The Kimberley Demersal Scalefish Fishery: Extent and Nature of the Resource and the Ability of a Trap Fishery to Exploit It

PART 1: A HISTORY OF FISHING ACTIVITIES IN THE REGION

Gabrielle B. NOWARA & Stephen J. NEWMAN

FISHERIES DEPARTMENT OF WESTERN AUSTRALIA

FISHERIES RESEARCH & DEVELOPMENT CORPORATION

FINAL REPORT
MARCH 1996
PROJECT 94/026

The Kimberley Demersal Scalefish Fishery: A History of Fishing Activities in the Region

Gabrielle B.
NOWARA
&
Stephen J.
NEWMAN

FISHERIES
DEPARTMENT
OF WESTERN
AUSTRALIA

FISHERIES
RESEARCH &
DEVELOPMENT
CORPORATION

Project
94/026

CONTENTS

List of Tables 3

List of Figures 5

1.0 Executive Summary 9

2.0 Background 12

3.0 Need 14

4.0 Objectives 15

5.0 Materials and Methods 15

5.1 The Kimberley Region 15

5.2 Foreign Fishing Data 16

5.2.1 Taiwanese Fishing Data 16

5.2.2 Analysis of Variance of CPUE 19

5.2.3 Indonesian Traditional Fishing 20

5.3 Fishery Independent Surveys 21

5.4 Other Fishery Data 22

6.0 Results 23

6.1 Taiwanese Fishing Activities 23

6.1.1 The Distribution of Fishing Catch and Effort 24

6.1.2 Composition of the Catch 26

6.1.3 Total Catch, Total Effort and Catch Per Unit Effort 27

6.1.4 Catch and Fishing Effort 29

6.1.5 Analysis of Variance of CPUE 30

6.2 Indonesian Traditional Fishing 41

6.3 Fishery Independent (CSIRO) Surveys 43

6.3.1 The Distribution of Catch, Effort and CPUE 43

6.4 Comparison of Catch Composition 44

6.5 Current Fisheries 45

6.5.1 Kimberley Demersal Scalefish Fisheries 45

7.0 Discussion 45

7.1 Current Status of the Demersal Finfish Resource 48
8.0 Conclusions 49
9.0 Acknowledgments 51
10.0 References 51
11.0 Intellectual Property 52

LIST OF TABLES

Table 1: Description of commercial family catch categories, their respective common names and the dominant species present in the catch of each category from Taiwanese pair trawlers from 1980 to 1990 17

Table 2: Numbers of trawlers, catch quotas and boundary changes for Taiwanese pair trawlers from 1980 to 1990 24

Table 3: Frequency of shots by Taiwanese pair trawlers by depth zone 25

Table 4: ANOVA table for log transformed total catch rates from Zones 1 and 3 only 30

Table 5: ANOVA table for log transformed catch rates of small lutjanids 31

Table 6: ANOVA table for log transformed catch rates of large lutjanids 32

Table 7: Comparisons of mean catch rates of large lutjanids between zones (significance level: * = $p < 0.05$; ** = $p < 0.01$) 33

Table 8: ANOVA table for log transformed catch rates of *Pristipomoides* species 33

Table 9: Comparisons of mean catch rates of *Pristipomoides* species between zones (significance level: * = $p < 0.05$; ** = $p < 0.01$) 34

Table 10: ANOVA table for log transformed catch rates of haemulids 34

Table 11: ANOVA table for log transformed catch rates of lethrinids 35

Table 12: ANOVA table for log transformed catch rates of mullids 36

Table 13: ANOVA table for log transformed catch rates of nemipterids 37

Table 14: Comparisons of mean catch rates of nemipterids between zones (significance level: * = $p < 0.05$; ** = $p < 0.01$) 38

Table 15: ANOVA table for log transformed catch rates of priacanthids 38

Table 16: ANOVA table for log transformed catch rates of serranids 39

Table 17: Comparisons of mean catch rates of serranids between zones (significance level: * = $p < 0.05$; ** = $p < 0.01$) 40

Table 18: ANOVA table for log transformed catch rates of synodontids 40

Table 19: Families and species of commercial importance and their proportion in the inspected catch of traditional Indonesian fishing vessels fishing around Scott and Ashmore Reefs 42

Table 20: Percent abundance (%) by family of CSIRO fishery independent survey data (1978-1980) and Taiwanese fishing data (1980 only) 44

List of Figures

Figure 1: The Kimberley region showing Zones 1 to 4 19

Figure 2: Chart showing major trawling grounds at 118°E-122°E used by the foreign pair trawl fleets from 1975-1978 as recorded by the WA Fisheries Department (Source: C. Ostle).......... 53

Figure 3: Chart showing major trawling grounds at 122°E-130°E used by the foreign pair trawl fleets from 1975-1978 as recorded by the WA Fisheries Department (Source: C. Ostle).......... 54

Figure 4.1: Distribution of total catch, effort and catch per hour for Taiwanese pair trawlers 1980-1990.......... 55

Figure 4.2: Distribution of catch, effort and catch per hour of small lutjanids by Taiwanese pair trawlers 1980-1990.......... 56

Figure 4.3: Distribution of catch, effort and catch per hour of large lutjanids by Taiwanese pair trawlers 1980-1990.......... 57

Figure 4.4: Distribution of catch, effort and catch per hour of *Pristipomoides* lutjanids by Taiwanese pair trawlers 1980-1990.......... 58

Figure 4.5: Distribution of catch, effort and catch per hour of haemulids by Taiwanese pair trawlers 1980-1990.......... 59

Figure 4.6: Distribution of catch, effort and catch per hour of lethrinids by Taiwanese pair trawlers 1980-1990.......... 60

Figure 4.7: Distribution of catch, effort and catch per hour of mullids by Taiwanese pair trawlers 1980-1990.......... 61

Figure 4.8: Distribution of catch, effort and catch per hour of nemipterids by Taiwanese pair trawlers 1980-1990.......... 62

Figure 4.9: Distribution of catch, effort and catch per hour of priacanthids by Taiwanese pair trawlers 1980-1990.......... 63

Figure 4.10: Distribution of catch, effort and catch per hour of serranids by Taiwanese pair trawlers 1980-1990.......... 64

Figure 4.11: Distribution of catch, effort and catch per hour of synodontids by Taiwanese pair trawlers 1980-1990.......... 65

Figure 5.1: Composition of Taiwanese pair trawl catch from 1980 to 1990 66

Figure 5.2: Composition of Taiwanese pair trawl catch in block 1721 in the Broome area from 1980 to 1990 67

Figure 5.3: Composition of Taiwanese pair trawl catch in block 1325 in the Holothuria Banks area from 1980 to 1990 67

Figure 5.4: Total catch, effort and CPUE for block 1721 in the Broome area 68

Figure 5.5: Total catch, effort and CPUE for block 1325 in the Holothuria Banks area 69

Figure 6.1: Total catch, total effort and catch per unit effort of the Taiwanese trawl fleet in the Kimberley region from 1980 to 1990 70

Figure 6.2: Catch, effort and catch per unit effort of small lutjanids for the Taiwanese trawl fleet in the Kimberley region from 1980 to 1990 71

Figure 6.3: Catch, effort and catch per unit effort of large lutjanids for the Taiwanese trawl fleet in the Kimberley region from 1980 to 1990 72

Figure 6.4: Catch, effort and catch per unit effort of *Pristipomoides* spp. for the Taiwanese trawl fleet in the Kimberley region from 1980 to 1990 73

Figure 6.5: Catch, effort and catch per unit effort of haemulids for the Taiwanese trawl fleet in the Kimberley region from 1980 to 1990 74

Figure 6.6: Catch, effort and catch per unit effort of lethrinids for the Taiwanese trawl fleet in the Kimberley region from 1980 to 1990 75

Figure 6.7: Catch, effort and catch per unit effort of mullids for the Taiwanese trawl fleet in the Kimberley region from 1980 to 1990 76

Figure 6.8: Catch, effort and catch per unit effort of nemipterids for the Taiwanese trawl fleet in the Kimberley region from 1980 to 1990 77

Figure 6.9: Catch, effort and catch per unit effort of priacanthids for the Taiwanese trawl fleet in the Kimberley region from 1980 to 1990 78

Figure 6.10: Catch, effort and catch per unit effort of serranids for the Taiwanese trawl fleet in the Kimberley region from 1980 to 1990 79

Figure 6.2: Catch, effort and catch per unit effort of synodontids for the Taiwanese trawl fleet in the Kimberley region from 1980 to 1990 80

Figure 7.1: Catch v effort graphs for Total catches, small lutjanid and large lutjanid catches of the Taiwanese pair trawlers from 1980 to 1990 81

Figure 7.2: Catch v effort graphs for *Pristipomoides* spp., haemulid and lethrinid catches of the Taiwanese pair trawlers from 1980 to 1990 82

Figure 7.3: Catch v effort graphs for mullid, nemipterid and priacanthid catches of the Taiwanese pair trawlers from 1980 to 1990 83

Figure 7.4: Catch v effort graphs for serranid and synodontid catches of the Taiwanese pair trawlers from 1980 to 1990 84

Figure 8.1: Catch per hour (geometric mean) for total catches of Taiwanese pair trawlers in zones 1 & 3 only for year, depth, shot start time and shot duration. These catch rates have been adjusted for the other main effects in the ANOVA model 85

Figure 8.2: Catch per hour (geometric mean) for catches of small lutjanids by Taiwanese pair trawlers for year, depth, shot start time and shot duration. These catch rates have been adjusted for the other main effects in the ANOVA model 86

Figure 8.3: Catch per hour (geometric mean) for catches of large lutjanids by Taiwanese pair trawlers for year, depth, shot start time and shot duration. These catch rates have been adjusted for the other main effects in the ANOVA model 87

Figure 8.4: Catch per hour (geometric mean) for catches of *Pristipomoides* spp. by Taiwanese pair trawlers for year, depth, shot start time and shot duration. These catch rates have been adjusted for the other main effects in the ANOVA model 88

Figure 8.5: Catch per hour (geometric mean) for catches of haemulids by Taiwanese pair trawlers for year, depth, shot start time and shot duration. These catch rates have been adjusted for the other main effects in the ANOVA model.................................. 89

Figure 8.6: Catch per hour (geometric mean) for catches of lethrinids by Taiwanese pair trawlers for year, depth, shot start time and shot duration. These catch rates have been adjusted for the other main effects in the ANOVA model.................................. 90

Figure 8.7: Catch per hour (geometric mean) for catches of mullids by Taiwanese pair trawlers for year, depth, shot start time and shot duration. These catch rates have been adjusted for the other main effects in the ANOVA model.. 91

Figure 8.8: Catch per hour (geometric mean) for catches of nemipterids by Taiwanese pair trawlers for year, depth, shot start time and shot duration. These catch rates have been adjusted for the other main effects in the ANOVA model.................................. 92

Figure 8.9: Catch per hour (geometric mean) for catches of priacanthids by Taiwanese pair trawlers for year, depth, shot start time and shot duration. These catch rates have been adjusted for the other main effects in the ANOVA model.................................. 93

Figure 8.10: Catch per hour (geometric mean) for catches of serranids by Taiwanese pair trawlers for year, depth, shot start time and shot duration. These catch rates have been adjusted for the other main effects in the ANOVA model.................................. 94

Figure 8.11: Catch per hour (geometric mean) for catches of synodontids by Taiwanese pair trawlers for year, depth, shot start time and shot duration. These catch rates have been adjusted for the other main effects in the ANOVA model 95

Figure 9.1: Distribution of total catch, effort and catch per hour by CSIRO experimental trawling 1978-1980...96

Figure 9.2: Distribution of catch, effort and catch per hour of lutjanids by CSIRO experimental trawling 1978-1980...97

Figure 9.3: Distribution of catch, effort and catch per hour of haemulids by CSIRO experimental trawling 1978-1980...98

Figure 9.4: Distribution of catch, effort and catch per hour of lethrinids by CSIRO experimental trawling 1978-1980...99

Figure 9.5: Distribution of catch, effort and catch per hour of mullids by CSIRO experimental trawling 1978-1980...100

Figure 9.6: Distribution of catch, effort and catch per hour of nemipterids by CSIRO experimental trawling 1978-1980...101

Figure 9.7: Distribution of catch, effort and catch per hour of priacanthids by CSIRO experimental trawling 1978-1980...102

Figure 9.8: Distribution of catch, effort and catch per hour of serranids by CSIRO experimental trawling 1978-1980...103

Figure 9.9: Distribution of catch, effort and catch per hour of synodontids by CSIRO experimental trawling 1978-1980...104

1.0 EXECUTIVE SUMMARY

1. The aim of this project was to collate all historical information regarding fishing activities relevant to the Kimberley demersal scalefish fishery.

2. Three primary sources of information were identified: foreign Taiwanese pair trawl fishing activities; traditional Indonesian fishing activities; and fishery independent (CSIRO) survey data.

3. The Taiwanese pair trawl fishing catch and effort from 1980 to 1990 was concentrated into two main regions, the Broome area (120°-122°E) and the Holothuria Banks area (124°-126°E) in the north. The catch and effort within these areas was also concentrated, with the majority of trawls undertaken in the mid-continental shelf region (60-100 m).

4. The Taiwanese catch rates of large lutjanids and haemulids was greater in the eastern sector of the Kimberley region, while the CPUE of the small lutjanids, lethrinids, mullids, nemipterids, priacanthids and serranids was higher in the western sector. The CPUE of *Pristipomoides* was highest in the deep slope waters near the shelf break.

5. The total catch of the Taiwanese pair trawl fishery reached a peak of 4 394 tonnes in 1985. Effort levels also reached a peak of 14 896 hours in 1985.

6. The composition of the Taiwanese catch changed markedly from 1984 to 1990 with large lutjanids, small lutjanids and *Pristipomoides* lutjanids comprising a substantially larger component of the catch in these latter years.

7. Comparison of the fishery independent survey data and the Taiwanese data suggests that considerable grading and discarding was taking place in the Taiwanese fishing operations.

8. The total CPUE of the Taiwanese pair trawl fishery in the Kimberley showed a significant decline over the duration of the fishery from 1980 to 1990. The historical account of the catch and effort levels in the Taiwanese pair trawl fishery indicates that the total catches increased with increasing effort up to 1985, and then decreased to lower levels of catch with respect to effort from 1986-1990.

9. The CPUE of nemipterids, priacanthids and haemulids declined significantly over the duration of the Taiwanese fishery. The CPUE of lethrinids and synodontids also declined over the duration of the Taiwanese fishery.

10. The substantial decline in CPUE of the Taiwanese vessels by 1986 suggests that the declining catch may have resulted from a decreasing abundance of fishes in the region. Furthermore, the continued reduction (post-1986) in fishing effort by the Taiwanese fleet was likely to be a combination of low abundance of fishes and changing licensing arrangements which made it more feasible for the Taiwanese to fish the more productive grounds of the Arafura Sea and NW shelf.

11. Caution is recommended in interpreting assumptions regarding the status of the demersal resource based only on Taiwanese CPUE data. CPUE data from the Taiwanese commercial fishery can be misleading because of biases associated with variable targeting practices, changing discard and retention practices and spatial shifts in fishing effort.

12. As a result the pooling of species into commercial catch categories, the poor understanding of discarding practices, and possible unknown variations in reporting

procedures over the duration of the Taiwanese fishery, the data has yielded little information that can be used to provide stock assessment advice for management of the current domestic demersal fisheries.

13. Traditional Indonesian vessels fishing in the MOU Box target species of the Lutjanidae, Lethrinidae, Serranidae and Labridae which are associated with the offshore reefs of the north-west and are not currently commercially important to the existing Kimberley Demersal Scalefish Fishery.

14. Large modernised Indonesian demersal longline vessels work along the edge of the AFZ adjacent to the waters of the Kimberley region, and target the high value reef associated species such as the lutjanids, lethrinids and serranids. These species are also the primary target species of the Kimberley Demersal Scalefish Fishery. The degree of connectivity between the demersal fish stocks in these regions is unknown.

15. Knowledge of the potential exploitable demersal resource east of 125°E in the Kimberley region and in depths greater than 150m is relatively limited. Determination of the extent and exploitation potential of demersal fishes in areas outside those currently fished is required in order to determine the extent of the demersal resource available to fishers.

16. Stock assessment and management advice is heavily dependent on understanding the extent of the demersal resource available to fishers, improved catch and effort information, and knowledge of those biological attributes of the key species that are needed in order to develop a model of the fishery.

2.0 BACKGROUND

The waters off the Kimberley coast of Western Australia (WA) have a long history of fishing, mainly by foreign vessels. Additionally, varying levels of subsistence fishing by traditional Indonesian fishermen have been ongoing through history. The region was considered to be part of the Commonwealth Northern Demersal Fishery which was fished by many industrialised foreign vessels until 1990, and which ranged from NW Cape (114°E) in WA almost to Cape York in Queensland (142°E). The Kimberley region is presently defined as the waters on the continental shelf bounded by 120°E and 129°E longitude (the border between WA and the Northern Territory) and 10°S and 20°S latitude (Fig. 1).

Experimental trawling off northern and north-western Australia was conducted as early as 1935 by the Japanese (Robins 1969, Sainsbury 1987). Further Japanese research surveys were carried out between 1962 and 1966, and from 1959 to 1963 there was a commercial Japanese fishery operation within the North-west Shelf (115°-119°E) region (Robins 1969, Sainsbury 1987). The Japanese fishing operations were all undertaken west of longitude 120°E. Russian research trawls were conducted from 1962 to 1973 in northern waters (Sainsbury 1987), but details of these surveys such as the locations fished and the catch composition are unavailable. Total catches from the Commonwealth Northern Demersal Fishery were greatest in the early 1970's (Jernakoff and Sainsbury 1990).

After the declaration of the 200 nautical mile Australian Fishing Zone in 1979 most fishing activities in northern and north-western waters off WA were managed by the Commonwealth Government. Foreign nations continued fishing these waters under access agreements in accordance with Australia's obligations under UNCLOS (United Nations Convention on the Law of the Sea). Taiwanese pair trawlers fished the waters of northern and north-western Australia from 1971 to 1990, and Chinese pair trawlers operated in 1989. From 1985 to 1990, Thai pair trawlers operated extensively in the adjacent Arafura Sea (132°-142°E) (Jernakoff and Sainsbury 1990). Most of the catch taken off the Kimberley coast in the 1980's was by Taiwanese pair trawlers. These vessels were 280-350 tonnes (gross tonnage) and 36-42 m in length (Ramm 1994).

In 1988, under the Offshore Constitutional Settlement (OCS), the Commonwealth passed jurisdiction for management of many of the fisheries off the WA coast to the WA Government. Since 1988, 11 of the 15 fisheries covered by the OCS arrangements have been managed solely by the Fisheries Department of WA (Anon 1988). Finfish fisheries of the Kimberley region which were transferred to the state included the Trap and Pot Fishery (landward of the 200 m isobath), and the Kimberley Line fishery, excluding tunas, (out to 12 nm) using hand, troll and drop lines.

In April 1992, management of the North-west Shelf Inshore Trawl Fishery was transferred to the state of WA. This transfer included waters between 120° and 123°45'E, landward of the 200 m isobath. The Fisheries Department of WA subsequently closed this area to fish trawling. The Commonwealth retained jurisdiction over trawl-based fisheries east of 123°45'E. This area (east of 123°45'E) formed part of the Timor Zone of the Commonwealth Northern Fish Trawl Fishery. In 1992 there were no trawlers operating in this zone, and in December 1992 the fishery was closed to new entrants (Fowler 1995).

Under new OCS arrangements introduced in February 1995, the WA Government became responsible for all fisheries taking fish by methods other than trawl in the waters east of 120°E and out to the 200 nm limit of the AFZ; with the exception of sharks taken east of Koolan Island (123°E) which are managed under a joint authority with the Commonwealth of Australia. In addition, fish trawling inside the 200 m isobath is under state jurisdiction (outside the 200 m isobath is still under Commonwealth jurisdiction). As under the previous OCS (1988) arrangements, the taking of tuna in WA waters and the taking of prawns in the Northern Prawn Fishery remains under Commonwealth jurisdiction (Fowler 1995).

In 1984, a domestic trap and line fishery developed off the Pilbara coast on the south western section of the North-west Shelf. Over recent years this has largely been replaced with a managed domestic fish trawl fishery. Since the departure of the foreign fleets in 1990, a trap fishery operating out of Broome has developed in the Kimberley region. Western Australia's experience in the Pilbara trap fishery was that the fishery intensified rapidly, then declined as fishers could no longer obtain adequate catch rates. The Kimberley trap fishery does not currently work all the grounds of the region and it is not known whether grounds suitable for traps exist outside the area currently exploited. There is an increasing interest in line fishing in the region.

The challenge for those responsible for the management of Western Australian fisheries is to utilise the demersal fish resource in the Kimberley area to an optimum sustainable level, whilst conserving fish stocks and habitats.

3.0 NEED

The Western Australian fishing industry has a need to develop new profitable fisheries for its existing fleet in order to take pressure off established fisheries where fishing effort levels are causing low profitability or threatening the viability of stocks. The northern areas formerly worked by foreign trawl fleets, such as those off the Kimberley coast, are thought to have good potential. CSIRO's research indicated that the decline in the foreign fishery on the NW Shelf was primarily due to trawl-caused habitat damage. Western Australia must therefore be cautious with the development of these fisheries.

While stock assessments are crucial and are currently being undertaken for the demersal fish stocks of the Pilbara, it is not appropriate yet in the less developed

Kimberley fishery. The primary need in the Kimberley at the moment is to describe the extent and nature of the resource and the fishable grounds. This work will be a foundation for future stock assessment research. Some information already exists, gathered by the Commonwealth agencies for the foreign fishery, but needs bringing together in a summary document.

4.0 OBJECTIVES

To bring together all existing information relevant to the Kimberley Demersal Scalefish Fishery and collate it into a summary report. This includes logbooks and observer reports from foreign commercial and feasibility fishing and research cruises, and trawl surveys by Northern Territory (NT) Fisheries and CSIRO.

5.0 MATERIALS AND METHODS

5.1 THE KIMBERLEY REGION

The Kimberley Region is defined as all waters on the continental shelf of north-western Australia from 120°E to approximately 129°E longitude, the border between Western Australia and the Northern Territory (defined in the Petroleum (Submerged Lands) Act 1982 - WA) and ranges from 10°S to 20°S latitude and extends out to the edge of the 200 nm limit of the AFZ. The Kimberley Region is characterised by distinct "wet" and "dry" seasons.

The "wet" season in the Kimberley region occurs from December to May with the mean average rainfall > 780 mm (mean av. > 130 mm $month^{-1}$) during this period (based on Bureau of Meteorology data up to 1975). During the wet season winds are generally from the west to north west emerging out of the Indian Ocean. The wet season is also characterised by cyclone activity. The frequency of cyclones in the Kimberley is highly variable, with fishing operations during the wet season dependent upon the prevailing weather conditions. The "dry" season from June to November has little rain with the mean average rainfall < 45 mm (mean av. < 7 mm month^{-1}) during this period and winds are generally from the east to south east and flow off the land.

5.2 Foreign Fishing Data

The Australian Fisheries Management Authority (AFMA), CSIRO Division of Fisheries and Northern Territory Fisheries were approached in order to obtain access to data and reports relevant to the Kimberley demersal fishery.

Two useful sources of foreign fishing vessel information were identified, Taiwanese pair trawling data for 11 years from 1980 to 1990 (inclusive), and one year (1989) of data from Chinese pair trawlers. In the original Taiwanese data, catch weights were recorded in kilograms in the years 1980 to 1987. In 1988 to 1990 the catch was recorded in number of boxes, and the average kilograms per box given. In these three years the number of boxes was multiplied by the average weight per box to give the total kilograms per shot. In the Chinese data (1989) catches were recorded as the number of boxes of fillets and an average weight per box. In this case box weights were multiplied by 3 to convert to whole weights, then multiplied by the number of boxes to provide and overall estimate of the weight of the catch. The Chinese data are not presented because the catch rates were unrealistically high, both in comparison with the Taiwanese data, and considering anecdotal evidence about their fishing practices available from Observer Reports.

5.2.1 Taiwanese Fishing Data

The spatial distribution of Taiwanese catch and effort data was examined by 1° grid blocks. The data were reported for total catches and independently by family categories in fishery logbooks collected by the former Commonwealth Australian Fisheries Service. The data for total catches and for the 10 commercially important categories were combined for all years between 1980 and 1990 and are presented by 1° blocks on identical maps. The categories presented are: haemulids, lethrinids, small lutjanids, *Pristipomoides* lutjanids, large lutjanids, mullids, nemipterids, priacanthids, serranids and synodontids.

The individual species represented in each of these family categories, and their relative abundance are given in Ramm (1994). The details of the dominant species in each of the commercial family categories and their common names are presented in Table 1.

Table 1: Description of commercial family catch categories, their respective common names and the dominant species present in the catch of each category from Taiwanese pair trawlers from 1980 to 1990.

Commercial Category	Common Names	Dominant Species
Large Lutjanids	red snappers, seaperch	*Lutjanus malabaricus*
Small Lutjanids	small snappers, seaperch	*Lutjanus vitta*
Pristipomoides Lutjanids	king snapper, jobfish	*Pristipomoides multidens*
Lethrinids	emperors, large-eye breams	*Lethrinus lentjan*
Haemulids	sweetlips, javelin-fish sand snapper, grunts	*Diagramma pictum*
Serranids	groupers, rock cods, coral trout	*Plectropomus maculatus* *Epinephelus areolatus*
Nemipterids	threadfin breams, coral breams, monocle breams	*Nemipterus furcosus*
Priacanthids	bigeyes	*Priacanthus tayenus*
Mullids	goatfish, red mullet	*Parapeneus heptacanthus*
Synodontids	lizardfish	*Saurida undosquamis*

The Taiwanese fishing vessels were made of steel and ranged in size from 280-350 tonnes (gross tonnage) and from 36-42 m in length (Ramm 1994). They were all relatively similar in size and it is assumed that the fishing power between vessels was also similar. The vessels operated demersal fish trawl nets with a head rope of approximately 100 m, an opening height of 6-12 m and a mesh size of 60 mm in the cod-end (Liu 1976, Ramm 1994). The trawl nets were towed between two vessels which were approximately 250-400 m apart.

Time series of catch, effort (hours trawled) and catch per unit effort (CPUE), plus and minus one standard error, were plotted for each of the 10 categories of fish from the Taiwanese catch. CPUE was calculated as catch per hour. Least squares regression was used to test if a significant relationship existed between CPUE over the duration of the fishery from 1980 to 1990. This was done for total catches and for each of the major commercial family categories.

Catch was also plotted against effort for total catches, and individually for each of the commercial categories of fish. The percentage abundance of each of the commercial family categories in the annual catch was plotted over the years 1980 to 1990.

One representative block from each of the two most heavily fished areas in the Kimberley region were selected, and the catch history from each of these blocks was examined over time to determine the fine scale spatial variability in species composition and abundance. Block 1721 (the north west corner of the 1° x 1° block is 17°S, 121°E) and block 1325 (the north west corner of the 1° x 1° block is 13°S, 125°E) were chosen because they had experienced the most consistent effort in the two most heavily fished areas over the years 1980 to 1990. The total catches (kg), total effort (h) and CPUE (kg/h) were plotted for each of the 11 years. In addition the abundance of the family categories was also plotted over the years.

5.2.2 ANALYSIS OF VARIANCE OF CPUE

A number of factors were considered when analysing the catch per unit effort data using Generalised Linear Models (GLM). The factor Year consists of 12 month periods from December of each year to the following November in order to include a complete wet and dry season. Season was divided into wet (December to May) and dry (June to November) based on median rainfall records. Depths were divided into 20 metre classes, with 1-40 m being pooled together because there were very few shots in this depth range. Depths fished included all those up to 165 metres, with the last category being all depths greater than or equal to 140 metres. The shot start times were divided into classes of 2 hr intervals over the 24 hour period. The duration of each trawl shot was divided into 1 hr classes. The Kimberley region was divided into 4 zones, along longitudinal lines (see Fig. 1) as a basis for analysis.

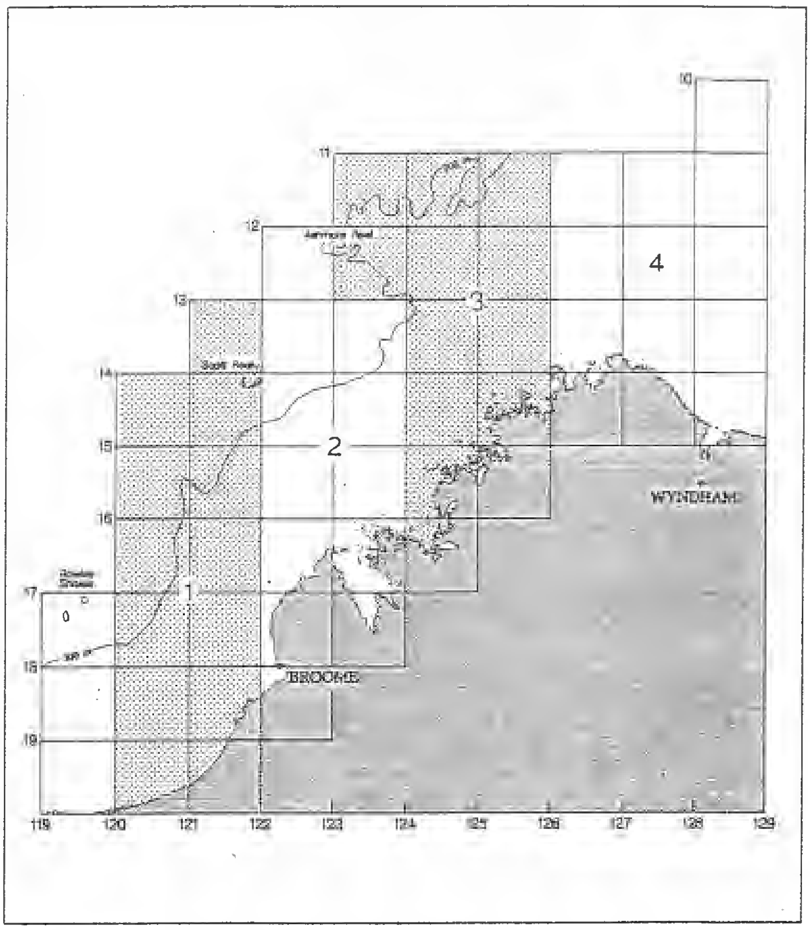


Figure 1: The Kimberley region showing Zones 1 to 4.

A log transformation was carried out on the catch rates before analysis. Where zero catches occurred, half the amount of the smallest catches was subsequently added to these zero values and then divided by the effort for that shot. For total catches this was calculated as 15 kg. For large lutjanids, small lutjanids, haemulids, lethrinids, priacanthids, nemipterids and mullids 6 kg was added, and for *Pristipomoides*, serranids and synodontids 1.5 kg was added.

Analysis of variance was used to investigate the main effects and interactions. A stepwise approach was used to find the significant main effects and interactions. The R-square, sums of squares (SS, type III) and means squares for each factor are presented. Type III SS from the SAS GLM procedure are the SS explained by a given factor after the other factors in the ANOVA are taken into account. The least squares means were used to compare the main treatment effects. These represent mean values which are adjusted for all other factors. Graphs of the geometric means (back transformed from the least squares means) are presented. All factors presented had a significant ($p < 0.001$) effect due to the large amount of data on which the analysis was based. As the data was not collected from a rigorous, balanced and orthogonal experimental design, the significance levels should only be used as a guide. A t-test was used to examine differences between means. To determine the relative importance of each of the factors, the proportion of the SS explained was also examined.

5.2.3 INDONESIAN TRADITIONAL FISHING

A third, less useful, source of data has been identified. Australian Fishing Zone (AFZ) Officers at Broome keep a database of boardings and apprehensions of Indonesian fishing vessels intercepted inside the AFZ. These data are available from 1972-1994.

These data contain only the number of kilograms of fish on board each vessel. There was no recording of individual species caught. The location of each inspection was recorded, which was usually one of their fishing locations, but not necessarily the only one. There is usually an anecdotal record of the locations fished.

Indonesian vessels using traditional fishing methods (eg. sail powered craft) are entitled to fish within a specified area of the Australian Fishing Zone in accordance with the 1974 Memorandum of Understanding (MOU) with the Indonesian Government. The MOU fishing zone is in essence bounded by Scott Reef and Browse Island in the south and Cartier Island, Ashmore Reef and the edge of the AFZ in the north.

5.3 FISHERY INDEPENDENT SURVEYS

Data from three years of surveys (1978-1980) undertaken in the Kimberley region of north western Australia by CSIRO have been examined. Trawls were conducted according to a stratified random sampling design, with stratification based on depth zones at 20-49m, 50-99m, 100-149m and 150-200m. Some shots were subsequently moved due to the unsuitability of the randomly chosen sites (Sainsbury unpub.). Demersal trawl nets (with cover nets) and two pelagic nets were used during these surveys. Catches from the pelagic nets were omitted from the analysis. The demersal trawl nets used were a Frank & Bryce 9" wing trawl with either a 10, 20 or 40 mm codend liner (which was used for 93% of the shots) and an Engel high opening bottom trawl, sometimes with a 20 mm codend liner.

Catch sampling was carried out by weighing and counting the number of each species for each shot. In some cases only weights or numbers were taken. Where numbers only were recorded, the weights were calculated using the mean individual weight for that species from when both were recorded. If this was unavailable then the mean individual weight for the family was used. In the few cases where numbers and weights in a particular family was not recorded, an average individual weight calculated from the total number of fish weighed and counted was used. Where less than 1 kg of a species occurred in the catch, its presence was noted, but not weighed or counted. These records were subsequently excluded from the analysis. Where very large catches occurred a subsample of the catch was individually weighed. When this occurred the data was multiplied out by the factor required to make it up to 100% of the catch. Weight of sponges was also recorded in the sampling, but this was excluded from the catch analysis.

The data were pooled for the three years and plotted on a 1° by 1° block grid showing total catches, effort (h) and CPUE (kg/h). Catch categories similar to those examined for the Taiwanese data were analysed. These were total catches and catches of the Lutjanidae, Lethrinidae, Mullidae, Haemulidae, Nemipteridae, Serranidae, Priacanthidae and Synodontidae. The catch composition expressed as the percentage these families made up of the total catch is presented in comparison with the Taiwanese trawl catch in 1980.

5.4 OTHER FISHERY DATA

Prior to the declaration of the AFZ in 1979, foreign vessel fishing activities in waters off the WA coast were monitored by the Special Investigations Section of the Fisheries Department of WA. Commonwealth waters at the time extended only to 12 nm from the coastal baseline, however all foreign vessel fishing activities in waters of the Kimberley region were monitored. Charts showing the areas in which foreign demersal trawling activity was concentrated between 1975 and 1978 were produced as a result of the information gathered during this monitoring program.

6.0 RESULTS

6.1 TAIWANESE FISHING ACTIVITIES

The Taiwanese data examined in detail in this study were recorded in logbooks which were a mandatory part of the access agreements between the Commonwealth of Australia and KKFC Pty Ltd (Kailis Kaosiung Fishing Company). Access arrangements regarding dates, number of pair trawlers, catch quotas and boundary changes in zones are presented in Table 2. Access to the Kimberley region from 1979 was initially from 12 nm (and in some areas 25 nm) from the coastal or island baseline to the 200 nm limit of the Australian Fishing Zone. This was reduced from 1987 as described in Table 2. A more detailed representation of the access to the entire northern area is given in Jernakoff and Sainsbury (1990).

Foreign vessel fishing activities off the WA coast were monitored by the Special Investigations Section of the Fisheries Department of WA prior to the declaration of the AFZ in 1979. The areas in which foreign demersal trawling activity was concentrated between 1975 and 1978 are shown in Figures 2 and 3.

The regulated minimum mesh size of the trawl net codend was 60 mm from 1979 until November 1989, then was increased to 90 mm. Prior to 1979, the mesh size had been 45 mm (Jernakoff and Sainsbury 1990). Hence for the majority of the time for which this data is presented, the mesh size was consistent.

Table 2: Numbers of trawlers, catch quotas and boundary changes for Taiwanese pair trawlers from 1980 to 1990.

Date	No. Vessels	Catch Quota	Boundary changes
1 Nov 79 - 31 Oct 80	not available	not available	not available
1 Nov 80 - 31 Oct 81	60 pairs trawlers ≤800 gross registered tonnes (grt) per pair	27,500 t	
1 Nov 81 - 31 Oct 82	same as above	20,000 t	
1 Nov 82 - 31 Jul 83	same as above	15,000 t	
1 Aug 83 - 31 Jul 84	same as above	20,000 t	
1 Aug 84 - 31 Jul 85	same as above	27,500 t	
1 Aug 85 - 31 Jul 86	same as above	27,500 t	
1 Aug 86 - 31 Jul 87	50 pairs trawlers ≤800 grt per pair	15,000 t	
1 Aug 87 - 31 Jan 88 (6 months)	50 pairs	7,500 t	western boundary moved from 116°E to 117°30'E. NW deepwater excised.
1 Feb 88 - 31 Oct 88 (9 months)	45 pairs	7,500 t (including a max. of 3000 t from Arafura zone)	Zones NWShelf (117°30'-123°E) Timor (123°-132°E) Arafura (132°-141°E)
1 Nov 88 - 31 Oct 89	30 pairs	NWS 5,000 t Timor 2,000 t Arafura 2,000 t	Zones NWShelf (117°30'-123°E) Timor (123°-131°E) Arafura (131°-136°46'E)
1 Nov 89 - 31 Oct 90	5 pairs 7 pairs (from 12.12.89)	NWS 2355 t Timor 520 t Arafura 910 t	

Source: Documents of Agreements between the Commonwealth of Australia and KKFC Proprietary Limited, AFMA and WA Fisheries Department files.

6.1.1 The Distribution of Fishing Catch and Effort

The distribution of total catch, total effort and catch per unit effort (CPUE) of the Taiwanese pair trawlers in the Kimberley for the combined period 1980 to 1990 are shown in Fig. 4.1. The CPUE throughout the region by 1° block was relatively similar except for the CPUE in blocks from 122°-123° E and 127°-128° E longitude. Fishing effort and catches were concentrated into two regions, the Broome area, in the localised vicinity of Broome extending from 120°-122°E longitude and the Holothuria Banks area in the more northern waters extending from 124°-126°E longitude, approximately between the Heywood Shoals area in the west and Holothuria Banks in the east. The catch and effort in these areas is also concentrated with the majority of trawls undertaken in the mid-continental shelf region (< 100 m, Fig. 4.1, Table 3). There has been little fishing effort by Taiwanese vessels in waters deeper than 140 metres or in offshore localities such as the oceanic atolls of Scott and Seringapatam Reefs (Fig. 4.1, Table 3).

Table 3: Frequency of shots by Taiwanese pair trawlers by depth zone.

Depth (m)	Frequency	Percent Frequency (%)
1-39	78	0.2
40-59	3473	10.8
60-79	13225	41.1
80-99	12553	39.0
100-119	2223	6.9
120-139	498	1.5
140 +	157	0.5

The CPUE of small lutjanids (Fig. 4.2) was greater west of 126° E, with the highest catches in the Broome area. The CPUE of small lutjanids was relatively low in the eastern sector (126°-129° E) of the Kimberley (Fig. 4.2). Conversely, the CPUE of large lutjanids was greater east of 122° E, with the highest catches recorded in the Holothuria Banks area and higher CPUE in the eastern sector of the Kimberley (Fig. 4.3). The highest CPUE of *Pristipomoides* lutjanids occurred in the deeper waters around the Ashmore Reef area, with higher catches recorded from the Holothuria Banks area (Fig. 4.4). Near-shore catches of *Pristipomoides* lutjanids were low, with the high CPUE associated with deep slope waters near the shelf break (Fig. 4.4). Catches of haemulids were generally concentrated in the near-shore region, associated with a higher CPUE (Fig. 4.5). The haemulid catch was higher in the Holothuria Banks area, with a corresponding higher CPUE in the eastern sector of the Kimberley (Fig. 4.5). The CPUE of lethrinids was relatively higher west of 126° E, with the highest catches in the Broome area (Fig. 4.6). The CPUE of lethrinids was relatively low in the eastern sector (126°-129° E) of the Kimberley (Fig. 4.6).

The CPUE of mullids was greater west of 122° E, with catches concentrated on the mid-continental shelf area, and the highest catches in the Broome area (Fig. 4.7). The catch and CPUE of mullids was low throughout the rest of the Kimberley (Fig. 4.7). The CPUE of nemipterids was low throughout the Kimberley (Fig. 4.8). Catches of nemipterids were higher in the Broome area with very low catches east of 122° E (Fig. 4.8). Priacanthid CPUE was relatively similar throughout the Kimberley with the highest catches recorded from the Broome area, except for almost no catches east of 127° E (Fig. 4.9). The CPUE of serranids was greater west of 123° E, with the highest catches in the Broome area (Fig. 4.10). The catch and CPUE of serranids was low throughout the rest of the Kimberley and very low east of 127° E (Fig. 4.10). Catches of synodontids were concentrated in both the Holothuria Banks and Broome areas (Fig. 4.11). CPUE of synodontids was higher in the northern (Ashmore Reef) section of the Holothuria Banks area, whilst higher catches were reported from the Broome area (Fig. 4.11).

6.1.2 COMPOSITION OF THE CATCH

The composition of the recorded catch for the entire Kimberley region from 1980 to 1990 are shown in Figure 5.1. The common names and the dominant species of each family represented in the catches from the Taiwanese pair trawlers are given in Table 1. Initially from 1980 to 1983 the fishery was dominated by nemipterids, lutjanids, lethrinids and other fish species. The relative contributions of each of the target families was also similar from 1980 to 1983 (Fig. 5.1). From 1984 to 1990 the composition of the catch changed markedly with large lutjanids, small lutjanids and *Pristipomoides* lutjanids comprising a substantially larger component of the catch (Fig. 5.1). The catch of lutjanids (large lutjanids, small lutjanids and *Pristipomoides* lutjanids combined) dominated the fishery from 1984 through to 1990 (Fig. 5.1).

As the Taiwanese catch was concentrated in the Broome area and the Holothuria Banks area of the Kimberley, the catch composition of representative 1° blocks in each area were examined. The catch composition of block 1721 (17° S, 121° E) in the Broome area is markedly different from the catch composition of block 1325 (13° S, 125° E) in the Holothuria Banks area (Fig. 5.2, 5.3). In the Broome area, block 1721, nemipterids dominate the catch from 1980 to 1990 (Fig. 5.2). The lutjanid catch increases over this period also with the relative contributions of each family group fluctuating from year to year. The catch composition of block 1721 is relatively stable despite a decline in both catch and effort levels from the peak in 1985, and a decline in CPUE from 1984 (Fig. 5.4). In the Holothuria Banks area, block 1325, nemipterids, lethrinids and lutjanids dominate the catch from 1980 to 1990 (Fig. 5.3). Large lutjanids form a greater proportion of the catch than in the Broome area (Fig. 5.3; see above). The catch composition of block 1325 is less consistent over time. This is possibly a reflection of the varying catch and effort levels over the duration of the fishery despite relatively constant levels of CPUE (Fig. 5.5).

6.1.3 Total Catch, Total Effort and Catch Per Unit Effort

The total catch from the Taiwanese pair trawl fishery increased to a peak of 4394 tonnes in 1985, and then dropped substantially to 821 tonnes in the following year and remained at low levels until fishing activities ceased in 1990 (Fig. 6.1). Effort followed a similar increase then decline, with low levels of effort from 1986 to 1990 (Fig. 6.1). CPUE (kg/hr) peaked in the early 1980's at over 400 kg/hr and declined to lower levels from 1984 (Fig. 6.1). From 1985 CPUE remained below 300 kg/hr. The total CPUE of the Taiwanese pair trawl fishery in the Kimberley showed a significant negative trend ($p < 0.001$) from 1980 to 1990. In 1983 and 1984 fishing activities were undertaken in more offshore areas than in previous years, concentrating around Ashmore Reef to the north. In 1988 fishing was undertaken around Scott Reef. Fishing by Taiwanese vessels at this offshore atoll reef was not recorded in any other year.

The total catch and total effort of most families followed a similar trend with both catch rates and effort levels being initially high, peaking in the mid 1980's, and subsequently declining to substantially lower levels in the latter years of fishing from 1986 to 1990 (Fig. 6.2-6.11). CPUE levels however, were specific to each commercial family group. CPUE of small lutjanids was relatively consistent over the duration of the fishery (1980-1990), however, CPUE declined substantially during 1986 (Fig. 6.2). CPUE of large lutjanids was variable, with no clear trend over the duration of the fishery. There was, however, a decline in CPUE from 1984-1986 (Fig. 6.3). The initial CPUE of *Pristipomoides* lutjanids was relatively low compared to subsequent years and showed a significant increase over the 11 years ($p<0.05$) (Fig. 6.4). Haemulid CPUE was relatively high until 1984, then declined rapidly and fluctuated at a lower level until 1990, when few individuals were recorded in catches (Fig. 6.5). The decline was significant ($p<0.05$). Lethrinid CPUE peaked in 1982 and subsequently declined to its lowest level in 1986 and was then variable at lower levels of CPUE until 1990 (Fig. 6.6).

The initial CPUE of mullids was relatively low compared to subsequent years and was relatively consistent from 1982 to 1990 (Fig. 6.7). CPUE of nemipterids increased gradually to a peak in 1983 and then declined substantially in 1984 despite increasing effort, and continually declined at a relatively slow rate until 1990 (Fig. 6.8). The nemipterid CPUE showed a significant ($p < 0.05$) decline over the duration of the fishery from 1980 to 1990 (see Fig. 6.8). Priacanthid CPUE decreased gradually from 1980 to 1990 (Fig. 6.9) and showed a significant ($p < 0.05$) negative trend over this period. Serranid CPUE was variable from 1980-1990, however, there was a rapid decline in CPUE from 1983-1986 (Fig. 6.10). The synodontid CPUE showed a general downward trend over the 11 years but with 1982 and 1983 being particularly low during the early 1980s (Fig. 6.11).

6.1.4 CATCH AND FISHING EFFORT

The history of catch and levels of fishing effort for the total catch indicates that catches increased with increasing effort up to 1985 and then decreased to lower levels of catch with respect to effort from 1986-1990 (Fig. 7.1). Similar histories of catch versus fishing effort were evident for the small lutjanids (Fig. 7.1) and nemipterids (Fig. 7.3). The catch and fishing effort history of the large lutjanids (Fig. 7.1) and the *Pristipomoides* lutjanids (Fig. 7.2) was relatively linear with catch levels correlated with effort levels, with the exception of 1984 when higher catches per unit of effort were obtained. This was associated with fishing activities in more offshore areas during this year.

The history of catch and fishing effort for mullids and priacanthids was also relatively linear with catch levels correlated with effort levels (Fig. 7.3). Catches decreased to relatively lower levels with respect to effort for the period 1986-1990. The lethrinid catch reached an asymptote at < 500 tonnes year^{-1} despite increasing levels of effort from 1982-1985, after which catches decreased to lower levels associated with decreasing effort (Fig. 7.2). The haemulid catch peaked at over 240 tonnes year^{-1} in 1984 and then crashed in 1985 to a catch level which was less than that in 1981 although effort had increased greater than 3 fold (Fig. 7.2). The catch of serranids did not increase above approximately 160 tonnes year^{-1} despite increasing levels of effort (Fig. 7.4). Serranid catch decreased substantially from 1985-1986 and was variable about lower levels with respect to effort to 1990. Catches of synodontids initially declined with increasing effort (1981-1983), increased in a linear manner with effort in 1984 and 1985 as the more northern grounds were fished and declined to lower levels from 1986-1990 (Fig. 7.4).

6.1.5 Analysis of Variance of CPUE

Total Catches

Table 4: ANOVA table for log transformed total catch rates from Zones 1 and 3 only.

R-square
0.28

Source	**df**	**Sums of squares**	**Mean Square**
Main effects			
zone	1	33 (<1%)	33
year	10	458 (2%)	46
season	1	26 (<1%)	26
depth class	6	352 (2%)	59
vessel	66	717 (3%)	11
time class	12	3161 (15%)	263
shot duration	5	304 (1%)	61
Error	31683	14880	0.47
Interactions (examined individually)			
year x zone	10	97 (<1%)	10
year x season	10	88 (<1%)	9
season x depth class	6	36 (<1%)	6

For total catches the analysis was restricted to Zones 1 and 3 as these had over 98% of the effort and were significantly different from, and had higher catches than the other two zones. Zones 2 and 4 were not significantly different from one another.

The factors which explain a large part of the sums of squares for total catch rates are the time class, depth class, year and differences between vessels. Over the 11 year period catch rates rose in the first few years then declined to their lowest levels in 85/86, increased again, ending at a higher level than the peak in 81/82 (Fig. 8.1). For total catch, catch rates were highest in the shallower waters and declined as depth increased (Fig. 8.1). The hours between 12 noon and 2 am had the highest catch rates over the 24 hr period (Fig. 8.1). The analysis showed that shots up to 3 hrs long produced high catch rates but shots longer than that resulted in much reduced catch rates (Fig. 8.1).

The interactions of year by zone, year by season and season by depth class were significant but formed only a small percentage of the total sums of squares.

Small Lutjanidae

Table 5: ANOVA table for log transformed catch rates of small lutjanids.

R-square 0.17			
Source	**df**	**Sums of squares**	**Mean square**
Main effects			
zone	3	201 (<1%)	67
year	10	1488 (3%)	148
season	1	28 (<1%)	28
depth class	6	1033 (2%)	172
vessel	66	2566 (6%)	39
time class	12	1109 (2%)	92
shot duration	5	591 (1%)	118
error	32103	37843	1.18
Interactions (examined individually)			
year x zone	26	421 (<1%)	16
year x season	10	546 (1%)	55
season x depth class	6	224 (<1%)	37

Inter-year variation was an important factor for small lutjanids, as were depth class, time class and differences between vessels. Catch rates were significantly different between zones 2 and 4 only, with catch rates in zone 2 being higher. Catch rates rose initially in the early 1980s, declining to a low in 1985/86 and rising again to peak in 1989/90 (Fig. 8.2). Catches of small lutjanids were highest in depths to 99 m then drop off sharply at greater depths (Fig. 8.2). The hours of highest catches over the 24 hr period were between 12 noon and 2 am (Fig. 8.2). Highest catch rates were obtained in shots of less than 1 hr for small lutjanids (Fig. 8.2) .

The year by zone, year by season and season by depth class interactions were significant but each accounted for only around 1% of the sums of squares.

Large Lutjanidae

Table 6: ANOVA table for log transformed catch rates of large lutjanids.

R-square			
0.41			
Source	**df**	**Sums of squares**	**Mean square**
Main effects			
zone	3	8519 (14%)	2840
year	10	1260 (2%)	126
season	1	129 (<1%)	129
depth class	6	1205 (2%)	201
vessel	66	2720 (4%)	41
time class	12	1201 (2%)	100
shot duration	5	364 (<1%)	73
Error	32103	37128	1.16
Interactions (examined individually)			
year x zone	26	680 (1%)	26
year x season	10	173 (< 1%)	17
season x depth class	6	29 (< 1%)	5

For the large lutjanids differences between the zones was the major source of variation. Other important factors were depth class, year, time class and differences between vessels. Comparisons of significantly different catch rates between the zones are presented in Table 7. Zones 3 and 4 had the highest CPUE. Over the 11 years catch rates of large lutjanids showed a peak in 81/82 then declined until 85/86. After that time the catch rates began increase again (Fig. 8.3). Catch rates were highest in the depth range 100-139m for these fish (Fig. 8.3). Peak catch rates were obtained between 12 noon and 2 am for this group (Fig. 8.3). Shots of less than 1 hr duration showed the highest catch rates for large lutjanids (Fig. 8.3).

Table 7: Comparisons of mean catch rates of large lutjanids between zones (significance level: * = p < 0.05; ** = p < 0.01).

Zone	1	2	3	4
1				
2				
3	**			
4	**	**		

Year by zone, year by season and season by depth class were significant interactions, but each accounted for 1% of the sums of squares or less.

Pristipomoides **species**

Table 8: ANOVA table for log transformed catch rates of *Pristipomoides* species.

R-square 0.53			
Source	**df**	**Sums of squares**	**Mean square**
Main effects			
zone	3	15847 (11%)	5282
year	10	956 (<1%)	96
season	1	6 (<1%)	6
depth class	6	16346 (11%)	2724
vessel	66	6740 (5%)	102
time class	12	1594 (1%)	132
shot duration	5	791 (<1%)	158
Error	32103	66825	2.08
Interactions (examined individually)			
year x zone	26	1386 (<1%)	53
year x season	10	1251 (<1%)	125
season x depth class	6	78 (<1%)	13

For *Pristipomoides* spp. zone and depth class variations were large, with differences between vessels and time classes also having large sums of squares. Catch rates between zones which were significantly different are presented in Table 9. Zone 3 had the highest catch rates, followed by zone 4. Over the 11 years catch rates peaked in 81/82 to 83/84 and in the last three years after being very low in the years 80/81 and 85/86 (Fig. 8.4). For the *Pristipomoides* spp. catch rates rose sharply in depths over

100m (Fig. 8.4). Catch rates were highest in between the hours of 12 noon and 2 am (Fig. 8.4). Catch rates declined with increasing shot duration (Fig. 8.4).

Table 9: Comparisons of mean catch rates of *Pristipomoides* species between zones (significance level: * = p < 0.05; ** = p < 0.01).

Zone	1	2	3	4
1				
2				
3	**			
4		**		

There was a significant year by zone interaction, year by season and year by depth class interaction, but each accounted for less than 1% of the total sums of squares.

Haemulidae

Table 10: ANOVA table for log transformed catch rates of haemulids.

R-square			
0.22			
Source	**df**	**Sums of squares**	**Mean square**
Main effects			
zone	3	801 (2%)	267
year	10	1165 (3%)	116
season	1	206 (<1%)	206
depth class	6	506 (1%)	84
vessel	66	3982 (9%)	60
time class	12	244 (<1%)	20
shot duration	5	650 (1%)	130
Error	32103	34192	1.07
Interactions (examined individually)			
year x zone	26	583 (1%)	22
year x season	10	1186 (3%)	118
season x depth class	6	70 (<1%)	12

For haemulids the biggest differences were between zones, years, seasons and differences between vessels. Zone 3 catch rates were significantly different (p<0.05) from, and higher than zone 1. Catch rates for haemulids fluctuated over the 11 years, with the lowest catch rates occurring in the latter part of the 1980s (Fig. 8.5). Catch rates were highest for haemulids in depths above 40 m and lowest between 100-140 m (Fig. 8.5). Catch rates for this group were highest between 12 noon and 2 am (Fig. 8.5). Shot durations of less than one hour showed the highest catch rates (Fig. 8.5).

The year by season interaction was the most important. Catch rates were higher in the dry season more often than in the wet season, but in 80/81, 83/84, 84/85, 86/87 and 88/89 wet season catch rates were higher. The year by zone and season by depth class interaction were also significant but accounted for less than 1% of the sums of squares.

Lethrinidae

Table 11: ANOVA table for log transformed catch rates of lethrinids.

R-square
0.29

Source	**df**	**Sums of squares**	**Mean square**
zone	3	182 (<1%)	61
year	10	1794 (3%)	179
season	1	21 (<1%)	21
depth class	6	6789 (10%)	1132
vessel	66	3496 (5%)	53
time class	12	1609 (2%)	134
shot duration	5	1130 (2%)	226
Error	32103	47527	1.48
Interactions (examined individually)			
year x zone	26	418 (<1%)	16
year x season	10	474 (<1%)	47
season x depth class	6	106 (<1%)	18

For lethrinids differences between the depth classes were most important, as were duration of the shot and year differences. The only significant differences in catch rates between the zones was between zones 2 and 4 for lethrinids. Zone 2 catch rates were higher. Over the 11 years the mid 1980s had low catch rates of lethrinids with higher catch rates before and after (Fig. 8.6). The highest catch rates of lethrinids were in depths down to 60m, after which they drop off dramatically (Fig. 8.6). Over the 24 hr period catch rates were highest between 12 noon and 2 am (Fig. 8.6). A shot duration of less than 1 hr obtained the best catch rates of lethrinids (Fig. 8.6).

Although the interactions of year by zone, year by season and season by depth class were significant they each accounted for less than 1% of the sums of squares.

Mullidae

Table 12: ANOVA table for log transformed catch rates of mullids.

R-square
0.33

Source	**df**	**Sums of squares**	**Mean square**
Main effects			
zone	3	2058 (5%)	686
year	10	1047 (3%)	105
season	1	206 (<1%)	206
depth class	6	566 (2%)	94
vessel	66	4600 (12%)	70
time class	12	423 (1%)	35
shot duration	5	635 (2%)	127
Error	32103	25162	0.78
Interactions (examined individually)			
year x zone	26	347 (<1%)	13
year x season	10	136 (<1%)	14
season x depth class	6	30 (<1%)	5

Differences between zones and variation amongst vessels were important for mullids. Depth class, year and shot duration differences accounted for similar amounts of the mean square. Zone 1 & 3 and 2 & 4 catch rates had significant differences ($p<0.01$) between the means, as did the means of zones 1 & 4 ($p<0.05$). Catch rates were highest in zone 1, followed by zone 2. Catch per hour of mullids increased steadily over the 11 years except for a decline in 85/86 (Fig. 8.7). Catch rates were consistently high to 100m, then declined in deeper water (Fig. 8.7). The period between 12 noon and 2 am had the highest catch rates over the 24 hr period (Fig. 8.7). Shots of less than 1 hr duration had the highest catch rate for mullids (Fig. 8.7).

Although the interactions of year by zone, year by season and season by depth class were significant they each accounted for less than 1% of the sums of squares.

Nemipteridae

Table 13: ANOVA table for log transformed catch rates of nemipterids.

R-square			
0.50			
Source	**df**	**Sums of squares**	**Mean square**
Main effects			
zone	3	5347 (7%)	1782
year	10	1221 (2%)	122
season	1	61 (<1%)	61
depth class	6	10125 (13%)	1688
vessel	66	5630 (7%)	85
time class	12	1071 (1%)	89
shot duration	5	284 (<1%)	57
Error	32103	39290	1.22
Interactions (examined individually)			
year x zone	26	530 (<1%)	20
year x season	10	845 (1%)	84
season x depth class	6	98 (<1%)	13

For nemipterids differences between zones and different depth classes were important ones. Year and vessel differences were also important. Significant differences ($p<0.01$) occurred in catch rates between zones 1 & 3, 1 & 4 and 2 & 4 (Table 14). Catch rates were highest in zone 1. Over the 11 years catch rates rose in the early 1980s, declined from 83/84 to 85/86 then rose again, with an extraordinarily high catch rate in 89/90 (Fig. 8.8). Catch rates increased as depth increased to 80m then begin to decline in deeper waters (Fig. 8.8). Apart from 8 am - 10 am catch rates of nemipterids were reasonably consistent throughout the 24 hr period (Fig. 8.8). Shot durations of less than 3 hours showed the highest catch rates of nemipterids (Fig. 8.8).

Table 14: Comparisons of mean catch rates of nemipterids between zones (significance level: * = p < 0.05; ** = p < 0.01).

Zone	1	2	3	4
1				
2				
3	**			
4	**	**		

Although the interactions of year by zone, year by season and season by depth class were significant they each accounted only for around 1% of the sums of squares.

Priacanthidae

Table 15: ANOVA table for log transformed catch rates of priacanthids.

R-square			
0.12			
Source	**df**	**Sums of squares**	**Mean square**
Main effects			
zone	3	319 (1%)	106
year	10	330 (1%)	33
season	1	10 (<1%)	10
depth class	6	232 (<1%)	39
vessel	66	1206 (4%)	18
time class	12	1092 (3%)	91
shot duration	5	619 (2%)	124
Error	32103	29774	0.93
Interactions (examined individually)			
year x zone		252 (<1%)	10
year x season		299 (<1%)	30
season x depth class		113 (<1%)	19

For priacanthids the proportion of the SS explained was low. Zone 1 & 3 and zone 2 & 4 catch rates were significantly different from each other (p<0.01). Highest catch rates were in zone 1, then in zone 3. Apart from a higher catch rate in 80/81, catch rates for priacanthids stayed around the same level until 86/87 when they began increasing, although the range was quite small (Fig. 8.9). The range in catch rates at different depths was again small, with depths to 120 m showing the higher catch rates (Fig. 8.9). Over the 24 hr period catch rates were highest between the hours of 12 noon to 2 am (Fig. 8.9). Shot durations of less than 1 hr produced the best catch rates for priacanthids (Fig. 8.9).

Although the interactions of year by zone, year by season and season by depth class were significant they each accounted for less than 1% of the sums of squares.

Serranidae

Table 16: ANOVA table for log transformed catch rates of serranids.

R-square			
0.27			
Source	**df**	**Sums of squares**	**Mean square**
Main effects			
zone	3	5529 (5%)	1843
year	10	1515 (1%)	152
season	1	358 (<1%)	358
depth class	6	1119 (1%)	187
vessel	66	5638 (6%)	85
time class	12	4168 (4%)	347
shot duration	5	1056 (1%)	211
Error	32103	74843	2.33
Interactions (examined individually)			
year x zone	26	669 (<1%)	26
year x season	10	278 (<1%)	28
season x depth class	6	33 (<1%)	6

For the serranids differences between zones were important, as were differences in time classes, vessels and year. Significant differences occurred between the means of zones 1 &3, 1&4 and 2 & 4 (Table 17). Catch rates were highest for zones 1 and 2. Serranid catch rates fluctuated over a small range over the 11 year period (Fig. 8.10). Depths of 40 - 59m were the most productive with catch rates declining as the depth increased (Fig. 8.10). There was a small range in catch rates over the 24 hr period, peaking between 2 pm and 12 midnight (Fig. 8.10). Shot durations of less than 1 hr produced the highest catch rate for serranids (Fig. 8.10).

Table 17: Comparisons of mean catch rates of serranids between zones (significance level: * = $p < 0.05$; ** = $p < 0.01$).

Zone	1	2	3	4
1				
2				
3	**			
4	*	**		

Although the interactions of year by zone, year by season and season by depth class were significant they each accounted for less than 1% of the sums of squares.

Synodontidae

Table 18: ANOVA table for log transformed catch rates of synodontids.

R-square
0.21

Source	**df**	**Sums of squares**	**Mean square**
Main effects			
zone	3	155 (<1%)	52
year	10	2930 (3%)	293
season	1	189 (<1%)	189
depth class	6	949 (1%)	158
vessel	66	12505 (14%)	189
time class	12	194 (<1%)	16
shot duration	5	217 (<1%)	43
Error	32103	71998	2.24
Interactions (examined individually)			
year x zone	26	889 (<1%)	34
year x season	10	2624 (3%)	262
season x depth class	6	472 (<1%)	79

For synodontids differences between years were the important, as were differences between vessels and depth classes. No significant differences occurred between the catch rates of the different zones. Catch rates of synodontids were generally higher in the first half of the 1980s and remained at the lower level for the last 4 years (Fig. 8.11). Catch rates were highest in depths to 120m for these fish (Fig. 8.11). Over the 24 hr period there was no discernible pattern in the catch rates and the range was small (Fig. 8.11). Catch rates were highest in shots of less than 1 hr duration (Fig. 8.11). Shots of longer intervals were similar to one another.

The year by season interaction was the most important interaction, accounting for nearly 3% of the sums of squares. In most years dry season catch rates exceeded wet season rates, but in 83/84, 84/85 and 88/89 wet season catch rates were higher.

6.2 INDONESIAN TRADITIONAL FISHING

Traditional Indonesian vessels fish mainly in the lagoons at Scott and Ashmore Reefs. The fish caught are primarily used for consumption on the fishing journey, the main objective of the trips being the collection of trepang (Holothurians), trochus, pearl oysters and shark (Russell & Vail 1988). Surplus demersal fish are dried and landed in Roti or Timor for sale or barter. A list of the fish species most likely to be taken can be obtained from Russell and Vail (1988). They inspected the catches of 11 perhaus (traditional Indonesian type I and type II fishing vessels). A total of 850 fish were inspected and identified. From this survey, the major species taken (making up 48.5% of the catch) was *Lethrinus ramak* (a synonym of *L. obsoletus*). This is believed to be a misidentification and it is probably *Lethrinus erythropterus* (Dr. Barry Hutchins, WA Museum, personal communication). Both these species occur in oceanic insulsar localities off the north west coast of WA and neither species is commercially important to the existing Kimberley Demersal Scalefish Fishery. Species identified in Russell & Vail's (1988) survey which are of commercial or potential commercial importance to the developing Kimberley demersal fishery are presented in Table 19.

Table 19. Families and species of commercial importance and their proportion in the inspected catch of traditional Indonesian fishing vessels fishing around Scott and Ashmore Reefs.

Family / Species	Proportion of inspected catch
Lutjanidae	22.2%
Lutjanus bohar	4.9%
L. decussatus	13.4%
L. gibbus	2.4%
L. kasmira	0.5%
L. lemniscatus	0.5%
L. monostigma	0.5%
Lethrinidae	62.6%
Lethrinus atkinsoni	2.1%
L. lentjan	10.9%
L. obsoletus	48.5%
L. olivaceous	0.7%
L. rubrioperculatus	0.4%
Serranidae	3.1%
Aethaloperca rogaa	0.2%
Cephalopholis argus	1.2%
C. cyanostigma	0.1%
C. urodeta	0.1%
Epinephelus merra	0.9%
E. polyphekadion	0.4%
Variola louti	0.1%
Caranx sp.	0.1%

Since 1992 there has been a steady increase in the number of traditional Indonesian vessels fishing illegally in areas of the AFZ east of the MOU Box. Associated with this is an increase in the number of large demersal longline vessels that work the provisional zone adjacent to the waters of the Kimberley region. These vessels (known as Type III or 'ice' boats) are large (ca. 22m) and equipped with modern navigational aids (eg. GPS, sounders) and modern fishing gear such as hydraulic line haulers (Wallner and McLoughlin 1995). These fishers target the high value reef associated species such as the lutjanids, lethrinids, serranids and labrids which are the primary target species of the Kimberley Demersal Scalefish Fishery.

From the results of this survey it appears that although the Indonesians do take some species of interest to the trap and line fishermen, they do not overlap to a great extent with the key species of importance in the current domestic fisheries.

6.3 FISHERY INDEPENDENT (CSIRO) SURVEYS

6.3.1 THE DISTRIBUTION OF CATCH, EFFORT AND CPUE

During the CSIRO experimental trawls effort was more concentrated in the western part of the Kimberley than in the east. The highest catch rates (CPUE) were obtained in the nearshore waters between 122° E - 123° E and 124° E - 125° E and near the shelf edge between 123° E - 124° E (Fig. 9.1). CPUE in the remaining areas were generally higher in the nearshore waters than further off the coast (Fig. 9.1).

For lutjanids catches were relatively high throughout the Kimberley, but CPUE was consistently higher in the area east of 124° E than in the western area (Fig. 9.2). Haemulid catches were exceptionally high in the 1° square block with 17° S and 121° E in its north-western corner, but did not show a correspondingly high CPUE. CPUE was exceptionally high in the block with 13° S and 123° E in its north-west corner (Fig. 9.3), however this was based on only one hour of fishing. CPUE was higher between 128° E and 129° E from nearshore to offshore than elsewhere. Both catches and CPUE for lethrinids were highest in the continental shelf waters between 120° E and 123° E, with the remaining area being much lower (Fig. 9.4).

For mullids catch rates were low throughout the Kimberley with a couple of blocks with higher CPUE whose NW corners are 15° S and 122° E and 15° S and 124° E (Fig. 9.5). Nemipterid catches and CPUE were generally higher west of 123° E than elsewhere in the Kimberley (Fig. 9.6). For priacanthids both catches and catch rates were generally low with the exception of the 1° square block at 15° S and 122 ° E (Fig. 9.7). Serranid catches were also generally low throughout the region, with the same block as for priacanthids having exceptionally high catches and CPUE (Fig 9.8). Synodontid catches and catch rates were highest around Ashmore Reef and surrounding shelf waters (Fig. 9.9).

6.4 COMPARISON OF CATCH COMPOSITION

The percentage by weight of each of the 8 families examined are compared for the Taiwanese fishery data and the CSIRO fishery independent survey data (Table 2). Nemipterids, lethrinids, priacanthids, lutjanids and serranids made up a much higher percentage of the catch of Taiwanese trawlers than the fishery independent survey trawl catches. Haemulids, mullids and other fish species made up a smaller percentage of the Taiwanese catch than survey catches.

Table 20: Percent abundance (%) by family of CSIRO fishery independent survey data (1978-1980) and Taiwanese fishing data (1980 only).

Family	CSIRO survey data 1978-1980	Taiwanese fishery data 1980 only
Synodontidae	3.8	3.3
Serranidae	1.8	3.5
Priacanthidae	0.5	3.7
Lutjanidae	10.4	18.4
Nemipteridae	4.4	22.4
Haemulidae	5.3	3.3
Lethrinidae	2.9	14.1
Mullidae	5.1	1.5
Other	65.8	29.8

6.5 CURRENT FISHERIES

6.5.1 KIMBERLEY DEMERSAL SCALEFISH FISHERIES

The demersal scalefish resource in the Kimberley is currently exploited by both line and trap fishermen. The total demersal catch over the last 3 years (1992-1994) has been between 700-800 tonnes annually. The catch is dominated by the Lutjanidae, in particular red emperor (*Lutjanus sebae*) and goldband snapper (*Pristipomoides multidens*), the Lethrinidae (NW snappers) and the Serranidae.

The catch of the trap fishermen in the Kimberley region increased rapidly from a modest 27 tonnes in 1989 to over 700 tonnes in 1993. The current composition of the trap catch is similar to that for the total demersal catch. The catch of line fishermen in the Kimberley region was generally less than 50 tonnes prior to 1994. The 1994 demersal line catch in the Kimberley Region was over 175 tonnes and continues to increase. The demersal line catch is dominated by the Lutjanidae, principally goldband snapper (*P. multidens*).

The current fishery principally targets the larger species which provide a higher economic return such as the lutjanids, lethrinids and serranids. The smaller species such as the nemipterids which have a lower economic return are currently only lightly exploited by fishermen in the Kimberley region. The fishery is primarily driven by market demands.

7.0 DISCUSSION

Total catch per hour obtained by the Taiwanese pair trawl fishery declined significantly over the 11 years of fishing 1980 to 1990. Whilst effort increased greatly in 1984-85, catch rates declined and may in part account for the sharp decline in effort and catches in 1986 and the continued lower level of fishing effort in the following years. Edwards (1983) suggests that the area off the Kimberley coast (the area he defines as the Timor Sea, 125^{o} to 132^{o}E) was a less favoured fishing ground by the Taiwanese, compared with the NW Shelf and the Arafura Sea. In addition the number of vessels licensed to fish (by the Department of Primary Industry, Canberra) and their catch quotas were reduced in each year after 1986. It is probable that effort was then concentrated on the more productive areas on the NW Shelf and the Arafura Sea. Therefore the decline in catch of the Taiwanese vessels during 1986 may have been due to a decrease in or low abundance of fishes as suggested by the CPUE data. However the continued reduction in fishing effort was more likely a reflection of licence arrangements which made it more profitable for the Taiwanese to fish the more productive grounds of the NW Shelf and Arafura Sea.

Of the commercial categories, three showed a significant decline over the duration of the Taiwanese fishery. These were the nemipterids, priacanthids and the haemulids. The lethrinids and synodontids also exhibited a declining trend in CPUE over time. The *Pristipomoides* lutjanids in contrast, showed a significant increase in CPUE over the 11 years of the Taiwanese fishery. However, caution must be used when interpreting this data as their is no detailed information about the discarded component of the catch over the duration of the fishery. Fishing practices in relation to the species targeted are known to have changed over the duration of the Taiwanese fishing activities on the North-west Shelf (Jernakoff and Sainsbury 1990).

In his analysis of the performance of the Taiwanese pair trawl fishery, Edwards (1983) found that in the Timor Sea the Nemipteridae and Lutjanidae dominated the catch until 1978, but in 1980 the Lutjanidae and Haemulidae were the most abundant. Edwards (1983) suggests that this may be due to greater discarding of the Nemipteridae in 1980. The Taiwanese data analysed in this report shows Nemipteridae to be the most abundant family in 1980, followed by Lutjanidae and then Lethrinidae. This is an substantial difference given that the areas largely overlap. The distribution maps show that much higher nemipterid catches occurred in the area from 120^{o}-125^{o}E which is the area included in this study but not in the area defined by Edwards (1983).

For the area off the Kimberley coast, nemipterids were the most abundant family group in the Taiwanese catch in the early 1980s, but from 1984 onwards they decreased and lutjanids became the most abundant group. Lutjanids and serranids increased as a proportion of the catch over the 11 years as did mullids. The other family categories remained fairly constant except for synodontids which declined as a proportion of the catch retained in the last few years. Unfortunately no fishery independent data is available for comparison after 1980. On the NW Shelf catches of large lutjanids and lethrinids increased in the Taiwanese fishery after 1986 (Jernakoff and Sainsbury 1990). CSIRO research data, however, showed that the abundance of these species actually declined. Jernakoff and Sainsbury (1990) believe that these large species were targeted by the Taiwanese in the latter part of the 1980s. They believe that the data show that making assumptions about the status of the resource based only on CPUE can be misleading because of biases introduced due to changes in targeting practices, spatial shifts in fishing effort and changes in discarding practices.

Comparing the abundance of family groups between the fishery independent survey data and the Taiwanese fishery data in 1980 shows that certain categories of fish are being selectively retained (see Table 2). Serranids, priacanthids, lutjanids, lethrinids and nemipterids make up between 2 and 7 times greater percentage in the Taiwanese catch than in the research survey catches. The much smaller percentage of other species in the Taiwanese catch indicates that considerable discarding was taking place.

When the history of catches in the two individual blocks was examined, the pattern was a similar one for both blocks. As effort increased over the years 1983 to 1985, CPUE declined, but began to recover by the last few years of the decade when fishing effort had been much less intense for several years.

Total catch rates from the Taiwanese pair trawl fishery declined gradually with increasing depth. Serranids showed a similar pattern. Haemulids and synodontids had fairly consistent catch rates throughout the depth range. The majority of the other categories of fish (small lutjanids, mullids, nemipterids and priacanthids) had higher catch rates above 100 or 120m. The large lutjanids and the *Pristipomoides* lutjanids had higher catch rates in deeper waters at 100-139m and over 120m respectively.

Peak catch rates for most categories of fish were between 12 noon and 2 am. Nemipterids had a consistent catch rate throughout the 24 hr period, except for a sharp drop at 8-10 am. The other exception was synodontids which were caught at a fairly consistent rate over the 24 hr period.

Variation in catch rates with shot duration showed that the highest total catches were obtained in shots of up to 3 hours. For most of the individual categories shots of less than 1 hr produced the highest catch rates, with rates dropping off again after 3 hours. The exception were synodontids, which had a second peak at 4-5 hour shots, probably due to their being unable to escape through the mesh as the codend filled.

7.1 CURRENT STATUS OF THE DEMERSAL FINFISH RESOURCE

In the current Kimberley fisheries most of the catch has been taken in the area west of 124°E. The total catch from this zone in 1994 in association with the catch of the Pilbara region is well in excess of the prudent Total Allowable Catch of 840 tonnes calculated by the CSIRO-chaired working group in 1991.

The area to the east of 125°E has been little fished, probably because of its distance from Broome and also the lack of a suitable port between Broome and Darwin. While the Commonwealth had a TAC of 1000 tonnes for this area based on large lutjanids its suitability for trapping is unknown and remains to be quantified.

In view of the rapidly increasing catch and number of vessels trapping in the Kimberley from 1989 to 1992, a preliminary freeze on access to the fishery was implemented in 1993. The purpose was to restrain fishing effort while a management plan was formulated.

Alterations to the Offshore Constitutional Settlement has seen management responsibility for all demersal scalefish fisheries out to the limit of the AFZ passed to the state of WA, except for fish trawling where WA has responsibility for waters on the landward side of the 200 m isobath. A draft management plan for the Northern Demersal Scalefish Fishery (NDSF), which covers the Kimberley region, is currently being developed by a Working Group appointed by the Fisheries Minister. This fishery will replace current arrangements for the Kimberley Trap Fishery (KTF) and the Kimberley Demersal Line Interim Managed Fishery (KDLIMF). Nine licence endorsements exist for the KTF and nine interim managed fishery permits for the KDLIMF. The trap endorsements are transferable, however the line permits are not.

8.0 CONCLUSIONS

These data provide useful information on the broadscale distribution and relative abundance of historical fishing catch and effort in the Kimberley Region. However, as a result of the pooling of species into commercial groups, the poor understanding of discard practices and retention rates (of both saleable and trashed fish) over the duration of foreign exploitation of the Kimberley demersal resource and possible unknown variations in reporting procedures, the data has yielded very little information that can be used to provide stock assessment advice for management of the current domestic demersal fisheries. Furthermore, the information derived from the logbooks of foreign fishing vessels is concentrated in specific areas targeting particular species groups and therefore does not provide a random or representative sample of the demersal fishes of the region.

The number of trap and line boats currently exploiting the grounds west of 125°E appears to be sufficient to fully exploit the stocks of demersal fish in that area, specifically the lutjanids, lethrinids and serranids. An accurate and precise assessment of the total resource available in this fishery, and the best method of exploiting it cannot be known until there is some knowledge of trapping, line fishing and potentially fish trawling in the area east of 125°E and in depths greater than 150 m. This will require an analysis of the species composition and relative abundance of the catch of each fishing method in areas outside those currently worked, and paying specific attention to the two regions mentioned above. Possible adverse effects of future demersal fish trawling on trappable grounds in the Kimberley Region should also be taken into account when methods of fish capture are reviewed for this fishery. Caution must be used when considering access by demersal fish trawlers because of the detrimental effects of trawling on fish habitats, species composition and relative abundance (eg. Sainsbury 1987, Moran et al. 1995).

The small catch estimates of demersal fish by traditional Indonesian fishing vessels is, at the moment, not considered to be a threat to the sustainability of the demersal fish stocks. However, localised depletions of lutjanids, lethrinids, serranids and labrids may occur at offshore insular localities as a consequence of the large numbers of fishing trips, usually of extended duration, permitted within the MOU. Concern exists over the potential impacts of the large motorised and modern Indonesian fishing vessels operating along the edge of the AFZ. The degree of connectivity of stocks across international boundaries in this region are not known. Furthermore, little is known of the magnitude of the catch by these vessels although it is expected to be substantial given that these boats have the capacity to take more than 20 tonnes of demersal scalefish per trip (Wallner and McLoughlin 1995).

To enable effective management of the fish stocks of the Kimberley region future assessments will require reliable and robust estimates of age, growth and mortality (both fishing and natural) for all the major demersal scalefish species of commercial significance. The stock structure and unit stock identification of the key demersal fish species in the Kimberley region and surrounding areas is also required for future stock assessments in addition to information on the degree of movement of individual fish in Australia's northern waters both east into the Arafura Sea and west into the Pilbara Fishery (NW Shelf).

9.0 ACKNOWLEDGMENTS

The assistance and co-operation of the staff of all following organisations who provided historical data for this project is gratefully acknowledged: Dr. Keith Sainsbury and colleagues (CSIRO Division of Fisheries, Tasmania), Graeme Morris (CSIRO Division of Fisheries, Cleveland), Dr. David Ramm (Fisheries Division, Northern Territory), Tim Skousen and Bill Anderson (AFMA), and Neil Sarti, Tom Morris and Colin Ostle from the Operations Division of the Fisheries Department of Western Australia. Dr. Nic Caputi and Neil Sumner (Research Division of the Fisheries Department of Western Australia) helped provide statistical advise and we are also indebted to Wilf Lehre (Research Division) for producing the maps.

10.0 REFERENCES

Anon. 1988. The Offshore Constitutional Settlement, Western Australia, 1988. Fisheries Department of Western Australia. Fisheries Management Paper No. 20: 31pp.

Edwards, R. R. C. 1983. The Taiwanese Pair Trawler Fishery in Tropical Australian Waters. Fisheries Research 2: 47-60.

Fowler, J. 1995. Management of the Northern Demersal Scalefish Fishery. Fisheries Department of Western Australia. Fisheries Management Paper No. 79: 25pp.

Jernakoff, P. and Sainsbury K. J. 1990. CSIRO's northern demersal finfish stock assessments: 1980 to 1989. Bureau of Rural Resources Information Paper No. IP/6/90. Bureau of Rural Resources, Department of Primary Industries and Energy, John Curtin House, Brisbane Avenue, Barton ACT. 169pp.

Liu, H.C. 1976. The demersal fish stocks of the waters of north and northwest Australia. Acta Oceanographica Taiwanica 6: 128-134.

Moran, M.J., Jenke, J., Cassells, G. and Nowara, G. 1995. Research for allocation of North-West Finfish resources among diverse user groups. Fisheries Department of Western Australia. Final Report on FRDC Project No. 91/28.

Ramm, D. C. 1994. Australia's Northern Trawl Fishery. Fisheries Division. Department of Primary Industry and Fisheries, Northern Territory Government. Fishery Report No. 32: 59pp.

Robins, J.P. 1969. N.W. Trawl Fishing. FINS (Fishing Industry News Service, Western Australia) 2 (5): 5-7, 12-13 (Dec., 1969).

Russell, B. C. and Vail, L. L. 1988. Report on Traditional Indonesian Fishing Activities at Ashmore Reef Nature Reserve. Project No. 8687/19 of the Australian National Parks and Wildlife Service Research and Surveys Program. Australian National Parks and Wildlife Service, Canberra and NT Museum of Arts and Sciences, Darwin. 179pp.

Sainsbury, K. J. Unpublished Manuscript. Final Report of the Australian Component of the Joint Eastern Indian Ocean Fishery Survey (JETINDOFISH Survey).

Sainsbury, K.J. 1987. Assessment and management of the demersal fishery on the continental shelf of northwestern Australia. pp. 465-503. In Polovina, J.J. and Ralston, S. (Eds.) 1987. Tropical snappers and groupers : biology and fisheries management. Westview Press, Boulder, Colorado. 659pp.

Wallner, B. and McLoughlin, K. 1995. Indonesian Fishing in Northern Australia. pp. 115-121. In Fishery Status Reports 1994 - Resource Assessments of Australian Commonwealth Fisheries. McLoughlin, K., Wallner, B. and Staples, D. (Eds). Bureau of Resource Sciences, Canberra. 144pp.

11.0 INTELLECTUAL PROPERTY

No patentable inventions or processes, or commercially significant developments have arisen specifically as a result of this Project.

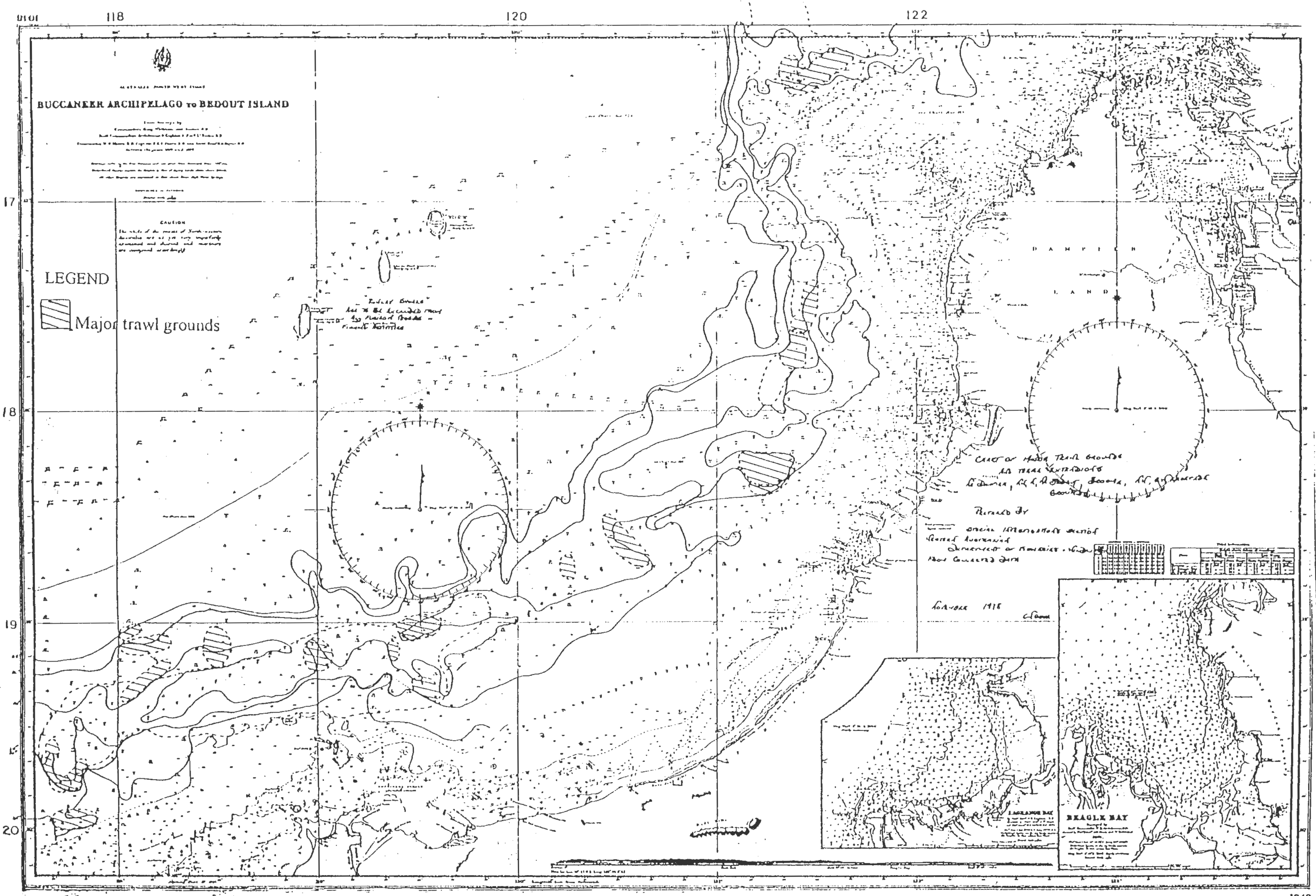


Fig. 2. Chart showing major trawling grounds at 118° E - 122° E used by the foreign pair trawl fleets from 1975 to 1978 as recorded by the WA Fisheries Department.
Source: C. Ostle

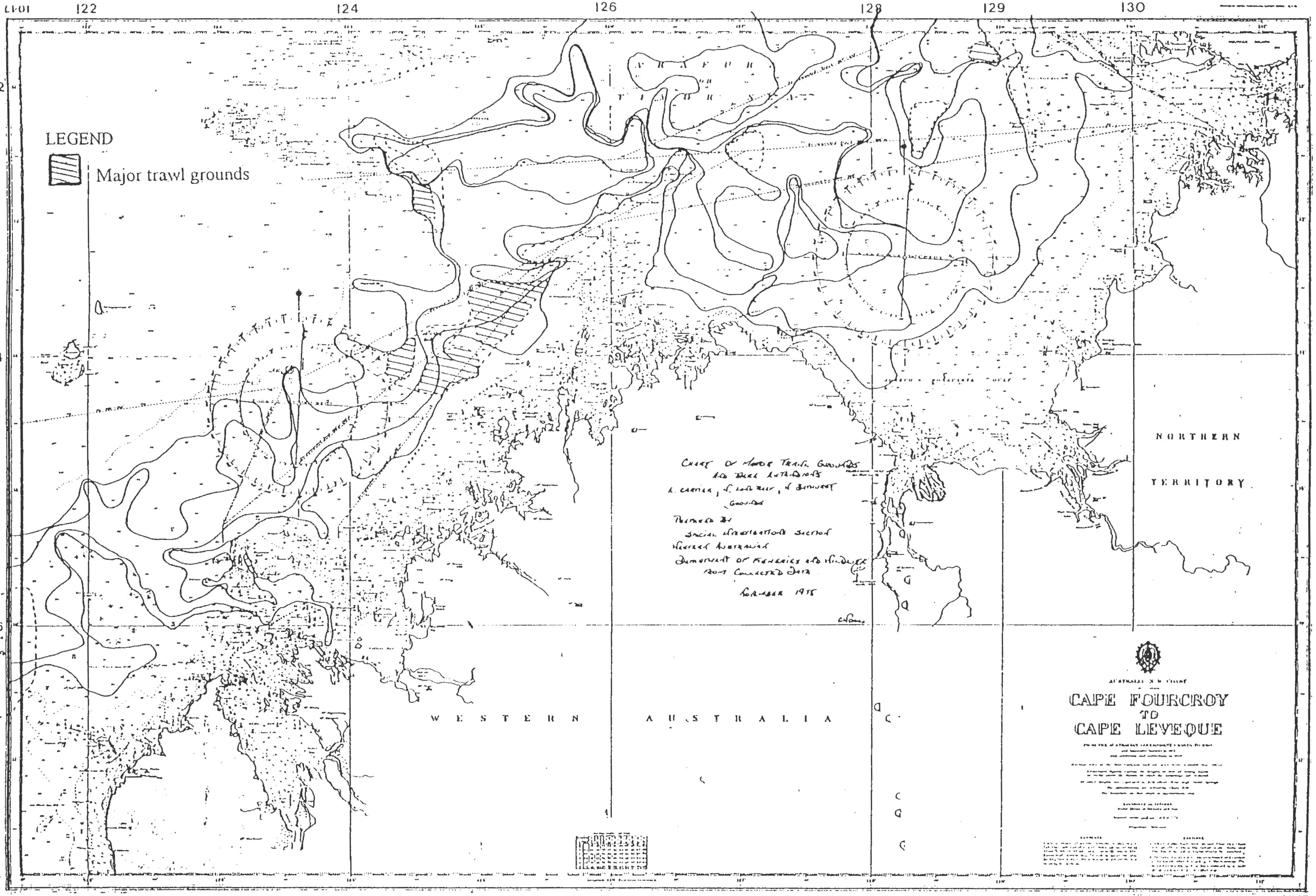


Fig. 3. Chart showing major trawling grounds at 122° E - 130° E used by the foreign pair trawl fleets from 1975 to 1978 as recorded by the WA Fisheries Department.

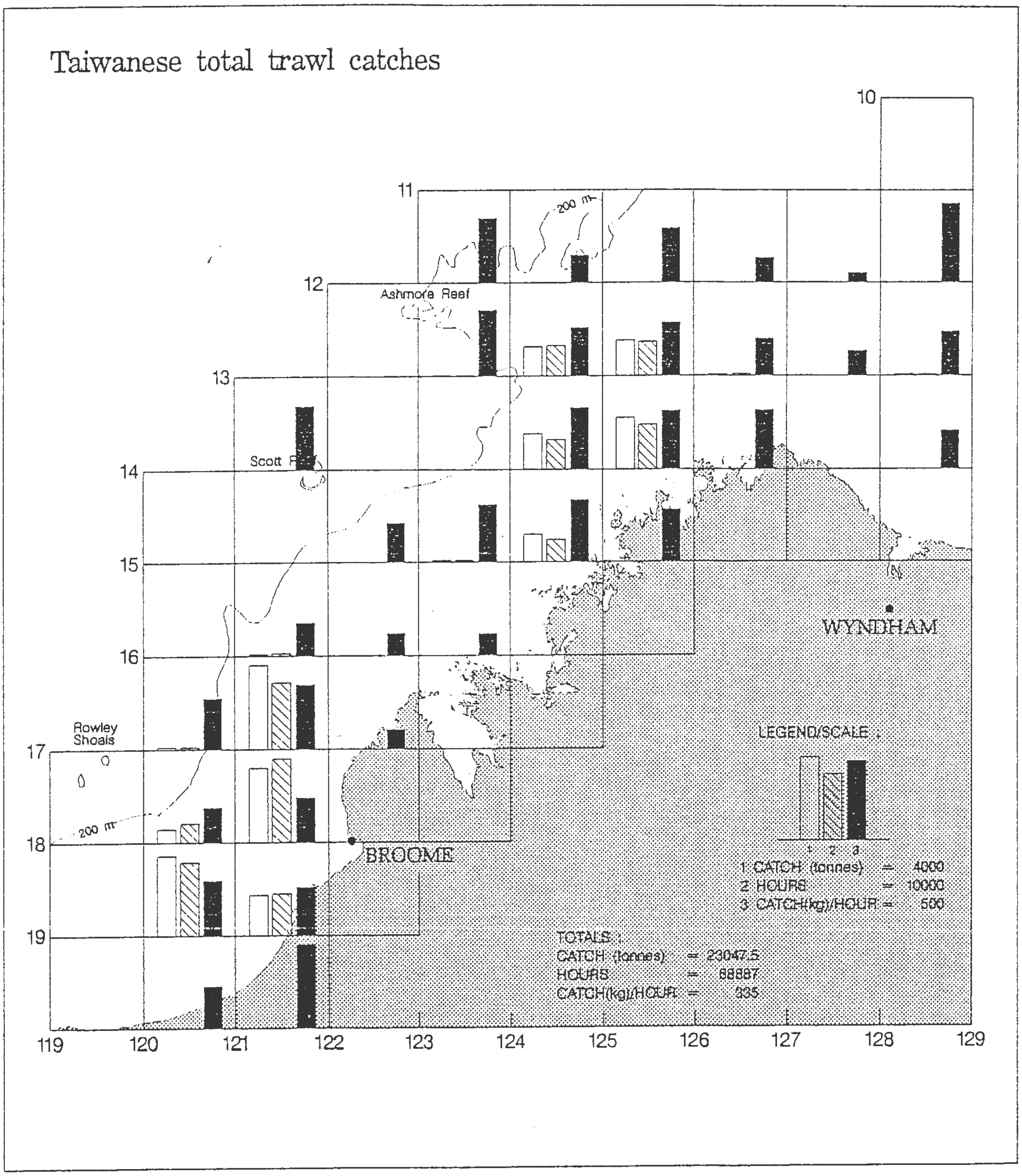


Figure 4.1. Distribution of total catch, effort and catch per hour for Taiwanese pair trawlers 1980-1990.

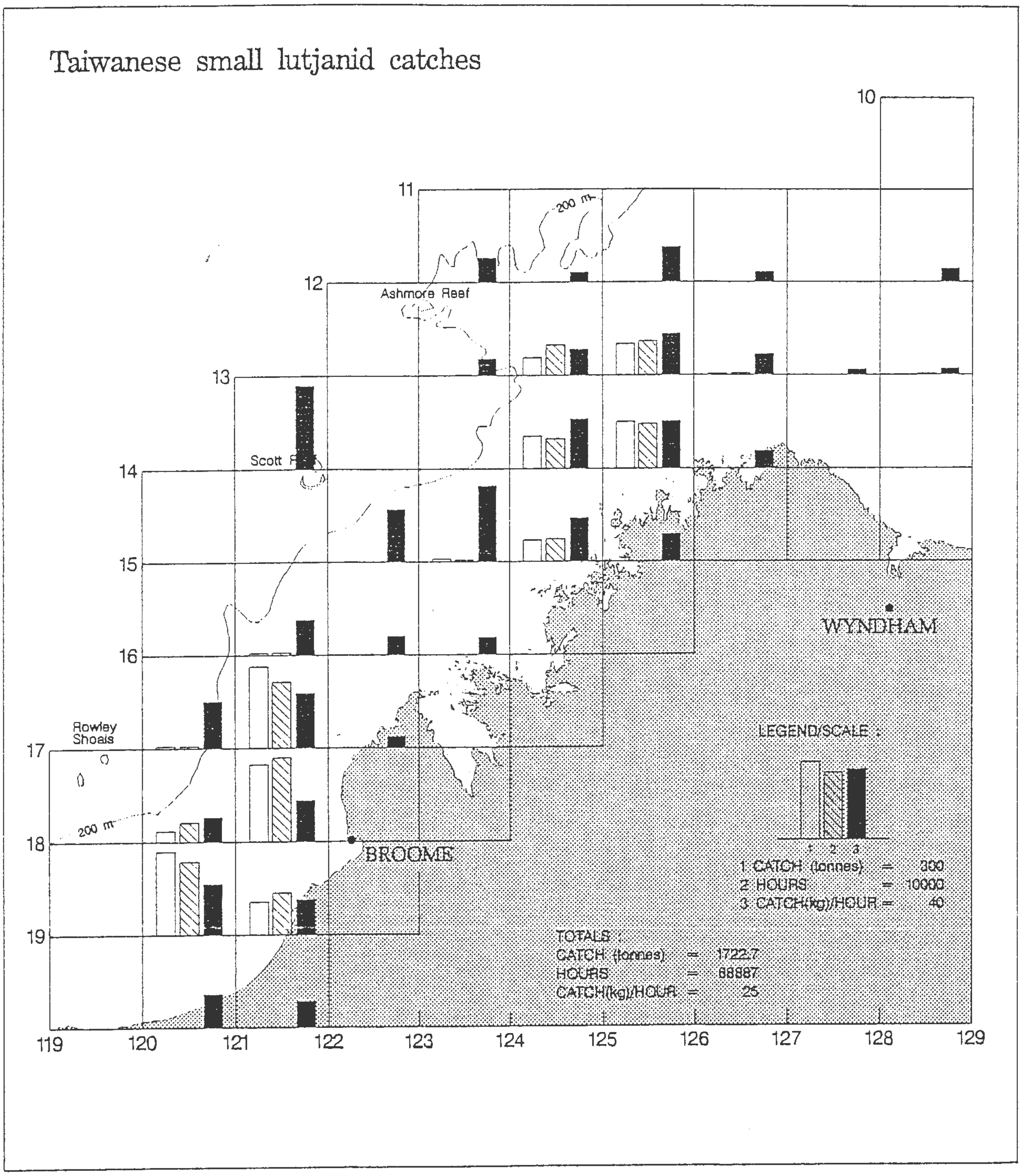


Figure 4.2. Distribution of catch, effort and catch per hour of small lutjanids by Taiwanese pair trawlers 1980-1990.

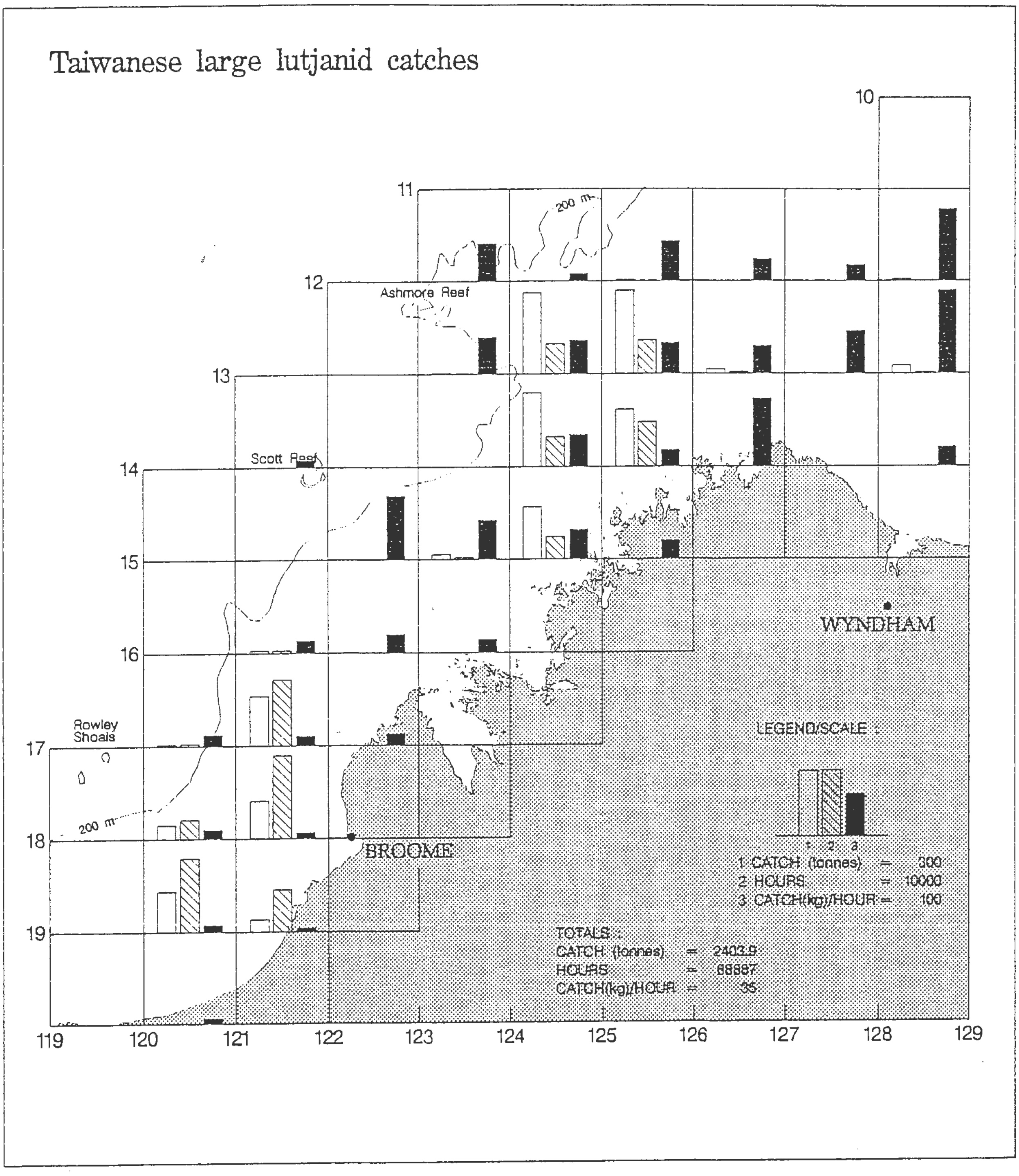


Figure 4.3. Distribution of catch, effort and catch per hour of large lutjanids by Taiwanese pair trawlers 1980-1990.

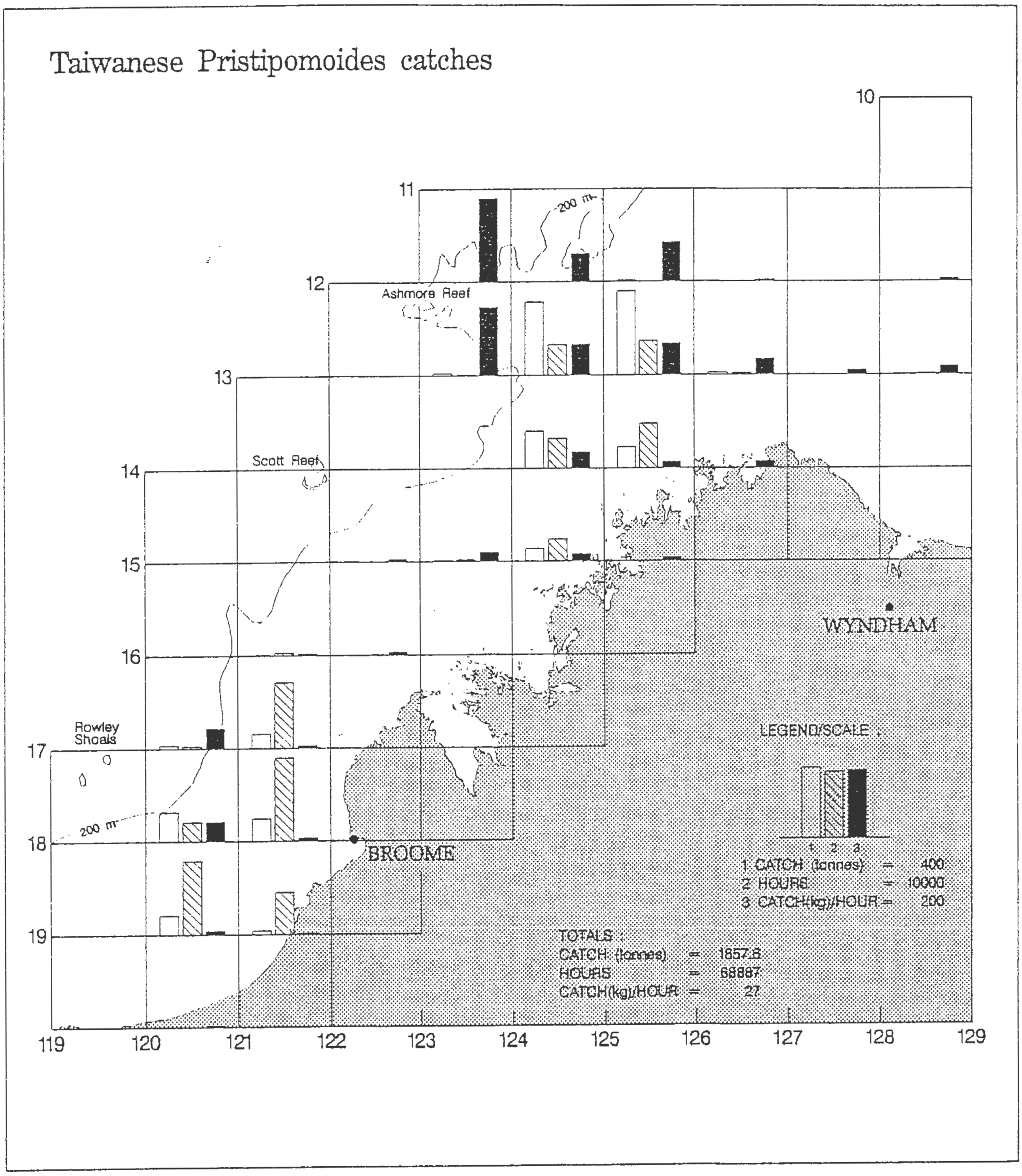


Figure 4.4. Distribution of catch, effort and catch per hour of *Pristipomoides* lutjanids by Taiwanese pair trawlers 1980-1990.

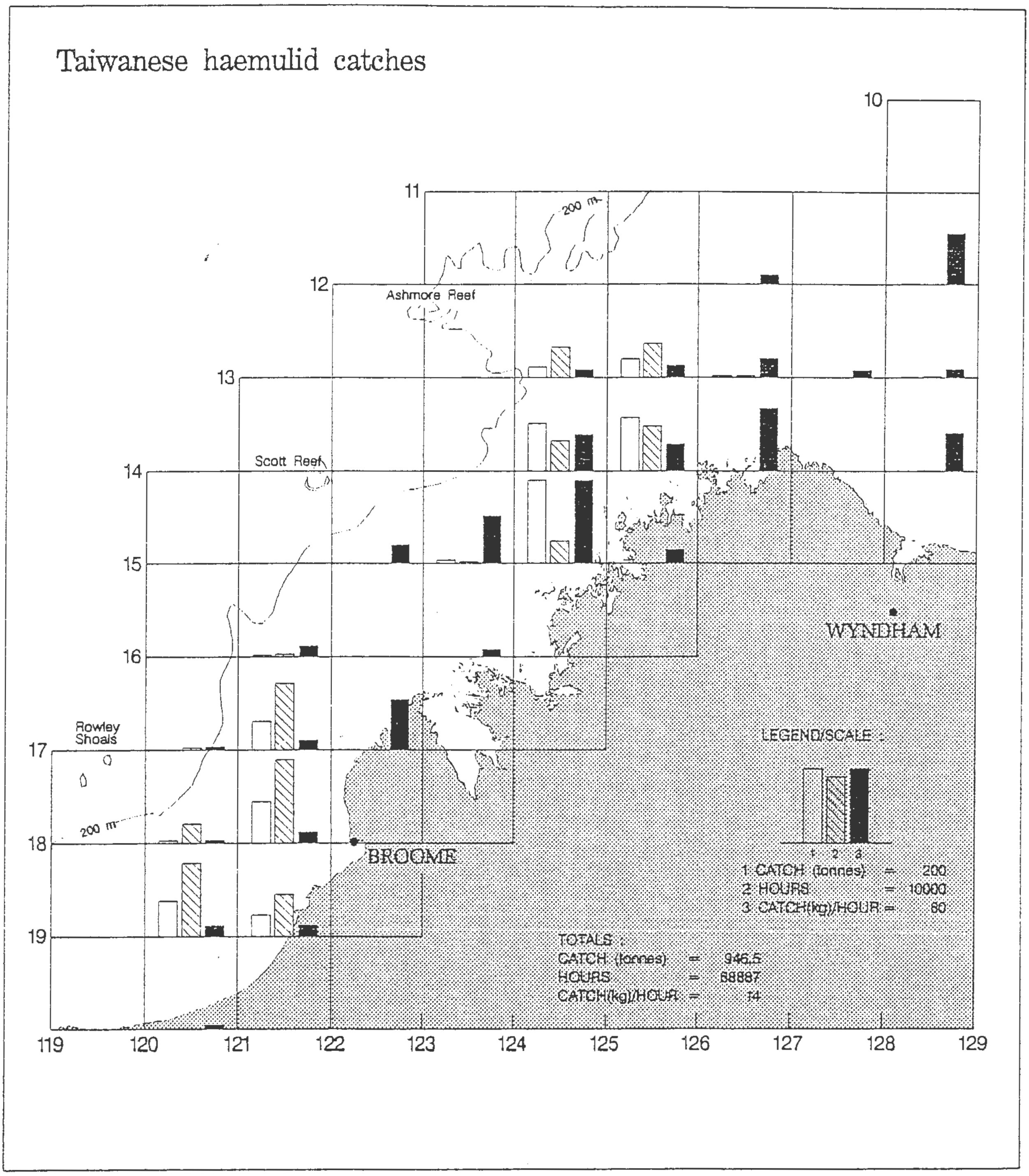


Figure 4.5. Distribution of catch, effort and catch per hour of haemulids by Taiwanese pair trawlers 1980-1990.

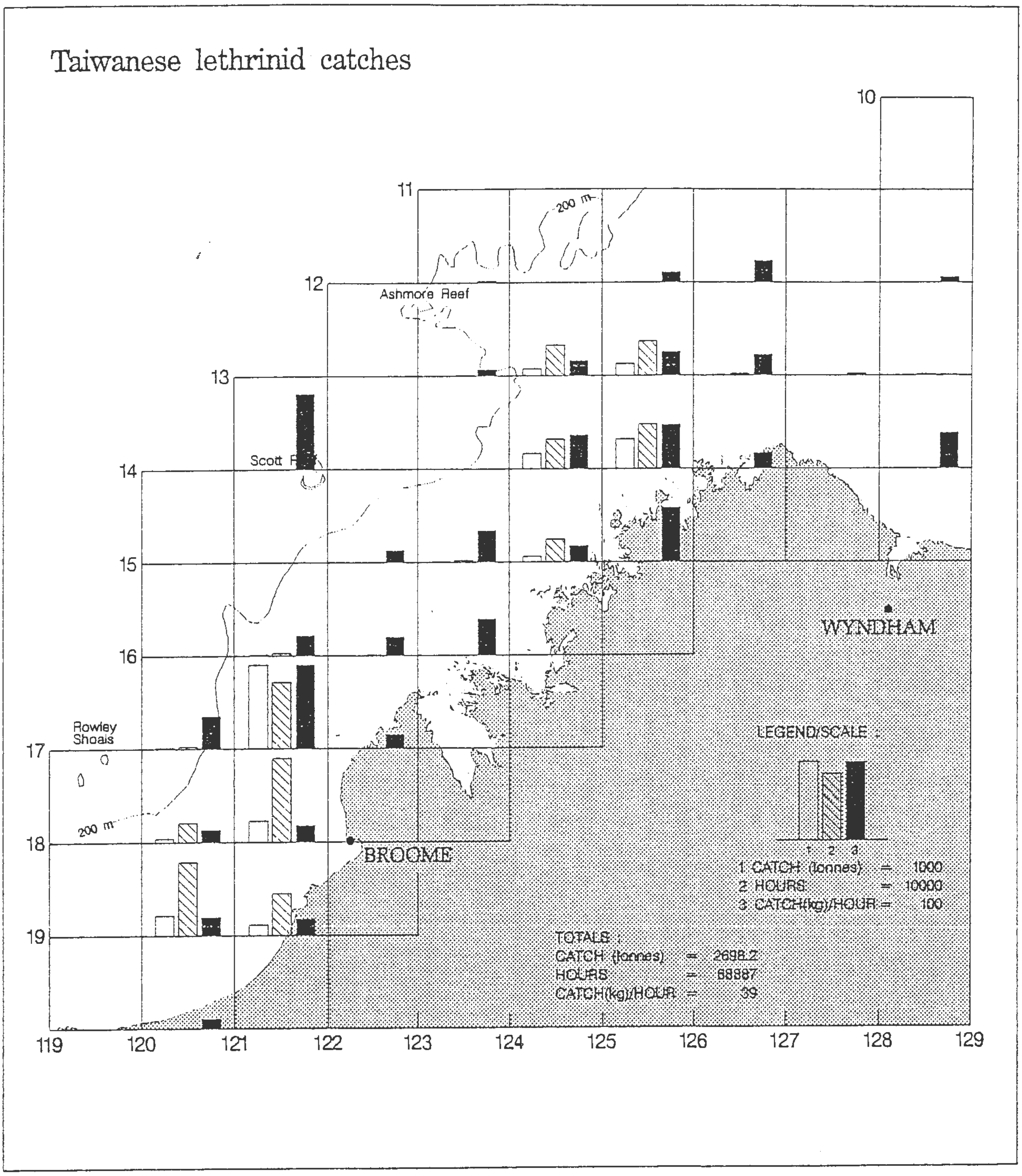


Figure 4.6. Distribution of catch, effort and catch per hour of lethrinids by Taiwanese pair trawlers 1980-1990.

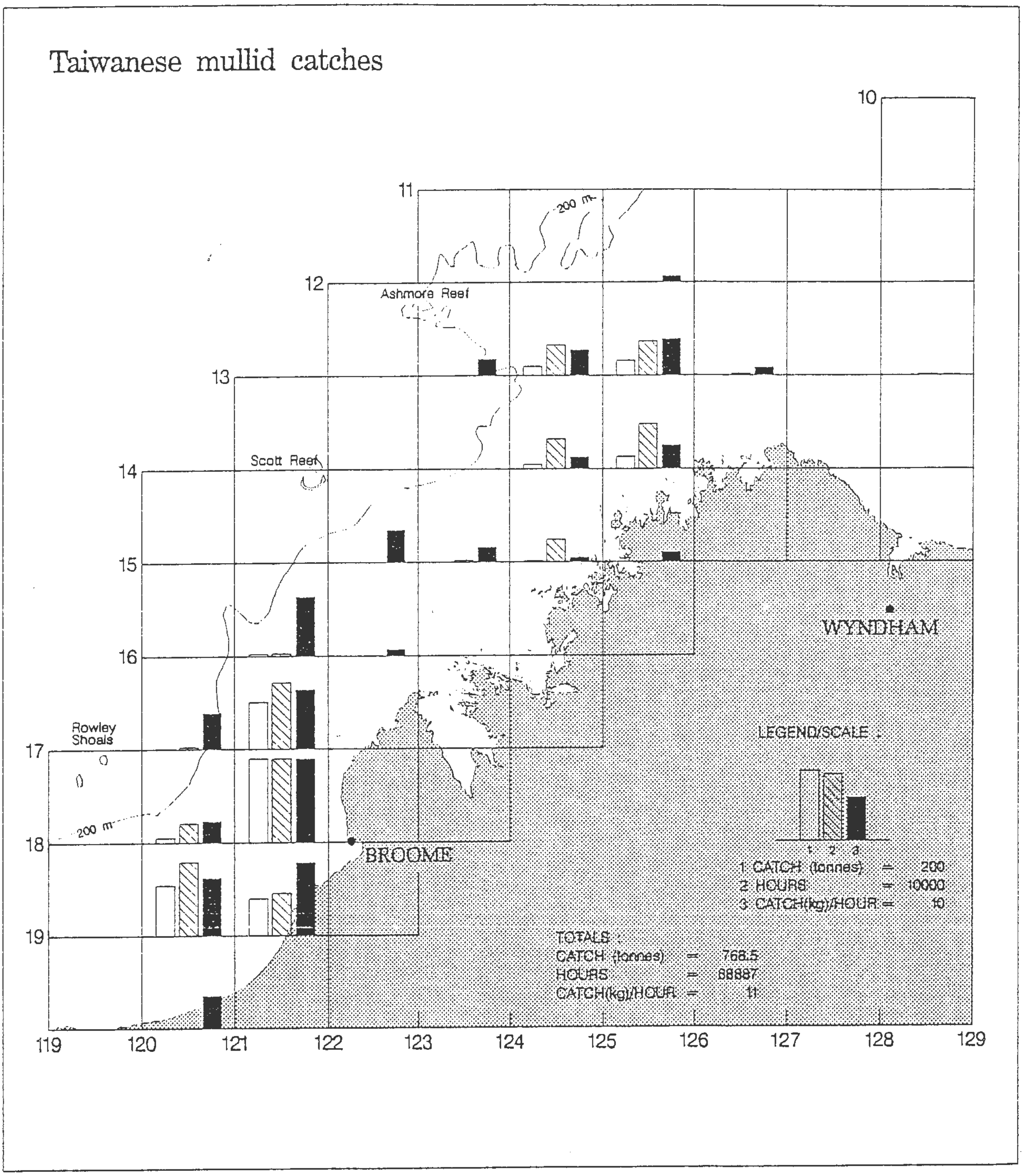


Figure 4.7. Distribution of catch, effort and catch per hour of mullids by Taiwanese pair trawlers 1980-1990.

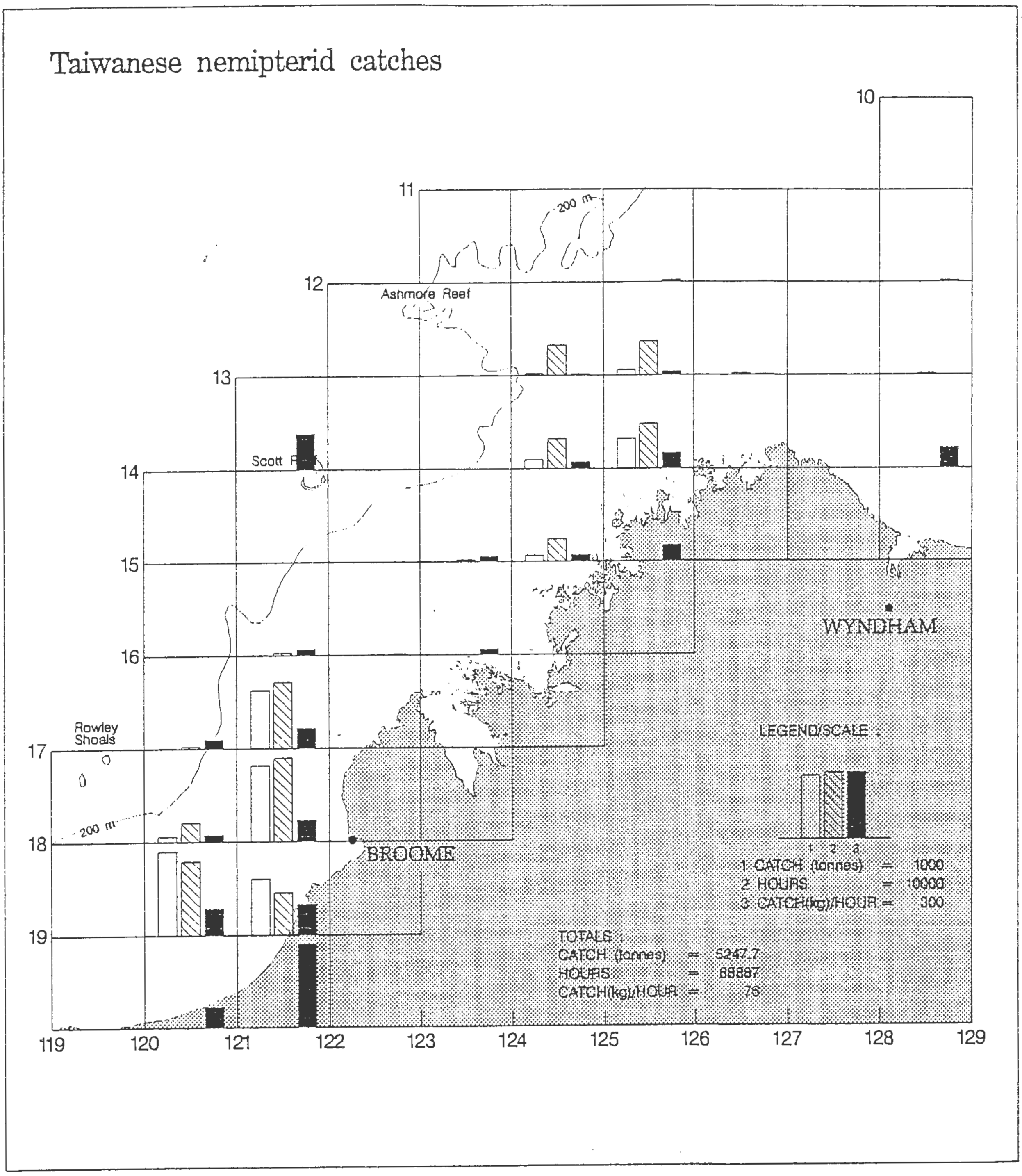


Figure 4.8. Distribution of catch, effort and catch per hour of nemipterids by Taiwanese pair trawlers 1980-1990.

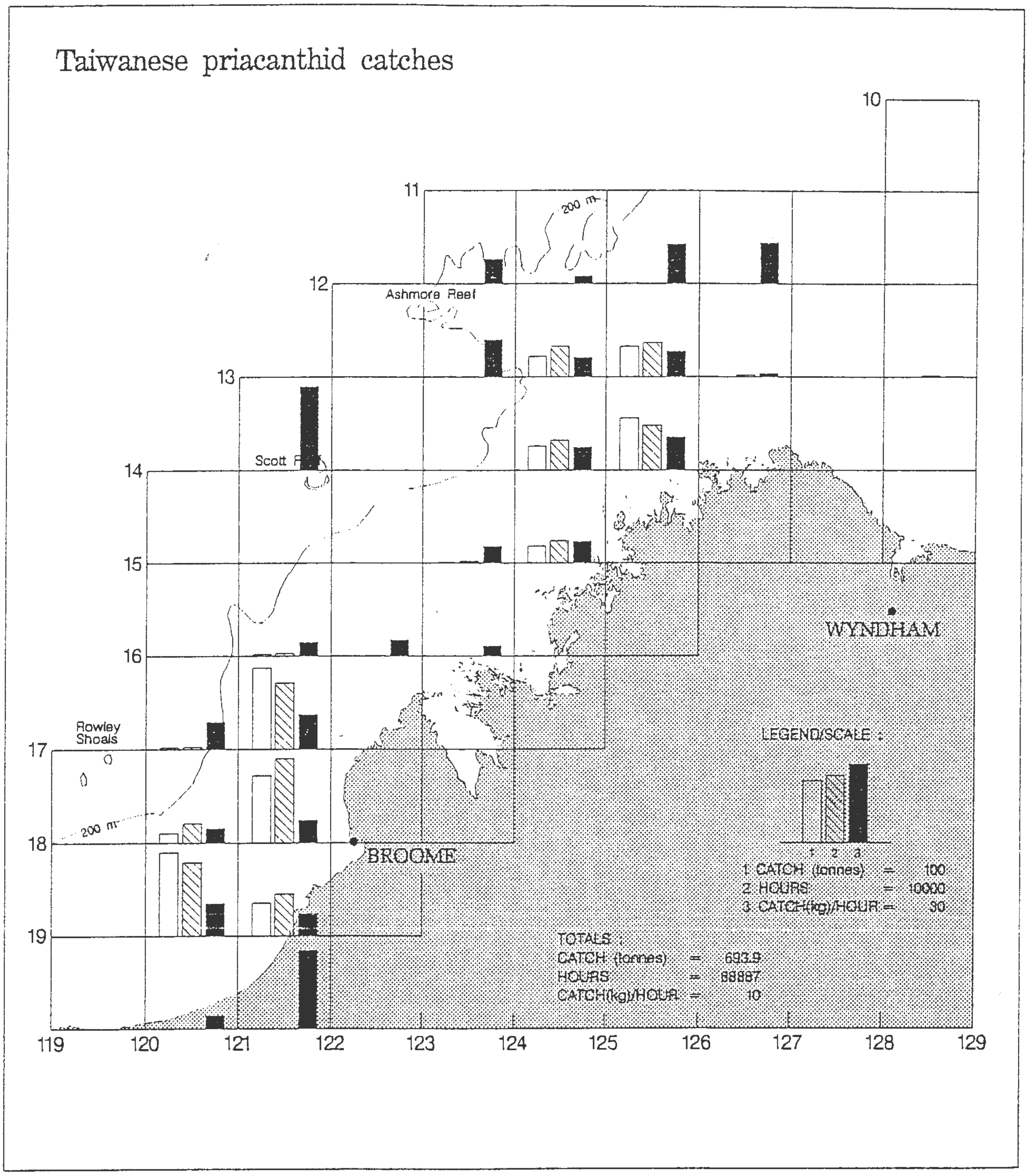


Figure 4.9. Distribution of catch, effort and catch per hour of priacanthids by Taiwanese pair trawlers 1980-1990.

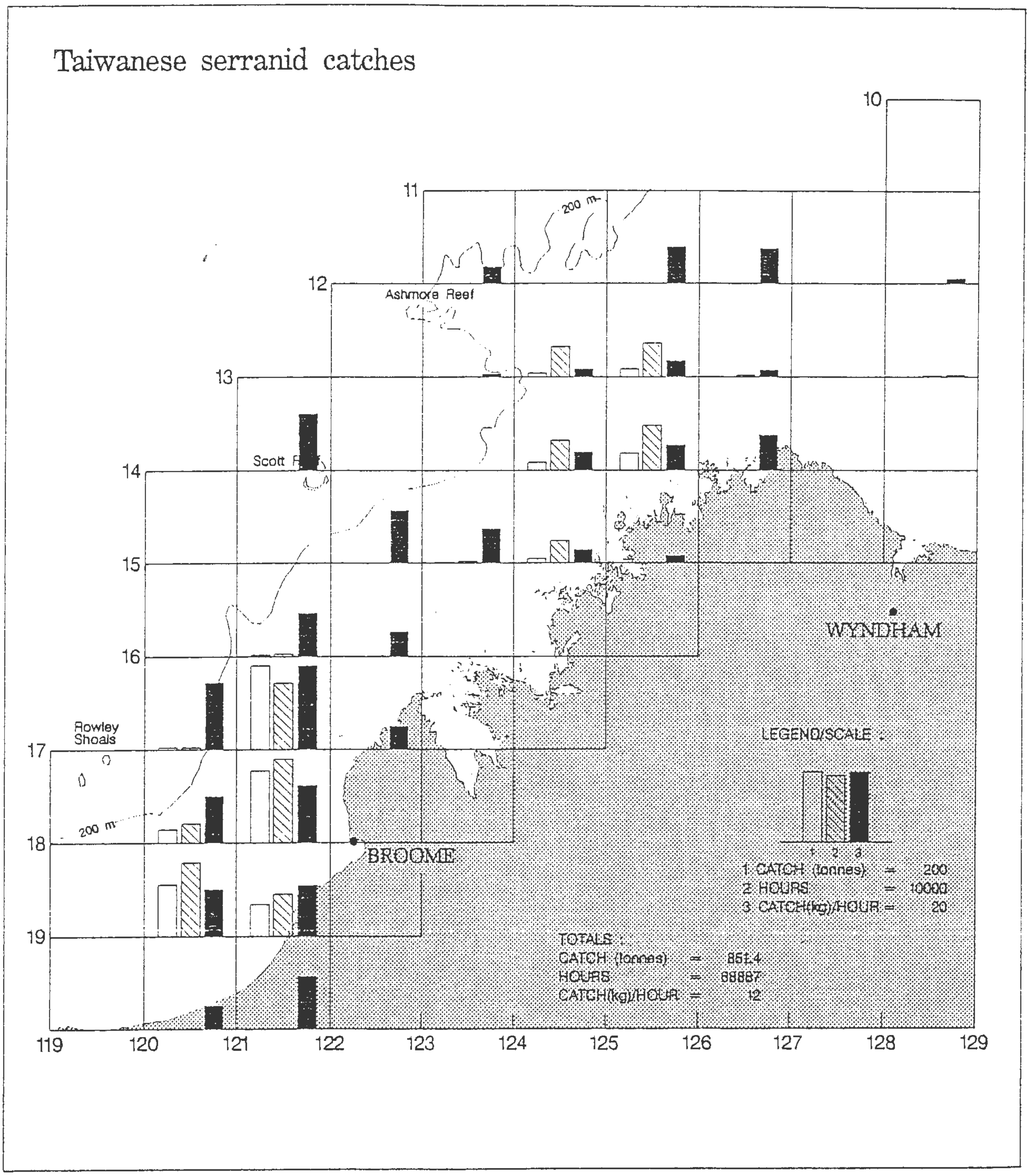


Figure 4.10. Distribution of catch, effort and catch per hour of serranids by Taiwanese pair trawlers 1980-1990.

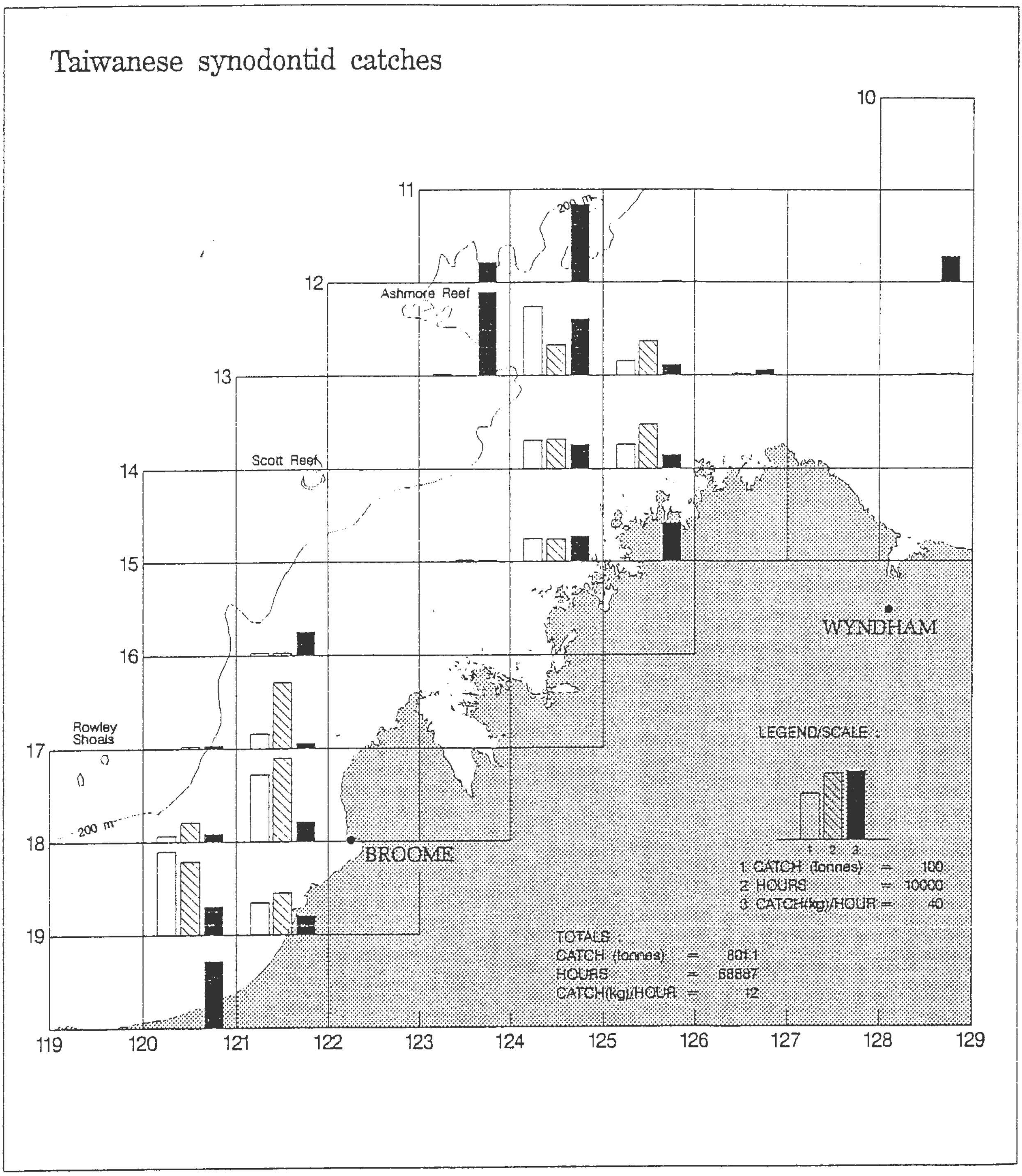


Figure 4.11. Distribution of catch, effort and catch per hour of synodontids by Taiwanese pair trawlers 1980-1990.

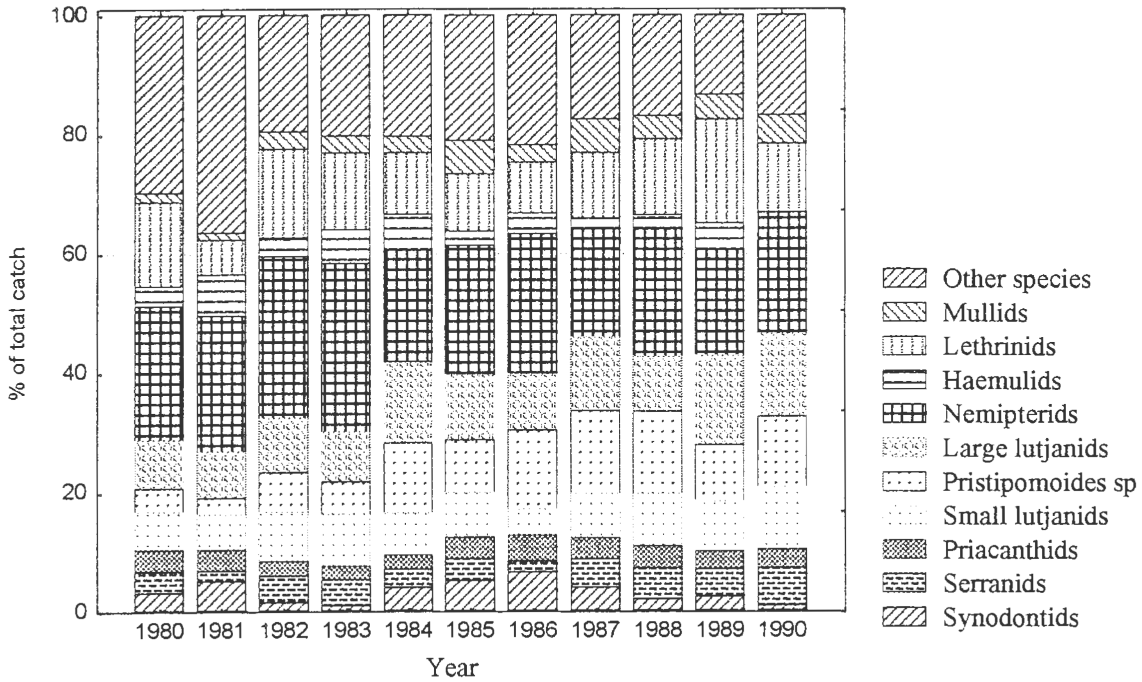


Fig. 5.1. Composition of Taiwanese pair trawl catch 1980-1990.

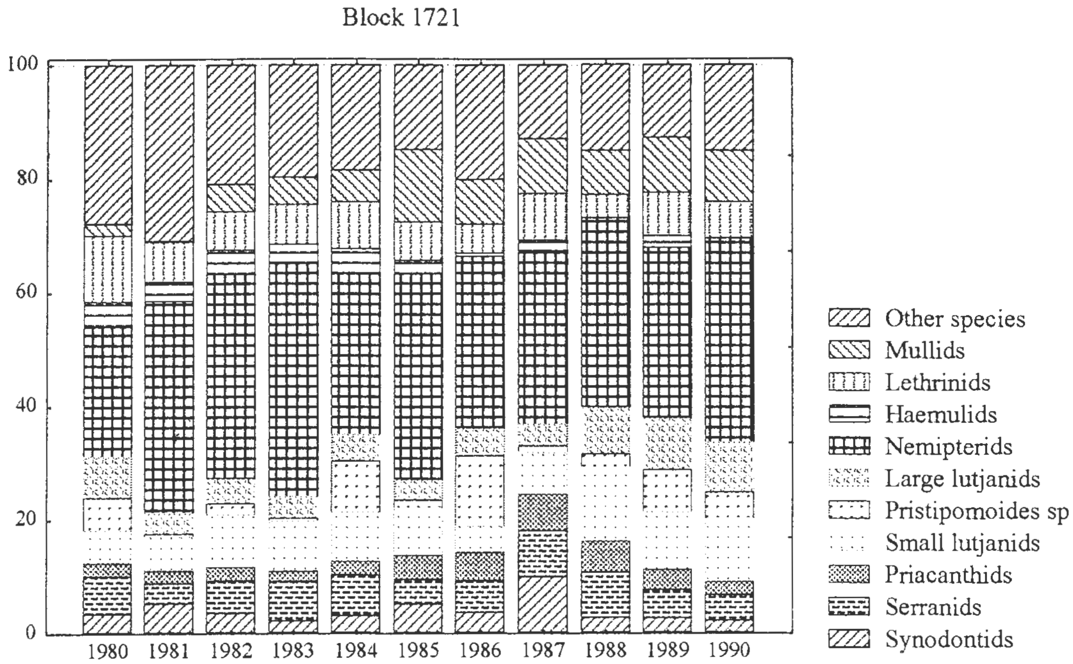


Fig. 5.2 Composition of Taiwanese pair trawl catch in block 1721 in the Broome area, 1980-1990.

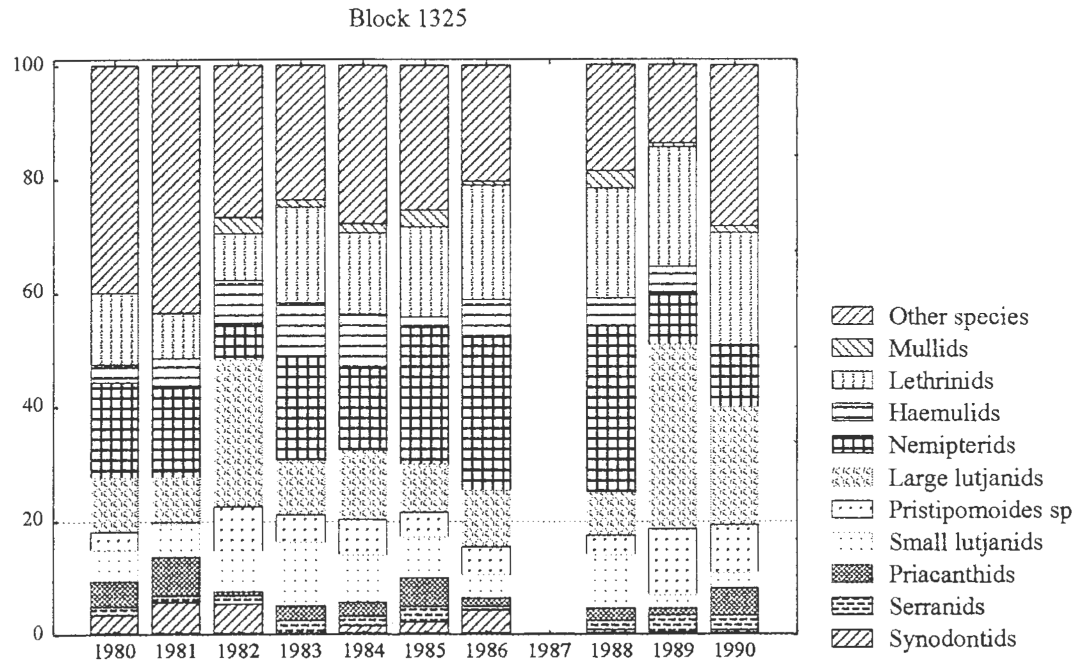


Fig. 5.3 Composition of Taiwanese pair trawl catch in block 1325 in the Holothuria Banks area, 1980-1990.

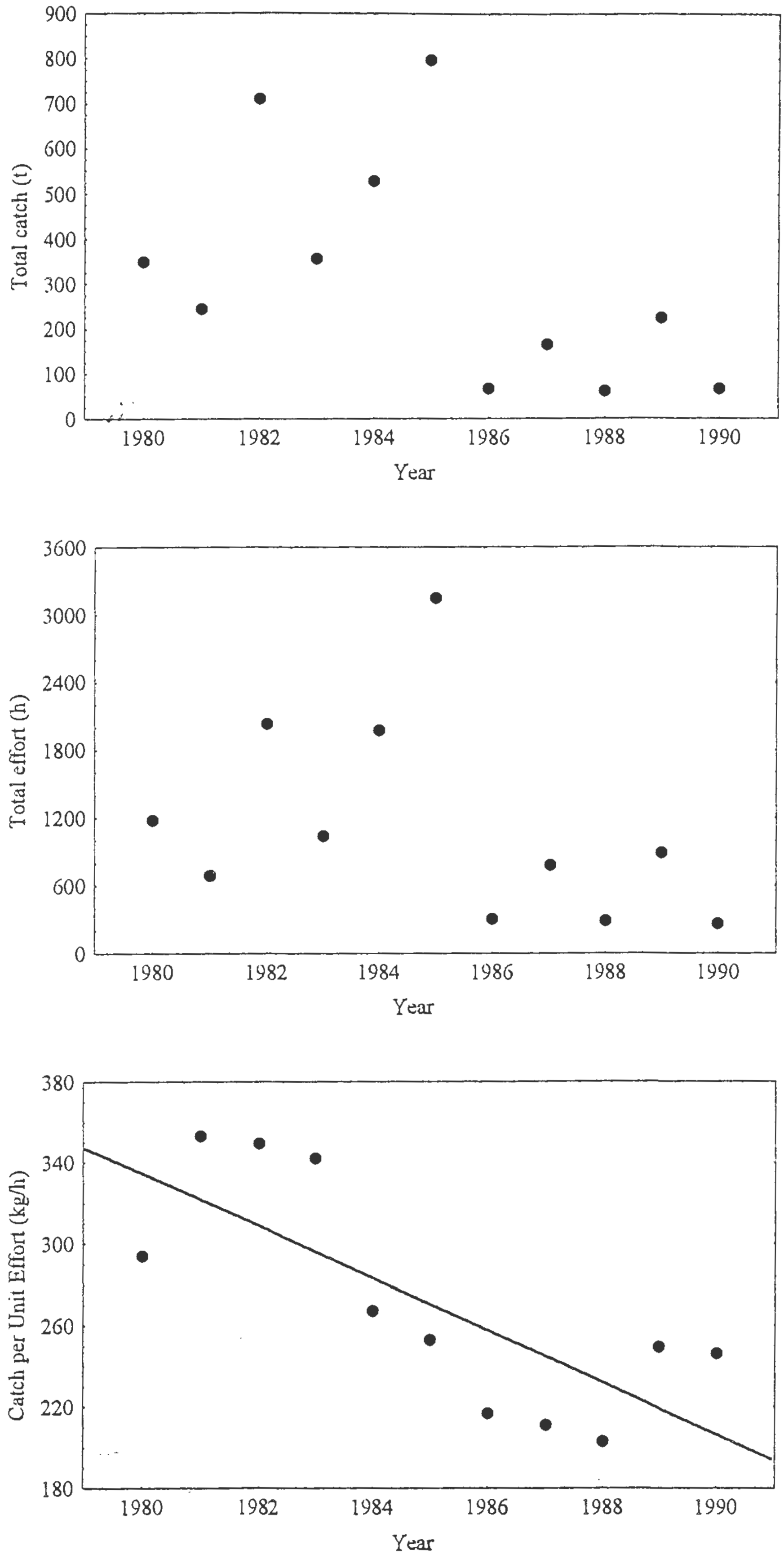


Fig. 5.4. Total catch, effort and CPUE for block 1721 in the Broome area.

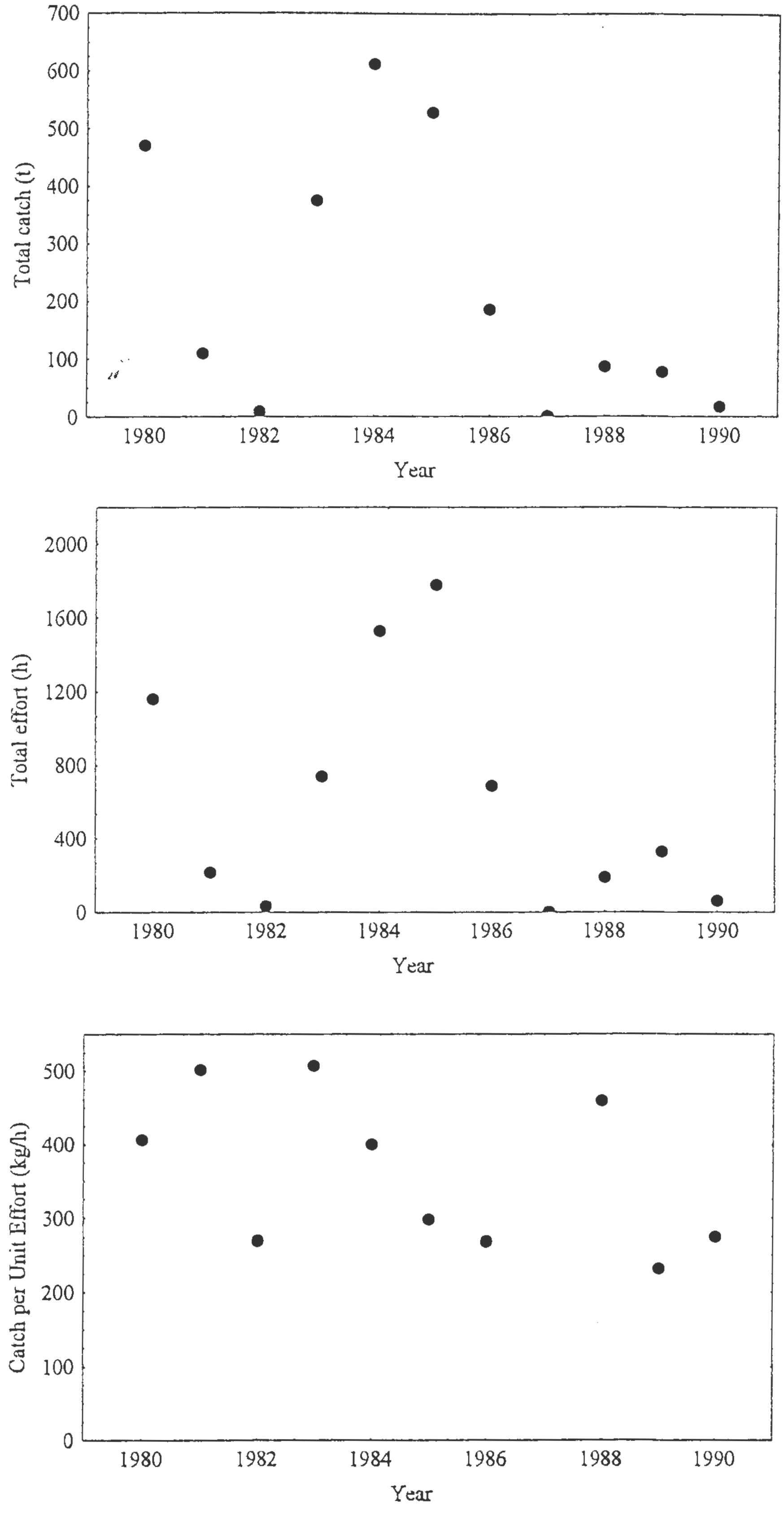


Fig. 5.5. Total catch, effort and CPUE for block 1325 in the Holothuria Banks area.

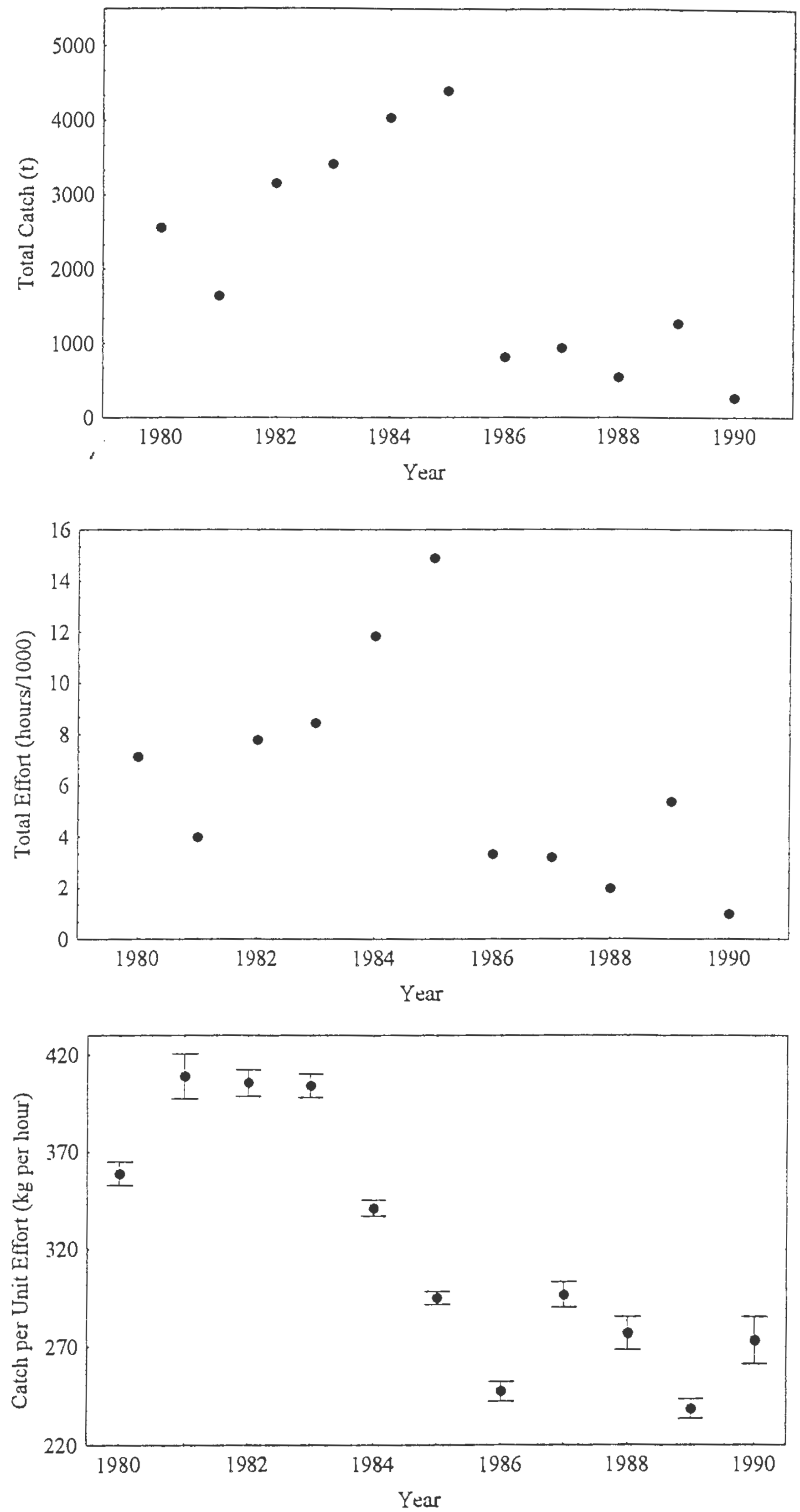


Fig. 6.1. Total catch, total effort and catch per unit effort of the Taiwanese trawl fleet in the Kimberley region from 1980 to 1990.

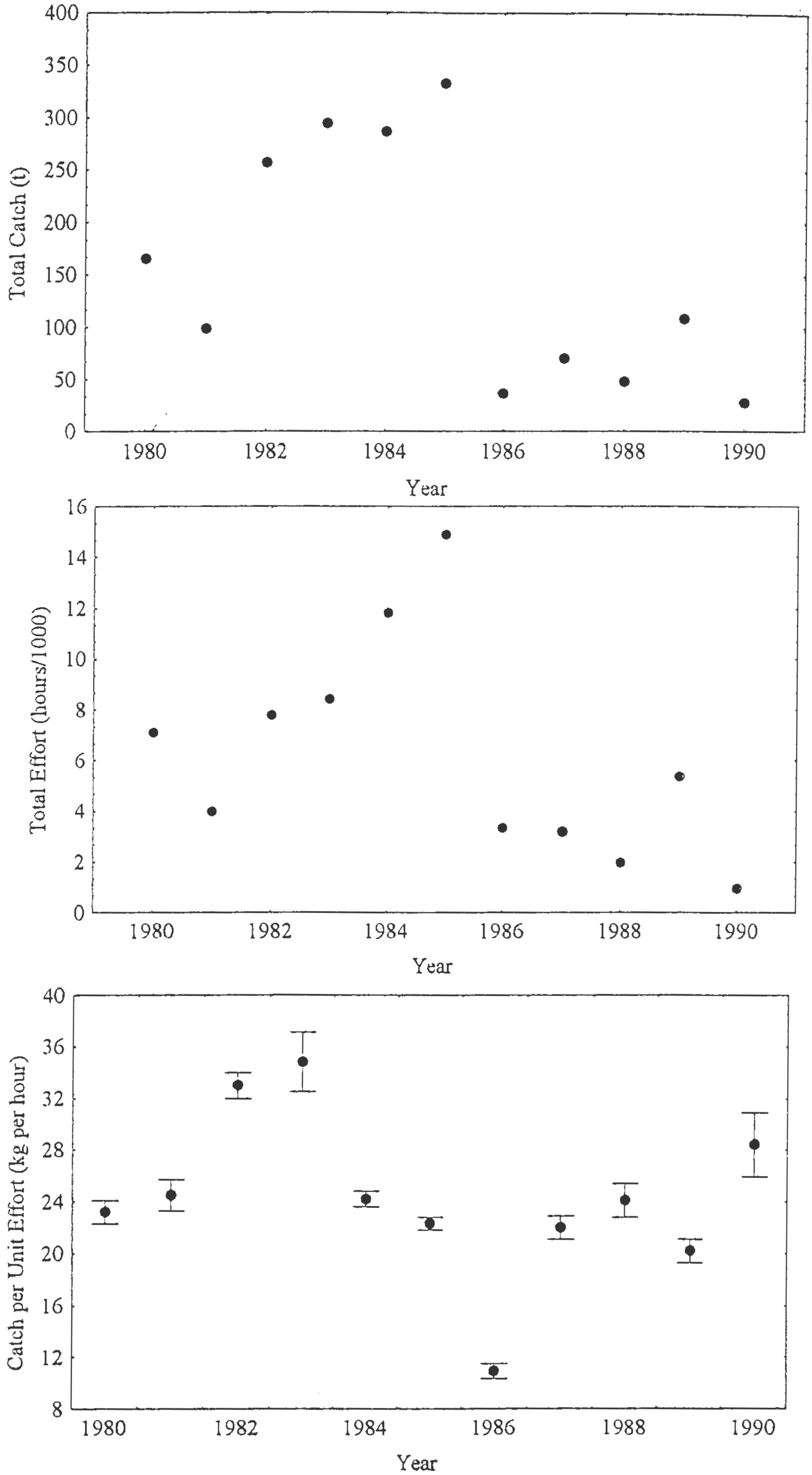


Fig. 6.2. Catch, effort and catch per unit effort of **small lutjanids** for the Taiwanese trawl fleet in the Kimberley region from 1980 to 1990.

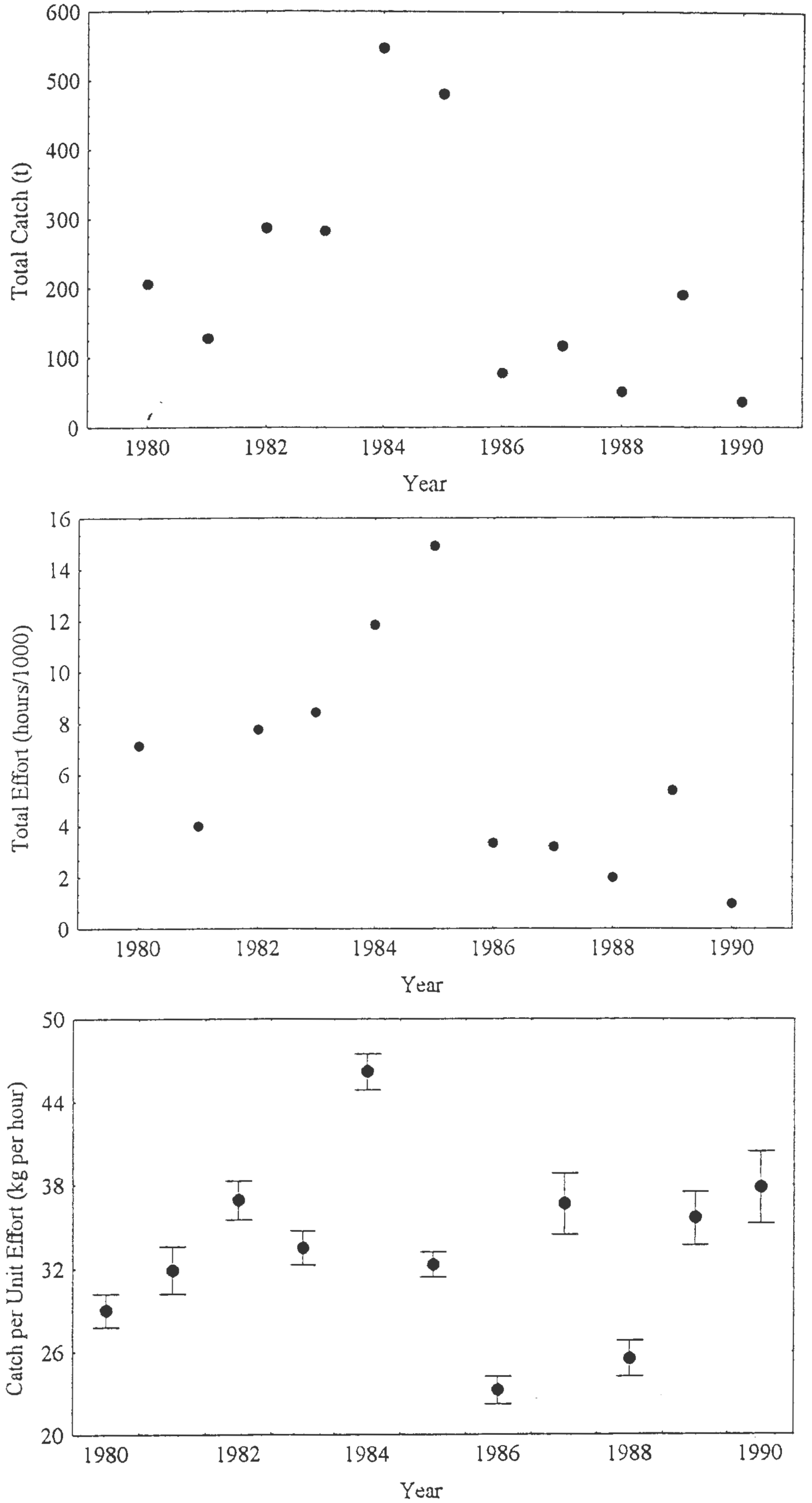


Fig. 6.3. Catch, effort and catch per unit effort of **large lutjanids** for the Taiwanese trawl fleet in the Kimberley region from 1980 to 1990.

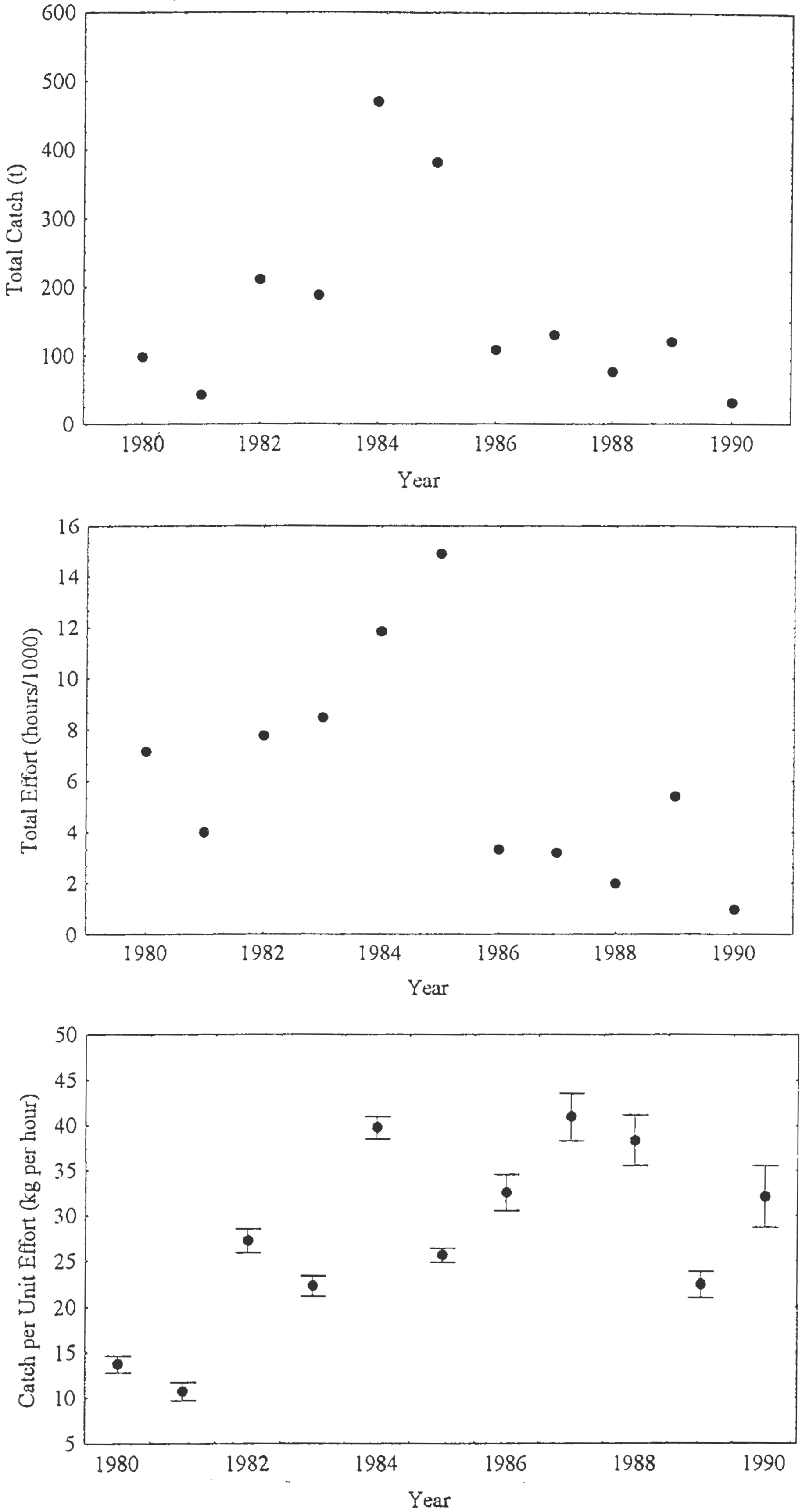


Fig. 6.4. Catch, effort and catch per unit effort of ***Pristipomoides*** **spp.** for the Taiwanese trawl fleet in the Kimberley region from 1980 to 1990.

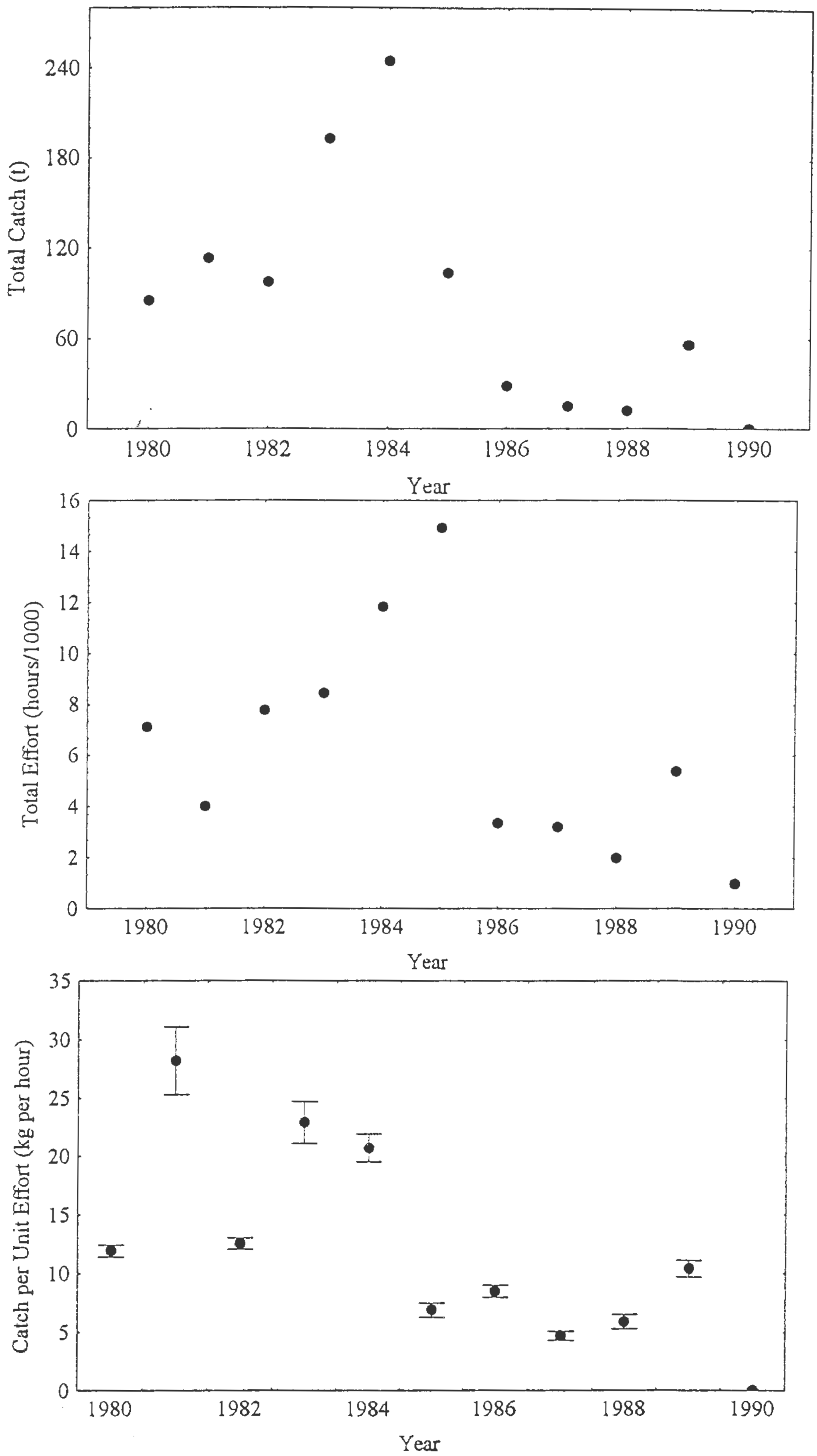


Fig. 6.5. Catch, effort and catch per unit effort of **haemulids** for the Taiwanese trawl fleet in the Kimberley region from 1980 to 1990.

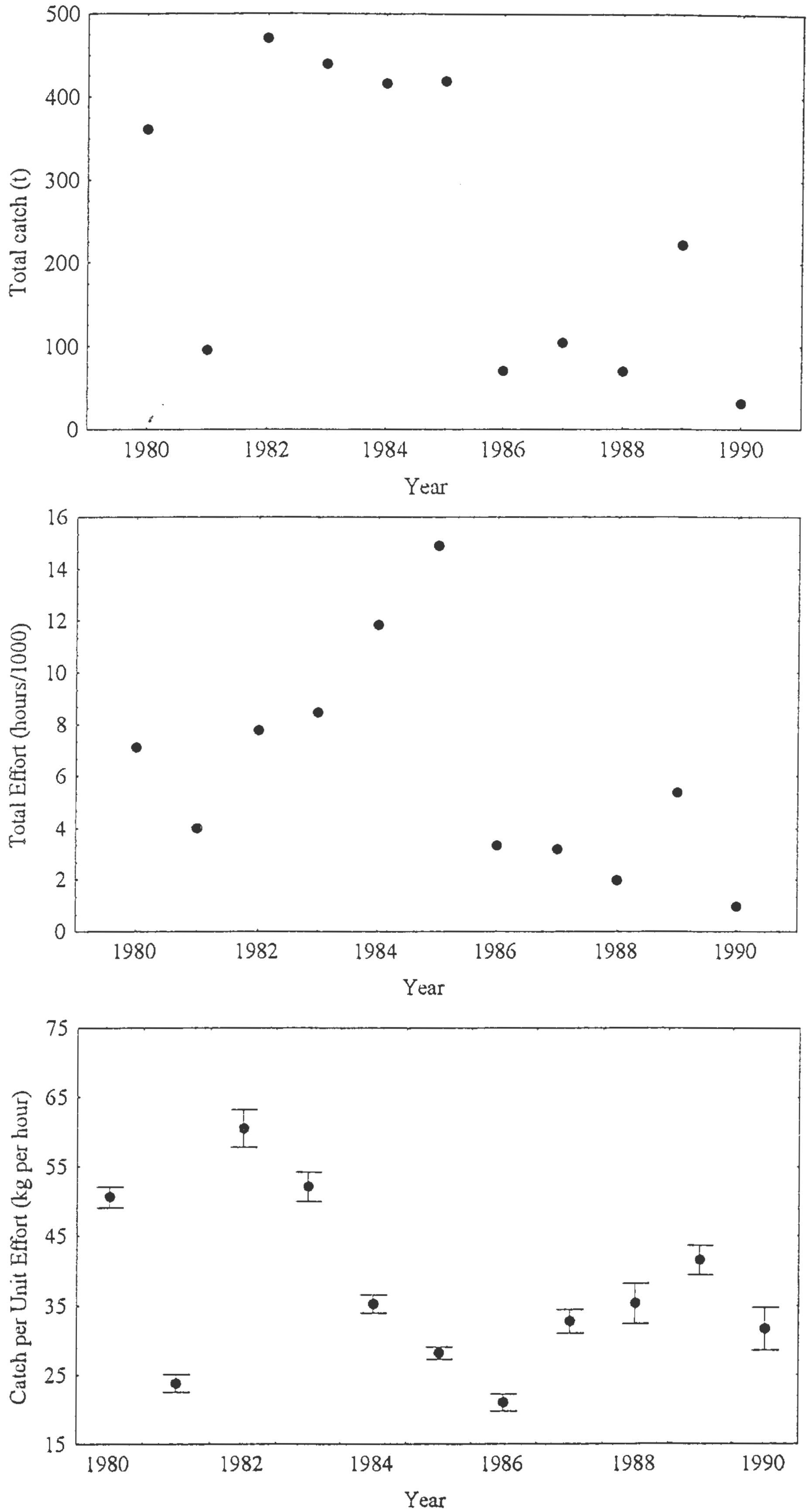


Fig. 6.6. Catch, effort and catch per unit effort of **lethrinids** for the Taiwanese trawl fleet in the Kimberley region from 1980 to 1990.

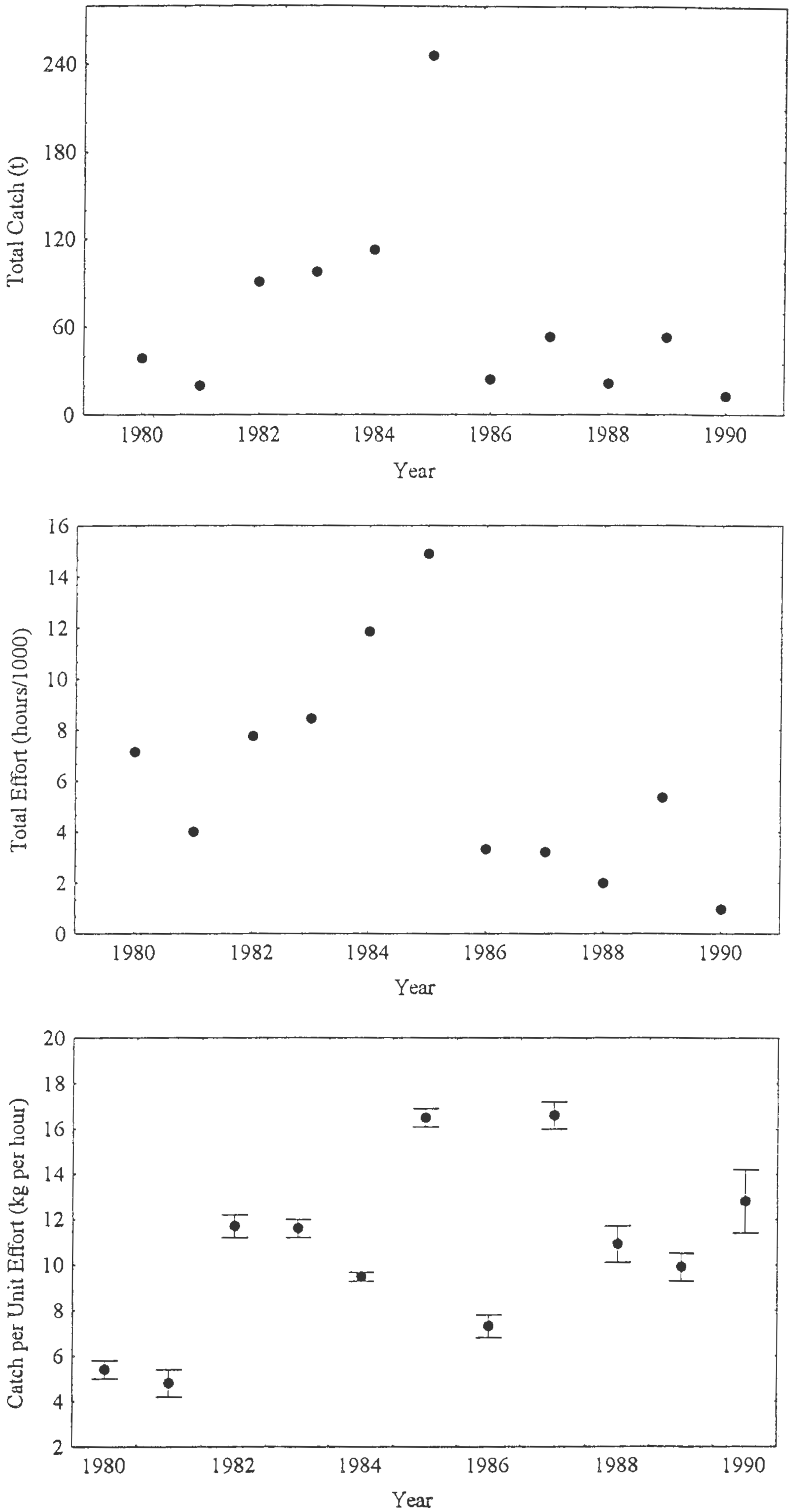


Fig. 6.7. Catch, effort and catch per unit effort of **mullids** for the Taiwanese trawl fleet in the Kimberley region from 1980 to 1990.

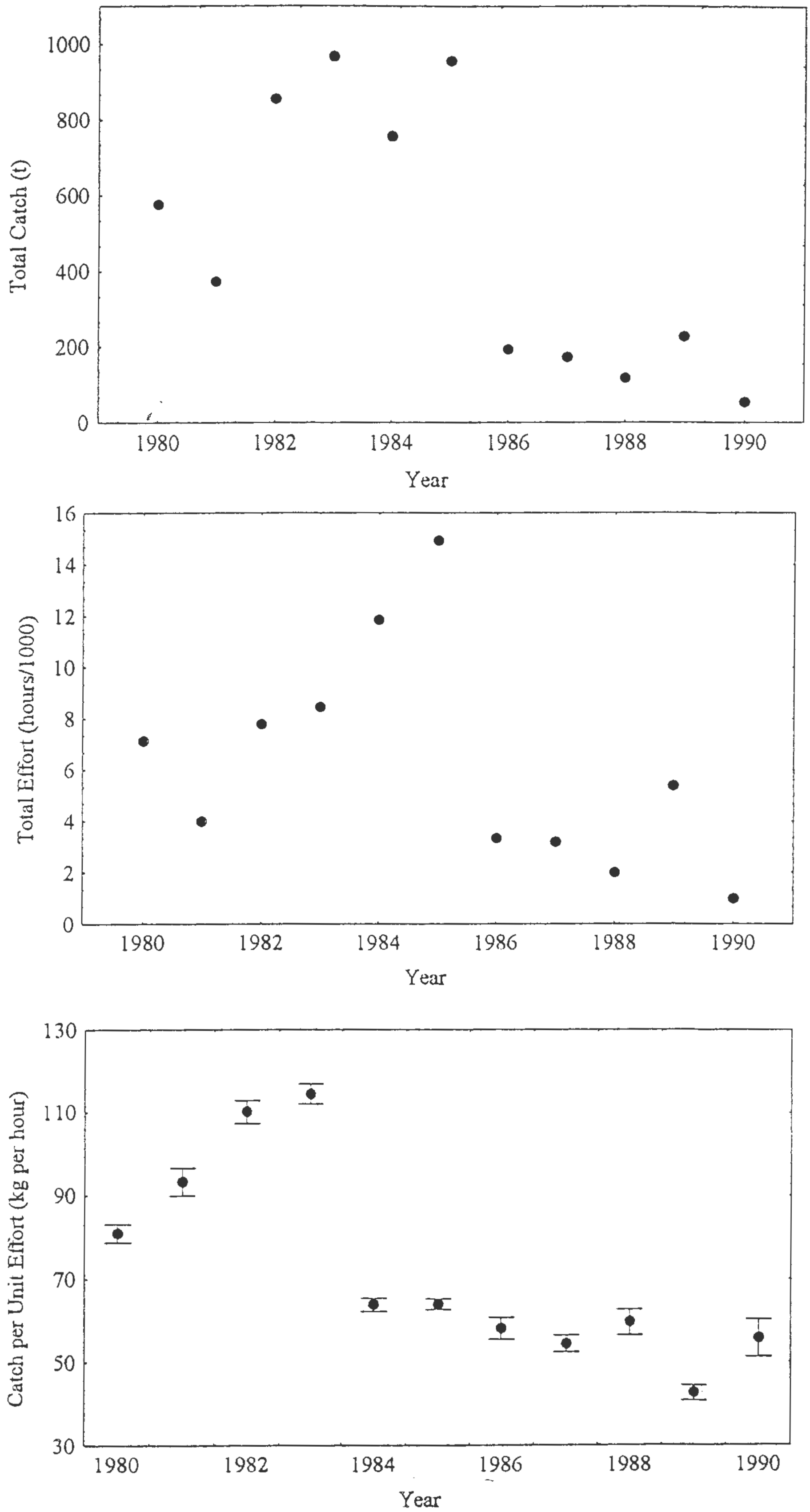


Fig. 6.8. Catch, effort and catch per unit effort of **nemipterids** for the Taiwanese trawl fleet in the Kimberley region from 1980 to 1990.

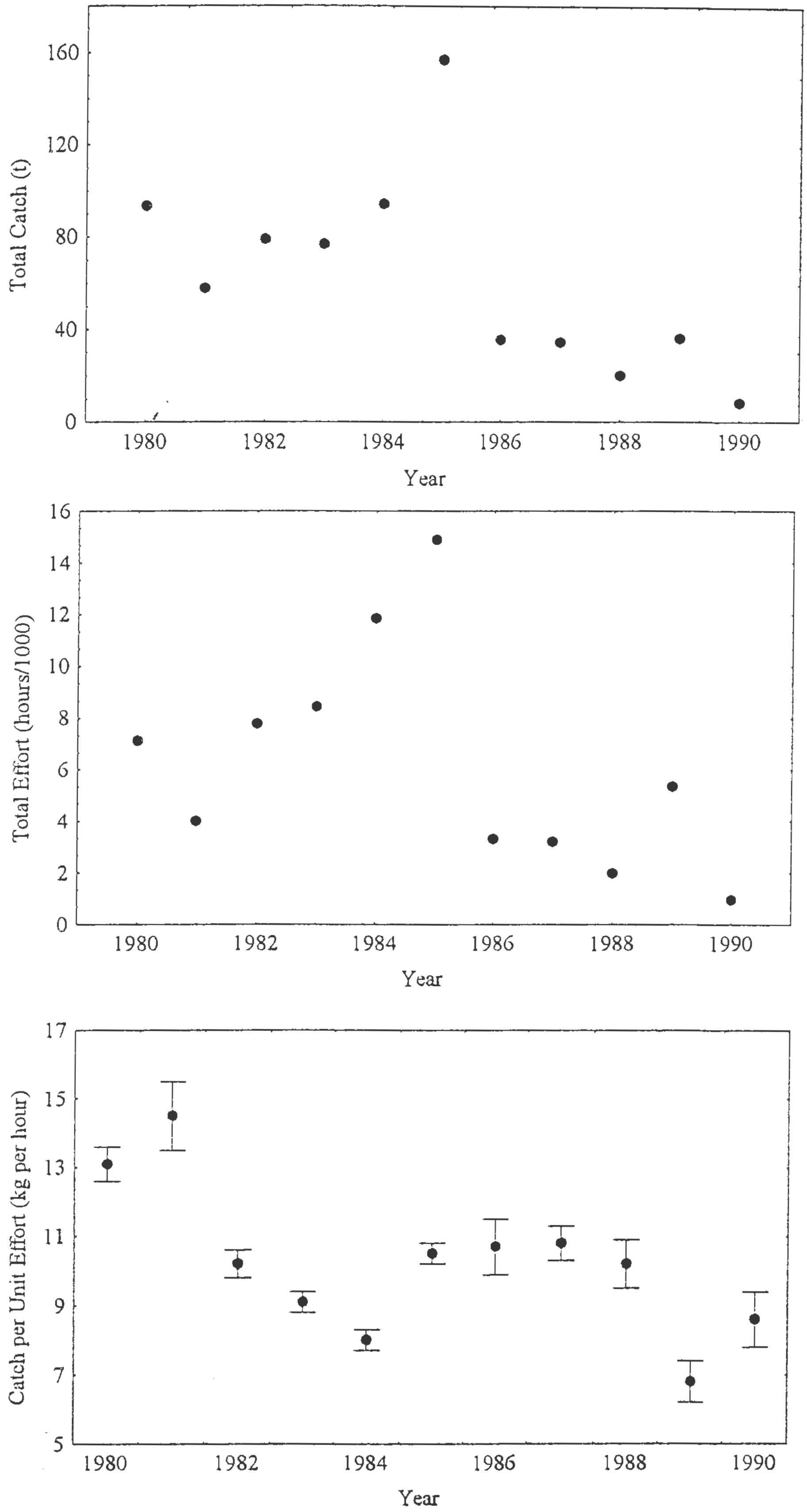


Fig. 6.9. Catch, effort and catch per unit effort of **priacanthids** for the Taiwanese trawl fleet in the Kimberley region from 1980 to 1990.

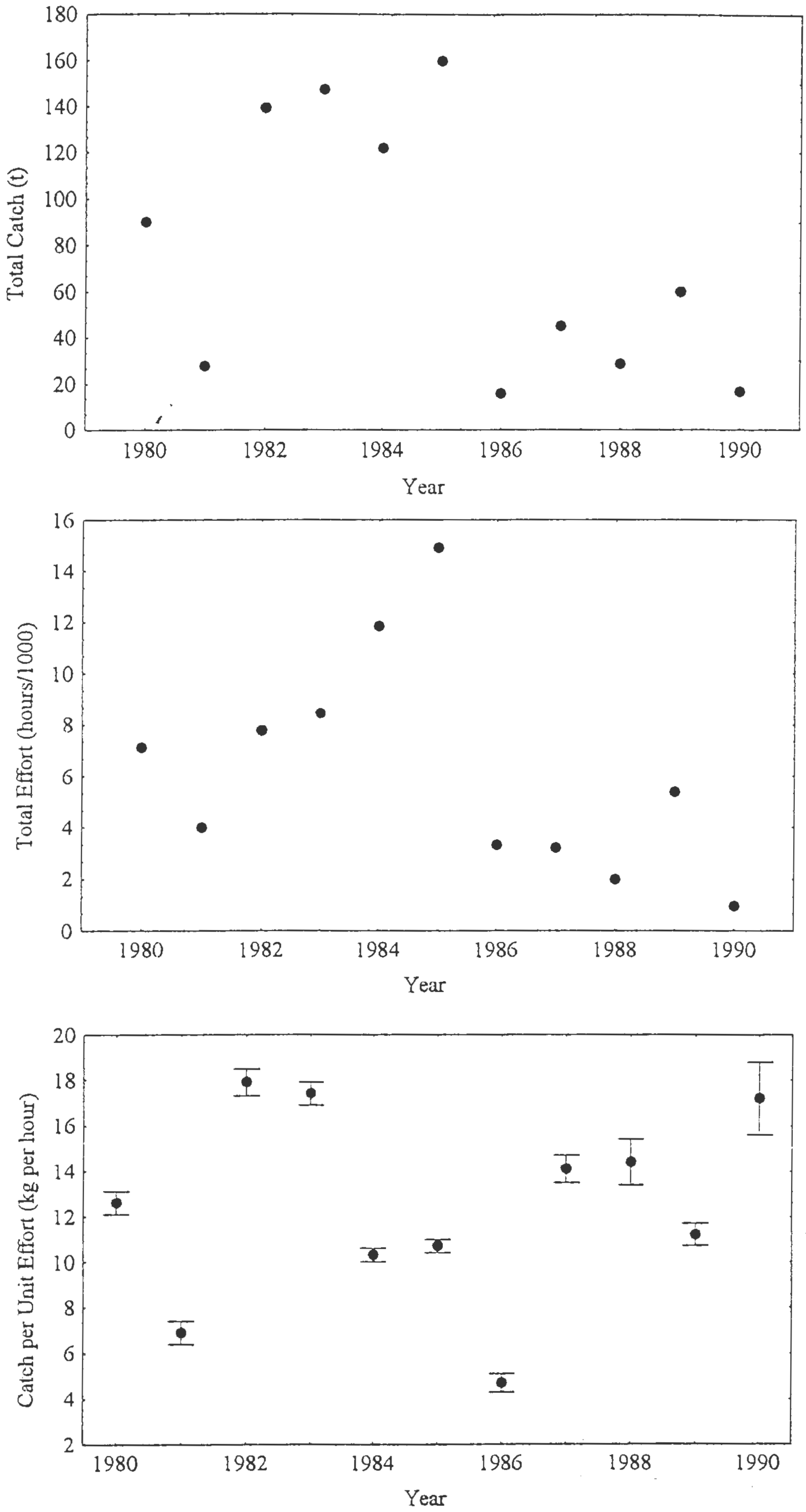


Fig. 6.10. Catch, effort and catch per unit effort of **serranids** for the Taiwanese trawl fleet in the Kimberley region from 1980 to 1990.

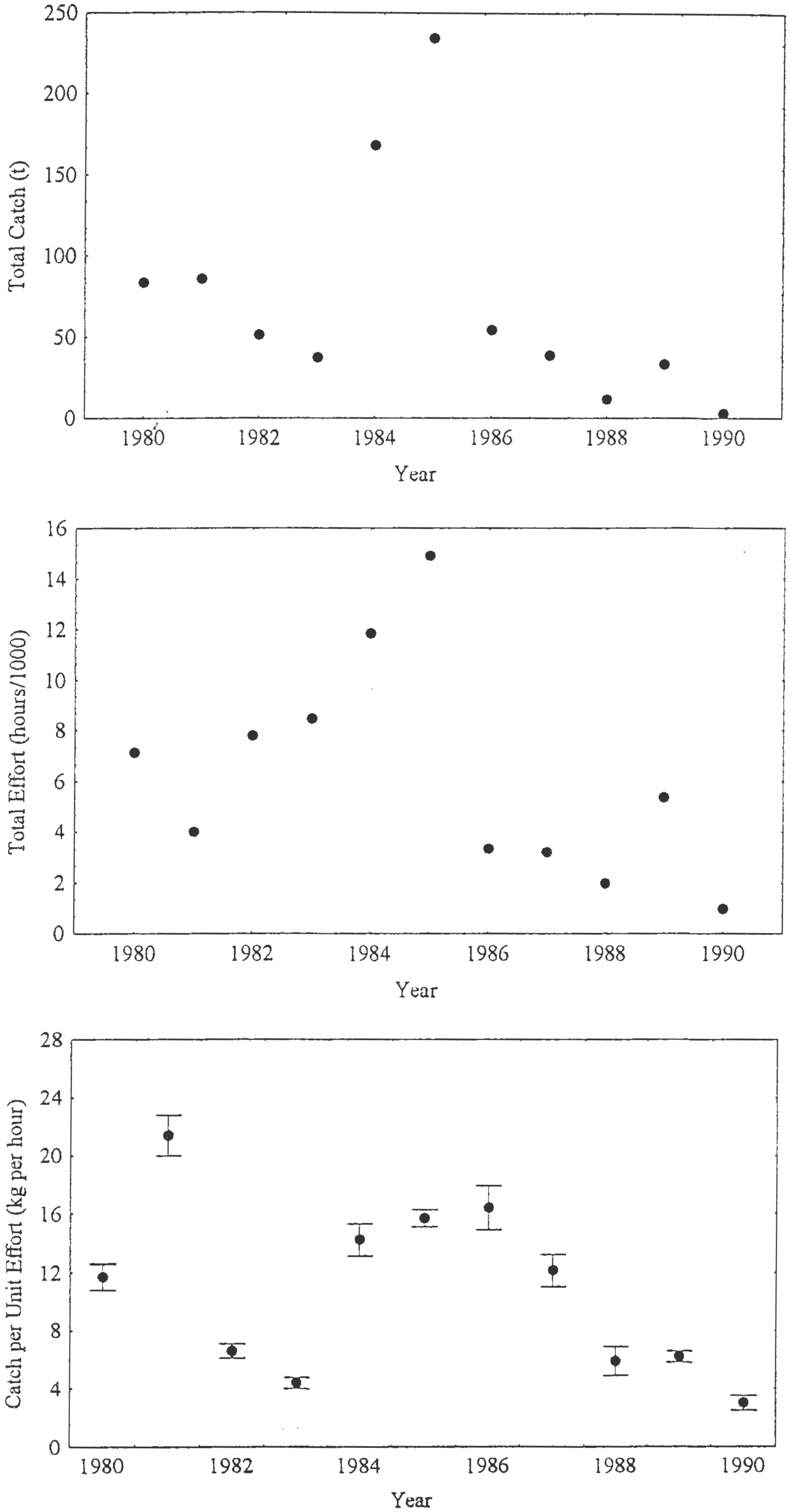


Fig. 6.11. Catch, effort and catch per unit effort of **synodontids** for the Taiwanese trawl fleet in the Kimberley region from 1980 to 1990.

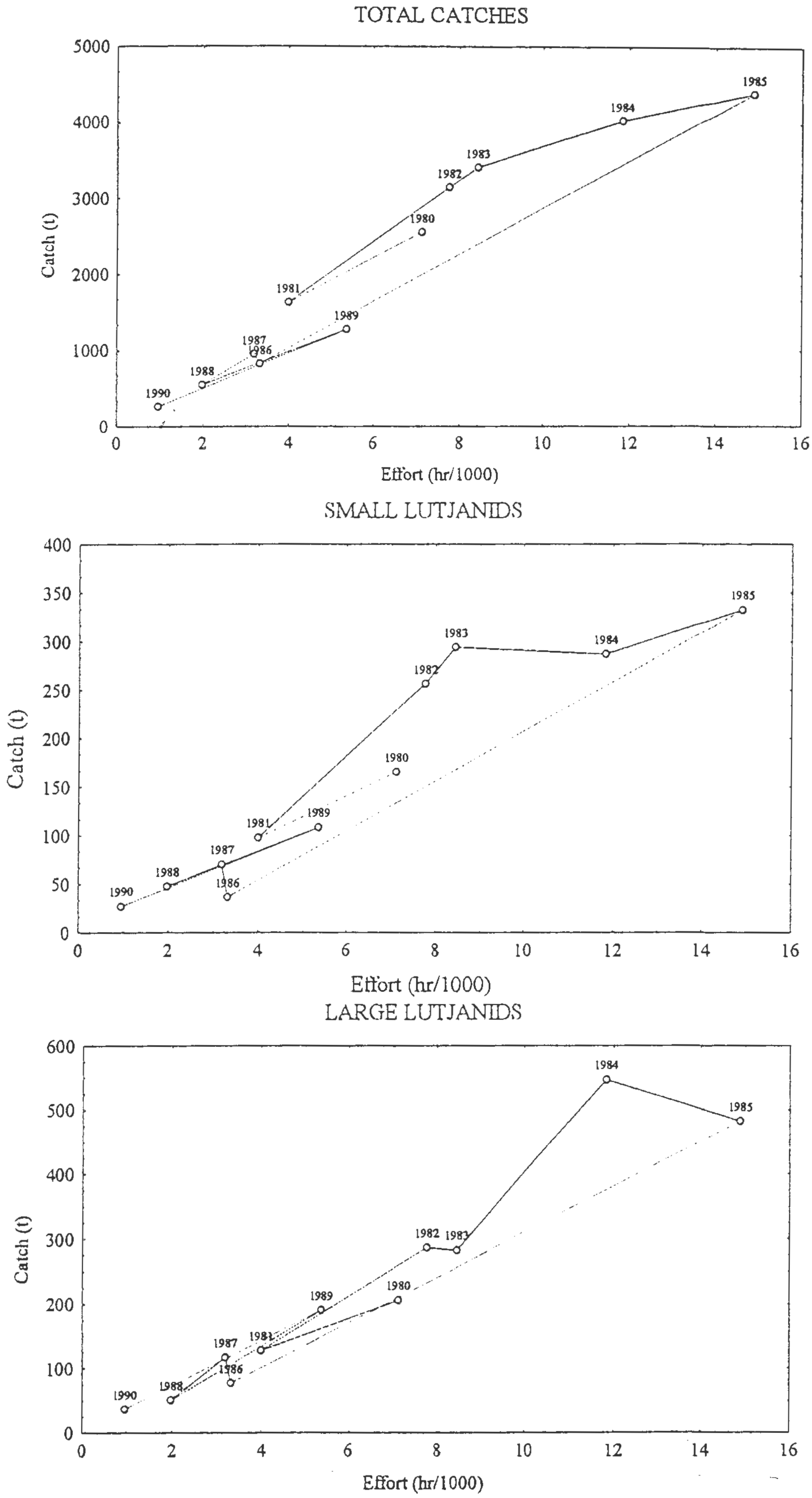


Fig. 7.1. Catch v effort graphs for Total catches, small lutjanid and large lutjanid catches of the Taiwanese pair trawlers from 1980 to 1990.

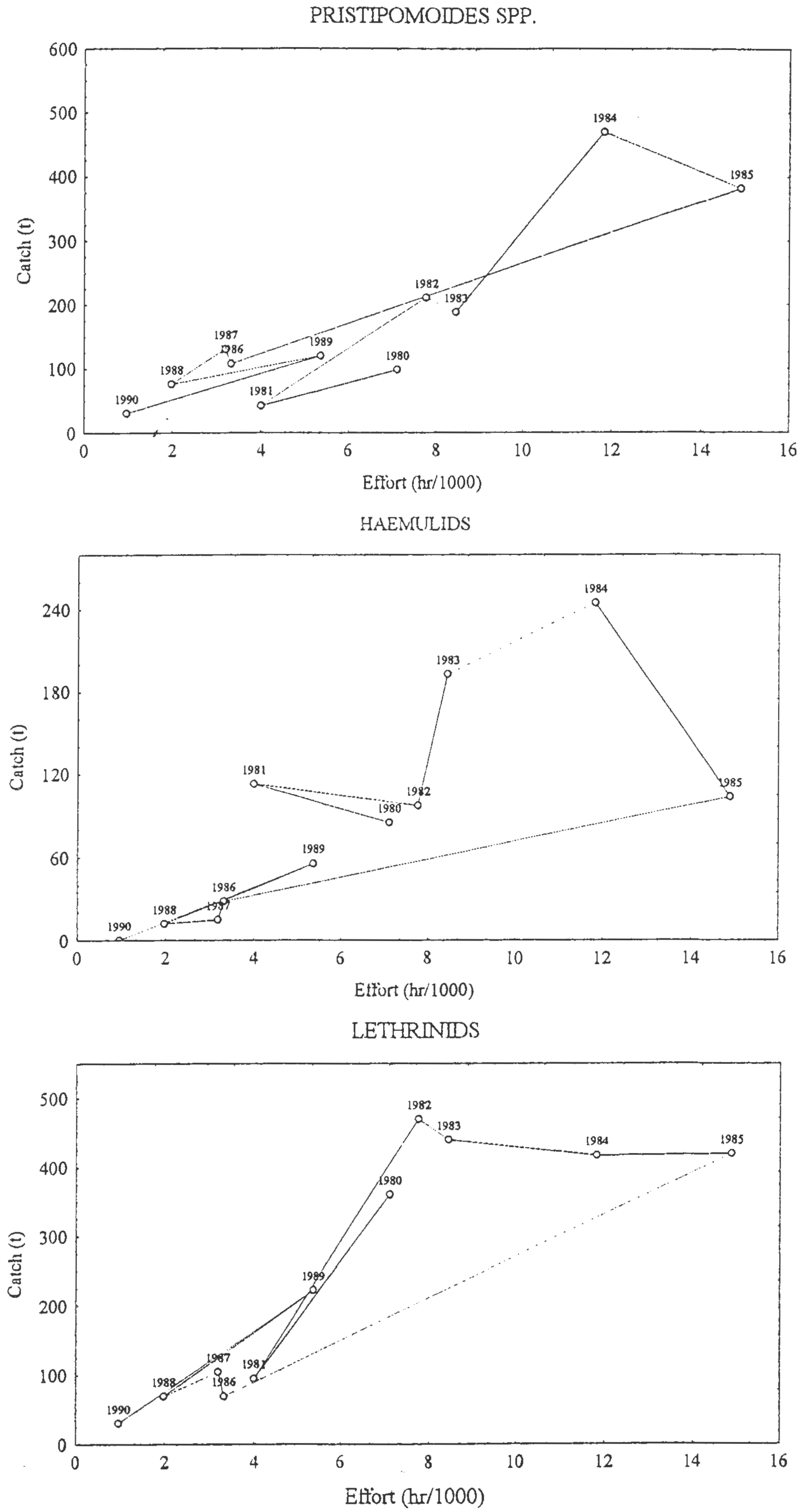


Fig. 7.2. Catch v effort graphs for Pristipomoides spp., haemulid and lethrinid catches of the Taiwanese pair trawlers from 1980 to 1990.

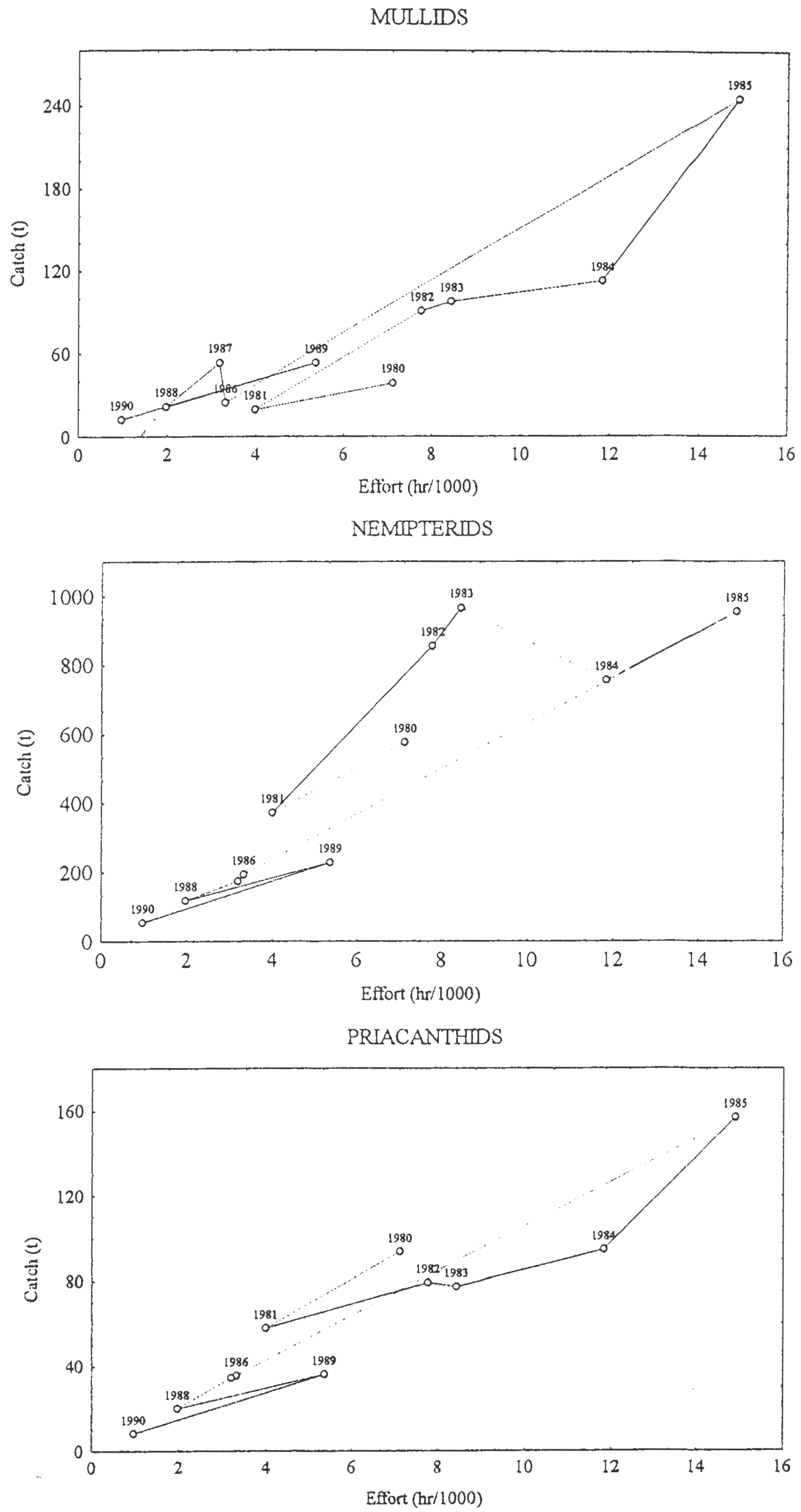
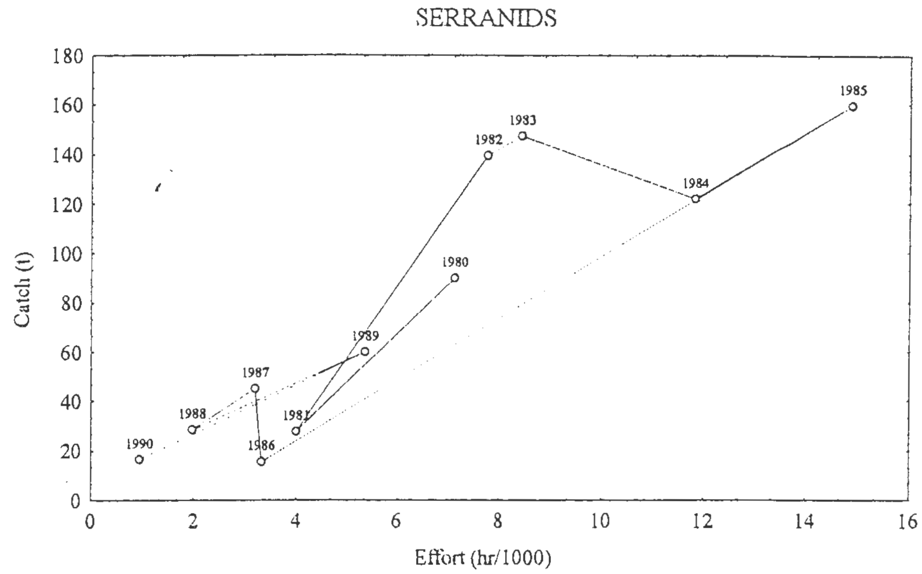


Fig. 7.3. Catch v effort graphs for mullid, nemipterid and priacanthid catches of the Taiwanese pair trawlers from 1980 to 1990.



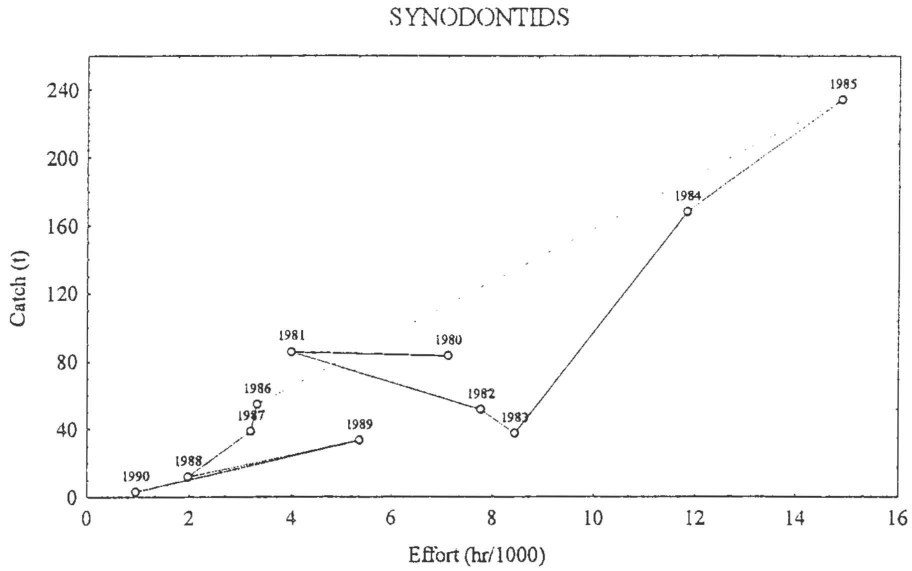


Fig. 7.4. Catch v effort graphs for serranid and synodontid catches of the Taiwanese pair trawlers from 1980 to 1990.

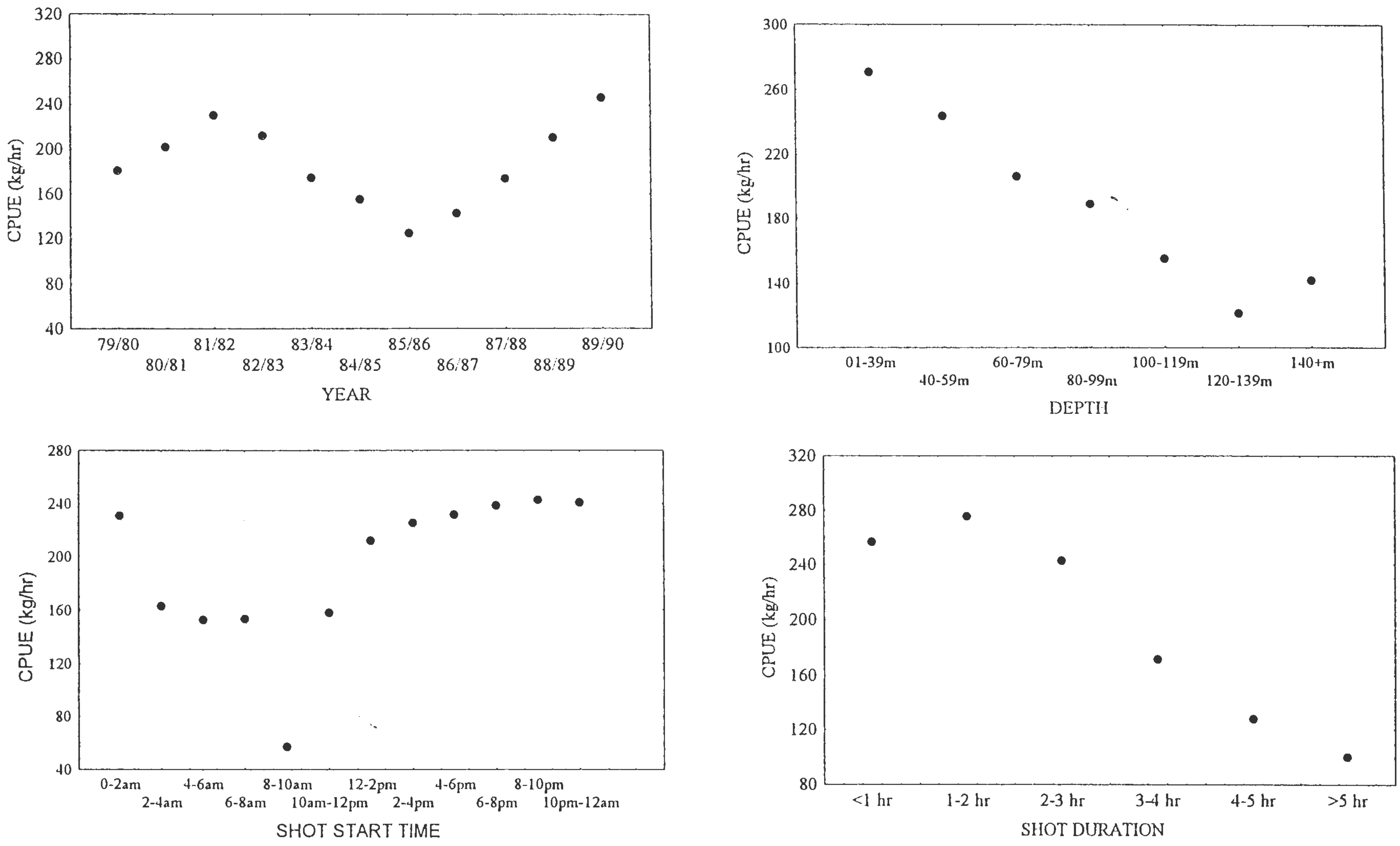


Fig. 8.1. Catch per hour (geometric mean) for total catches of Taiwanese pair trawlers in zones 1 & 3 only for year, depth, shot start time and shot duration. These catch rates have been adjusted for the other main effects in the ANOVA model.

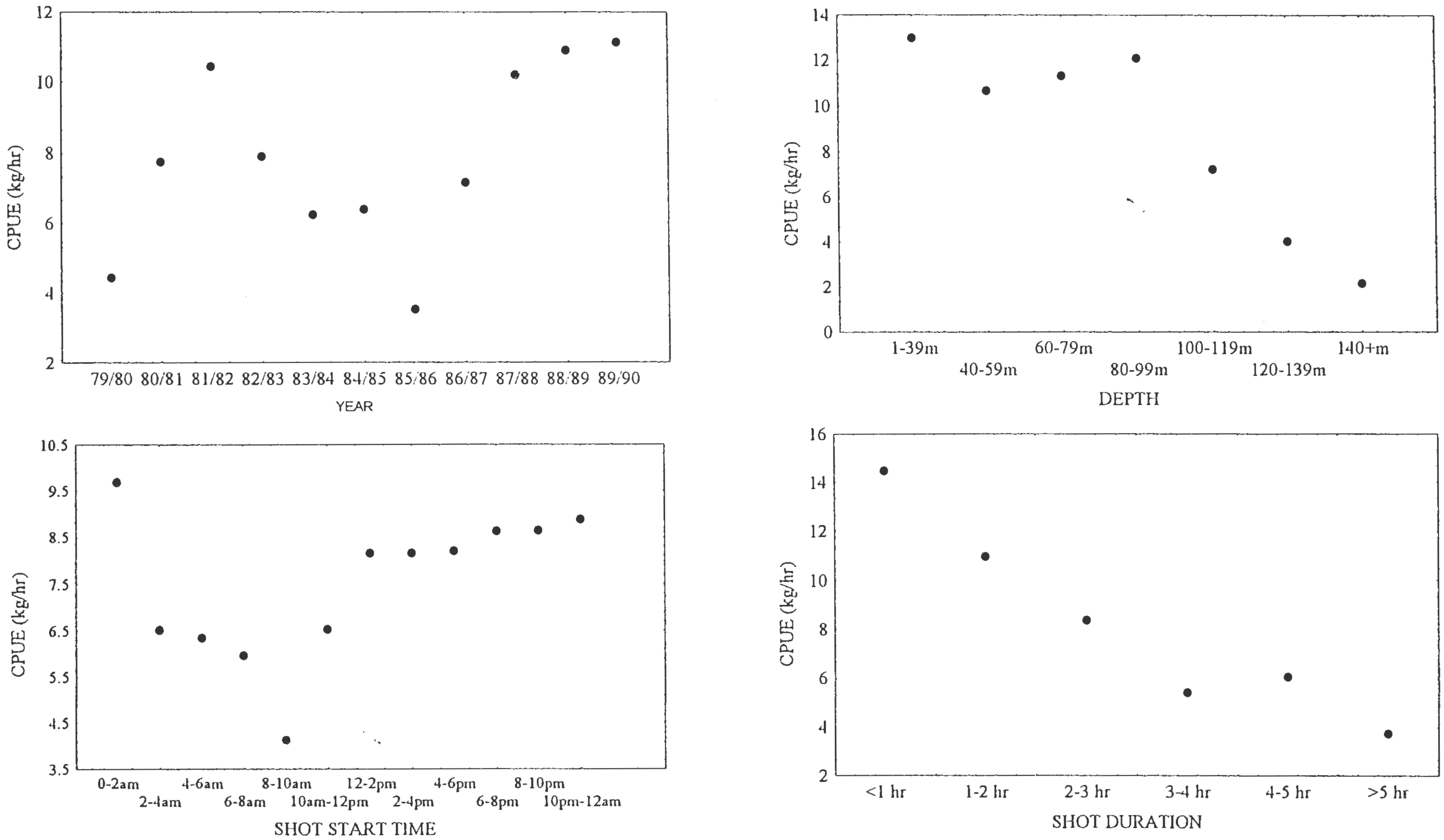


Fig. 8.2. Catch per hour (geometric mean) for catches of small lutjanids by Taiwanese pair trawlers for year, depth, shot start time and shot duration. These catch rates have been adjusted for the other main effects in the ANOVA model.

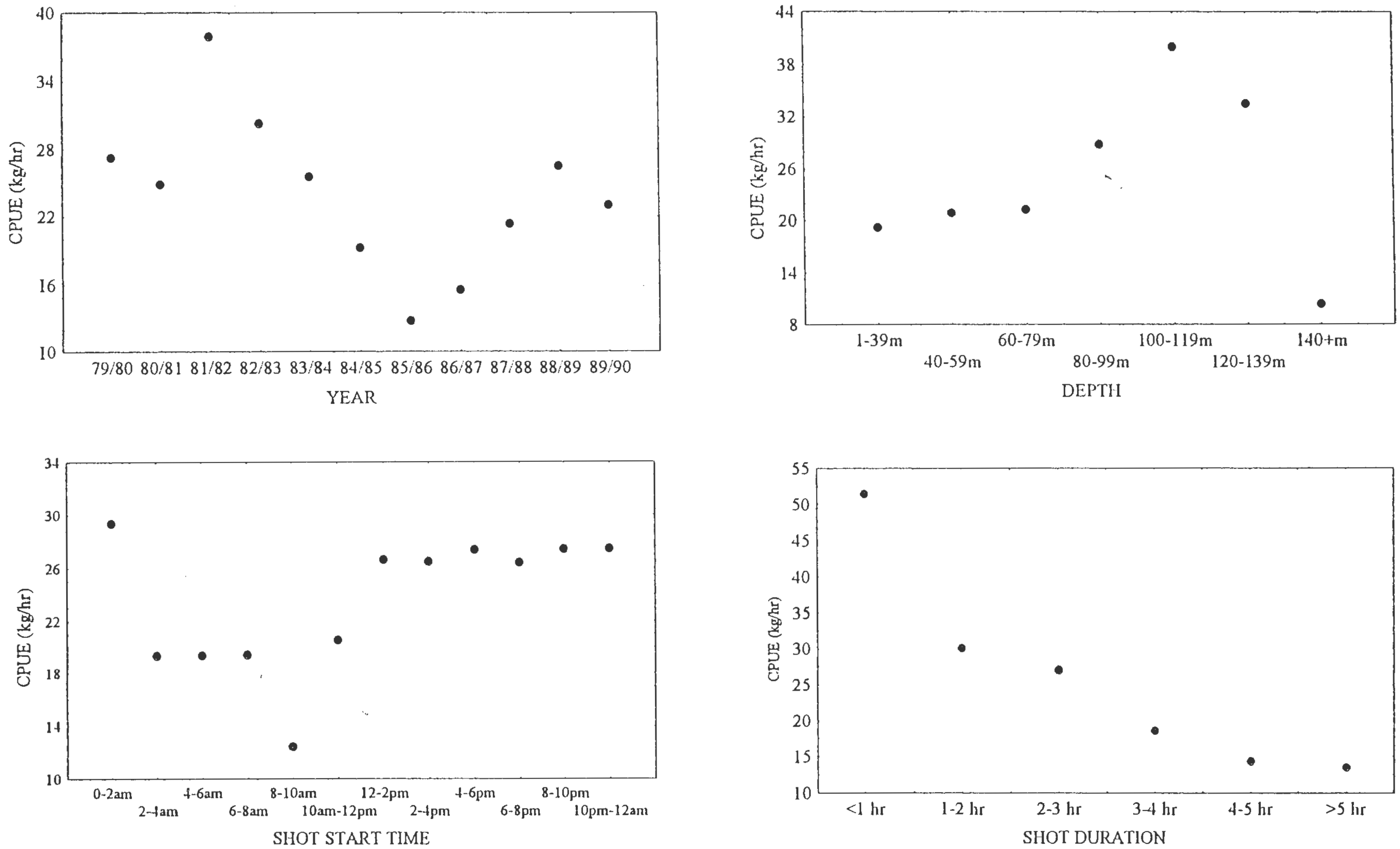


Fig. 8.3. Catch per hour (geometric mean) for catches of large lutjanids by Taiwanese pair trawlers for year, depth, shot start time shot duration. These catch rates have been adjusted for the other main effects in the ANOVA model.

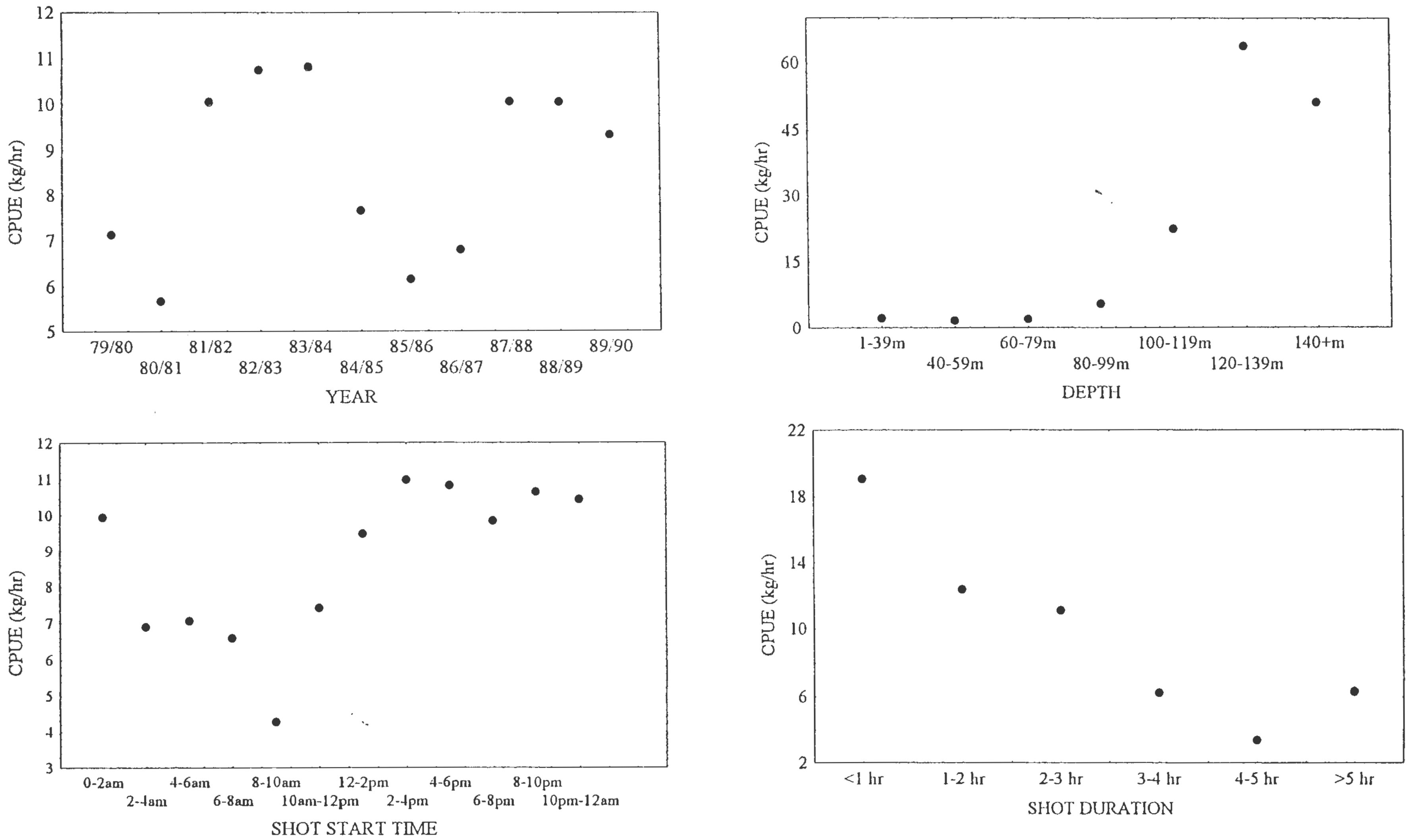


Fig. 8.4. Catch per hour (geometric mean) for catches of *Pristipomoides* spp. by Taiwanese pair trawlers for year, depth, shot start time and shot duration. These catch rates have been adjusted for the other main effects in the ANOVA model.

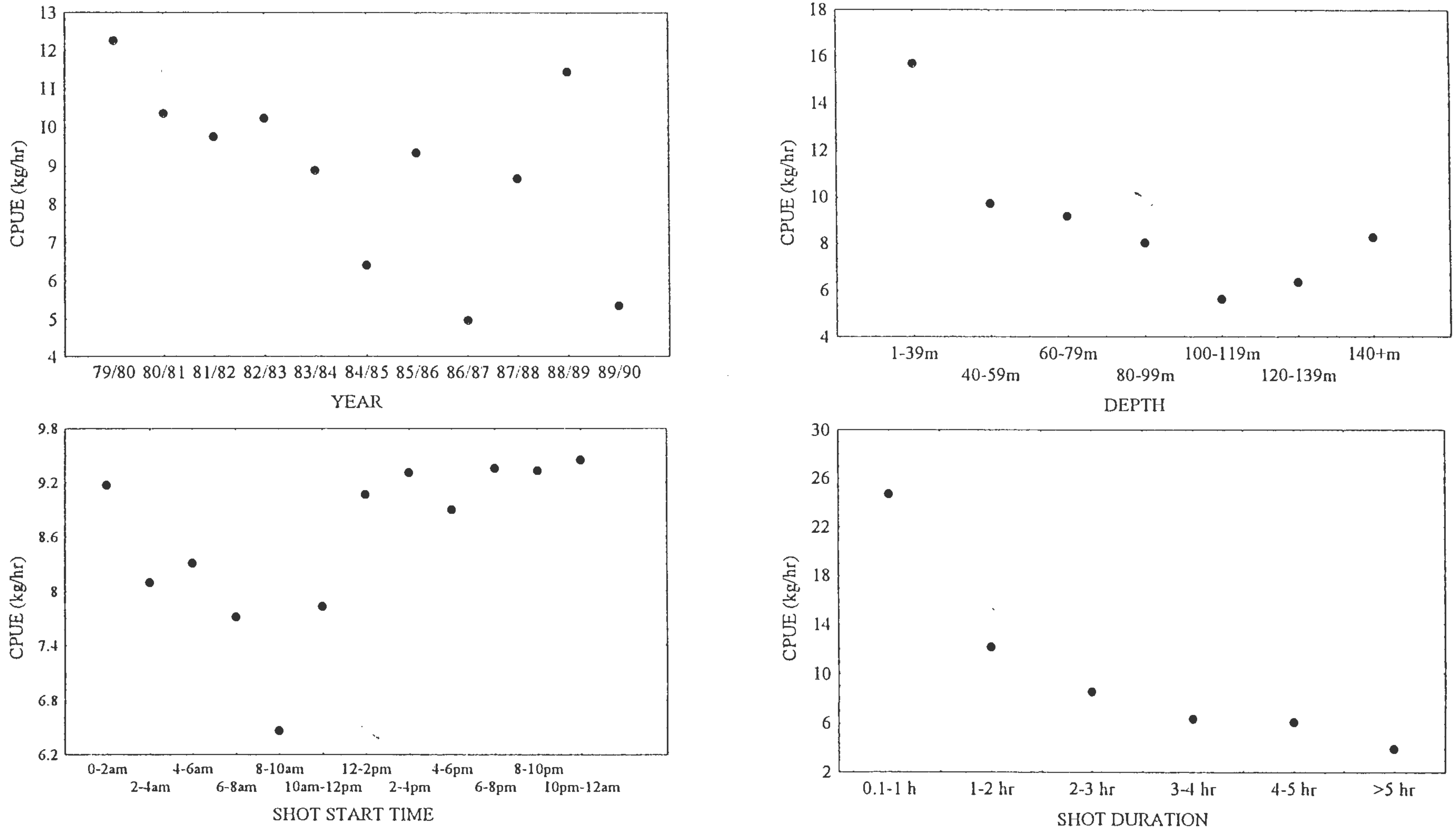


Fig. 8.5. Catch per hour (geometric mean) for catches of haemulids by Taiwanese pair trawlers for year, depth, shot start time and shot duration. These catch rates have been adjusted for the other main effects in the ANOVA model.

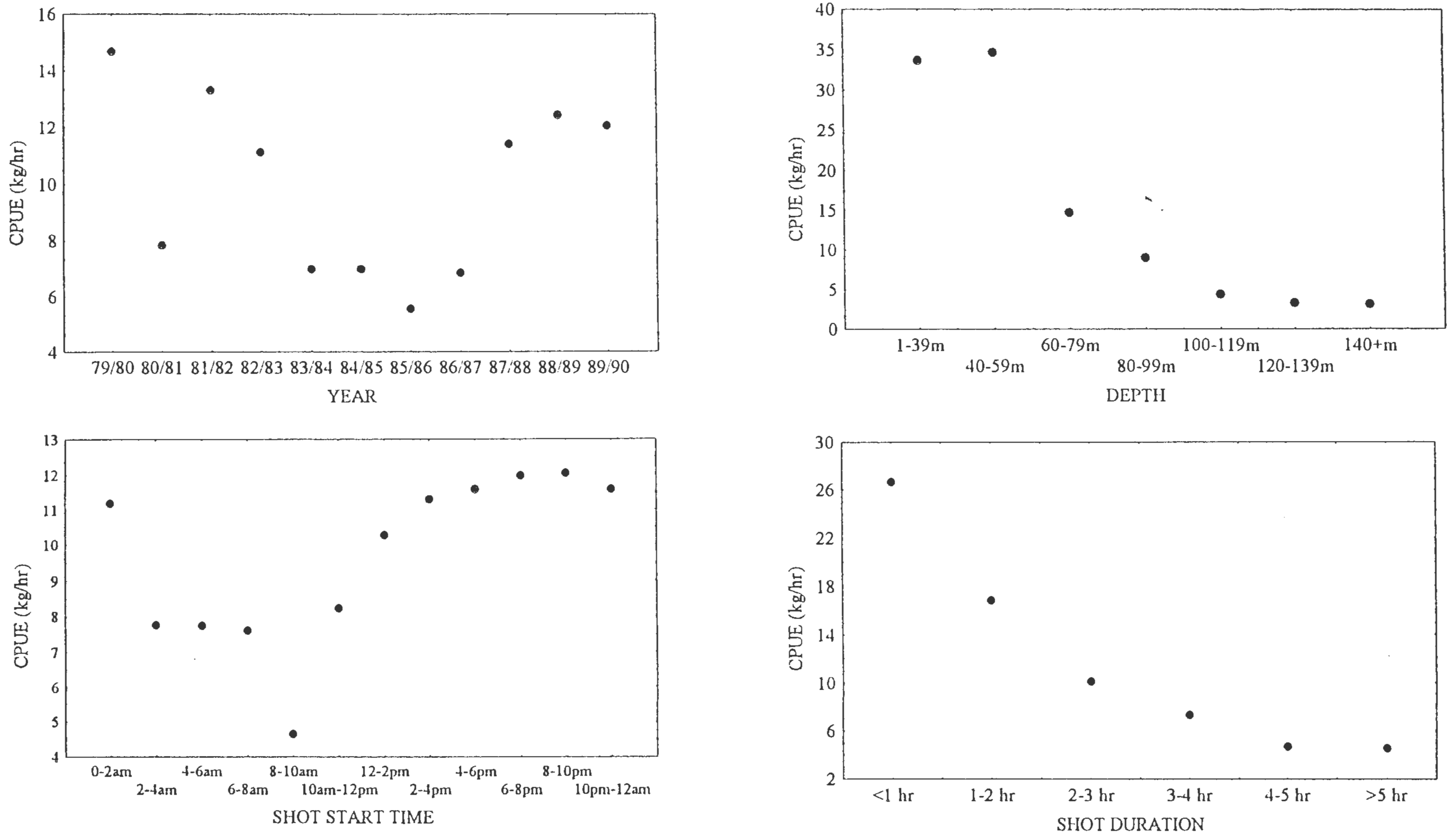


Fig. 8.6. Catch per hour (geometric mean) for catches of lethrinids by Taiwanese pair trawlers for year, depth, shot start time and shot duration. These catch rates have been adjusted for the other main effects in the ANOVA model.

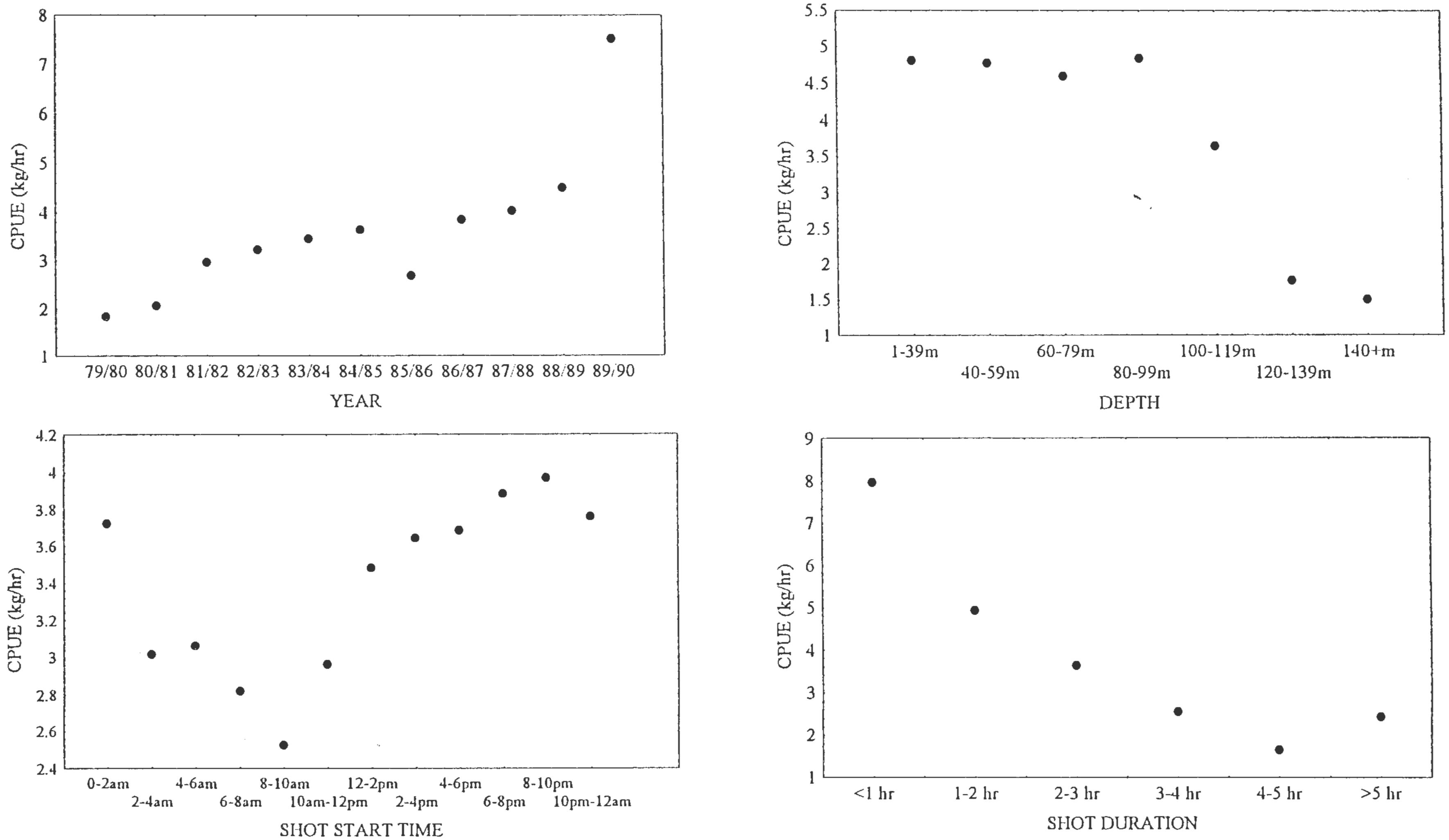


Fig. 8.7. Catch per hour (geometric mean) for catches of mullids by Taiwanese pair trawlers for year, depth, shot start time and shot duration. These catch rates have been adjusted for the other main effects in the ANOVA model.

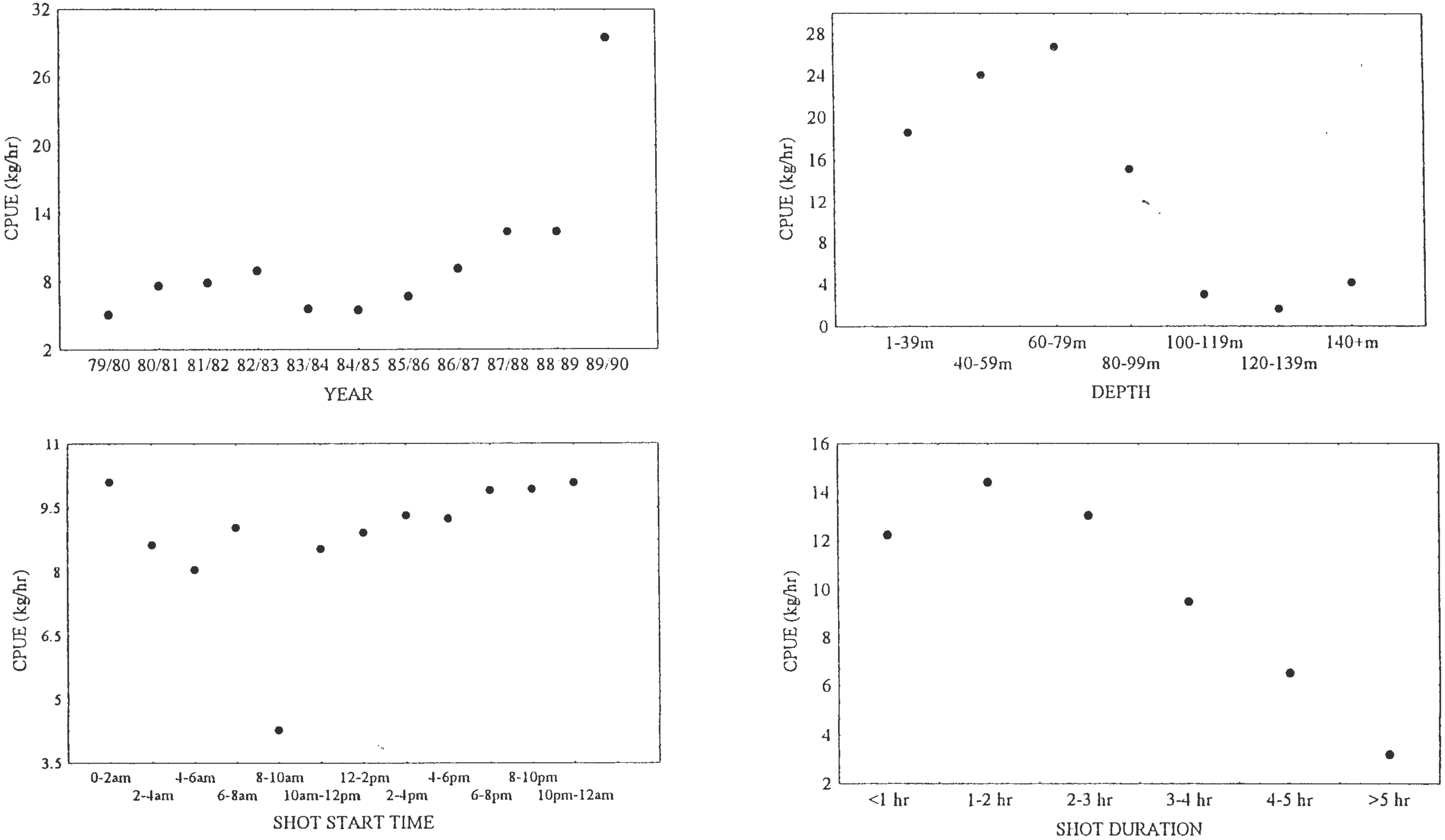


Fig. 8.8. Catch per hour (geometric mean) for catches of nemipterids by Taiwanese pair trawlers for year, depth, shot start time and shot duration. These catch rates have been adjusted for the other main effects in the ANOVA model.

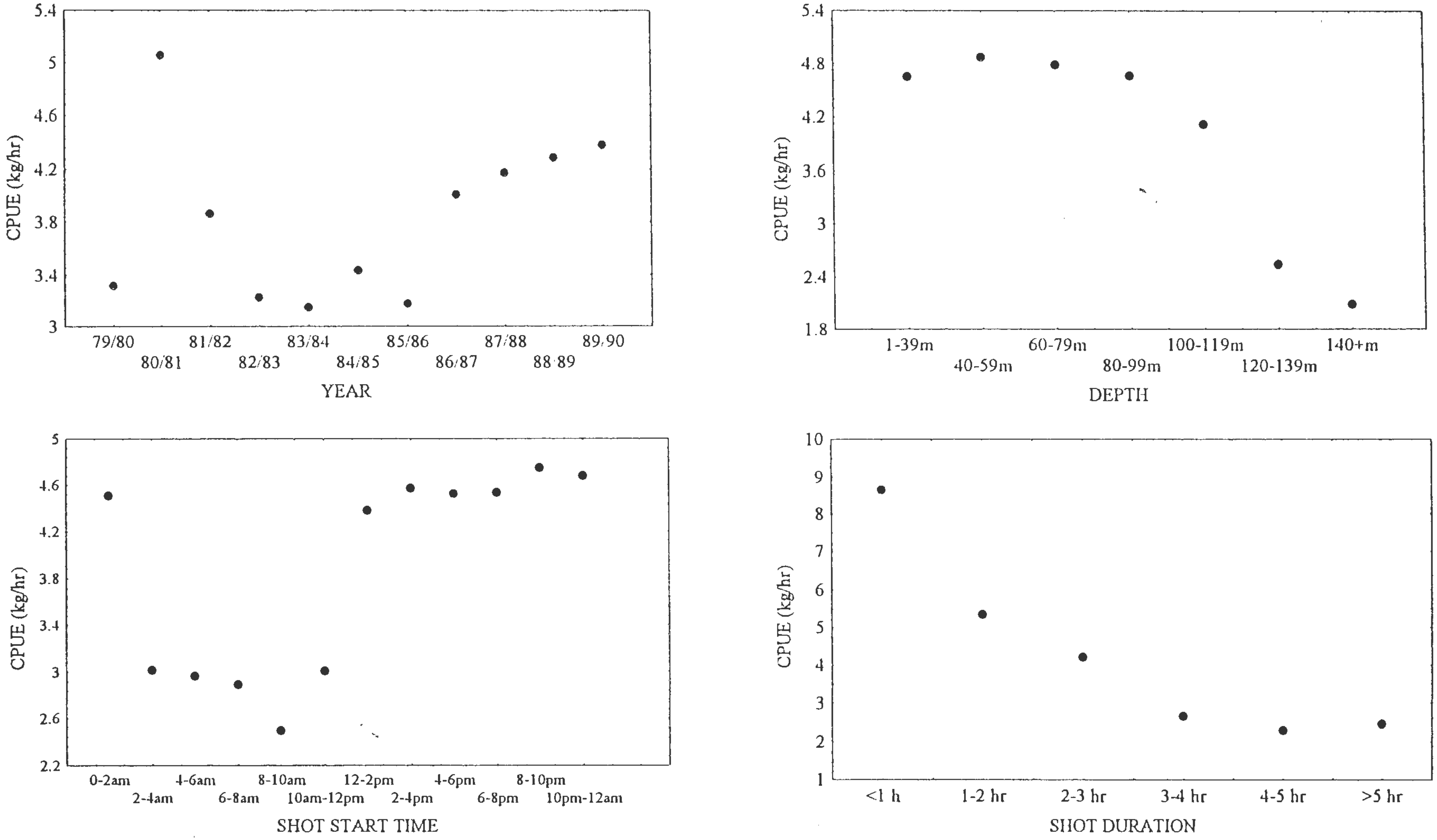


Fig. 8.9. Catch per hour (geometric mean) for catches of priacanthids by Taiwanese pair trawlers for year, depth, shot start time and shot duration. These catch rates have been adjusted for the other main effects in the ANOVA model.

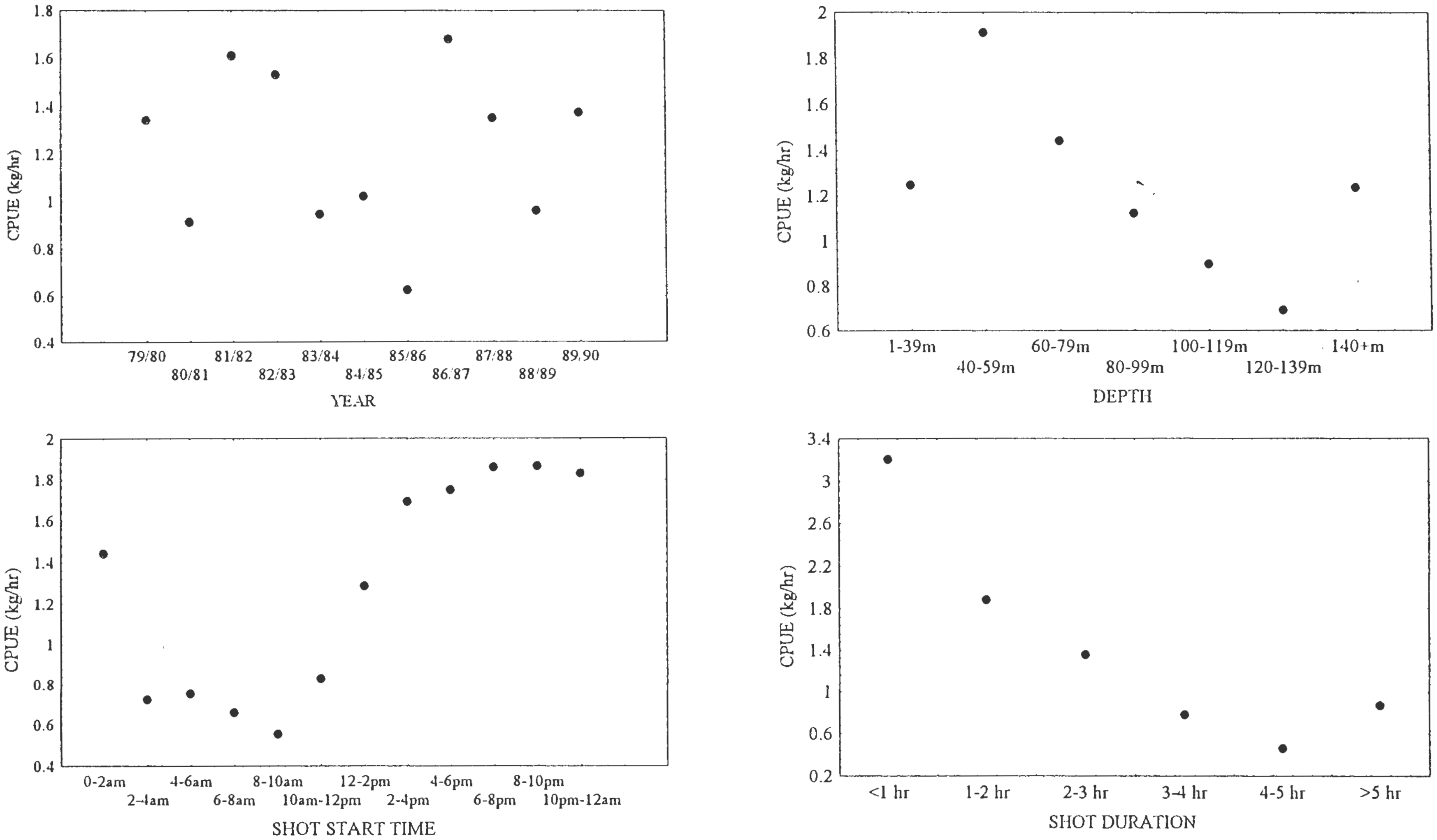


Fig. 8.10. Catch per hour (geometric mean) for catches of serranids by Taiwanese pair trawlers for year, depth, shot start time and shot duration. These catch rates have been adjusted for the other main effects in the ANOVA model.

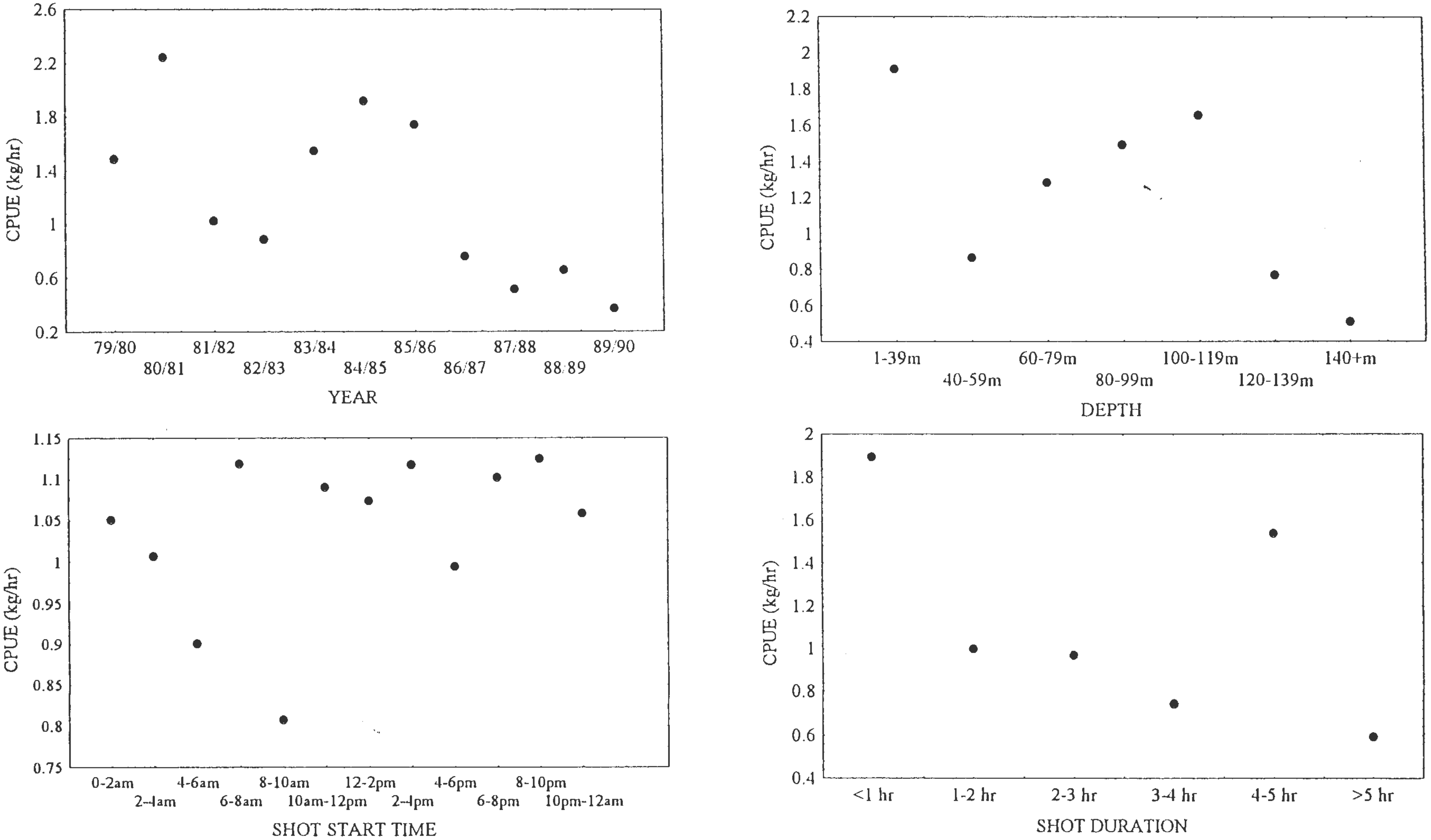


Fig. 8.11. Catch per hour (geometric mean) for catches of synodontids by Taiwanese pair trawlers for year, depth, shot start time and shot duration. These catch rates have been adjusted for the other main effects in the ANOVA model.

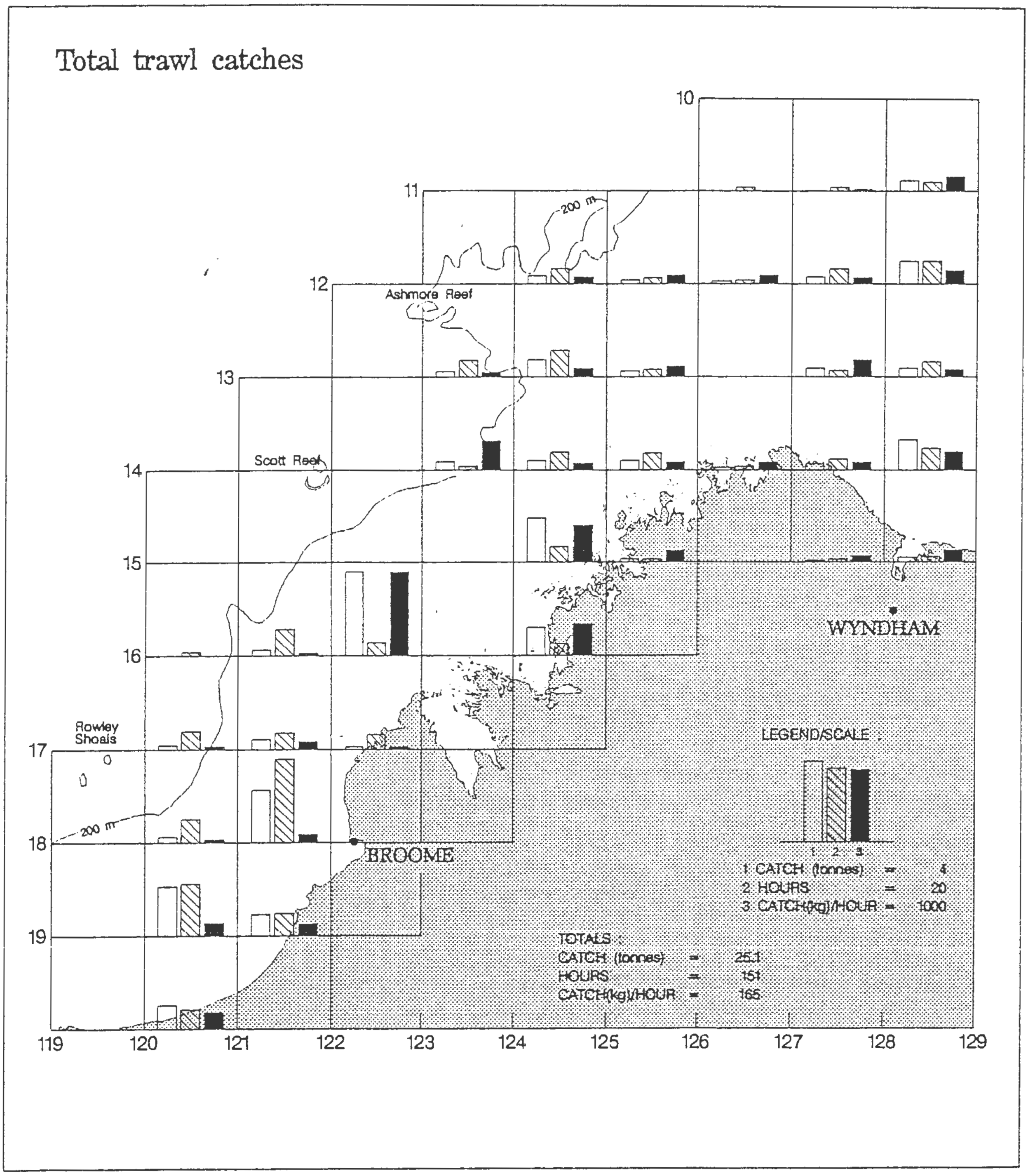


Figure 9.1. Distribution of total catch, effort and catch per hour by CSIRO experimental trawling 1978-1980.

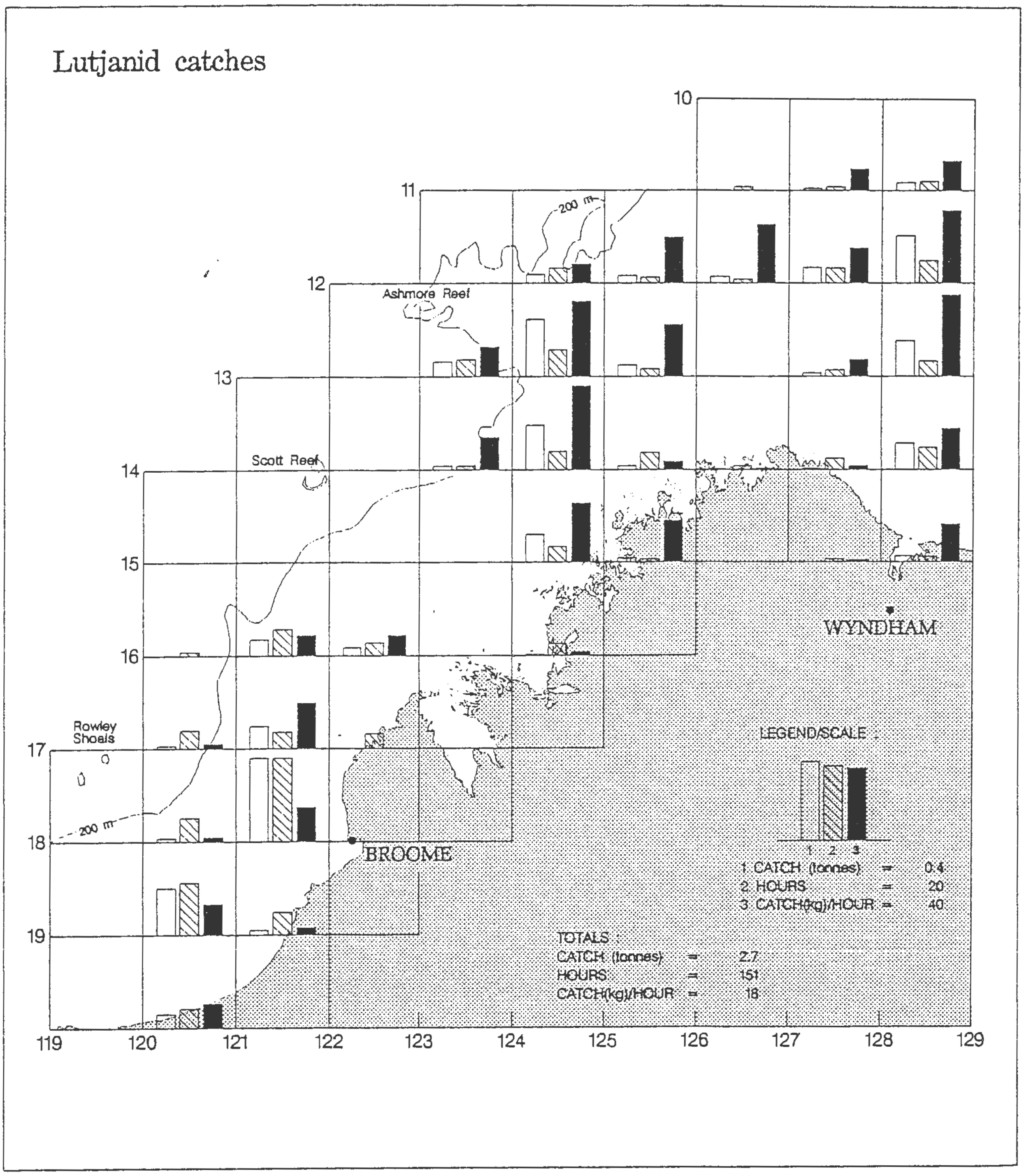


Figure 9.2. Distribution of catch, effort and catch per hour of lutjanids by CSIRO experimental trawling 1978-1980.

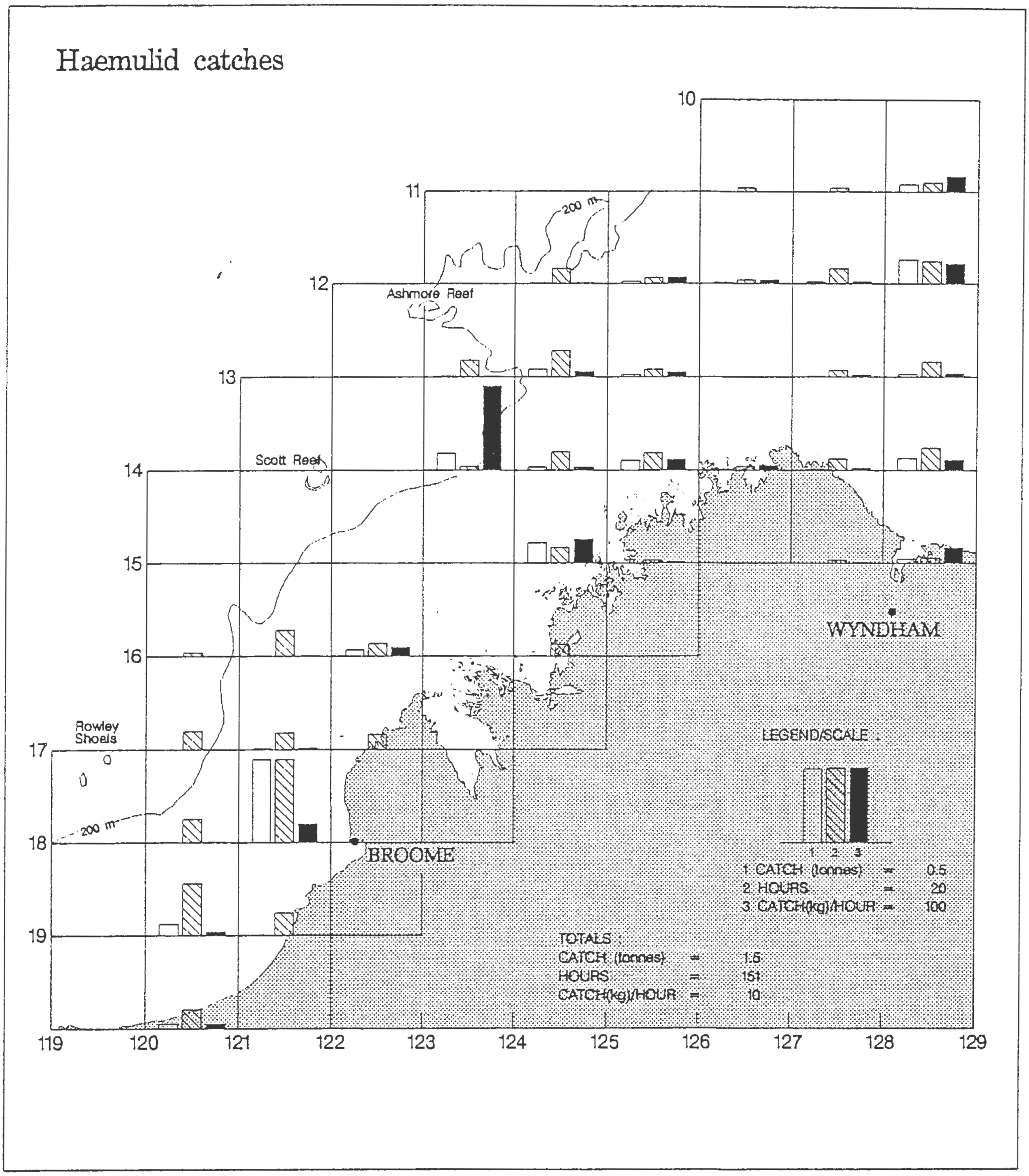


Figure 9.3. Distribution of catch, effort and catch per hour of haemulids by CSIRO experimental trawling 1978-1980.

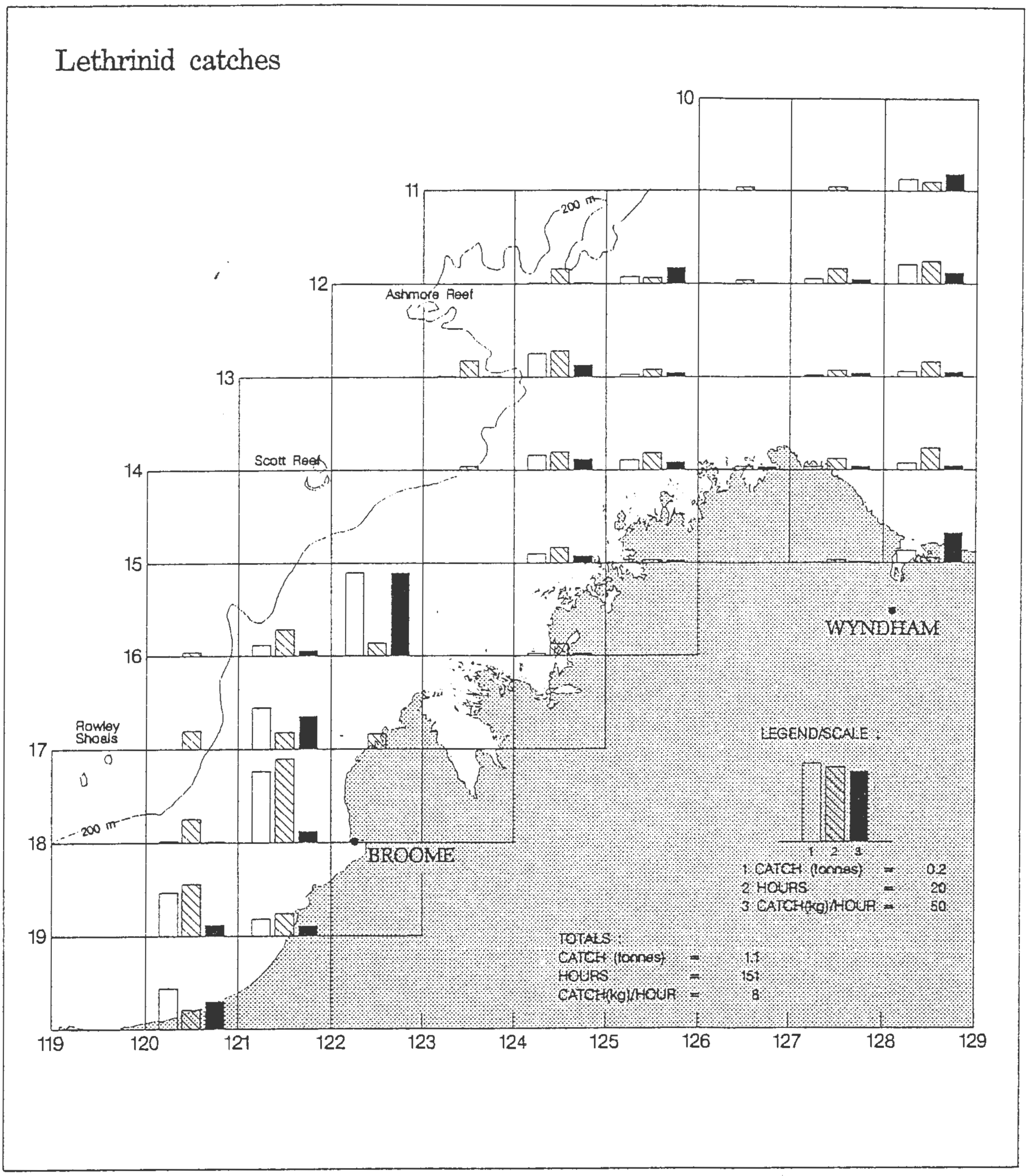


Figure 9.4. Distribution of catch, effort and catch per hour of lethrinids by CSIRO experimental trawling 1978-1980.

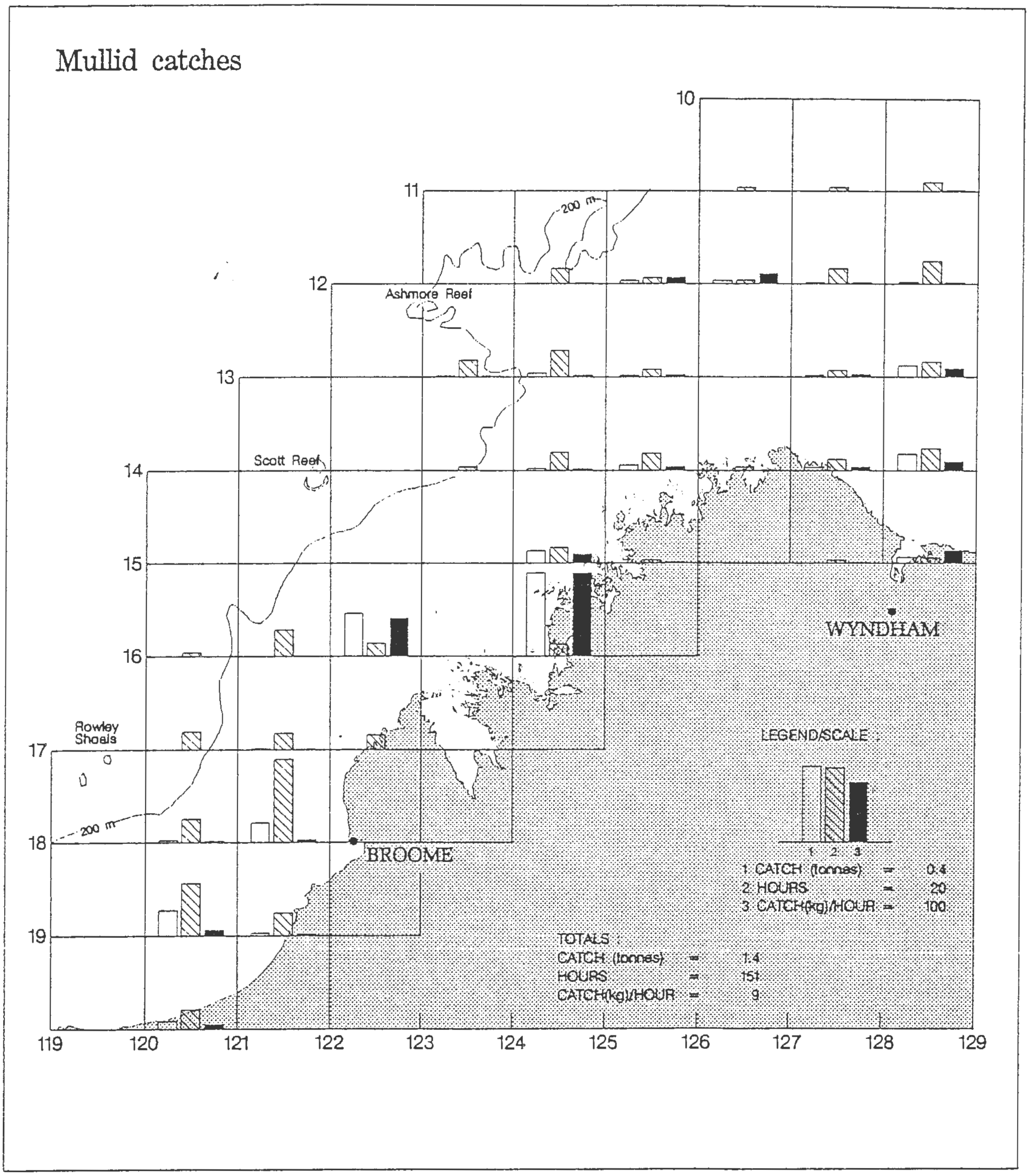


Figure 9.5. Distribution of catch, effort and catch per hour of mullids by CSIRO experimental trawling 1978-1980.

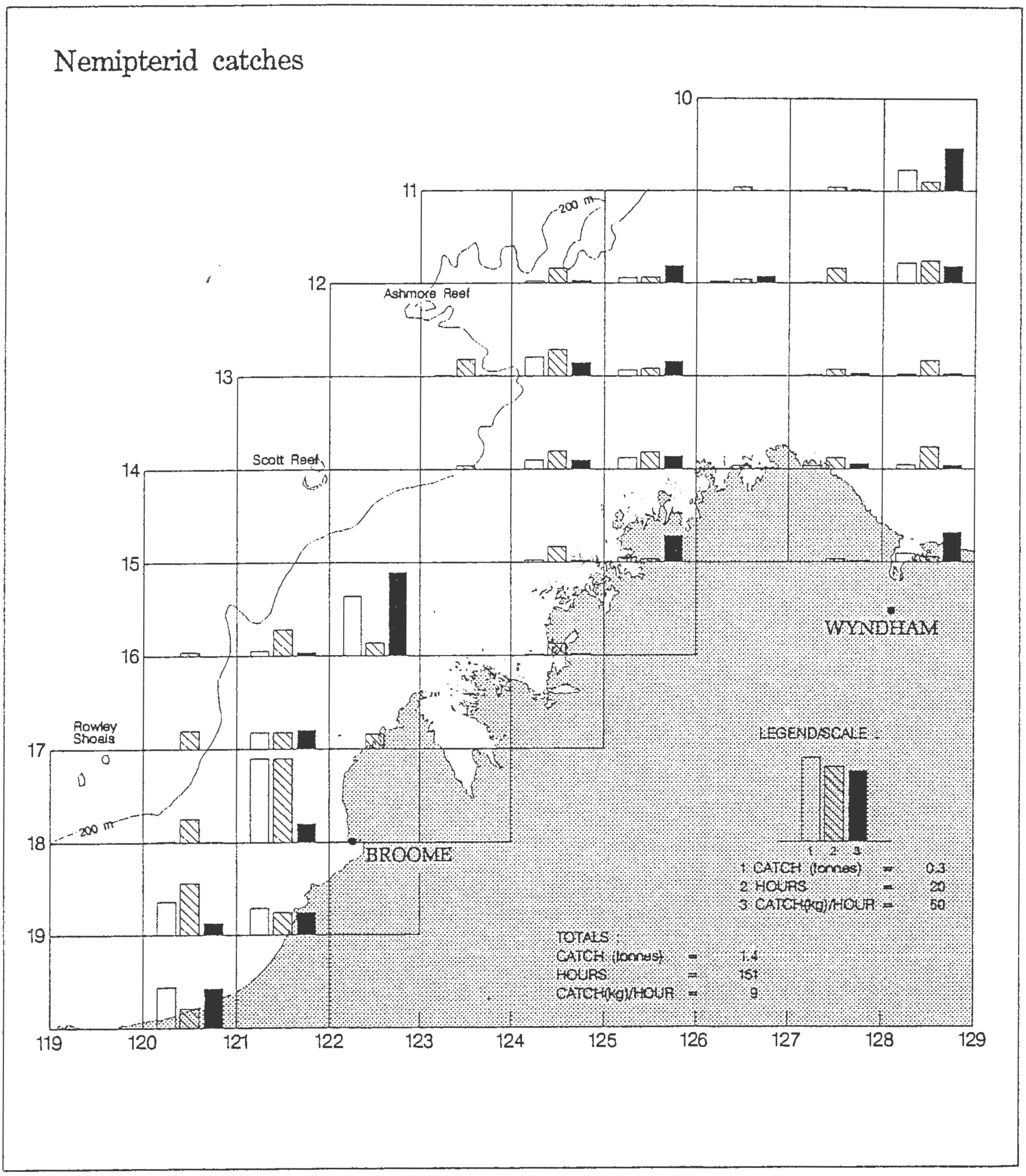


Figure 9.6. Distribution of catch, effort and catch per hour of nemipterids by CSIRO experimental trawling 1978-1980.

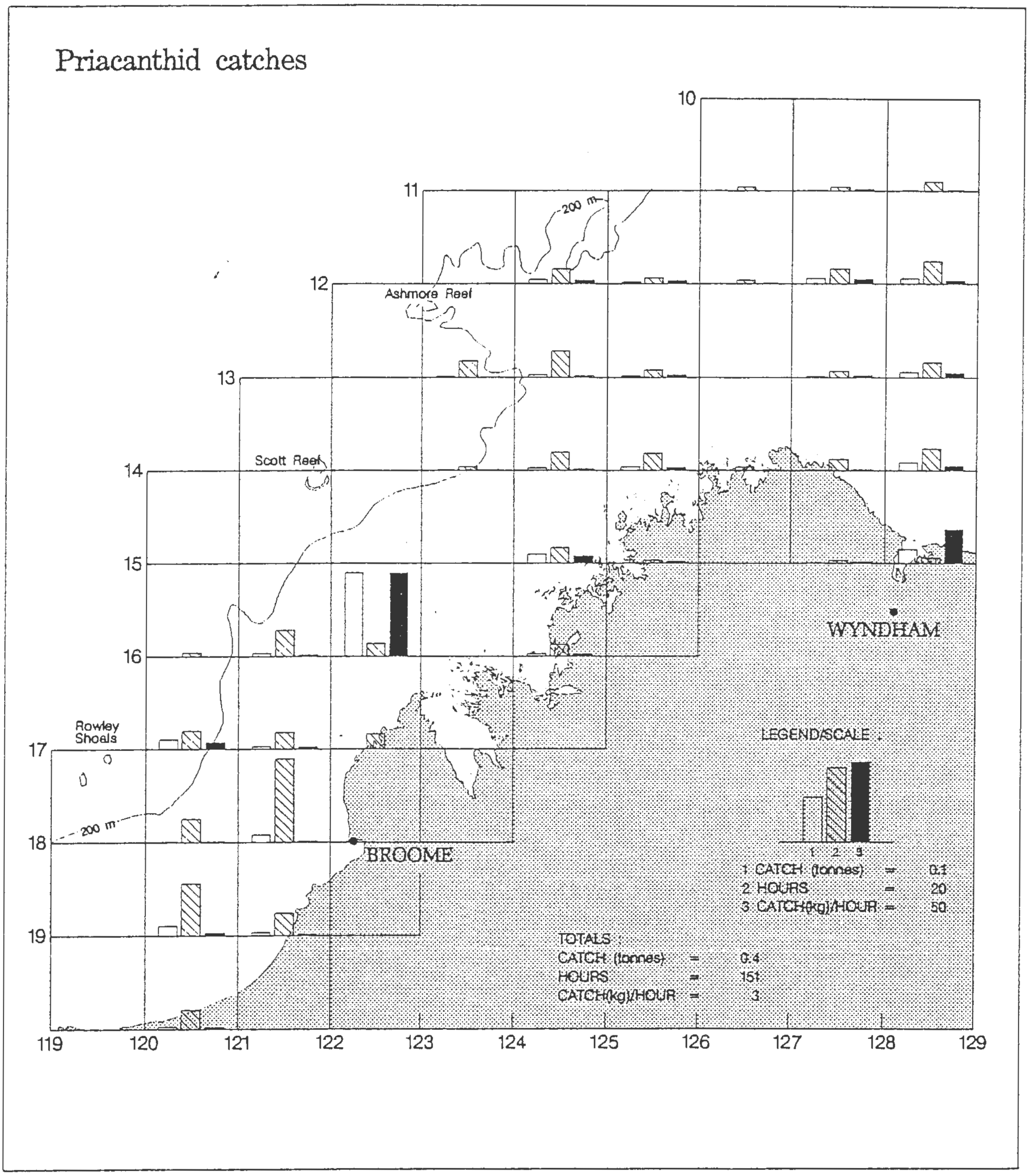


Figure 9.7. Distribution of catch, effort and catch per hour of priacanthids by CSIRO experimental trawling 1978-1980.

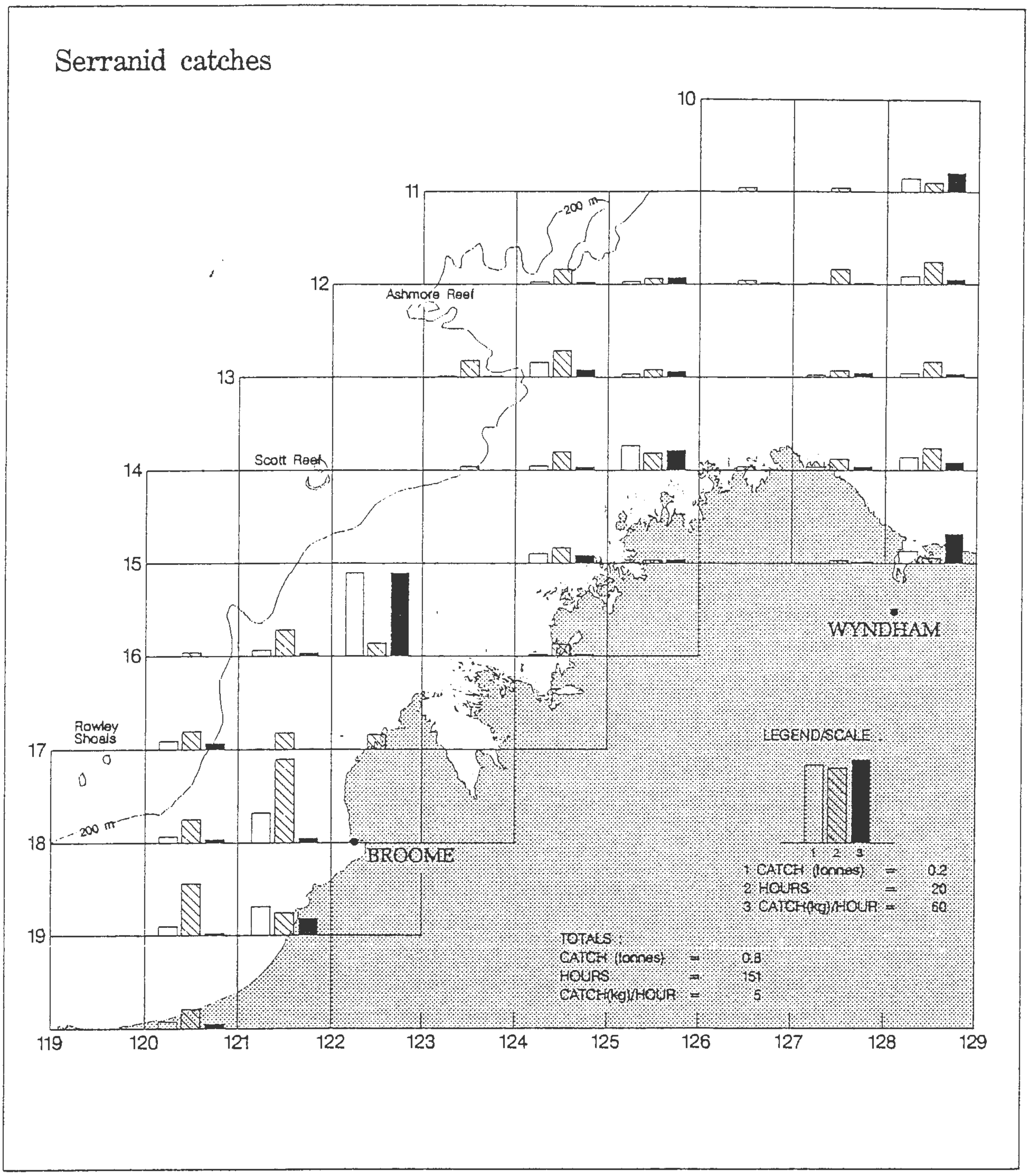


Figure 9.8. Distribution of catch, effort and catch per hour of serranids by CSIRO experimental trawling 1978-1980.

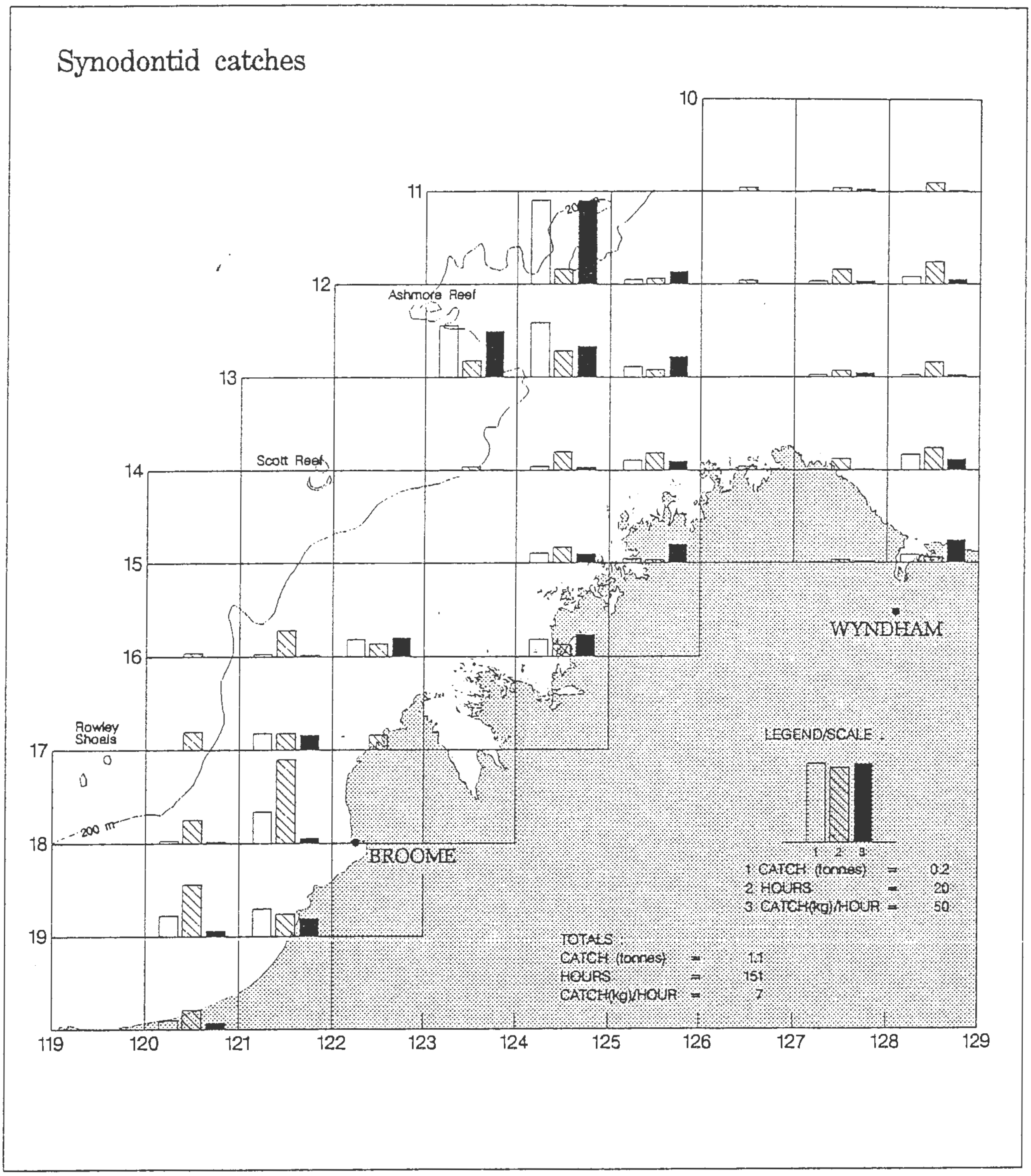


Figure 9.9. Distribution of catch, effort and catch per hour of synodontids by CSIRO experimental trawling 1978-1980.