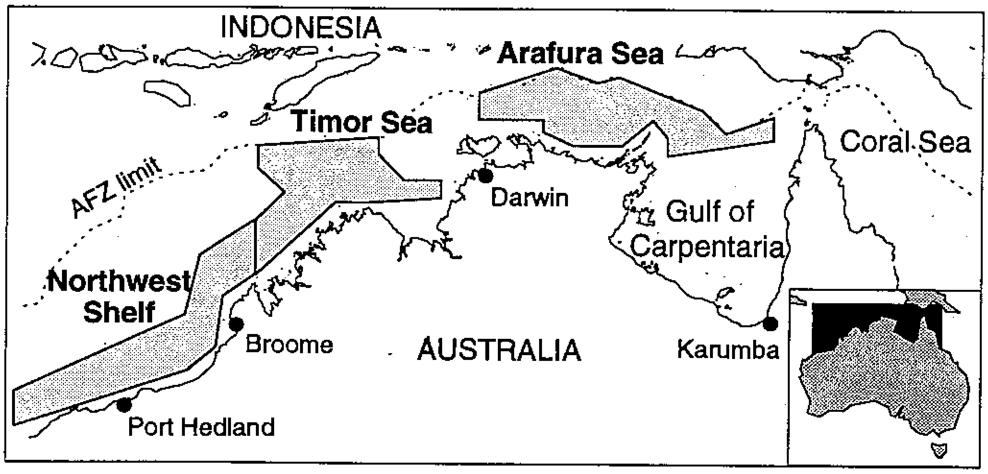
AUSTRALIA'S NORTHERN TRAWL FISHERY

FISHERY REPORT No. 32



DAVID C. RAMM

FISHERIES DIVISION

DEPARTMENT OF PRIMARY INDUSTRY AND FISHERIES

MAY 1994

Northern Territory Government

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SUSTAINABLE FISHERIES

THE DEPARTMENT OF PRIMARY INDUSTRY AND FISHERIES IS COMMITTED TO THE PRINCIPLES AND PRACTICES OF SUSTAINABLE FISHERIES

Definition:

Sustainable fisheries is the use of practices and systems which maintain or enhance:

- the economic viability of fisheries production;
- the natural resource base; and
- other ecosystems which are influenced by fisheries activities.

Principles:

1. Fisheries productivity is sustained or enhanced over the long term.
2. Adverse impacts on the natural resource base of fisheries and associated ecosystems are ameliorated, minimised or avoided.
3. Harmful residues resulting from the use of chemicals for fisheries are minimised.
4. The nett social benefit (in both dollar and non-dollar terms) derived from fisheries is maximised.
5. Fisheries systems are sufficiently flexible to manage risks associated with the vagaries of climate and markets.

SUSTAINABLE FISHERIES IN THE NORTHERN TERRITORY

AUSTRALIA'S NORTHERN TRAWL FISHERY

Final Report to the
Fisheries Research and Development Corporation
on Project 86/049

Assessment of the Status, Composition and Market Potential
of Demersal Trawl Fish Resources in Northern Australian Waters

FISHERY REPORT No. 32

DAVID C. RAMM

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DEPARTMENT OF PRIMARY INDUSTRY AND FISHERIES
GPO BOX 990, DARWIN NT 0801, AUSTRALIA

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CONTENTS

SUMMARY

Ramm, D.C. (1994). Australia's northern trawl fishery. Final report to the Fisheries Research and Development Corporation on project 86/049 "Assessment of the Status, Composition and Market Potential of Demersal Trawl Fish Resources in Northern Australian Waters". Northern Territory Department of Primary Industry and Fisheries. *Fishery Report* **32**, 59pp.

Project 86/049 "Assessment of the Status, Composition and Market Potential of Demersal Trawl Fish Resources in Northern Australian Waters" was funded by the Northern Territory Fisheries Division and grant 86/049 from the former Fishing Industry Research Trust Account during 1986-1990. It aimed to assess the size and extent of groundfish (demersal fish) resources in the northern sector of the Australian Fishing Zone (AFZ) using fishery logbook and observer data. However, most data from 1985 onwards were not being processed, and resulted in major project delays. In 1988, the Fisheries Division initiated processing of northern fish trawl logbooks, and later observer and longline fishery data, under the umbrella of project 86/049 and on behalf of the former Australian Fisheries Service. Logbooks from Taiwanese pair trawlers (1988-90), Thai stern trawlers (1985-90), Chinese pair trawlers (1989) and domestic stern trawlers (1987-93), and northern trawl fishery observer data (1989-90) were processed and analysed as part of project 86/049.

Australia's northern trawl fishery is a multi-species, multi-fleet shelf fishery operating on the Northwest Shelf (114-123°E), and in the Timor (123-129°E) and Arafura (131-142°E) Seas. Groundfish resources have been fished continuously since 1971 by Taiwanese distant-water pair trawlers (length: 36-42m, gross tonnage: 280-350t) which dominated the fishery until 1986 with effort >30000h·year^{-1} mostly on the Northwest Shelf between 116-119°E and 19-21°S, and Arafura Sea between 136-138°E and 9-11°S. Thai stern trawlers (26-42m, 115-350t) fished in the Arafura Sea during 1985-90 with effort >30000h·year^{-1} during 1988-90 mostly between 133-137°E and 10-11°S. Another Chinese pair trawler fleet, from Zhejiang Province, fished on the Northwest Shelf and in the Timor Sea during 1989 with a total effort of 6251h, and a fledgling Australian stern trawl fleet has operated sporadically in the Arafura Sea for a total of 2793h during 1987-90. Licensing of Taiwanese and Thai trawlers in the AFZ was discontinued in 1990 following increased trawling by domestic vessels.

Twenty four commercial catch categories, representing at least 69 species of fish, squid and cuttlefish, were identified from observer data. Most categories were dominated by single species such as *Lethrinus lentjan* (Lethrinidae/emperor), *Lutjanus malabaricus* (red Lutjanidae/red snapper), *Lutjanus vittus* (small Lutjanidae/small snapper), *Nemipterus furcosus* (Nemipteridae/threadfin bream), *Pristipomoides multidens* (goldband Lutjanidae/goldband snapper or jobfish), *Psenopsis humerosa* (butterfish), *Saurida undosquamis* (Synodontidae/lizardfish) and *Trichiurus lepturus* (Trichiuridae/hairtail). Total retained catch for all fleets during 1972-90 was approximately 229000t on the Northwest Shelf, 47000t in the Timor Sea and 126000t in the Arafura Sea. Nemipteridae was the dominant category on the Northwest Shelf (≤8377t·year^{-1}), while red Lutjanidae dominated catches in the Timor (≤1091t·year^{-1}) and Arafura Seas (≤4191t·year^{-1}). Other important categories included Lethrinidae (≤4076t·year^{-1}) and Synodontidae (≤4276t·year^{-1}) on the Northwest Shelf, Carangidae (≤1528t·year^{-1}) in the Timor Sea, and butterfish (≤3057t·year^{-1}) and Nemipteridae (≤2811t·year^{-1}) in the Arafura Sea. Estimation of maximum sustainable yield (MSY) from standardised annual catch and effort data fitted to Walters and Hilborn's difference equation was attempted for all categories and zones, but was obtained only for about 24 of the possible 75 combinations of category and zone. MSY was estimated for 9 categories (e.g. Lethrinidae 5288t·yr^{-1}, red Lutjanidae 1528t·yr^{-1}, Nemipteridae 4520t·yr^{-1}) on the Northwest Shelf, 12 categories (e.g. Lethrinidae 1168t·yr^{-1}, red Lutjanidae 750t·yr^{-1}, Nemipteridae 377t·yr^{-1}) in the Timor Sea, and butterfish (3018t·yr^{-1}) in the Arafura Sea.

Research conducted under project 86/049 identified inadequacies in fishery data and collection methods and provided a catalyst for processing outstanding logbook and observer data, reviewing trawl fishery data collection strategies for AFZ observers and estimating biomass and yield for snappers in the Timor and Arafura Seas through Project 90/015 "Assessment of Demersal Fish Stock in Northern Australian Waters between 127-137°E". The project also provided fundamental fishery data for analysis by stock assessment working groups.

ACKNOWLEDGMENTS

I gratefully acknowledge Messrs Darryl Grey and Bill Anderson, Mrs Christine Julius and Dr Rex Pyne, Fisheries Division, for initiating the project, Dr Yongshun Xiao, Fisheries Division, Dr Keith Sainsbury, CSIRO Division of Fisheries, and Dr Derek Staples, Bureau of Resource Sciences, for their valuable assistance and discussions during analyses, and Mrs Bev Akers and Mr Steve Wilmore, Fisheries Division, for processing and verifying logbook and observer data (1985-92). I also wish to thank AFZ fishery observers, especially Messrs Bill Anderson, Jeff Wessel, Mick Baron and Phil Schubert, Commonwealth Department of Primary Industries and Energy, for collecting logbook and observer data, Dr Rusty Branford, Commonwealth Department of Primary Industries and Energy, for funding data processing and providing management advice, masters and crews of trawlers and observer platforms, including Capt David Tomlinson of RV "Flamingo Bay" (observer platform 1985-88), for their collaboration in acquiring data, and my colleagues at the Fisheries Division for help throughout the project.

This study was funded by the Northern Territory Fisheries Division and the Fisheries Research and Development Corporation (grant 86/049).

BACKGROUND

Project 86/049 "Assessment of the Status, Composition and Market Potential of Demersal Trawl Fish Resources in Northern Australian Waters" was funded by the Northern Territory Fisheries Division and grant 86/049 from the former Fishing Industry Research Trust Account during 1986-1990. The major objective was to assess the size and extent of groundfish (demersal fish) resources in the northern sector of the Australian Fishing Zone (AFZ) using fishery logbook and observer data. These groundfish resources, in international waters prior to the declaration of the AFZ in 1979, had been fished extensively by Japanese stern trawlers during 1959-1963 and by Taiwanese pair trawlers during the 1970s. Taiwanese vessels continued trawling under licence after 1979, and in 1985 Thai stern trawlers based in Darwin began fishing in the Arafura Sea under a joint-venture agreement. Licensing of Taiwanese and Thai trawlers in the AFZ was discontinued in 1990 following increased trawling by domestic vessels. Management of the fishery has been under Commonwealth jurisdiction since 1979, but may be transferred to the Northern Territory in 1995 following review of the Offshore Constitutional Settlement agreement.

In 1987, at the start of the project, fishery logbook data and limited observer data were available from the former Commonwealth Australian Fisheries Service for Taiwanese pair trawlers fishing during 1979-1985. Taiwanese catch and effort data prior to 1979 were available from the Kaohsiung Fishingboat Commercial Guild, Kaohsiung, and Demersal Fish Research Center, Institute of Oceanography, National Taiwan University, Taipei; Edwards (1983) and Sainsbury (CSIRO, GPO Box 1538 Hobart 7001 Australia, unpub. data) summarised these data. Over the study period, fishing effort by Thai stern trawlers increased rapidly in the Arafura Sea, and this fleet dominated groundfish trawling in the northern AFZ during the late 1980s. Unfortunately, AFZ logbook data for this fleet were not able to be processed in real time by the former Commonwealth Australian Fisheries Service, and lead to major project delays. In 1988, the Fisheries Division initiated processing of northern demersal fisheries data under the umbrella of project 86/049 and on behalf of the former Australian Fisheries Service. A Memorandum of Understanding was signed in 1989, and the Fisheries Division processed and verified logbook data for Taiwanese pair trawlers (1988-90), Thai stern trawlers (1985-90), Chinese pair trawlers (1989) and domestic stern trawlers (1987-93), and northern trawl fishery observer data (1989-90). The Fisheries Division also entered logbook data for Taiwanese demersal longliners (1990-91) and northern longline fishery observer data (1990-91). Trawl data collected until 1990 were analysed in project 86/049.

Project findings are reported here as a collation of three papers, a fishery status report and an industry article either published, or submitted for publication:

- Ramm, D.C., and Xiao, Y. (in press). Demersal fisheries in northern Australia. Proceedings of the 3rd Asian Fisheries Forum, Singapore, 1992. Presented by Ramm. See pages 5-8.
- Ramm, D.C. (1989). The demersal trawl fishery of the Arafura Sea. In "Proceedings of the Mexico - Australia Workshop on Marine Sciences, July 6-17 1986" (Ed. E.A Chavez). pp. 317-22. Presented by Sainsbury, CSIRO Division of Fisheries, Hobart. See pages 9-21.
- Ramm, D.C., and Xiao, Y. (submitted). Catch, effort and yield in Australia's northern trawl fishery. Proceedings of the International Workshop on Tropical Groupers and Snappers, Campeche, 1993. Presented by Ramm. See pages 22-35.
- Anon (1992). Northern Fish Trawl. Fishery Status Report, Bureau of Rural Resources, Canberra. See pages 36-39.
- Ramm, D.C. (submitted). Estimation of biomass and fishery yield for snapper stocks in northern Australian waters. Northern Territory Fishing Industry News, Darwin. See pages 40-42.

Project findings also contributed to the book "Australian Fisheries Resources" (Kailola, Williams, Stewart, Reichelt, McNee and Grieve, Bureau of Resource Sciences and Fisheries Research and Development Corporation, 1993) and provided fundamental fishery data for analyses by stock assessment working groups convened by the former Australian Fisheries Service and the Australian Fisheries Management Authority, including:

- Sainsbury, K., Campbell, R., Klaer, N., McLoughlin, K., Ramm, D., and Reichelt, R. (1990). Fisheries Assessment Working Group Report, Northern Fisheries Research Committee, Canberra.
- Sainsbury, K., Campbell, R., Brewer, D., Harris, A., McLoughlin, K., Ramm, D., Staples, D., Xiao, Y., and Knuckey, I. (1991). Trawl Fisheries Assessment Working Group Report, Northern Fisheries Research Committee, Canberra.
- Blaber, S., Staples, D., McLoughlin, K., Newton, G., Campbell, R., Brewer, D., Stevens, J., Ramm, D., Buckworth, R., Slack-Smith, R., Hall, N., Johnson, G., Adisukresno, S., Naamin, N., Badrudin, M., and Muchsin, I. (1992). Stock Assessment Working Group Report, Australia-Indonesia Workshop on Arafura Sea Fisheries, 9-13 November 1992, Darwin.

Project findings are also regularly supplied in response to industry requests for data and information, and have been presented at industry, scientific and public meetings including:

- Fisheries Research and Development in the Northern Territory (Jan 1992 and Dec 1992);
- Pre-Season NORMAC Workshop (1991);
- stock assessment working groups (1987-1992);
- AFZ Observer Programme working group meetings (1988, 90);
- annual conferences of the Australian Society for Fish Biology (1988, 89, 90, 91);
- annual conferences of the Australian Marine Science Association (1990);
- Mexico - Australia Workshop on Marine Sciences (Merida, 1986);
- 3rd Asian Fisheries Forum (Singapore, 1992);
- International Workshop on Tropical Groupers and Snappers (Campeche, 1993);
- Fisheries Seminar at University of British Columbia (Vancouver, 1994);
- ABC TV News and The 7^{30} Report (1990, 92); and,
- public and school presentations (eg Anula Primary School, Casuarina High School).

Research conducted under project 86/049 identified inadequacies in fishery data and collection methods and provided a catalyst for:

- processing outstanding logbook and observer data (see pages 43-46);
- reviewing trawl fishery data collecting strategies for AFZ observers (see pages 47-58); and,
- estimating biomass and yield for snappers in the Timor and Arafura Seas through Project 90/015 "Assessment of Demersal Fish Stock in Northern Australian Waters between 127-137°E" with funding from the Fisheries Division, Fisheries Research and Development Corporation (grant 90/015) and Australian Fisheries Management Authority (see page 59).

Project findings will also contribute to a new project "Collation and Analysis of Fishery Data from the Australian and Indonesian Sectors of the Arafura Sea" jointly conducted by the Fisheries Division and Bureau of Resource Sciences, with financial support by the Australian Fisheries Management Authority during 1994-95.

DEMERSAL FISHERIES IN NORTHERN AUSTRALIA

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Paper presented by Ramm at the 3rd Asian Fisheries Forum, Singapore, 1992, and in press in the Forum proceedings.

Abstract

Demersal fisheries in Australia's northern waters (114-142°E) harvest up to 72000t·yr^{-1}, mostly trawl caught crustacean and fish. Target species vary with market demands, and include fish of the genera *Carcharhinus*, *Lutjanus*, *Nemipterus*, *Pristipomoides*, *Psenopsis* and *Saurida*, mud crab *Scylla serrata*, pearl oyster *Pinctada maxima*, and prawns of the genera *Metapenaeus* and *Penaeus*. Most fisheries operate in narrow depth zones along an inshore-offshore gradient: trapping for mud crabs in estuaries; trawling for penaeids in depths of 20-40m; diving for pearl oysters on offshore banks (30-40m); trawling for fish (50-90m); and fishing for deepwater snapper and crustacean near the shelf break.

Introduction

The first commercial demersal fishery in northern Australian waters may be traced to the 1700s, when Macassan fishermen from Sulawesi, Indonesia, visited coastal areas in search of bêche-de-mer (MacKnight, 1976). A century later, hardhat divers began harvesting silverlip pearl oyster, *Pinctada maxima* (Brownfield, 1953). Demersal fish resources on the Northwest Shelf were explored and fished by Japanese trawlers during 1959-63 (Suzuki *et al*, 1964; and, Robins, 1969 in Sainsbury, 1987). Intensive fishing in northern Australia began with Taiwanese pair trawlers in the Arafura Sea in 1971 (Liu *et al*, 1978). Later the fleet operated west and south to the Northwest Shelf. By 1974, finfish catches from northern Australia accounted for 64% of the total Taiwanese pair trawler catches (Liu, 1976). The 1970s also saw the development of a trawl fishery for penaeid prawns in the Gulf of Carpentaria.

Catch and effort statistics for Australian fisheries, and data on fishing operations and target species, are maintained by a wide variety of research organisations, and reflect Australia's constitutional arrangements for fishery management. Most of these data are not readily available in the literature. Here, we draw together information from Federal, State and Territory fishery agencies, and present the current (1990-92) status of demersal fisheries in northern Australian waters, between Northwest Cape (22°S, 114°E) and Cape York (11°S, 142°E). These waters include the Australian sectors of the Timor and Arafura Seas, Northwest Shelf, Gulf of Carpentaria and Torres Strait (Fig. 1). Detailed catch and effort data are presented for 3 major fisheries: Northern Prawn; Northern Fish Trawl; and Pearl Oyster.

Current Status of Demersal Fisheries

Demersal fisheries in northern Australia with catches ≥200t·yr^{-1} are listed in Table 1. The total landed value is currently estimated at \$A278m·yr^{-1}, and catches include 13740t·yr^{-1} of penaeid prawns and 7795t·yr^{-1} of fish. Many of the smaller fisheries (<500t·yr^{-1}) are in a developmental phase. For example, annual catches in the Timor Sea Reef Fishery increased from 29t in 1987, to 360t in 1991, with the development of fishing techniques and markets for the target species *Pristipomoides multidens* (Ramm, unpub data). Most fisheries operate in narrow depth zones along an inshore-offshore gradient. Trapping for mud crabs occurs in estuaries, while penaeids are generally trawled in depths of 20-40m. Pearl oysters are taken from offshore banks by diving to 30-40m. Further offshore, demersal fish are harvested in depths of 50-90m on the Northwest Shelf, and in the Timor and Arafura Seas. The Timor Sea Reef Fishery operates in depths of 120-180m, and trawlers in the Northwest Slope Fishery fish off the continental shelf in depths of 300-600m.

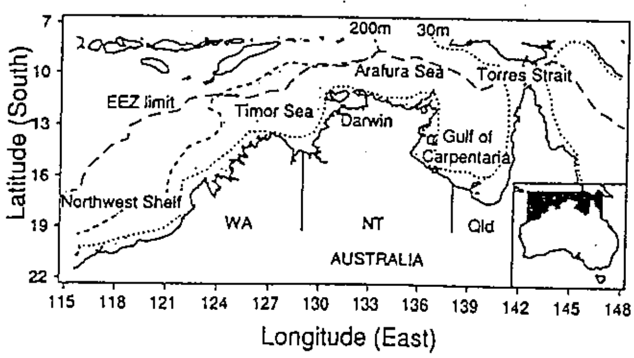

Figure 1. Northern Australian waters adjacent to Western Australia (WA), Northern Territory (NT) and Queensland (Qld). Major fishing grounds, EEZ boundary, and 30m and 200m isobaths are indicated.

Table 1. Current status of demersal fisheries in northern Australian waters between 114-142°E. The fishing regions are: Northwest Shelf (NwS), Timor Sea (TiS), Arafura Sea (AS), Gulf of Carpentaria (GoC) and Torres Strait (ToS). The major region for each fishery is underlined. Sources of information are listed below.

Fishery	Gear	Region	Target Species	Annual Catch	Value $A
Northern Prawn	trawl (twin rig)	GoC AS TiS	*Penaeus* spp *Metapenaeus* spp	12040t[a]	115m[b]
Torres Strait Prawn	trawl (twin rig)	ToS	*Penaeus* spp	1700t[b]	13m[b]
Northern Fish Trawl	trawl (stern)	AS NwS TiS	*Lutjanus* spp *Lethrinus* spp	6700t[c]	7m[c]
Northwest Slope	trawl (stern)	NwS	*Metanephrops australiensis* deepwater penaeids and carids	220t[b]	2m[b]
Pearl Oyster	diving	NwS TiS AS ToS	*Pinctada maxima*	600000shell[d,e]	129m[b]
Torres Strait Rock Lobster	diving	ToS	*Panulirus ornatus*	200t[b]	4m[b]
Timor Sea Reef	trap dropline	TiS	*Pristipomoides* spp	360t[c]	2m[c]
Northwest Shelf Trap	trap	NwS	*Lutjanus* spp *Lethrinus* spp	460t[f]	3m[f]
Northwest Shelf Line	line	NwS	*Carcharhinus* spp	275t[f]	1m[f]
Mud Crab	trap	estuaries	*Scylla serrata*	300t[e,g]	3m[e]

[a]Margot Sachse, Australian Fisheries Management Authority, pers comm, November 1992; [b]Anon (1992); [c]Ramm, unpub data; [d]Lindsay Joll, WA Fisheries Department, pers comm, November 1992; [e]Rosemary Lea, NT Department of Primary Industry and Fisheries, pers comm, December 1992; [f]Mike Moran, WA Fisheries Department, pers comm, November 1992; [g]Ian Knuckey, NT Department of Primary Industry and Fisheries, unpub data.

Northern Prawn Fishery

The Northern Prawn Fishery (NPF) is one of Australia's most valuable fisheries, with annual landings currently valued at A$115m (Anon, 1992). This trawl fishery operates predominantly in the inshore waters (mostly <40m) of the Gulf of Carpentaria (136-142°E). Fishing also extends westwards, through the inshore region of the Arafura Sea, to waters up to 100m deep in Joseph Bonaparte Gulf (127-130°E). The NPF has two distinct and successive operational phases: a target fishery for banana prawns *Penaeus merguiensis* during April - May; and, a mixed species fishery for tiger prawns *P. esculentus* and *P. semisulcatus*, and to a lesser extent endeavour prawns *Metapenaeus ensis and M. endeavouri* and king prawn *P. latisulcatus*. The mixed species fishery also catches Indian banana prawn *P. indicus* in Joseph Bonaparte Gulf. Trawlers range from 13-28m in length and tow twin prawn nets with headline lengths ≤25m (Sachse 1992). All vessels process prawns on board into 3-10kg freezer packs; product is mostly exported to Japan and Europe.

Annual catches vary markedly (Fig. 2), with 7000t of banana prawns, and 4000t of tiger prawns landed in 1991 (Sachse, 1992). Such fluctuations in catches may be related to environmental and biological variables (eg Staples, 1985). Bycatch is an important component of the catches. Bycatch to prawn ratios during the mixed species fishery ranged from 8-21:1 with fish dominating the catches (≤228kg·h^{-1}), and the total catch of bycatch during the 1988 mixed species fishery was estimated at 47000t (Ramm *et al*, 1990; Pender *at al*, 1992); 97% of the bycatch was discarded at sea. Selective methods of harvesting tiger prawns

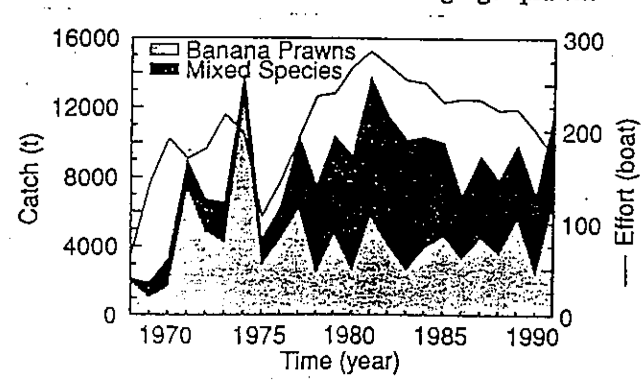

Figure 2. Annual variations in catch (t) of banana prawns and mixed species, and effort (boat) in the Northern Prawn Fishery. Sources: Somers and Taylor (1981); Sachse (1992); Margot Sachse, pers comm.

are being investigated (Buckworth and Cann, in press). Trawling during the target fishery for banana prawns is highly selective, with little bycatch being caught.

The NPF is managed by input controls including: limited entry; defined fishing seasons (April-June, August-November) and grounds; daylight fishing bans; buy-back schemes; unitisation; and, gear restrictions. The current management strategy aims to decrease effort in the fishery by reducing the fleet to about 130 vessels by 1993.

Northern Fish Trawl Fishery

The Northern Fish Trawl Fishery (NFTF) is a multi-species shelf fishery operating on the Northwest Shelf (114-123°E), and in the Australian sectors of the Timor Sea (123-129°E) and Arafura Sea (131-142°E). Intensive fishing by Taiwanese pair trawlers occurred on the Northwest Shelf during the 1970s. Foreign fleets continued fishing under licence agreements following the ratification of Australia's Exclusive Economic Zone (EEZ) in November 1979: Taiwanese pair trawlers (1979-90); Thai-Australian stern trawlers (1985-90, Arafura Sea only); and, Chinese pair trawlers (1989, Northwest Shelf and Timor Sea). Fishing was intensive on the Northwest Shelf during the 1970s peaking at 79860h in 1974, with a marked shift in effort to the Arafura Sea grounds during the 1980s (max 61238h in 1989) (Ramm and Sainsbury, unpub data). However, fluctuations in effort should be interpreted cautiously due to marked variations in fishing powers between fleets, and gear (eg pair trawling vs stern trawling). Small domestic fleets presently operate on the Northwest Shelf (17600h in 1991, Mike Moran, WA Fisheries Department, pers comm, November 1992) and in the Arafura Sea (3600h in 1991, Ramm, unpub data).

Total annual retained catches peaked at 37100t on the Northwest shelf in 1973, and 10000t in the Arafura Sea in 1983 (Fig. 3). Up to 24 commercial categories of fish have been recorded in the NFTF (Sainsbury, 1987; Ramm and Sainsbury, unpub data). The major categories on the Northwest Shelf are *Nemipterus* spp ($\leq$8400t·yr^{-1}), *Saurida* spp ($\leq$4300t·yr^{-1}), *Lethrinus* spp ($\leq$4100t·yr^{-1}) and *Lutjanus* spp ($\leq$3900t·yr^{-1}), and in the Arafura Sea *Lutjanus* spp ($\leq$4500t·yr^{-1}), butterfish *Ariomma indica* and *Psenopsis humerosa* ($\leq$3400t·yr^{-1}), *Nemipterus* spp ($\leq$2800t·yr^{-1}) and *Saurida* spp ($\leq$1200t·yr^{-1}). Trawling effort in the Australian sector of the Timor Sea has been low ($\leq$8700h·yr^{-1}), and the main categories are *Lutjanus* spp ($\leq$1600t·yr^{-1}) and carangids ($\leq$1500t·yr^{-1}).

Sainsbury (1987) concluded that intensive fishing with conventional demersal trawls on the Northwest Shelf during the 1970s resulted in a shift in community structure: *Lutjanus* and *Lethrinus* spp were replaced by *Nemipterus* and *Saurida* spp; the overall biomass remained constant. Intensive trawling, and associated removal of benthos may be related to changes in the demersal ichthyofauna. These structural changes, and an increased market demand for red snappers (*Lutjanus malabaricus, L. erythropterus, L. sebae*) contributed to the shift in effort to the Arafura Sea during the late 1980s. The NFTF within this area has now developed into a fishery for red snappers; most other components are discarded. Mindful of the Northwest Shelf experience, the use of semi-pelagic trawls for selectively fishing red snappers was investigated (Ramm *et al*, in press), and introduced to the fledging domestic fleet as a management measure to reduce damage to the benthos caused by conventional trawls.

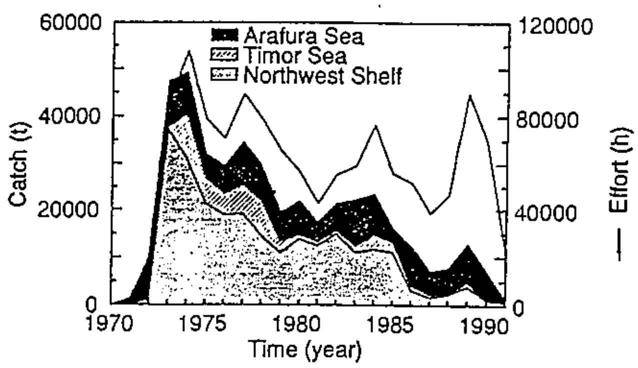

Figure 3. Annual variations in catch (t) on the Northwest Shelf and the Australian sectors of the Timor and Arafura Seas, and effort (h) in the Northern Trawl Fishery. Sources: logbook and observer data; Sainsbury (1987); Mike Moran, pers comm; and, Ramm and Sainsbury, unpub data.

Pearl Oyster Fishery

The Pearl Oyster Fishery is one of Australia's oldest and richest fisheries. Silverlip pearl oysters *Pinctada maxima* were harvested by divers for mother-of-pearl on the Northwest Shelf, Darwin Harbour and in Torres Strait during the late 1800s. By 1900, Broome (18°S, 122°E) was a major pearling centre. Trends in catch and effort are confounded by changes in fishing power (eg mechanisation in the 1930s), cyclones, World Wars, and the dwindling demand for mother-of-pearl following the introduction of plastics in the 1940s (Brownfield, 1953; Dybdahl and Rose, 1986; Colgan and Reichelt, 1990). In 1955, the industry was restructured, and pearl culture farms were established based on Japanese techniques (eg Mizumoto, 1979).

The fishery is now centered on the harvest of culture shell from the Broome area in depths of 10-37m (Fig. 4). Shells are also harvested further west (114-118°E, catch: 35-50000 shell·yr^{-1}, Lindsay Joll, WA Fisheries Department, pers comm, November 1992), and in waters adjacent to the Northern Territory (mostly 129-135°E, quota: 120000 shell·yr^{-1}, Rosemary Lea, NT Department of Primary Industry and Fisheries, pers comm, December 1992). Suitable shells are transported to coastal farms near Broome, Darwin or Coburg Peninsula (11°S, 132°E) for culture. The current annual value of pearl oyster catches and pearl culture is estimated at $A129 million (Anon, 1992).

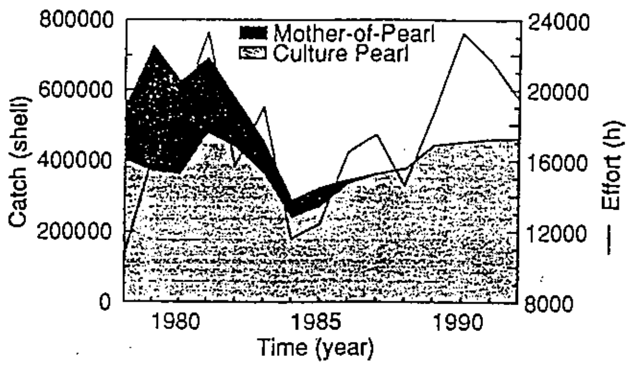

Figure 4. Annual variations in catch (shell) and effort (h) in the Pearl Oyster Fishery in the Broome area. Source: Lindsay Joll, pers comm.

Conclusion

Australia's northern demersal fisheries are either fully exploited (NPF, Pearl Oyster), or undergoing development. The NFTF was considered fully exploited in 1990; however fishing effort in the Arafura Sea was dramatically reduced during 1991-92 following the departure of foreign fishing fleets and marketing difficulties encountered by the fledging domestic fleet. Difficulties in marketing tropical fish, which also apply in the Timor Sea Reef Fishery, are related to factors such as: the remoteness of fishing grounds; freight costs to markets in southern Australia or overseas; continuity of supply; and, poor Australian consumer acceptability and/or awareness of tropical fish.

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THE DEMERSAL TRAWL FISHERY OF THE ARAFURA SEA

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ABSTRACT

Since the declaration of the Australian Fishing Zone in 1979, the demersal resources of Northern waters, including the Arafura Sea, have been exploited by Taiwanese and Thai trawlers. The important taxa in the fishery of the Arafura Sea include members of the Centrolophidae, Haemulidae, Lutjanidae and Nemipteridae. In 1986, the retained catch from trawlers operating in the Northern waters of Australia was approximately 20 x 10^3 t; the quota for this region is 35 x 10^3 t,

A study is underway to provide information for the management of the demersal resource of the Arafura Sea, and the development of the fishery. The study focusses on understanding the ecology of abundant taxa and the markets available to the product; and would benefit greatly from collaboration with similar studies in other tropical regions.

INTRODUCTION

The demersal resource of the continental shelf off Northern Australia has been harvested commercially by Japanese, Taiwanese and Thai vessels since the early 1930's. Other nations, including Australia, Korea and Russia, have surveyed the trawling grounds in this region. Since the declaration of the Australian Fishing Zone (AFZ) in November 1979, the resource within the Australian sector of the Arafura Sea has been exploited by Taiwanese pair trawlers and, recently, by Thai stern trawlers. Australian operators have expressed an interest in the resource, although only fishing trials have been conducted to date. Fishing within the AFZ is monitored by government agencies using log books, radio reports and observers. The observers board the trawlers regularly and gather detailed data, such as the composition of the total catch at the level of species and the mean weights of individuals of the dominant species, which are not recorded routinely during commercial operations. These kinds of data are vital for the management of the demersal resource.

This paper focusses on the exploitation of, and ongoing research on, the demersal resource of the Australian sector of the Arafura Sea (Fig. 1). The data on the catches by Taiwanese and Thai trawlers during 1985 and 1986 were collected by the AFZ observers.

PHYSICAL ASPECTS OF THE ARAFURA SEA

During the wet season (November-March), prevailing winds from the North West drive the surface waters in the Arafura Sea eastward (Newell, 1973), thus forming regions of the upwelling off the Australian coast (Cushing, 1975). The temperature of the water during this period ranges approximately from 29-30°C at the surface, to 27-28°C at a depth 60 m (RRC Edwards pers. obs., February 1982). During the dry season (May-September), the winds are usually from the South East, and temperatures range from 25-26°C at the surface, to 23°C at 50 m (Newell, 1973).

The Australian sector of the Arafura Sea covers an area of about 212 x 10^3 km^2 (Edwards, 1983). Most of the substrate within this sector lies at depths of 50-70 m, and consists of muddy sand with isolated patches of hard substrate dominated by sessile invertebrates. Similar morphological features exist beyond the limit of the AFZ.

EXPLOITATION OF THE RESOURCE

Taiwanese Fleet

Taiwanese pair trawlers have fished in the Arafura Sea since 1971. The fishing effort during 1985/86 was concentrated between 133°00' - 137°00' East and 9°30' - 11°00' South (Fig. 1). The vessels are made of steel and up to 500 t in size, and operate a net with a head rope of about 100 m, an opening height of 6-12 m and a mesh size of 60 mm in the cod-end (Liu, 1976; Sainsbury, 1984a; Edwards, unpubl ms.). In the Arafura Sea, fishing is confined to daylight and averages five shots per day, with the net hauled alternatively on to vessels in each pair. The net is towed for a mean duration of 2.1 - 2.3 h (Table 1a) with the vessels steaming 250 - 400 m apart (D. Tomlinson, pers. obs., April 1987). The rate at which the net sweeps the substrate is estimated at 0.33 - 0.37 km^2/h (Liu, 1976; Edwards, 1983), and the mean catch rates during 1985/86 were around 800 kg/h (Fig. 2a). Once on deck, the catch is sorted into commercial categories, washed, and frozen either whole or headed in boxes of 28-37 kg (Table 1a); fish not retained by the vessel (trash) are dumped overboard. The mean proportion of the catch retained by the vessels increased significantly from 45% of the total catch in 1985, to 57% in 1986 (Fig. 2a, Table 1a). The dominant taxon in the retained catch was Lutjanidae (mostly *Lutjanus malabaricus*), and other important taxa included: Ariommatidae (*Ariomma indica*); Carangidae; Carcharhinidae, Centrolophidae (*Psenopsis humerosa*); Dasyatididae; Haemulidae (*Diagramma pictum*); Hemigaleidae; Lethrinidae (mostly *Lethrinus lentjan*); Nemipteridae; Sciaenidae; Sepiidae (cuttlefish); Serranidae; Synodontidae; and Trichiuridae (Fig. 3). Species recorded commonly within these families are listed in Appendix 1. The proportion of important taxa in the retained catch (Fig. 4a), and the relative abundance of Lutjanidae (Fig. 5) varied during 1986. It is likely that these fluctuations reflect spatial or seasonal variations, or both, in the abundance of important taxa. The biomass of fish retained by the Taiwanese fleet operating in the Northern waters of the AFZ, including the Arafura Sea, is estimated presently at 15.9 x 10^3 t/yr (R. Lea, pers. comm., April 1987).

THAI FLEET

Thai stern trawlers have operated in the Arafura Sea since November 1985, and their fishing effort is concentrated between 133°00' - 136°00' East and 10°00' - 11°00' South (Fig. 1). The vessels are made of wood, are up to 300 t in size and tow a net with a head rope of 44-68 m, an opening height of 5-6 m, and a mesh size of 60 mm in the cod-end (W. Siriachi, pers. comm., April 1987). The trawlers operate throughout the day, towing the net for a mean duration of 3.6 h (Table 1b), and averaging six shots per day. The catch is sorted into commercial categories, washed, and frozen whole in boxes of 18 - 22 kg (Table 1b). The mean catch rates during 1985-86 were approximately 250 kg/h (Fig. 2b), with some 65% of the total catch retained (Table 1b). The dominant taxon in the retained catch was Lutjanidae (mostly *Lutjanus malabaricus*), and other important taxa included: Ariidae (*Arius thalassinus*); Carangidae, Carcharhinidae, Dasyatididae, Formionidae (*Apolectus niger*); Haemulidae (*Diagramma pictum*); Hemigaleidae; Lethrinidae (mostly *Lethrinus lentjan*); Mullidae; Nemipteridae; Priacanthidae; Sepiidae; Serranidae; Sphyraenidae; and Synodontidae (Fig. 6). The proportion of important taxa in the retained catch (Fig. 4b), and the relative abundance of Lutjanidae (Fig. 7) showed little variation during 1986. The biomass of fish retained by the Thai fleet up to March 1987 was estimated at 4.3 x 10^3 t (R. Lea, pers. comm., April 1987).

RESEARCH AND MANAGEMENT

Tropical demersal trawl fisheries, such as that in the Arafura Sea, are characterized by their exploitation of multispecies stocka (e.g. Simpson, 1982). Many of these fisheries within the Indo-Pacific region, including the Gulf of Tahiland and the South China Sea, have seen major impacts on demersal communities through overexploitation. Much of the present knowledge on the management of fisheries is based on temperate single species fisheries and cannot be extrapolated to the tropical situation. The main difficulties facing managers of multispecies fisheries are the poor understanding of the biology of the taxa, and their interactions within a community. Recent studies within the AFZ of Northern Australia (e.g. Edwards, 1983, unpub. ms.; Liu, 1976; Liu *et al.*, 1985; Okera, 1982; Sainsbury, 1984a,b) have provided some information on the selectivity of trawl nets, the biology of abundant species, and the exploitation biomass of the demesal resource. Estimates of this latter parameter for the Australian sector of the

Arafura Sea range from 2.0 - 4.5 t/km² (in Sainsbury, 1984a). Such estimates led to a quota of 35 x 10³ t allocated to bi-lateral foreign fishing operators, 10 x 10³ t to joint venture foreign fishing operators, and the balance available to Australian operators.

Australian research on the demersal resource of the Arafura Sea is based on two sources of data: data supplied by the fishing masters in the form of radio reports and log books and, data collected by observers onboard the vessels. The former kind of data provides information on the location and amount of fishing effort, and the weight of the retained catches in terms of the commercial categories of fish. These data provided useful information on the distribution of fishing effort and the total weight of the retained catches, but yield very limited ecological information due to the pooling of species into commercial groups, the poor understanding of trashing practices and, to a lesser extent, unknown variations in reporting procedures. The data collected by observers provide fundamental information for understanding the ecology of demersal fish and, consequently, the management of the demersal resource. These data provide estimates on: the proportion of fish retained and trashed in trawl; the mean weight of retained individuals of economically important species; and the total weight of retained species. Occasionally, data are collected on the composition of the component of the catch which is trashed, and the lengths of individuals of selected species.

The management of the demersal resource of the Arafura Sea, and the development of the trawl fishery, requires research on: the ecology of the resource; the processes for catching and handling the fish; and the local and international markets for the products. The research would benefit greatly if it were conducted in collaboration with similar studies in other parts of the World.

Based on the study of Edwards (1983; unpub. ms.), the major objectives of the present study on the demersal trawl fishery of the Arafura Sea are to: determine the status of the fishery; investigate the spatial and temporal variations in the abundance, growth rates, and spawning periods of selected species; estimate the maximum sustainable yield within the AFZ; and, investigate the markets available to the product landed in Australia. This study is funded, in part, by a grant from the Fishing Industry Research Trust Account, and relies heavily on the data collected regularly by the observers.

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TABLE 1

Selected characteristics of the Taiwanese and Thai fishing operations in 1985 and 1986. The mean, range, 95% confidence limits (c.l.) of the mean, and sample size (n) are given for the duration of the trawl, the proportion of the catch retained, and the weight of a box of fish.

(a) Taiwanese Fleet	mean	range		95% c.l.		n
		min	max	lower	upper	
Duration of trawl (h)						
1985	2.28	1.50	3.50	2.17	2.39	49
1986	2.12	1.60	3.25	2.09	2.16	153
Proportion of catch retained (%)						
1985	45	21	72	39	51	23
1986	57	21	84	53	61	54
Weight of a box of fish (kg)						
1985	30.9	29.4	32.0	30.6	31.2	49

(a) Thai Fleet	mean	range		95% c.l.		n
		min	max	lower	upper	
Duration of tralw (h)						
1985	3.59	14.3	4.75	3.47	3.70	88
1986	3.59	2.17	5.30	3.54	3.64	288
Proportion of catch retained (%)						
1985	58	30	77	47	69	11
1986	71	29	90	66	76	46
Weight of a box of fish (kg)						
1985	18.4	10.6	20.0	17.8	19.0	88
1986	21.7	17.0	30.0	21.5	21.5	285

APPENDIX 1

Checklist of fish recorded commonly by AFZ observers aboard Taiwanese and Thai vessels fishing in the Arafura Sea.

SCIENTIFIC NAME	COMMON NAME
CARCHARHINIDAE (sharks)	
Carcharhinus dussumieri	wide-mouthed blackspot shark
Carcharhinus plumbeus	sandbar shark
Carcharhinus sorrah	sorrah shark
Rhizoprionodon acutus	milk shark
HEMIGALEIDAE (fossil sharks)	
Hemigaleus microstoma	weasel shark
Hemipristis elongatus	fossil shark
RHYNCHOBATIDAE (shovelnose-rays, shark rays)	
Rhina ancylostoma	shark ray
Rhynchobatus djiddensis	white-spotted shovelnose ray
DASYATIDIDAE (stingrays)	
Amphotistius kuhlii	blue-spotted stingray
Amphotistius sp. 1	brown stingray
Himantura uarnak	coachwhip stingray
SYNODONTIDAE (lizardfishes)	
Saurida micropectoralis	short-finned lizardfish
Saurida sp. 1	white-spotted lizardfish

Saurida undosquamis	checkered lizardfish
Synodus sageneus	bamded lizardfish
Synodus variegatus	variegated lizardfish
Trachynocephalus myops	painted saury
ARIIDAE (catfishes	
Arius thalassinus	giant salmon catfish
SERRANIDAE (rock-cods and coral-trout)	
Epinephelus areolatus	yellow-spotted rock-cod
Epinephelus maculatus	brown-spotted rock-cod
Epinephelus rankini	Rankin's rock-cod
Epinephelus sexfasciatus	six-banded rock-cod
Plectropomus maculatus	coral-trout
PRIACANTHIDAE (big-eyes)	
Priacanthus hamrur	black-spot big-eye
Priacanthus macracanthus	large-spined big-eye
Priacanthus tayenus	qthreadfin big-eye
RACHYCENTRIADAE (black kingfishes)	
Rachycentron canadus	black kingfish
CARANGIDAE (trevalies, scads and queenfishes)	
Alectis ciliaris	round-headed pennanfish
Alepes sp.	small-mouth scad
Alute mate	yellow-tail scad
Carangoides chrysophrys	long-nosed trevally
Carangoides fulvoguttatus	yellow-spotted trevally
Carangoides gymnostethus	bludger trevally
Carangoides humerosus	bludger trevally
Carangoides malabaricus	Malabar trevally
Carangoides talamparoides	white-tongued trevally
Caranx bucculentus	blue-spotted trevally
Decapterus macrosoma	slender scad
Decapterus russellii	Indian scad
Gnathanodon speciosus	golden trevally
Megalaspis cordyla	finny scad
Selar boops	ox-eye scad
Selar crumenophthalmus	big-eye scad
Selaroides leptolepis	yellow-striped trevally
Seriolina nigrofasciata	black-banded kingfish
Uraspis uraspis	white-tongued jack
FORMIONIDAE (eyebrow-fishes)	
Apolectus niger	black pomfret
LUTJANIDAE (sea-perches and snappers)	
Lutjanus argentimaculatus	mangrove-jack
Lutjanus erythropterus	high-brow sea-perch
Lutjanus johni	John's sea-perch
Lutjanus malabaricus	saddle-tailed sea-perch
Lutjanus russelli	Russell's snapper
Lutjanus sebae	red emperor
Lutjanus vittus	one-band sea-perch

Pristipomoides multidens	gold-band snapper
Pristipomoides typus	threadfin snapper
NEMIPTERIDAE (threadfin-breams, monocle-breams and whiptails)	
Nemipterus furcosus	rosy threadfin-bream
Nemipterus hexodon	orante threadfin-bream
Nemipterus mesoprion	yellow-tipped threadfin-bream
Nemipterus metopias	yellow-cheeked threadfin-bream
Nemipterus peronii	notched threadfin-bream
Nemipterus virgatus	yellow-lipped threadfin-bream
HAEMULIDAE (sweetlips and javelin-fishes)	
Diagramma pictum	painted sweetlip
LETHRINIDAE (emperors and sea-breams)	
Gymnocranius elongatus	swallow-tail sea-bream
Gymnocranius griseus	naked-headed sea-bream
Gymnocranius robinsoni	blue-lined sea-bream
Lethrinus choerorynchus	lesser spangled emperor
Lethrinus fraenatus	blue-lined emperor
Lethrinus lentjan	red-spot emperor
Lethrinus nebulosus	spangled emperor
SPARIDAE (snappers)	
Argyrops spinifer	long-spined snapper
SCIAENIDAE (croakers)	
Argyrosomus sp.	orange croaker
Protonibea diacanthus	spotted croaker
TRICHIURIDAE (hairtails)	
Trichiurus lepturus	large-headed hairtail
MULLIDAE (goatfishes)	
Parupeneus chrysopleuron	yellow-banded goatfish
Parupeneus indicus	Indian goatfish
Parupeneus pleurospilus	spotted golden goatfish
Upeneus moluccensis	gold-band goatfis
Upeneus sulphureus	sunrise goatfish
Upeneus sp.	orange-barred goatfish
SHYRAENIDAE (sea pikes)	
Sphyraena forsteri	blotched sea-pike
Sphytaena obtusata	long-finned sea-pike
Sphyraena putnamiae	military sea-pike
SCOMBRIDAE (mackerels)	
Rastrelliger kanagurta	Indian mackerel
Scomberomorus commerson	narrow-handed spanish-mackerel
Scomberomorus munroi	Munro's spanish mackerel
Scomberomorus queenslandicus	school spanish-mackerel
CENTROLOPHIDAE (butterfishes)	
Psenopsis humerosa	black-spot butterfish
ARIOMMATIDAE (eyebrow-fishes)	
Ariomma indica	Indian eyebrow-fish

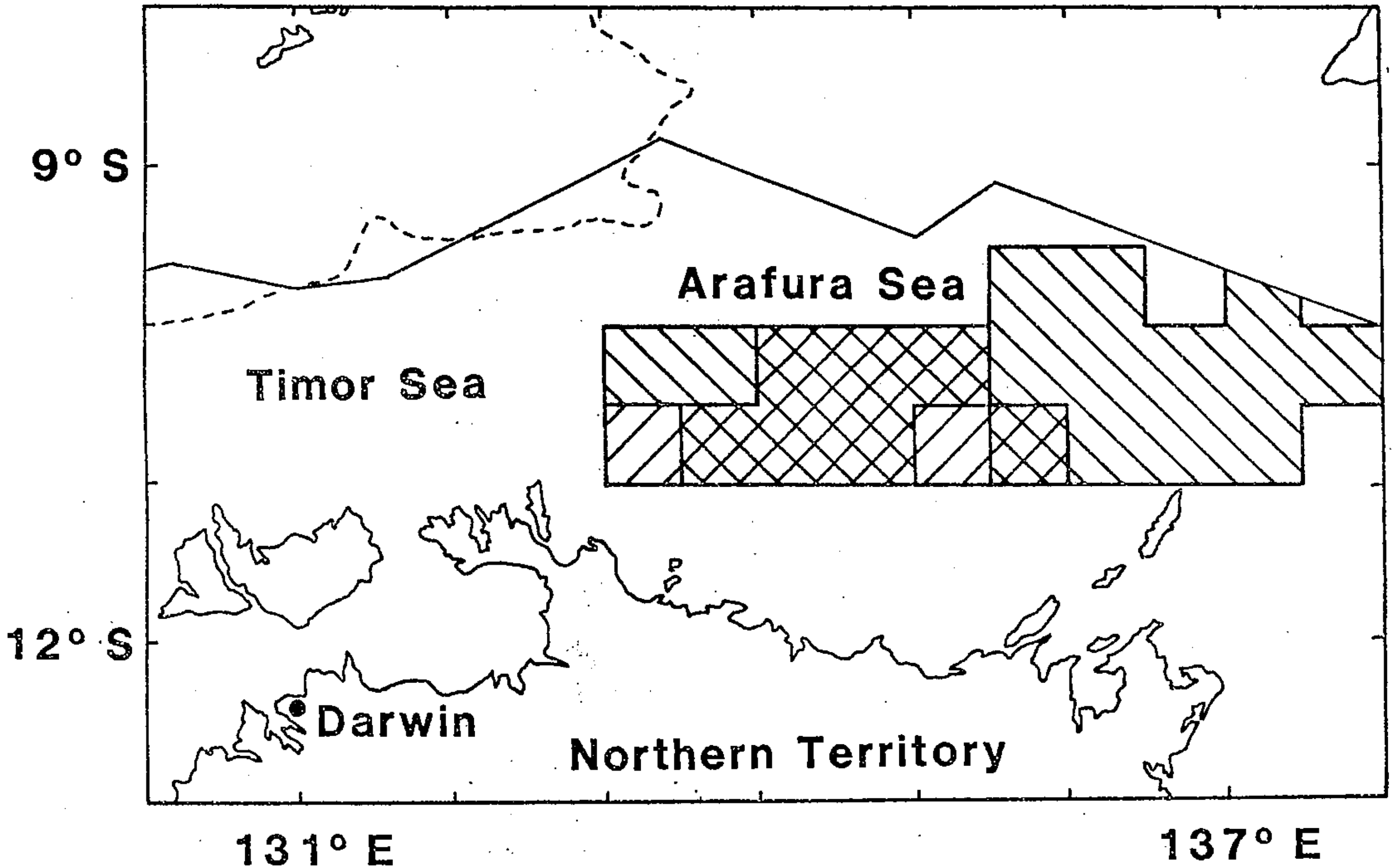

FIG. 1. Areas in which samples were collected by AFZ observers aboard Taiwanese vessels (\\\) and Thai vessels (///) trawling in the Arafura Sea during 1985 and 1986. The approximate outer limits of the AFZ (__) and continental shelf (---) are shown.

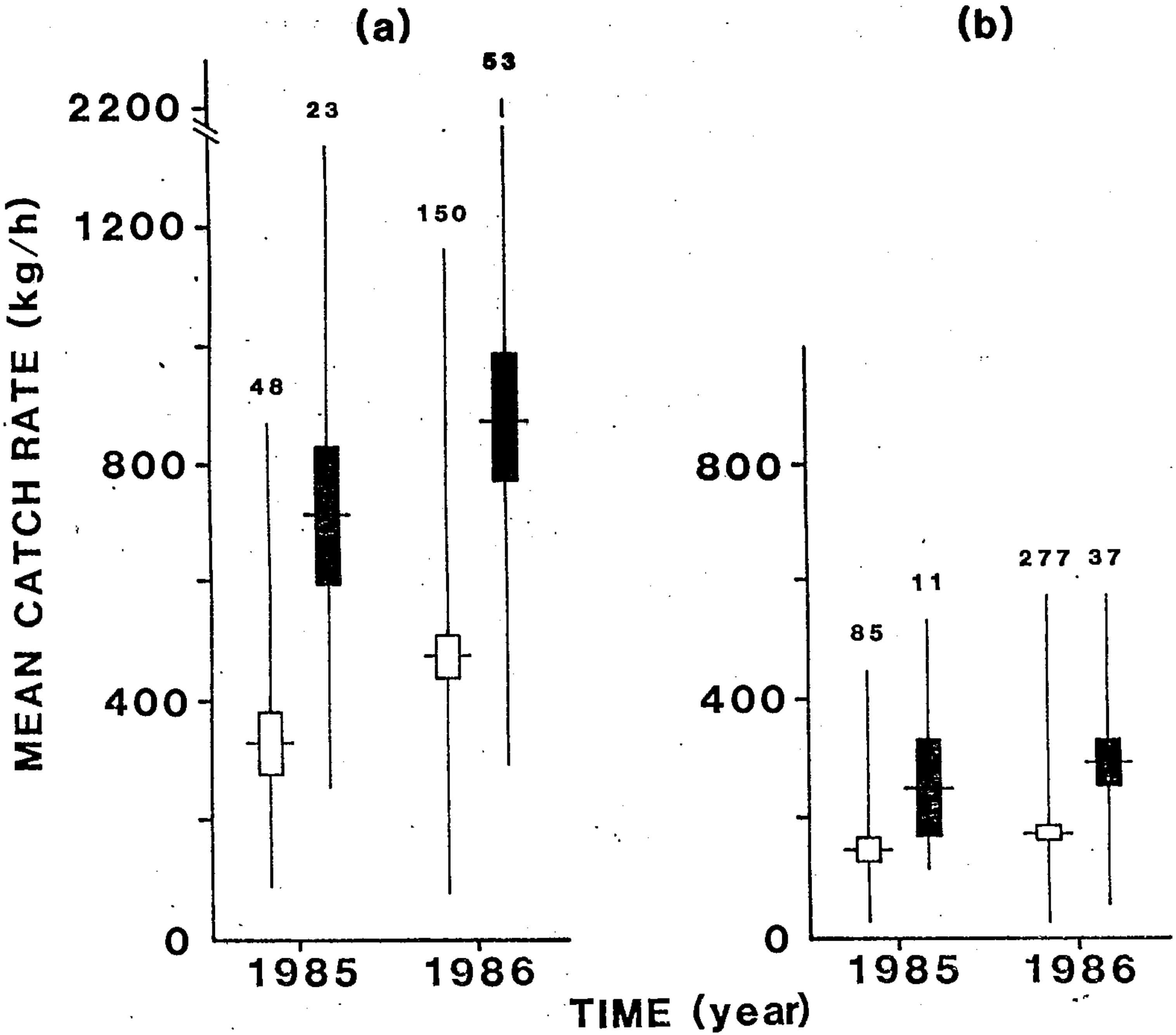

FIG. 2. Mean weight of the total catch (■) and retained catch (□) per hour of trawling for the Taiwanese fleet (a) and Thai fleet (b) in 1985 and 1986. The error bars represent the ranges and the 95% confidence limits of the means, and the sample size is indicated.

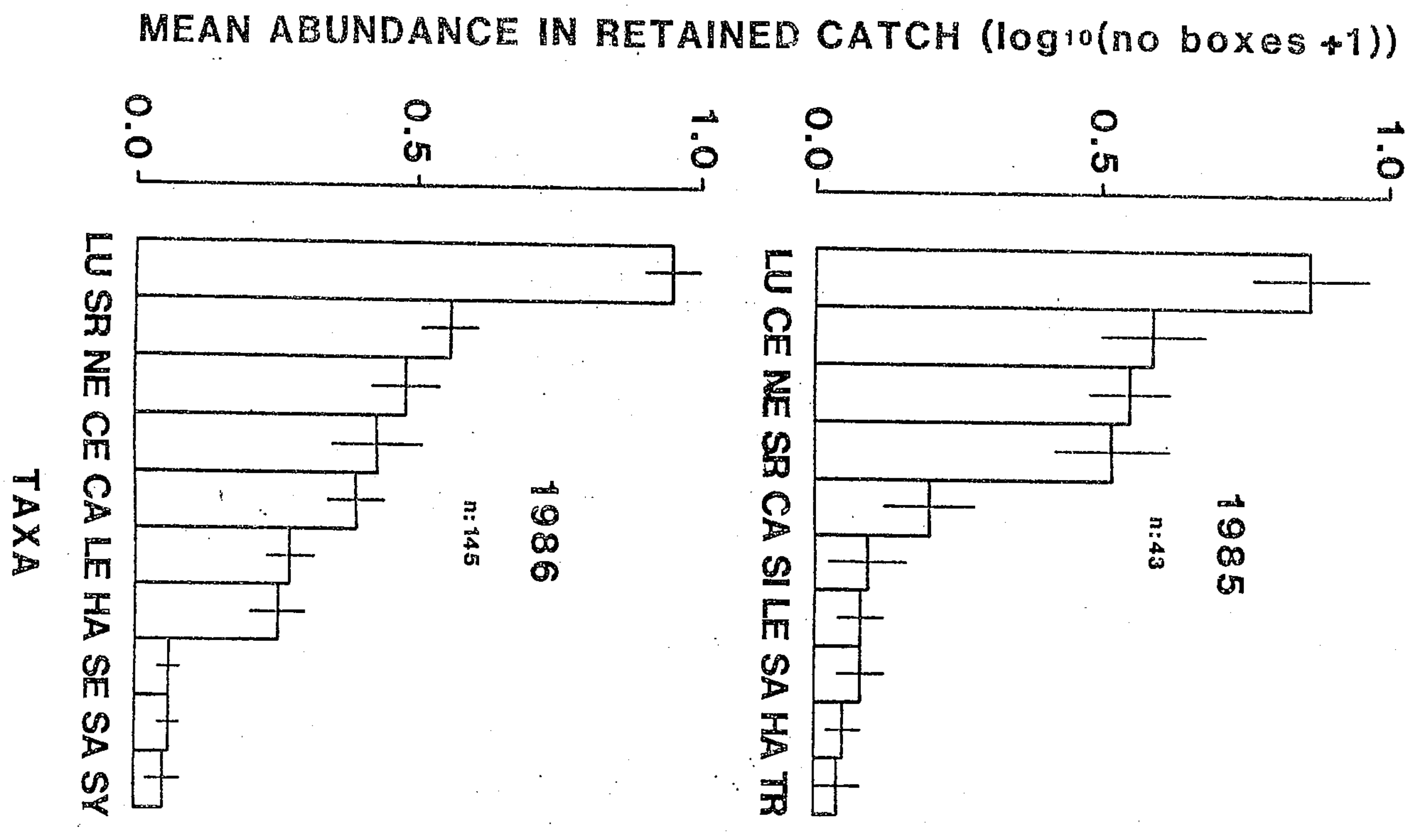

FIG. 3. Geometric mean abundance of the main taxa retained in the catch of Taiwanese vessels in 1985 and 1986. The taxa are: Carangidae (CA); Centrolophidae and Ariommatidae (CE); Haemulidae (HA); Lethrinidae (LE); Lutjanidae (LU); Nemipteridae (NE); Sepiidae (SA); Serranidae (SE); Sciaenidae (SI); Carcharhinidae, Hemigaleidae and Dasyatididae (SR); Synodontidae (SY); and, Trichiuridae (TR). The error bars represent the 95% confidence limits of the means, and the mean weight of a box of fish is approximately 31 kg (Table 1a).

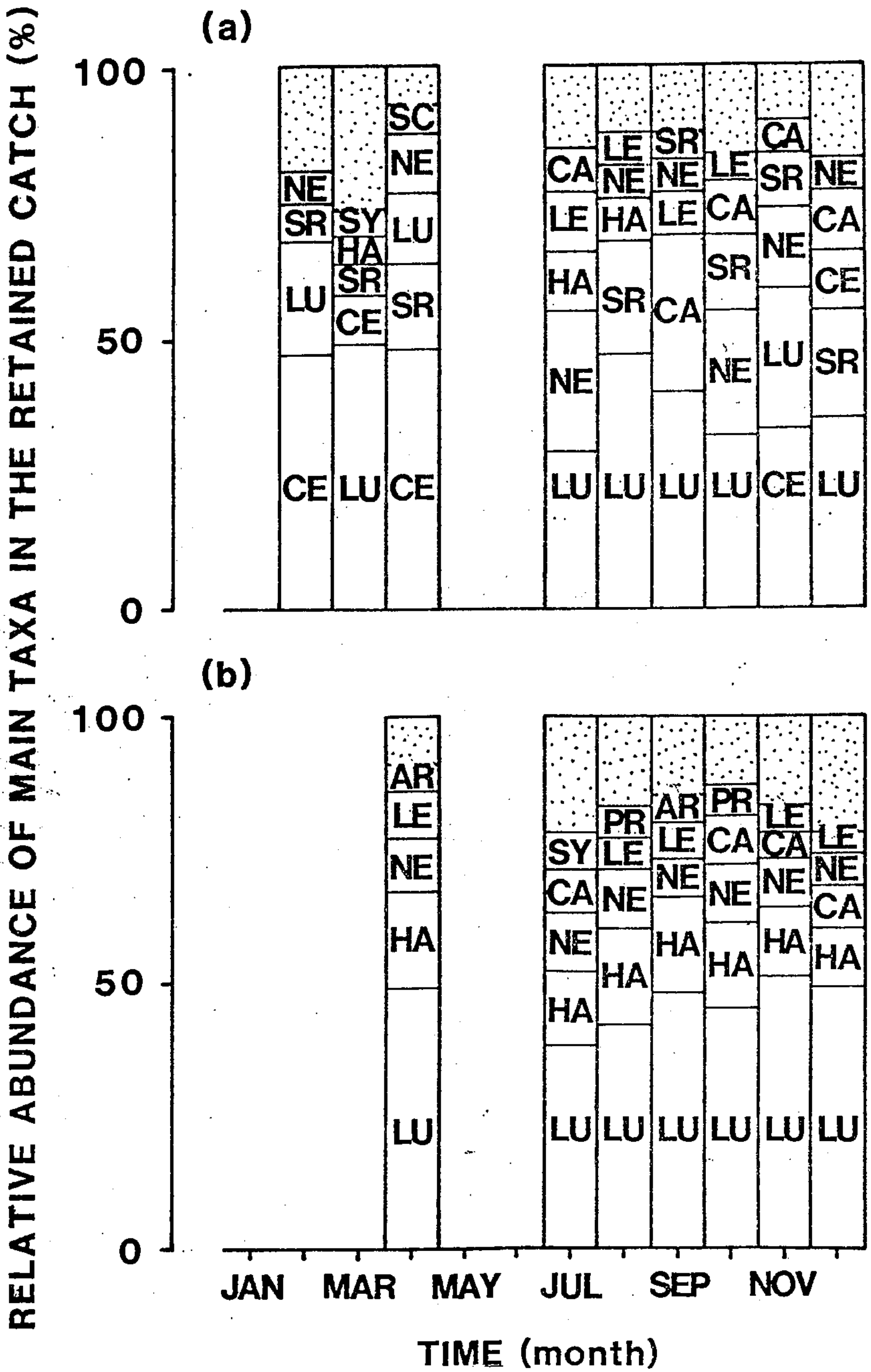

FIG. 4. Monthly variations in the relative abundance, by weight, of the mean taxa in the retained catch of Taiwanese vessels (a) and Thai vessels (b) in 1986. The taxa include: Ariidae (AR); Priacanthidae (PR); Scombridae (SC); taxa listed in the caption of Fig. 3; and other taxa (⁘). The numbers of samples collected each month are given in Figs. 5 and 7.

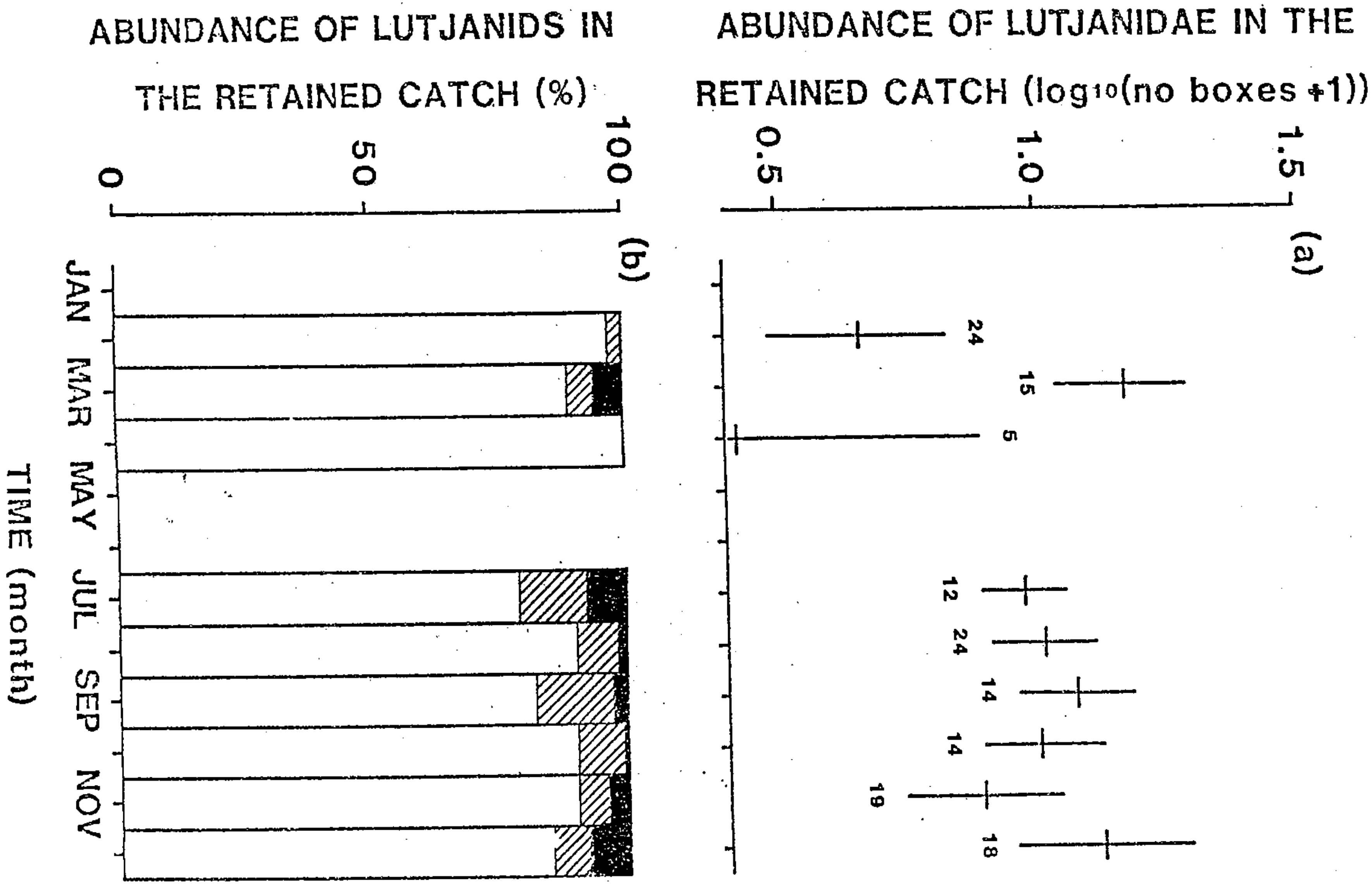

FIG. 5. Geometric mean abundance (a) and relative abundance (b) of Lutjanid species retained in the catch of Taiwanese vessels in 1986. The catches of Lutjanids consists mostly of: *Lutjanus argentimaculatus*, *L. erythropeterus*, *L. johnii*, *L. malabaricus*, and *L. sebae* (□); *L. russelli* and *L. vittus* (▨); and *Pristipomoides multidens* and *P. typus* (■). The means are plotted with their 95% confidence limits, and the number of samples collected each month is shown. Samples were not collected in January, May and June.

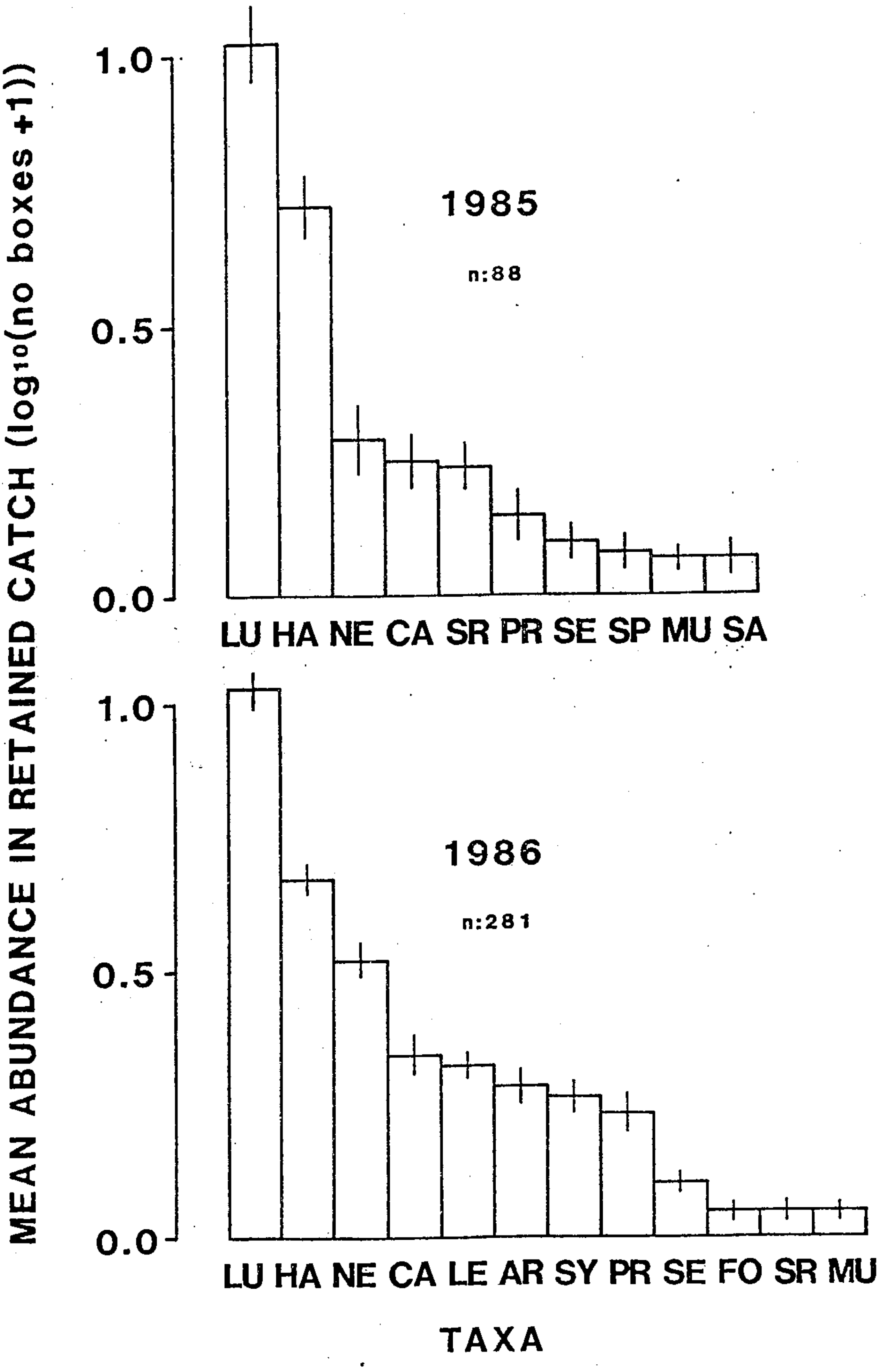

FIG. 6. Geometric mean abundance of the main taxa retained in the catch of Thai vessels in 1985 and 1986. The taxa include: Formionidae (FO); Mullidae (MU); Sphyraenidae (SP); and, some of the taxa listed in the captions of Figs. 3 and 4. The error bars represent the 95% confidence limits of the means, and the mean weight of a box of fish is approximately 20 kg (Table 1b).

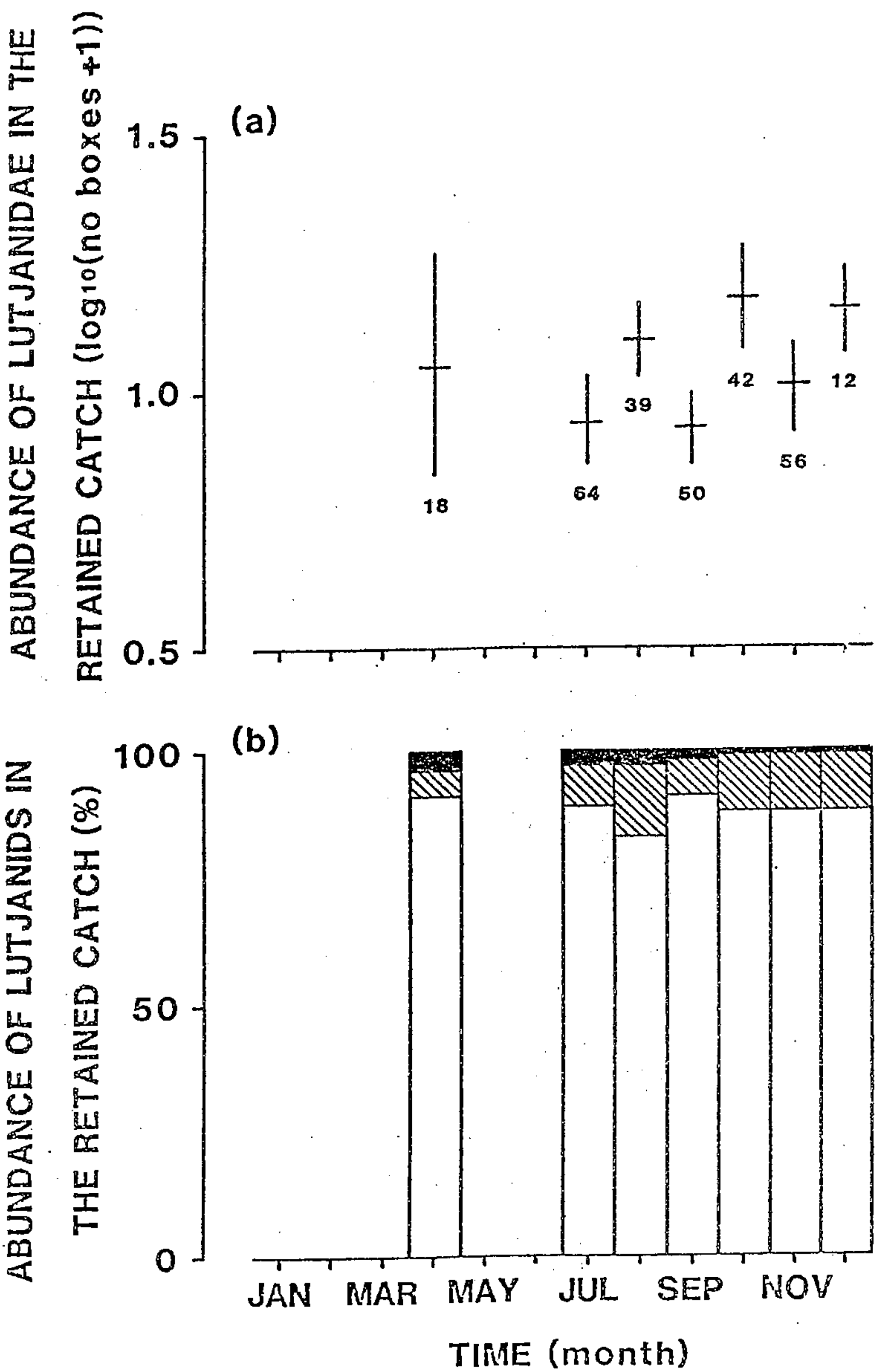

FIG. 7. Geometric mean abundance (a) and relative abundance (b) of Lutjanid species retained in the catch of Thai vessels in 1986. The key to the Lutjanid species is given in the caption of Fig. 5. The means are plotted with their 95% confidence limits, and the number of samples collected each month is shown. Samples were not collected during January - March, and in May and June.

CATCH, EFFORT AND SUSTAINABLE YIELD FOR AUSTRALIA'S NORTHERN TRAWL FISHERY

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Abstract

Australia's northern trawl fishery is a multi-species, multi-fleet shelf fishery operating on the Northwest Shelf (114-123°E), and in the Timor (123-129°E) and Arafura (131-142°E) Seas. Groundfish resources have been fished continuously since 1971, and total annual retained catches reached 37100t on the Northwest Shelf in 1973, 9100t in the Timor Sea in 1974, and 9000t in the Arafura Sea in 1983. Red Lutjanidae, mainly *Lutjanus malabaricus*, dominated catches in the Arafura (≤4191t·year^{-1}) and Timor Seas (≤1091t·year^{-1}), and was a major catch component on the Northwest Shelf (≤2182t·yr^{-1}). Other major commercial categories included *Nemipterus* spp. (≤8377t·yr^{-1}), *Saurida* spp. (≤4276t·yr^{-1}) and *Lethrinus* spp. (≤4076t·yr^{-1}) on the Northwest Shelf, and *Ariomma indica* and *Psenopsis humerosa* (≤3057t·yr^{-1}) and *Nemipterus* spp. (≤2811t·yr^{-1}) in the Arafura Sea. Catch per unit effort data were standardised and maximum sustainable yields estimated, where possible, using surplus production model.

Introduction

Groundfish resources of the Northwest Shelf and Timor and Arafura Seas, on Australia's northern continental shelf, were fished extensively by Japanese stern trawlers during 1959-1963 (Sainsbury, 1987), Taiwanese pair trawlers during 1971-1990, and Thai stern trawlers during 1985-1990. The Japanese fleet targeted Lethrinidae on the Northwest Shelf (Sainsbury, 1987), while Taiwanese trawlers retained predominantly Carangidae, Lutjanidae, Nemipteridae and Synodontidae (e.g. Liu, 1976; Liu *et al.*, 1978; Chen *et al.*, 1979; Edwards, 1983; Sainsbury, 1987, 1988, 1991). The fishery developed rapidly and total annual catch reached 49200t in 1974 (Sainsbury, 1991 and CSIRO, GPO Box 1538 Hobart 7001 Australia, unpub. data), representing about 30% of the then total catch from Australian waters, and 60% of the catch taken by Taiwanese distant-water pair trawlers (Liu, 1976). Early estimates of maximum sustainable yield (MSY) for groundfish were based on Gulland's approximation of $MSY=0.5MB_0$ where M is natural mortality rate, and B_0 is unexploited biomass estimated using swept area method with net width as effective trawl pathwidth. These estimates varied considerably depending on values of M, and area of trawl grounds. Liu (1976) and Liu *et al.* (1978) obtained MSYs of 336000t·yr^{-1}, 250000t·yr^{-1} and 447000t·yr^{-1} for all commercial groundfish species on the Northwest Shelf, Timor Sea and Arafura Sea (Australian and Indonesian sectors), respectively, assuming M=1.0 and total shelf area. Sainsbury (1982) estimated a MSY of 87000t·yr^{-1} for all commercial groundfish species on the Northwest Shelf using M=0.5 and actual area trawled in 1973. Edwards (1983) assumed M=0.3 and 'areas of concentration of effort' in estimating MSYs of 36000t·yr^{-1}, 20000t·yr^{-1} and 30000t·yr^{-1} for all commercial groundfish species on the Northwest Shelf, Timor Sea and Arafura Sea (Australian sector only), respectively. Sainsbury (1982, 1984) also estimated sustainable yields for major commercial categories by fitting data from the Northwest Shelf to alternative surplus production models.

Sainsbury (1991) developed an adaptive management strategy for groundfish on the Northwest Shelf based on observed changes in community structure during 1960-83, where relative abundances of Lethrinidae, Lutjanidae and Serranidae, and incidentally caught sponges, decreased significantly over time, while those of Nemipteridae and Synodontidae increased significantly, and those of Carangidae, Haemulidae and Sparidae did not change. Further, Sainsbury (1991) established that Lethrinidae and Lutjanidae had a higher probability of occurring in habitat with large epibenthos than in open sand habitat, while Nemipteridae and Synodontidae preferred open sand habitat. Sainsbury (1987) concluded that trawling on the Northwest Shelf may have modified benthic habitats and caused long-term changes in community structure.

Major changes in fishing practice occurred following the ratification of Australia's Fishing Zone (AFZ) in 1979. Groundfish trawling, now managed by the federal Department of Primary Industries and Energy, was confined to management zones on the Northwest Shelf, and in the Timor and Arafura Seas, and user conflicts with the domestic shrimp fishery were minimised by excluding fish trawlers from shallow shrimp rich waters, including the Gulf of Carpentaria. Fishing by foreign trawlers continued, under licence, and effort shifted from the Northwest Shelf to the Arafura Sea to target *Lutjanus malabaricus*. Concerns were raised about the inadequacy of fishery data from the Timor and Arafura Seas (e.g. Jernakoff and Sainsbury, 1990). Here, we report catch and effort data for the entire trawl fishery in northern Australia during 1972-90, and discuss implications of our findings for management of, and future research into, that fishery.

Method

Our study covered groundfish trawl data from the Northwest Shelf (115-123°E) and the Australian sectors of the Timor (123-131°E) and Arafura (131-141°E) Seas from 1971 when fishing began in the Arafura Sea, to 1990 when foreign licence arrangements were discontinued (Fig. 1). Annual retained catch and effort data to 1979 were based on Edwards (1983) and Sainsbury (1991; CSIRO, GPO Box 1538 Hobart 7001 Australia, unpub. data) (Appendix 1). The federal Department of Primary Industries and Energy supplied tow-by-tow logbook data for 1980-90 and observer data for box weights and species composition for commercial categories from 1192 tows (3700h) on the Northwest Shelf and in the Arafura Sea during 1985-87. Logbook catch data (number of boxes·tow^{-1} by category) were converted to weight using box weights declared in logbooks or measured by observers. Distant-water fleets operating in the AFZ were also monitored by surveillance and weekly radio reports. There was a good correspondence between these sources of information and fishing activities reported by observers and logbooks (Ramm, unpub. data), and all logbooks were assumed to be recovered. Further, logbook data quality was good, with only 0.2% of effort data missing, and 93.5% of catch data reported by commercial categories. Thus no corrections were applied to the data.

Catch per unit effort (CPUE) for each commercial category was standardised by fleet, zone and year using annual catch and effort data (1972-90) fitted to the multiple linear regression model

$$\log(U_{ijt})=\log(U_{111})+\log(\alpha_i)+\log(\beta_j)+\log(\gamma_t)+\varepsilon_{ijt},$$

where U_{ijt} is CPUE for fleet i in zone j during year t, U_{111} is CPUE for fleet 1 in zone 1 during year 1, α_i is relative fishing power of fleet i, β_j is relative abundance in zone j, γ_t is relative abundance in year t, and ε_{ijt} is an error term with a mean of zero and a constant variance (e.g. Hilborn and Walters, 1992). Standardised CPUE and effort for each zone were fitted, by multiple linear regression, into Walters and Hilborn's (1976) difference equation

$(U_{t+1}/U_t)-1=r-(r/kq)U_t-qE_t$,

where U_t and U_{t+1} are standardised CPUE during years t and t+1 respectively, E_t is standardised effort during year t, r is intrinsic population growth rate, q is catchability, and k is carrying capacity. Alternative fits using Polovina's (1989) extension of this model assuming an identical intrinsic population growth rate r among zones and a time-series method (Hilborn and Walters, 1992) resulted in little improvement in goodness-of-fit.

Results

Taiwanese distant-water pair trawlers (length: 36-42m, gross tonnage: 280-350t) dominated the fishery with effort >30000h·year^{-1} during 1973-1986 (Table 1; Edwards, 1983; Sainsbury, 1991) mostly on the Northwest Shelf between 116-119°E and 19-21°S, and Arafura Sea between 136-138°E and 9-11°S (Fig. 2a). Thai stern trawlers (26-42m, 115-350t) fished in the Arafura Sea during 1985-90 with effort >30000h·year^{-1} during 1988-90 mostly between 133-137°E and 10-11°S (Table 1, Fig. 2b). Another Chinese pair trawler fleet, from Zhejiang Province, fished on the Northwest Shelf and in the Timor Sea during 1989 with a total effort of 6251h, and a fledgling Australian stern trawl fleet has operated sporadically in the Arafura Sea for a total of 2793h during 1987-90 (Table 1).

Taiwanese trawlers generally fished on the Northwest Shelf (depth fished: 50-80m) during April-August and in the Timor (60-90m) and Arafura (40-75m) Seas during October-March (Fig. 3). Trip and tow duration averaged 59.1day (SE=1.3day, n=447) and 2.2h (SE<0.01h, n=186278), respectively. Interestingly, fishing was conducted throughout the day on the Northwest Shelf and Timor Sea (7 tow·day^{-1}), and from dawn to dusk in the Arafura Sea (0530-1930h, 5 tow·day^{-1}). In contrast, Thai trawlers fished throughout the day (6 tow·day^{-1}) and year in the Arafura Sea (50-75m), with a mean trip and tow duration of 27.6day (SE=0.8day, n=319) and 4.0h (SE<0.01h, n=45709), respectively.

Twenty four commercial categories, representing at least 69 species of fish, squid and cuttlefish, were identified from observer data (Appendix 2). Most categories were dominated by single species such as *Lethrinus lentjan* (Lethrinidae), *Lutjanus malabaricus* (red Lutjanidae), *Lutjanus vittus* (small Lutjanidae), *Nemipterus furcosus* (Nemipteridae), *Pristipomoides multidens* (goldband Lutjanidae), *Psenopsis humerosa* (butterfish), *Saurida undosquamis* (Synodontidae) and *Trichiurus lepturus* (Trichiuridae). Total retained catch for all fleets during 1972-90 was approximately 229000t on the Northwest Shelf, 47000t in the Timor Sea and 126000t in the Arafura Sea (Table 2 a-c, Appendix 1). Nemipteridae was the dominant category on the Northwest Shelf (≤8377t·yr^{-1}), while red Lutjanidae dominated catches in the Timor (≤1091t·yr^{-1}) and Arafura Seas (≤4191t·yr^{-1}). Other important categories included Lethrinidae (≤4076t·yr^{-1}) and Synodontidae (≤4276t·yr^{-1}) on the Northwest Shelf, Carangidae (≤1528t·yr^{-1}) in the Timor Sea, and butterfish (≤3057t·yr^{-1}) and Nemipteridae (≤2811t·yr^{-1}) in the Arafura Sea.

Observer data indicated that the proportion of the total catch retained by trawlers varied little between fleets and zones, with Taiwanese vessels retaining 67%, by weight, of the catch (SE=12%, n=61) on the Northwest Shelf and 53% (SE=14%, n=101) in the Arafura Sea, and Thai trawlers retaining 63% (SE=16%, n=109) in the Arafura Sea. However, marked differences existed in discard practices, at the category level, between fleets particularly in the Arafura Sea where butterfish, Trichiuridae and Rachycentridae were retained by Taiwanese trawlers but trashed by Thai vessels, while Ariidae were retained by Thai vessels but trashed by Taiwanese vessels (Table 2 a-c, Fig. 4).

Standardisation of CPUE revealed marked variation in fishing power between fleets, zones and years (Table 3). The fishing power of Thai trawlers, relative to Taiwanese trawlers, ranged from 0.10 for *Loligo* spp. to 5.63 for Ariidae, with an overall value of 0.56. Geographic variations in relative abundances were also marked, with categories such as Ariidae, Carangidae and Sphyraenidae occurring throughout the fishery, Mullidae and Nemipteridae being predominant on the Northwest Shelf, Haemulidae and goldband Lutjanidae occurring mostly in the Timor Sea, and butterfish and Trichiuridae being predominant in the Arafura Sea. Coefficients of relative annual abundance varied widely for many categories during 1980-82. Estimation of MSY from annual catch and effort data fitted to Walters and Hilborn's difference equation was attempted for all categories and zones, but was obtained only for about 24 of the possible 75 combinations of category and zone (Table 4). MSY was estimated for 9 commercial categories (e.g. Lethrinidae $5288t \cdot yr^{-1}$, red Lutjanidae $1528t \cdot yr^{-1}$, Nemipteridae $4520t \cdot yr^{-1}$) on the Northwest Shelf, 12 categories (e.g. Lethrinidae $1168t \cdot yr^{-1}$, red Lutjanidae $750t \cdot yr^{-1}$, Nemipteridae $377t \cdot yr^{-1}$) in the Timor Sea, and butterfish ($3018t \cdot yr^{-1}$) in the Arafura Sea.

Discussion

Although only 69 species of fish were identified from observer data, Australia's northern trawl fishery is a truly a multi-species fishery. Sainsbury *et al.* (1984) reported 531 species commonly taken in trawls between 30-150m on the Northwest Shelf and Timor and Arafura Seas. Russell and Houston (1989) concluded that 231 species of fish were caught by groundfish trawlers in the Arafura Sea, of which about 100 species were retained with 23 species accounting for 70% of total catch by weight. While most species are widespread within the Indo-Pacific, distinct changes in fish fauna occur near 123°E (Sainsbury, 1991) and 132°E (Ramm *et al.*, 1990). Thus Nemipteridae was the dominant catch component on the Northwest Shelf and a major commercial category at other grounds, while Lethrinidae and Synodontidae were important on the Northwest Shelf, red Lutjanidae dominated catches in the Timor and Arafura Seas, Carangidae was important in the Timor Sea, and butterfish occurred predominantly in the Arafura Sea.

MSY estimates for Lethrinidae, red Lutjanidae and Nemipteridae on the Northwest Shelf are within the range of values determined by Sainsbury (1987, 1991) for various model scenarios. Whilst there are previous estimates of sustainable yield for groundfish in the Timor and Arafura Sea (e.g. Edwards, 1983; Dalzell and Pauly, 1989), none have previously been attempted for individual species or species groups. Our analyses indicated that the majority of available fishery data was inadequate for use in stock assessment, particularly in the Arafura Sea. Many factors contributed to this problem, including long-term changes in discard practice, targeting and management regimes. Edwards (1983) reported low logbook recovery rates prior to the declaration of the AFZ, and complete recovery thereafter. He also reported that effort increased in the Arafura Sea during 1978-79 due to targeting of Loligo spp. Other operational changes included an increase in minimum codend mesh size, from about 45mm (stretched mesh) prior to 1979, through 60mm during 1979-89, to 90mm thereafter (Jernakoff and Sainsbury, 1990). Sainsbury and Ramm (1988 in Jernakoff and Sainsbury, 1990) identified limitations in the observer data and concluded that available data were insufficient to interpret logbook data and estimate sustainable yields. They recommended that quality of data on fishing operations, retained catch and total catch, species composition of retained and discarded catch and length-frequency distributions of key species be improved for viable stock assessment. Finally, assessments for the Arafura Sea also require fishery data for the Indonesian sector, which are presently lacking.

Although the results from this study are generally inconclusive, the analyses have directed recent research on groundfish in the Timor and Arafura Seas (e.g. Blaber *et al.*, 1992). Identification of large uncertainties in interpreting logbook data had led to fishery-independent trawl surveys in the Timor and Arafura Seas between 127-137°E (D. C. Ramm, unpub. data) and Gulf of Carpentaria (S. J. M. Blaber, CSIRO, PO Box 120 Cleveland 4163 Australia, unpub. data), and the development of a project aimed at collating fishery catch and operational data for groundfish fisheries in both Australian and Indonesian sectors of the Arafura Sea (D. C. Ramm and D. J. Staples, unpub. data). Alternative assessment of groundfish stocks are now underway using biomass data from trawl surveys.

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Table 1. Total number licensed trawlers and fishing effort (h) in Australia's northern trawl fishery during 1980-90.

Fleet	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Number of Licensed Trawlers											
Australian	0	0	0	0	0	0	0	2	2	8	3
Thai	0	0	0	0	0	3	7	7	13	14	11
Taiwanese	104	72	72	72	80	64	44	22	18	12	4
Zhejiang	0	0	0	0	0	0	0	0	0	8	0
Effort on Northwest Shelf											
Australian	0	0	0	0	0	0	0	0	0	0	0
Thai	0	0	0	0	0	0	0	0	0	0	0
Taiwanese	36448	31379	38996	29891	38546	38022	12203	4960	7153	10139	665
Zhejiang	0	0	0	0	0	0	0	0	0	1974	0
Effort in Timor Sea											
Australian	0	0	0	0	0	0	0	0	0	0	0
Thai	0	0	0	0	0	0	27	0	103	389	0
Taiwanese	2242	1944	1687	2672	6959	6188	2991	1449	569	981	367
Zhejiang	0	0	0	0	0	0	0	0	0	4277	0
Effort in Arafura Sea											
Australian	0	0	0	0	0	0	0	58	1399	0	1336
Thai	0	0	0	0	0	2597	17924	25672	31413	61317	41739
Taiwanese	17959	9881	13948	28219	29935	7173	16862	3941	2610	22	1470
Zhejiang	0	0	0	0	0	0	0	0	0	0	0

Table 2. Retained catch (t) by fleet in Australia's northern trawl fishery during 1980-90 on (a) Northwest Shelf, (b) Timor Sea and (c) Arafura Sea. Data by category inadequate for Thai and Australian fleets in the Arafura Sea during 1985-86 and 1987-88, respectively.

(a) Catch (t) on Northwest Shelf

Category	Taiwanese											Zhejiang
	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1989
Ariidae	35	18	32	0	1	0	0	0	0	0	0	0
butterfish	2	2	2	2	0	4	2	0	1	1	0	1
Carangidae	820	746	842	469	485	578	128	45	66	45	1	13
Formionidae	58	165	45	28	38	40	5	2	1	28	0	11
Haemulidae	223	100	149	133	131	126	19	9	10	139	0	122
Lethrinidae	1729	1164	1855	1114	944	1004	226	138	186	410	19	954
Loligo spp.	42	67	133	50	62	78	14	4	7	9	1	0
Lutjanidae small	546	580	917	680	832	761	136	69	197	234	25	15
Lutjanidae goldband	172	117	253	94	367	260	60	13	101	170	20	12
Lutjanidae red	636	409	717	364	411	561	95	39	130	284	22	141
Mullidae	484	654	784	652	678	696	129	87	53	93	12	5
Nemipteridae	3665	4008	3884	3634	3853	3115	829	291	677	563	48	18
Priacanthidae	306	316	303	153	173	216	47	37	51	56	6	4
Rachycentridae	139	171	51	61	2	20	39	0	12	9	0	0
Sciaenidae	6	9	2	1	4	3	0	0	0	1	0	0
Scombridae	13	1	42	1	3	9	1	1	1	3	0	7
Sepiidae	285	422	821	609	536	413	79	29	70	104	3	0
Serranidae	261	109	272	238	214	208	29	50	81	102	16	17
sharks and rays	298	264	400	246	284	224	52	19	35	52	2	13
Sparidae	247	136	180	125	115	126	39	13	75	61	0	2
Sphyraenidae	103	70	124	44	50	49	14	1	5	2	0	0
Synodontidae	887	739	558	387	557	651	271	104	324	118	3	7
Trichiuridae	13	18	5	0	0	2	0	1	0	0	0	0
mixed taxa	1610	813	1048	661	712	864	165	45	132	136	25	236
total retained catch	12579	11098	13418	9745	10451	10007	2378	998	2212	2618	201	1575

(b) Catch (t) in Timor Sea

Category	Taiwanese											Zhejiang	Thai
	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1989	1989
Ariidae	3	1	0	0	0	0	0	0	0	0	0	0	0
butterfish	0	4	0	4	10	7	1	6	1	0	0	12	0
Carangidae	74	94	25	76	120	61	5	8	12	3	1	3	1
Formionidae	8	37	0	0	3	22	24	1	0	1	0	6	0
Haemulidae	34	94	31	136	201	54	25	7	12	24	0	196	9
Lethrinidae	88	41	57	138	250	172	56	36	38	64	15	228	2
Loligo spp.	2	3	0	0	0	2	1	5	0	1	1	0	0
Lutjanidae small	36	38	36	117	168	139	24	33	19	7	6	219	2
Lutjanidae goldband	27	37	139	146	446	336	78	124	29	46	13	237	1
Lutjanidae red	100	100	153	202	578	382	69	98	27	140	28	631	18
Mullidae	1	2	5	11	38	39	6	14	7	1	1	2	0
Nemipteridae	103	78	22	120	172	182	79	24	39	12	20	2	1
Priacanthidae	26	18	17	25	66	62	21	6	5	4	3	6	0
Rachycentridae	13	2	1	3	1	9	0	0	2	0	0	0	0
Sciaenidae	0	0	0	26	57	1	0	0	0	0	0	0	0
Scombridae	6	0	0	0	8	1	0	1	2	1	0	4	0
Sepiidae	22	8	6	29	76	68	21	12	5	6	2	5	1
Serranidae	11	6	6	25	30	29	2	8	3	9	2	24	2
sharks and rays	63	25	9	25	91	38	11	11	5	17	7	38	0
Sparidae	2	15	5	22	20	22	4	3	0	1	0	0	0
Sphyraenidae	15	5	3	3	14	3	0	1	0	0	0	0	0
Synodontidae	23	47	9	2	108	118	38	2	4	3	0	17	0
Trichiuridae	6	1	3	1	1	1	0	0	0	0	0	0	0
mixed taxa	307	109	50	90	224	248	56	52	13	15	13	229	0
total retained catch	971	765	577	1201	2684	1995	524	450	225	354	114	1834	40

(c) Catch (t) in Arafura Sea. Data by category inadequate for Thai fleet during 1985-86, and Australian fleet during 1987-88.

Category	Taiwanese											Thai						Australian
	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1985	1986	1987	1988	1989	1990	1990
Ariidae	23	2	13	8	15	6	0	0	0	0	0	0	0	187	248	247	189	0
butterfish	197	142	955	3057	323	286	894	61	82	0	37	0	0	0	0	0	0	0
Carangidae	607	329	568	651	833	179	207	89	6	0	3	0	0	152	335	663	429	0
Formionidae	199	85	76	98	52	32	96	35	15	0	29	0	0	46	135	255	91	0
Haemulidae	205	90	189	258	447	80	134	37	8	0	0	0	0	139	208	385	295	2
Lethrinidae	105	65	86	166	332	57	175	71	34	0	30	0	0	188	248	469	272	11
Loligo spp.	329	418	735	108	98	23	13	2	1	0	0	0	0	8	5	13	11	0
Lutjanidae small	27	61	148	94	283	82	114	44	17	0	16	0	0	121	141	224	180	2
Lutjanidae goldband	35	8	13	128	78	16	35	14	5	0	14	0	0	39	67	122	122	1
Lutjanidae red	978	758	923	2095	2965	721	1274	384	257	3	164	0	0	1394	2184	4188	2550	222
Mullidae	42	60	2	5	2	3	7	2	1	0	1	0	0	14	12	12	10	0
Nemipteridae	1015	585	609	694	390	191	436	144	95	0	20	0	0	199	273	268	225	0
Priacanthidae	71	13	12	3	5	2	6	3	0	0	0	0	0	21	43	98	56	0
Rachycentridae	0	0	0	2	3	2	4	1	0	0	0	0	0	0	0	0	0	0
Sciaenidae	39	23	122	69	39	30	22	0	10	0	0	0	0	7	15	12	2	0
Scombridae	132	64	103	86	152	8	17	2	7	0	1	0	0	56	41	66	58	1
Sepiidae	49	34	82	106	109	30	39	14	8	0	3	0	0	65	51	73	72	0
Serranidae	17	5	11	21	47	6	14	4	1	0	4	0	0	33	47	96	58	1
sharks and rays	338	284	411	612	973	274	399	98	60	0	29	0	0	21	38	116	150	6
Sparidae	19	29	3	2	26	2	14	5	4	0	3	0	0	2	13	34	40	1
Sphyraenidae	57	19	25	15	37	7	15	8	12	0	0	0	0	11	7	16	17	0
Synodontidae	62	95	50	17	8	26	31	9	4	0	4	0	0	67	39	103	134	0
Trichiuridae	1005	390	31	89	16	3	0	0	25	0	0	0	0	0	0	0	0	0
mixed taxa	841	222	295	620	614	234	346	100	56	0	42	0	0	78	120	327	347	8
total retained catch	6392	3782	5464	9004	7848	2299	4293	1126	710	4	398	337	2691	3499	4290	7787	5308	249

Table 3. Standardisation of CPUE (kg·h^{-1}) for Taiwanese and Thai fleets in Australia's northern trawl fishery during 1972 - 90. Annual catch and effort data were fitted to $\log(U_{ijt}) = \log(U_{111}) + \log(\alpha_i) + \log(\beta_j) + \log(\gamma_t) + \varepsilon_{ijt}$ where U_{ijt} is CPUE for fleet i in zone j during year t, U_{111} is CPUE for the Taiwanese fleet on the Northwest Shelf during 1972, α_2 is relative fishing power of the Thai fleet, β_j is relative abundance in the Timor (2) and Arafura (3) Seas, and γ_t is relative annual abundance during 1973-1990, and ε_{ijt} is an error term. Annual catch and effort during 1972-79 were based on Edwards (1983) and Sainsbury (1991; CSIRO, GPO Box 1538 Hobart 7001 Australia, unpub. data).

Category	Regression			Standardisation Parameters								
	F	P	Adj r^2	U_{111}	α_2	β_2	β_3	γ_{73}	γ_{74}	γ_{75}	γ_{76}	γ_{77}
Ariidae	8.038	0.056	0.847	1.02	5.63	1.14	0.79	1.00	1.00	1.00	1.00	1.00
butterfish	17.920	0.000	0.894	0.09	1.00	12.97	268.88	1.00	1.00	1.00	1.00	1.00
Carangidae	3.788	0.001	0.535	36.02	1.47	1.54	1.67	0.36	1.27	0.54	1.14	0.92
Formionidae	2.813	0.024	0.440	1.33	0.57	2.35	6.55	1.00	1.00	1.00	1.00	1.00
Haemulidae	4.938	0.001	0.615	3.30	0.75	5.31	2.89	1.00	1.00	1.00	1.00	1.00
Lethrinidae	7.300	0.000	0.703	39.09	0.72	1.19	0.24	1.13	1.12	0.91	1.02	0.85
Loligo spp.	3.101	0.015	0.477	1.82	0.10	0.77	2.71	1.00	1.00	1.00	1.00	1.00
Lutjanidae small	4.890	0.000	0.593	24.58	0.76	1.24	0.27	1.12	1.07	0.80	0.26	0.83
Lutjanidae goldband	13.463	0.000	0.822	16.39	0.57	5.95	0.35	1.00	1.00	1.00	1.00	1.00
Lutjanidae red	6.496	0.000	0.658	22.78	0.70	3.75	4.12	0.66	0.80	0.67	0.27	0.51
Mullidae	6.261	0.000	0.661	15.81	0.64	0.19	0.03	1.00	1.00	1.00	1.00	1.00
Nemipteridae	7.430	0.000	0.696	147.46	0.21	0.47	0.50	1.40	1.25	0.86	0.67	0.88
Priacanthidae	7.074	0.000	0.723	10.83	2.31	1.21	0.08	0.23	1.22	0.48	0.39	0.91
Rachycentridae	4.243	0.019	0.641	0.90	1.00	0.82	0.19	1.00	1.00	1.00	1.00	1.00
Sciaenidae	2.555	0.110	0.496	0.10	0.12	18.68	17.96	1.00	1.00	1.00	1.00	1.00
Scombridae	5.775	0.001	0.697	0.10	0.94	5.40	10.01	1.00	1.00	1.00	1.00	1.00
Sepiidae	8.549	0.000	0.737	6.51	0.63	0.72	0.32	1.00	1.00	1.00	1.00	1.00
Serranidae	4.824	0.000	0.612	3.33	1.07	0.81	0.15	1.14	0.95	1.48	4.70	1.85
sharks and rays	9.805	0.000	0.766	6.55	0.07	1.72	4.37	1.00	1.00	1.00	1.00	1.00
Sparidae	3.696	0.005	0.523	15.21	0.39	0.63	0.15	1.00	1.00	1.00	1.00	1.00
Sphyraenidae	2.627	0.035	0.422	0.83	0.36	1.25	1.32	1.00	1.00	1.00	1.00	1.00
Synodontidae	7.498	0.000	0.702	66.20	1.07	0.51	0.18	1.26	1.77	1.15	1.49	1.03
Trichiuridae	5.959	0.010	0.724	0.33	1.00	3.92	28.88	1.00	1.00	1.00	1.00	1.00
mixed taxa	15.117	0.000	0.840	27.85	0.24	1.65	1.16	1.00	1.00	1.00	1.00	1.00
total retained catch	8.896	0.000	0.728	434.61	0.56	1.38	0.98	1.10	1.20	0.99	0.97	0.99

Category	Standardisation Parameters (cont.)												
	γ_{78}	γ_{79}	γ_{80}	γ_{81}	γ_{82}	γ_{83}	γ_{84}	γ_{85}	γ_{86}	γ_{87}	γ_{88}	γ_{89}	γ_{90}
Ariidae	1.00	1.00	1.22	0.40	0.94	0.38	0.62	1.00	1.00	1.62	1.76	0.89	1.00
butterfish	1.00	1.00	0.68	1.02	1.70	1.78	0.70	1.15	1.03	1.44	1.25	1.07	1.00
Carangidae	1.07	0.51	0.59	0.68	0.48	0.44	0.37	0.32	0.12	0.16	0.15	0.09	0.05
Formionidae	1.00	1.00	1.21	2.89	0.75	0.52	0.27	0.79	0.80	0.40	0.35	0.83	1.00
Haemulidae	1.00	1.00	1.24	1.37	1.20	1.55	1.39	0.84	0.58	0.58	0.63	1.73	1.00
Lethrinidae	1.12	0.67	0.86	0.67	0.84	0.87	0.83	0.70	0.60	0.94	1.11	1.17	1.08
Loligo spp.	1.00	1.00	1.16	2.19	4.46	0.85	0.77	0.54	0.27	0.51	0.27	0.53	1.00
Lutjanidae small	0.85	0.48	0.42	0.77	1.02	0.87	1.00	1.01	0.50	0.90	1.02	0.54	1.03
Lutjanidae goldband	1.00	1.00	0.23	0.18	0.38	0.44	0.56	0.45	0.31	0.45	0.56	0.67	1.00
Lutjanidae red	0.60	0.38	0.61	0.65	0.85	0.72	0.78	0.80	0.42	0.70	0.84	1.33	1.09
Mullidae	1.00	1.00	0.82	1.78	0.64	0.93	0.75	1.27	0.72	1.58	1.21	0.50	1.00
Nemipteridae	0.68	0.38	0.70	0.74	0.42	0.56	0.35	0.44	0.39	0.39	0.64	0.26	0.39
Priacanthidae	0.96	0.33	1.44	0.98	0.82	0.33	0.40	0.51	0.44	0.52	0.66	0.49	0.68
Rachycentridae	1.00	1.00	5.76	2.85	1.08	1.24	0.20	1.24	2.01	1.71	2.99	1.00	1.00
Sciaenidae	1.00	1.00	1.63	2.04	2.29	2.75	1.53	0.66	0.75	1.44	2.30	1.00	1.00
Scombridae	1.00	1.00	5.19	6.38	8.86	2.94	2.14	0.92	0.98	1.29	2.17	1.83	1.00
Sepiidae	1.00	1.00	1.48	1.43	1.92	2.37	2.05	2.00	1.18	1.51	1.51	1.24	1.00
Serranidae	1.41	1.41	1.92	1.07	1.65	2.28	2.05	1.67	0.67	2.35	1.98	3.15	3.80
sharks and rays	1.00	1.00	1.27	1.14	0.91	0.93	1.14	0.87	0.56	0.61	0.74	1.06	1.00
Sparidae	1.00	1.00	0.27	0.66	0.20	0.22	0.29	0.22	0.22	0.22	0.59	0.30	1.00
Sphyraenidae	1.00	1.00	3.97	2.24	2.21	0.95	1.48	0.88	1.04	0.73	1.20	0.42	1.00
Synodontidae	0.75	0.62	0.32	0.59	0.22	0.06	0.14	0.35	0.26	0.15	0.20	0.13	0.15
Trichiuridae	1.00	1.00	2.44	1.42	0.46	0.32	0.06	0.12	1.00	0.60	1.00	1.00	1.00
mixed taxa	1.00	1.00	1.90	0.93	0.74	0.73	0.67	0.90	0.50	0.53	0.57	0.48	1.00
total retained catch	0.91	0.62	0.78	0.78	0.75	0.75	0.63	0.61	0.47	0.55	0.64	0.53	0.59

Table 4. Annual catch and effort in Australia's northern trawl fishery during 1972-90 fitted to Walters and Hilborn's difference equation $(U_{t+1}/U_t)-1=r-(r/kq)U_t-qE_t$ where U_t and U_{t+1} are CPUE (kg·h^{-1}) during years t and t+1 respectively, E_t is effort (h) during year t, r is intrinsic population growth rate, q is catchability (h^{-1}), k is carrying capacity (t) and MSY is annual maximum sustainable yield (t). Standardised data were fitted by multiple linear regression, and annual catch and effort during 1972-79 were based on Edwards (1983) and Sainsbury (1991; CSIRO, GPO Box 1538 Hobart 7001 Australia, unpub. data).

Category	Northwest Shelf						
	F	P	Adj r^2	r	q	k	MSY
Ariidae	0.000	0.000	0.000	2.35	0.0000000	0	0
butterfish	0.586	0.631	-0.261	1.16	0.0000065	24	7
Carangidae	5.026	0.021	0.321	-0.61	-0.0000281	1893	-287
Formionidae	1.516	0.293	0.114	0.30	-0.0000126	-60	-4
Haemulidae	0.991	0.425	-0.002	0.90	0.0000101	617	139
Lethrinidae	4.056	0.039	0.264	0.76	0.0000014	27824	5288
Loligo spp.	1.707	0.249	0.136	0.96	0.0000157	436	105
Lutjanidae small	10.400	0.002	0.525	1.71	-0.0000017	-12360	-5294
Lutjanidae goldband	1.230	0.349	0.049	1.04	0.0000119	1170	303
Lutjanidae red	5.288	0.017	0.323	1.01	0.0000034	6068	1528
Mullidae	7.440	0.019	0.589	1.95	0.0000051	3954	1932
Nemipteridae	3.819	0.044	0.238	1.91	0.0000191	9477	4520
Priacanthidae	4.594	0.026	0.285	1.74	-0.0000044	-1965	-854
Rachycentridae	2.077	0.241	0.264	3.17	0.0000398	114	90
Sciaenidae	0.271	0.787	-0.574	-1.00	-0.0000136	-25	6
Scombridae	0.518	0.620	-0.137	0.25	0.0000026	177	11
Sepiidae	3.472	0.090	0.354	0.52	-0.0000091	-791	-104
Serranidae	2.428	0.122	0.144	1.35	0.0000062	1522	514
sharks and rays	2.074	0.196	0.193	0.53	0.0000028	2595	346
Sparidae	1.386	0.320	0.088	1.14	0.0000019	3431	978
Sphyraenidae	0.979	0.429	-0.005	0.21	-0.0000018	-423	-22
Synodontidae	1.217	0.322	0.023	1.94	0.0000186	5428	2635
Trichiuridae	0.000	0.000	0.000	-1.04	0.0000000	0	0
mixed taxa	2.065	0.197	0.191	0.57	0.0000032	8241	1183
total retained catch	6.448	0.009	0.377	113.24	-0.0004040	-806	-22814

Category	Timor Sea						
	F	P	Adj r^2	r	q	k	MSY
Ariidae	0.000	0.000	0.000	-.67	0.0000000	0	0
butterfish	13.775	0.068	0.865	1.65	0.0000162	98	41
Carangidae	0.489	0.623	-0.064	0.31	-0.0000129	-2061	-159
Formionidae	47.690	0.102	0.969	3.32	0.0002930	33	27
Haemulidae	1.467	0.303	0.105	0.79	0.0001240	444	88
Lethrinidae	3.988	0.041	0.260	0.74	0.0000074	6287	1168
Loligo spp.	0.511	0.703	-0.484	2.85	0.0008820	5	3
Lutjanidae small	20.665	0.000	0.698	1.99	0.0000400	769	383
Lutjanidae goldband	1.864	0.224	0.161	0.69	0.0000795	1692	293
Lutjanidae red	6.972	0.007	0.399	1.03	0.0000268	2915	750
Mullidae	6.989	0.022	0.571	1.76	0.0000146	254	112
Nemipteridae	2.598	0.105	0.151	0.45	0.0000187	3342	377
Priacanthidae	4.704	0.025	0.292	2.08	0.0000182	627	326
Rachycentridae	3.547	0.220	0.560	-1.12	-0.0008260	3	-1
Sciaenidae	0.000	0.000	0.000	-.73	0.0000000	0	0
Scombridae	0.000	0.000	0.000	2.00	0.0000867	14	7
Sepiidae	0.697	0.529	-0.072	0.29	0.0000230	425	31
Serranidae	2.086	0.159	0.113	1.03	0.0000051	1367	352
sharks and rays	3.241	0.101	0.332	0.46	0.0000559	273	31
Sparidae	1.285	0.371	0.087	1.18	0.0000624	73	22
Sphyraenidae	0.777	0.563	-0.126	0.59	0.0000501	47	7
Synodontidae	0.898	0.428	-0.012	0.42	-0.0000125	-2295	-240
Trichiuridae	57.918	0.017	0.966	-1.24	-0.0001770	-40	12
mixed taxa	2.056	0.198	0.190	0.57	0.0000210	2011	286
total retained catch	6.543	0.008	0.381	200.91	-0.0032610	-143	-7182

Category	Arafura Sea						
	F	P	Adj r^2	r	q	k	MSY
Ariidae	0.413	0.682	-0.202	0.46	0.0000044	1422	162
butterfish	6.656	0.039	0.618	1.21	0.0000038	9977	3018
Carangidae	0.266	0.774	-0.195	0.18	0.0000048	4590	210
Formionidae	0.972	0.424	-0.006	0.18	-0.0000112	-493	-22
Haemulidae	1.636	0.261	0.124	0.09	-0.0000168	-118	-3
Lethrinidae	5.455	0.021	0.389	0.94	0.0000017	4883	1153
Loligo spp.	6.671	0.024	0.558	-1.01	-0.0000369	1026	-259
Lutjanidae small	9.784	0.003	0.557	1.58	-0.0000063	-767	-303
Lutjanidae goldband	1.299	0.331	0.062	0.68	-0.0000050	-415	-70
Lutjanidae red	6.248	0.010	0.368	9.52	-0.0000759	-742	-1767
Mullidae	6.980	0.022	0.571	1.02	-0.0000073	-53	-14
Nemipteridae	2.700	0.098	0.159	-0.30	-0.0000153	8583	-642
Priacanthidae	1.516	0.284	0.103	0.63	-0.0000089	-75	-12
Rachycentridae	9.547	0.223	0.851	-0.45	-0.0000667	5	-1
Sciaenidae	0.178	0.840	-0.223	0.31	0.0000048	603	47
Scombridae	0.667	0.543	-0.080	0.38	0.0000081	760	71
Sepiidae	0.034	0.966	-0.273	-0.01	0.0000019	-2568	6
Serranidae	10.408	0.008	0.677	1.36	-0.0000382	-16	-5
sharks and rays	1.197	0.357	0.042	-0.75	-0.0000122	-4649	873
Sparidae	6.064	0.030	0.530	0.44	-0.0000165	-25	-3
Sphyraenidae	4.399	0.058	0.430	-0.25	-0.0000174	134	-8
Synodontidae	5.953	0.012	0.355	-0.02	-0.0000321	9	0
Trichiuridae	0.281	0.780	-0.561	-0.26	-0.0000159	360	-23
mixed taxa	10.662	0.007	0.682	-0.65	-0.0000206	-19276	3142
total retained catch	6.267	0.010	0.369	606.72	0.0079550	62	9421

Appendix 1

Effort (h) for the Taiwanese fleet in Australia's northern trawl fishery during 1972-79 on (a) Northwest Shelf, (h) Timor Sea and (c) Arafura Sea based on Edwards (1983) and Sainsbury (1991; CSIRO, GPO Box 1538 Hobart 7001 Australia, unpub. data).

Ground	1972	1973	1974	1975	1976	1977	1978	1979
Northwest Shelf	500	64545	79860	57767	46592	56413	40998	33500
Timor Sea	2017	1512	8673	6664	5911	7063	8324	8357
Arafura Sea	17425	19334	19083	14412	18208	25951	29250	23544

Retained catch (t) for the Taiwanese fleet in Australia's northern trawl fishery during 1972-79 on (a) Northwest Shelf, (b) Timor Sea and (c) Arafura Sea based on Edwards (1983) and Sainsbury (1991; CSIRO, GPO Box 1538 Hobart 7001 Australia, unpub. data). Zeros may be missing values.

(a) Catch (t) on Northwest Shelf

Category	1972	1973	1974	1975	1976	1977	1978	1979
Ariidae	0	0	0	0	0	0	0	0
butterfish	0	0	0	0	0	0	0	0
Carangidae	34	866	1462	685	1168	1060	889	595
Formionidae	0	0	0	0	0	0	0	0
Haemulidae	0	0	0	0	0	0	0	0
Lethrinidae	30	4076	2653	2866	1841	2000	1701	754
Loligo spp.	0	0	0	0	0	0	0	0
Lutjanidae small	13	1762	1281	1148	469	777	755	411
Lutjanidae goldband	0	0	0	0	0	0	0	0
Lutjanidae red	21	2182	1487	1107	336	557	596	297
Mullidae	0	0	0	0	0	0	0	0
Nemipteridae	39	8377	7935	5034	4531	4518	3432	2169
Priacanthidae	12	70	618	369	327	318	392	209
Rachycentridae	0	0	0	0	0	0	0	0
Sciaenidae	0	0	0	0	0	0	0	0
Scombridae	0	0	0	0	0	0	0	0
Sepiidae	0	0	0	0	0	0	0	0
Serranidae	3	374	226	275	168	193	121	156
sharks and rays	0	0	0	0	0	0	0	0
Sparidae	0	0	0	0	0	0	0	0
Sphyraenidae	0	0	0	0	0	0	0	0
Synodontidae	16	2711	4276	3356	3062	3199	1952	1937
Trichiuridae	0	0	0	0	0	0	0	0
total retained catch	273	37143	31256	21289	18929	19080	14488	10764

(b) Catch (t) in Timor Sea

Category	1972	1973	1974	1975	1976	1977	1978	1979
Ariidae	0	0	0	0	0	0	0	0
butterfish	0	0	0	0	0	0	0	0
Carangidae	59	29	1528	322	611	640	873	239
Formionidae	0	0	0	0	0	0	0	0
Haemulidae	0	0	0	0	0	0	0	0
Lethrinidae	61	55	598	416	425	640	627	197
Loligo spp.	0	0	0	0	0	0	0	0
Lutjanidae small	58	52	467	456	18	492	431	187
Lutjanidae goldband	0	0	0	0	0	0	0	0
Lutjanidae red	109	40	1091	329	62	503	958	522
Mullidae	0	0	0	0	0	0	0	0
Nemipteridae	162	168	955	389	159	942	602	167
Priacanthidae	12	10	236	34	18	148	114	21
Rachycentridae	0	0	0	0	0	0	0	0
Sciaenidae	0	0	0	0	0	0	0	0
Scombridae	0	0	0	0	0	0	0	0
Sepiidae	0	0	0	0	0	0	0	0
Serranidae	3	3	25	27	327	64	50	32
sharks and rays	0	0	0	0	0	0	0	0
Sparidae	0	0	0	0	0	0	0	0
Sphyraenidae	0	0	0	0	0	0	0	0
Synodontidae	76	42	392	295	327	444	371	177
Trichiuridae	0	0	0	0	0	0	0	0
mixed taxa	0	0	0	0	0	0	0	0
total retained catch	871	785	9121	5550	4496	6333	7381	2597

(c) Catch (t) in Arafura Sea

Category	1972	1973	1974	1975	1976	1977	1978	1979
Ariidae	0	0	0	0	0	0	0	0
butterfish	0	0	0	0	0	0	0	0
Carangidae	0	0	0	0	0	0	0	0
Formionidae	0	0	0	0	0	0	0	0
Haemulidae	0	0	0	0	0	0	0	0
Lethrinidae	0	0	0	59	116	83	221	230
Loligo spp.	0	0	0	0	0	0	0	0
Lutjanidae small	0	0	0	28	53	77	95	46
Lutjanidae goldband	0	0	0	0	0	0	0	0
Lutjanidae red	1402	1158	771	841	907	912	685	427
Mullidae	0	0	0	0	0	0	0	0
Nemipteridae	2110	2811	2597	1371	1560	1266	1130	784
Priacanthidae	0	0	0	0	0	0	0	0
Rachycentridae	0	0	0	0	0	0	0	0
Sciaenidae	0	0	0	0	0	0	0	0
Scombridae	0	0	0	0	0	0	0	0
Sepiidae	0	0	0	0	0	0	0	0
Serranidae	0	0	0	0	0	0	0	0
sharks and rays	0	0	0	0	0	0	0	0
Sparidae	0	0	0	0	0	0	0	0
Sphyraenidae	0	0	0	0	0	0	0	0
Synodontidae	396	907	1190	234	454	220	162	123
Trichiuridae	0	0	0	0	0	0	0	0
mixed taxa	0	0	0	0	0	0	0	0
total retained catch	8165	9536	8817	5090	6026	9150	7689	6073

Appendix 2

Species composition of commercial categories in Australia's northern trawl fishery based on observer data for Taiwanese and Thai fleets during 1985-87.

Category/Family	Species	Relative abundance (% weight of category)
Ariidae	*Arius thalassinus*	100
butterfish		
Ariommatidae	*Ariomma indica*	21
Centrolophidae	*Psenopsis humerosa*	79
Carangidae	*Alepes* sp.	4
	Carangoides uii	11
	Carangoides chrysophrys	11
	Carangoides gymnostethus	18
	Carangoides humerosus	4
	Carangoides malabaricus	4
	Caranx bucculentus	11
	Gnathanodon speciosus	4
	Megalaspis cordyla	22
	Selar boops	7
	Selaroides leptolepis	2
Formionidae	*Apolectus niger*	100
Haemulidae	*Diagramma pictum*	100
Lethrinidae	*Lethrinus choerorynchus*	29
	Lethrinus fraenatus	2
	Lethrinus lentjan	64
	Lethrinus nebulosus	1
	Lethrinus nematacanthus	4
Loligo spp.	*Loligo* spp.	100
Lutjanidae small	*Lutjanus russelli*	6
	Lutjanus vittus	94
Lutjanidae goldband	*Pristipomoides multidens*	91
	Pristipomoides typus	9
Lutjanidae red	*Lutjanus argentimaculatus*	1
	Lutjanus erythropterus	24
	Lutjanus johni	3
	Lutjanus malabaricus	70
	Lutjanus sebae	2
Mullidae	*Parupeneus pleurospilus*	100
Nemipteridae	*Nemipterus celebicus*	1
	Nemipterus furcosus	69
	Nemipterus hexodon	28
	Nemipterus virgatus	1
	Scolopsis monogramma	1

...continued

Category/Family	Species	Relative abundance (% weight of category)
Priacanthidae	*Priacanthus hamrur*	21
	Priacanthus tayenus	79
Rachycentridae	*Rachycentron canadus*	100
Sciaenidae	*Protonibea diacanthus*	80
	Argyrosomus sp.	20
Scombridae	*Rastrelliger kanagurta*	100
Sepiidae	*Sepia* spp.	100
Serranidae	*Epinephelus areolatus*	38
	Epinephelus coiodes	24
	Plectropomus maculatus	38
sharks and rays		
Carcharhinidae	*Carcharhinus dussumieri*	29
	Rhizoprionodon acutus	6
	Rhizoprionodon taylori	6
Hemigaleidae	*Hemipristis elongatus*	6
Dasyatididae	*Himantura uarnak*	12
Rhynchobatidae	*Rhynchobatus djiddensis*	41
Sparidae	*Argyrops spinifer*	100
Sphyraenidae	*Sphyraena putnamiae*	100
Synodontidae	*Saurida micropectoralis*	18
	Saurida sp.1	5
	Saurida undosquamis	77
Trichiuridae	*Trichiurus lepturus*	100
mixed taxa		
Labridae	*Choerodon cephalotes*	28
	Choerodon schoenleinii	6
	Choerodon sp.	6
Haemulidae	*Hapalogenys kishinouyei*	6
Glaucosomatidae	*Glaucosoma burgeri*	6
Lethrinidae	*Gymnocranius elongatus*	6
Ephippididae	*Platax batavianus*	6
Scaridae	*Scarus ghobban*	12
Carangidae	*Seriolina nigrofasciata*	6
Siganidae	*Siganus fuscescens*	12
Teraponidae	*Terapon jarbua*	6

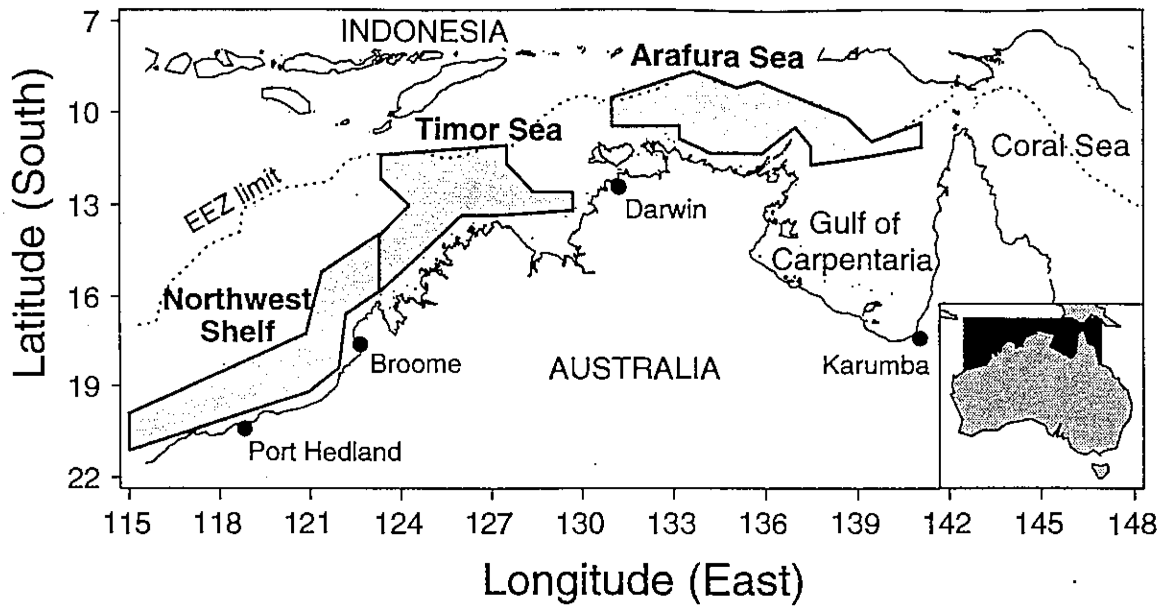


Figure 1 Fishery management zones (shaded) in Australia's northern trawl fishery: Northwest Shelf (115-123°E), Timor Sea (123-131°E), and Arafura Sea (131-141°E).

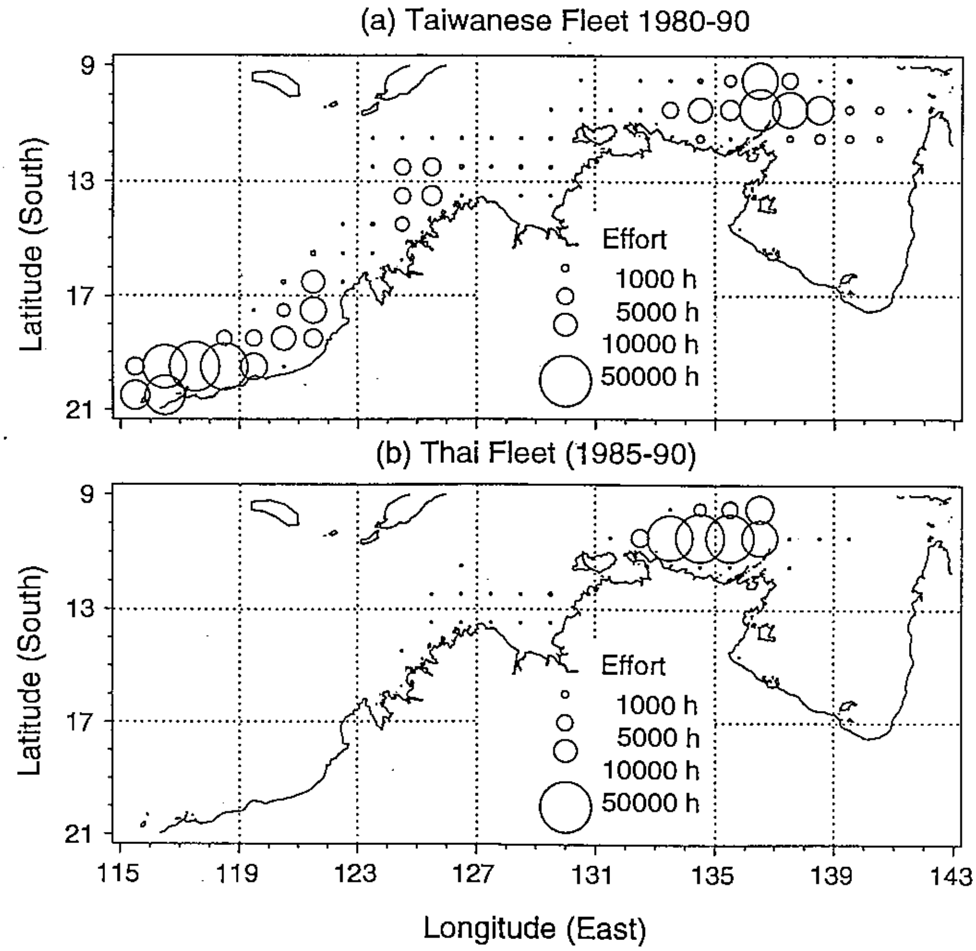


Figure 2 Total fishing effort, by degree grid, for (a) Taiwanese and (b) Thai fleets in Australia's northern trawl fishery during 1980-90.

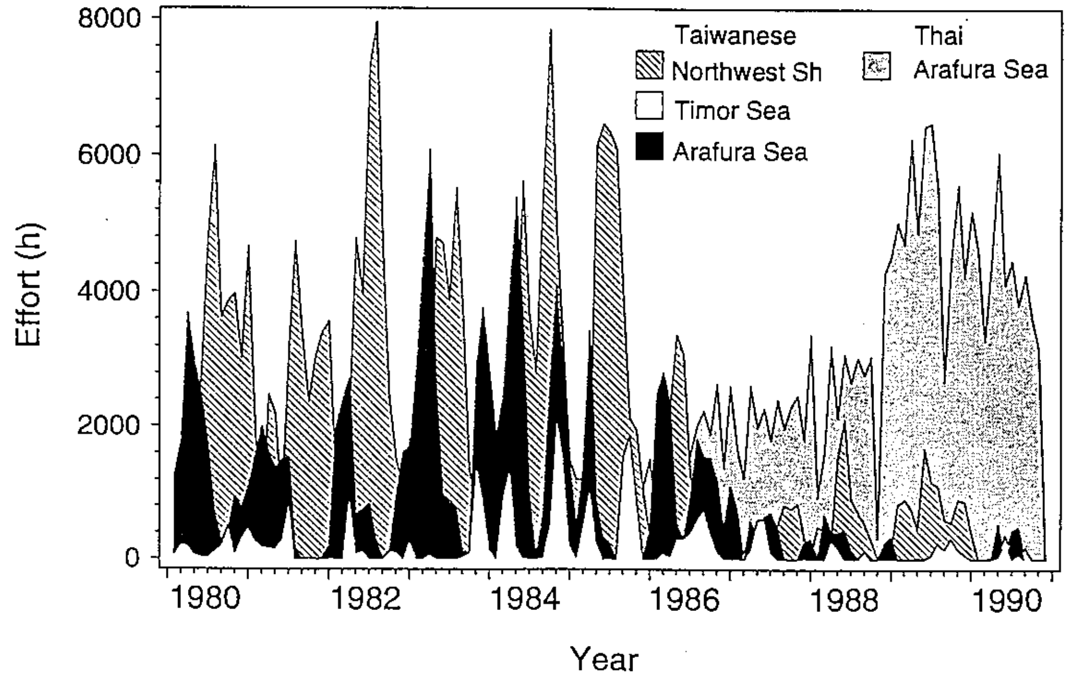


Figure 3 Monthly effort for Taiwanese and Thai fleets in Australia's northern trawl fishery during 1980-90. Taiwanese fleet on the Northwest Shelf (cross hatch), and in the Timor (white) and Arafura Seas (black); Thai fleet in the Arafura Sea (stipple).

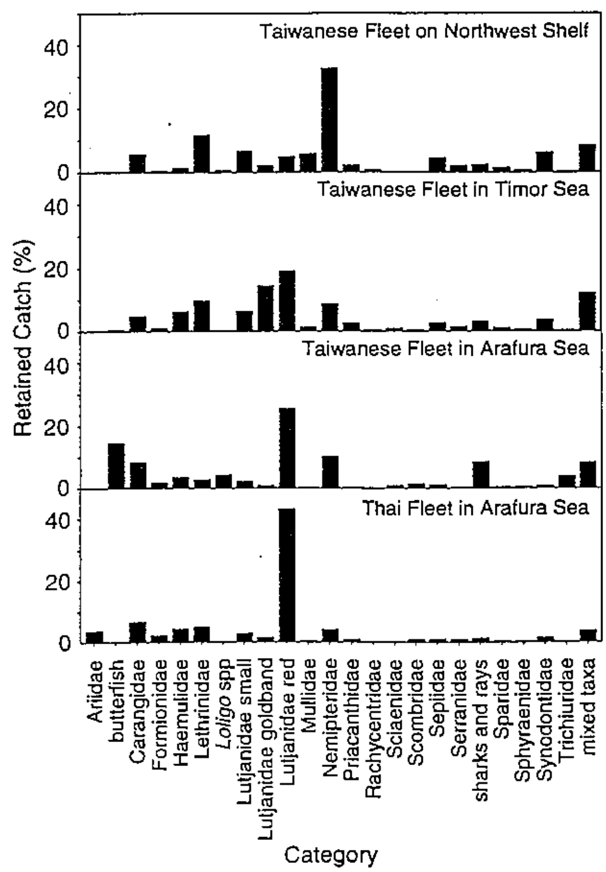


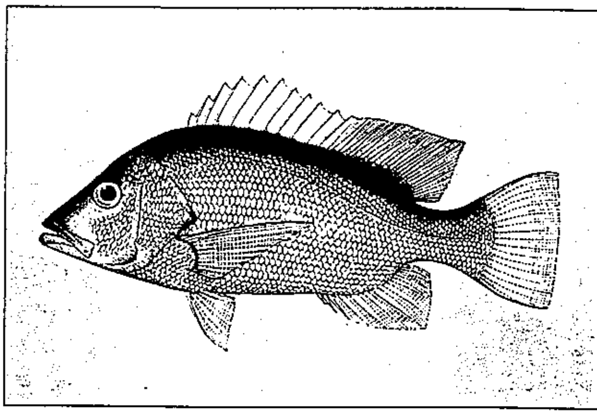
Figure 4 Retained catch (%) by commercial categories for Taiwanese and Thai fleets in Australia's northern trawl fishery during 1980-90.

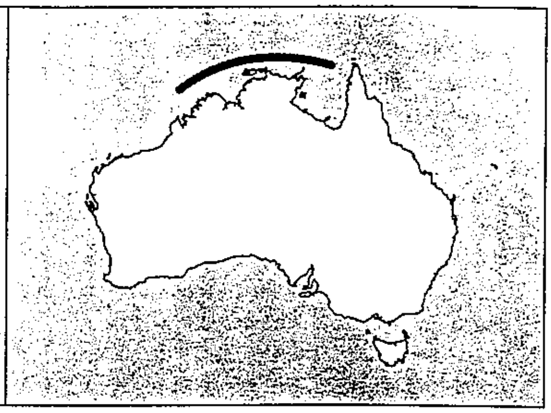
Northern Fish Trawl

Prepared by the former
Bureau of Rural Resources
February 1992

Fishery Status Report

February 1992





- The Northern Fish Trawl Fishery is a diverse multi-species fishery, but current fishing targets only the saddle-tail snapper.
- Previous heavy fishing by foreign vessels has resulted in reduced stocks of the larger species preferred by Australian and overseas markets.
- Sustainable yield estimates are not precise and scientists recommend that a cautious approach be taken in setting limits on the number of trawlers allowed to fish.
- Current assessment is limited to selected species. Any changes in fishing techniques and/or markets would alter the total catch, the value of the fishery, and the assessment.

Main Features

Status	-	**Fully exploited (selected species)**
Catch trend	-	**Variable**
Current catch (1990–91)	-	**500 tonnes**
Commercial value (1990–91)	-	**$A1m**
Long-term potential yield	-	**Unknown**
Recommended yield (1992)	-	**1200–4500 t (all zones)**
Total allowable catch (TAC)	-	

	1991	1992
Timor Zone	**1200 t**	**1000 t**
Arafura Zone*	**2000 t**	**2000 t**

*** includes Gulf of Carpentaria in 1992**

Main fishing method	-	**Demersal and semi-demersal trawl**
Recreational component	-	**Small**
Management method	-	**Limited number of vessels (based on TAC)**

DEPARTMENT OF PRIMARY INDUSTRY AND FISHERIES

CSIRO AUSTRALIA

BRR

About the Fishery

The fishery extends across northern Australia from the Gulf of Carpentaria in Queensland to Collier Bay in Western Australia (see map next page). In 1991, it was divided into the Timor Zone and the Arafura Zone. The main method of fishing is by trawling using demersal or semi-demersal otter trawl gear. Trawling is prohibited in part of the Timor Sea where a trap and line fishery is developing.

The northern demersal fish resources are a diverse mixture of species. Only a small proportion (5–10%) of the fish available are commercially important at present. These large snappers, such as the saddle-tail snapper or scarlet sea perch (*Lutjanus malabaricus*) and other large lutjanids, are the preferred species for the current Australian and overseas markets. Recent research surveys have shown that saddle-tail snapper constitutes 70–80% of the total catch of large red snappers.

Trawling began in northern and north-western Australian waters with experimental fishing by the Japanese in 1935. Very few Australian fishers showed interest in trawling for fish in these northern waters, so foreign vessels (including Taiwanese, Thai and Chinese) have been licensed to operate in various northern and north-western sectors of the Australian Fishing Zone (AFZ) since 1979. These foreign vessels were phased out by 1991 and none operate within the fishery at present.

There are now 6 Australian trawlers licensed to fish in the Arafura Zone but none in the Timor Zone. Current fishing activity targets the saddle-tail snapper. This species is not known to form dense aggregations and inhabits both coastal waters and inshore reefs to depths to 100 m throughout the Indo-West Pacific. Maximum size for saddle-tail snapper is approximately 100 cm, which is reached in about 10 years. It matures when 4–5 years old and approximately 60 cm long.

In 1990–91, only 500 tonnes (t) of fish were taken, with an estimated value of $A1m. This is considerably less than catches of previous years by foreign fishing vessels (see graph). Product is sold in Australia and Europe.

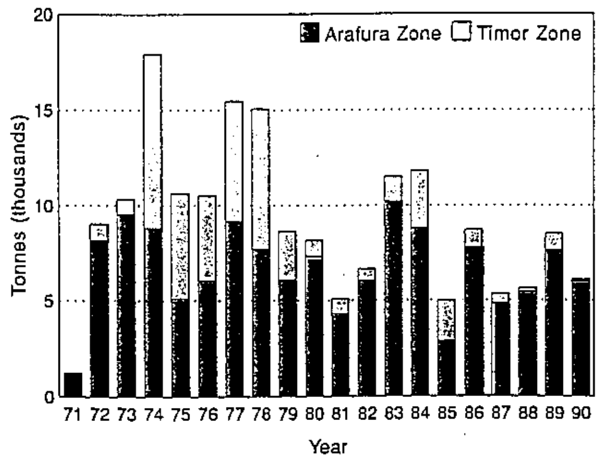
Total allowable catch (tonnes) 1988–92
(Note management objectives changed in 1990)

	Timor Zone	Arafura Zone
1988	5000	8500
1989	4000	8000
1990	1200	2000
1991	1200	2000
1992	1000	2000*

*Arafura Zone now includes part of Gulf of Carpentaria.

Despite the high potential yield for the wide range of species available, there is still considerable uncertainty about the commercial viability of the fishery. The main problems are high costs due to the area's remoteness and variability in both the domestic and overseas markets.

Northern Fish Trawl catch



Total allowable catches (TACs) are set each year (see table). These TACs are not used directly as output controls but are used to determine the number of vessels licensed to fish based on the expected catch per boat. Between 1979 and 1989, management was based on TACs set to maximise the total catch of all species combined. This management objective, however, conflicted with the longer-term goal of developing a domestic fishery, and in 1989 the management objective changed to maximising the sustainable catch of the larger, more valuable species. Since 1988, TACs have been set for the different management zones. In 1991, TACs were 2000 t for the Arafura Zone and 1200 t for the Timor Zone. A minimum net mesh size of 90 mm also applies. To avoid habitat destruction, the use of 'environmentally friendly' semi-demersal trawl gear is encouraged.

Monitoring and previous assessments

Yield estimates since 1979 have been based on commercial logbook data, information collected by AFZ observers and research vessel data. Catch and effort data for fish trawling are available from Taiwanese logbooks (annual reports 1972–1979), and AFZ logbook data for the Taiwanese (1980–1990), Thai (1985–1990) and Chinese fleets (1989). Catch data were recorded as the number of boxes of fish retained for each commercial category.

Fishery monitoring data from AFZ observers are also available but are patchy. Some fleets were not sampled at all during some years. These data, however, were used to provide the mean weight of boxes and estimates of the relative species composition within commercial categories.

Previous assessments of the size of the resource have resulted in widely varying yield estimates. For example, Taiwanese scientists estimated a potential yield of 529000 t in the early 1980s, a figure 10 times greater than that estimated by Australian scientists. Changes in management objectives, fishing practices, and lack of data on discarded catch make it difficult to provide a reliable stock assessment. Precise estimates of sustainable yield are not possible. Accordingly, a conservative approach has been adopted in setting TACs, based on experience with similar fisheries in other parts of the world—especially the Gulf of Thailand, where severe overfishing has occurred.

Current Status

Stocks and Areas

The Arafura Sea is regarded as a faunal region separate from the Timor Sea, but there are no definitive data on the stock structure of fish in either region and data on movements or migrations are scarce. Stock assessments were carried out separately for the Arafura and Timor Zones because they are managed separately. In addition, assessments were carried out for the Gulf of Carpentaria, parts of which will be open to fish trawling in 1992. The new zone will include both the old Arafura Zone and the top of the Gulf of Carpentaria and will be known as the Arafura and Gulf of Carpentaria Zone.

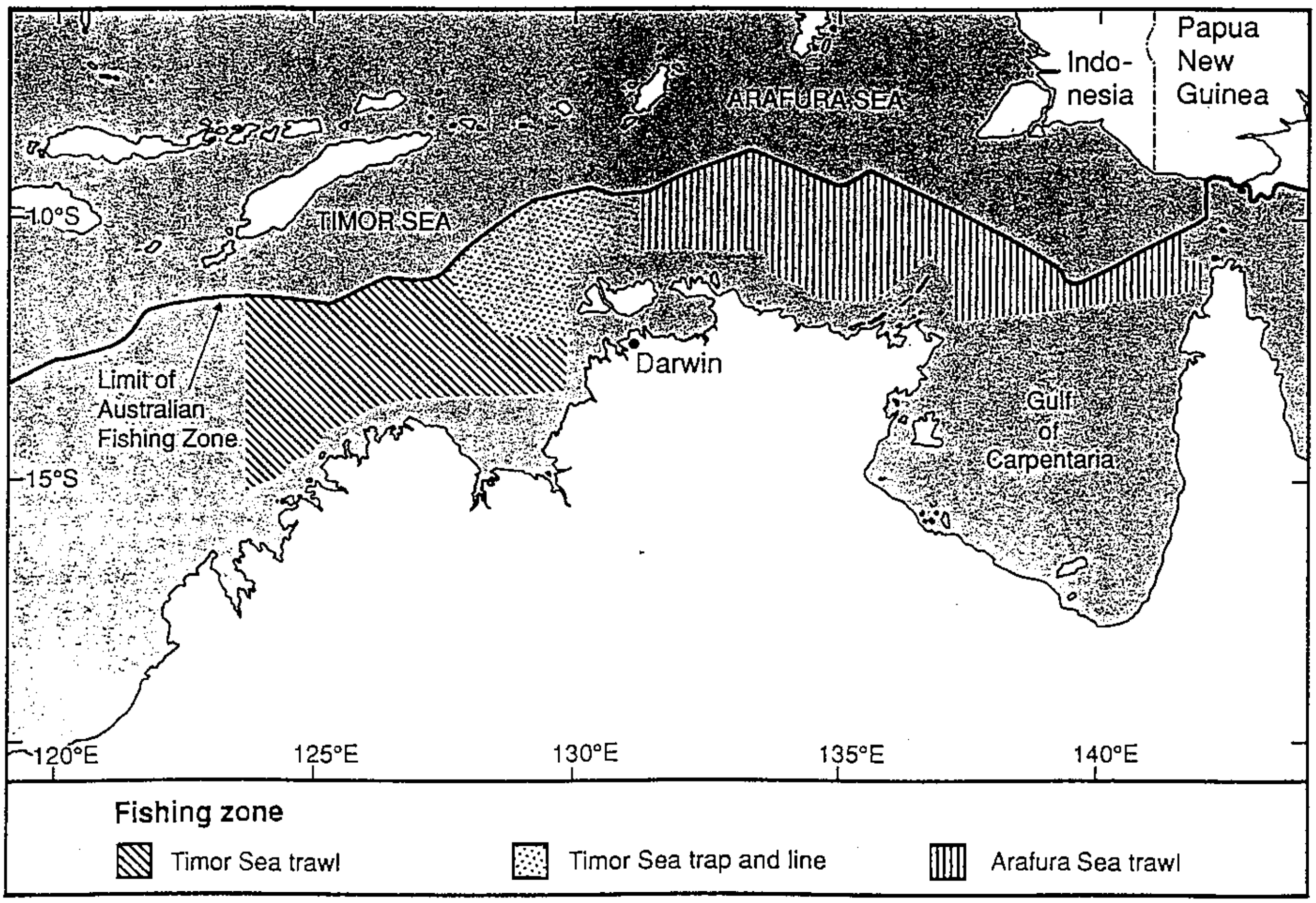
1991 Assessment

Two recent research surveys (one in the Arafura Sea and part of the Timor Sea carried out by the Northern Territory Fisheries Division and one in the Gulf of Carpentaria carried out by CSIRO) provided independent estimates of the stock biomass and species composition. Stock assessment in the first instance was based on the sustainable yields of the main commercial species, the saddle-tail snapper of 600 g or greater. The results of this were then extrapolated to include all large red snappers using catch composition data from the research surveys.

Two methods of assessing the current status of the stock were used. The first was an analysis of catch and effort data using surplus production modelling (see table next page). The fishing effort was standardised to account for different fishing power among the fleets, and the increases in catch rates since 1980 were assumed to be a result of increased targeting.

The alternative method, the yield per recruit analysis, uses biological parameters of growth and mortality to determine the productivity of the stock and the sustainable fishing level ($F_{0.1}$). These are then combined with current estimates of the biomass obtained from the research surveys.

As in previous years, the yield per recruit method gives considerably more optimistic estimates of sustainable yields than does the surplus production method.



Estimates of sustainable yields (tonnes) for large red snapper in the Northern Fish Trawl Fishery

Method	Timor Zone	Arafura Zone	Gulf of Carpentaria
Yield per recruit	675–2528	2500–9370	2690–10060
Surplus production	–	500–2080	535–1788

Uncertainties in the assessment

Both methods of analysis involve considerable uncertainty. The yield per recruit analysis is based on growth and natural mortality estimates derived from a population of saddle-tail snapper from north-western Australia. Current biomass estimates were derived from recent research surveys by assuming that all the fish in the path of the net would be retained, and that the bridles had a positive herding effect thus making the effective swept area 33% greater than the size of the net.

Surplus production models are too simplistic to represent the complex dynamics of the fishery, particularly the changes in fishing practices. To take into account the increased catch rates since 1980, a sub-model was used to represent the increasing catchability assumed to have occurred through increased targeting of saddle-tail snapper by fishers. There are no data available to test this assumption.

The quantitative effect of fishing in adjacent Indonesian waters is unknown. If movement of fish is occurring across the shelf in the Arafura Sea, this fishing could impact on the Northern Fish Trawl Fishery.

Future assessment needs

Four critical pieces of information are required for improving future assessments:

- data on the catch taken by vessels in adjacent Indonesian waters;
- estimates of net retention and herding for saddle-tail snapper;
- estimates of growth and mortality for the fish stocks of the Arafura Sea and Gulf of Carpentaria;
- data on stock structure and the degree of movement of individual fish in northern waters.

The surplus production model requires the use of catch and effort data, which in a complex fishery such as the Northern Fish Trawl Fishery, must be standardised between fleets, vessels, area and species groups, and allow for discarding.

Management Implications

Noting the uncertainties in the estimates and the unknown catches of fleets in adjacent Indonesian waters, scientists recommended a conservative approach to the allocation of entitlements to fish in Australian waters.

Catches in previous years have been higher than the 1991 recommended sustainable yield of 1200–4500 t. This situation was rectified to some degree in 1990 with the setting of a much lower TAC and the phasing out of foreign trawl fishing activity from northern Australian waters. Because of earlier high fishing pressure, however, the assessment suggests that annual catches of 3000–4000 t may still continue to reduce the existing biomass to levels considerably lower than that required for maintaining the maximum sustainable yield. If the stock is depleted, it would take 4–5 years to rebuild to the optimum biomass level, even in the absence of fishing.

This assessment is valid only if fishers continue to target saddle-tail snapper. Any change in fishing practices would require a re-assessment of the current situation. If, for example, market prices for other species increase, the fishery's potential yield and profitability could change dramatically. Such changes are likely and should be monitored.

On the basis of the scientific advice and the need for conservative management, TACs have been set as 1000 t for the Timor Zone and 2000 t for the Arafura and Gulf of Carpentaria Zone for 1992. Based on the known fishing power of the fleet, this will allow up to 4 endorsements in the Timor Zone and up to 6 in the Arafura and Gulf of Carpentaria Zone.

Prepared by the Bureau of Rural Resources, [illegible] Canberra. This report is based on information supplied by the Northern Territory [illegible] Fisheries, CSIRO, Division of [illegible] Northern Fish Trawl Fishery [illegible] Saddle-tail snapper drawn by [illegible] Map drawn by [illegible]

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ESTIMATION OF BIOMASS AND FISHERY YIELD FOR SNAPPER STOCKS IN NORTHERN AUSTRALIAN WATERS

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Article submitted for publication in 'Northern Territory Fishing Industry News' in December 1993.

Red snapper (mostly *Lutjanus malabaricus* and *L. erythropterus*) and goldband snapper (mostly *Pristipomoides multidens* and *P. typus*) have been continuously fished in northern Australian waters since 1971. The main fishing grounds are located on the Northwest Shelf, and in the Timor Sea, Timor Box, Arafura Sea and Gulf of Carpentaria (Fig. 1). Biomass and fishery yields for these snapper stocks were recently assessed by scientists from the NT Fisheries Division and the AFS/AFMA convened Northern Trawl Fisheries Assessment Working Group (1989-92). Annual fishery yields ($t \cdot yr^{-1}$ tonnes per year) were estimated by 'surplus production model' with logbook and observer data from foreign and domestic vessels, and 'yield per recruit model' with survey and biological data. Some of the assumptions underlying the models and data sets cannot be validated at present because of inadequate information and/or methodology. Thus annual yields are given for a 'most likely' range of values (Table 1); the lower value being more conservative and less risky than the upper value.

The surplus production model used logbook data covering the entire commercial history of the trawl fishery or the trap and dropline fishery. Yield for red snapper was estimated from catch and effort data from the Taiwan Fisheries Research Institute (Taiwanese trawlers 1971-79) and former Australian Fisheries Service (Taiwanese, Thai and domestic trawlers 1979-92), and AFZ observer data (1985-87). Although the logbook data cover a long time series (22 years), there is uncertainty in their interpretation because of inadequate data on discarding and sorting practices, and fishing gear and operation. In 1992, the Northern Trawl Fisheries Assessment Working Group considered that these logbook data were presently unreliable, and that associated discarding and sorting practices, and fishing gear and operation required thorough documentation prior to further analysis. Yield for goldband snapper was estimated from monthly return data from the NT Fisheries Division (domestic trap and dropline vessels 1987-92). Interpretation of these data was limited by the short time series available (6 years), and possible interactions with the trawl fishery in the Timor Sea.

The yield per recruit model used survey data and available biological data. Yields for both goldband and red snappers were estimated from trawl survey data from the Timor Sea and Timor Box (127-131°E, NT Fisheries Division 1990), Arafura Sea (NT Fisheries Division 1990, 1992), and Gulf of Carpentaria (CSIRO 1990, 1991). Underlying assumptions in interpreting these data included: 90-100% of snappers in the mouth of the survey trawl are retained by the advancing net (Frank and Bryce net with 38mm stretched mesh in codend); snappers are herded by the trawl with a resultant effective trawl pathwidth of 30-60 m; all species of goldband and red snappers have growth and reproduction strategies similar to those observed for *L. malabaricus* on the Northwest Shelf (only available data); snappers within the region surveyed are uniformly distributed between trawlable and non-trawlable habitats; and, there is no large-scale seasonal and/or annual movements of snappers. The validity of some of these assumptions is uncertain because of limited knowledge on the biology and distribution of snappers in northern Australia and efficiency of the survey gear.

In conclusion, annual yields estimated by yield per recruit are considered more reliable than those estimated by surplus production. Thus conservative annual yields for red snapper, based on present knowledge, are 600t·yr^{-1} in the Timor Sea, 1300t·yr^{-1} in the Timor Box, 3900t·yr^{-1} in the Arafura Sea and 4100t·yr^{-1} in the Gulf of Carpentaria, leading to an overall yield estimate of about 10500t·yr^{-1} for northern Australian waters (assuming a yield of approximately 600t·yr^{-1} on the Northwest Shelf). Conservative annual yields for goldband snapper, based on present knowledge, are 100t·yr^{-1} in the Timor Sea, 400t·yr^{-1} in the Timor Box and 100t·yr^{-1} in the Arafura Sea, leading to an overall yield estimate of about 700t·yr^{-1} in northern Australian waters (assuming a combined yield of less than 100t·yr^{-1} for the Northwest Shelf and Gulf of Carpentaria). Historically, snappers have been exploited at levels close to these annual yields, with trawl catches of red snapper up to 5400t·yr^{-1} in 1989, and goldband snapper up to 900t·yr^{-1} in 1984. Departure of foreign trawlers at the end of 1990 has resulted in a marked decrease in catches of red snapper (<1000t·yr^{-1}). However, catches of goldband snapper have remained relatively high (400t·yr^{-1}) due to developments in the domestic trap and dropline fishery.

Determination of allowable catches for snappers in northern demersal fisheries, including trap, dropline and trawl, will require further dialogue between industry and fishery managers, and clear identification of management objectives (eg maximise yield, maximise profit, maximise employment or maximise conservation). At the same time, current and proposed research by the NT Fisheries Division is aimed at improving yield estimates by:

- maintaining a comprehensive catch and effort database for demersal finfish fisheries in northern waters;
- documenting past discarding and sorting practices, and fishing gear and operation (in collaboration with the Bureau of Resource Science);
- obtaining information on the biology and population dynamics of red and goldband snappers in waters between 127-137°E;
- investigating herding in *L. malabaricus* and effective trawl pathwidth of the survey trawl;
- investigating herding in other snappers and effective trawl pathwidth of the survey trawl (FRDC proposal 1994-95);
- investigating non-trawl methods for catching red snapper (FRDC proposal 1994-95);
- conducting repeat trawl surveys (proposal);
- experimental determination of goldband snapper stocks (pilot study, FRDC proposal 1994-95); and,
- modelling population dynamics of snappers, and refining fishery models and stock assessments.

Funding is actively being sought to undertake the proposed research.

Table 1. Annual fishery yields for red and goldband snappers estimated by 'surplus production model' with logbook and observer data from foreign and domestic vessels, and 'yield per recruit model' with survey and biological data. Some of the assumptions underlying the models and data sets cannot be validated at present because of inadequate information and/or methodology. Thus annual yields are given for a 'most likely' range of values; the lower value being more conservative and less risky than the upper value. Survey data, and subsequent assessment, for the Timor Sea only covered waters east of 127°E (*). Source: Northern Trawl Fisheries Assessment Working Group (1989-92); and, Ramm (unpublished data).

Region	Yield ($t \cdot yr^{-1}$) Surplus Production	Yield ($t \cdot yr^{-1}$) Yield Per Recruit
Red Snapper		
Gulf of Carpentaria	500-1800	4100-16400
Arafura Sea	500-2000	3900-10000
Timor Box	-	1300-2900
Timor Sea	-	600-2500 *
Northwest Shelf	400-800	-
Goldband Snapper		
Gulf of Carpentaria	-	-
Arafura Sea	-	100-400
Timor Box	400	400-1000
Timor Sea	-	100 *
Northwest Shelf	-	-

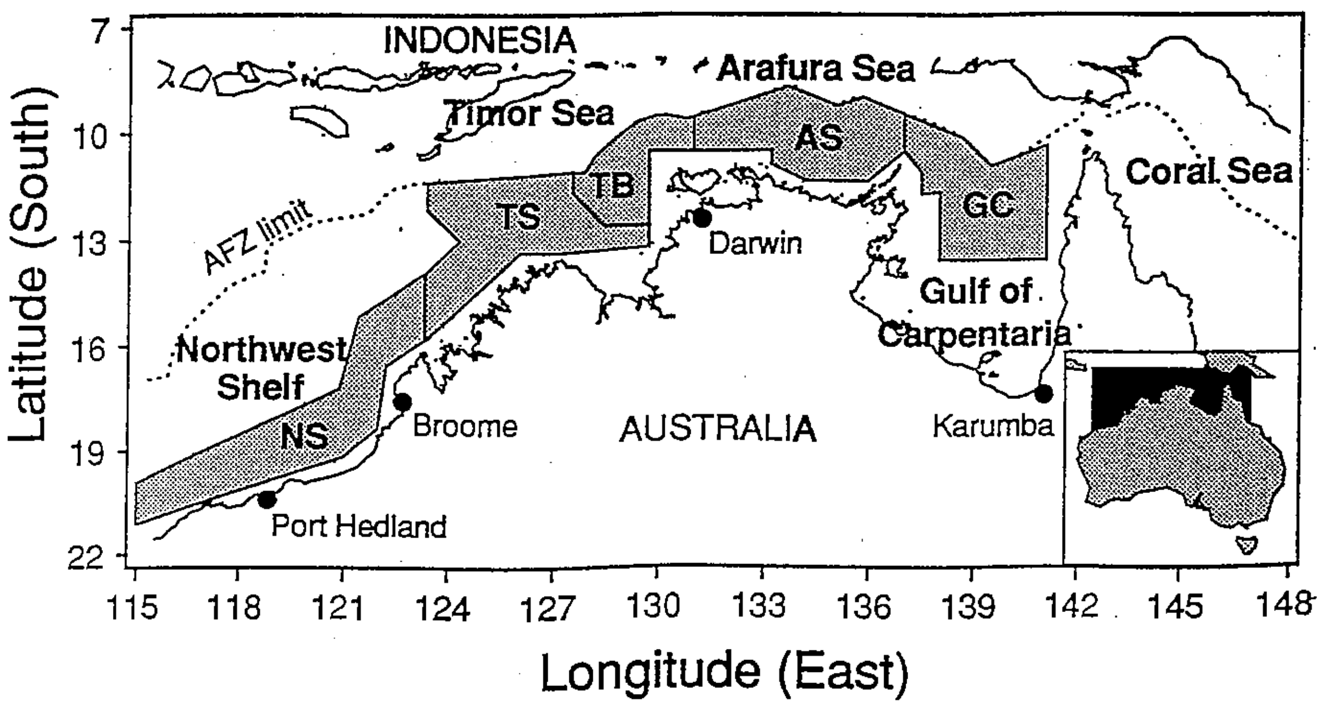

Figure 1 **Northern Australian waters including Northwest Shelf (NS), Australian sector of the Timor Sea (TS), Timor Box (TB), Australian sector of the Arafura Sea (AS) and Gulf of Carpentaria (GC).**

PROCESSING OF LOGBOOK DATA BY THE NORTHERN TERRITORY FOR AND ON BEHALF OF THE COMMONWEALTH

Fisheries Division
Department of Primary Industry and Fisheries
GPO Box 990, Darwin NT 0801, Australia

Situation in 1988

The capacity to analyse data on catch and effort within real-time (3-6 months from the point of collection) is an essential pre-requisite for the sound management and development of a fishery. In fisheries which are undergoing significant development, such as the demersal trawl fisheries off northern Australia, only real-time data can provide the essential information necessary for scientists and managers to assess changes and trends in or between fisheries or specific fishing operations. In turn, the information generated can be used in an informed and orderly manner to adjust management development strategies and quotas within a minimal response time.

The collection and supply of catch information is a statutory responsibility of the present licensees under the relevant fisheries legislation. At present, access to logbook data from the demersal trawl fishery off northern Australia (Northwest Shelf, Kimberley - Timor region, Arafura Sea) is confined to catch and effort data from Taiwanese pair trawlers up to 1987. Data from the Thai stern trawlers are not yet available on computer. The Seanorth Pty Ltd Thai stern trawlers have operated in the Arafura Sea since late 1985 and constitute the major fishing activity (50-60% of the total effort) in that region since 1987. Without access to the logbook data on catch and effort from this stern trawl fleet, the level of exploitation of the demersal trawl resource in the Arafura Sea region, as an example, cannot be assessed.

Under the present system the backlog of data is likely to increase as the number of vessels (both foreign and Australian) operating in these developing fisheries increases and diversifies.

Memorandum of Understanding

In 1989, the Fisheries Division and the former Australian Fisheries Service signed a Memorandum of Understanding for processing logbook data from the northern demersal (non-prawn) trawl and pelagic fisheries under Commonwealth jurisdiction in Darwin by the Fisheries Division, for and on behalf on the Commonwealth. Essentially, the data would be front-end loaded in Darwin and maintained on an AFZ Information System database in Canberra. At that time, the Fisheries Division was responsible for the management and deployment of Observer and Foreign Liaison staff from Darwin, and research staff were engaged in project 86/049. The major benefits of having the logbook data processed in Darwin were:

- one centralised point within the operational area for the collection and collation of data;
- electronic data processing in real-time;
- direct access to both observers and scientists assessing northern stocks thus enabling resolution of any problems encountered with interpretation of logbook data; and,
- storage of data in a format compatible with other AFZ Information System databases.

The following data were processed and verified:

- Taiwanese pair trawler logbook data (1988-90);
- Thai stern trawler logbook data (1985-90);
- Chinese pair trawler logbook data (1989);
- domestic stern trawler logbook data (1987-93);
- northern trawl fishery observer data (1989-90);
- Taiwanese demersal longliner logbook data (1990-91); and,
- northern longline fishery observer data (1990-91).

Northern trawl fishery logbook data

Logbook data, recorded tow by tow (shot by shot), are held by the Fisheries Division and the Australian Fisheries Management Authority. These data are available in flat ASCII files from Dr David Ramm, Fisheries Division, GPO Box 990, Darwin NT 0801, phone 089-897686. Each record contains the following fields.

<u>1st line of record</u> (tow/shot data)
A4,I7,2I4,2(2I5,I6),I4,I6,F5.1,1X,2I1,1X,6A1

```
AAAA 000000 000 000 0000 0000 00000 0000 0000 00000 000 00000 00.0 00 AAAAAA
**** CALL SIGN
     ****** DATE(ddmmyy GMT)
            *** TOW NUMBER
                *** DEPTH(m)
                    **** TIME/SHOOTING GEAR (hhmm GMT)
                         **** LATITUDE/SHOOTING GEAR (ddmm)
                              ***** LONGITUDE/SHOOTING GEAR (dddmm)
       TIME/HAULING GEAR (hhmm GMT) ****
            LATITUDE/HAULING GEAR (ddmm) ****
               LONGITUDE/HAULING GEAR (dddmm) *****
                               TRAWL DURATION (hmm) ***
                             ESTIMATED TOTAL CATCH (kg) *****
                                     DECLARED BOX WEIGHT (kg) ****
                                               DATA TYPE CATCH      *
                                               DATA TYPE PROCESSING *
                                                      ERROR FLAGS 1-6 ******
```

<u>next lines of record</u> (retained catch)
2X,I6,F7.1

```
  000000 0000.0
  ****** COMMERCIAL CATEGORY
         ****** QUANTITY
```

<u>last line of record</u> (total retained catch)
2X,I6,F7.1

```
  000000 0000.0
  ****** TOTAL RETAINED CATEGORY (always 999000)
         ****** QUANTITY
```

The logbook data cover two types of data. The types are identified by the DATA TYPE fields in line 1 of each record. DATA TYPE CATCH refers to the type of quantity declared in the catch data. There are 2 options:
- number of boxes of fish where DATA TYPE CATCH = 0; and,
- weight (kg) of fish where DATA TYPE CATCH = 1.

DATA TYPE PROCESSING refers to the types of processing declared in the catch data. Again, there are 2 options:
- whole fish where DATA TYPE PROCESSING = 0; and,
- fillets where DATA TYPE PROCESSING = 1.

The verification routine checked for repeated records based on CALL SIGN, DATE, TOW NUMBER, and TIME LATITUDE LONGITUDE SHOOTING GEAR; repeated records were deleted. Other checks activated flags on error (or potential error) as outlined below:

Type of Verification		Error Flag
RANGES (ERROR FLAG 1)		**R**
hours	≥ 00 to < 24h	
minutes (time and lat/long)	≥ 00 to < 60min	
degrees latitude	> 8 to ≤ 22°S	
degrees longitude	≥ 114 to ≤ 141°E	
months	≥ 1 to ≤ 12	
years	≥ 1985 to ≤ 1990	
days	= calendar	
depths	> 25 to < 150m	
TRAWL DURATION (ERROR FLAG 2) declared TRAWL DURATION = (TIME HAULING - TIME SHOOTING) +/- 10% declared TRAWL DURATION <= 6 h		**D**
TOW SEQUENCE (ERROR FLAG 3) tows are in chronological sequence with respect to DATE and TIME		**S**
DISTANCE TRAWLED (ERROR FLAG 4) Vessel speed and operation determined by DATE, TIME LATITUDE LONGITUDE SHOOTING GEAR and TRAWL DURATION from consecutive records assuming trawl speed ≤ 4 knots, and steaming speed ≤ 12 knots		**P**
TOTAL RETAINED CATCH (ERROR FLAG 5) sum of retained catch = declared total retained catch		**N**
CATCH REPORTED FOR EACH TOW (ERROR FLAG 6) retained catch > 0 if TRAWL DURATION > 0 TRAWL DURATION > 0 if retained catch > 0		**F**

Catch data refer to 25 commercial categories. Each category has a 6-digit code based on the CSIRO system:

Category[a]	Code	Comment
Ariid	188000	
butterfish	445999	*Ariomma indica*/*Psenopsis humerosa*
Carangid	337992	scads (Thai trawlers)
Carangid	337991	trevallies (Thai trawlers)
Carangid	337000	trevallies (Taiwanese/Chinese trawlers)
Formionid	339000	
Haemulid	350000	
Lethrinid	351000	
Loligo spp	620000	
Lutjanid SN1	346991	small snapper
Lutjanid SN2	346992	*Pristipomoides* spp
Lutjanid SN3	346993	large snapper
Lutjanid SN4	346004	*Lutjanus sebae* (Thai trawlers)
mixed taxa	999999	
Mullid	355000	
Nemipterid	347000	
Priacanthid	326000	
Rachycentrid	335000	
Sciaenid	354000	
Scombrid	441000	
Sepiid	610000	
Serranid	311000	
sharks/rays	018999	
Sparid	353000	
Sphryraenid	382000	
Synodontid	118000	
Trichiurid	440000	
Total retained	999000	

[a] See page 33 for a species list

COLLECTION OF DATA FROM THE NORTHERN DEMERSAL FISHERIES OF THE AFZ BY AUSTRALIAN OBSERVERS

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Discussion paper for the Observer Program Working Group meeting, Canberra, November 1988.

INTRODUCTION

Drs Sainsbury and Ramm met in Hobart between 25 - 29 July 1988 to re-assess the northern demersal fisheries in the AFZ. The northern demersal fisheries and their assessments are becoming more complex as more fishing nations, with different gear, vessel types, species preferences, catch retention practices and economic environments, become involved. The management regime is based on a total retained catch quota (irrespective of species and partitioned by fleet) and the assessments are derived from logbook data on the quantity of fish retained by commercial category. As a result, the resource assessments rely heavily upon an understanding of retention and discard practices of the fishermen, and the ability to determine the status of the main species comprising the commercial categories. It was intended that the re-assessment would incorporate recent data on these issues. In particular it was intended to:

(i) use the data from the Observer Programme to define the size specific discard practices for each of the main fish species and commercial categories for each the main fishing fleets (ie Taiwanese and Thai);

(ii) use the data from the Observer Programme to estimate the size composition and total catch of the main commercial species - these data were to be used to examine the utility of the size compositions in detecting changes in mortality and providing early (ie. before seen in the retained catch) warning of recruitment decline, and to attempt to assess the status of some of the main commercial species;

(iii) examine the Thai logbook data and integrate, for the first time, these catches with the Taiwanese catch data for the areas in which both fleets operate; and,

(iv) re-assess the estimates of the yield available and optimal mesh size in each management area in the light of the new information (i-iii above and the post-1984 Taiwanese logbook data, which have become available for analysis since the last assessment was performed).

This work-programme, strongly drawing upon data collected by the AFZ Observer programme, is crucial to the scientific assessment of the resources and the biological sustainability of the present fishery management regime. Data collected by the observers between 1985 and 1987 (calendar years) only were available for examination.

Furthermore, in the course of attempting the work it became apparent that certain vital pieces of information are not being collected from the fishery. These data are essential for interpretation of the daily logbook data, and for reconstruction of both the total harvest from the resource and the overall harvesting pressure on any individual species. The information contained within the present set of "observer data" are not sufficient to:

- assess the reliability of the logbook data;
- allow development of mathematical models of the resource species and their exploitation; or,
- allow development and assessment of scientifically sound advice on management of the resource.

The purpose of this note is to reiterate the data required for assessment of the northern demersal fisheries, to draw attention to important deficiencies in the present data, and to suggest some sampling strategies which would improve the utility of the data collected through the Observer Programme.

COLLECTION OF OBSERVER DATA

Objectives

The rationale and objectives of data collection have been described at various times since the introduction of the Observer Programme in 1979. The types of data required from the Observer programme for assessing the reliability of logbook data and interpreting these data for the purposes of management are:

(1) details on the fishing operation (vessel, date, time, gear, mesh size, etc);
(2) the retained weight of fish by commercial category (ie checking logbook records) and the total weight of catch;
(3) the species composition of the total and retained catch; and,
(4) the length-frequency distributions of key species in the total and retained catch.

These data are not required from every trawl, provided they are collected on a sampling basis from which it is possible to reconstruct the whole-fishery totals for appropriate time intervals.

Observer data on the quantity of fish retained by commercial categories provide information on two issues:

- independent Observer and fisherman data from the same catch allows estimation of size and frequency of genuine measurement or procedural errors in the fisherman data, and any detected systematic errors can then be corrected in a known and documented manner so that their effects can be included in future analysis of the logbook data (compare the situation in which such systematic errors are learned by individual Observers and that knowledge gradually spreads, altering as it spreads the data recorded in the logbooks but leaving little trace of what and when the changes were or little indication of the effect on the logged data);

- Comparison of logbook entries in the presence and absence of an Observer allows detection of bias in the logged data and assessment of the reliability of these data.

The determination of the species composition of the total and retained catch is necessary to:

(1) allow more correct application of multiple 'single species' fishery management models which form the basis of the present fishery assessments - to date the lack of appropriate data has forced application of these models to species groups, rather than the individual species for which they were derived;

(2) allow correct account to be taken of the effect of fishing by different fleets, with different discard and retention practices, when assessing the status of the resource - this is particularly important for fisheries in which the composition of the fleet is expected to change (such as the northern demersal fisheries) and for species which have different desirabilities in the different fleets;

(3) allow detection of the status of the species comprising the commercial categories, so avoid sequential collapse of component species within a category being masked (until it is too late) by high catches of other species in the category; and,

(4) allow intercalibration of commercial catches and research vessel catches, so that changes in resource abundance can be separated from changes in fishing strategy and retention practices.

Collection of length-frequency distributions will:

(1) allow calculation of the population parameters for individual species to be used as input to fishery management models;

(2) provide an early warning of any impending recruitment failure to major stocks; and,

(3) allow the size at which fish are discarded to be incorporated into calculations of yield and optimal mesh size - with the present mix of fleets operating, it is thought that this will greatly influence assessments of the northern demersal resource.

Data required

Data which must be consistently collected using standard or relatable techniques over a long period of time (at least 2 generation times, or about 8-10yrs for the major species) are listed below. As mentioned above, these data are not required from every trawl, provided they are collected on a sampling basis from which it is possible to reconstruct the whole-fishery totals for appropriate time intervals.

FISHING OPERATION

- vessel identification (indexed to provide vessel size, power and capacity)
- date
- time
- position
- depth
- duration of trawl
- gear description (indexed to give net type, door type, cod-end mesh)

RETAINED CATCH

- Weight of individual fish boxes for each commercial category (data must specify the number of boxes weighed, and the commercial category to which they relate). If estimates or "accepted" representative values are used by the Observer for field calculation of total catch, these "accepted" box weights should not be recorded as if they were actual measurements.
- Number of boxes retained by commercial categories (based on independent counts by Observers).
- Species composition of each commercial category. Records must specify the commercial category of the box, and the number of individuals and their combined weight for each species present in the box. As a check, it is desirable to have recorded the total weight of the box before processing begun.
- Length-frequency distributions of key species. Sufficient information must be available to allow estimation of the absolute numbers in each size class, not just the relative numbers.

TRASHED PORTION OF THE CATCH

- Estimation of total weight of trashed portion.
- Number of individuals and their combined weight for species of economic importance.
- Length-frequency distributions of key species. Sufficient information must be available to allow estimation of the absolute numbers in each size class, not just the relative numbers.

The length-frequency distributions of the trashed and retained portion of key species, and an estimate of the absolute number of individuals of these species in the total catch are crucial to the application of powerful assessment techniques such as cohort analysis. To date data limitations have prevented application of all but very crude techniques of resource assessment.

LIMITATIONS OF THE PRESENT DATA SET

A major and general problem of the Observer programme is the lack of description of the data collected and the sampling methods used. Repeatedly the search for understanding of just what data have been collected, and how the methods have evolved over the past few years, depends upon the recollection of the people involved with the sampling. This situation is appalling when one considers the huge investment of funds and man hours this programme has received since 1979.

Although the data presently collected through the Observer programme generally cover the topics listed above, certain vital data have been omitted. As a result, the present Observer data set is of very limited use in improving resource assessments. The limitations are due to two broad types of omission, both flowing from lack of consideration of the ultimate uses to which the data are to be put.

Omission 1

There are a number of omissions or errors of protocol in providing the information needed to derive fishery wide estimates from the sample data, and these have seriously compromised the data collected to date. Correction of these difficulties in future data collection is relatively easy, and requires little alteration in Observer operation. Examples of this are:

- Observer and fishermen counts of boxes are apparently not always independent.

- As far as we can ascertain, all of the data on the weights of species within boxes (ie within commercial categories) record the weight for just a single species. It is known that boxes may contain up to 4 species, and so the procedure by which the present data were collected must be clarified before the data can be used sensibly. We believe that recent (post 1987) data include weights for boxes containing more than one species. The procedures presently being used to select boxes and species for weighing need to be defined.

- Over the past year, lengths of individuals have been measured for selected species taken from the total catch. However, this information must be complemented by additional data if it is to be used to estimate the size composition of the total catch or of the retained catch. The additional data are:
  - An estimate of the sampling fraction (ie the fraction of individuals of that species in that catch which were measured. This is usually derived from an estimate of the total weight caught and the weight measured); and,
  - separate length-frequency distributions for individuals trashed and retained.

- On some occasions measurements of the size composition of retained and discarded individuals of a species were collected separately (ie. only retained size compositions were collected from some catches and only discarded compositions were collected from the others). This does not allow direct calculation of the size specific retention probability. Size specific retention probabilities are best estimated from the size composition of retained and discarded fish from the same catches.

- For major species the ratio by weight and numbers of retained to discarded individuals is recorded from a subsample of the unsorted catch, but this ratio cannot be related to any absolute quantity to allow calculation of the total quantity retained, discarded or caught. Here there is need for an estimate of either the weight of that species retained from the catch, the total catch of that species, or the total weight of that species discarded. Exceptions to this limitation may be provided by a few commercial categories (not the major ones), which are composed of just one species.

Omission 2

The sampling effort is not well distributed among the various fleets and regions, resulting in excessive data on some variables and operations but extremely patchy data on others (Table 1). The development of a more suitable allocation of sampling effort, such as that proposed in a separate discussion paper by Ramm (Table 2), will require considerable cooperation between Observers, managers of observers and users of the data. Examples of this problem are as follows.

- Since the cancellation of the permanent observer platform in June 1987 there has been <u>no</u> observation of the Taiwanese fleet in the Arafura and Timor Seas or on the Northwest Shelf; the Taiwanese catch is about 1/2 the total catch. In the general context of the very "patchy" nature of the data on which resource assessments must be based, it is also noteworthy that to date no logbook data on fishing effort and catch by the Thai fleet have been entered on the AFZIS database, and no logbook data on retained catch by commercial categories were collected during the first 2yrs of the Thai operations.

- There has been very little Observer coverage of the Northwest Shelf since 1982, and there has been no coverage of the Timor sea catch (Thai or Taiwanese up until mid-1988).

- Over the past few years there appears to have been an excessive allocation of sampling effort to obtaining fish box weights, and an under-allocation to sampling the other variables that are needed to use the fish box weight data to improve resource assessment (eg species composition within boxes, and weight of the same species discarded).

Improvements in resource assessment require a long-term collection of data of the types listed above by standard observation and recording methods, as well as shorter term special studies of particular problems as they arise. The long-term data must be collected at regular intervals from all regions fished (ie NW Shelf, Timor, Arafura) so as to provide continuity of information for each fishery, rather than collected intermittently from the area (or problem) of current interest so as to provide a discontinuous time series in all areas (or problems). Similarly, sampling must cover all types of vessels exploiting the resource (eg fee-fishing pair trawlers, joint-venture trawlers, Australian trawlers, etc.), and not just those currently of most interest or easiest to access. The fisheries operating on the northern demersal resources are now both multispecies and multifleet, and an essential requirement for their successful management is the availability of consistent information on each fleets impact on the resource. The present and historical data collection do not meet this requirement.

IMPROVEMENTS TO THE COLLECTION OF DATA

We identified two sampling strategies which would provide the data required for improved resource assessment of the northern demersal fisheries. The advantages and disadvantages of these strategies, both statistically and logistically, can only be determined from the results of a pilot study. This pilot study should be undertaken immediately (eg January 1989). Some of the sampling methods, such as the collection of length-frequency data, require a relatively high degree of cooperation from the crew of the trawlers. However, it is re-emphasized that such samples are not required from all vessels visited by Observers. The results of the pilot study would be used to define standard sampling techniques for long-term field collections. The resulting standard techniques may include aspects of both strategies. Wherever possible these techniques will incorporate existing methods used by Observers working in teams of 2 on board commercial trawlers.

The two strategies differ in the method for estimating the species composition of the catch, the size composition of retained and discarded individuals of key species, and the weight of the trashed and retained portions of the catch. Strategy 1 makes greater use of the sorting of the catch performed by the fishermen than does strategy 2, and so for the same sampling effort should provide greater precision in the derived estimates (eg the size composition and weight caught for key species) than strategy 2. However strategy 1 may be more difficult to implement than strategy 2. The two strategies are outlined briefly below.

STRATEGY 1

For 30% of shots monitored:

- record details of fishing operation;
- select one or more key species (Appendix 1);
- intercept the sorted catch and measure ALL* individuals of selected key species (**L1**);
- gather ALL* individuals of selected key species which are trashed; ALL of these fish are to be measured when feasible (**L2**).

[* These size compositions could be provided on a sampling basis, provided that representative samples can be taken and the sampling fraction (ie the proportion of the total number which are selected for measurement) can be specified.]

For another 30% of shots monitored:

- record details of fishing operation;
- obtain a sample (approximately 100Kg or 10 trays) from the total catch;
- measure all individuals of commercial species (indicating whether retained **L3** or trashed **L4**); and,
- obtain the bulk weight of the remaining trashed portion (**WT**).

For remaining shots monitored:

- record details of fishing operation;
- sample weights of fish boxes for each commercial category (**WB**);
- number of boxes retained by commercial categories (**NB**); and,
- number (**NF**) and weight (**WF**) of each species in boxes of each commercial category.

STRATEGY 2

For 30% of shots monitored:

- record details of fishing operation;
- obtain a large sample of the total catch (the proportion of the catch that should be sampled needs to be determined, but could be up to 1/4);
- measure all individuals of commercial species (indicating whether retained **L5** or trashed **L6**);
- obtain the bulk weight of the remaining trashed portion (**WT**); and,
- number of boxes retained by commercial categories (**NB**).

For remaining shots monitored:

- record details of fishing operation;
- sample weights of fish boxes for each commercial category (**WB**);
- number of boxes retained by commercial categories (**NB**); and,
- number (**NF**) and weight (**WF**) of each species in boxes of each commercial category (occasionally the size composition of these retained species should also be recorded to provide a check of the trash sampling and sorting procedure).

RECONSTRUCTION OF RETAINED AND TOTAL CATCHES

ASSESSING THE RELIABILITY OF THE LOG-BOOK DATA

- Compare NBs with corresponding entries in logbook.
- Compare retained CPUE of vessel with and without Observers on board.

THE WEIGHT OF THE TOTAL AND DISCARDED CATCH

Use known length-weight relationships with L3,L4 (strategy 1) or L5,L6 (strategy 2) to convert lengths of individuals of commercial species to weights of fish retained (**W1**) and discarded (**W2**). Determine weight of the retained catch (**Wret**) using NBs and WBs. Then :
TOTAL WEIGHT DISCARDED = **Wret** * (sum(**W2**) + **WT**) / sum(**W1**) .
Similarly, the weight of the total catch can be calculated.

THE WEIGHT OF KEY SPECIES RETAINED AND DISCARDED

For each species: Retained weights given by **WF**. Apply known length-weight relationships to L1,L2 (strategy 1) or L5,L6 (strategy 2) to give sample weights of retained (**W1**) and discarded catch (**W2**).

WEIGHT OF SPECIES DISCARDED= **WF*W2/W1**

Similarly, the total weight of that species caught can be calculated.

SIZE COMPOSITION OF KEY SPECIES RETAINED AND DISCARDED

Strategy 1 - Absolute length-frequencies for key species retained or discarded are given by L1,L2. There is a certain amount of redundancy in strategy 1, in that L3,L4 duplicates the size composition information of L1,L2. Since L3,L4 are likely to provide less precise estimates of size composition than L1,L2 it may be possible to eliminate the collection of these data (although the total weight of the fish in L3 and L4 are still required for reconstruction of the total catch from the retained catch). These alternatives would be examined using the data from the pilot study.

Strategy 2 - Absolute length-frequencies for key species caught can be calculated by rescaling L5,L6 by a factor F. Converting L5 of species retained to weights of individuals retained (**W3**), and assuming the proportion of each commercial species in the sample is equal to that in the retained catch, then: **F = Wret / sum(W3)**.

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Table 1
Annual patterns of foreign fishing effort (A) and Observer effort (B) in northern waters since 1985. The fishing effort is given for Taiwanese pair trawlers (TP), and joint-venture Thai stern trawlers (S).

(A) - TOTAL FISHING EFFORT (percent of hours trawled)

REGION	1985 TP	1985 S	1986 TP	1986 S	1987 TP	1987 S	1988 TP	1988 S
Arafura Sea	15	2	34	33	23	55	12	54
Kimberley - Timor	11	-	7	-	7	-	3	1
Northwest Shelf	72	-	26	-	15	-	30	-
TOTAL (hours)	49000		45000		27000		37000+	

(B) - OBSERVER EFFORT
(percent of total number of shots monitored by Observers)

REGION	1985 TP	1985 S	1986 TP	1986 S	1987 TP	1987 S	1988 TP	1988 S
Arafura Sea	20	38	28	52	15	81	0	97
Kimberley - Timor	0	-	0	-	0	-	0	3
Northwest Shelf	42	-	20	-	4	-	0	-
TOTAL shots monitored	223		550		409		322+	
% of fishing effort	1		4		5		3	

Table 2
Quota allocated to Taiwanese pair trawlers (TP), Chinese pair trawlers (CP), and joint-venture Thai stern trawlers (S) in northern waters during 1988-89, and proposed allocation of Observer effort under constraints imposed during 1988-89. The Observer effort is given as number of days in the field per team of 2 Observers (team days).

REGION	ALLOCATED QUOTA (%) TP	CP	S	PROPOSED OBSERVER EFFORT TP	CP	S
Arafura Sea	10	0	28	18	0	50
Kimberley - Timor	10	9	2	18	16	4
Northwest Shelf	26	15	0	46	28	0
TOTALS	19650t			180 team days		
% of quota allocated				3-5		

APPENDIX 1

Preliminary list of key species of fish for the Northwest Shelf, Timor Sea, and Arafura sea.

SPECIES name	code	REGION NW Shelf	Timor	Arafura
Carcharhinus dussumieri	018009	•	•	•
Saurida micropectoralis	118005		•	•
Saurida undosquamis	118001	•	•	•
Saurida sp 1	118006	•		
Epinephelus rankini	311010	•		
Epinephelus aeroelatus	311009	•	•	•
Priacanthus tayenus	326003		•	•
Carangoides chrysophrys	337011	•	•	•
Lutjanus sebae	346004	•	•	•
Lutjanus malabaricus	346007	•	•	•
Lutjanus erythropterus	346005	•	•	•
Lutjanus russelli	346012	•	•	•
Lutjanus vittus	346003	•	•	•
Pristipomoides multidens	346002	•	•	•
Pristipomoides typus	346019		•	•
Nemipterus furcosus	347005	•	•	•
Nemipterus hexodon	347014		•	•
Diagramma pictum	350003	•	•	•
Gymnocranius robinsoni	351005		•	
Lethrinus choerorynchus	351001	•	•	
Lethrinus lentjan	351007	•	•	•
Lethrinus nebulosus	351008	•	•	
Argyrops spinifer	353006	•		•
Parupeneus pleurospilus	355004	•		
Psenopsis humerosa	445007		•	•

RELATED RESEARCH FRDC PROJECT 90/015 ASSESSMENT OF DEMERSAL FISH STOCKS IN NORTHERN AUSTRALIAN WATERS BETWEEN 127 - 137°E

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Project 90/015 "Assessment of Demersal Fish Stock in Northern Australian Waters between 127-137°E" was funded by the Fisheries Division, Fisheries Research and Development Corporation (grant 90/015) and Australian Fisheries Management Authority. It aimed to obtain the first fishery-independent estimate of the size of demersal fish stocks in the northern sector of the Australian Fishing Zone, including the northern trawl fish management zones (TFMZs), between longitudes 127-137°E. Random demersal trawl surveys were conducted in depths of 20-200m during October - December 1990 and September -October 1992 with a standard Frank and Bryce net. In addition, gear calibration experiments were conducted during 1992 to evaluate the effect of herding and the level of escapement of target species, including *Lutjanus malabaricus* (red snapper). Specimens of *L. malabaricus* and other species were collected during both surveys to provide information on age, growth, mortality and reproduction of these fish in the Arafura Sea (Ramm, Xiao, Coleman and Lloyd, unpub. data).

A simple herding model was development by Ramm and Xiao (submitted) relating fish catch to net width and door spread, allowing appropriate definition and estimation of effective herding distance, effective trawl pathwidth, and other interesting herding parameters, and improving the swept area method. Analysis of trawl catch data using a special case of this model indicated that herding occurred in at least 14 of 36 abundant northern Australian groundfish. For *L. malabaricus*, the target species in the trawl fishery, the effective pathwidth was 36m (standard error: 6m) for the survey trawl configuration with a door spread of 60m and a net width of 15m. Survey results were provided to the Northern Fisheries Assessment Working Group in 1991 and 1992. Based on a yield per recruit model with $F_{0.1}$ strategy, the sustainable annual yield for *L. malabaricus* in the Arafura Sea TFMZ was estimated at 2500-9500t (Northern Fisheries Assessment Working Group Reports 1991, 1992).

The project has provided valuable data on relative abundance, biomass and biology of major species of fish in the Timor and Arafura Seas. These data, and information on herding and escapement, lead to the first fishery-independent estimate of yield for *L. malabaricus* in this region (Ramm and Xiao, in prep). Prior yield estimates, based on logbook and observer data, were considered less reliable than those derived from survey data. Some project findings, and related research, have been reported in:

Ramm, D.C., and Xiao, Y. (submitted JB906). Herding of groundfish and effective pathwidth of trawls. *Canadian Journal of Fisheries and Aquatic Sciences*, **00**, 0-0.

Ramm, D.C., and Xiao, Y. (in press). Demersal fisheries in northern Australia. Proceedings of the 3rd Asian Fisheries Forum, Singapore, 1992.

Ramm, D.C., and Xiao, Y. (submitted). Catch and effort in Australia's northern trawl fishery. Proceedings of the International Workshop on Tropical Groupers and Snappers, Campeche, 1993.

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