy shark

The length distribution measured in late 1978 for combined male and female gummy shark had a single mode, close to the mean, of 68 cm (Fig. 7c). The mean partial weight was 5.7 kg. The distribution of lengths had a slight positive skewness (Sk = 0.396). In September 1984 (Fig. 8e), the mode was 57 cm; the mean partial length was 60 cm (42 measurements) and the associated mean partial weight was 4.1 kg (8 measurements). In summer 1985 (Fig. 8f), both the mode and the mean were 62 cm in partial length (42 measurements).

D. Relationship between fishing for shark and other types of fishing.

Annual shark catches of less than 1 tonne live weight (0.63 tonne landed weight) per boat were considered to have been taken incidentally to fishing operations directed at other target species. Therefore, boats which caught less than 1 tonne live weight per year (up to approx. 21 kg live weight per week for a 48 week year) were arbitrarily excluded from the following comparison. The total number of these boats is shown for selected years in Table 7. The arbitrary definition of a shark boat has thus been set as one catching 1 tonne live weight or more per year for the selected period, ie. 1975/76 to 1983/84.

To gain some idea of the annual catching performance of individual boats in the 'shark fleet' thus defined, the fleet was arbitrarily divided into boats which caught 1 to 5 tonne live weight per year (0.63 - 3.1 tonne landed weight per year) and those which caught more than 5 tonne live weight. On this basis, the former group was defined as 'part-time/seasonal', and the latter group (> 5 tonne live weight per year) was defined as 'active/seasonal and/or full-time'. Table 7 therefore shows the numbers and percentages of boats in each catch class and the relative proportions of 'active' or 'part-time' boats for selected years between 1975/76 and 1983/84. The mean catch/boat for 'part-time' and 'active boats' is also shown for the same years in Table 7. It is immediately apparent that a greater proportion (ie. ca. 60%) of the shark fleet is comprised of 'part-time' boats which have caught little more than 2 tonne live weight (1.3 tonne live weight) per boat per year for those years shown. In 1983/84 'part-time' boats comprised 57% of the defined fleet. In the same year, 56 boats were defined as 'active' shark boats, with a mean annual catch of 18.4 tonnes live weight per boat (11.6 tonnes landed weight). The proportion of boats in each category has remained relatively stable since 1975/76 even though the number of boats in the 'active' class more than doubled while the number of 'part-time/seasonal' boats shared a 50% increase over this period.

During the field trip of Nov/Dec 1982, the skippers of a group of 72 boats which may have caught shark at some stage during the year, were interviewed to ascertain the proportions of the target species in their annual catches. From Table 6, 18 of these boats would have been classified as 'part-time' and 30 would have been classified as 'active'; catches of remaining boats were classified as 'incidental'. The results of this survey are possibly biased in that the sample contains a larger number of south coast fishermen than west coast fishermen, because the season during which the survey was conducted corresponded with the start of the rock lobster season and these fishermen were not as easy to contact as were the others. The survey also did not take in the fishermen north of Greenhead (30°04'S 114°58'E) who caught shark. Species catches of 60 out of the 72 sample boats whose skippers were interviewed in Nov/Dec 1982 are shown in Figure 9a. The remaining 12 boats, although they had been fishing for shark up to June 30 1982, did not qualify for inclusion in Fig. 9a, because they did not actually catch shark during fiscal 1982/83. The breakdown of the total catch of these 60 boats shows that 852 tonnes or 35% was shark, 1173 tonnes (50%) was tuna, 145 tonnes (7%) was large scalefish, 142 tonnes (6%) was bait and 54 tonnes (2%) was rock lobster. Data from 1982/83 and not 1983/84 have been used in Figures 9 and 10 as this was the last year before fishing intentions and traditions were altered by the effects of the tuna quotas i.e. it is more representative than the current spectrum of operations. From the time of the introduction of the tuna quotas, some

fishermen said they intended to spend more time targetting on shark and other scalefish, others said they would await the effect of reductions in tuna quotas on their overall fishing strategy, whilst the remainder were unsure if the (then) newly established tuna quotas would affect them at all.

To give a clearer regional picture, these data have been divided up into west coast (Figure 9b) and south coast components (Figure 9c). Figure 9b shows, for the west coast members of the sample, that large scalefish (18%) are second in importance to shark (46%), together comprising nearly two thirds of the total catch of this group, followed by rock lobster (13%), tuna (12%) and then bait (10%). By contrast, Fig. 9c indicates clearly that more tuna (57% of the total) than shark (34%) was caught by the south coast sample group in 1982/83 and bait (5%) was the next most important catch by weight followed by rock lobster (4%). This result altered significantly after 1984 as the effect of the tuna quota was felt.

Figure 10a-c gives the values of fish and crustacea shown in Figure 9a-c. Figure 10a shows that shark is worth over half of the total value of the catch of the 60 fishermen, although from Fig. 9a, much less shark is caught than tuna. Differences between species in the value per unit catch are clearer when the west coast (Fig. 10b) catch values are compared with those from the south coast (Fig. 10c). Hence on the south coast, shark was most valuable, tuna was second, followed by bait fish, large scalefish and rock lobster. On the west coast however, the value ranking was rock lobster, shark, bait fish, large scalefish and tuna lowest.

Directed effort by boats on shark and towards species such as rock lobster, tuna, bait and other fish was compared in Figure 11 according to which fishing method was used and whether the boat was 'active' or 'part-time' when fishing for shark. Both the mean catch per boat and the mean number of days fished for each target group are shown. For example, when 'active' net fishermen were compared with 'part-time' net fishermen, it was seen that, except for the mean shark catch of 18.7 tonnes live weight per boat as against 2.8 tonnes for the 'part-time' group, there was little difference in their respective mean catches of rock lobster, tuna, bait or other. The 'part-time' net group, however spent 26% more time fishing for rock lobster, slightly more time poling tuna and nearly twice as much time pursuing bait fish than the 'active' net fishermen. Small sample sizes in the other categories made it difficult for further statistical comparison within each fishing method group, even though an indication of the trends was provided in Figure 11.

V. DISCUSSION

A. Catch and Effort

There is no doubt that the expansion of the total shark catch in W.A., from the trough of 1974/75 to the peak of 1981/82, was due to very large increases in the total fishing effort. The major part of the effort increase was generated by gillnet boats. Like the expansion seen in the gillnet boat component of the shark fishery, there has been a similar growth in handliners from 95 boats in 1975/76 to 152 boats in 1983/84, but a slightly smaller increase in the numbers of longline boats, i.e. from 32 in 1975/76 to 49 in 1983/84 (Table 8). However, due to the far greater fishing power of nets compared with handlines or longlines, the greatest impact was clearly from gillnets. It was shown that the main way in which gillnet effort had risen was through gear length increases in most regions.

In the development of the measure of effort, it was assumed that most fishermen set their nets about once per 24 hour period. This proved to be correct for west coast and Albany fishermen. The assumption was incorrect for some of the Esperance fishermen and the calculated nominal effort is underestimated by a factor of 2 for those who operate this way in that region. Unfortunately the effort data cannot be precisely estimated due to recording problems generated by fishermen on their ABS monthly returns (see Appendix 1). It is hoped that improved logbook effort data will help rectify this problem.

Another assumption was that shark fishermen worked approximately the same number of days each year. Notwithstanding the yearly changes in the number of good weather days suitable for fishing, it is felt that another factor which has probably determined the days fished at least for those fishermen classed as 'part-time', was the period available after commitments to other target fisheries had been met. On the west coast, 'part-time' shark fishermen who were also rock lobster fishermen were likely to have the same period available to fish shark each year. On the south coast, reduction of tuna quotas has increased the fishing pressure on the shark resource. Observable changes have occurred in two ways. Firstly, there has been an increase in the size of the fleet concentrating on shark. More effort days have been directed onto shark by those tuna boats remaining in that industry. In turn catch rates have fallen (e.g. Esperance), forcing those fishing shark either to set more gear in order to maintain catches or search for new grounds. For many, this can only be achieved by venturing into deeper fishing grounds, which contain a largely untested shark resource. The alternative is to move far from their home port, for which extra capitalisation and running costs will be required.

Much fishing effort expended on sharks was generated by the fleet of 66 'part-time' (or 'seasonal') boats which

spent a significant part of their fishing year targetting on other species (Fig 11). On the west coast, the other fishing activity was rock lobster potting, whereas on the south coast the fleet caught southern bluefin tuna during the species eastward migration. There has been no attempt to measure some of the other variables which, for simplification, have been treated as constants when summing effort from different gillnet boats in different regions. Obviously, differences in the catching power of different nets have occurred as a result of :

1. differences in mesh size used

2. how the nets have been hung, which may have affected "drop-out" rates

3. different retention rates of mono- and multifilament nets

4. interactions between nets of different fishermen set on the same grounds, both simultaneously and sequentially

5. changes during sets due to reductions in the effectiveness of nets through large sharks tangling them or biting off headlines and/or footlines.

6. nets in poor condition.

The combination of these influences on a net was, of necessity, measured by the catch retained on board.

In 1983/84 the mean CPUE of all species combined in W.A. was at its lowest value since 1977/78. That the increase in effort has failed to generate an increase in catch was shown by the decline in CPUE, for regions from Geraldton south. It has been stated by fishermen that economic catch rates are not being made in some regions. This could be due to a combination of factors including long histories of fishing and effort competition between boats. It has been alleged that falling catch rates in the past few years have forced some operators out of this fishery, whilst others are struggling and have had to rely more heavily on other target species, or to set even more fishing gear to maintain catches.

Of still greater concern is the large reserve of fishing gear owned by the 'part-time' fleet which may be brought into even greater use in the future. On the south coast, where tuna quotas are now in place, there may be a large increase in effort in the shark fishery. However, when those rock lobster boats which participate on a part-time basis in the west coast shark fishery have experienced a bad rock lobster season, the effect of their increased off-season pressure on the shark fishery will be very significant.

The question of whether a stock-recruitment relationship can be demonstrated for each of the 3 main species needs

to be considered. In a workshop in March 1983, the South Eastern Fisheries Committee accepted that a relationship could be demonstrated for the Bass Strait gummy shark fishery. Under high levels of fishing pressure which significantly reduce the population, compensatory mechanisms come into play to enhance the abundance of juvenile stocks. However, this is very much a function of the mesh sizes being used. Wood, Ketchen and Beamish (1979) found that reductions in the juvenile mortality rate helped maintain the yield of dogfish stocks in the eastern Pacific, when fishing pressure increased. Allen (1983) has presented mathematical arguments based on data from the Victorian gummy shark fishery which suggested that compensatory growth changes may have a beneficial influence on fecundity and offset some of the loss of potential yield when the level of fishing increases. If such response mechanisms exist in species in the W.A. fishery, it would augur well for its future conservation. Unfortunately, insufficient work has been done on the principal W.A. species to ascertain if stock-recruitment relationships can be demonstrated.

Historically, it has been shown overseas that single species shark fisheries are difficult to conserve in the long term. Under high levels of fishing effort, shark fisheries usually cannot produce yields that are sustainable in time. Holden (1974) has presented examples of shark fisheries which have collapsed outright or been reduced to a stock level where fisheries are not economically viable. The fisheries which failed included the California soupfin shark fishery (which is the same species as the eastern school shark in Australia), the basking shark fishery in the Irish Sea and the Scottish-Norwegian spiny dogfish fishery. On the other hand, the tendency to over-exploit a species may be maintained past the time when catches become uneconomic, by supplementary catches of one or more other species.

B. Species

It should be clearly recognised that, due to many fishermen not splitting their total shark catch into species before sale, indices of relative abundance of individual species must be regarded as preliminary estimates. Subsequently it is expected that re-analysis of ABS statistics in the light of field sampling data, and new logbook information, will enable the revision of estimates of relative abundance of the major shark species.

(i) Whiskery shark

CPUE for whiskery shark in W.A. has been declining in the past 3 years in all regions (Fig. 4). The W.A. CPUE remains at the lowest level since 1975/76 and the Metropolitan region has the most serious problem. In 1983/84, CPUE averaged 12 kg/gillnet km.day which is less than 1 live shark per kilometre of net set. From a comparison of length

at birth (Whitley, 1948; Heald, unpublished) with size composition of the landed catch (Fig. 7a), it was clear that whiskery shark were fished as an adult or near adult under the current mesh size regime. If the declining CPUE was attributable to a fall in recruitment, catch rates, which have been slow to fall may never recover i.e. recruitment overfishing would be deemed to have occurred. This slow response is a result of the low numbers of young born to each breeding female and the possibility that some of the sexually mature females in the population may breed biennially as with some other species of shark. Fortunately for this species at least on the west coast, fishing grounds do not yet extend to the westward depth limit of its distribution. On the west coast, the current fishing grounds do not extend much past 70fm, and the species was occasionally found to depths of 160fm during an exploratory trawl survey (Heald, unpublished). There has also been a lack of juvenile whiskery shark caught by any of the fishing methods used for shark. Indeed they might occupy a different habitat from the adults, or be too small to mesh in the 7" and 6½" gillnets currently being used. Size composition evidence from the west coast dominated metropolitan market samples has shown no change in modal size over a 7 year period. Excluding effects of mesh selectivity, which may have changed in that time with changes in the proportions of 6½" and 7" mesh being used by the shark boat fleet, this provides tenuous evidence of a high escapement. These would be whiskery shark smaller than 52 cm partial length; the smallest market size being selected for by the mesh regime being used.

(ii) Bronze whaler shark

The bronze whaler segment of the fishery was based almost entirely on a single species, Carcharhinus obscurus. Fishing grounds for bronze whaler covered only part of the geographic and depth range of the species in W.A. From size composition evidence, and assuming the size at birth was not greatly different from that found in South Africa (Bass, d'Aubrey & Kistnasamy 1973); catches in most regions and seasons were made up almost entirely of newly born young of the year and juvenile shark. Adult bronze whaler shark have been found in deep water (100fm, Heald, unpublished) and would therefore mainly be vulnerable to capture when they move inshore. This happens in summer and autumn when there is an increase in the number of adolescent and adult shark in waters of 40 fm or less, where most fishing occurs. It is possible that some of the large pregnant female bronze whalers move into coastal waters to take advantage of warmer temperatures or the more plentiful food supply for the young during the dropping season,

although as stated above, the adults of both sexes make a relatively small contribution to the total catch. Size composition data for spring 1984 and summer 1985 did not reveal the presence of larger bronze whalers seen in the summer 1978 sample, and these 2 distributions were dominated by a large juvenile recruit class. Bias in marketing may have been equally responsible for the apparent decline in the proportion of medium and large bronze whaler at the major markets.

In South African waters, the average litter was 10 pups (Bass, d'Aubrey and Kistnasamy 1973) which agreed well with the few fecundity records which are available from W.A. waters. The low fecundity was associated with a breeding frequency of once per 2 years. The age at first breeding is not known.

The bronze whaler fishery has relied on recruitment from each year's new cohort, an observation made once again in market samples in 1985. The adult stock which produces this annual cohort occupies a habitat which is rarely exposed to gillnet fishing, so it therefore appears that the bronze whaler component of the overall shark fishery may be less likely to be affected by increases in fishing pressure. Although to date the W.A. average CPUE has shown no cause for concern over the 9 year period shown in Fig. 5a there may well be a long lag period associated with age at first breeding.

(iii) Gummy shark

There has been some doubt expressed in W.A. about the taxonomic status of the cool temperate stock of white-spotted gummy shark fished in W.A. Identification of specimens from deep water north and south of the Abrolhos Is and many specimens taken during the cruise off the north W.A. coast, (Gloerfelt-Tarp and Kailola 1984; G. Leyland, pers. comm.) has shown that the species Mustelus manazo occurs here and is wide ranging in deep water in W.A. between latitudes 13°S and 28°S. Even more importantly, there is a real possibility that the W.A. cool temperate species of white-spotted gummy shark may be a different stock from that in south-eastern Australian waters. A key character to which Whitley (1945) referred in his paper was the absence of uterine partitions separating embryos in W.A. specimens whereas they were present in Victorian specimens. At the time of writing an attempt is being made to separate stocks of gummy shark, if more than one occurs in catches. Urgent attention is being given via an expanded field study, to resolve this problem. For the purposes of catch and effort statistics in this paper, gummy shark is thought of as one species (see III A, p16).

Gummy shark (Mustelus antarcticus) were more abundant on the W.A. south coast through the Albany and Esperance fishing regions but less abundant from west of Walpole to Bunbury. This species was caught over most of its geographic range in W.A.; the same species apparently being caught in inshore waters from Albany to Geraldton. In Australia, gummy shark populations range from Shark Bay to southern Queensland waters. In the eastern Australian fishery for gummy shark, fishermen operate in deeper waters than they do in W.A. but Victorian data shows that Mustelus antarcticus is more abundant to approximately 40 fm than in deeper eastern Australian waters.

On the W.A. south coast, the gummy shark population extends into 120 fm, (H. Spengler, pers. comm.) which is beyond the current fishing range of the W.A. gillnet fleet. Although in W.A. gummy shark is not being fished over all of its depth range, a low abundance of gummy shark may occur in deeper waters, as in the Bass Strait gummy shark fishery so the current fleet may be effectively exploiting the gummy shark stock over most of its depth range. A single tag recovered in Western Australia from the Eastern States tagging programme (Walker 1983) has suggested that a very slight degree of mixing can occur between W.A. and Victorian gummy shark populations. The southern W.A. fishery on gummy shark may be drawn from a single stock distributed across the entire Great Australian Bight, or there may be 2 stocks whose populations are sympatric. Thus fishing strategies in Victoria, South Australia and Tasmania may have a slight effect on recruitment into the W.A. fishery and vice versa.

There is some evidence to suggest that Port Jackson shark have filled a niche progressively vacated by gummy shark (Mustelus antarticus) as numbers became reduced by fishing. This was reflected in changes to the relative abundances of the gummy shark and Port Jackson shark populations off Busselton between 1943 and 1975/76 (Appendix 2). According to Whitley (1943), gummy shark used to comprise 56% of the catch by number in normal longline sets during that year. However, in a 1975/76 longline survey of the Geographe Bay area (Walker 1979), it was interesting to note that, between 1943 and 1975/76, there had been a significant increase in the mean catch per hook of Port Jackson shark, coincidentally with a decrease in the catch per hook of gummy shark. This observation pointed to a historic decline in gummy shark in this region.

There is another example of the apparent effect of reduced gummy shark abundance. It has been reported by some south coast fishermen that the chinaman leather jacket, Nelusetta ayraudi, has become very abundant in recent years. It has also

been stated by some fishermen that newly hatched chinaman leather jacket form part of the diet of gummy shark at that time of the year. It is thus possible that high fishing mortality on gummy shark has reduced its abundance thereby allowing improved survival and recruitment of the leatherjacket.

C. Regions

The broad overview of the W.A. fishery given in Figure 3a, which was achieved by combining species and regions, will tend to conceal any problems which are or could be developing with a particular species or in a certain region. However when data were separated into different regions (Figs 4-6), the Metropolitan whiskery shark fishery (Fig 4d) clearly had a lower CPUE compared with other regions, which suggested a real difference in the state of the fishery here. Some of the more obvious reasons for the occurrence of such differences are :

(i) That each region has a unique history of fishing with exploitation rates which for historic reasons, increase at a different rate in each region.

(ii) The total available fishing ground as measured by the length of coastline, and the CPUE of each species of shark on those grounds differ in each region.

(iii) A different species composition occurs in each region (Table 10).

D. Boats, gear and techniques

There have been improvements in all areas of shark fishing when compared with fishing techniques used in the early 1970's. Among the most obvious were increases in boat size and specialization which allowed boats to fish for shark more efficiently. They included increased use of hull designs which were planing or semi-planing, and automatic recovery of nets and longlines. Increased usage of navigational and fishing aids have also been noted. Reduced catch rates and larger overheads have forced many shark fishermen to fish more gear and set gear more often.

E. Fishing intentions of shark fishermen.

Fishermen who set gillnets or longlines depended moderately to heavily on their catches of scalefish associated with the shark. In addition, both the 'active' shark boats, as well as the 'part-time' shark boats needed to engage in other fisheries such as tuna on the south coast, and rock lobster on the west coast to support their shark commitments. It could readily be argued that those fishermen whose catch of shark was below 5 tonnes live weight per year (incidental and part-time boats) really belonged to a wetfish fleet, a proportion of which may target on shark at certain times of the year.

VI. CONCLUSIONS.

During the last 10 years, the W.A.-based shark fishery has undergone a period of unprecedented growth. The shark fishery is fully exploited in the regions from Metropolitan to Esperance inclusive in the depth ranges currently worked. The increase in catch has been a direct result of a rapid effort escalation by the gillnet-dominated fleet. The effort expansion has been brought about by a 200% increase in the number of boats in the wetfish fleet and by a 240% increase in the mean length of nets set by gillnet boats. Despite a freeze on the total number of boats in coastal fisheries, introduced by the Fisheries Minister in September 1983 (Anon 1983), the fleet target fishing towards shark has continued to increase in the absence of regulations to prevent licensed boats from equipping to fish for shark. This increase has been brought about by 'active' shark boats increasing the total length of gill net set and/or fishing harder, an upgrading of effort by boats which now catch small quantities of shark, and by a spillover from the boats which previously concentrated on southern bluefin tuna.

In contrast to the more southern regions of the fishery, the shark resource in the Exmouth and Northwest regions was only lightly exploited. In their coastal zones, these northern regions contain a practically unexploited mixed species shark resource. Some successful marketing of northwest shark species has been achieved by Northern Territory shark fishermen both within Australia and overseas. This might also be taken up by any W.A. fishermen fishing in northern areas of W.A.

For the purposes of this report, the southern shark fishery is assumed to be based on 3 principal species : whiskery, bronze whaler and gummy shark. Although further taxonomic work may reveal 2 southern stocks of gummy shark, it was previously believed that a single stock occurred between southern Western Australia and Bass Strait. From the data series as presented in Figs 4-6 spanning 9 years, there were clear signs in the CPUE of problems with the whiskery shark fishery. There may also be problems with gummy shark on the south coast, especially at Esperance due both to the conservative measure of effort used in this report (for reasons explained in Appendix 1) and the under-reported gummy shark catch. There is no doubt about the large increase in effort which has been measured in all regions. For bronze whaler shark, CPUE seems to have been more affected by natural changes in recruit abundance than by variation in effort. To achieve a well regulated fishery, it is very clear that important basic biological data on the main species is urgently required in W.A. Information is lacking on age composition, growth rates, natural mortality rate, fecundity, age at first breeding, size at birth and a knowledge of any interactions between the main species of whiskery, bronze whaler and gummy shark which may have been positively or adversely affected by fishing. For a first approximation, it may be acceptable to apply values obtained in South Africa as estimates for the bronze whaler population in W.A., and values from Victorian research for gummy shark in W.A. In the medium to long term, however, the parameters needed for the W.A. shark

fishery will have to be verified by a sustained field research programme to study growth, reproduction and movements.

During the analyses of the catch data, it became obvious that more precision was needed in catch information recorded by ABS. It is suggested that it would be particularly beneficial to include some extra shark species codes. This would have the advantage of separating and saving information on species such as thickskin, eastern school, grey nurse, pencil and hammerhead which is being recorded by some fishermen but lost during computer processing. In turn, this may help reduce the magnitude of the 'other shark' category so that better estimates might be obtained of the contribution of bronze whaler, whiskery and gummy shark species in the composition of mixed catches now being allocated to 'other shark'. An attempt should also be made to clarify the headings on the Commercial Fisheries Production Monthly Return so that there is no chance that different types of information will be recorded in the same column (Appendix 1 and Appendix Figure 1). Specifically, it is suggested that the word "total" replace "average" in the column B heading (Appendix Figure 1) to prevent gillnet fishermen from recording the average length of the separate pieces of net instead of the total length of net used per day.

Supplementary information gained from the shark research logsheets has been useful for providing a first indication of gear and fishing, however a greater level of co-operation is desired. Logbooks can be a source of very recent information which would not otherwise be available for up to 18 months later, due to processing delays with late monthly returns. A new logsheet has been designed, to enable information for the 2 principal fishing methods to be obtained on a set by set basis. This logsheet has been incorporated into a bound and printed logbook. However, a much greater logbook response from fishermen is needed to provide a reliable data base and it is hoped that the publication of this report and a concerted field programme to publicise the logbook during its pilot stage, will help to convince fishermen of the importance of providing correct and timely logbook information. Without such co-operation the interests of their fishery can never be fully served. The difficulties described in this report should be sufficient to convince all fishermen of the need for a greater response to logbooks.

VII ACKNOWLEDGEMENTS

I am most grateful to a number of people for their assistance in the preparation of this report. To Dr D. Hancock, Mr B. K. Bowen and Mr R. Lenanton for constructive criticism; to Mr N. Caputi and Mr N. Hall for statistical and mathematical advice. Thanks also go to the following people: principally Miss Tracy Sellers, for various tasks concerned with the preparation of this report, including construction of figures and tables and assistance with the proof reading (Ms M. Platell and Mr R. Sellers also). To all those fishermen who have expressed interest in and support for shark research, I give my sincere thanks.

VIII REFERENCES

Abramson, N.J. (1971). 'Computer programs for fish stock assessment.' F.A.O. Fisheries Technical Paper No. 101. Rome. 98pp.

Allen, K.R. (1983). 'A possible population model for application to sharks'. Background document, South Eastern Fisheries Committee Shark Assessment Workshop, March 1983.

Anon, (1983). 'Future management of Western Australian developed and underexploited fisheries'. Dept. of Fisheries Discussion Paper. 17pp.

Bass, A.J., D'Aubrey, J.D. and Kistnasamy, N. (1973). 'Sharks of the east coast of southern Africa 1. The genus Carcharhinus (Carcharhinidae). South African Association for Marine Biological Research, Investigational Report No. 33. 168 pp.

Cohen, A.C. (1966). 'Estimation of parameters for a mixture of normal distributions.' Technometrics 8(3), 445-446.

Gloerfelt-Tarp, T. & Kailola, P.J. (1984). 'Trawled fishes of Southern Indonesia and Northwestern Australia.' Published by ADAB, DGF Indonesia and GTZ. Singapore.

Gulland, J.A. (1969). 'Manual of methods for fish stock assessment'. Part 1. Fish Population Analysis. F.A.O. Manual in Fisheries Science No. 4. Rome. 154 pp.

Hancock, D.A., Edmonds, J.S. and Edinger, J.R. (1977). 'Mercury in shark in Western Australia. A preliminary report'. Fish. Res. Bull. West. Aust. 18, 22pp.

Holden, M.J. (1974). 'Problems in the rational exploitation of elasmobranch populations and some suggested solutions,' in 'Sea Fisheries Research', 117-138. F.R.Harden-Jones (Ed.), Logos Press, London.

Walker, M.H. (1979). 'An inventory of the marine resources of the Bunbury marine area and Geographe Bay'. Rep. Fish. Dept. West. Aust. 37, 46 pp

Walker, T.I. (1983). 'Investigations of the gummy shark, Mustelus antarcticus Gunther, from south-eastern Australian waters. Report to Fishing Industry Research Committee. 94 pp.

Whitley, G.P. (1943). 'Preliminary report on the longline shark fishery at Bunbury, W.A. 9pp. Mimeo.

Whitley, G.P. (1945). 'New sharks and fishes from Western Australia. Part 2.' The Aust. Zool. 11 (1), 1-42.

Whitley, G.P. (1948). 'New sharks and fishes from Western Australia. Part 4. The Aust. Zool. 11, 259-276.

Wood, C.C, Ketchen, K.S. and Beamish, R.J. (1979). 'Population dynamics of spiny dogfish (Squalus acanthias) in British Columbia waters. J. Fish. Res. Bd Can. 36, 647-656.

TABLE 1. Regional catches of shark in W.A. (kg live) in 1949 compared with the catch of other fish and crustacea. The shark catches are expressed as a percentage of the total fish and crustacea catch (T.F.C.C.).

PORT	SHARK CATCH	OTHER FISH	CRUSTACEA	SHARK PROPORTION OF T.F.C.C.	TOTAL CATCH
SHARK BAY	1 264	212 071		0.6%	213 335
GERALDTON	4 899	172 092	1 145 199	0.4%	1 322 190
FREMANTLE	50 426	276 050	242 539	8.9%	569 015
MANDURAH	2 455	157 259	7 541	1.5%	167 255
BUNBURY	37 872	769 976	19	4.7%	807 867
ALBANY	21 682	1 735 475		1.2%	1 757 157
HOPETOUN	52 852	430 117		10.9%	482 969
REGIONAL TOTALS	171 450	3 753 040	1 395 298	3.2%	5 319 788

TABLE 2. Shark species caught by commercial fishermen in W.A. An asterisk (*) denotes that the species is not usually sold for human consumption in W.A.

FAMILY (GROUP)	SCIENTIFIC NAME AND AUTHOR		W.A. COMMON NAME(S)	COMMON NAMES ELSEWHERE
CARCHARHINIDAE (Whalers)	Carcharhinus obscurus (Lesueur, 1818)		bronze whaler	dusky shark
	C. brachyurus (Günther, 1870)		copper shark,bronze whaler	copper shark
	C. plumbeus (Nardo, 1827)		thickskin shark	sandbar shark
	C. brevipinna (Muller & Henle, 1839)		blacktip, inkytail	long-nosed grey shark
	C. sorrah (Valenciennes, 1839)		blacktip	sorrah
	Galeocerda cuvieri (Lesueur, 1822)	*	tiger shark	tiger shark
TRIAKIDAE (Smoothounds)	Furgaleus ventralis (Whitley, 1943)		whiskery, reef shark	sundowner, reef shark
	Mustelus antarcticus Günther, 1870		gummy shark	smoothound
	Galeorhinus galeus (Macleay, 1881)		eastern school	school, snapper shark
	Hypogaleus hyugaensis (Miyosi, 1939)		pencil, western school, clearnose	lesser soupfin
ORECTOLOBIDAE (Carpet sharks)	Orectolobus ornatus halei (de Vis, 1883)		Gulf wobbegong	-
	O. species		western, banded wobbegong	-
	O. maculatus (Bonnaterre, 1788)		spotted wobbegong	-
	Sutorectus tentaculatus (Peters, 1864)		cobbler carpet shark	-
SPHRNIDAE (Hammerheads)	Sphyrna lewini (Griffith & Smith, 1834)		hammerhead	scalloped hammerhead
	S. zygaena (Linnaeus, 1758)		hammerhead	smooth hammerhead
SQUATINIDAE (Angel sharks)	Squatina tergocellata McCulloch, 1914		ornate angel shark	-
	S. australis Regan, 1906		angel shark	-
SQUALIDAE (Dogfish)	Squalus megalops (Macleay, 1881)		piked dogfish	piked dogfish
	Centrophorus moluccensis Bleeker, 1860	*	endeavour dogfish	endeavour dogfish
ODONTASPIDAE	Eugomphodus taurus (Rafinesque, 1810)		grey nurse shark	ragged toothed sand shark
ISURIDAE (Pointers)	Carcharodon carcharias (Linnaeus, 1758)	*	white pointer	great white, white death
	Isurus oxyrinchus Rafinesque, 1810		mako, blue pointer	short-finned mako
HETERODONTIDAE	Heterodontus portusjacksoni (Meyer, 1793)	*	Port Jackson shark	-
HEPTRANCHIDAE (7-Gill sharks)	Heptranchias perlo (Bonnaterre, 1788)		one-fin shark	7-gill shark

TABLE 3. The 1983/84 regional and total shark catches by method are shown in tonnes live weight. Within each region the proportion of the catch taken by a fishing method is shown as a % of the regional catch.

REGION	GILLNET	LONGLINE	HANDLINE	DROPLINE	MINOR METHODS	REGIONAL CATCH BY ALL METHODS
NORTHWEST	5.0	-	-	2.2	0.2	7.4
Proportion	67.6%			29.7%	2.7%	
EXMOUTH	2.1	-	5.2	0.2	1.1	8.6
Proportion	24.4%		60.5%	2.3%	12.8%	
GERALDTON	44.5	5.9	5.9	1.2	trace	57.5
Proportion	77.4%	10.3%	10.3%	2.1%		
METROPOLITAN	269.4	8.8	17.7	2.0	3.7	301.6
Proportion	89.3%	2.9%	5.9%	0.7%	1.2%	
BUSSELTON	430.6	3.6	3.0	trace	0.3	437.5
Proportion	98.4%	0.8%	0.7%		0.1%	
ALBANY	113.7	57.6	14.0	0.2	1.5	187
Proportion	60.8%	30.8%	7.5%	0.1%	0.8%	
ESPERANCE	250.1	11.5	1.4	-	0.2	263.2
Proportion	95.0%	4.4%	0.5%		<0.1%	
TOTAL CATCH	1115.4	87.4	47.2	5.8	7.0	1262.8
Proportion	88.3%	6.9%	3.7%	0.5%	0.6%	100%

(*) The formula for interconverting live weight and partial weight (= landed weight (Australian Bureau of Statistics Monthly return) cleaned weight or dressed weight) is:

LIVE WEIGHT (tonnes) = (LANDED WEIGHT(kg) x 1.59) / 1000

TABLE 4. Details of boat construction and equipment in 1982/83 from Marine and Harbours files.

CHARACTERISTIC	GILLNET			LONGLINE			HANDLINE		
	NO. OF BOATS	MEAN	RANGE	NO. OF BOATS	MEAN	RANGE	NO. OF BOATS	MEAN	RANGE
HULL LENGTH (m)	59	11.4	4-24	21	11.3	5-15	12	12.3	6-16
GROSS TONNAGE (t)	59	12.5	1-55	20	11.4	1-38	12	11.3	1-29
MAIN ENGINE POWER (kW)	47	132	11-326	10	145	72-284	10	151	105-203
RADAR FITTED	29			16			9		
ECHO SOUNDER FITTED	76			26			25		
TOTAL BOATS	77			26			25		

FOOTNOTES:

1. The following hull types were in use by the fleet of boats which caught shark: aluminium, bondwood, ferrocement, fibreglass, planked wood and steel. The most common type of hull design used by gillnetters was bondwood (28 boats); for long-liners was also bondwood (11 boats) but handline boats were mostly fibreglass.

2. For gillnet and longline boats, the most frequent number of crew used was 2; handline boats used 3 crew. The maximum number of crew used was 4.

TABLE 5. The mean length of gill net (metres) used per boat and the number of gillnet boats (N) operating in each region for the years 1975/76 to 1983/84. In addition the actual number of boats, irrespective of region, is shown. The ratio D/A shows the change in mean net length per boat for each region over the 9 year period. The boat growth ratio (*) is the ratio of the mean number of boats fishing in 1982/83 and 1983/84 to the mean number of boats fishing in 1975/76 and 1976/77, i.e. (C+D/A+B).

YEAR REGION	1975/76 A	1976/77 B	1977/78	1978/79	1979/80	1980/81	1981/82	1982/83 C	1983/84 D	MEAN NET LENGTH (m)	BOAT GROWTH RATIO (*)	D/A NET RATIO
Northwest	130	102		266	129	279	158	226	480	191		3.7
N	2	2		4	3	5	5	4	2		1.5	
Exmouth	215	377	171	267	393	342	145	171	223	292		1.0
N	2	5	2	5	8	12	9	7	12		2.7	
Geraldton	410	414	320	367	515	554	670	1 051	985	531		2.4
N	4	1	6	8	10	19	22	12	19		6.2	
Metropolitan	608	686	734	677	657	668	974	1 301	1 554	720		2.6
N	25	24	30	46	50	59	45	41	61		2.1	
Busselton	1 323	1 113	1 221	1 159	1 215	1 450	1 665	1 893	2 133	1 338		1.6
N	12	13	19	20	30	28	29	28	33		2.4	
Albany	622	842	783	875	878	879	1 501	1 532	1 692	924		2.7
N	24	20	21	24	26	22	26	36	30		1.5	
Esperance	618	688	767	919	1 315	1 670	2 848	2 949	2 582	1 226		4.2
N	16	18	26	29	27	23	17	21	24		1.3	
TOTAL GILLNET BOATS (N)	79	77	93	123	134	147	133	161	158		2.0	
Year Mean(m)	686	755	807	789	885	919	1 288	1 598	1 659	1 002		2.4

$$\text{Boat growth ratio} = \frac{(\text{Number of boats in 1982/83} + \text{Number of boats in 1983/84})/2}{(\text{Number of boats in 1975/76} + \text{Number of boats in 1976/77})/2}$$

$$= \frac{(\text{Number of boats in 1982/83} + \text{Number of boats in 1983/84})}{(\text{Number of boats in 1975/76} + \text{Number of boats in 1976/77})}$$

TABLE 6. This table shows the means and ranges for: length of gillnet or longline used or alternatively, the number of hooks used by dropline and handline boats in the sample encountered on the November-December 1982 field trip. Boats are grouped by region visited and by fishing method used within each region. As some boats use a combination of gears, the number of different boats operating in each region may be less than the sum of the figures given in the 'size of sample' column.

FISHING METHOD BY REGION	SIZE OF SAMPLE	MEAN (A)	VARIANCE	RANGE OF VALUES (Length or No.	SAMPLE SIZE AS A PERCENTAGE OF BOATS USING THIS METHOD
METROPOLITAN REGION (B) : 11 DIFFERENT BOATS IN SAMPLE					
Gillnet boats	8	1200	0.77	230-2300	19.5
Handline boats	3	4	0.33	4-5	7.3
Longline boats	4	1700	0.21	1200-2300	26.7
Dropline boats	1			60 (C)	
BUSSELTON REGION : 27 DIFFERENT BOATS IN SAMPLE					
Gillnet boats	24	2100	2.46	360-6500	88.9
Longline boats	4	3100	12.94	400-8400	57.1
Dropline boats	5	49	277.00	30-72	UNKNOWN
ALBANY REGION : 19 DIFFERENT BOATS IN SAMPLE					
Gillnet boats	6	1300	0.46	500-2200	27.3
Longline boats	14	7400	11.37	1400-12000	66.7
ESPERANCE REGION : 15 DIFFERENT BOATS IN SAMPLE					
Gillnet boats	11	4200	2.83	1400-6500	64.7
Longline boats	4	9900	0.69	9200-11000	33.3

(A) refers to either the mean length of gillnet or longline or number of hooks used on handlines or droplines.

(B) sample was a low proportion of boats operating in Metropolitan region.

(C) sample comprised the number of hooks from a single boat, not the range.

TABLE 7. The numbers of boats by catch class landing shark in W.A., and the proportion (PPN) of 'active' and 'part-time' boats in the fleet is shown for 6 selected years. Boats have been arbitrarily divided according to their annual catch into 'part-time/seasonal' boats (those catching up to 5 tonne live weight of shark per year) and 'active seasonal'/'full-time' (those boats catching more than 5 tonnes live weight per year). Boats catching less than 1 tonne of shark each year, are assumed to have taken this shark catch incidentally to other target fishering operations.

CATCH CLASS (tonnes live weight)	ANNUAL NUMBERS OF BOATS AND PROPORTION OF SHARK FLEET WITHIN CATCH CLASSES											
	1975/76	PPN	1978/79	PPN	1980/81	PPN	1981/82	PPN	1982/83	PPN	1983/84	PPN
INCIDENTAL CATCHES OF SHARK < 1t	105		142		166		148		151		201	
PART-TIME												
1-2t	29	46.0%	45	40.9%	46	34.6%	34	29.1%	45	37.2%	44	36.1%
3-5t	14	22.2%	22	20.0%	36	27.1%	32	27.4%	24	19.8%	22	18.0%
PART-TIME BOATS SUB-TOTAL	43	68.3%	67	60.9%	82	61.7%	66	56.4%	69	57.0%	66	57.0%
ACTIVE												
6-10t	10	15.9%	22	20.0%	23	17.3%	18	15.4%	23	19.0%	26	21.3%
11-20t	6	9.5%	14	12.7%	16	12.0%	18	15.4%	19	15.7%	16	13.1%
21-30t	3	4.8%	7	6.4%	8	6.0%	10	8.5%	6	5.0%	8	6.6%
31-60t	1	1.6%			4	3.0%	4	3.4%	2	1.7%	5	4.1%
60+t							1	0.9%	2	1.7%	1	0.8%
ACTIVE BOATS SUB-TOTAL	20	31.7%	43	39.1%	51	38.3%	51	43.6%	52	43.0%	56	45.9%
NO. OF ACTIVE AND PART-TIME BOATS	63		110		133		117		121		122	
Mean Catch/Boat (Part-time)	2.8		2.8		3.1		3.2		2.9		3.0	
Mean Catch/Boat (Active)	15.2		13.8		16.5		22.8		18.1		18.4	
TOTAL SHARK CATCH (tonnes)	435		781		1056		1328		1156		1262	

FOOTNOTES A. In 1983/84, the proportions of the 201 boats in the incidental shark catch class by principal fishing method were: 53% handline, 23% gillnet, 10% longline and 14% other fishing methods.

B. In 1983/84, the proportions of the 66 boats in the part-time catch class by principal fishing method were: 79% gillnet, 10% longline, 9% handline and 2% other methods.

C. In 1983/84, the proportions of the 56 active boats by principal fishing method were: 91% gillnet, 7% longline and 2% handline.

TABLE 8. The annual numbers of longline and handline boats operating in each region and the total numbers of boats by method, irrespective of region, are shown. The boat growth ratio (G+H/E+F), see below, expresses any trend in boat numbers over the 9 year period computed by averaging the number of boats operating from 2 recent years compared with 2 earlier years. A ratio less than 1 signifies a reduction in the numbers of boats using longlines or handlines in each region. Dropline boat numbers for 1983/84 are shown. Note that the total number of boats per method and region (*) exceeds the true number operating when boats fish shark in more than 1 region and with more than 1 fishing method in any fiscal year.

REGION AND FISHING	1975/76 E	1976/77 F	1977/78	1978/79	1979/80	1980/81	1981/82	1982/83 G	1983/84 H	BOAT GROWTH RATIO (G+H)/(E+F)
Northwest										
Handline			1			1				
Dropline									1	
Exmouth										
Longline								1		
Handline	3	3	6	16	11	17	16	11	13	4.0
Dropline									2	
Geraldton										
Longline			1	1	3	1	2	8	5	
Handline	25	23	23	42	58	52	42	51	48	2.1
Dropline									11	
Metropolitan										
Longline	13	8	12	16	20	25	17	12	17	1.4
Handline	33	27	29	41	54	58	42	45	50	1.6
Dropline									6	
Busselton										
Longline	6	2	6	9	9	6	7	10	5	1.9
Handline	14	12	11	15	14	14	18	16	18	1.3
Dropline									1	
Albany										
Longline	10	7	14	9	19	18	20	18	17	2.1
Handline	23	18	14	19	17	24	25	18	25	1.1
Dropline									1	
Esperance										
Longline	5	2		7	10	12	12	5	5	1.4
Handline	3	2	3	4	1	1	3	2	5	1.4
Dropline										
TOTAL NUMBER OF BOATS PER METHOD AND REGION (*)										
Longline	32	19	30	36	54	55	55	45	49	1.8
Handline	95	80	85	130	147	158	133	143	152	1.7
Dropline									22	

$$\text{Boat growth ratio} = \frac{(\text{Number of boats in 1982/83} + \text{Number of boats in 1983/84})/2}{(\text{Number of boats in 1975/76} + \text{Number of boats in 1976/77})/2}$$

$$= \frac{(\text{Number of boats in 1982/83} + \text{Number of boats in 1983/84})}{(\text{Number of boats in 1975/76} + \text{Number of boats in 1976/77})}$$

TABLE 9. The regional shark catch (tonnes live weight) by month for 1983/84 shows the seasonality of landings. Peak catching months are shown by an underline. When comparing other tables note the difference in catch which results from the exclusion of skates and rays from this table.

MONTHS (1983/84)	7/83	8/83	9/83	10/83	11/83	12/83	1/84	2/84	3/84	4/84	5/84	6/84	TOTAL
REGIONS													
NORTHWEST	0.2	0.7	1.3	-	1.4	-	-	-	-	0.6	1.0	2.2	7.4
EXMOUTH	0.4	0.8	1.1	1.5	0.6	-	0.3	1.3	0.4	0.7	0.8	0.6	8.5
GERALDTON	4.3	3.9	9.4	5.2	2.6	6.8	5.3	1.7	3.7	4.9	3.5	5.6	56.9
METROPOLITAN	17.3	17.5	28.5	35.1	31.0	31.9	18.4	20.9	33.0	22.7	14.9	25.8	297.0
BUSSELTON	3.7	4.3	47.2	75.0	56.8	57.8	34.1	52.3	44.5	47.4	7.7	6.7	437.5
ALBANY	16.9	13.1	14.6	37.9	18.5	12.6	16.8	13.1	10.3	10.1	5.2	13.8	182.9
ESPERANCE	35.0	14.5	26.4	18.1	9.8	24.1	23.8	25.9	26.8	16.5	13.2	29.2	263.3
TOTAL CATCH	77.8	54.8	128.5	172.8	120.7	133.2	98.7	115.2	118.7	102.9	46.3	83.9	1 253.5

TABLE 10. The 1983/84 shark species landings (in tonnes live wt) for each region and the total catch by all methods for each region and species.

COASTAL REGIONS	WHISKERY (A)	BRONZE WHALER (B)	GUMMY (C)	CARPET SPP. (D)	OTHER SHARK (E)	SKATES & RAYS	REGIONAL CATCH OF ALL SPECIES	% OF TOTAL SPECIES CATCH
1. NORTHWEST		1.4			5.9		7.3	0.6%
2. EXMOUTH	0.1	1.2			7.2		8.5	0.7%
3. GERALDTON	13.0	14.0	0.5	1.0	28.2	0.7	57.4	4.5%
4. METROPOLITAN	57.2	103.9	8.8	15.0	112.2	4.6	301.7	23.9%
5. BUSSELTON	125.5	168.8	8.0	13.2	121.9	trace	437.4	34.6%
6. ALBANY	38.1	40.9	33.0	7.9	64.1	3.0	187.0	14.8%
7. ESPERANCE	48.1	30.5	86.5	2.4	95.7		263.2	20.8%
TOTAL SPECIES CATCH	282.0	360.7	136.8	39.5	435.2	8.3	1 262.5	100.0%
SPECIES PROPORTION OF TOTAL CATCH	22.3%	28.6%	10.8%	3.1%	34.5%	0.7%		

NOTES :

(A),(C) Only 1 species in all areas currently fished.

(B) Mostly 1 species in regions 3-7, but up to 5 species included for this common name in regions 1-2, but not treated in this report.

(D) A group of 4 species, 1 or 2 of which usually predominate each region.

(E) Other shark may be comprised of species in footnotes (A)-(D) inclusive, the proportions of which vary markedly with area; or may include at least 10 species; viz. thickskin, pencil, hammerhead (2spp), eastern school, mako, grey nurse and angel shark (2spp),saw shark, long-nosed grey shark and 7-gill shark.

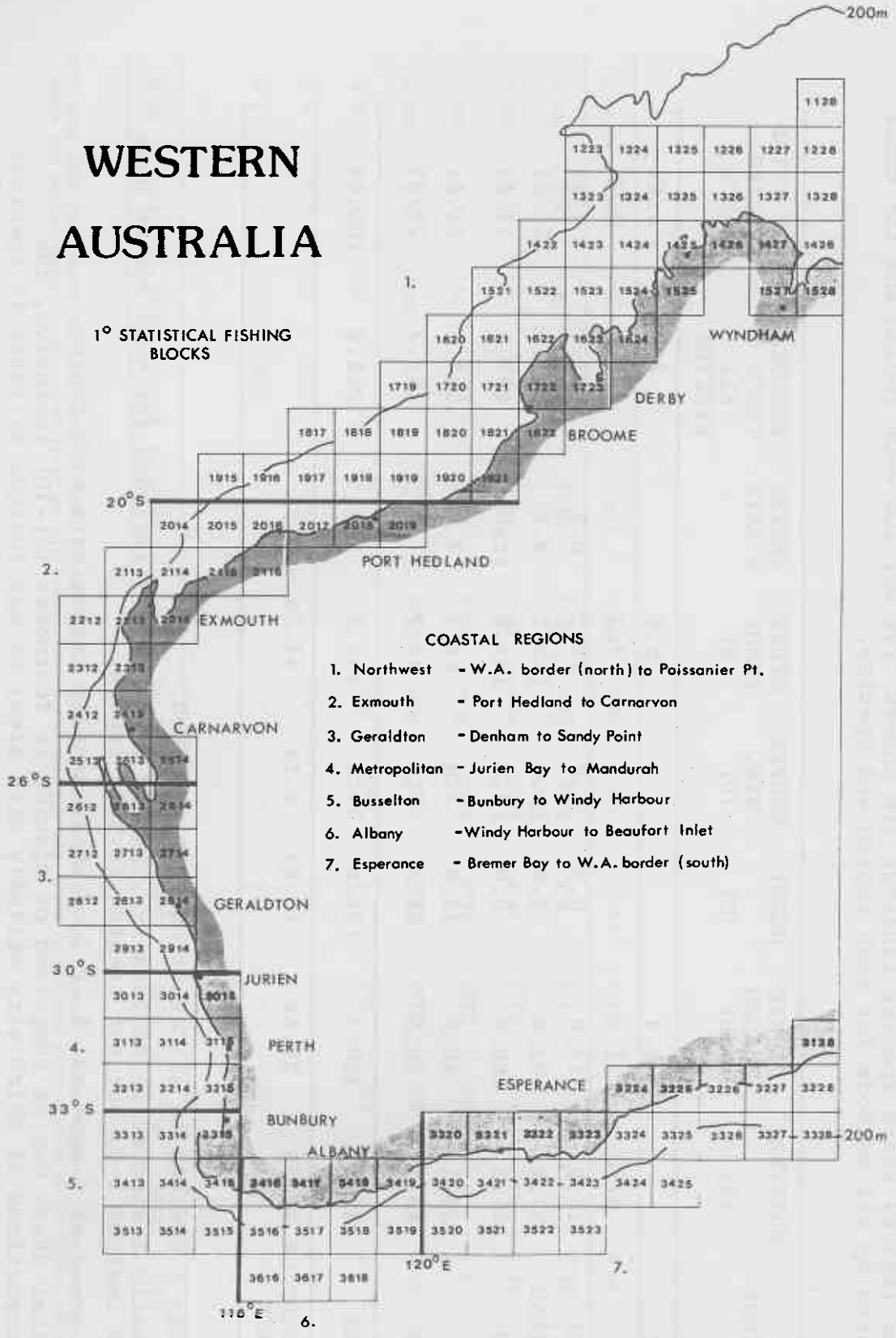


Figure 1. The W A coast, divided into shark fishing regions composed of 1°degree ABS blocks and the 200 m contour are shown.

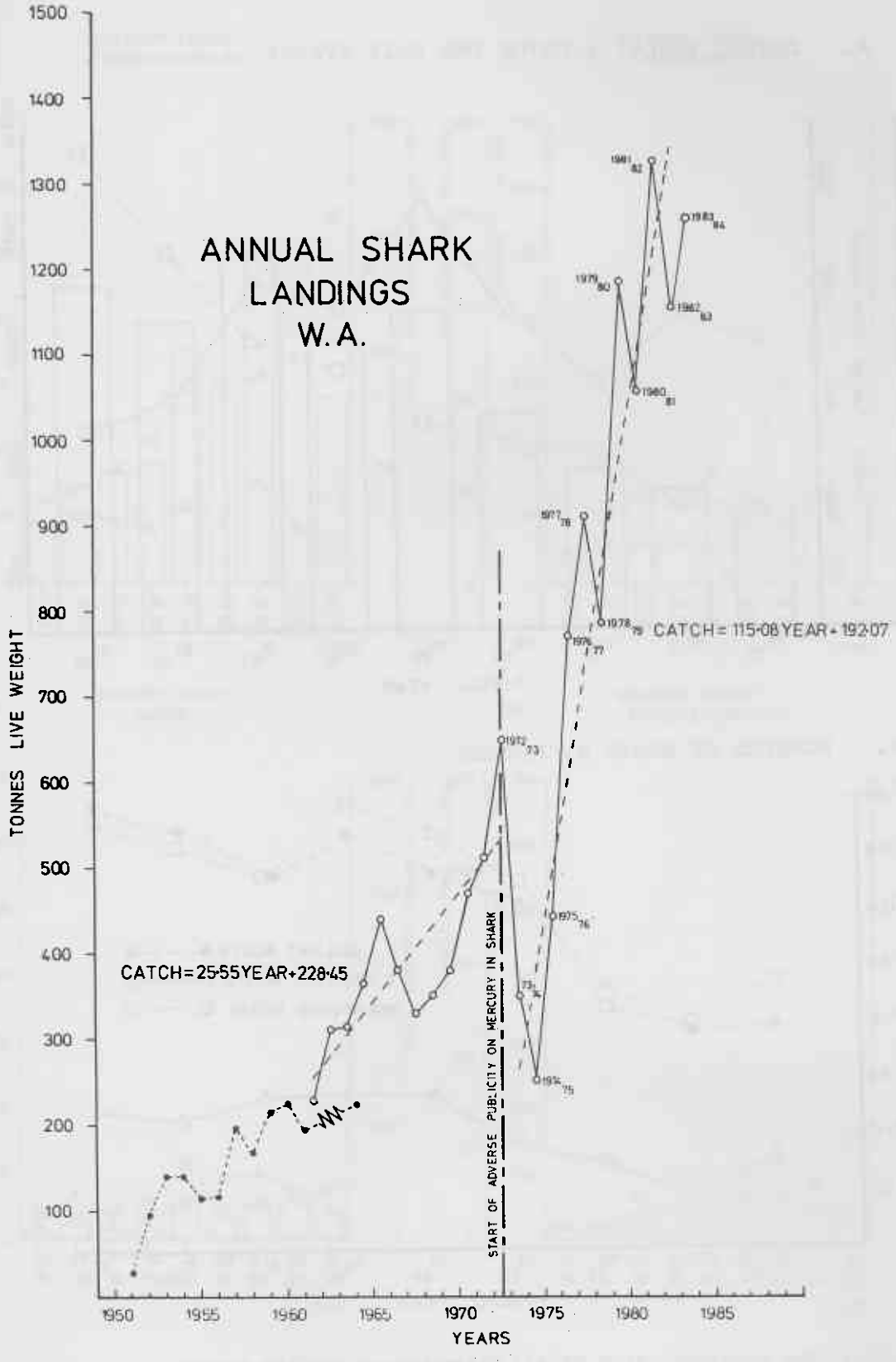
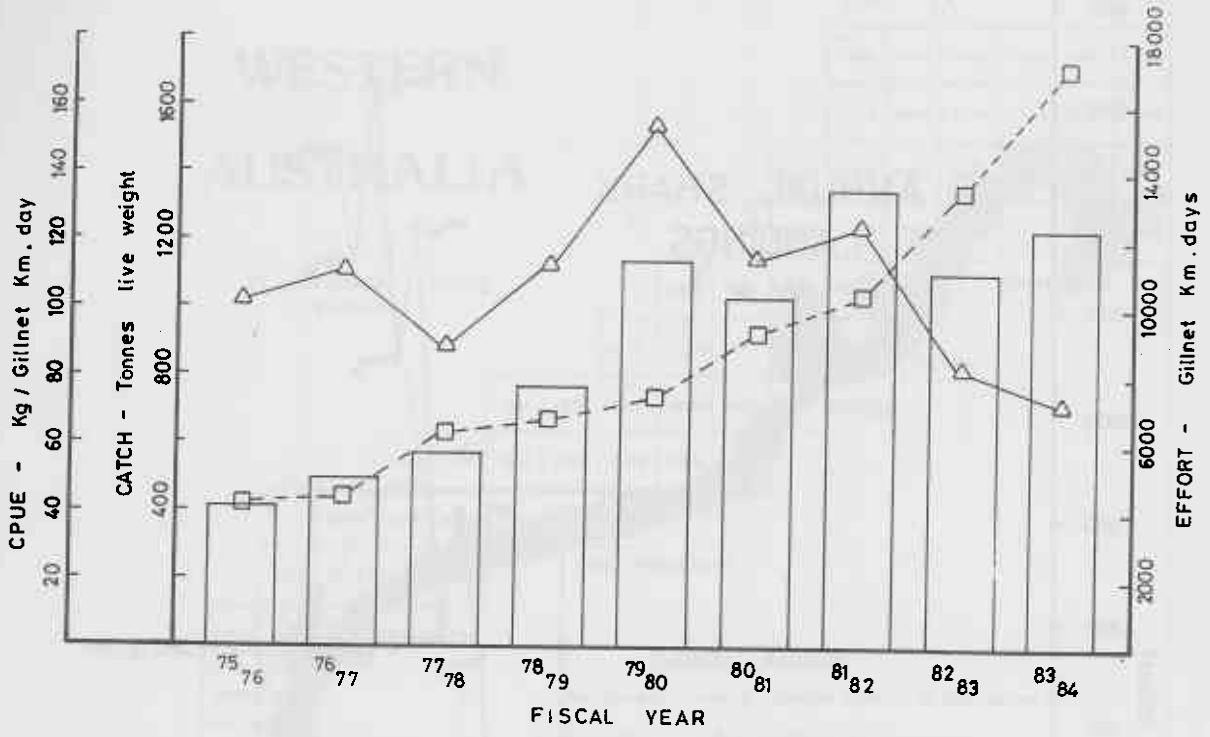


Figure 2 . The total annual catch of shark in W.A., in tonnes live weight by calendar year (●.....●, Fisheries Department records) and fiscal year (o————o, ABS records) is given.

A. CATCH, EFFORT & CATCH PER UNIT EFFORT



B. NUMBERS OF BOATS BY METHOD

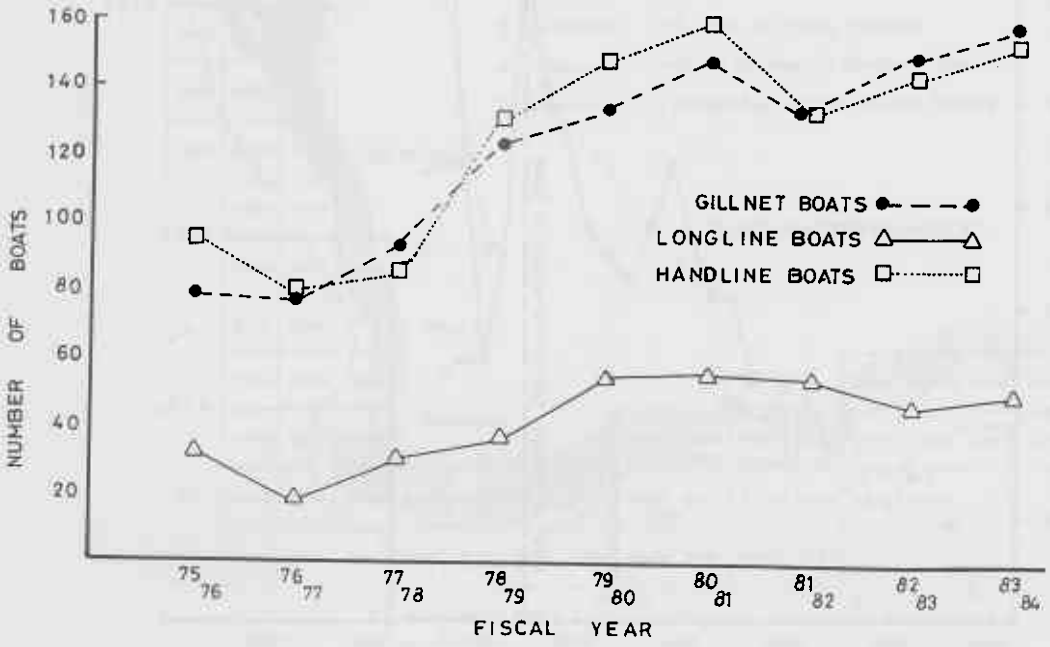


Figure 3(a) The combined catch of all elasmobranch species except skates and rays for the statistical regions Geraldton to Esperance is shown in tonnes live weight by histogram bars. Effort is shown in equivalent units of gillnet km. days (□- - - - - - - - - - - -□) and catch per unit of effort (CPUE) is shown as kg/gillnet km. days (△————————△).

(b) The total number of gillnet, longline and handline boats from 1975/76 to 1983/84 are shown, irrespective of region .

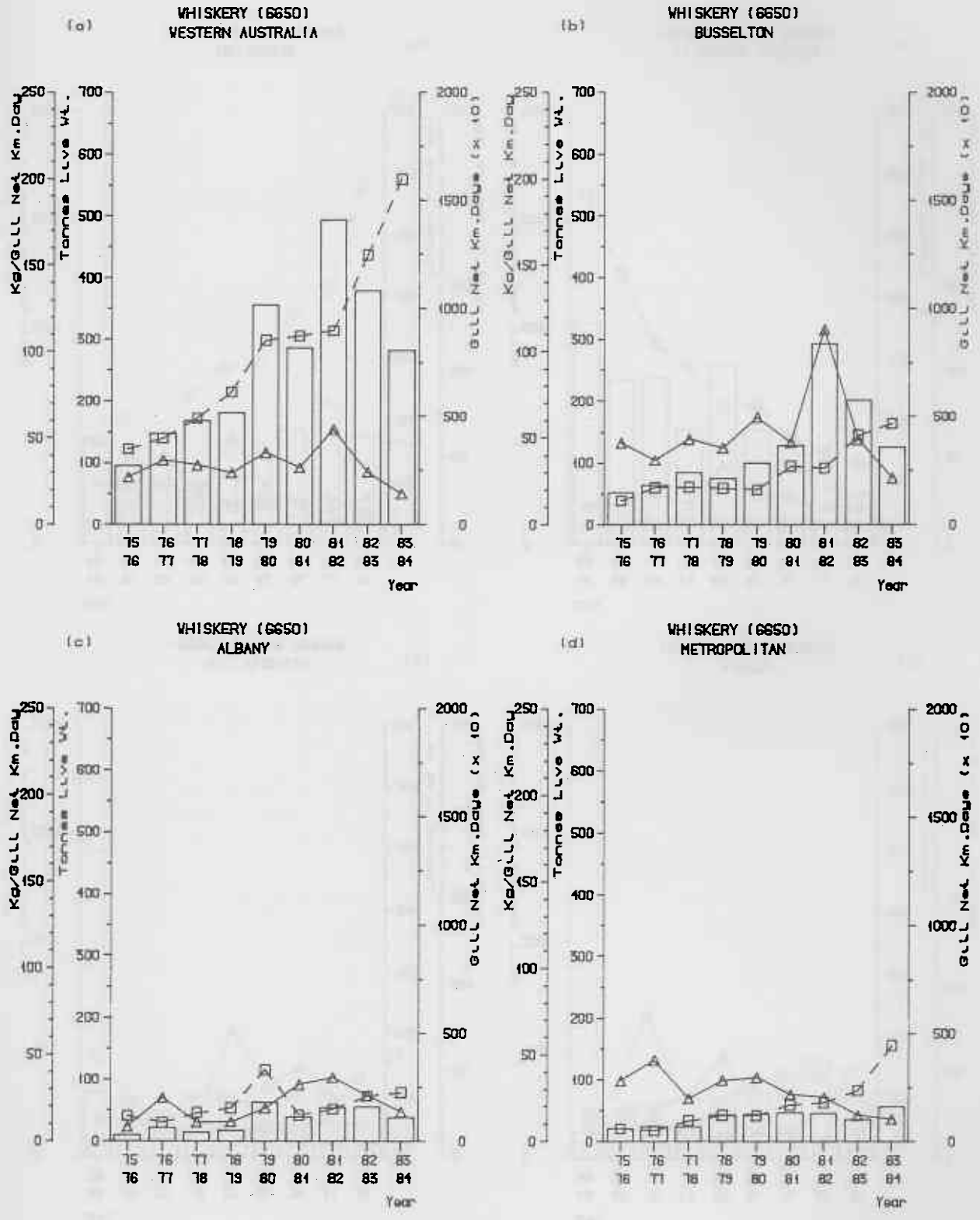


Figure 4. The catch of whiskery shark (tonnes, bars), effort (gillnet km.days, □ - - - - - -□) and catch per unit of effort (kg/gillnet km.day, △————△) for (a) W.A. [but excluding Northwest and Exmouth regions], (b) Metropolitan region, (c) Busselton region and (d) Albany region from 1975/76 to 1983/84.

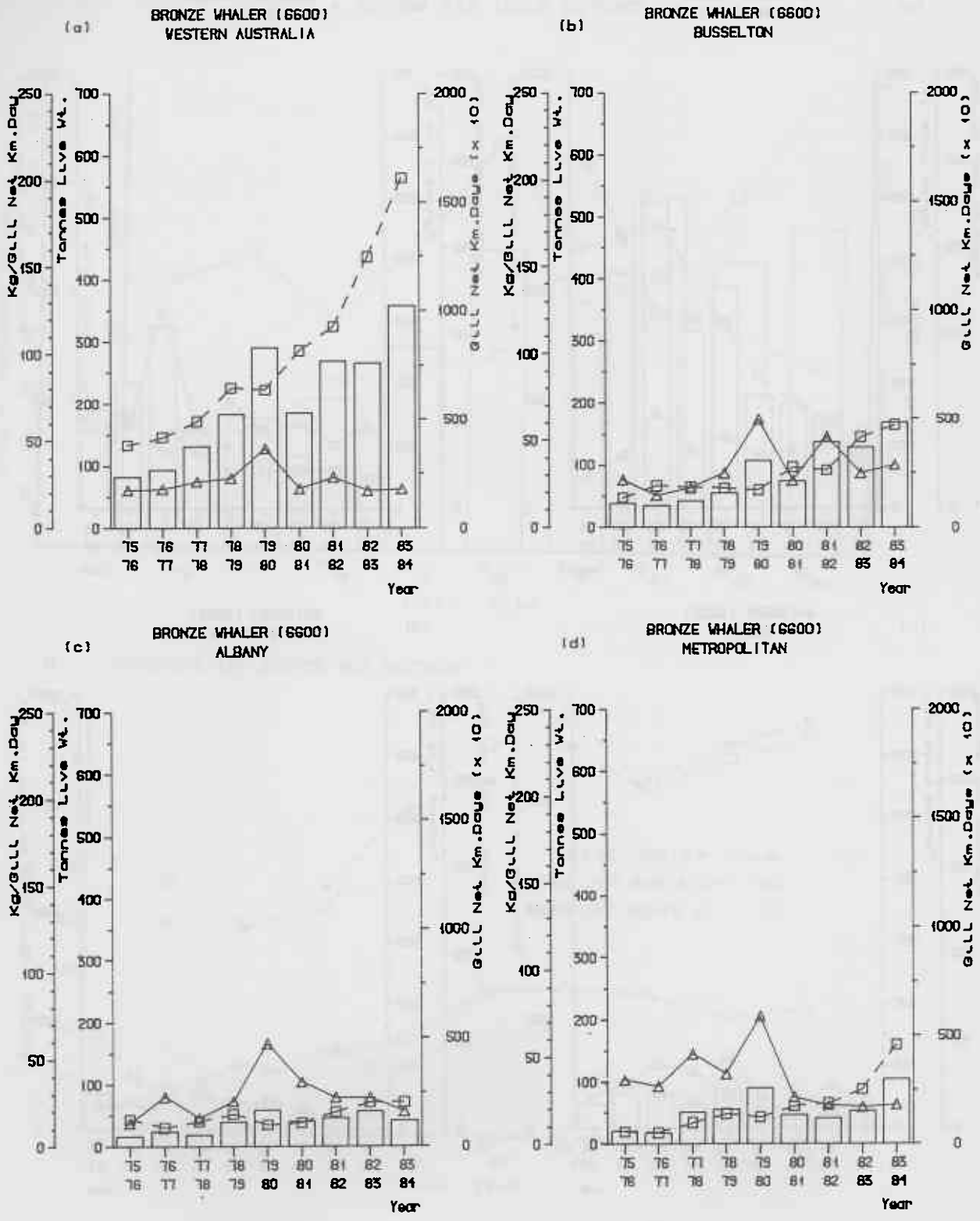


Figure 5. The catch of bronze whaler shark (tonnes, bars), effort (gillnet km.days, □- - - - - - □) and catch per unit of effort (kg/gillnet km.day △————————△) for (a) W.A. [excluding Northwest and Exmouth regions], (b) Metropolitan region, (c) Busselton region and (d) Albany region from 1975/76 to 1983/84.

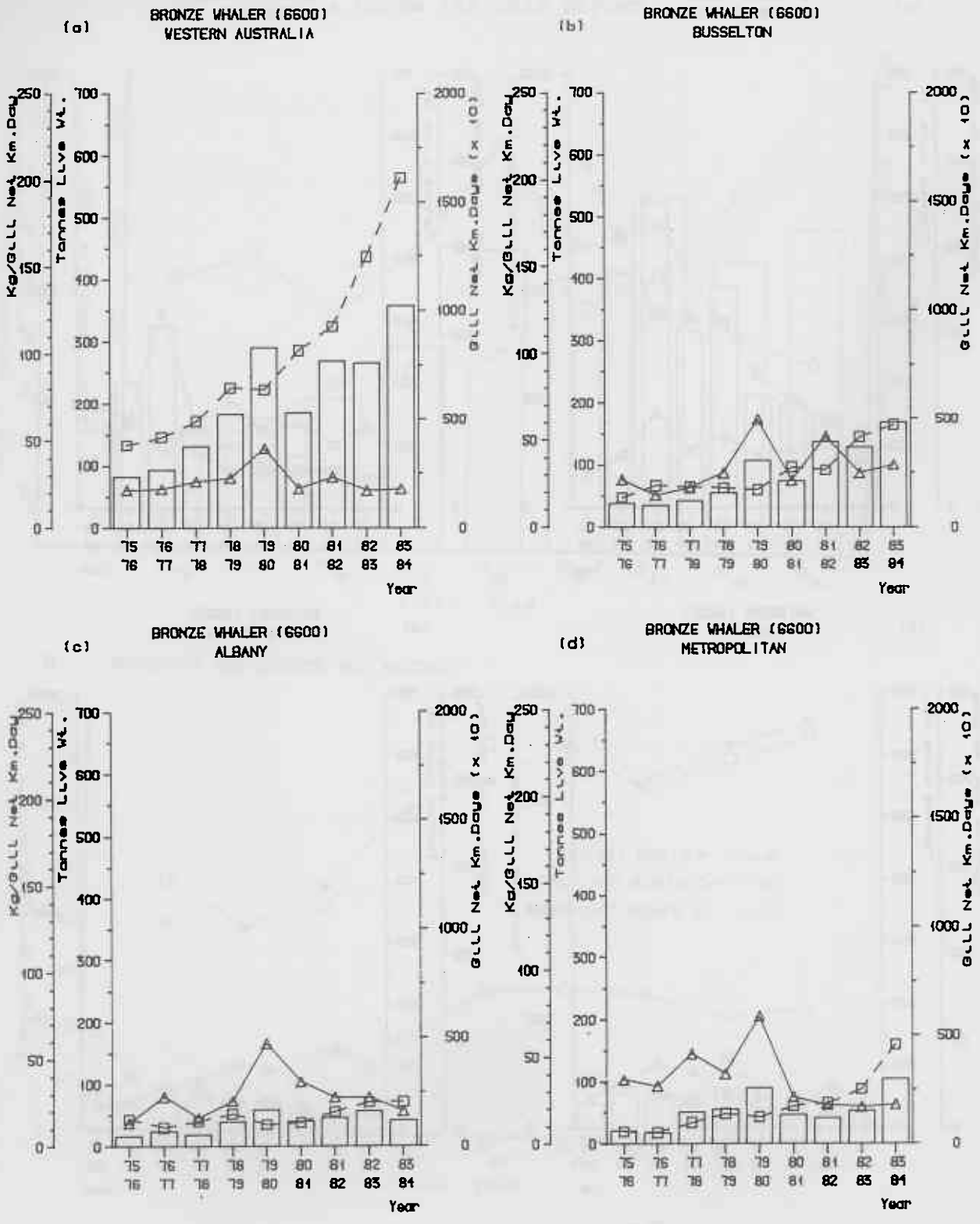


Figure 5. The catch of bronze whaler shark (tonnes, bars), effort (gillnet km.days, □- - - - - - □) and catch per unit of effort (kg/gillnet km.day △————————△) for (a) W.A. [excluding Northwest and Exmouth regions], (b) Metropolitan region, (c) Busselton region and (d) Albany region from 1975/76 to 1983/84.

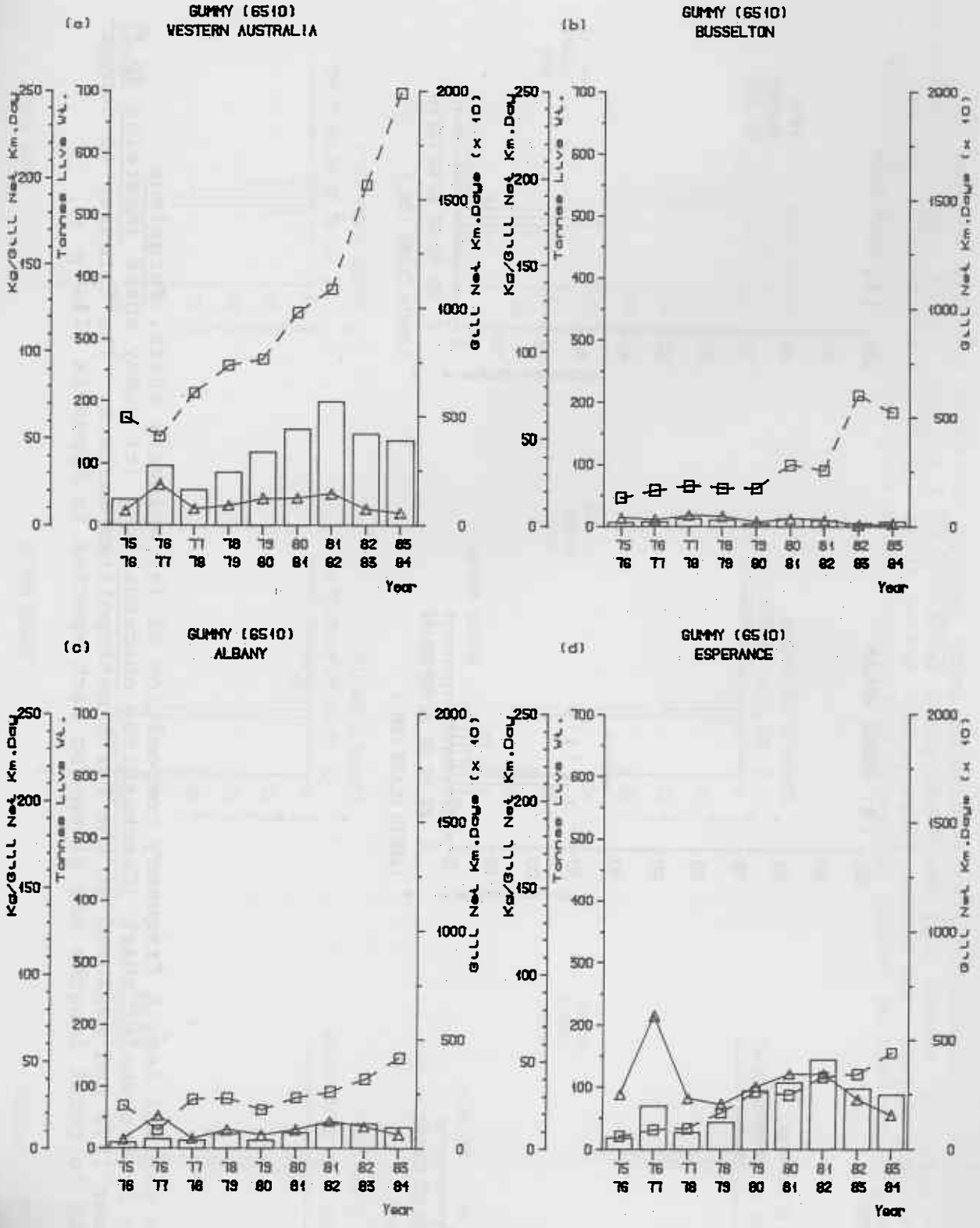


Figure 6. The catch of gummy shark (tonnes, bars), effort (gillnet km.days □ - - - - - -□) and catch per unit of effort in kg/gillnet km.day (△————————△) for (a) W.A. [but excluding Northwest and Exmouth regions], (b) Busselton region, (c) Albany region and (d) Esperance region from 1975/76 to 1983/84.

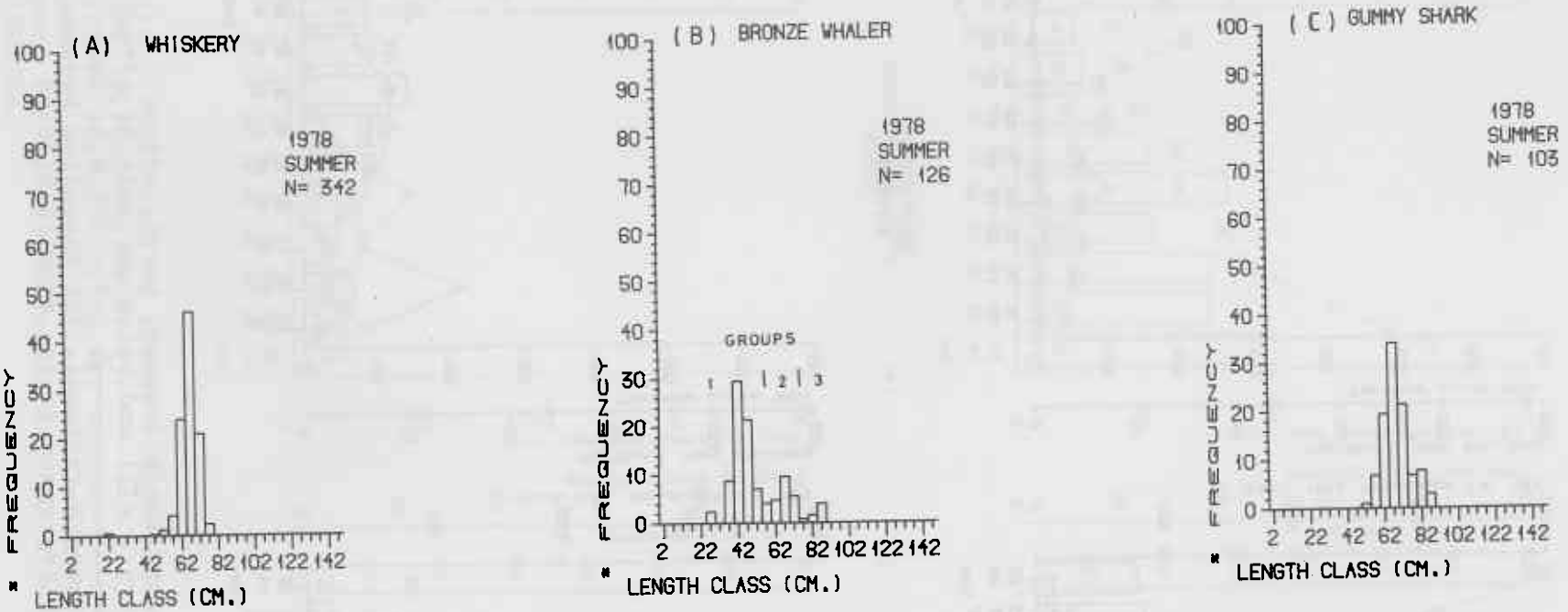


Figure 7. The partial length frequency composition of (a) whiskery shark, Furgaleus ventralis, (b) bronze whaler shark (Carcharhinus obscurus) and (c) gummy shark (Mustelus sp.) caught in summer 1978 and measured at the Perth metropolitan markets. The formulae to convert partial lengths to total lengths are given for each species in Appendix III, p 71.

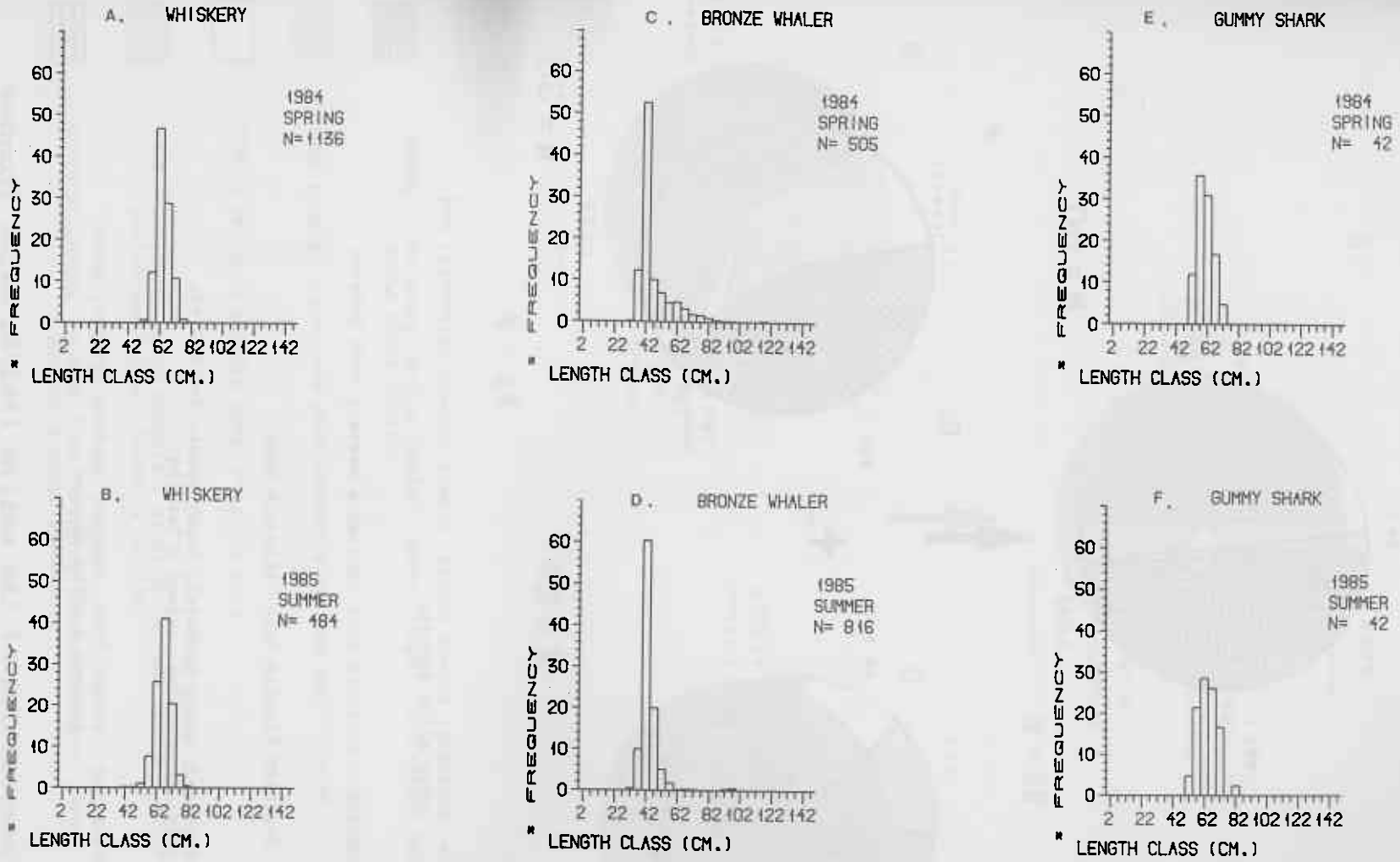
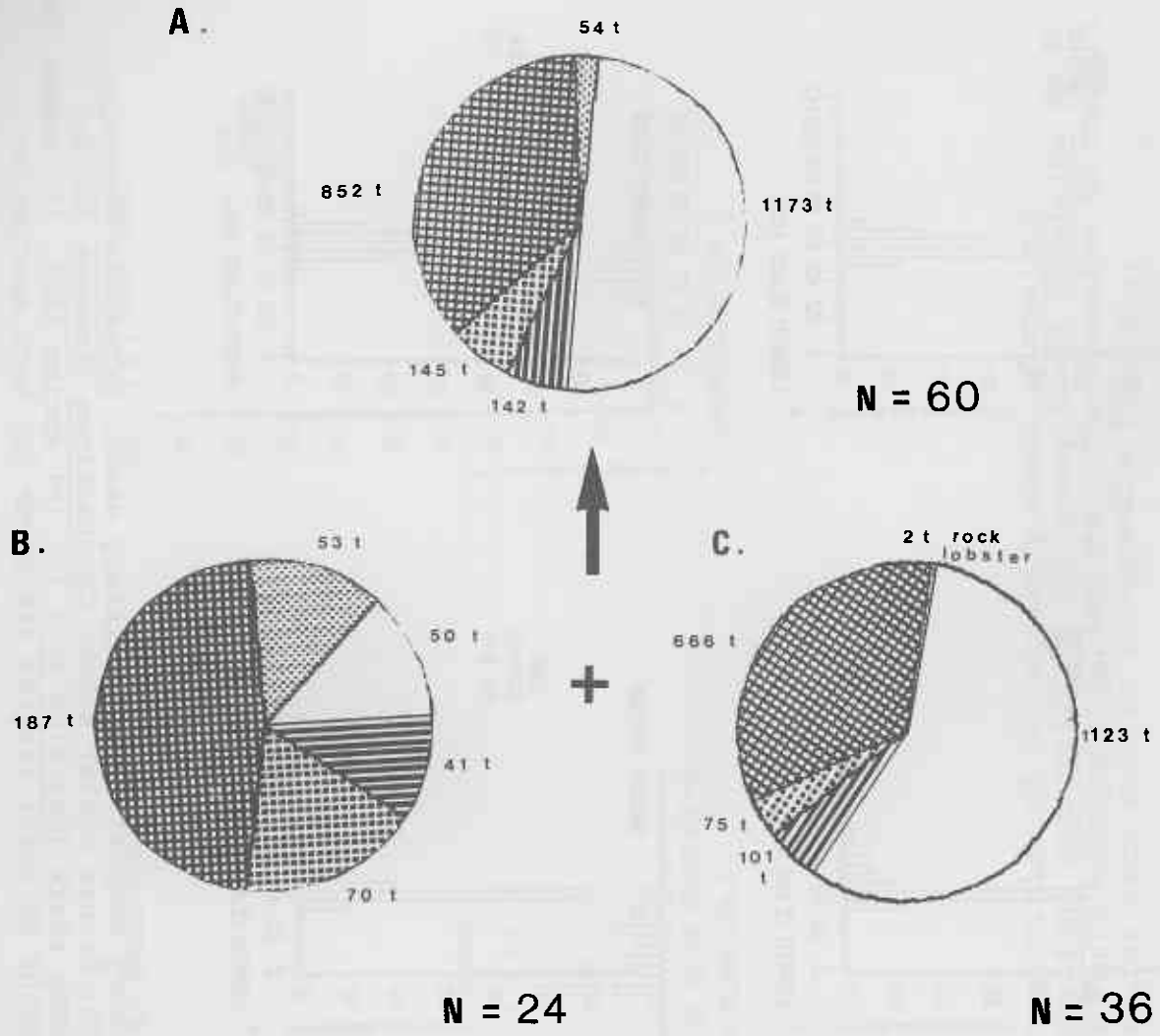


Figure 8. The partial length frequency composition of whiskery shark, Furgaleus ventralis, for (a) spring 1984, (b) summer 1985; bronze whaler shark, Carcharhinus obscurus for (c) spring 1984, (d) summer 1985 and gummy shark (Mustelus sp.) for (e) spring 1984, (f) summer 1985. The formulae to convert partial lengths to total lengths are given for each species in Appendix III, p 71.



SHARK - Whiskery, bronze whaler, gummy, carpet, thickskin, and other minor species

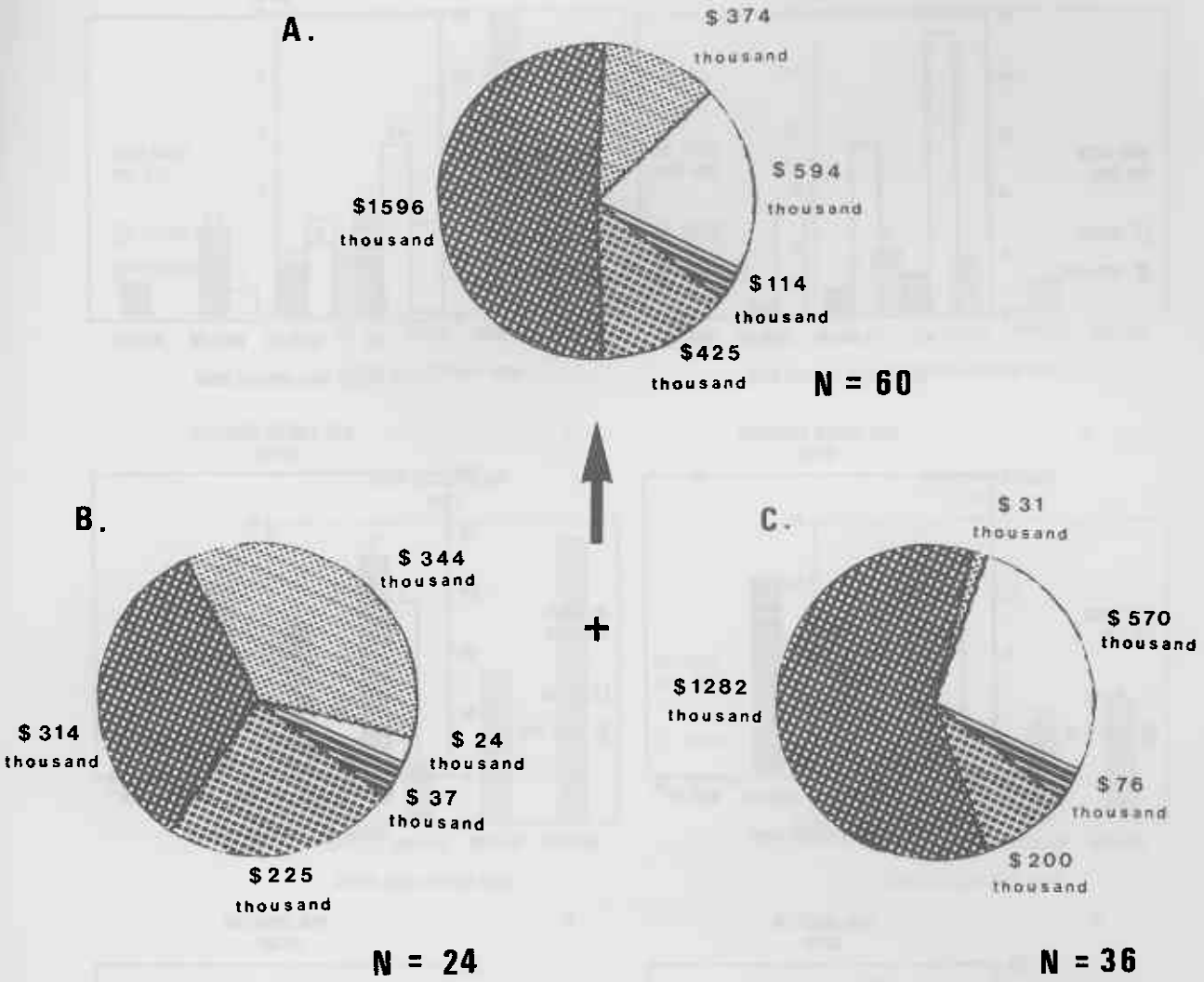
ROCK LOBSTER - Southern rock lobster & western rock lobster

TUNA - Southern bluefin tuna, skipjack tuna

BAIT - Pilchard, scaly mackerel, sandy sprat, sea mullet, yellow-eye mullet, salmon & herring.

LARGE SCALEFISH - Samson fish, snapper, jewfish, groper, queen snapper & other species

Figure 9. The composition of the entire 1982/83 catch (tonnes live) from all fishing activities of (a) the total group of 60 boats encountered on the 1982 field study, (b) the 24 west coast boats and (c) the 36 south coast boats. In this sample, bait species were taken by various methods such as purse seines, beach seines and gillnets, whereas large scalefish were those either caught on the same gear and at the same time as shark or by handline on or near grounds worked for shark.



SHARK - Whiskery, bronze whaler, gummy, carpet, thickskin, and other minor species

ROCK LOBSTER - Southern rock lobster & western rock lobster

TUNA - Southern bluefin tuna, skipjack tuna

BAIT - Pilchard, scaly mackerel, sandy sprat, sea mullet, yellow-eye mullet, salmon & herring.

LARGE SCALEFISH - Samson fish, snapper, jewfish, groper, queen snapper & other species

Figure 10. The wholesale value of the 1982/83 catch of the same sample group of boats whose catch composition is shown in Figure 9. The pie diagrams show (a) the value of the combined catches of the 60 boats from the west & south coasts, (b) the value of the total catches of 24 west coast boats & (c) the value of the total catches of 36 south coast boats.

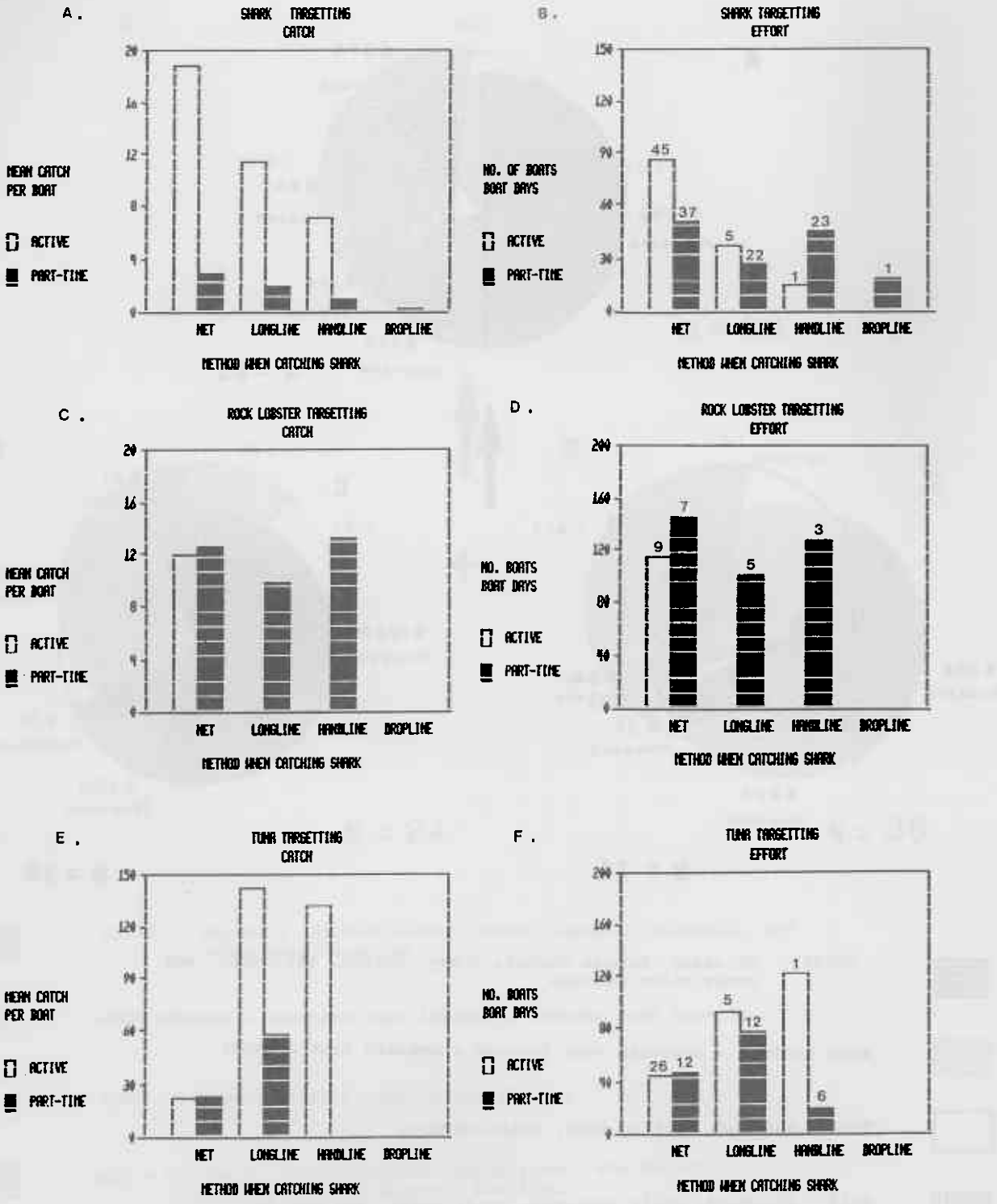


Figure 11. Mean target species catch per boat (tonnes live) in 1982/83 when the fleet of boats (which caught shark during the year) were directed at (a) shark, (c) rock lobster, (e) tuna, (g) bait and (i) other species groups. Mean nominal effort (boat days, histogram bars) and number of boats operating (figures on top of the bars) are given for (b) shark, (d) rock lobster, (f) tuna, (h) bait and (j) other species groups. Only those shark fishermen who were defined as active or part-time (see definition, section IVD) were selected and they were placed in method categories by the method they principally used when fishing for shark. Bait is defined as salmon , mullet species, herring, scaly mackerel, anchovy, sandy sprat, pilchard, butterfish, and bream. 'Other species groups' includes jewfish, mackerel, snapper, baldchin groper, Samson fish, jack, crabs, prawns, squid, mussels, abalone, and other large scalefish not defined as bait.

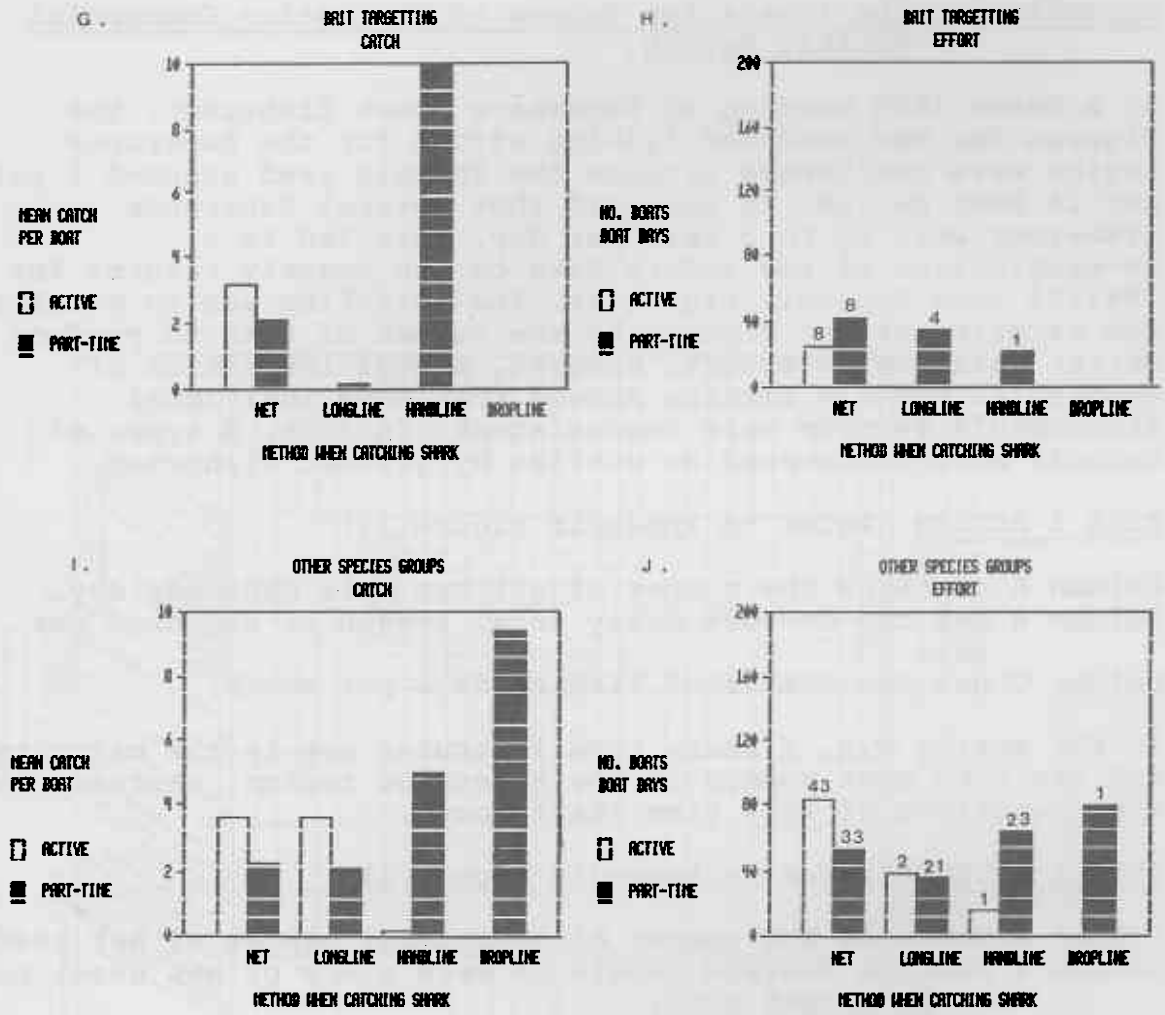


Figure 11 . Mean target species catch per boat (tonnes live) in 1982/83 when the fleet of boats (which caught shark during the year) were directed at (a) shark, (c) rock lobster, (e) tuna, (g) bait and (i) other species groups. Mean nominal effort (boat days, histogram bars) and number of boats operating (figures on top of the bars) are given for (b) shark, (d) rock lobster, (f) tuna, (h) bait and (j) other species groups. Only those shark fishermen who were defined as active or part-time (see definition, section IVD) were selected and they were placed in method categories by the method they principally used when fishing for shark. Bait is defined here as salmon , mullet species, herring, scaly mackerel, anchovy, sandy sprat, pilchard, butterfish, and buffalo bream. 'Other species groups' includes jewfish, mackerel, snapper, baldchin groper, Samson fish, skipjack, crabs, prawns, squid, mussels, abalone, and other large scalefish not defined as bait.

Appendix 1. The Australian Bureau of Statistics Commercial Monthly Return.

At a March 1985 meeting of Esperance shark fishermen, the figures for the combined fishing effort for the Esperance region were challenged because the formula used assumed 1 set per 24 hour period. It was said that several Esperance fishermen work up to 3 sets per day. This led to a re-examination of the effort data on the monthly returns for 1983/84 (see Appendix Figure 1). The intention was to multiply the existing effort figures by the number of sets to produce a better estimate of effort. However, manual inspection of commercial monthly returns showed that some individual fishermen's records were inconsistent. In fact, 3 types of records were discovered as entries by gillnet fishermen.

TYPE 1 RETURN (Refer to Appendix Figure 1.)

Column A contains the number of gillnet sets made per day.
Column B has the correct daily total length of net used per set.
Column C has the number of fishing days per month.

In the entire W.A. fishery type 1 returns are in the majority, and are even more common in the Esperance region, representing the operations of full time shark boats.

TYPE 2 RETURN (Refer to Appendix Figure 1)

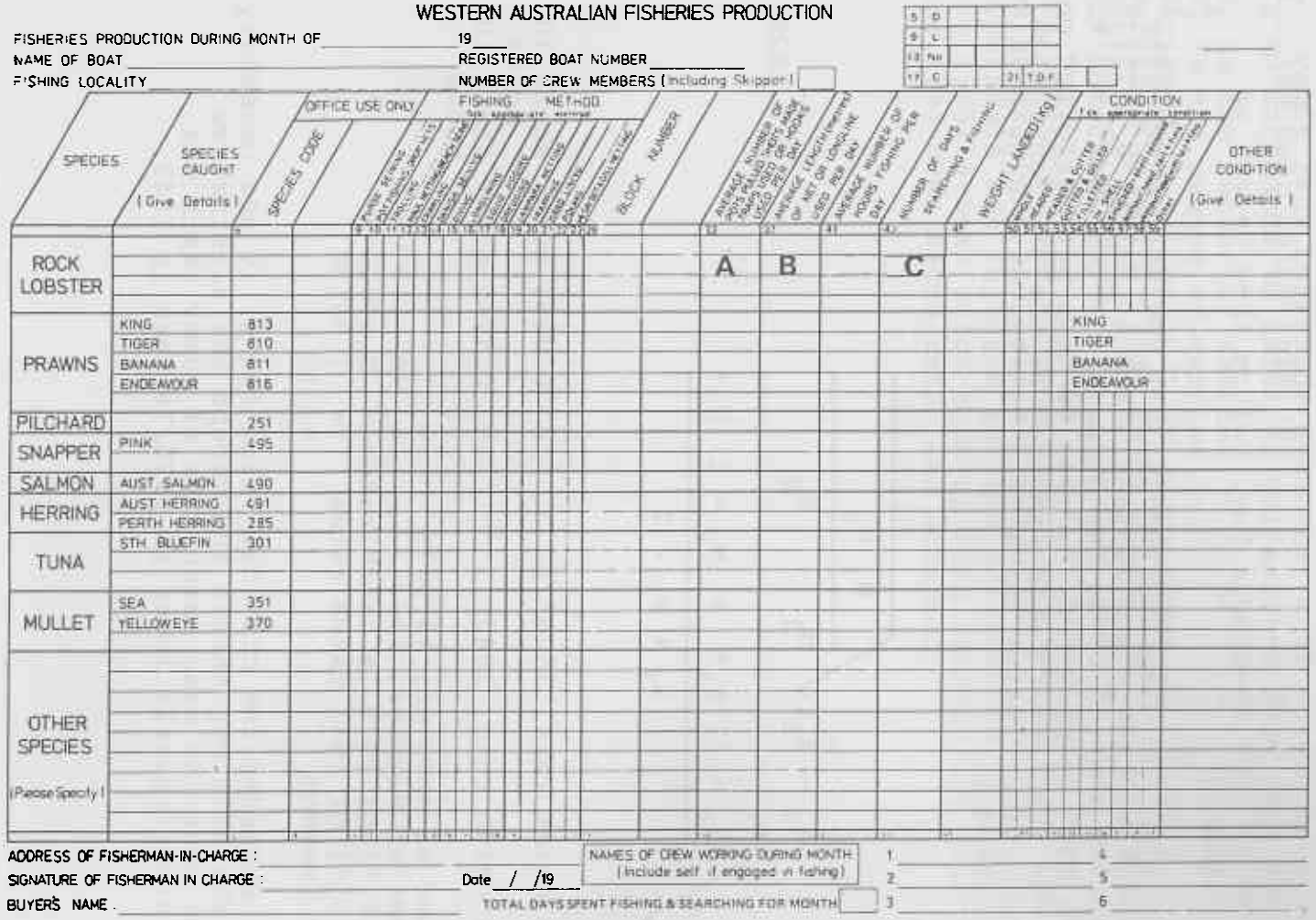
Column A contains the number of individual pieces of net used
Column B has the average length of each piece of net used, not total length used.
Column C contains the number of fishing days per month.

Type 2 returns were found to be in a minority.

TYPE 3 RETURN (Refer to Appendix Figure 1)

Column A contains the number of pieces of net used.
Column B contains the correct daily total length of net used.
Column C contains the number of fishing days in the month.

Type 3 returns were in the minority and thus the best estimate of gillnet effort that can be obtained at present from the formula can only incorporate number of days fished and gillnet length. However it was confirmed at a meeting at Busselton in March 1985 that shark fishermen on the west coast in general set once per 24 hour period. Thus it will not be possible to incorporate number of sets per day into the formula until each individual shark fisherman's operational strategy has been documented. This type of data (the Shark Database) was gathered on the October 1985 field trip.



Appendix Figure 1. The commercial fisheries production monthly return.

Appendix 2. Changes in gummy shark abundance in Geographe Bay.

In 1943, Mr G.P. Whitley, a noted Australian fish taxonomist, prepared a report on the newly established shark fishery of W.A. operating out of Bunbury at that time (Whitley, 1943). He used a series of longline sets to determine the catch rates and species composition of shark. Walker (1979) compared Whitley's results with the results of his own longline survey carried out some 30 years later in the same general region. Although the longline sets were made in June and July by Whitley but April, October and November by Walker, the comparison was thought to be valid because advice from fishermen suggested that gummy shark did not show much seasonality in terms of abundance or migration to or from Geographe Bay, before they became so scarce in catches.

In order to test the null hypothesis that the mean catch rate of gummy shark was not significantly lower in Walker's 1975/76 longline survey than in 1943, the Student's t-test was used to compare the mean catch rates. A 1-tailed test was performed on the data, and the results were examined at the 95% confidence limits. The critical value for t is 1.753 for this test with 15 degrees of freedom.

Therefore,

$$t(calc) = (\bar{X}_1 - \bar{X}_2)\sqrt{\frac{N_1 . N_2}{N_1 + N_2}} \Big/ \sqrt{\frac{(N_1 - 1)\, S_1^2 + (N_2 - 1)\, S_2^2}{N_1 + N_2 - 2}} = 2.1520$$

where,

$\bar{X}_1$ is mean catch rate, 1975/76 = 0.0056 gummy shark/100 hooks

$\bar{X}_2$ is mean catch rate, 1943, = 0.9945 gummy shark/100 hooks

N_1 is number of samples, 1975/76 = 7

N_2 is number of samples, 1943 = 10

Variance (S_1^2) of 1975/76 catch rates = 0.00005

Variance (S_2^2) of 1943 catch rates = 1.30530

Degrees of freedom = 15

As t(calc) exceeded the critical value for t, it was necessary to reject the null hypothesis and accept the alternative hypothesis, that the mean catch rate of gummy shark was therefore significantly lower in 1975/76 than in 1943.

To determine if the opposite was true for Port Jackson sharks in Geographe Bay, i.e. that this species had increased in abundance between the two surveys, a similar hypothesis was erected. The null hypothesis was that the mean catch rate for Port Jackson shark in 1975/76 was not significantly higher than the mean catch rate in 1943. Once again, the means were tested using a Student's t-test at the 99% confidence limits. For this 1-tail test, the critical value for t was 2.57. Values used in the formula were :

$\overline{X}_1$, the mean catch rate 1975/76	=	1.955 Port Jackson shark/100 hooks
$\overline{X}_2$, the mean catch rate 1943	=	0.161 Port Jackson shark/100 hooks
N_1 is the number of samples 1976/76	=	9
N_2 is the number of samples 1943	=	10
Variance (S_1^2) of 1975/76 catch rates	=	3.9277
Variance (S_2^2) of 1943 catch rates	=	0.3689
Degrees of freedom	=	17

Evaluation of the formula gave a calculated value for t of 5.74 which exceeded the critical value of t. Therefore the null hypothesis was rejected and the alternative hypothesis, that the 1975/76 mean catch rate of Port Jackson was greater than the 1943 mean catch rate, was accepted.

Appendix 3. Size composition methods and regressions.

A. Size composition methods

To convert market measurement data from partial length (PL) to total length (TL) and to be able to predict a partial weight from a known PL, a series of regressions were calculated. The PL/TL series were based on measurements made at sea on field trips between 1975 and 1982 whereas the PW/PL series were obtained from earlier field trips and from market measurements between 1974 and 1978 and were recommenced from spring 1984 at the Metropolitan markets. The lines of best fit for the data were linear regressions for the PL/TL data but curvilinear regressions for the PW/PL data.

When the plotted distributions for size composition were inspected, it was found that there were 3 component distributions in the bronze whaler data. A computer programme, NORMSEP, written by Abramson (1971), based on the statistical techniques of Cohen (1966) was chosen to separate these component distributions. The procedure estimates the means, variances, and proportions of the component normal distributions forming the total length frequency distribution of the bronze whaler sample. It should be noted that the results produced approximate the true values as the sample size was insufficient to allow the routine to produce a precise result.

The NORMSEP method makes several assumptions :

(1) The need to know the exact number of component distributions. This assumption is satisfied in the results for bronze whaler.

(2) The need for a visible separation between component distributions. This is also reasonably well satisfied in the results.

(3) The need for an adequate sample size. Cohen (1966) has suggested that there should be at least 500 observations for distributions with more than 2 components. This criterion was not satisfied in the results for the bronze whaler summer 1978 sample, in which the total was 126.

B. Regressions

1. Whiskery shark

The TL/PL regression for whiskery shark, based on 238 observations was :

$$PL = 0.53802\ TL - 2.3083$$

The PW/PL regression equation which was used to calculate the mean weight at the modal class was :

$PW = (5.82 \times 10E\ -5)\ PL^{2.77}$ based on 61 observations.

2. Bronze whaler shark

The TL/PL regression for bronze whaler shark, based on 159 observations was :

$$PL = 0.41616\ TL - 0.2402$$

and the PW/PL regression for this species was :

$PW = (1.45 \times 10E\ -4)\ PL^{2.74}$ based on 90 observations.

3. Gummy shark

The TL/PL regression for gummy shark, based on 215 observations was :

$$PL = 0.5245\ TL + 0.6898$$

and the PW/PL regression based on 49 observations was:

$$PW = (1.36 \times 10E\ -5)\ PL^{3.06}$$