Study of the By-Catch, Processing By Products and Waste in Queensland and New South Wales

Prepared for the National Seafood Centre
Brisbane

by

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March 1994

FOREWORD and DISCLAIMER

This report has been prepared for the National Seafood Centre, Brisbane, Queensland.

It is based on information gathered by the author from published reports, unpublished documents and by means of interviews with a number of persons believed to be reputable and reliable.

I believe the report to be accurate but it contains estimates and evaluation of future events and I accept no liability for the information herein, hence readers should make their own enquiries to satisfy themselves on all matters.

Nick V Ruello

ACRONYMS and GLOSSARY of TERMS

ABARE	Australian Bureau of Agriculture and Resource Economics
AQIS	Australian Quarantine and Inspection Service
FMA	Fish Marketing Authority of NSW
FRDC	Fisheries Research & Development Corporation
NPF	Northern Prawn Fishery Prawn fishery covering the area from Cape Yorke at the north east corner of the Gulf of Carpentaria through to Cape Londonderry at the western margin of Joseph Bonaparte Gulf, managed by the Commonwealth government.
NSC	National Seafood Centre
NT	Northern Territory
QDPI	Queensland Department of Primary Industry
QFMA	Queensland Fish Management Authority
CSIRO	Commonwealth Scientific and Industrial Research Organisation, the Fisheries Division of.
by- catch	The (non target) animals and plants taken incidentally in the net.
by product	Products manufactured incidentally to the principal or major activity of the factory or fishing vessel.
cephalopod	soft bodied molluscs with head and "feet" adjoining eg octopus, squid and cuttlefish
echinoderm	sea urchins and sea cucumbers
elasmobranch	fishes with a soft backbone consisting of cartilage, that is, the sharks and rays.

et al	and others
modus operandi	operating methods and procedures
sp.	abbreviation for the word species, singular (one species)
spp.	abbreviation for the word species, plural (more than one species).
taxa	plural of taxon, a zoological grouping of related species
teleost	fishes with bony backbones

Guide to fish family name terminology

The ---- dae ending on a word denotes a family name eg *Sciaenidae* the jewfish or croaker family of fishes, and the fish (singular, one individual or species) is referred to in English as a sciaenid. The plural (more than one individual or species) is referred to as sciaenids.

The --ae ending is dropped or is replaced with an --s at the end of the name according to singular or plural.

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EXECUTIVE SUMMARY

Introduction

The by-catch of NSW and Queensland trawl fisheries, and seafood processing by products and waste, were examined by means of a literature search and interviews with industry operatives and researchers.

The study was undertaken to gather information to assist the National Seafood Centre in the planning of Research and Development support for total utilisation of the catch.

The research objectives were :

to provide a qualitative and quantitative assessment of the composition, volume and seasonal availability of by-catch and of seafood processing by products and waste.

identify any significant weaknesses and gaps in existing data and current data collection procedures

provide recommendations on how the information and research gaps may be rectified so that industry can take full advantage of the existing data base and future fisheries research.

By-Catch Availability and Utilisation

The literature study revealed a large number of research projects primarily aimed at describing the composition and relative abundance of the target species and by-catch as part of a broader study on the fisheries ecology of an area or the impact of trawling on the fauna.

Consequently while these papers invariably contain a list of the species recorded, and often the number of animals observed, **there is very little information available on the actual volume of individual species or the size of the animals caught; data on seasonality are also scarce or unavailable.**

The best estimates of prawn and by-catch volumes are those calculated from species abundance data obtained by observers aboard fishing

trawlers and the log book fishing effort data on the fleet, but such **reliable and sufficiently detailed estimates are only available for the western Gulf of Carpentaria.**

Because of the different research objectives and methodology, notably time of day, or year, and the actual sampling procedures, the results of **different studies cannot be directly contrasted or compared or their by-catch weights aggregated.** Furthermore the **results presented in most published reports are insufficient for industry use:** they were essentially written for use and review by other researchers and do not often address the needs of industry.

If the current and prospective studies on by-catch and the effects of trawling on fish are to serve industry as well as researchers - and the results to be fully available to industry - there is a need to review the *modus operandi* of biological research, data collection and data base management.

It is recommended that:

Applied fisheries researchers should meet to bring about a more uniform approach to fish names, survey methodology, data collection, database management and access, and to overcome the shortage of fish weight data.

Industry communication be reviewed and upgraded so that industry can better understand and use the results of publicly funded fisheries research.

FRDC should consider funding such a meeting if special funding is required.

By-catch is most abundant in Torres Strait and the Gulf of Carpentaria where an **estimated total of almost 40000 tonnes** of fish and shellfish are found each year. Most **(>90%) of this is currently discarded** essentially because its current value is insufficient to cover the costs of handling, transport and marketing. Bugs, squid, and some prime fish species are retained, for domestic sale.

By contrast, prawn fisheries in **inshore areas such as Botany Bay and Moreton Bay are characterised by a large by-catch retention rate** which has led to conflicts with other groups in the fishing and wider community.

Fishermen in such areas are selling whatever by-catch is marketable today and the **by-catch sales in such areas cannot be increased significantly** because of biological and regulatory limits on the different species; in Botany Bay the by-catch in the 1993-94 season has outweighed the prawn landings.

The oceanic fisheries of NSW and eastern Queensland currently yield bugs, squid, octopus, cuttlefish, red mullet and blue swimmer crabs and selected prime fish species as by-catch. However these areas are capable of providing modest increases in by-catch volume as market demand changes and more species can be marketed profitably.

Notwithstanding the inherent difficulties associated with remote locations in northern Australia, the **Gulf of Carpentaria is regarded as having substantial potential for** increasing the landings and **sale of by-catch.**

This potential can be capitalised **by fishermen working more closely with processors and other buyers to develop better** handling, packing and **supply coordination** procedures to stimulate market demand for selected species already known to consumers.

New technology and new products are not the only solution to overcoming long standing problems; old technology such as sun drying of fish may well be profitable given the growing demand for dry and exotic products in Australia and elsewhere.

Species identified as capable of greater utilisation and warranting closer industry attention are the **red mullet, shovel nose rays** and other fish in northern Australia and the **catfish, minor prawn and crab species** in eastern Australia.

The **potential for greater utilisation** of by-catch **in eastern Australia is probably lower** than that for northern Australia because of a smaller variety and volume of seafood and the constraints posed by current conflicts over resource sharing.

It is recommended that the FRDC and QCFO consider funding a bioeconomic study of the Gulf of Carpentaria by-catch focussing on selected species, such as goatfish (red mullet).

Seafood Processing By Products and Waste

Seafood processing with Australian raw material mostly entails fish filleting or peeling/cooking of prawns and bugs and the freezing of such products in small general purpose factories.

The shucking of Queensland saucer scallops is the outstanding processing activity in the two states and production of more than 1250 tonnes of meat is expected for 1993. **The scallop also poses the greatest challenge and opportunity in the by products and waste utilisation area.**

By product manufacturing is very small scale, in terms of variety and value, principally because of the small size and scope of the seafood processing industry, and related seasonal supply problems, and because of a correspondingly small investment in formal R & D. Fish **meal is the outstanding by product** and some 1200 tonnes was produced in NSW in 1993.

The vast majority of seafood waste generated in the two states, **is being dumped**, including some 3000 tonnes of scallop shell and about 1000 tonnes of scallop "gut" each year.

The scallop situation is expected to improve in 1994 as a new plant opens to convert shell to calcium powder but there appears to be a substantial amount of waste from the smaller processing factories and the many fish merchants in Sydney and Brisbane that could be pooled collected and utilised.

It is recommended that :

NSC and FRDC seek expressions of interest and fund an economic study of the costs and benefits of establishing a seafood waste collection system for Sydney.

NSC calls for expression of interest in research on the utilization of scallop gut and shell.

1. INTRODUCTION and BACKGROUND

The by-catch of many of the major fisheries and fishing grounds in Australia have been studied since Maclean's work in Moreton Bay, Brisbane in the late 1960's (Maclean 1972).

However most research on by-catch in Australian waters has been primarily designed to investigate the impact of trawling on particular estuaries, coastal areas, fish communities or selected species, and there has been very little research on the economic importance or utilisation of by-catch in this country.

Despite the obvious economic importance of the by-catch to the Australian fishing and seafood industry the research by Pender and coworker's on the Northern Prawn Fishery is the only one undertaken specifically to investigate the abundance and commercial utilisation of the by-catch.

There is however some valuable information on the species composition, relative abundance and discarding of by-catch species scattered in 23 of the papers reviewed by the author as part of the present study. An annotated bibliography is given at the end of this report (chapter 8) as a guide to the content and the relationship between these more pertinent papers in the literature.

The by products manufactured by seafood processors and the disposal or utilisation of fish processing wastes have also attracted increasing attention in recent years as industry and government promote the practice of value adding and the need for greater utilisation of the catch and maximising the economic benefits from the nation's fish resources.

The National Seafood Centre, which seeks to increase the economic and social benefits for the fishing industry and the people of Australia, has therefore commissioned a study on the the by-catch in Queensland and NSW and the by products and waste from processing operations in these states. In short a study of waste fish and fish waste.

The study was undertaken to gather information to assist the NSC in the planning of Research and Development support for the total utilization of the catch.

1.1 Study Objectives

The objectives of the study were:

To provide a qualitative and quantitative assessment of the type, volume and seasonal availability of by-catch and by products;

identify the significant weaknesses and gaps in existing data and current data collection procedures.

and

provide recommendations on how the information gaps may be rectified so that industry can take full advantage of the existing data base and future studies on fish distribution and abundance or the effects of fishing on fisheries resources.

2. RESEARCH METHODOLOGY

The composition, abundance and seasonal availability of by-catch was investigated by means of a literature search initiated through the National Seafood Information Service and a review of the published papers, reports and unpublished information gathered by the writer.

Where necessary, and possible, total abundance estimates were made by the author after taking account of the most recent research results and the comments of researchers and industry leaders. Full details on the assumption, calculations and extrapolations made are noted in the discussion for each fishery.

Industry interviews were conducted with the managers of 38 processing firms selected on the basis of known or likely involvement with the various fisheries and products of interest to this study. Almost all of these interviews were conducted by telephone, with few personal interviews, and explored the firm's by-catch utilisation, by product manufacture and waste utilisation.

The respondent was encouraged to be as quantitative as possible in discussion and confidentiality was assured and respected when requested. Where possible the source of information is quoted and the present author's interpolations and estimates identified as such. Research and preparation of the draft report were undertaken between 21 December 1993 and 19 January, 1994.

It should be noted that many factors influence the relative abundance and diversity of the by-catch as indicated by trawl catches of commercial trawlers or research vessels.

These include

* research program design and objectives
* fishing/sampling gear: net design and overall size
  mesh size, particularly in cod end
* trawling strategy: random or selected areas
* annual (year to year) variations in biological productivity
* seasonal changes in productivity: summer to winter etc
* lunar fluctuations: some species more abundant during darks, others during full moon

* daily (day to day) fluctuations
* day to night fluctuations in many species
* rainfall, runoff and salinity, particularly in or adjacent to estuaries
* latitude and water temperature: species diversity is often greater in the tropics than in the temperate waters.

These factors will be discussed further later in the report, but it should be noted here that data from one study should not be directly compared to that of another without consideration of the variables outlined above. Furthermore the findings need to be interpreted in the light of the year they were noted, given the substantial changes recorded in fishing effort, landings and marketing practices in the past ten years.

2.1 Report structure and data presentation

Chapter three reviews the by-catch composition, abundance and availability, chapter four covers the retention and utilisation of the by - catch and chapter five reviews the manufacture of by products and waste in the two states.

By-catch composition and abundance is discussed separately for each of the major fisheries or fishing ground reflecting the ecological situation and the scope of the various research papers and reports. Observations and discussion on the retention, utilisation and sale of by-catch however has been organised and presented for each state rather than for each fishery because discarding, handling and marketing practices are essentially the same within each state while the marketing opportunities and practices differ from NSW to Queensland. A separate section on the utilisation of the by-catch from each fishery would entail unnecessary repetition.

By products and waste utilisation is also discussed on a state basis rather than for each fishery because most processors handle product from more than one fishery.

The level of quantitative information on composition, and abundance of by-catch and by products in the following pages generally reflects that available at the time of writing.

3. BY-CATCH COMPOSITION AND ABUNDANCE

Detailed information on the species composition of the by-catch in Queensland and New South Wales fisheries abounds in the scientific literature and stems mainly from five research groups:

NSW State Fisheries research cruises with FRV Kapala and the organisation's studies on the impact of trawling in various NSW estuaries and coastal areas.

CSIRO's research on Torres Strait, Gulf of Carpentaria and Moreton Bay (Queensland),

QDPI Fisheries Branch's work on the prawn trawling areas on the central and northern Queensland coast.

University of Queensland's research on the by-catch in Moreton Bay, starting with Maclean's work in the 1960's.

The NT Fisheries Division and its work on the Northern Prawn Fishery.

These groups have published a series of papers on their research, usually with some overlap in the content of the various papers and the annotated bibliography in chapter eight can be used as a guide to date and relationships of these publications.

Table 1, on the next page, summarises the research methodology and the type of information in key reports on by-catch studies in Queensland and NSW.

Table 1. Key by-catch research project reports and information available.

Area	Study Type	Year	Key Reference	Information Available
Moreton Bay	Biological surveys Trawler catches	1979-81 1983-84	Stephenson et al '82 Wassemberg & Hill '89	Species list & nos. of individual fish % composition of major groups
Townsville	Biological surveys	1985-86	Dredge 1989	Species list & nos. of individual fish
E. Gulf of Carp.	Biological surveys	1987-88	Blaber et al '90	% composition of FISHES
W. Gulf of Carp.	Trawler catches	1988	Pender et al '92	Estimates of spp. tonnage & data on average weight,utilisation
Torres Strait	Trawler catches	1986-88	Harris & P '90	% composition of major groups & fish families
NSW Estuaries	Trawler catches in 5 areas	1989-92	Kennelly 1993	Total by-catch: prawn & nos. of key by-catch spp.
NSW Oceanic	Trawler catches from 4 ports	1990-92	Kennelly 1993	Total by-catch: prawn & nos. of key by-catch spp.
	Biological surveys	1990-92	Graham et al '93b	Species list & nos. of individual fish & some data on weight and lengths from FRV Kapala cruises

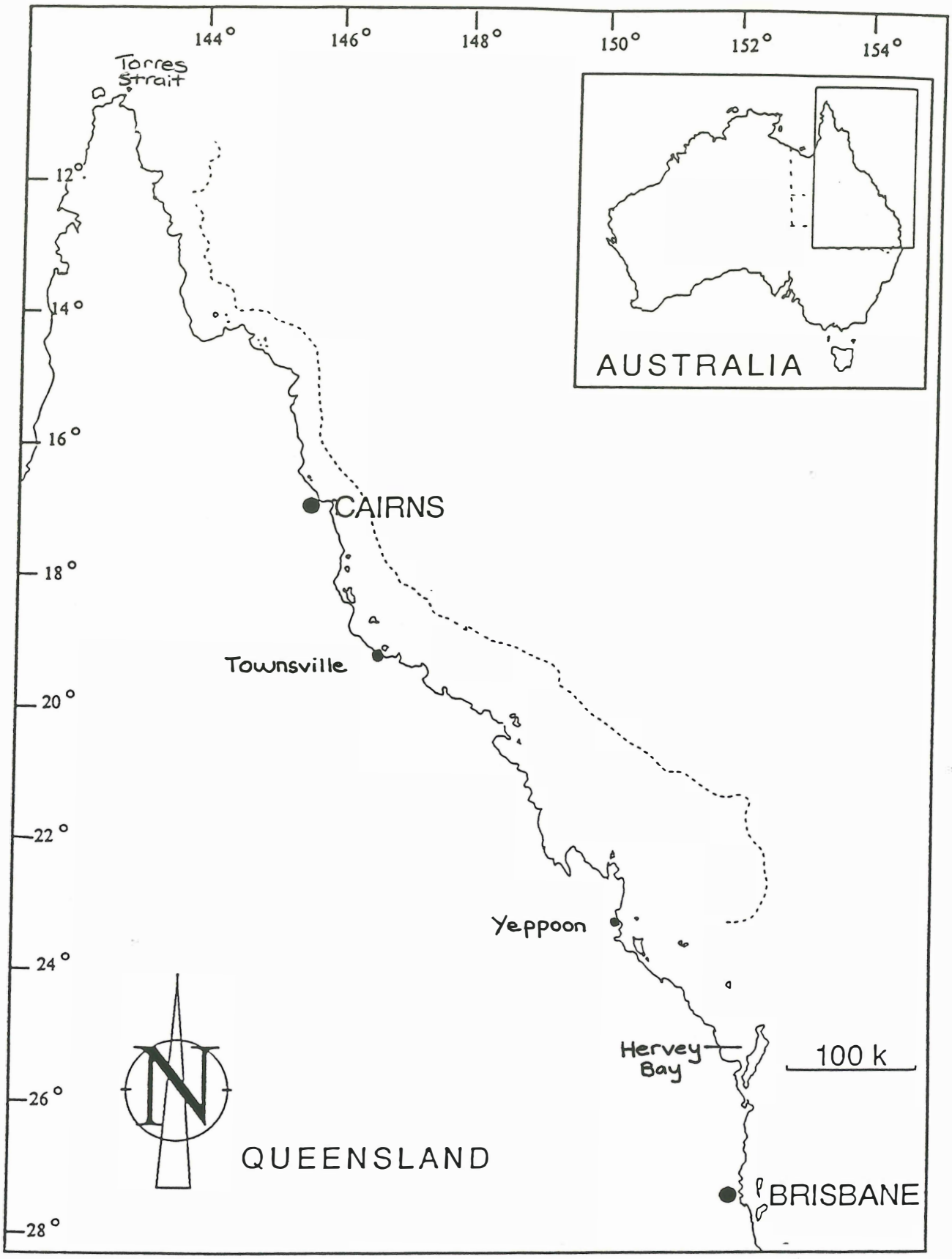


Fig. 1 Map of Eastern Queensland

3. 1 Queensland

The most important fisheries in Queensland are the trawl fisheries of the east coast, Torres Strait and the Gulf of Carpentaria, with prawns being the principal target species although scallops are sometimes the target in the area between Bundaberg and Townsville (Fig 1). These fisheries have all been subjected to considerable research by fisheries scientists and while there is a substantial body of data available on by-catch composition there is very little information on the actual abundance (in terms of tonnage) and size range of the different species in most study areas.

3.11 Moreton Bay

Maclean (1972) and Stephenson et al (1982 a, b) from the University of Queensland examined the by-catch from trawling in Moreton Bay, from commercial trawlers and research vessels respectively, and Hyland (1985) recorded some observations on by-catch in the Logan River and adjacent area of Moreton Bay. More recently Wassenberg and Hill (1989, 1990) investigated the discarding and survival of by-catch from commercial trawls.

Maclean's work was undertaken in the late 1960's and his data are therefore less relevant and useful than those gathered later by Stephenson's or Wassenberg's team.

Stephenson's and Wassenberg's papers indicate that the ratio of by-catch to prawns taken by trawling is about 6:1. Thus based on recent landings of approximately 500 tonnes of prawns per annum the volume of by-catch from Moreton Bay can be estimated at about 3000 tonnes per annum.

Stephenson et al's 1982 b report has an extensive list of the species and numbers taken by trawling in Moreton Bay, and it is evident from Wassenberg and Hills research too that crustaceans dominate the by-catch in this area (See next page).

Table 2 summarises the data for Moreton Bay discarded by-catch ie species not considered to be of commercial value at the time by the trawler skippers. Wassenberg has advised the present author that very little by-catch was retained - essentially large sand crabs *Portunus pelagicus*, bugs and squid - and the data on discards can be treated as if it was the entire by-catch.

Table 2. Composition of Moreton Bay by -catch estimates 1983-84 (prepared from Wassenberg and Hill 1989, table 2 and 3)

Category	**% of catch**
Crustacea	52.2
Elasmobranchs	15.4
Bony fish	8.4
Echinoderms	17.9
Cephalopods	3.0
Debris	3.0
Crustacean Category	
Sand crab	85.2
Clicker prawns	1.5
Penaeid prawns	4.8
Others	8.5

It is interesting to note, from Table 2, that the by-catch was dominated by crustacea and elasmobranchs (sharks and rays), principally the commercial sand crab species *Portunus pelagicus.*

From an extrapolated by-catch of some 3000 tonnes per year the sand crab represents about 44% or more than 1320 tonnes. The rays and sharks represent some 460 tonnes and the echinoderms (sea urchins starfish and cucumbers) represent almost 540 tonnes.

The total (extrapolated) fish by-catch was only 252 tonnes; the notable ones are the (small) flounders, whiting and flathead and the dominance of the cardinal fishes (family Apogonidae, small non commercial fishes usually less than 15 cm long.

Abundance data on the individual fish species are not presented here because it is based on 27 trawl shots and a few kilos of fish only.

Hylands (1985) records of large numbers of *Arius* spp [catfish] in the Logan River are noteworthy given the increasing demand for catfish in the last few years. These catfish made up a third of the total catch, by weight, of the prawn beam trawl and may represent a substantial underutilised resource.

3.12 East Coast

The by-catch off the east coast of Queensland has received little attention from fisheries research workers and the little research undertaken to date has focussed on the fauna in relation to management of marine parks and provides no data on commercial trawler practices regarding capture or retention of by-catch.

Michael Dredge and coworkers from the QDPI have recorded the composition and numerical abundance of by-catch species on the prawn trawling grounds off central Queensland (Townsville area, 18-19°S) while QDPI and CSIRO scientists are currently studying by-catch species on the far northern coast of Queensland but neither of these studies give an indication of the volume or weight of prawns to by-catch nor the sizes of the various fishes etc in the by-catch.

Hence the likely by-catch weight can, for now, only be estimated from the prawn landings by multiplying by some number representing the by-catch : prawn ratio. Say 5:1 to 10:1 as indicated by Slavin (1982) in his review of by-catch from tropical and temperate waters.

The numerical abundance data and other information in Dredge (1988,1989), Jones and Derbyshire (1988), Watson et al (1990) and Blaber et al (1993) however can be used for an examination of the relative abundance of particular groups or species, as follows.

Dredge (1988,1989) reported that the research trawl by-catch near Townsville, in an area where some 2000 tonnes of prawns are trawled each year, contained 477 taxa and was dominated by crustacea (42% by number) and bony fishes (37%).

We can obtain an estimate of total by-catch in this area by assuming it is about 5 times, say, the prawn catch of 2000 tonnes, that is, 10000 tonnes or more of by-catch.

A sand crab *Portunus tenuipes* was the single most abundant species and a threadfin bream *Nemipterus celebicus* the most abundant fish species in 1986. The fish fauna was dominated by species of the family Nemipteridae (threadfin bream), the flatfish families Bothidae and Pleuronectidae and the flathead family Platycephalidae, but as noted earlier no data on volumes is available.

Dredge noted that the by-catch composition was remarkably dynamic with relatively few species being present throughout the year and with the dominant species changing over time. Watson et al (1990) in a later analysis of the same Townsville data concluded that the location of the trawl site was more important than the time of the year in determining the distribution of many of the by-catch species.

These studies were not designed to study seasonal changes in the abundance of by-catch and they cannot be used to make any definitive remarks on seasonality, but Dredge (1989) has graphs showing the proportion of animals taken in each month of the year.

The early results of an ongoing study by QDPI and CSIRO on the trawl by-catch by research vessels in northern Queensland near Cape York indicate that the by-catch in this area is dominated numerically by fishes of the *Lethrinus* spp (Sweetlips), *Upeneus* (goatfish/red mullet) and *Leiognathus* spp (Pony fishes) (see Appendix 1) although crustacea also make up a large part of the catch.

This work has not yet produced any data on weight of the individual by-catch species or total by-catch but it is still progressing and some observations on by-catch weights and seasonal changes should be available in later reports (N Gribble, QDPI, personal communication).

Fishermen and processors suggest that the by-catch off NE Queensland is not too much different from that of Torres Strait but research results indicate that there are too many variables for such a general conclusion. What can be concluded, at this time, is that the east coast fauna is diverse, and as in other areas, the by-catch is dominated by a small number of species - Dredge (1989) reported that five species

made up more than 50% of the by-catch in his study off Townsville- and can change noticeably from month to month.

3.13 Gulf of Carpentaria

The research work by Blaber and team in Albatross bay in the eastern Gulf of Carpentaria and that by Pender and colleagues in the western side of the Gulf of Carpentaria (Northern Prawn Fishery) has provided much valuable information on the composition and abundance of the by-catch along both sides of the Gulf of Carpentaria. Penders work is exceptionally useful as it gives information on the size range and commercial utilisation of many of the fish and shellfish caught.

Albatross Bay

Blaber et al (1990) undertook seven research cruises in Albatross Bay with a program of trawl surveys to sample fish [note: fish only] in four depth zones and recorded a total of 237 species of fish.

The dominant families were Leiognathidae (pony fishes), Haemulidae (javelin fish) and Clupeidae (herrings, sardines and bony bream) and *Leiognathus bindus,* a pony fish, the most dominant species, accounted for almost 12% by weight of the fish by-catch.

The prawn fishery in Albatross Bay averaged 600 tonnes in 1987-88 and assuming that the fish to prawn catch ratio was 6:1 say (as indicated from Pender et al 1992 and Harris and Poiner's 1990 work) the fish catch would have totalled about 3600 tonnes.

Table 3 shows the mean biomass (kg per hectare) as reported by Blaber et al for of the 23 most abundant species of fish taken at night; these 23 species accounted for 79 % of the total biomass.

The second column in Table 3 shows the estimated tonnage of these fish, calculated by using Blaber's information on percentage contribution to total biomass and the 3600 tonne estimate of total fish catch.

Table 3. Biomass (kg /ha) and tonnage of the 23 most abundant species of fish caught in night trawls in Albatross Bay, Gulf of Carpentaria (Data from Blaber et al 1990)

Species	Biomass	Tonnes
Leiognathus splendens	19.0	540.36
Pomadasys trifasciatus	12.0	341.28
Leiognathus equulus	11.0	312.84
Pomadasys maculatus	10.0	284.40
Upeneus sulphureus	6.0	170.64
Johniops vogleri	5.3	150.73
Johnius amblycephalus	4.6	130.82
Gerres filamentosus	4.1	116.60
Dasyatis thetidus	3.7	105.22
Pomadasys kaakan	3.4	96.69
Anodontostoma chacunda	2.7	76.78
Carcharhinus tilstoni	2.0	56.88
Arius macrocephalus	1.9	54.03
Terapon theraps	1.8	51.19
Arius thalassinus	1.8	51.19
Polynemus multiradiatus	1.8	51.19
Carcharhinus sorrah	1.7	48.34
Carcharhinus amblyrhynchos	1.7	48.34
Himantura toshi	1.7	48.34
Leiognathus bindus	1.7	48.34
Leiognathus leuciscus	1.2	34.12
Nemipterus hexodon	1.2	34.12
Carcharhinus macloti	1.1	31.28

From a detailed statistical analysis of their data Blaber et al concluded that of the 31 most abundant species, 15 showed significant variation in abundance from day to night; 11 species showed seasonal patterns of abundance and that the abundance of 23 species was significantly correlated with depth of water.

Blaber et al found the day time catches to be approximately twice the volume of night ones but night time estimates were tabled above so that they can be contrasted with the night time estimates and commercial fishing data of other researchers in northern Australia.

Leiognathus bindus -- the most abundant fish during daylight hours is a small pony fish species attaining a length of only 90 mm; pony fishes, are small tasty fish with limited market demand, currently coming from the Asian community alone.

The *Pomadasys* species, known as javelin fishes, are an excellent table fish growing to beyond 450 mm according to Grant (1985) but not often retained because of the small size of the fish commonly caught according to Willing and Pender 1992. *Upeneus sulphureus* is known as sunrise goatfish, the goatfish or red mullets are a group of fishes often retained from the by-catch. The *Carcharinus* are the whaler or black tip shark species.

The retention and commercial utilisation of these species from the western Gulf of Carpentaria by-catch has however been recorded by Pender and Willings (1990) who noted [for the NPF as a whole] that 97% of the by-catch by weight was discarded at sea and only valuable species such as bugs and squids and some species of fish were retained for domestic markets.

This is discussed further in Section 4.

3.14 Western Gulf of Carpentaria

Pender and colleagues studied the by-catch from commercial trawlers operating in various areas of the NPF over three bimonthly periods in 1988 and recorded 218 taxa and information on the discarding, retention and marketing practices of the trawler operators for 42

marketable species. Their 1992 paper is exceptional and exemplary in that it is the only one reviewed in this report that records the size range of the by-catch observed at sea.

Fortuitously Blaber et al's data from the eastern Gulf is based on samples taken from a net with a 50 mm mesh cod end, the same size as that normally used by commercial trawlers, in 1987 and 1988; therefore Pender's findings in the west can be contrasted with those of the eastern Gulf of Carpentaria.

The 1988 total prawn catch for the entire Gulf of Carpentaria was 5800 tonnes (CSIRO data) while the catch from the Groote and Limmen Bight fishing area, Ponders et al's western Gulf of Carpentaria area (WGOC), totalled approximately 2740 tonnes. The total by-catch in the WGOC area was 23198 tonnes representing a ratio of 8.5:1 prawn. Their total by-catch estimate for the entire NPF was 47000 tonnes representing by-catch to prawn ratio of 8.1 : 1.

Table 4 shows the make up of the by-catch from the western Gulf of Carpentaria according to the major biological groups, in tonnes and as a percentage of the total catch. It should be noted that this represents the catches over approximately six months fishing ; two closures prohibit trawling for about six months.

Table 4. Estimated catch of major categories of by-catch in the Western Gulf of Carpentaria (adapted from Pender et al 1992, table 5)

Category	tonnes	% total catch
Fish	17399	67
Sharks & rays	2255	9
Crustaceans	967	4
Molluscs	1128	4
Echinoderms	644	3
Sponges	483	2
Other invertebrates	161	1
Reptiles	161	1
Total by catch	23198	

Table 5 shows the estimated tonnage caught and percentage volume observed for the dominant fish families in the the NPF study area (data extracted from Pender et al 1992).

Pender et al found that the catch in the western Gulf of Carpentaria represents the bulk of the of the NPF by-catch hence the NPF data provide a reliable estimation of the by-catch in the (western) Gulf.

The dominant fish are the grinners, threadfin breams, pony fishes (dollar fishes), trevallies and goatfish (Table 5). The grinners (Synodontidae) are clearly the dominant fish species on both the eastern and western areas of the Gulf, but the relative ranking of the other species differs somewhat.

The dominant crustacea were the crab families (507 tonnes, 48%). The commercial sand crab *Portunus pelagicus* was the outstanding species making up 83% of the Portunid crabs. Bugs represented 14% (149 tonnes) of the crustaceans.

The molluscan catch consisted of 532 t squids (46%), 412 t of scallops (35%), 140 t of cuttlefish (12%) and 55 t of octopus (5%).

Table 5. Fish in the by-catch of the NPF study area, 1988.
(Extracted from Pender et al 1992, table 7)

Family Name	Common Name	Tonnage	% Catch
Synodontidae	Grinner	3654	19
Nemipteridae	Threadfin	2788	14
Leiognathidae	Dollar fish	1892	10
Carangidae	Trevally	1596	8
Mullidae	Goatfish	1243	6
Monacanthidae	Leatherjacket	1137	6
Gerreidae	Silver biddy	682	4
Clupeidae	Sardine/Herring	559	3
Ariidae	Catfish	557	3
Haemulidae	Javelin fish	524	3
Apogonidae	Cardinal fish	499	3
Platycephalidae	Flathead	460	2
Muraenesocidae	Pike eel	458	3
Teraponidae	Grunters	436	2
Psettodidae	Halibuts	293	2
Lutjanidae	Tropical snapper	235	1
Bothidae	Flounder	208	1
Polynemidae	Threadfin salmon	202	1
Serranidae	Cods/Coral trout	199	1
Priacanthidae	Big eye	194	1
Plotosidae	Eel tail catfish	164	1
Sciaenidae	Croaker	157	1
Scombridae	Mackerel	135	1
Sillago spp.	Whiting	128	1
Sphyraenidae	Sea pike	122	1
Engraulidae	Anchovy	112	1
Tetraodontidae	Toad/Pufferfish	97	1

3.15 Torres Strait

Harris and Poiner (1990) assessed the composition and quantity of the by-catch from commercial prawn trawling in Torres Strait from the results of seven trawl surveys and the fishery effort from log book records, over two years 1985 and 1986.

They estimated the total weight of the by-catch at 6930 t (∓900 t) in 1985 and 4630 t (∓710 t) in 1986. This included shellfish, sharks, rays turtles and snakes, see Table 6, but teleost fishes were the largest component: 5520 t (∓970 t) in 1985 and 2910 t (∓510 t) in 1986.

They noted that bugs and squid are retained but that all other components of the by-catch are discarded. Nemipteridae (threadfin bream) and Synodontidae (grinners) were the dominant fish families and made up 14 and 13% respectively of the teleost fish catch by weight (Table 7).

A noteworthy finding is that the Leiognathidae (pony fishes) formed only about 1% of the by-catch in the Torres Strait; this family is one of the most important fish families along both sides of the Gulf of Carpentaria (Blaber et al 1990, Pender et al 1992) and north eastern Queensland (Blaber et al 1993).

Harris and Poiner (1990) found little change in the composition of fish by-catch from one year to the other but the fish to prawn ratio changed from 5.1 :1 in 1985 to 3.3 : 1 in 1986.

They found no evidence of seasonality for most by-catch groups but reported that the percentage of the leatherjacket family Monacanthidae changed noticeably from 11.6 to 3.4 % from 1985 to 1986 probably as a result of commercial fishing effort.

Table 6. Percentage composition by weight of Torres Strait catch in 1985 and1986 (Adapted from Harris and Poiner,1990 table 3).

Taxon	1985 Percent	1986 Percent
Prawn, commercial	13.6	16.7
By-catch		
Sponge		0.0
Prawn, non-commercial	-	3.7
Shovel-nose lobster	-	1.7
Rock lobster	0.1	4.8
Crab	-	7.7
Scallop	-	3.0
Squid	0.1	4.8
Cuttlefish	0.9	1.4
Octopus	0.3	0.2
Shark	0.4	0.5
Ray	0.9	2.0
Teleost	68.8	52.3
Snake	0.1	0.2
Turtle	2.3	0.3
Unidentified	12.5	5.4

Table 7. Percentage composition of the main fish (teleost and elasmobranch) families in the Torres Strait by-catch 1985 & 1986. (Data from Harris and Poiner 1990, table 4 and text).

Family	1985		1986	
	% Weight	Tonnes	% Weight	Tonnes
Nemipteridae	14.0	970.20	16.1	745.43
Synodontidae	13.3	921.69	12.6	583.38
Monacanthidae	11.6	803.88	3.4	157.42
Priacanthidae	6.3	436.59	10.0	463.00
Bothidae	5.4	374.22	5.7	263.91
Platycephalidae	5.2	360.36	3.7	171.31
Dasyatidae	0.8	55.44	3.4	157.42
Plotosidae	1.5	103.95	0.4	18.52
Dactylopteridae	2.3	159.39	1.0	46.30
Scorpaenidae	1.8	124.74	0.8	37.04
Serranidae	1.8	124.74	1.2	55.56
Apogonidae	2.3	159.39	4.8	222.24
Carangidae	2.5	173.25	2.8	129.64
Leiognathidae	1.0	69.30	1.8	83.34
Mullidae	3.5	242.55	3.4	157.42
Labridae	2.9	200.97	3.8	175.90
Callionymidae	3.8	263.34	2.5	115.75
Gobiidae	1.3	90.09	2.9	134.27
Tetraodontidae	4.2	291.06	3.2	148.16
Scolopsidae	4.7	325.71	5.4	250.02
Total	90.2	6250.86	89.1	4125.33

3.2 New South Wales

Trawling is permitted for prawns in five NSW estuaries: the Clarence River, the Hunter River, Hawkesbury River, Port Jackson (Sydney Harbour) and in Botany Bay (Figure 2). Prawn trawling is allowed along the entire NSW coast, but oceanic fishing effort is essentially concentrated in the area between Newcastle and the Queensland border except for a small amount of deep water trawling for royal red prawns.

The commercial prawn trawling by-catch composition and numerical abundance in the Clarence, Hawkesbury, Port Jackson and Botany Bay were estimated by NSW Fisheries scientists by means of log book data on fishing effort and the scientific observers' records of sample catches.

Similar studies were also undertaken for the oceanic prawn fishery, on trawlers operating from the Clarence River, Ballina, Coffs Harbour and Port Stephens, all north of Sydney (Figure 2).

In addition, research surveys by the FRV Kapala off Brunswick Heads, the Clarence River, Tuncurry and Newcastle have provided substantial information which complement the data on commercial trawler by-catch.

South of Sydney most offshore fishing effort is directed at mixed fish species (other than the small royal red fishery) and the composition of the landings of the commercial fleet has not been systematically studied until 1993, by NSW Fisheries.

NSW Fisheries has just completed one years field work on the by -catch of trawlers operating from Ulladulla and Eden, on the south coast of NSW, as part of a major research program on the South East Trawl undertaken by various government fisheries agencies. No information was available for inclusion in this report but a preliminary report on this work is expected later this year.

FRV Kapala has undertaken many trawl surveys along the NSW south coast over a period of more than 15 years and there are species lists and data on individual trawl shots recorded in approximately one hundred Cruise Reports; a synthesis of the information in this vast body of literature was beyond the scope of the present study.

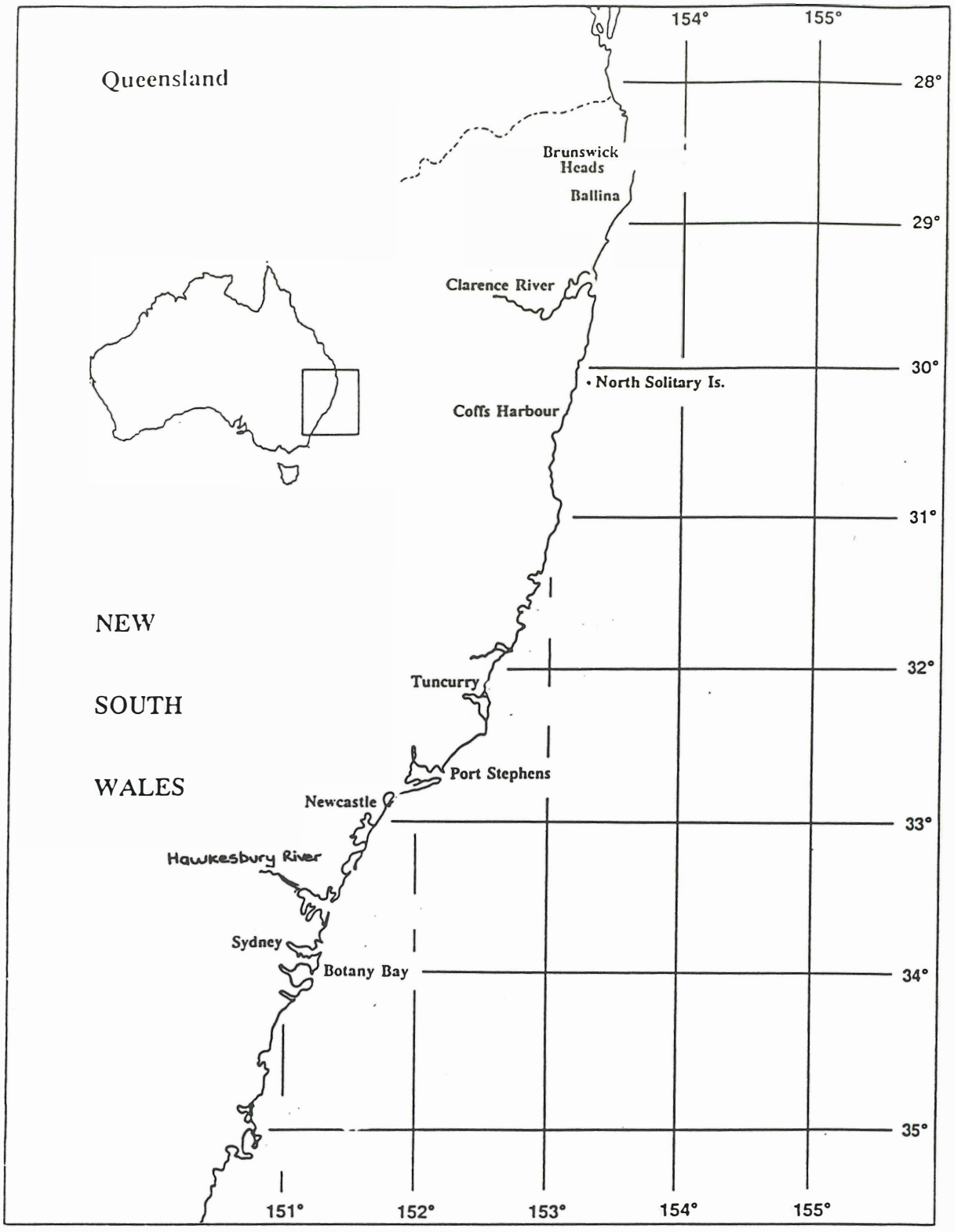


Fig. 2 Map of New South Wales

3.21 Estuarine Prawn Fisheries

The by-catch from five NSW estuarine prawn fisheries in 1991-2 was recorded by Kennelly (1993) as 421 tonnes while the prawn landings totalled some 488 tonnes. The catch weights and numbers for each of the five areas: Botany Bay, Port Jackson, Hawkesbury River, Clarence River and Lake Wooloweyah (an area on the Clarence River) for three years are shown in Figure 3 on the next page (from Kennelly's Fig 1).

A full check list of the species recorded in the by-catch of the commercial trawlers in three of these areas is included in Kennelly's 1993 report (Appendix N) and Table 8 (below) shows the number of species for each fishery and the number of commercial species (in parentheses).

Table 8. Total number of species and number of commercial species

Fishery	Fish spp	Crustacean spp	Mollusc spp
Botany	134(48)	11(6)	12(9)
Port Jackson	96 (32)	11(5)	10(7)
Hawkesbury	92 (31)	8*	7*

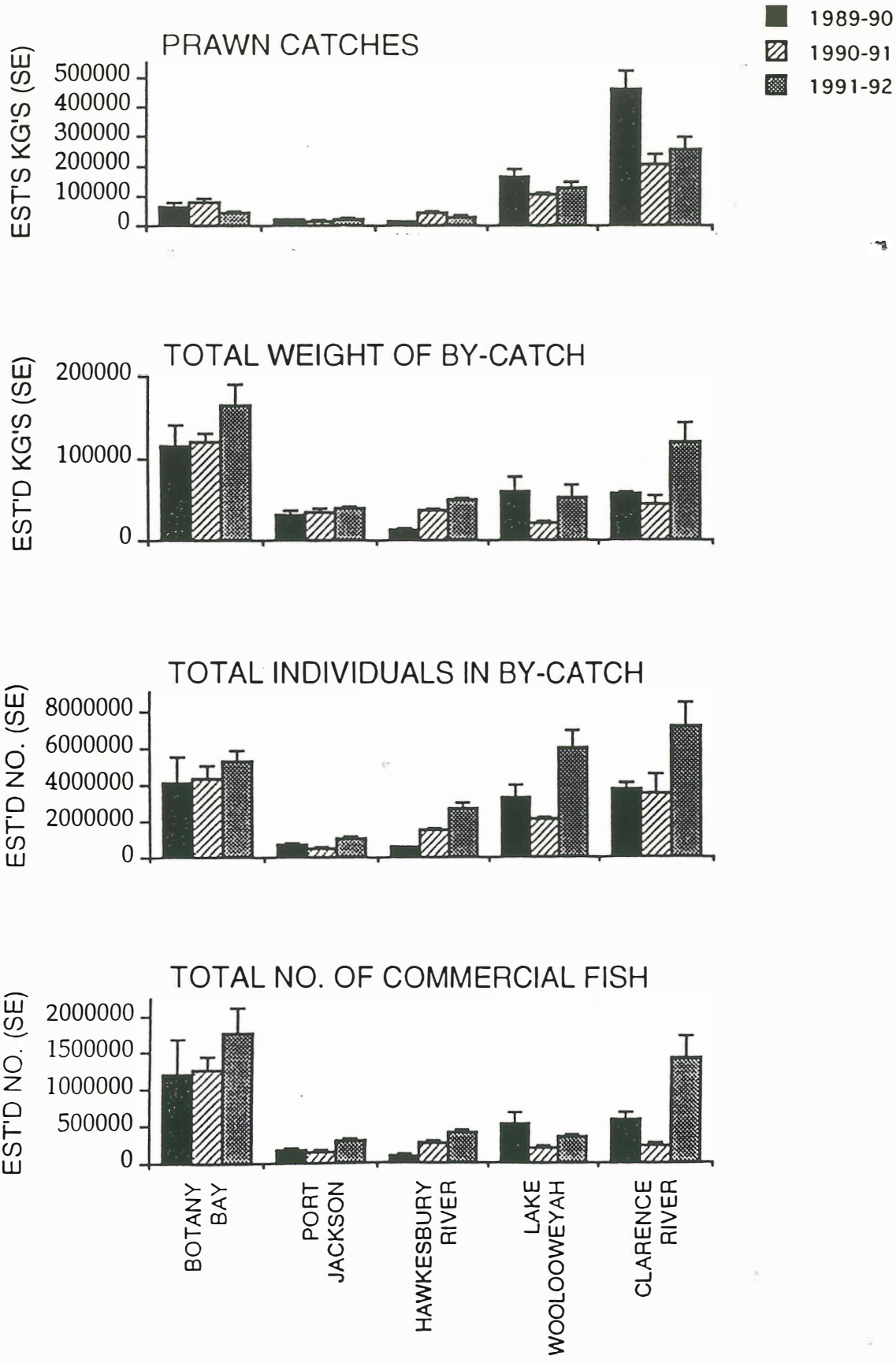
* Numbers of commercial species not indicated in Kennelly's report.

It should be noted that trawling is permitted all year round in the Hawkesbury River but that the other estuarine areas are only open to trawling from December to May inclusive.

Figure 3 shows quite substantial year to year changes in weight of the prawn and by-catch taken by trawlers. The Clarence River is the largest prawn fishery and it shows quite marked changes in by-catch:to prawn ratio from one year to the next; prawns clearly outweighed the by-catch in 1989-90 and in 1990-91.

For Botany Bay, Port Jackson and the Hawkesbury River the by-catch weight was greater than the prawn catch for each of the three years The Botany Bay by-catch to prawn ratio remained relatively steady at about 2 or 3 to 1 over the three years studied and by-catch weight exceeded 100 tonnes each year.

Figure 3. Weight and numbers recorded for prawn and by-catch from five estuarine studies (Kennelly 1993)



Kennelly's report also has graphs showing the estimated number of commercial fish species taken by the trawlers at each of these fishing areas and these are attached as Appendix 2 at the back of this report.

The commercial species selected for detailed study by Kennelly and coworkers were:

Bream
Flounder, large tooth,
Flathead, dusky
Flathead, eastern blue spot
Flathead, northern sand
Mullet
Mulloway
Snapper
Tailor
Tarwhine
Trevally
Whiting, red spot
Whiting, sand
Whiting, trumpeter
Crab, blue swimmer

These species were selected because they are of interest to commercial and/or recreational fishermen (G. Liggins, NSW Fisheries, personal communication).

No data on the weight of the individual fish by-catch species are given and hence the abundance cannot be calculated at this time.

The graphs in Appendix 2 indicate that Botany Bay had large numbers of eastern blue spot flathead, whitings, trevally and large toothed flounder and blue swimmer crabs. The Hawkesbury River trawlers caught large numbers of mulloway while the Clarence River trawlers caught large numbers of bream.

By-catch numbers of commercial species were relatively low in Port Jackson but dusky flathead was a dominant commercial species during the study (Appendix 2).

Kennelly (1993) also has graphs showing the length frequency distribution of the bream samples and of seven other fish species for this study.

Graphs of the monthly catches of prawns and by-catch for each estuary were included in information letters sent to participating fishermen (Kennelly 1993, Appendix M).

Kennelly and coworkers are still analysing data from this study and **have not yet described the seasonal changes** in the by-catch from these estuaries.

Gray et al 1990 have studied the composition and numerical abundance of the Hawkesbury River by-catch and recorded some observations on seasonal availability. They found more species in the warmer half of the year in both 1986 and 1987 but while numerical abundance was greater in the colder months in 1986 more individuals were caught in the winter and spring in 1987.

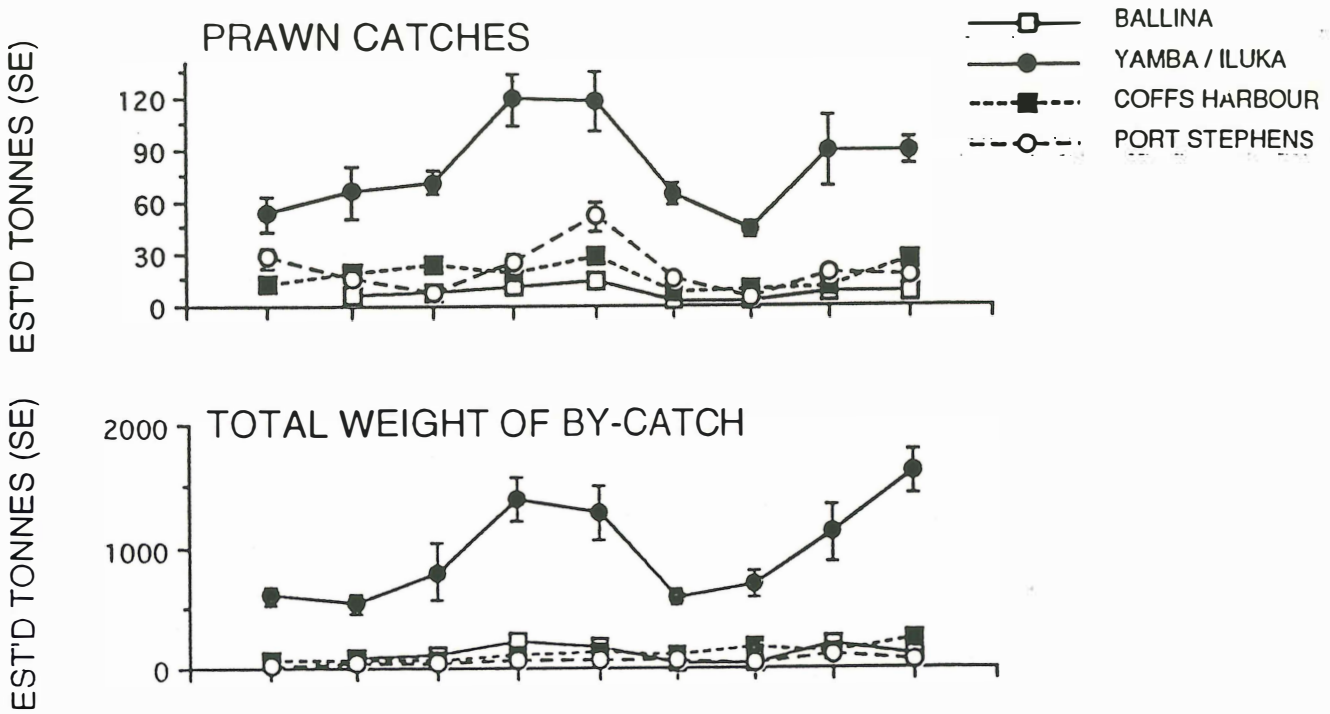
3.22 Oceanic Prawn Fisheries

The tonnage of prawns and by-catch recorded from the oceanic prawn fishery study by NSW Fisheries in 1991-2 is shown in Figure 4 (reproduced from Kennelly 1993 Figure 6). The total by-catch to prawn weight over the three year study period was recorded as 11311 tonnes to 1119 tonnes.

By-catch to prawn ratio ranged from about 3:1 at Port Stephens, 7:1 at Coffs Harbour, 12:1 from Yamba and 16:1 at Ballina. These four fishing ports account for the overwhelming majority of the state's oceanic prawn catch (K Graham and G Liggins NSW Fisheries, personal communication).

Fig.4 Prawn and by-catch weight estimates for four NSW ocean grounds

(From Kennelly1993, Figure 6)



Kennelly (1993) noted that the Yamba ground recorded the largest tonnage of by-catch (8167 tonnes) because of the large fishing fleet based in this area and the large number of days fishing recorded by this fleet. More than four thousand tonnes was recorded for Yamba in 1991/92 compared to 282 tonnes for Port Stephens.

Another notable feature of Figure 4 is the remarkable parallel between the prawn catch and the by-catch tonnage for the Yamba fleet suggesting that the ratio of by-catch to prawn in this area shows relatively little variation in comparison to the other areas.

The numbers of individuals of the selected commercial species recorded in the by-catch during each of the quarterly surveys were presented in graphical form by Kennelly 1993 and these are reproduced here as Appendix 3.

The species selected for the numerical studies were

Dory, john
Flounder, large toothed
Flounder, small toothed
Flathead, eastern blue spot
Flathead, spiky
Flathead, marble
Flathead, tiger
Hairtail
Leatherjacket
Mulloway
Perch, ocean
Redfish
Red mullet
Ray, shovel nose
Shark, gummy
Snapper
Tarwhine
Teraglin
Trevally
Whiting, stout
Whiting, red spot
Whiting, trumpeter

Bug, Balmain
Bug, smooth
Calamari
Crab, blue swimmer
Crab, three spot
Octopus
Cuttlefish
Squid, broad and slender
Squid, bottle

Species of particular interest are bugs, cuttlefish, octopus, squid, and red mullet because they are species that are mostly caught as by-catch, (although some trawlers target squid at times in the Hawkesbury River) and are almost always retained and sold.

A full check list of the species recorded in the by-catch of the commercial trawlers in each of these coastal areas is included in the appendix to Kennelly's 1993 report and table 9 (below) shows the number of species recorded for each group of animals:

Table 9. Numbers of species recorded in each study area

Fishing Ground	Fish spp	Crustacean spp	Mollusc spp
Ballina	41	10	5
Yamba-Iluka	46	8	8
Coffs Harbor	41	7	7
Pt Stephens	52	8	8

Further information on the by-catch species off the Clarence River is available from the FRV Kapala research work carried out at the same time (see following page) as that by Kennelly's scientific observers on the trawlers.

The graphs in Appendix 3 (at the back of this report) indicate that:

* The Yamba fleet caught large numbers of red mullet, eastern blue spot flathead, snapper and smooth bugs.

* The Port Stephens fleet caught large numbers of tiger flathead and redfish.

* The Coffs Harbor fleet had caught large numbers of cuttlefish while the Ballina fleet consistently had the smallest volume of by catch.

As indicated earlier the fishing fleet in these last three areas are the smallest of the four, as are the extrapolated by-catch. An approximate guide to the total weight of some of the key by-catch species caught and sold is provided by the sales figures of the Sydney Fish Market auction and this is shown in section 4.2.

3.23 Oceanic waters- FRV Kapala Surveys

In addition to the research work undertaken from commercial prawn trawlers, NSW Fisheries staff undertook a series of trawl surveys from the FRV Kapala to complement the scientific observers' data. Eight surveys were made between May 1990 and April 1992 and these covered inshore and offshore areas from Brunswick Heads, Clarence River (Yamba-Iluka) Tuncurry and Newcastle.

The Newcastle offshore ground surveyed by the Kapala is also fished by trawlers targeting fish, and the Kapala data for Newcastle provides the best guide available to date of the catch composition on the fish trawling grounds.

There is a large amount of data on the individual trawl shots in the two detailed reports on this study (Graham et al 1993 a, b) as well as lists of each species and their frequency of occurrence at each site, but little data on the weight of almost all by-catch species.

Graham et al's reports also contain length frequency data on many of the more commonly caught commercial and non-commercial species of fish, crustaceans and molluscs.

The Kapala found a total of 353 species of fish, 212 inshore and 248 offshore, and that the distribution of fish species varied among depths more than among geographical locations. On the Newcastle grounds for example only 37% of the species were caught both inshore (10-21 m) and offshore (64-77 m).

Twelve species were recorded from all eight grounds. Six were commercially exploited: shovel nosed ray, red gurnard, sand flathead, red spot whiting, red mullet and smooth backed flounder. The non commercial fish were numbfish, red bullseye, yellowtail, slender scad, common sea pike and smooth boxfish.

Red spot whiting were at times common on all grounds and shovel nose rays, red gurnard and sand flathead were generally more common on the offshore grounds.

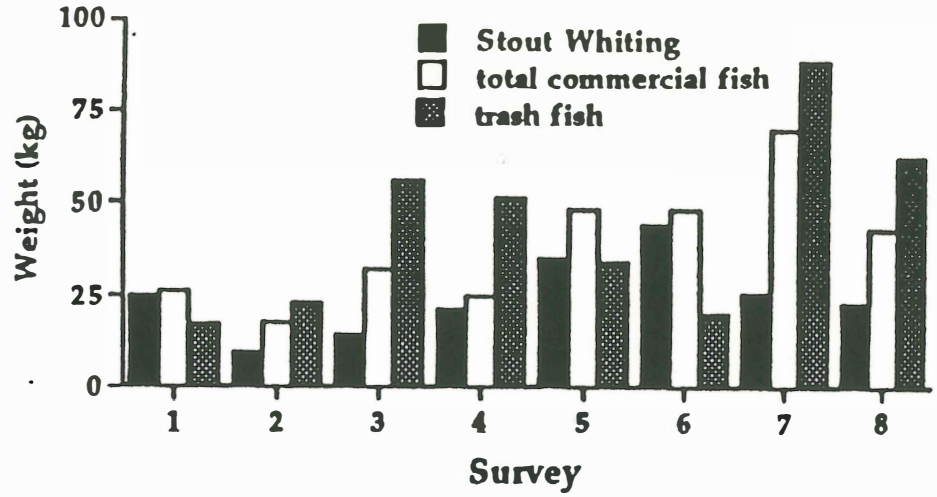
Red mullet and smooth backed flounder were generally more common on the offshore grounds especially off Brunswick and the Clarence. Yellowtail, slender scad and sea pike are primarily pelagic species and were occasionally caught in large numbers, especially inshore. Smooth boxfish were common inshore.

Graham et al (1993 a, b) reported noticeable differences in the abundance from one survey to another **but the data have not yet been subjected to a detailed analysis for seasonal fluctuations** in abundance; further papers are yet to be produced from these surveys by the research team.

By-catch to prawn weight varied considerably from one area to another and from inshore to offshore and ranged from 2:1 (Newcastle) to 101: 1 (Brunswick) but the ratios were often higher than those recorded by Kennelly from the commercial fleet. Graham et al reported that the weight of by-catch taken by Kapala was noticeably higher when there was little or no commercial fishing around the time of their surveys, because of the (large) number of fish taken by the fishing fleet.

Figure 5 reproduced from Graham et al (1993 b) shows the weight of stout whiting, total commercial fish and trash fish for the Brunswick and Clarence inshore ground for the eight surveys; stout whiting is a marketable species often retained for sale by trawlers. The by-catch to prawn ratio for survey one was 94:1 for Brunswick and 6:1 for the

Figure 5. Stout whiting and totol commercial fish catch for Brunswick and Clarence inshore grounds (extracted from Graham et al 1993, fig 23)



Clarence; prawn catches were too small on the other seven cruises for a comparison of by-catch to prawn weight.

Some of the more noteworthy observations recorded on by-catch were on some non-commercial crabs and box fish off Newcastle and Tuncurry respectively. Smooth boxfish formed " a major part of the trash by-catch" on the Tuncurry inshore ground; the smooth boxfish is a non-commercial species, effectively inedible because of the armour like bony plates in its skin.

During most surveys on the Newcastle offshore ground the coral crabs *Charybdis miles* and *C. bimaculata* formed " about half of the trash component " with mean catches ranging from 12 to 62 kg per hour; catches of non commercial crustaceans were very low on other grounds. (Graham et al 1993).

4. BY-CATCH RETENTION AND UTILISATION

The variety and volume of by-catch landed by trawlers is determined by several marketing factors, the size and refrigeration facilities of the fishing vessel as well as the biological productivity of the fishing grounds and fishery regulations (prohibitions) prevailing at the time. In essence, fishermen land whatever species or product they anticipate they can sell at a profitable price and have holding facilities for.

Harris and Poiner (1990) recorded that approximately 99% of the by-catch in the Torres Strait in 1985-86 was discarded and Pender et al (1992) noted that 97% of the by-catch volume in the NPF was discarded in 1988.

The retention rate today is undoubtedly higher and in the last few years the by-catch has constituted a substantial part of the earnings for trawlers. But the majority of the by-catch is discarded fundamentally because it is not valuable today, **most fish are too small or unwanted for existing markets.**

There is **very little quantitative information in the various research reports on the by-catch actually landed and sold** and much of the following chapter is necessarily based on industry interviews, market data and information noted in fishermen's log books.

Most processors or other seafood buyers purchase whatever by-catch they feel they can resell to their customers, hopefully at a profit. But in essence most buyers are often in an "all or nothing" situation, they are obliged to buy the common commercial species of by-catch such as bugs, squid and prime fish, and some of the less marketable, species if they wish to buy the prawns, scallops etc.

Small vessels are restricted by space and only retain the more valuable by-catch species such as bugs and squid. Trawlers working in Torres Strait which transfer their catch to barges ("mother ships") or transport vessels are also selective in the by-catch they retain because the transshipment costs represent a large percentage of the returns on the less valuable species. It is simply uneconomic to retain any fish which does not have an assured market demand and ready sale.

are needed for the preservation and storage of the prawn catch and some of the less valuable by-catch species (such as cuttlefish) that are retained at other times are discarded.

Trawlers with only dry refrigeration facilities (freezers) often discard sand crabs even though they are a valuable product, because frozen crabs are brittle and do not handle well when frozen. Vessels with brine or ice refrigeration normally retain legal sized sand crabs and sand crabs are one of the most common and valuable by-catch in eastern Australia.

Trawlers operating from near major markets of Sydney or Brisbane have a large market demand for many varieties of fish and shellfish and lower transport costs and they can profitably retain many more of the by-catch species taken in their trawls, as indicated in the following sections.

4.1 Queensland

The scientific literature and interviews with fishermen and seafood buyers indicate that very few species, about 10% of fish, in the by-catch of trawlers working in Queensland waters are retained, most species and individuals are just dropped overboard. Furthermore the weight of by-catch landed for sale is normally small, although whiting landings from Moreton Bay are reported as large at times (Morton 1993) as noted below

Company owned trawler operators enjoy some economies of scale in fish handling and marketing costs and are encouraged by the managers to carefully handle marketable by-catch species. The great advantage they have is that they can pool the different varieties of by-catch from their fleet landings and build up a sizeable parcel of each for sale.

Consequently they commonly land a far greater variety and volume than the independent operators who often have smaller vessels and poorer facilities for handling and storing by-catch.

As noted in section 3.1 the grinners and pony fishes make up a large percentage of the by-catch weight in northern Australia but the low market value of these species, especially for small individuals, means that very few fish are landed and sold. The principal commercial fish species such as barramundi, coral trout, bream, cods etc have a minimum legal length and this restricts their landings too.

The catch statistics managed by the QDPI provide some quantitative information on the tonnage of various species which are essentially a trawl caught product. These include bugs, squid, cuttlefish, and octopus.

These species are generally just quickly sorted, and landed fresh or frozen in the whole form and are not processed in any way. Squid is now such a valuable commodity that the catch on the larger trawlers is often graded into small, medium and large.

Trawler landings of these species from eastern Queensland are given in table 10, below.

Table 10 Estimated E. Qld. catch of selected species
(From provisional 1993 catch records, QDPI)

Category	Catch (tonnes)
Catfish	7
Red mullet	0
Squid	1094
Cuttlefish	6
Octopus	9
Bugs	385
Coral prawn	43
Mantis shrimp	0

For species such as sand crabs, trawler catches probably represent about 40% of the annual landings of about 450 tonnes and Moreton Bay catches represent about 72% or 130 tonnes of these trawl caught crabs, according to an unpublished QFMA report of 1992.

Trawlers are also responsible for substantial landings of winter (diver) whiting from Moreton Bay and there are reports of landings of 100 kg per night according to a recent report by Morton (1993). The actual landings of the several marketable whiting species are in doubt because of confusion regarding fish identity and in the classification of fishermens returns, according to Morton.

The situation regarding landings of the majority of marketable by-catch species however is unclear because the discarding and marketing practices vary so much from vessel to vessel and change with time.

Pender et al (1992) reported that bugs were retained by 100% of NPF trawlers, while only 70% retained squid, 40% retained scallops and less than 40% retained octopus and cuttlefish in the late 1980's but industry observers report that these species are now regularly landed for sale by almost all vessels.

Species of fish which are referred to as 1 st quality by fishermen and buyers and are commonly retained include:

Barramundi
Coral trout
Greasy cod,
Mangrove jack,
Red emperor
Reef cod
Snapper
Spanish mackerel

fish of about 400 gm or larger are usually bled, gilled and gutted and snap frozen head on in standard trawler cartons, but sometimes fillets are produced (scaled and left skin on) and packed from the larger fish. Very large fish such as jewfish, mackerel and tuna are often packed in hessian or plastic sacks.

Other species such as:

Black jew
Salmon
Trevally
Doggie, Spotted or Indian mackerel

are less valuable and referred to as second quality fish and are simply packed and frozen. There are reliable reports from fishermen of occasional landings of 500 kg or more of schooling fish species such as jewfish or mangrove jacks.

Sharks and Sea Dragons

Some noteworthy by-catch are sharks and sea dragons (pipe fish) because of the very keen demand for these export products, as indicated by the regular advertisements by prospective buyers in the Australian trade press. Fishermen are selling small lots, of several kilos, of sea dragons and total landings are estimated at about 1-2 tonnes per year.

Although prices as high as $80 per kilo are a strong incentive for fishermen to retain these fish (and sea horses) and increase landings, there is a general feeling amongst fishermen that the resource is probably heavily fished and unlikely to yield more fish.

Sharks have long been a valuable fish but the demand for sharks has risen in the past year as the interest in these fish extended from flesh and fins to livers and skeleton cartilage ("backbone"). The consumption of this cartilage has reportedly a beneficial medicinal effect on people suffering from some forms of cancer and stimulated demand for shark.

Although there is increasing interest from processors wishing to make more use of sharks as flesh, skins, teeth, jaws, fins, liver, oil and backbone cartilage there is an equal concern amongst fishermen that the resource is heavily fished, and perhaps abused, when large fish are deprived of their fins and jaws and then dumped over the side.

Another novel use of marine animals has been the tanning of fish (and snake) skins to make leather for decorative items. One skin trader estimates that total (wet) skin demand could be about 5-10 tonnes per annum, principally barramundi, shark and red emperor, but he suggests that other species with large scales can be also utilised.

Minor Prawn Species

The catch statistics derived from fishermens log book records also show that more than 40 tonnes of coral prawn were landed in 1993 from 112 Queensland east coast trawlers, only about one fifth of the fleet. These prawns are a by-catch species, with a smaller size and harder shell and a lower price than the target prawn species.

These species are often overlooked in that they are not landed by many vessels and not always carefully handled on board and consequently represents by-catch species with potential for greater utilisation in terms of volume and value.

4. 2 New South Wales

It is evident from the variety of fish and shellfish sold in the Sydney Fish Market that many by-catch species are marketable if the fish or shellfish have attained a certain size. The species lists in Graham et al (1993 a Appendix 3) indicate that commercial species represent approximately 30% of the fish species recorded in their oceanic surveys.

The retention and sale or the discarding of various species/individuals is determined by many factors as outlined earlier, and controlled by various fishery regulations.

NSW trawler operators are prohibited from selling any individuals of species of fish which have a prescribed minimum length if they are taken in estuaries or at sea south of Smoky Cape. Other species and the oceanic area north of Smoky Cape do not have such restrictions.

The species with size limits and trawler fishing restrictions are:

blackfish
bream
flathead
kingfish
mullet, sea
mulloway (jewfish)
school shark
snapper
tailor
tarwhine
teraglin
whiting, sand

Many of the remaining fish species have some market value and are often sold. These species are commonly trumpeter whiting, red spot whiting, stout whiting, red mullet, flounders, leather jackets and shark species and bugs, crabs, octopus, cuttlefish, squids and some shells are also retained.

Graham et al (1993 b) found that the volume of "commercial" species overall is substantially less than the volume of "trash" fish on the NSW north coast prawn trawling grounds.

Although some NSW by-catch from northern NSW is sold locally the majority is forwarded to the Sydney Fish Market for sale and the NSW Fish Marketing Authority (FMA) statistics provide the best data set on by-catch sales from NSW fisheries.

Table 11 shows the volume and average price of selected fish and crustaceans sold in 1991-92 by the FMA. The species I have selected for inclusion in this table are those which can be regarded essentially as by-catch species, with most of the volume coming from trawlers.

It should be noted that the importance of by-catch is far greater than that indicated by the data in this table because many by-catch species are put into one fish box simply labelled and sold as "Mixed" (and some has been sold locally).

A species of particular interest in Table 11 is the octopus which is invariably a by-catch species and one which has enjoyed strong growth in volume and price over the past decade as discussed in chapter 6.

The Clarence River and the Coffs Harbor Cooperative's are the largest suppliers of octopus to the FMA and the Clarence Cooperative is also the largest supplier of red mullet to the market (unpublished data). The by-catch now represents a large part of the earnings for prawn trawlers working offshore from these ports and on many occasions the weight of by-catch landed exceeds that of prawns.

In Sydney because of the large demand for seafood of all sorts small prawn trawlers working in Botany Bay or Port Jackson regularly land a variety of fish and shellfish which far outweighs their prawns.

The Botany Bay trawlers with their regular landing and sale of ton shells (*Tonna sp)* , mantis shrimp, catfish, trumpeter whiting, octopus, squid, cuttlefish, blue swimmer crabs and other species probably utilise more of their total catch, in terms of variety and volume than any other Australian trawl fishery.

Table 11. Sydney Fish Market sales volumes and prices 1991/92 year (extracted from NSW Fish Marketing Authority Report 1992).

Species	Tonnes	$/kg
Barbounia (red mullet)	41.98	3.05
Catfish tails	21.86	3.13
Cuttlefish	171.00	1.36
Flounder	25.37	1.93
Jackets/Rough/Mixed	58.98	1.62
Moonfish	4.28	4.79
Ribbonfish	46.48	0.67
Whiting/Red spot	315.03	1.40
Whiting/Trumpeter	32.61	2.36
Shark/Angel	192.47	2.62
Shark/Banjo	13.22	1.22
Shark/Carpet	81.10	2.98
Shark/Dog	72.84	2.97
Shark/Green eye	120.27	1.79
Shark/Gummy	14.90	3.37
Shark/Snapper	3.19	4.01
Shark/Other	201.49	2.82
Stingray & Skate flaps	45.98	1.03
Bugs/Green	34.26	7.78
Bugs/cooked	19.83	7.25
Octopus	489.38	2.89
Shells	8.49	2.54
Squid/bottle	4.79	2.61
Squid/other	269.12	1.83

5. PROCESSING BY PRODUCTS and WASTE

Most of the seafood processors in eastern Australia have small scale processing plants undertaking some elementary form of processing, usually filleting fish, peeling/boiling crustacea and freezing and packing such products. Few companies carry out any elaborate transformation of the raw materials and consequently there are few highly processed seafood products or by products manufactured.

The major waste product of seafood processing is fish frames and trimmings from fish gutting, filleting or canning operations and the common waste utililisation strategy is to find the least costly method of disposal; in Queensland scallop shell is the dominant waste.

Only a few companies manage to derive any profit from the waste from their processing operations, some simply dispose of it down the drain while most pay to have waste removed from their premises.

5.1 Queensland

Queensland has a long coastline yielding a vast array of fish, crustacea, molluscs and other animals and the seafood processing industry consists of a small number of specialists working principally with one species and a large number of general or opportunistic companies processing whatever seafood is plentiful.

The processing industry is concentrated on the east coast and the factories in the Gulf of Carpentaria and Torres Strait essentially only pack and freeze seafood for sale or processing elsewhere.

The east coast processors based from the Gold Coast through to far north Queensland include about 20 specialists concentrating mainly on scallops, prawns or mullet and exotic items such as shark fins and sea dragons while another 30 or so plants receive and clean/fillet several fish species such as reef fish and mullet, tailor, whiting, pack or freeze squid, cook and /or peel prawns, bugs and crabs.

Despite the biological diversity of raw material and the relatively large number of processors in Queensland most activity revolves around

preserving or transforming the seafood rather than any elaborate manufacturing process and there is little in the way of by products. The notable exceptions are fish meal and oil, mullet gizzard, shark fins and fish skins, and recently shark "backbone".

Mullet roe was once a by product of mullet filleting but for some companies the roe is the principal product manufactured and the fillets (and gizzard) are the by products

5.11 Southern Queensland

There are approximately a dozen companies in the area between the Gold Coast and Brisbane's northern suburbs which process a variety of seafoods or essentially specialise in mullet or prawns. There are also two specialist seafood companies located in far northern NSW which source much of their mullet and prawns in Queensland and their activities will be discussed here too.

Four companies in the northern NSW-southern Queensland area interviewed reported that mullet processing was a major activity of the enterprise between May and August, these four companies account for the bulk of the mullet catch that goes to the processing sector. Mullet processing is essentially concentrated in the winter months following the spawning migration of fish up the east coast.

The primary activity is the extraction packing and freezing of mullet roe and milt (from the females and males respectively) for export; the gizzard, representing about 1% of the fishes weight, is a relatively new by product extracted from the digestive system and frozen in 1 kg bags.

The gutted female fish are also filleted or sometimes on-sold to another company; male mullet are frozen and exported whole or filleted for domestic sale too. The four companies' aggregate production of mullet frames was reported as 700 tonnes for 1993.

Of this :

some 20 tonne of heads was packed as crab bait

some 80 tonne of heads was packed and sold interstate as crayfish bait

and almost 600 tonne of frames was dumped, with the exception of small volumes of gut sold as bait.

The aggregate production of mullet waste from Queensland could not be estimated with any precision because companies do not have detailed records of processing for males/females as whole or fillets etc and because of the unknown flow of mullet from NSW fishermen to Queensland processors and from Queensland to NSW processors but it would appear to have been less than 1000 tonnes.

Five of the six companies in this southern region which reported prawns as one of their major activities (heading and peeling) had small volumes of waste, less than 50 tonnes per annum, and the aggregate of the six was estimated at approximately 400 tonnes for 1993. I estimate total production of prawn waste for the state at about 630 tonnes.

It should be noted that prawn processing activity in Queensland in 1993 was carried out for much of the year, with material from the east coast and the Gulf, and was substantially greater than in the past few years because of strong overseas demand, and may not be repeated in the coming few years according to industry operatives.

Fish processing in southern Queensland, excluding mullet, is generally small scale and covers a variety of species, as noted earlier. A species of interest here is winter whiting, a by-catch of trawler operations; only small tonnages are destined for factory filleting and the total waste produced from these fish is of the order of a hundred tonnes.

Most of the (mixed) fish waste produced by processors in southern Queensland in 1993 - about a thousand tonnes - ended up at a tip, and about a hundred tonnes was reportedly " minced and sent down the drain". Processors reported a wide range of dumping costs from zero to $47 per tonne; at an average of about $10 per tonne the dumping charges add up to about $10000.

Several processors reported that they have in the past been able to give away their waste to a rendering company which converts it to fish meal;

the rendering company has closed this plant while it is building a new plant and will again be taking fish waste from processors at the end of this year.

A large seafood processing business in the Brisbane area and utilising a variety of Queensland and interstate seafood converts its fish waste into a liquid emulsion (silage) in a custom built plant- producing several hundred tonnes in 1993.

5.12 Hervey Bay - Yeppoon Area

There are 15 processing companies in the area from Hervey Bay to Yeppoon which shuck scallops as a principal activity; most volume comes in from November to February-March and another harvest is usual in winter-spring after spawning. Five of the larger producers were interviewed and their estimated meat production and waste disposal (in tonnes) are summarised below in Table 12. (Production of half shell product is very low volume).

Table 12. Estimates of scallop processing and waste production, 1993

Company	Meat(t)	Shell(t)*	"Gut" (t)	
A	75	225 stockpiled	75	dumped
B	90	270	90	all dumped at sea
C	100	300	100	all dumped at sea
D	120	360 stockpiled	120	dumped
E	400	1200	400	all dumped at sea
TOTAL	785	2355	785	

*Industry observers advised that that gut weight is almost equal to that of the meat and that shell weight is approximately three times meat weight.

The so called "gut" consists of the mantle (frill), the digestive system and the reproductory organs of the scallop. The author has eaten, with pleasure, a Japanese shelf-stable packaged snack food made from scallop mantle marinated in soy and honey.

Scallop shell is being stockpiled by several companies in the hope that a market will be developed for scallop shell in the near future. There has been considerable interest in the Hervey Bay-Bundaberg area for many years in the development of a manufacturing plant to macerate or powder the scallop shell for calcium production for industrial use.

A new company is indeed developing a processing plant in this area to convert scallop shell to fine calcium powder and is scheduled to commence operations "after Easter". It is being built to handle an input of up to 6000 tonnes per year and it is clear from the table above that there is a large supply of raw material in this area.

The aggregate production of scallop meat for Queensland for 1993 will probably exceed 1250 tonnes according to information available at the time of writing hence the total weight of scallop "gut" and shell will exceed 5000 tonnes, representing the greatest single item of seafood waste in Queensland and probably for eastern Australia as a whole.

In a good year, with a scallop production of 1500 tonnes of **meat** there is approximately 4500 tonnes of shell available. However the volume of scallop shell is dependent on the form of the major product manufactured; a move to more scallop sold on the **"half shell"** would mean a corresponding reduction in the volume of shell waste.

These central Queensland companies also process other seafoods (fish filleting and bug/prawn peeling) but volumes are small and the largest aggregate waste production other than scallops was 100 tonnes per annum from a company which ploughed it into nearby paddocks.

One company in the area also produces an unusual array of seafood and by products: dried beche de mer, shark fins and sea dragons. The tonnage of these items is very small : approximately ten, five and far less than one tonne respectively, of raw material in 1993. It has produced a small volume of shark "backbone" and liver oil by a simple sun drying method and is exploring the feasibility of tanning fish skins and producing other decorative items from marine animals.

The company is hoping to expand its production of shark fins, cartilage and oil in 1984 but reports that it is experiencing difficulty in locating fishermen who are willing to provide raw material at reasonable prices while it is developing expertise and markets for these products.

A second seafood processing company in this area is also undertaking trials on a shark backbone product for export to Asia and has plans to process shark flesh, fins, oil and backbone in 1994.

5.13 North Queensland

The area between Townsville and Cairns is home to a half a dozen regularly active seafood processing or trading companies including three prawn processors and an exotic skin marketing company.

The skin buyer reports that while there is vast superficial interest in exotic skins, including fish skins, for decorative use (bags, shoes, wallets and belts) the demand is very small and narrow. The recession has effectively put this business " on the back burner for now" but the principal is hopeful for the future.

The prawn processors buy prawns from the east coast, Torres Strait and the Gulf of Carpentaria and sell them in the whole form and convert some, usually the soft and broken to meat, and some to cutlets; the actual product flow depends on market demand and has been variable in the last few years.

Processing activity is small and waste output of crustacean heads and tail shell is less than 50 tonnes per year for all but one plant, in Cairns, which has an estimated total waste of about 100 tonnes. Waste is disposed of locally, dumped at little or no charge but attempts are made to give it away for bait and burley; one of the smaller companies reported its waste disposal cost as $6.50 per week.

The small general processors report waste production of far less than 50 tonnes per annum (aggregate of fish and crustacean material) and dispose of this by giving it away for bait or burley or in industrial waste bins at very little cost.

5.2 New South Wales

The seafood processing industry in NSW is characterised by the heterogeneity of the business entities and their processing activities and the absence of any dominant product. The enterprises range from public companies to small family businesses and the processing activities include the simple fish filleting or prawn cooking(boiling) operations, fish smoking as well as canning and the elaborate manufacturing of surimi products.

Overall there is relatively little in the way of elaborate seafood processing in the state other than a handful of companies involved in the manufacture of canned, breaded or surimi products. Most processing enterprises, more than two thirds (including the fishermens cooperatives) are simply engaged in fish cleaning or filleting and the packing of the resultant seafood product.

With the notable exception of a fish cannery and the northern NSW company producing mullet roe noted earlier (chapter 5.1) by products manufacturing is essentially non existent because most manufacturing companies produce several primary products (often with imported processed raw material) and end up with fish waste material which they then seek to dispose of in the most cost effective manner.

Consequently the outstanding seafood waste produced in NSW is fish frames (including heads and guts) and trimmings. There are only three regions or centres of activities where substantial volumes are generated, these are Sydney, Wollongong and Eden on the south coast.

In other areas the few companies in the district produce small amounts of waste, averaging less than a tonne per week, which they dispose of cheaply, at municipal tips, or by giving it away for bait/burley to commercial or recreational fishermen or through disposal in the adjacent waterway.

5.21 Sydney

Because of the large volumes of fish coming to Sydney, predominantly from the South East Trawl, and the growing demand for skinless boneless fillets several thousand tonnes of fish frames and trimmings are produced in the greater Sydney area each year. Most of this fish waste is produced at the Sydney Fish Market at Pyrmont where many businesses clean and fillet their fish.

Three companies process large volumes of seafood in Sydney, one manufacturing surimi based products from domestically caught fish, and each generate more than three tonnes of waste per week on average. The combined output of these companies was about 1300 tonnes of fish heads, guts backbones, skin and trimmings (small volumes of prawn heads etc are sometimes in the waste too) last year.

The seafood waste from these three companies and that from the Sydney Fish Market are picked up daily by truck by a rendering company which renders this and other animal wastes into meal and oil at its plant on the outskirts of Sydney. This rendering company took in approximately 2800 tonnes of seafood waste in 1993 (producing about 560 tonnes of meal) and is happy to receive more provided it can pick up and transport it cheaply; it does not pay for the fish waste.

Other small scale processors in Sydney, and fish merchants, (producing a tonne or less of waste per week) have their waste removed, usually at some varying cost (nil to $200 per month), by a local waste disposal company. There are probably about 15 such firms producing about a tonne of fish waste per week in the Sydney suburbs.

5.22 Wollongong

There are four small scale businesses undertaking simple processing activities and one company producing a range of seafood products in the Wollongong area: fillets, prawn meat and breaded squid products. The small businesses dispose of almost all of their waste - mostly fish frames and occasionally prawn heads and shells- through the local waste pick up services; a very small part is given away as bait /burley.

This one large dedicated seafood processing factory in the area, produces anything from one to fifty tonnes of waste per week, mostly fish frames but with substantial tonnage of prawn waste at times; in total several hundred tonnes of fish waste and some 50 tonnes of prawn heads and shells last year.

It disposes of fish waste by burial on farm land outside the city and takes prawn waste to the local tip. This company's fish intake and waste production is likely to fall in 1994 in line with the reduction in Total Allowable Catch for orange roughy.

5.22 Eden

This small seaside town, with a large fishing fleet operating in the South East Trawl, has one fish cannery and three small enterprises which often clean and fillet fish and occasionally undertake other seafood processing operations such as scallop shucking. The fish waste from the three fish processors is given (free) to the cannery which converts this as well as its own waste into meal and oil.

The combined throughput of the fish meal plant was some 3000 tonnes of raw material last year (producing about 600 tonnes of meal); mostly its own trimmings from the tuna and Australian salmon cannery line, with some fish imported.

The company can utilise greater tonnage of fish waste for meal manufacture but fish meal manufacturing is reportedly not a particularly profitable business and it is currently engaged in Research & Development aimed at increasing the value of it fish trimmings/ meal and oil.

One of the fishing-processing companies in Eden last year collected and sold several tonnes of shark livers to an interstate company which converted these to oil. This activity also is reportedly only marginally profitable, because of the low oil content of the local shark, and may not develop any further.

6. DISCUSSION and RECOMMENDATIONS

6.1 By-catch availability and utilisation

There is ample evidence of a vast volume and variety of by-catch in the Queensland and NSW trawl fisheries. From the information reviewed in chapter 3 we can derive a crude estimate of the total by-catch available in a year simply by adding up the estimates for the different fishing areas shown in table 13.

Assuming a by-catch to prawn ratio of 5: 1 for the prawn fisheries along the NSW and eastern Queensland coast we could extrapolate and estimate total by-catch for NSW and Queensland at more than 80000 tonnes. A higher ratio would yield even larger by-catch estimates.

As noted earlier different methodologies were used by different research groups and each estimate varies in its standard error or reliability. Harris and Poiner (1990) for example estimated the by-catch in Torres Strait in 1986 as 4630 tonnes with a standard error of $\pm$ 730 tonnes.

Therefore an aggregate estimate for the NSW and Queensland prawn fisheries would be a very crude one and should be used cautiously.

It should also be noted that some of these estimates are based on fishing practices of the late 1980's. Fish stocks vary in abundance from year to year and fishing effort in many fisheries is now a little lower, [vessel numbers halved in the Gulf of Carpentaria (Pender et al 1992)] and by-catch retention rates are now undoubtedly higher.

Furthermore the by-catch tonnages are those recorded during targeted fishing operations within a prescribed fishing season hence all year round fishing would presumably produce greater tonnages. But greater fishing effort and retention of by-catch species would probably bring about a gradual reduction in the catches (Harris and Poiner 1991, Graham et al 1993) and therefore the by-catch estimates in Table 13 should only be considered as a first guide to abundance or availability.

As indicated earlier the availability of by-catch for commercial purposes is dependent on biological productivity, fishing effort and fisheries regulations.

Table 13 By-catch Estimates for Queensland and New South Wales trawl fisheries

Area	Estimate (t)	Year	Source or basis of estimate
Torres Strait	5800	1985 & 86	Harris & Poiner 1990
Gulf of Carpent	30000+	1988	Extrapolated from Pender et al 1992
E Qld oceanic	32000	current	based on a 5:1 by-catch to current prawn catch
Moreton Bay	3000	current	based on a 6:1 by-catch to current prawn catch Stephenson et al 82, Wassenberg & Hill 1989
NSW estuaries	500	1991 +	Kennelly 1993
NSW oceanic prawn grounds	7500	1992 +	Kennelly 1993 and 5:1 by-catch to prawn

A detailed analysis of original research reports is needed in order to extract meaningful information on a particular species because of the influence of research methodology and biological factors on the abundance estimates. For some fisheries there is little or no information publicly available; the necessary information has not been analysed or remains in the original field or computer files of the researcher.

The data presented in almost all published reports is certainly not sufficient for an assessment of monthly or seasonal changes in by-catch and one would need to examine the original database for such information particularly for that on a particular species or group. These problem are discussed below in section 6.3.

Industry and research people estimate the percentage of by-catch retained at less than 10%, principally because many fish are too small for current commercial uses, and given that the greatest volume of by-catch was recorded in northern Australia where discard rate is highest the national average is probably less than 5%. This is far lower than the world average of 50 % (Andrew and Pepperell 1992) and a long way from the Indian situation where 99% of the catch from prawn trawlers is utilized (Gulland and Rothschild 1984).

However there are a number of estuarine and coastal prawn fisheries in NSW where much of the by-catch is indeed retained and contributes substantially to the fishermen's earnings.

In Botany Bay, the weight of by-catch sold this 1993-4 season has exceeded the prawn catch while the by-catch of prawn trawlers working offshore from the Clarence and Coffs Harbor ports - principally octopus, squid and red mullet - often exceeds their prawn landings.

6.11 Greater utilisation of the By-Catch

Increased retention of by-catch, in much of eastern Australia, is fraught with sociopolitical problems because of the existing conflict over resource use amongst different fishing groups and others who compete for the fish stock or use of the aquatic environment. Indeed there is considerable research being undertaken in Australia with the objective of reducing the by-catch in prawn trawls.

In Queensland, a recent government enquiry has been followed up with a new Fisheries Bill which seeks to restrict further the landings of by-catch from trawlers.

Moreton Bay prawn trawlers now land many species from their by-catch, and by-catch is a critical part of their regular income, and they are accused of targeting whiting or crabs at times. The large numbers of sand crabs and whiting in the by-catch from Moreton Bay has become a major problem area for the Queensland fishing industry (see Morton 1993).

Most trawlers operating from ports in NSW and eastern Queensland commonly land all by-catch which has any market value and there is difficulty in defining what constitutes by-catch for the fish trawlers working south of Sydney given that this area has long been a mixed species fishery landing more than 20 species for market.

Catfish represent by-catch species on the east coast (and northern Australian waters) which can and should be singled out for greater utilisation. They are not favoured angling species, attract no affection from any ecological or environmental group but it are highly regarded as food fish by many Asians (see below) and still capable of yielding greater volumes from estuarine and inshore waters for the markets.

Fishermen and buyers in eastern and northern Australia should collaborate and work more closely in order to get more of these fish species to the consumers who are willing to pay for these fish.

Other by-catch species in eastern Australia seen as capable of increased landings without generating complaints and conflict are the various coral and hardback prawns and minor crab species (*Portunus* and *Charybdis*) taken off the NSW and Queensland coast.

Despite the absence of detailed information on these species there may be an opportunity for the establishment of new businesses which specialise in the handling and/or processing of selected by-catch such as these minor crustacean species and "exotic" fish such as catfish.

The minor crustacean species and catfish are regarded by the author as having the greatest potential for increased utilisation and therefore deserving the highest priority for attention by industry and

governments wishing to maximise the economic returns from the fish resources in eastern Queensland and NSW.

Table 14 shows the authors assessment of the opportunity or potential for increased utilisation of the various seafood groups in NSW and eastern Queensland. This assessment is based on relative abundance, current utilisation status and likely demand. Thus species such as squid and bugs are listed as having the lowest potential for increased returns simply because they are essentially fully utilized in these regions.

The evolution from trash to a valuable by-catch species seems to have taken about 10 years for species such as bugs and squid but it can occur in a far shorter time.

Small octopus became a popular food over a period of about five years in the late 1980's in Sydney after they were featured on the menus of trendy restaurants and then in the food columns of newspapers and magazines. Sydney Fish market annual reports show that 223 tonnes were sold in 1984/5 at an average price of $2.05 per kilo while in 1989/90 with a supply of 466 tonnes the average price had risen to a remarkable $4.05.

Catfish are experiencing a similar dramatic increase in supply and average prices in Sydney, as a result of the influx of Indochinese refugees and immigrants in NSW. These "new Australians" are also responsible for growing imports of pomfrets from southeast Asia and the strong demand for local black pomfret, formerly a discarded trash fish in northern Australia.

There are still unutilized or underutilized fish in the northern waters of eastern Queensland but these are also found in Torres Strait and the Gulf of Carpentaria where the larger vessels are generally better equipped to handle by-catch. Therefore the Gulf is seen by the author as offering the greatest potential for increased returns from Australian by-catch, as discussed below.

Table 14 Eastern Queensland and NSW by-catch sold and priority/ opportunity for greater utilisation

(Tonnage extrapolated from provisional Qld logbook data and 1992 FMA data)

Locality	By catch	Tonnes sold 1993	Priority/ Opportunity
Eastern Queensland	Squid	1200	C
	Bugs	400	C
	Coral prawn	45	A
	Octopus	10	B
	Catfish	8	A
	Cuttlefish	6	B
	Minor crab species	5 *	A
New South Wales	Octopus	500	C
	Squid	300	C
	Whiting, red spot	300	B
	Cuttlefish	200	C
	Bugs	60	C
	Leather jackets	60	C
	Rays	50	B
	Goatfish (Red mullet)	50	C
	Whiting trumpeter	32	C
	Catfish	25	A
	Shells	10	C
	Minor prawn species	5*	A
	Minor crab species	5 *	A
Fishing Season and Unloading Points	Ocean waters catch is high late summer to autumn; estuaries worked December to April or May	Moreton Bay & Hervey Bay are major landing areas for eastern Qld fleet	Iluka-Yamba Newcastle and Sydney are major areas for NSW

*Authors estimates

Potential in the Gulf of Carpentaria

The greatest potential for increased utilisation of the by-catch lies in northern Australia, particularly the Gulf of Carpentaria, where (its remoteness and high transport costs notwithstanding) there is variety and volume in the by-catch. It should be remembered that the by-catch estimates shown earlier in table 13 are based on the recent prawn seasons of about seven months duration.

The Gulf of Carpentaria has the advantage that it does not have the resource conflicts that are common to the east coast fisheries and it has sunshine and open spaces which lend themselves to low cost fish drying operations (which would not be welcomed in most areas on the east coast).

The future here may lie in a return to the past, and old technology such as sun drying, and not necessarily new products and new technology. The high electricity, water and transport costs in these remote areas rule out the prospects of surimi, fish meal or silage manufacture for the foreseeable future according to industry operatives.

Table 15, reproduced directly from Pender et al 1992, clearly shows the potential from the Northern Prawn Fishery study area (As noted earlier, data on Penders NPF study area essentially represents the Gulf of Carpentaria)

The several species of grinners, threadfin bream and red mullet are present in very large volumes but like most by-catch they are only small individuals -- average weight of 70, 37, and 36 grams respectively, according to Pender-- which currently have a very low market value as table fish.

However each of these fish groups has one species which makes up more than half of the group's catch therefore larger individuals can be selected from the catch and retained for sale. The pony fishes are popular amongst Asians, as fresh or dry product, and also abundant in the north and capable of solar drying and ordinary (non refrigerated) road transport to southern cities.

Table 15 **Species composition, and estimated catch (t) of potential commercial categories of bycatch.** The estimated catch is for the study area during the 1988 mixed species fishery.

Commercial Category	Species	Catch (t)
shark	*Carcharhinus dussumieri, C.sorrah, C.tilstoni, Rhizoprionodon acutus, Hemipristis elongatus*	230
eel	*Muraenesox cinereus*	460
bony bream	*Anadontostoma chacunda*	110
sardine	*Dussumieria elopsoides, Sardinella albella*	<10
herring	*Pellona ditchela*	230
wolf-herring	*Chirocentrus dorab*	40
grinner	*Saurida micropectoralis, S.undosquamis, S.sp.2*	3650
Bombay duck	*Harpadon translucens*	<10
fork-tail catfish	*Arius thalassinus*	560
eel-tail catfish	*Euristhmus lepturus*	170
flathead	*Cymbacephalus nematophthalmus, Platycephalus endrachtensis P.indicus, Suggrundus macracanthus*	210
cod	*Epinephelus areolatus, E.quoyanus, E.coioides*	100
six-banded cod	*Epinephelus sexfasciatus*	110
big-eye	*Priacanthus tayenus*	190
whiting	*Sillago* spp.	130
black kingfish	*Rachycentron canadus*	10
trevally	*Absalom radiatus, Alectis indicus, Alepes* sp., *Alute mate, Carangoides chrysophrys, C.hedlandensis, C.humerosus, C.malabaricus, C.talamparoides, Caranx bucculentus, C.para, Gnathanodon speciosus, Seriolina nigrofasciata, Ulua aurochs, Uraspis uraspis, Lactarius lactarius*	1090
scad	*Decapterus russellii, Megalaspis cordyla, Scomberoides tol, Selar boops, S.crumenophthalmus, S.leptolepis*	550
black pomfret	*Apolectus niger*	20
snapper	*Lutjanus carponotatus, L.erythropterus, L.lutjanus, L.malabaricus, L.russelli, L.sebae, L.vittus*	240
threadfin bream	*Nemipterus furcosus, N.hexodon, N.marginatus, N.nematopus N.peronii, Pentapodus porosus, Scolopsis taeniopterus, S.vosmeri*	2790
painted sweetlip	*Diagramma pictum*	<10
javelin-fish	*Pomadasys kaakan, P.maculatum*	250
emperor	*Lethrinus lentjan, L.nematacanthus*	20
croaker	*Argyrosomus* sp.,*Johnius amblycephalus, J.coitor,J.vogleri Nibea* sp.,*Otolithes ruber*	160
goatfish	*Parupeneus pleurospilus, Upeneus asymmetricus, U.bensasi U.luzonius, U.moluccensis, U.sulphureus,U.sundaicus,U.*sp.2	1240
mullet	species?	40
barracuda	*Sphyraena barracuda, S.forsteri, S.obtusata*	120
threadfin salmon	*Polydactylus multiradiatus*	200
tuskfish	*Choerodon cephalotes, C.monostigma, Xiphocheilus typus*	<10
hairtail	*Trichiurus lepturus*	20
Indian mackerel	*Rastrelliger kanagurta*	100
school mackerel	*Scomberomorus queenslandicus*	38
butterfish	*Psenopsis humerosa*	<10
halibut	*Psettodes erumei*	290
flatfish	*Arnoglossus waitei, Engyprosopon grandisquama, Grammatobothus polyophthalmus, Pseudorhombus argus P.arsius, P.elevatus, P.diplospilus, P.spinosus Psettina gigantea,* Pleuronectidae, *Aseraggodes* sp. *Pardachirus pavoninus, Zebrias quagga, Cynoglossus* sp. *Paraplagusia bilineata, P. guttata*	250
tufted sole	*Dexillichthys muelleri*	20
octopus	species?	60
cuttlefish	Sepiidae	140
squid	*Loligo* spp.	530
scallop	*Amusium pleuronectes*	410
prawn killer	*Squilla* spp.	85
bug	*Thenus orientalis*	150
swimmer crab	*Portunus pelagicus, P.sanguinolentus, Charybdis cruciata*	250
TOTAL	all categories	15300

Not shown on this table is the Rhyncobatidae (shovel nose rays) for which the catch estimate was 1864 tonnes. Pender et al omitted this family from the table because they did not consider that these fish had any commercial potential at the time (1998-1991).

The wings or "skate flaps" from such boneless fish are edible and the fish have significant value today, given that they are easily cut up and packed and the fins and stomach bags have commercial value too according to Pender et al (1992).

Table 16 show the estimated by-catch from the Gulf of Carpentaria and the Torres Strait and the author's assessment of the potential or opportunity for greater utilisation of the various seafood groups.

The red mullet (goatfishes) and the shovel nose rays appear to have the greatest potential and are accorded the highest priority for increased industry attention by virtue of their abundance and existing market demand domestically, and overseas too for the goatfishes.

The grinners, threadfin breams and the bullseyes represent a second priority level for attention by industry. They are also relative abundant and these are known to Asians in Australia and elsewhere but their likely market demand and value is assessed to be lower.

The other groups shown in Table 16 are assessed as having the least potential for increased utilisation for a variety of reasons. This ranking of potential is necessarily very subjective in the absence of detailed information on the size composition of the fish in the catch and hence their prospective market value.

The paucity of information on fish sizes also makes it difficult to indicate the most profitable market pack for these fish. Profitable sales of fresh fish from the northern prawn fishery to the eastern cities or overseas are unlikely to eventuate in the near future (because of transport costs) therefore some form of frozen pack is indicated.

A 10 kilo trawler carton packed with two 5 kg bags and plate frozen would appear to be a good starting point for market development or better market penetration but the most effective or efficient specifications need to be determined in conjunction with prospective buyers.

Table 16 Gulf of Carpentaria and Torres Strait by-catch availability and opportunity/priority for greater utilization.

Fish or shellfish family	Estimates of Abundance (t)		Priority/ Opportunity
	Gulf of Carpen*	Torres Strait#	
Grinners	3654	750	B
Threadfin bream	2788	850	B
Dollar (pony) fish	1892	75	C
Rays	1864	900	A
Trevallies	1596	150	C
Goatfish (red mullets)	1243	200	A
Leatherjackets	1137	475	C
Silver bellies (silv. biddy)	682	NK	C
Sardines and Herrings	559	NK	C
Fork tailed catfishes	557	NK	B
Javelin fishes	524	NK	C
Cardinal fishes	400	190	C
Flatheads	460	265	C
Pike eels	458	NK	C
Grunters (Trumpeters)	436	NK	C
Halibuts	293	NK	C
Tropical snappers	235	NK	C
Flounders	208	NK	C
Threadfin salmon	202	NK	C
Cods and Coral trouts	194	90	C
Big eyes (Red Bullseyes)	194	450	B
Eel tailed catfishes	164	60	B
Skates and Rays	NK	NK	A
Squid	530	NK	C
Scallop	410	NK	C
Bugs	150	NK	C
Cuttlefish	140	NK	C
Octopus	60	NK	C
Hardback & coral prawns	NK	NK	B
Fishing Season and Unloading Points	The NPF peak season is Apr-July	Vessels unload to mother ships, or Cairns or other home ports	

* Estimates for 1988 from Pender et al 1992

\# Average of 1985 and 1986 estimates from Harris and Poiner 1990

The 10 kilo trawler carton is inexpensive, widely available and accepted in the Australian trade but an overseas buyer may have a different demand and require a smaller sized or more sophisticated pack.

Some form of on-board value adding such as filleting of fish or heading/shelling of crustaceans, may be possible with the larger species or with the larger individuals but again these options too will need to be explored with prospective buyers in order to better meet customer needs.

Capitalising on this Potential in Northern Australia -- Better Industry Collaboration

Processors often cite seasonal shortages or inconsistent supply as a problem in market development while fishermen point to a weak market demand and prices and consequently there is something of an impasse on marketing some by-catch. This old problem may be overcome if buyers and fishermen concentrate on developing the market together for one or two selected groups of fish rather than many or all species at once.

The goatfishes or red mullet (Mullidae) lend themselves well for a market development exercise. These species are well known to the European consumers in Australia and overseas and are already established in the marketplace. Some small unknown volume of red mullet from northern Australia finds its way to southern markets but it is just another by-catch species in a plain carton and with no regular or continuous supply.

With a planned marketing program where fishermen and buyers get together preseason and make a commitment to focus on and handle more goatfish say --with better size grading and packaging, a bold northern Australia branding and a more reliable supply --it is likely that such by-catch can be promoted so that **market demand and prices increase for the benefit of all parties.**

This type of closer collaboration and cooperative effort (without any formal Cooperatives structure) between buyers and sellers may help to overcome the common problem of unreliable supply/lack of high volume material that is repeatedly noted in studies on fish processing

(ASTEC 1988, Hassall 1989) and the recent survey of value added fish and seafood processors by Yann Campbell Hoare and Wheeler (1993).

Some industry people are sceptical about the benefits of such marketing programs, and in order to gain industry commitment and support for such a proposal, it may be beneficial to first introduce the idea via an industry workshop.

The workshop could focus on the concept of total or greater utilisation of by-catch and examine selected species such as red mullet, or topics such as the opportunities for sun drying of seafood in northern Australia.

Furthermore a bioeconomic study of the by-catch in the Gulf, focussing on the total landings, volumes, size composition and market value of selected species/products such as the goatfish is required to provide up to date biological and economic data.

Such data could be used to stimulate interest in greater utilisation of by-catch and also act as the keystone for an industry workshop.

Information coming out of a bioeconomic study and workshop could be used to set up a marketing project team to plan a market development project for the goatfish or other selected group, or undertake any other project recommended by the workshop.

Recommendation

The FRDC and QCFO should consider funding a bioeconomic research program on Gulf of Carpentaria by -catch focussing on selected species, such as goatfish.

Assuming that such a study comes up with some positive findings, an industry workshop should be held to explore the opportunities for greater utilisation of by-catch.

6.2 By Products and Waste

Although there is a multitude of seafoods, curios and decorative items that can be produced from the variety of animals in Australian waters there are less than a dozen by products manufactured in eastern Australia, as shown in Table 17, below.

Table 17 Utilisation of Australian marine animals
(By products are marked in bold type)

Animal	Current or prospective products and by products
Barramundi	Fillets, **Skin** for leather
Baler shell	Flesh and shell
Bugs	Whole, tails, meat
Catfish	Tail flesh and **eggs** ; **skull** (crucifix) as curio
Jewfish	Flesh and swim **bladder**
Mantis shrimp	Cheliped (claw) used as jewellery or curio
Mullet	Whole, fillets, roe, milt, **gizzard**, surimi, gut as bait Heads and whole fish as cray or crab **bait** Frames for **meal** and **oil**, or **emulsion**
Prawns	Whole, tails, cutlets, meat, bait heads and shells as soup stock/flavouring
Scallops	Meat, half shell scallop; gut for crab bait **Shells** for Calcium powder
Sea dragon	Dried for aphrodisiac production
Shark	Trunk, fillet, **fins**, "**backbone**", **livers** and oil **Jaws and teeth** curios; **skin** for leather **Saw** off saw shark used as curio
Shovelnose ray	Flesh, **stomach bag** and fins
Squid	Whole, tubes, rings, bait
Ton shell	Flesh
Whiting	Whole, fillets, small fish as bait or animal feed

The small size and elementary nature of most seafood processing operations in Queensland and NSW are principally responsible for this situation but the corporate culture in these companies also plays a role, as discussed at the end of this section.

A typical industry comment, from a company mostly involved in prawn processing, follows:

> *We have looked at everything, prawn heads for flavouring or for restaurants, for chitin manufacture. The problem is our volumes are too small and we don't know what we will get next week or next year, so we give away a bit to restaurants and dump the rest"*

There is apparently no continuous supply or high volume raw material input for economy of scale in most plants to profitably develop by products, and the few recent developments noted have been in novel or decorative items rather than food.

Mullet represents the only species where there is a concentrated input of raw material in a well defined season (winter) but mullet landings vary markedly from year to year too. Queensland scallops represent the only raw material with substantial volume available for at least six months of the year but these are not consecutive months.

The small volumes of seafood waste and the lack of continuity of supply, coupled with poor markets, also are responsible for the lack of interest in silage manufacture in this country. One company which has a substantial waste volume reports that:

> *'There are lots of ways that you can get rid of waste theoretically but for us it's easier and cheaper to dump it"*

The most notable exception regarding by product manufacture is fish meal. It is manufactured by a cannery in southern NSW and in Sydney by a rendering plant obtaining its raw materials free from processors in the inner Sydney suburbs. In Brisbane a new rendering plant is being constructed to again process meal from fish waste.

Both the NSW, and the Queensland rendering company are prepared to take in more raw material from the fishing industry but because of the reported marginal (small) profit in meal manufacture in Australia -- due to strong competition in international markets --they are not able to pay for by-catch fish or fish processing waste. This means that fishermen cannot catch and sell fish for meal manufacturing in the immediate or near future.

However it may be possible to increase the volume of fish waste and trimmings in the local manufacture of fish meal, and at the same time reduce dumping costs, through the development of a fish waste collection system in Sydney to pool (aggregate) small volumes of waste.

If small scale processors and fish merchants could take their fish waste to one or more hub locations which can act as a pooling and pick up depot for the surrounding region the fish meal manufacturer may profitably be able to pick up such aggregations of waste.

Recommendation

> *The NSC and FRDC call for expression of interest in an economic study of the costs and benefits of establishing a seafood waste collection system for Sydney.*

Tables 18 and 19 summarise the by products manufacture and waste utilisation estimates for NSW and Queensland respectively in 1993 and the authors recommendations for priorities for industry and government attention.

Thus the fish frames currently dumped by small scale processors and the fish merchants in Sydney warrant the highest priority for attention in NSW while the scallop waste produced in Queensland is seen as offering the greatest potential and opportunity for industry in that state and deserving the highest priority for R and D, as discussed below.

Table 18. NSW By Products and Waste Utilisation 1993.
NSW -Qld border area processing activities are included in Table 19 with Queensland.
(Other sizable processing firms do not use Australian fish or do not have any by products)

Locality	By product	Volume (tonnes)	Availability	Facilities/Utilisation	Priority/ Opportunity
Sydney				Chill, freeze and boiling facilities available.One meal plant.	
Fish Market	Fish heads and frames	1500	Year round	Converted to meal	B
Fish Processors	Fish heads and frames	1300	Year round	Converted to meal	B
Small businesses	Fish heads and frames	750	Year round	Dumped	A
Wollongong				Chill, freeze, breading (one) and boiling facilities available	
	Fish heads and frames	600	Year round	Dumped or buried	B
	Prawns heads and shell	100	Year round	Dumped	B
Eden				Chill, freeze, boiling and cannery (one) facilities available	
	Fish heads and frame	3000	Year round	Converted to meal	B
	Shark liver	5	Sporadic	Converted to oil, interstate	B

Table 19. Queensland By products and Waste Utilisation 1993.
(Includes NSW border area processing activities)

Locality	By product	Volume (tonnes)	Availability	Facilities /Utilisation	Priority/ Opportunity
Brisbane -NSW border area	Mullet heads and frames	1000	Mostly May-Aug	Chill, freeze and boil facilities available. One silage and meal plant. 600+ t dumped, 100 t frozen as bait	B
	Mullet gizzard	20	Mostly May-Aug	Frozen 10 x 1 kg packs	C
	Fish heads and frames	<1000	Year round	300+ t dumped; some as meal	B
	Silage	< 500	Year round	Custom (company) process	C
	Fish meal	< 500	Year round	Custom (company) process	C
	Prawn heads and shells	450	Year round	400+ t dumped	B
Hervey Bay-- Yeppoon	Scallop shell	4500	Split season Most Nov-Mar	Chill, freeze, boil and drying facilities available Dumped or stockpiled	A
	Scallop gut	1500	Most Nov-Mar	Almost all dumped	A
	Assorted fish heads and frame	300	Year round	Dumped Bait use is negligible	C
	Prawn heads and shell	60	Year round	Dumped	C
	Shark backbone	3	Year round	Freeze and/ or dry	B
	Shark fins	20	Year round	Sun dried	B
Townsville - Cairns	Prawn heads and shell	180	Year round	Chill, freeze and boil facilities available Dumped	B
	Fish heads and frames	< 100	Year round	facilities available)	C

Scallop By Product and Waste

The most interesting and challenging area for by product manufacture and waste utilisation lies in the scallop waste produced in Queensland where about 3000 tonnes of scallop shell and about 1000 tonnes of "gut" is potentially available for conversion into some useful and profitable product(s) each year.

Although some of this is being disposed of at sea at supposedly small cost the real disposal costs of this shell and gut is estimated to be of the order of $50000-100000 per annum and any reduction in this cost should be welcomed.

This volume of waste product will apparently provide sufficient stock feed for some plant(s) located in the area between Hervey Bay and Yeppoon where the scallop processing factories are concentrated.

The scallop "gut" also represents a challenge for new product development as it is edible and supposedly nutritious. As noted earlier this is converted into a pleasant snack food in Japan and R & D could prove profitable with this abundant material.

Recommendation

The NSC call for expressions of interest, and provide funds for research and development on the utilisation of saucer scallop. shell and gut.

Novel Products

The other attractive area of by product manufacture lies in the decorative and curio lines such as fish and shark skins for leather for bags, wallets etc. The manufacture of the leather goods such as wallets and bags provides flow-on benefits to other sectors of the economy, in other states even, where goods are handmade. Indeed an unusual example of value adding in the fishing industry.

Fish skins and leather are by products with strong economic potential given that the economic recession is lifting in the USA and Europe, where the strongest demand for these novel products is reported to be.

Although this is a developing market it is not likely to lead to an enormous increase in volume of raw material required but it does represent an area for substantial economic growth if fishermen and buyers can work together to build up demand and prices for the raw material and finished goods.

Another by product which can help increase utilisation of fish resources is the cartilage skeleton ("backbone") of shark. There are at least two companies in Queensland undertaking small scale manufacturing of this product for export sale.

While the expansion of market demand for this product seems unlikely to use up large tonnages of material it represents a classical example of development of a valuable by product from what was formerly waste and shark backbone is seen as having medium potential for further market development and ranked as B priority in table 17 . Nevertheless novel medicinal products can suddenly become very fashionable and desirable and demand could increase remarkably fast.

The latest by product to emerge from Australian seafood processors is the gizzard from mullet. This represents only a small tonnage of a valuable product, once treated simply as bait, simply packed and frozen in Australia for subsequent processing in Taiwan.

Yann Campbell Hoare and Wheeler (1993), in their recent survey of the seafood processing industry reported that industry respondents felt that the most likely developments in their industry over the next five years would include:

* the introduction of new products
* more ready to cook meals
* and the emergence of new packaging

However the present author was repeatedly told that Australian industry lacked the funds for R & D on new products and packaging and therefore was pleased that overseas buyers were happy to buy many seafoods such as gizzards, raw and in simple packs.

The small capitalisation of most Australian seafood processors undoubtedly constrains the development of new products or packaging and particularly for "new" by-catch species/products such as those found in the northern areas of Australia. But the corporate culture of many seafood companies also accounts for the lack of R and D and the paucity of by products.

Almost all of the companies interviewed in the present study see themselves as processors of seafood and only occasionally experiment with new products or packaging. Only three of the companies interviewed would consider themselves to be food manufacturers and have ongoing or formal R and D programs.

In short, it appears that the opportunities for increasing utilisation and economic benefits from by-catch may come equally from a new more cooperative approach to marketing from all parties as from the development of new products, by products or new technology.

6. 3 Data Gaps and Research needs

While almost all by-catch studies by fisheries scientists have produced a checklist of the species composition there is only one fishery or area studied for which there is adequate information on volume of most by-catch species **and** the general size of the fish or shellfish caught **Without this type of detailed quantitative data it is difficult to make reliable business plans and prudent investments.**

Because much of the by-catch at any time is deemed to be trash very little attention is given to these species by research scientists or fishermen and they are simply being thrown over the side and consequently there is very little or no information available on most discards. Thus species which may be abundant but unutilized now but with potential economic importance at some later time are ignored.

This situation should not be allowed to continue if the fishing industry aims to utilize more of the catch. Information should be collected on the more common /abundant/prospective important by-catch species, and above all there is an outstanding need for weight data.

The rapid growth in demand for catfish and black pomfret, as outlined earlier in section 6.1, demonstrates this point well.

Biologists commonly examine fish samples for length, often to collect data for studies on age and growth, as part of most fisheries research programs but the weight of individual fish is less commonly measured. But the value of seafood is determined by size and size range (amongst other things) and without an indication of the size (weight and weight range) of the fish, data on numerical abundance alone are essentially meaningless for commercial decision making.

Knowing how many fish were caught per hour or hectare is of little value if you do not know if they were 10 gm fish worth nil or 10 kilo fish worth $7 per kilo.

Detailed and precise measurements using electronic scales are desirable but in the absence of adequate resources (machinery or manpower) simple observation and records on a few individuals (small/average/large) are better than no data at all.

The shortage of weight data in published research studies can be overcome to some degree by utilising the available data on the length-weight of various species. Pender et al 1990 for example determined the length-relationship for more than 40 important by-catch species in order to be able to utilise the length data collected on subsequent routine sampling trips on trawlers.

Graham et al (1992) investigated the optimum duration of tows and the optimum number of tows required to survey the relative abundance of trawlable species in a limited time in order to develop a uniform and optimum methodology. Given that the determination of weight as well as length would add to the work time involved in sampling at sea some research on the optimum method of collecting weight data may be warranted.

Recommendations

Researchers should be encouraged and assisted by funding agencies to collect weight data on samples of the more important -- commercially and ecologically -- by-catch species in their studies.

Funds should be made available for a study of the length-weight relationship of selected by-catch species in northern and eastern Australia in order to allow use of the length distribution information available in the published reports on by-catch studies, now and with information from future fisheries and marketing studies.

Research workers on different projects have been using different research methodology and sampling gear and because of the varying sampling timetable, procedures, data management and analysis, direct comparisons between one study and another is time consuming if not impossible.

In reports for industry there is a need for a clearer indication of the :

* sampling plan (day/night, monthly/quarterly, new/full moon etc)
* the fishing gear
* the treatment of data on groups such as sponges, reptiles etc

to avoid confusion as to the significance of findings.

There is also a need to give a clearer indication of the fishing effort underpinning various estimates; some information on the number of vessels and days and not just the total vessel-days.

The plethora of sampling procedures, data management and modes of presenting data makes an assessment of the by- catch in different fisheries extremely difficult and fraught with error. More uniform methods by applied fisheries researchers would allow for a safer extrapolation and aggregation of by-catch data and really enhance the value of current research programs.

Similarly more uniformity in data management, at sea and ashore, would mean that the original data is more user friendly and accessible to industry and a larger number of researchers now and in the future.

Also, industry needs access to the database for detailed information on particular species or precise information on monthly or quarterly changes in abundance, unless it is made available in special reports. The typical research report does not have sufficient information for companies to make sound business judgments.

An analogy can be made with museum collections which are preserved and catalogued according to a worldwide code of practice so that visiting researchers can easily access and utilise the material years later.

Recommendations

Researchers currently investigating the effects of trawling, fish distribution or by-catch etc should meet to review their research plans, methodology and data management in order to:

Promote the adoption of more uniform methodology so that results from one study can more easily be compared to those of another and so that the data base can be accessed by future researchers. from government and industry.

FRDC should promote the adoption of uniform methods in any studies it is funding, and consider sponsoring a special workshop on this topic if necessary.

Another weakness in the available literature is the profusion of common names for fish and the subsequent confusion relating to many species having the same name such as bream, jewfish etc.

Some reports list scientific names without the common name or marketing name being given; this makes for a difficult reading and evaluation of the study and assessing the likely market value of the by-catch. Many ordinary readers do not have the necessary resources to find the correct common or marketing name for most species.

The scientific as well as the common name needs to be noted in reports and species, genus or family name should be accompanied by a common name for the species, family etc at all times.

Given the multitude of names and the confusion surrounding the classification of fish (and shellfish) some sort of uniformity on fish names is desirable and the set of recommended marketing names for fish developed by the Australian Fisheries Service in 1988 should be considered mandatory for common names of the commercial species.

Recommendation:

The adoption of the fish names in the book Recommended Marketing Names For Fish, developed by the Australian Fisheries Service in 1988. should be encouraged amongst researchers, in order to have uniform names and minimise confusion. The use of these names should be mandatory in projects funded by national bodies such as FRDC, NSC and AFMA.

Furthermore the scientific as well as the common name should be given in reports and the species, genus or family name should be accompanied by a common name for the species, family etc at all times.

With the growing number of studies on the effect of trawling and the increasing industry participation and interest in such work the question of technical jargon and general communication difficulties arises.

Many fishermen and processors have difficulty interpreting graphs and other research results and they are not familiar with much of the fisheries and biological terminology despite their frequent usage in magazines such as Australian Fisheries.

Most of the research papers published in scientific journals are peer reviewed and are very difficult for a lay person to read and understand, furthermore they often contain little of interest to business people looking for information which they can use.

Therefore there is a need for special communication with industry operatives to keep them abreast of progress to date and to communicate valuable findings, valuable to industry -- not an ecologist or journal editor -- without delay.

Recommendation

Research reports to be issued to industry should be specially prepared taking account of the reader-customer interests and needs, and all technical terms explained in a glossary.

They should not be reprints, photocopies or a rearrangement of material originally prepared for a scientific audience.

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Detailed report on quarterly biological surveys, at sea off 4 ports, from May 1991 to April 1992. Extensive data on individual trawl shots and lists species caught. Second phase of earlier report; summarises findings from all eight cruises.

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Describes the species composition, distribution and numerical abundance of the by-catch from various sections of the river estuary. Notes that there is no apparent differences in the numbers of species and individuals caught in open and closed areas at the head of the estuary.

Harris A N and Poiner I R, 1990. By-catch of the prawn fishery of Torres strait; composition and partitioning of the discards into components that float or sink. Australian Journal Marine Freshwater Research 41, 37-52.

Has considerable quantitative detail on the abundance of various by-catch groups and species (percentage and tonnage) and describes the by-catch to prawn ratio observed from March 1985 to August 1986.

Harris A N and Poiner I R, 1991. Changes in species composition of demersal fish fauna of Southeast Gulf of Carpentaria, Australia, after 20 years of fishing. Marine biology 111, 503-519.
Describes how certain taxa including some leatherjackets change in abundance probably as a result of fishing effort and the discarding of by-catch.

Hill B J and Wassenberg T J, 1990. Fate of discards from prawn trawlers in Torres Strait. Australian Journal Marine Freshwater Research 41, 53-64.
Discusses the fate of various by-catch species as they are discarded from the trawlers according to whether they sink or float and are eaten by scavengers, birds etc.

Hyland S J, 1985. The Moreton Bay, Queensland, beam trawl fishery for penaeid prawns. In *Second Australian National Prawn Seminar* (Eds P C Rothlisberg, B J Hill and D J Staples) pp 205-211. (Cleveland, Qld)
Brief notes on the by-catch species and relative abundance, by weight, from monthly daylight beam trawl sampling from august 1982 to January 1984.

Jones, C M and Derbyshire, K. 1988. Sampling the demersal fauna from a commercial penaeid prawn fishery off the central Queensland coast. Memoirs of the Queensland Museum 25, 403-15.
Covers the same work as the Dredge reports; has an extensive species list too

Kennelly S J, 1993. Study on the by catch of the NSW east coast trawl fishery. Final Report to FRDC. Project No 88/108. ISBN 0 7310 2096 0, 520 p.
A compendium of research papers plus a summary of the overall research program on five estuarine fishing areas and four oceanic prawn fisheries includes several unpublished internal reports:

Kennelly, S J and Liggins 1992. Preliminary report on the by-catch of prawn trawling in the Clarence River and Lake Wooloweyah NSW Fisheries, Internal Publication, 1992

S J Kennelly & G W Liggins 1992. Preliminary information on the prawn trawl by-catch projects work in the Hawkesbury River.

Also has graphs of total by-catch:prawns and numbers of key commercial species in the by-catch.

Maclean J L, 1972 An analysis of the catch by trawlers in Moreton Bay (Qld) during the 1966-67 prawning season. Proceedings of the Linnean Society of New South Wales 98, 35-42.
Short lists of species and weights; very old, outdated information.

Pender P and Willing R, 1989. Trash or Treasure? Australian Fisheries 48(1), 35-36.

A short progress report on the sampling work of the NT Fisheries Division's study on by-catch of the NPF. See later papers and final report (1992) by these authors.

Pender P J and Willing R S, 1990. Northern Prawn Fishery by-catch with market potential. Fishery Report 20, Northern Territory Dept Primary Industry and Fisheries. 52 pp.

Describes the variation in night time catch rate of 123 by-catch species recorded on commercial trawlers in the 1988 tiger prawn fishery, for six areas between the Limmen Bight (Gulf of Carpentaria) and Joseph Bonaparte Gulf (WA). Notes and comments on the utilisation and potential of the dominant species and families are presented as well as some summary information on the size of the fish and shellfish observed. Colour plates of the 48 principal species are included.

P Pender, Willing R and Cann B, 1992. NPF by-catch a valuable resource? Australian Fisheries 51(2), 30-31.

Briefly discusses the possible uses and potential of major by-catch species from the NPF; essentially a very short summary of the key points in the final report (following paper).

Pender P J, Willing R S and D C Ramm, 1992. Northern Prawn Fishery By-catch Study: Distribution, abundance, size and use of by catch from the mixed species fishery. Fishery Report 26, Northern Territory Dept Primary Industry and Fisheries. 70 pp.

The final, and most detailed, report on this study of the NPF by Pender and Willing and coworkers; it is an overview of the research project and it also adds to the information reported in their Fishery Report 20 (1990) with tables on the catch per hr of each species for each sampling area. This paper and Fishery Report 20 provide an excellent coverage of the commercial potential of the by-catch in the Western Gulf of Carpentaria and the entire NPF as it was in 1988-1991.

Rainer S F, 1984. Temporal changes in a demersal fish and cephalopod community of an unexploited coastal area in northern Australia. Australian Journal of Marine and Freshwater Research 35, 747-68.

Found that leatherjackets *Paramonacanthus* spp the pony fish *Equulites leuciscus* the tripod fish *Tripodichthys blochii* and the saury *Saurida undosquamis* were the numerically dominant species in trawl survey of the south eastern Gulf of Carpentaria over 13 months in 1963-64.

Ramm D C, Pender P J, Willing R S and Buckworth R C, 1991. Large-scale spatial patterns of abundance within the assemblage of fish caught by prawn trawlers in northern Australian waters. Australian Journal Marine Freshwater Research 41, 79-95

Discusses distribution and relative abundance of fish species or taxa collected at night in the NPF from the Gulf of Carpentaria to Joseph Bonaparte Gulf, May 1988 to May 1989 from commercial trawlers. Relative abundance (number of fish per hour of a standard trawl) in the eastern shallow, eastern deep, western shallow and western deep areas are summarised in three tables.

Stephenson, W Chant, D C and Cook, S D 1982 a. Trawled catches in northern Moreton Bay. I. Effects of sampling variables. Memoirs of the Queensland Museum 20(3), 375-86.

Monthly biological surveys over three sites over 26 months from April 1979; has numerical abundance and species lists but no useful volume data.

Wassenberg T J and Hill B J, 1989. The effect of trawling and subsequent handling on the survival rates of the by catch of prawn trawlers in Moreton Bay, Australia. Fisheries Research 7, 99-110.

Includes a table on the average weight and composition of total discards (by weight) of 12 trawls from commercial trawlers in Moreton Bay from September 1983-February 1986. Has similar data on the bony fish families for six catches and crustacean discards and the seven abundant fish species over 27 catches.

Wassenberg T J and Hill B J, 1991. Partitioning of material discarded from prawn trawlers in Moreton Bay. Australian Journal Marine Freshwater Research 41, 27-36.

Reviews results of discard studies from September 1985 to March 1989 particularly the size composition of fish in the trawler by catch: 90% weighed less than 20 g and almost all were below 40 g.

Watson R A, Dredge M L C and Mayer D G,1991. Spatial and seasonal variation in demersal trawl fauna associated with a prawn fishery on the central barrier reef. Australia. Australian Journal Marine Freshwater Research 41, 65-77.

Describes the distribution and relative abundance of some species collected during monthly trawl sampling (on the new moon) from Jan 1985 to December 86 at eight sites in a small area off Townsville worked by prawn trawlers. Abundance data is sparse and given only as the natural log of the number taken per standard trawl. Notes that distribution of key species was affected more by the location of sample sites than by the time of the year when samples were taken.

Willing R S and Pender P J, 1989. Length-weight relationships for 45 species of fish and three invertebrates from Australia's Northern Prawn Fishery. Technical Bulletin 142, Northern Territory Dept Primary Industry and Fisheries. 57 pp.

Graphs the length frequency distribution of specimens sampled during a study of by-catch from chartered and commercial trawlers in 1987 and in the 1988 tiger prawn fishery; describes the relationship between length and weight both mathematically and graphically.

9. ACKNOWLEDGEMENTS

Many industry people from companies around the country helped with information and deserve acknowledgement, but shall remain nameless in order to preserve commercial confidentiality for their company.

In the government and research sector, I would like to record my thanks to:

P Appleton, QFMA

P Browne, AQIS

M Dredge, J Glaister, N Gribble and N Trainor, QDPI

M Broadhurst, K Graham, S Kennelly, G Liggins, NSW Fisheries

P Smith, ABARE

M Sachse, AFMA

B Taylor, T Wassenberg, CSIRO

APPENDIX

Appendix 1. Numerical abundance of animals taken in preliminary sampling Far north Qld , CSIRO-QDPI study (from Blaber et al 1993, table 11)

Species	Total n
Lethrinus nematacanthus	2384
Nemipterus peronii	**162**
Rhynchostracion nasus	**313**
Pentapodus porosus	415
Suggrundus isacanthus	188
Upeneus tragula	**1010**
Portunus rubromarginatus	765
Synchiropus rameus	70
Apogon fasciatus	**173**
Synodus hoshinonis	32
Nemipterus hexodon	**55**
Selaroides leptolepis	119
Amusiidae	765
Carinosquilla carinata	1
Trixiphichthys weberi	1
Penaeoidae: Solenoceridae	1
Carangoides hedlandensis	1
Scyllarus demani	1
Amusium pleuronectes	**96**
Ascidiacea	11
***Leiognathus* sp.**	**849**
Suggrundus macracanthus	6
Caranx bucculentus	18
Scolopsis taeniopterus	**952**
Upeneus sundaicus	**166**
Priacanthus tayenus	**262**
Pentaprion longimanus	**12**
Apogon ellioti	**237**
Anchisomus multistriatus	4
Pseudorhombus diplospilus	**66**
Lepidotrigla argus	**41**

APPENDIX 2

Reproduced from Kennelly 1993
with original figure numbers

Estuarine Fisheries

FIGURE 2

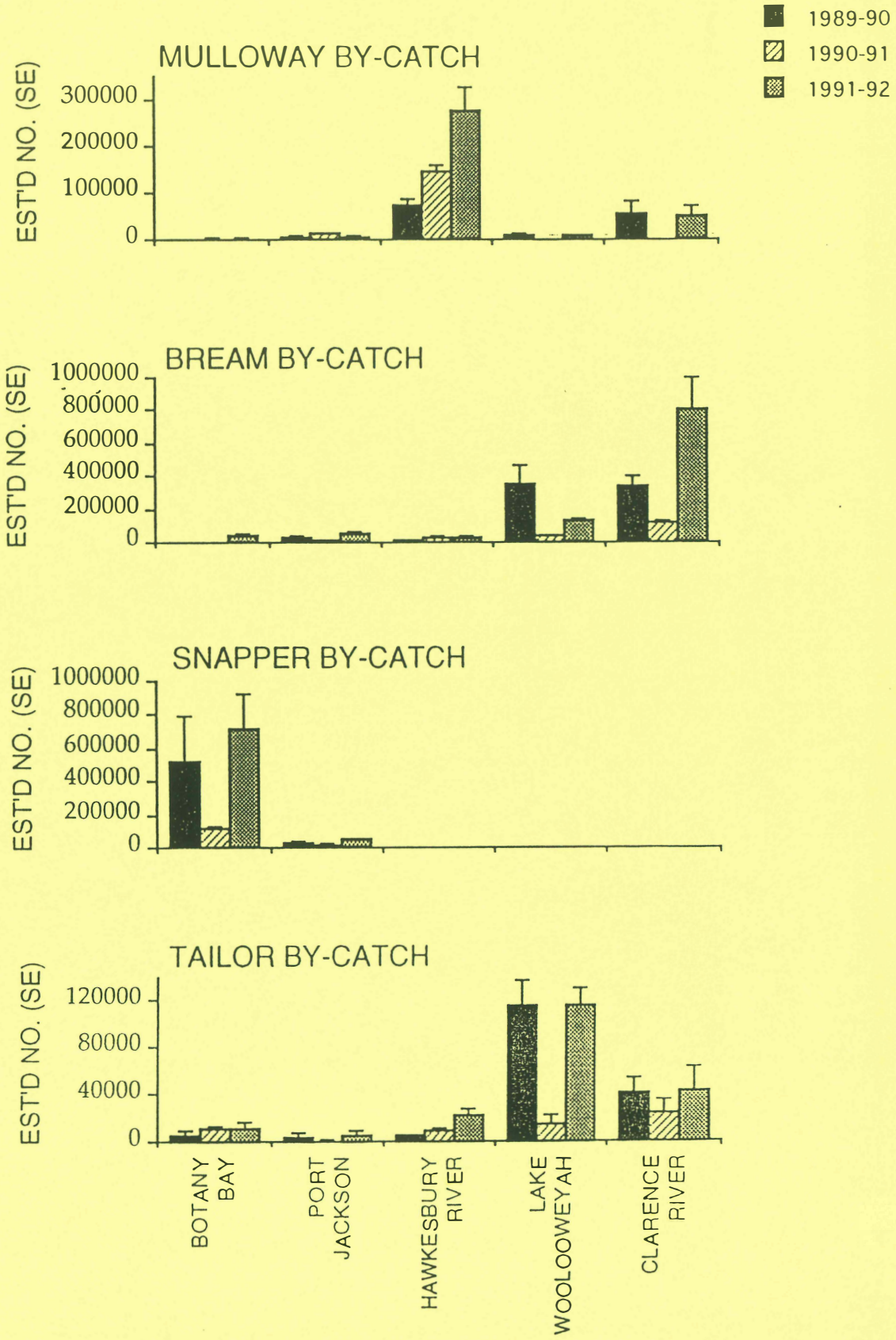
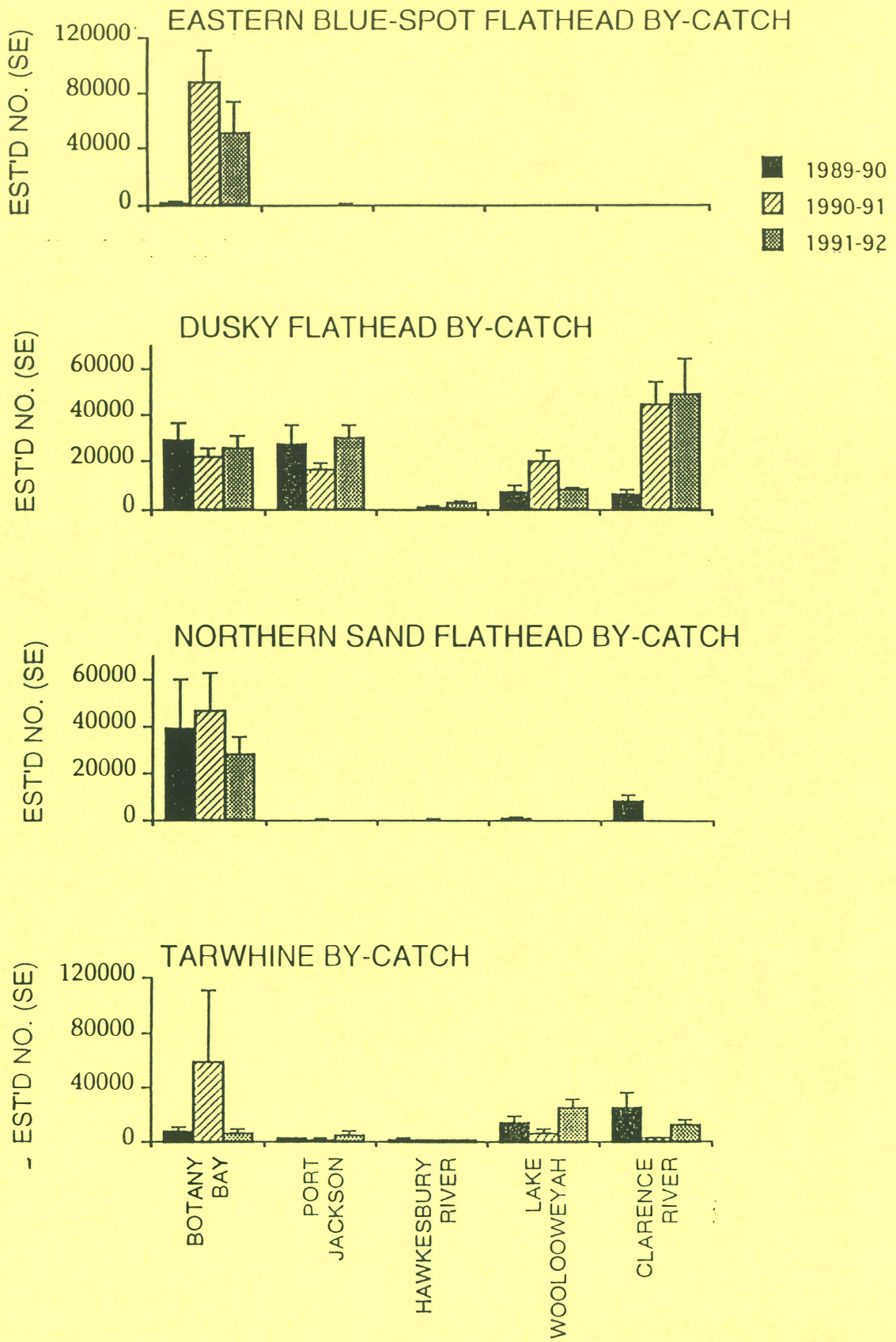

1989-90
1990-91
1991-92
MULLOWAY BY-CATCH
EST'D NO. (SE)
300000
200000
100000
0
BREAM BY-CATCH
EST'D NO. (SE)
1000000
800000
600000
400000
200000
0
SNAPPER BY-CATCH
EST'D NO. (SE)
1000000
800000
600000
400000
200000
0
TAILOR BY-CATCH
EST'D NO. (SE)
120000
80000
40000
0
BOTANY BAY
PORT JACKSON
HAWKESBURY RIVER
LAKE WOOLOOWEYAH
CLARENCE RIVER

FIGURE 3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EST'D NO. (SE)
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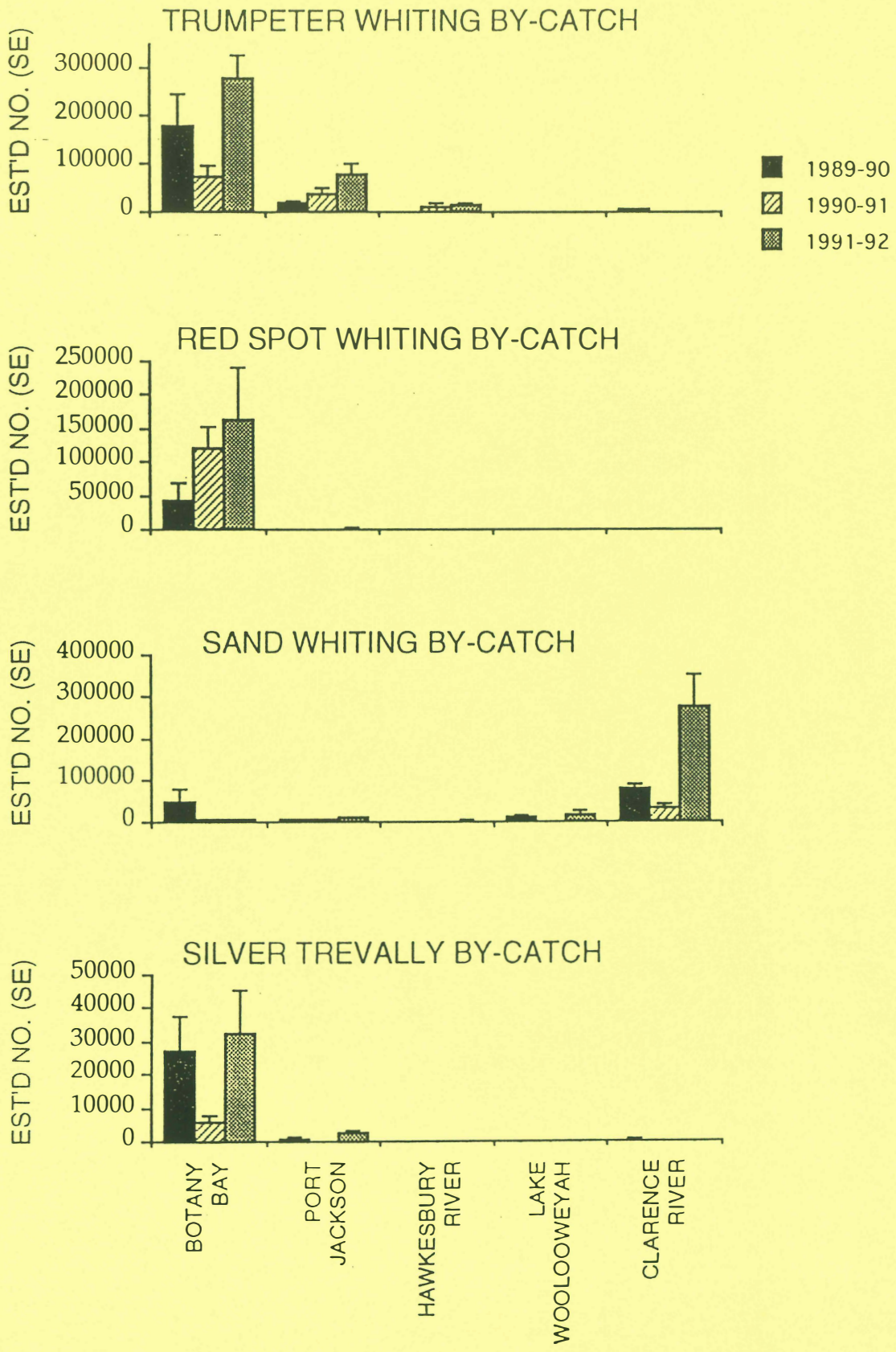
80000
40000
0
1989-90
1990-91
1991-92
DUSKY FLATHEAD BY-CATCH
EST'D NO. (SE)
60000
40000
20000
0
NORTHERN SAND FLATHEAD BY-CATCH
EST'D NO. (SE)
60000
40000
20000
0
TARWHINE BY-CATCH
EST'D NO. (SE)
120000
80000
40000
0
BOTANY BAY
PORT JACKSON
HAWKESBURY RIVER
LAKE WOOLOOWEYAH
CLARENCE RIVER

FIGURE 4


TRUMPETER WHITING BY-CATCH
EST'D NO. (SE)
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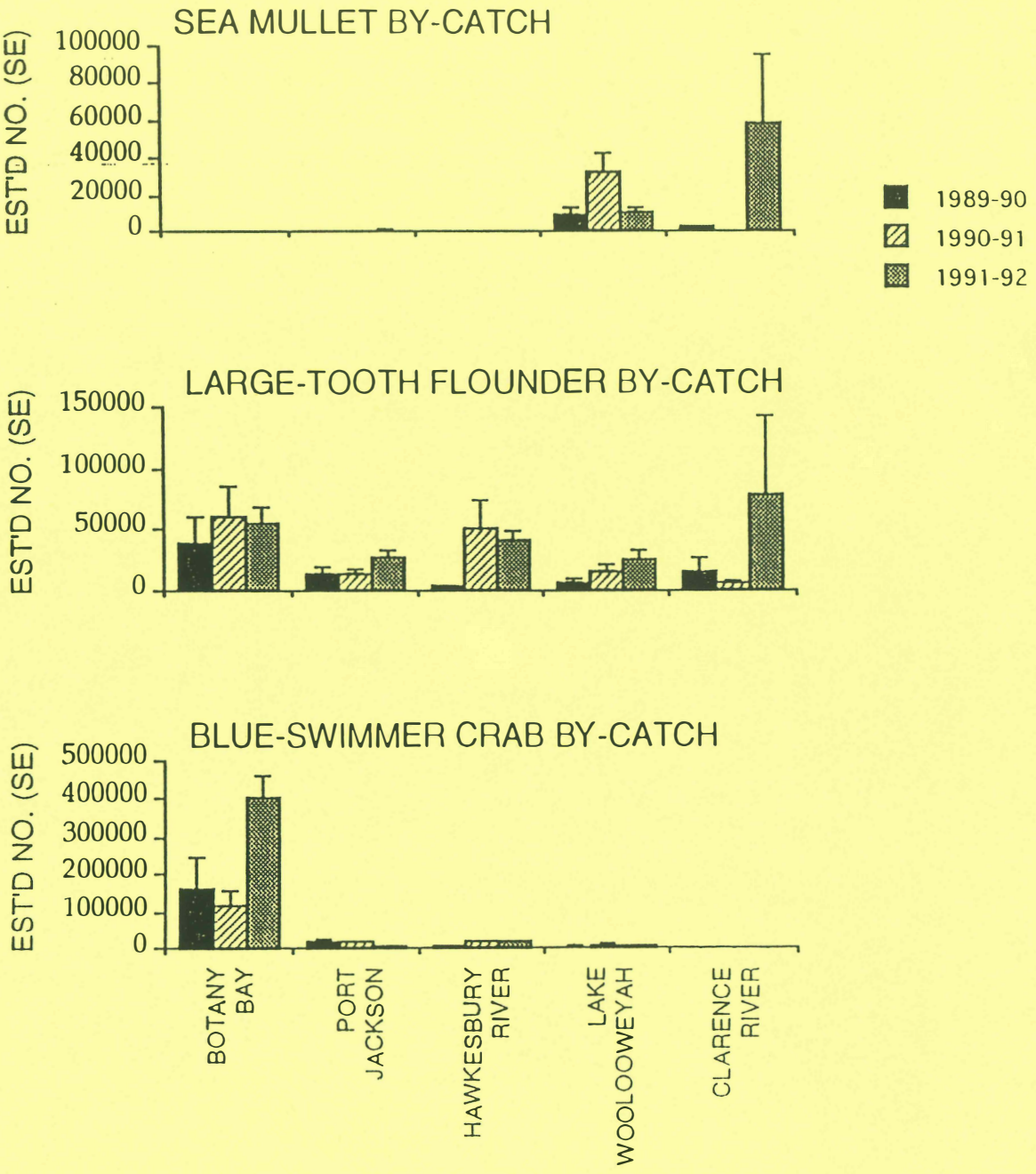
200000
100000
0
1989-90
1990-91
1991-92
RED SPOT WHITING BY-CATCH
EST'D NO. (SE)
250000
200000
150000
100000
50000
0
SAND WHITING BY-CATCH
EST'D NO. (SE)
400000
300000
200000
100000
0
SILVER TREVALLY BY-CATCH
EST'D NO. (SE)
50000
40000
30000
20000
10000
0
BOTANY BAY
PORT JACKSON
HAWKESBURY RIVER
LAKE WOOLOOWEYAH
CLARENCE RIVER

FIGURE 5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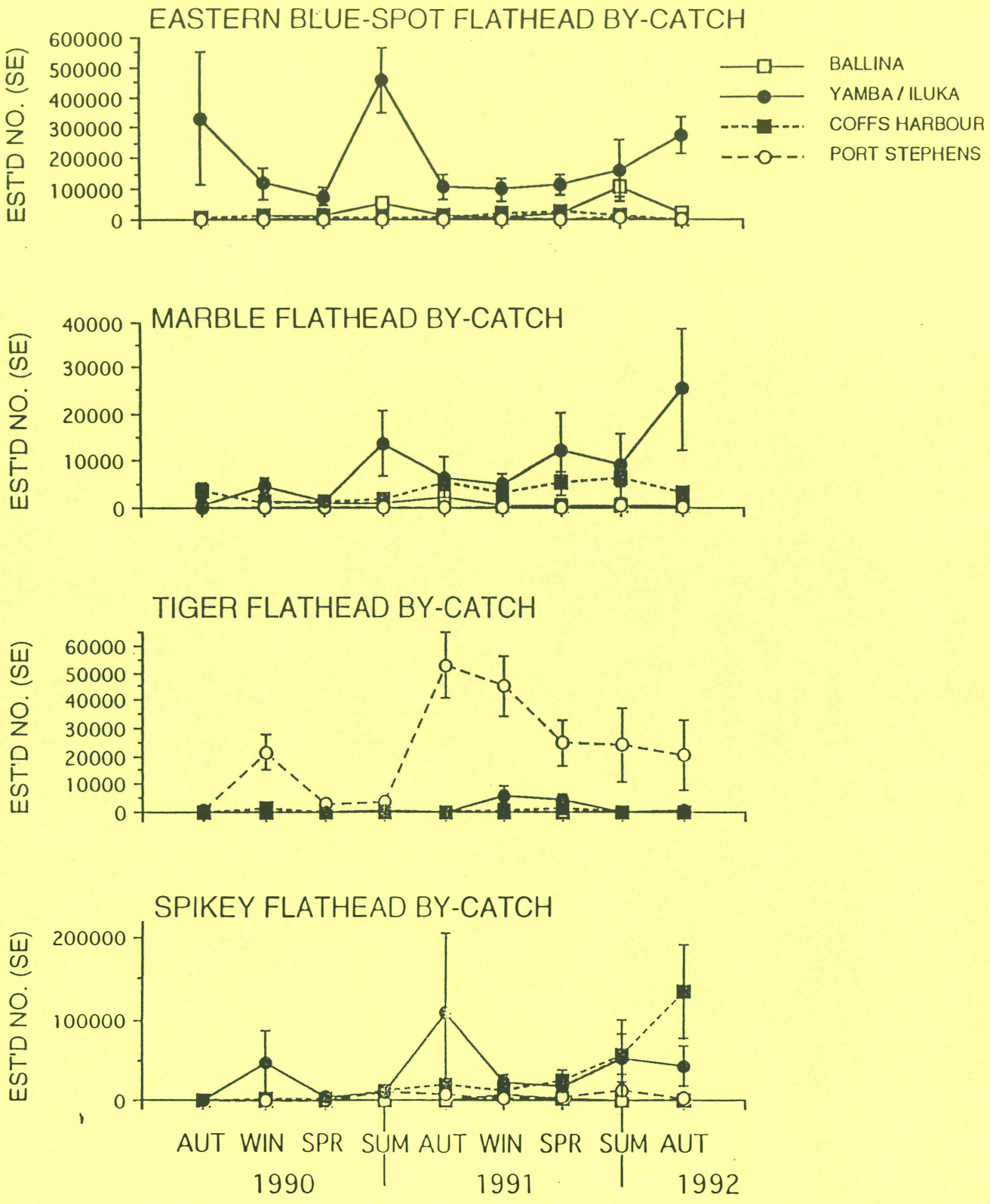
80000
60000
40000
20000
0
LARGE-TOOTH FLOUNDER BY-CATCH
EST'D NO. (SE)
150000
100000
50000
0
BLUE-SWIMMER CRAB BY-CATCH
EST'D NO. (SE)
500000
400000
300000
200000
100000
0
BOTANY BAY
PORT JACKSON
HAWKESBURY RIVER
LAKE WOOLOOWEYAH
CLARENCE RIVER
1989-90
1990-91
1991-92

APPENDIX 3

Reproduced from Kennelly 1993
with original figure numbers

Oceanic Fisheries

FIGURE 7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EST'D NO. (SE)
600000
500000
400000
300000
200000
100000
0
BALLINA
YAMBA / ILUKA
COFFS HARBOUR
PORT STEPHENS
MARBLE FLATHEAD BY-CATCH
EST'D NO. (SE)
40000
30000
20000
10000
0
TIGER FLATHEAD BY-CATCH
EST'D NO. (SE)
60000
50000
40000
30000
20000
10000
0
SPIKEY FLATHEAD BY-CATCH
EST'D NO. (SE)
200000
100000
0
AUT WIN SPR SUM AUT WIN SPR SUM AUT
1990
1991
1992

FIGURE 8

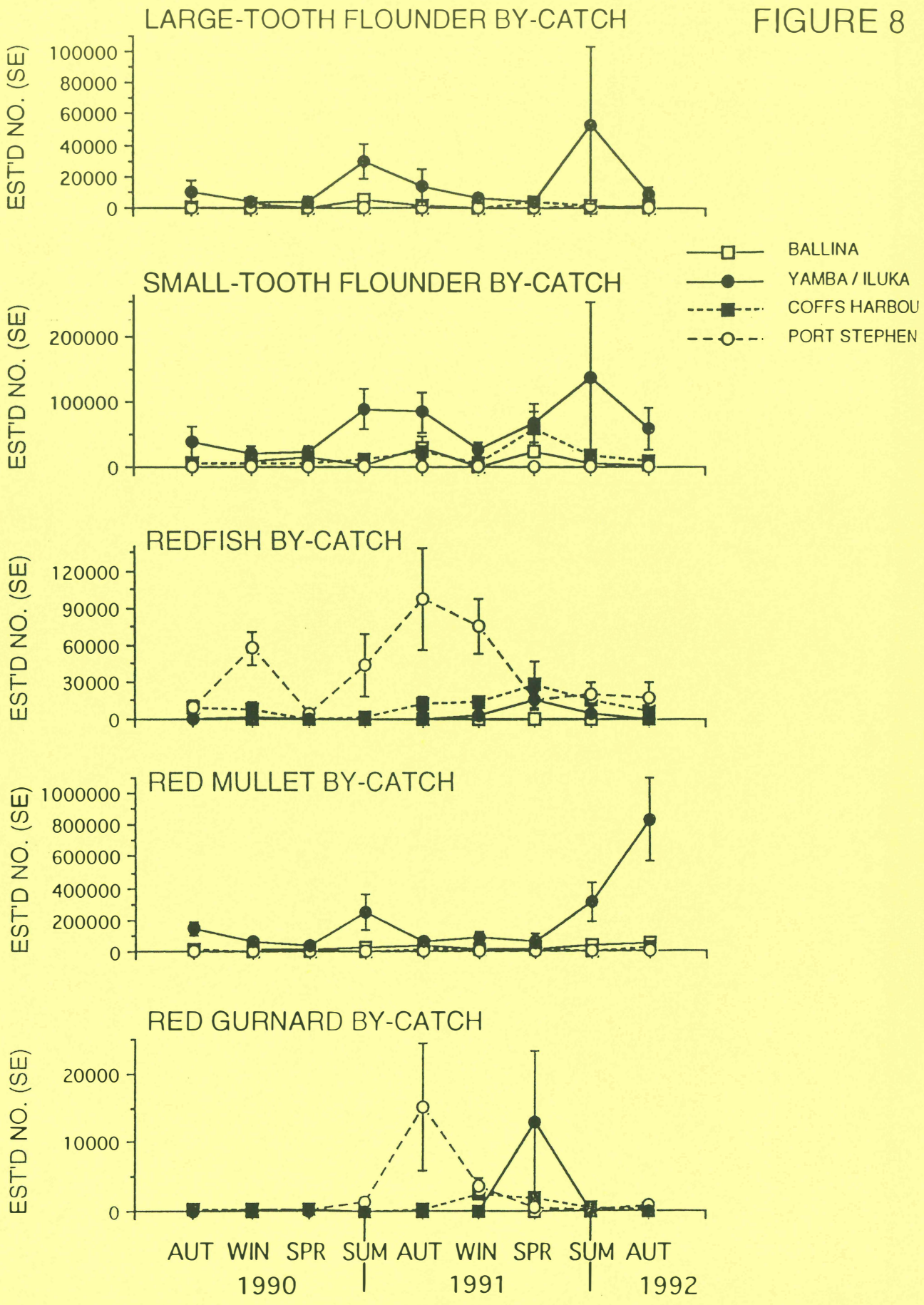

LARGE-TOOTH FLOUNDER BY-CATCH
EST'D NO. (SE)
100000
80000
60000
40000
20000
0
SMALL-TOOTH FLOUNDER BY-CATCH
EST'D NO. (SE)
200000
100000
0
REDFISH BY-CATCH
EST'D NO. (SE)
120000
90000
60000
30000
0
RED MULLET BY-CATCH
EST'D NO. (SE)
1000000
800000
600000
400000
200000
0
RED GURNARD BY-CATCH
EST'D NO. (SE)
20000
10000
0
AUT WIN SPR SUM AUT WIN SPR SUM AUT
1990
1991
1992
BALLINA
YAMBA / ILUKA
COFFS HARBOU
PORT STEPHEN

FIGURE 9

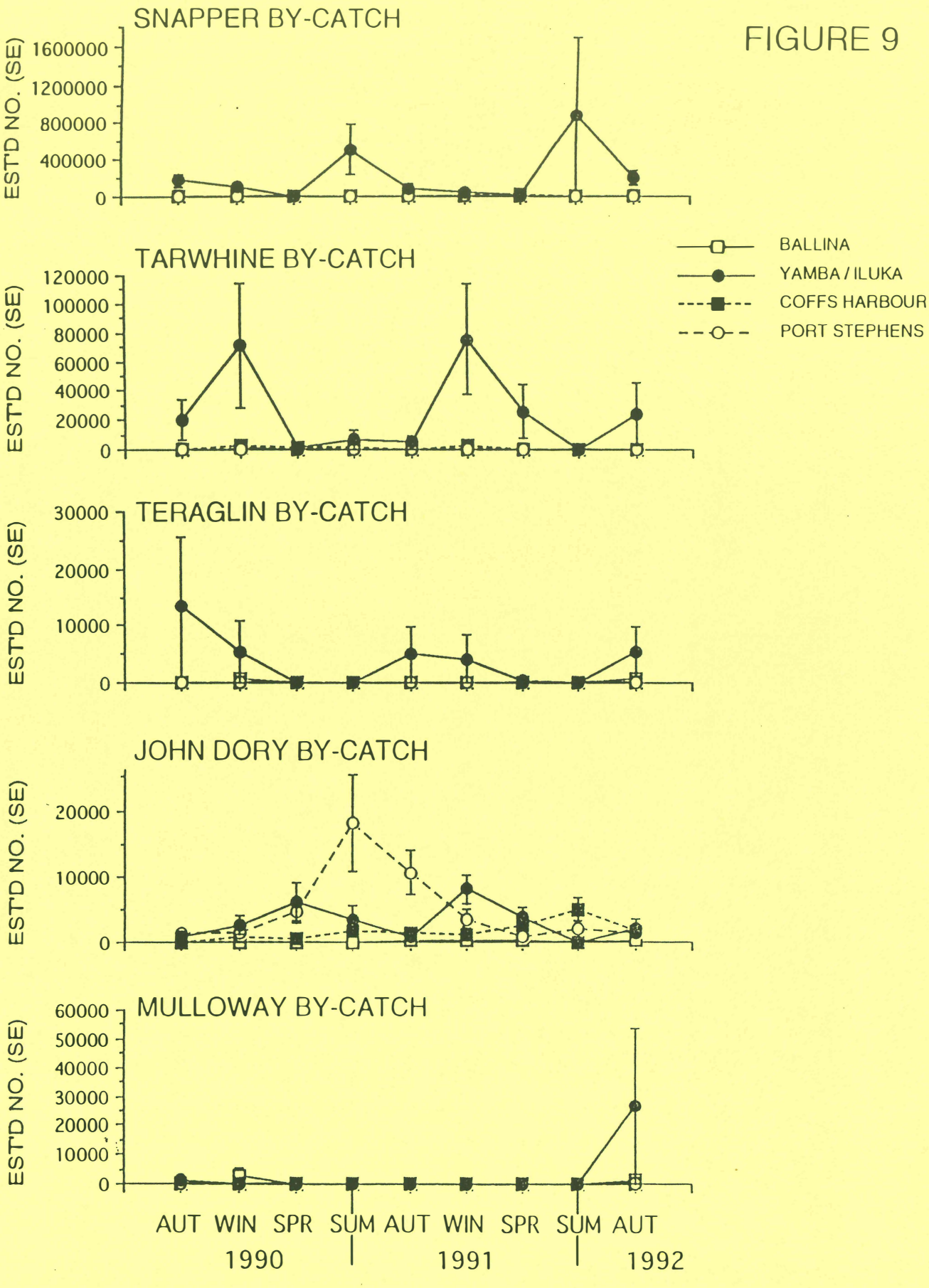

SNAPPER BY-CATCH
EST'D NO. (SE)
1600000
1200000
800000
400000
0
TARWHINE BY-CATCH
EST'D NO. (SE)
120000
100000
80000
60000
40000
20000
0
TERAGLIN BY-CATCH
EST'D NO. (SE)
30000
20000
10000
0
JOHN DORY BY-CATCH
EST'D NO. (SE)
20000
10000
0
MULLOWAY BY-CATCH
EST'D NO. (SE)
60000
50000
40000
30000
20000
10000
0
BALLINA
YAMBA / ILUKA
COFFS HARBOUR
PORT STEPHENS
AUT WIN SPR SUM AUT WIN SPR SUM AUT
1990
1991
1992

FIGURE 10

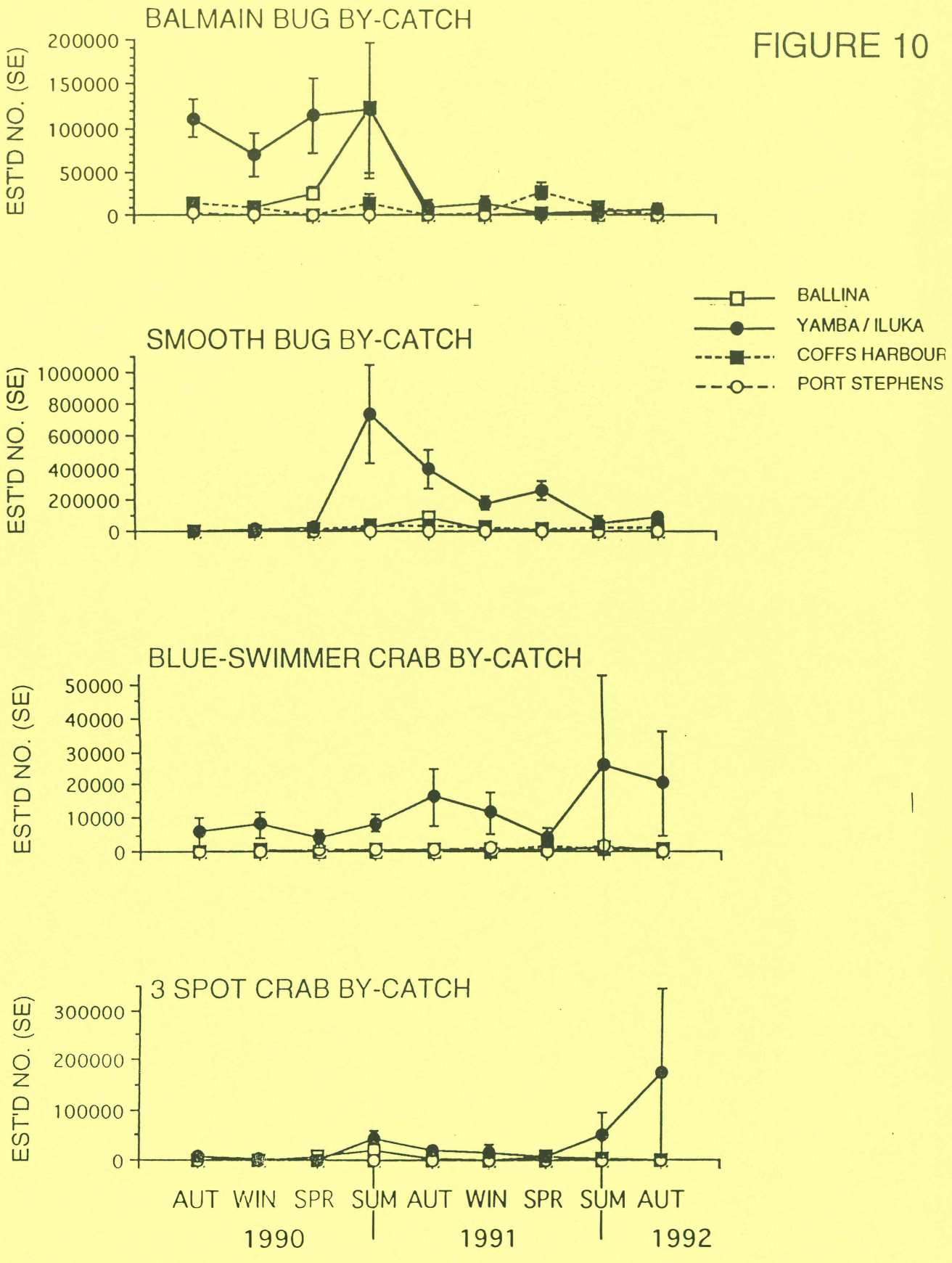

BALMAIN BUG BY-CATCH
EST'D NO. (SE)
200000
150000
100000
50000
0
SMOOTH BUG BY-CATCH
EST'D NO. (SE)
1000000
800000
600000
400000
200000
0
BLUE-SWIMMER CRAB BY-CATCH
EST'D NO. (SE)
50000
40000
30000
20000
10000
0
3 SPOT CRAB BY-CATCH
EST'D NO. (SE)
300000
200000
100000
0
AUT WIN SPR SUM AUT WIN SPR SUM AUT
1990
1991
1992
BALLINA
YAMBA / ILUKA
COFFS HARBOUR
PORT STEPHENS

FIGURE 11

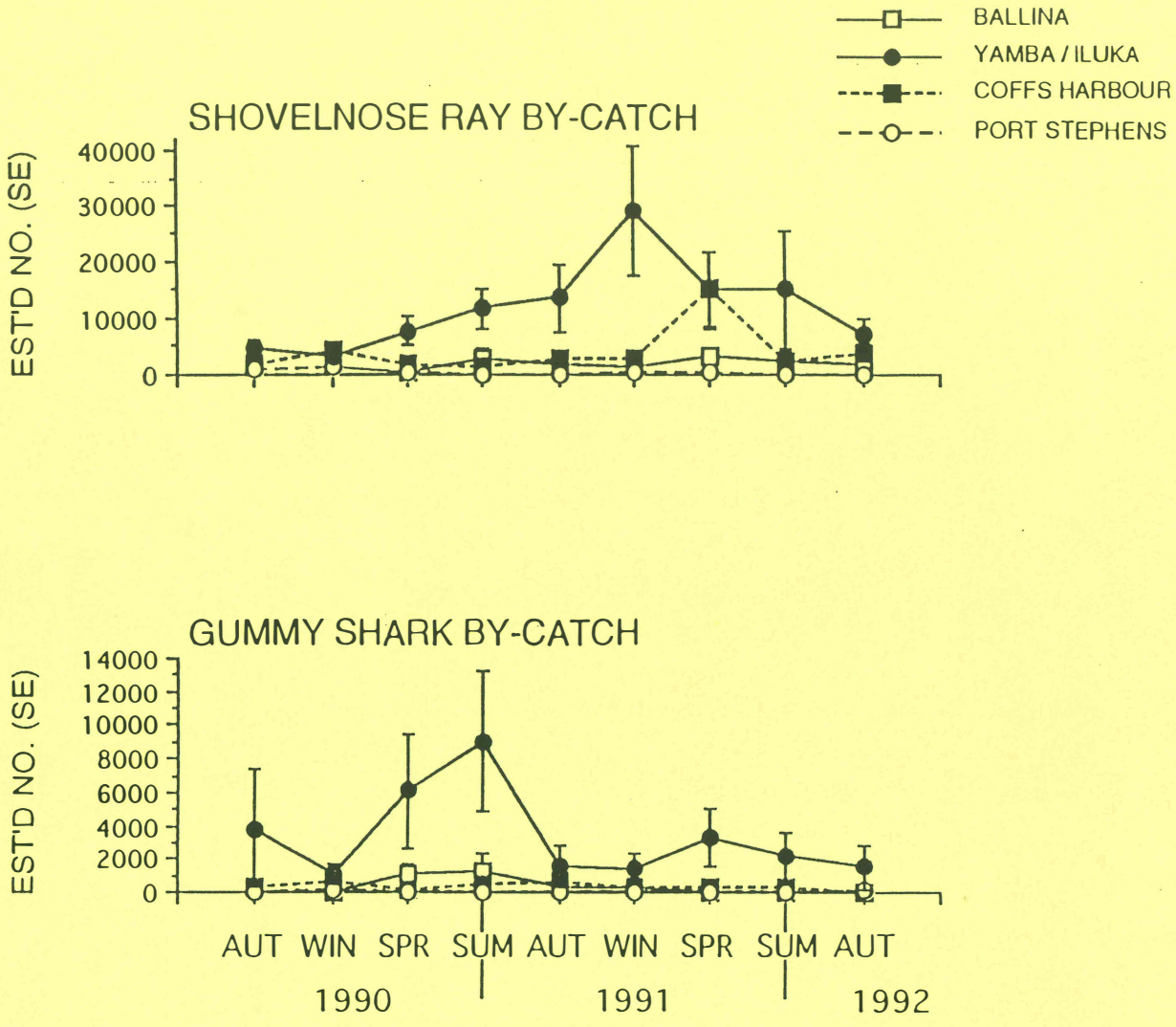
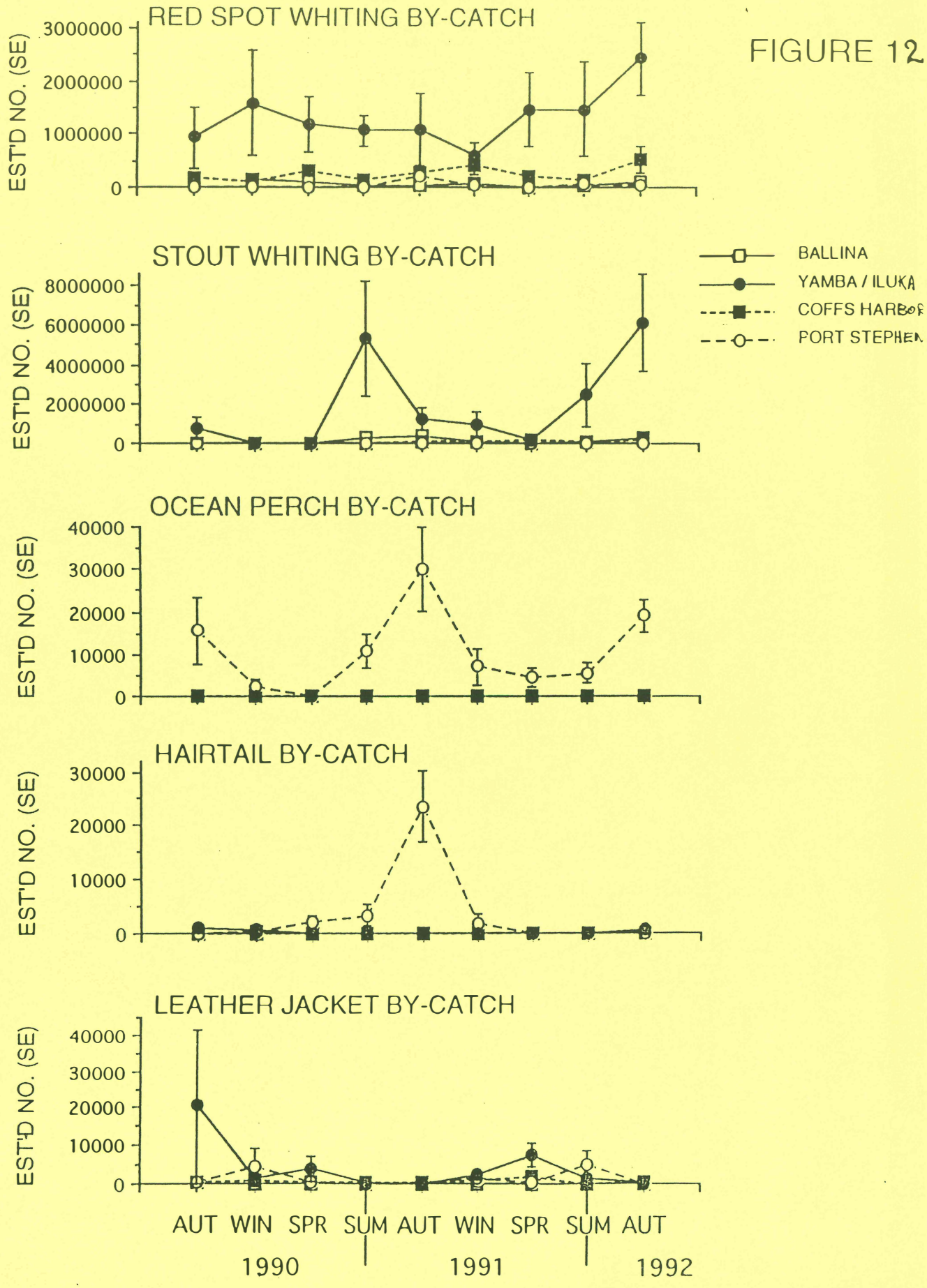

BALLINA
YAMBA / ILUKA
COFFS HARBOUR
PORT STEPHENS
SHOVELNOSE RAY BY-CATCH
EST'D NO. (SE)
40000
30000
20000
10000
0
GUMMY SHARK BY-CATCH
EST'D NO. (SE)
14000
12000
10000
8000
6000
4000
2000
0
AUT WIN SPR SUM AUT WIN SPR SUM AUT
1990
1991
1992

FIGURE 12.


RED SPOT WHITING BY-CATCH
EST'D NO. (SE)
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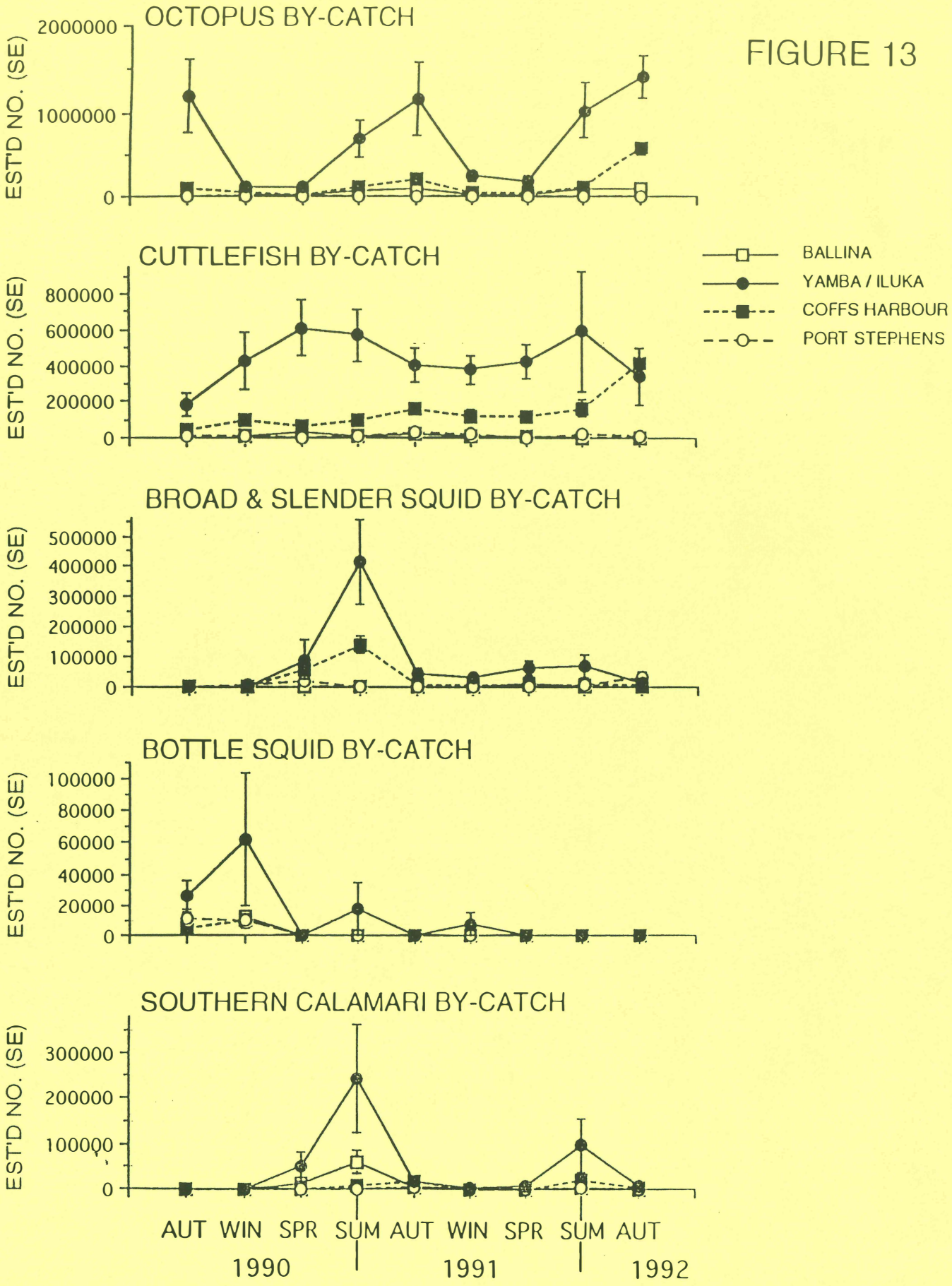
2000000
1000000
0
STOUT WHITING BY-CATCH
EST'D NO. (SE)
8000000
6000000
4000000
2000000
0
BALLINA
YAMBA / ILUKA
COFFS HARBOUR
PORT STEPHENS
OCEAN PERCH BY-CATCH
EST'D NO. (SE)
40000
30000
20000
10000
0
HAIRTAIL BY-CATCH
EST'D NO. (SE)
30000
20000
10000
0
LEATHER JACKET BY-CATCH
EST'D NO. (SE)
40000
30000
20000
10000
0
AUT WIN SPR SUM AUT WIN SPR SUM AUT
1990
1991
1992

FIGURE 13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EST'D NO. (SE)
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1000000
0
CUTTLEFISH BY-CATCH
800000
600000
400000
200000
BROAD & SLENDER SQUID BY-CATCH
500000
400000
300000
200000
100000
BOTTLE SQUID BY-CATCH
100000
80000
60000
40000
20000
SOUTHERN CALAMARI BY-CATCH
300000
200000
100000
AUT WIN SPR SUM AUT WIN SPR SUM AUT
1990
1991
1992
BALLINA
YAMBA / ILUKA
COFFS HARBOUR
PORT STEPHENS